Scott Base Redevelopment

Draft Comprehensive Environmental Evaluation

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Table of Contents

List of Figures

List of Tables

Acronyms

ACM: Asbestos-containing material
AHT: Antarctic Heritage Trust
AN8: Aviation kerosene used as a low-temperature diesel
ASMA: Antarctic Specially Managed Area
ASPA: Antarctic Specially Protected Area
ATCM: Antarctic Treaty Consultative Meeting
ATS: Antarctic Treaty System
BESS: Battery Energy Storage System
CCAMLR: Commission for the Conservation of Antarctic Marine Living Resources
CEE: Comprehensive Environmental Evaluation
CEMP: Construction Environmental Management Plan
CEP: Committee for Environmental Protection
CHP: Combined heat and power
CIROS: Cenozoic investigations of the western Ross Sea
COMNAP: Council of Managers of National Antarctic Programmes
EC: Electrical conductivity
EIA: Environmental Impact Assessment
EIES: Electronic Information Exchange System
EMS: Environmental Management System
FT: Front transition
GHG: Greenhouse gases
GIFA: Gross internal floor area
GIS: Geographical Information System
HFC: Hillary Field Centre
HSM: Historic Sites and Monuments
IEC: International Electrotechnical Commission
IEE: Initial Environmental Evaluation
IGY: International Geophysical Year
IMO: International Maritime Organization
JLP: Joint Logistics Pool
LCA: Life-Cycle Assessment
LGP: Latitudinal Gradient Programme
LTS: Long-Term Science
MAV: Maximum acceptable values
MBR: Membrane bioreactor
MPA: Marine Protected Area
MPEC: Marine Environmental Protection Committee
MWAC: Modified Wilson and Cook (passive dust sampler)
NDACC: Network for the Detection of Atmospheric Composition Change
NIWA: National Institute of Water and Atmospheric Research
NSF: National Science Foundation
PAH: Polycyclic aromatic hydrocarbon
PCB: Polychlorinated biphenyls
POLENET: Polar Earth Observing Network
PV: Photovoltaic
RIWE: Ross Island Wind Energy network
RORO: Roll-on-roll-off
Ross-RAMP: Ross Sea Region Research and Monitoring Programme
ROV: Remotely operated vehicle
SCAR: Scientific Committee of Antarctic Research
SPMT: Self-propelled modular transporter
TAE: Trans-Antarctic Expedition
TEU: Twenty-foot equivalent unit
TPH: Total petroleum hydrocarbons
USAP: United States Antarctic Program
VSA: Visual Site Assessment
WWTP: Wastewater treatment plant

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Public notification

All public comments on the draft Comprehensive Environmental Evaluation are welcome and can be directed by email to SBRdraftCEEfeedback@mfat.govt.nz. Public feedback will close on Sunday 16 May 2021.

Non-technical summary

Introduction

This draft Comprehensive Environmental Evaluation (CEE) has been prepared by Antarctica New Zealand to assess the potential environmental impacts associated with the proposed Scott Base Redevelopment and replacement of the Ross Island Wind Energy network. The proposed activities are required because the current Scott Base buildings, facilities and associated infrastructure are reaching the end of their functional life and safety and environmental risks are escalating.

The three wind turbines of the Ross Island Wind Energy network have a design capacity of 990kW and an end of life period of 2030. The current Ross Island Wind Energy network was developed to supply renewable energy to the existing station and infrastructure. Energy modelling for the proposed Scott Base indicates that the total energy load is higher than the current Scott Base energy load. Therefore, replacement of the existing Ross Island Wind Energy network, in conjunction with the Scott Base Redevelopment, is proposed in order to optimise and utilise logistics and construction resources. The larger design capacity will support the increased energy load of the proposed Scott Base and provide more renewable energy for Ross Island (both Scott Base and McMurdo Station (United States)).

This draft CEE has been prepared following the requirements of Article 3, Annex I to The Protocol on Environmental Protection to the Antarctic Treaty, the Revised Guidelines for Environmental Impact Assessments in Antarctica (Resolution 1 (2016)) and applicable New Zealand legislation.

The scope of this draft CEE includes two main components:

1. The Scott Base Redevelopment; and
2. The Ross Island Wind Energy network replacement.

Description of the proposed activities

The **Scott Base Redevelopment** involves the full replacement of the existing Scott Base with a new station. The site for the proposed activities is Pram Point, where the current station is located. The Scott Base Redevelopment proposes the deconstruction and removal of the existing Scott Base. Civil works including bulk earthworks are proposed to prepare the site and improve the safety of operations on the Scott Base to McMurdo Station road. Foundation and enabling works, including the relocation of some Long-Term Science experiments are also part of the proposed activities.

The new station is proposed to be fully constructed in New Zealand and shipped as modules in a single voyage on a large vessel, to be assembled again once on Pram Point. The proposal includes a temporary wharf consisting of bollards and cantilevered frames to accommodate the vessel at Pram Point. A temporary station, also on Pram Point, is proposed to support both the Scott Base Redevelopment and New Zealand's scientific and environmental protection programmes during the proposed activities. The proposed Scott Base is designed to be more efficient, resilient, and sustainable in order to provide a safe and healthy environment for its occupants and support the New Zealand science programme for the next 50 years.

The **Ross Island Wind Energy network replacement** was developed to the feasibility stage at the time of preparing this draft CEE with two options under investigation. The first option is to install three new turbines to supply 80% of the proposed Scott Base's energy demand. The second and preferred option is to install four new turbines to supply 98% of the demand. Both options are supported by a battery energy storage system to provide continuous energy in periods of low wind. The proposed activities place the new wind turbines on Crater Hill, where the current turbines are located. The proposed activities include the removal of the existing turbines and their foundations and their replacement with three or four larger wind turbines, placed on new foundations. The replacement of all ancillary plant (e.g. cabling, frequency converter, electrical substation) is also proposed.

The temporal scope for the Scott Base Redevelopment begins in the austral summer of 2021/22 until the end of the 2026/27 austral summer. The Ross Island Wind Energy network replacement is proposed to begin in the austral summer of 2023/24 until the austral summer of 2025/26.

The seasonal activities for the proposed project are:

Season 0 (2021/22) – Testing of foundation design and completion of Long-Term Science relocation;
Season 1 (2022/23) – Shipping and staging of equipment and plant, temporary station site preparations, prepare staging areas, commencing construction of new buildings in New Zealand;
Season 2 (2023/24) – Construction of a temporary base, Scott Base to McMurdo road realignment, water and wastewater intake and outlet structures installation, bulk fuel tank platform establishment and the preparation and piling for a temporary wharf, construction of new buildings in New Zealand;
Season 3 (2024/25) – Existing Scott Base decommissioning and deconstruction, bulk earthworks, piling/foundations, establishment of a haul road from temporary wharf to building site, temporary wharf bollard installation and first new wind turbine installation, construction of new buildings in New Zealand;
Season 4 (2025/26) – Finalise bulk earthworks and haul road, piling/foundations, decommission existing wind farm, install remaining turbines and commission new wind farm, install fenders on temporary wharf, ship new building modules to Pram Point, install new building modules on foundations, fit out and recommission new buildings over the winter of 2026; and
Season 5 (2026/27) – Occupy new Scott Base, deconstruct temporary Scott Base and remaining structures, final earthworks to finish building access ramps, demobilise plant and containers back to New Zealand.

Summary of alternatives
The alternative of not proceeding with the Scott Base Redevelopment was considered at the initiation of the project. The alternative was discounted because it would result in the closure of Scott Base, as the critical life support systems and infrastructure at Scott Base is at the end of its life. Alternatives for the design of the proposed Scott Base, its location on Pram Point, the type of civil and mechanical engineering solutions to build and operate the proposed station, as well as the logistics for the project and the deconstruction of the existing station were identified and assessed to identify preferred solutions.

The alternative of not upgrading the wind farm was considered. "Do nothing" would result in the wind farm being decommissioned after 2030 and Ross Island relying entirely on fossil fuels. The alternative was discounted because it goes against New Zealand's commitment to managing its environmental impacts in Antarctica.

Description of the environment
Pram Point and Crater Hill are representative of an ice-free environment that has been the receptor of significant and ongoing human impacts for more than 60 years. Despite extensive ground disturbance moss, lichen and algae and micro-fauna are found around Scott Base and the wider Pram Point area. No significant vegetation has been recorded on Crater Hill. The Pram Point nearshore marine environment displays high biodiversity, as well as historical anthropogenic debris in some places. Wildlife is largely limited to Weddell seals that congregate on the sea ice in front of Scott Base. No birds breed at Crater Hill but Snow Petrels (Pagodroma nivea) are occasionally seen there. Antarctic Specially Protected Area No. 122 Arrival Heights is located near Crater Hill and Historic Site and Monument No. 75 Hut A (Trans Antarctic Expedition Hut) is found within the Scott Base footprint. No non-native species are known to be established in the terrestrial or in the nearshore marine environment.

Environmental Impact Assessment

This draft CEE presents a full Environmental Impact Assessment of the proposed activities. The methodology for the impact assessment is informed by the Guidelines for Environmental Impact Assessments in Antarctica (Resolution 1 (2016)) and follows a four-step analysis including:

1. Identifying the **aspects** arising from the proposed activities;
2. Identifying the **environmental receptors** that may be affected;
3. Identifying the **impacts**; and
4. Assessing the **significance** of the identified impacts.

The assessment identifies a range of direct, indirect and cumulative impacts on environmental receptors. The most significant potential impacts expected to arise from the proposed activities are:

- The release of greenhouse gases contributing to global climate change;
- Changes to the physical landscape, to watercourses and meltwater pathways and disturbance of the permafrost;
- Changes to soil quality, release of soil salts and changes of the depth to ice-cement;
- Physical damage, destruction and modification in the distribution, abundance or biodiversity of terrestrial flora and micro fauna; and
- Contamination of the nearshore marine environment and smothering of the nearshore biota from increased sediment discharges.

The operation of the proposed Scott Base and wind farm, on completion of the proposed activities, is expected to result in the following environmental impacts:

- Changes to baseline intrinsic values as a result of the changes in the appearance of Scott Base and the wind farm; and
- Changes in the intensity of potential contamination of the terrestrial and marine environments from accidental releases of hazardous substances due to increased volumes of hazardous substances stored at Scott Base.

In general, the proposed activities are expected to deliver a number of benefits on the environment including:

- Reduced contribution to global climate change thanks to increased generation of renewable energy and greater efficiency of buildings and systems of the proposed station;
- Reduced contamination of the local marine environment through best practice wastewater treatment;
- Reduced risk of introduction of non-native species with fit-for-purpose dedicated biosecurity facilities;
- Increased ability to support scientific research through improved lab spaces and better facilities;
- Improved resilience supporting New Zealand’s ability to conduct scientific research safely and efficiently; and
- Improved facilities that support the wellbeing and health and safety of Scott Base’s occupants better than the current station.

Mitigation measures

Preventative mitigation measures were considered at the outset of the project and integrated into the design of the proposed Scott Base. In summary, preventative mitigation measures include:

- Selecting an existing, highly impacted site, rather than finding a new, less impacted, site for Scott Base;
- Developing and applying a bespoke rating tool to build a sustainable Antarctic station;
- The proposal to upgrade the Ross Island Wind Energy network to support either 80% or 98% renewable energy use by Scott Base;
- Restricting construction and operational activities to the highly impacted operational area as far

as practicable;

- Construction of the proposed station in New Zealand, thereby minimising the transport of materials and waste between New Zealand and Antarctica and reducing the build time;
- Early engagement of the preferred main contractor with environmental management requirements;
- The utilisation of existing infrastructure to establish a temporary base; and
- A full-time environmental advisor dedicated to the Scott Base Redevelopment project.

Mitigation measures for the proposed activities are planned to be delivered through Antarctica New Zealand's Environmental Management System and project-specific mitigation and monitoring measures. A Construction Environmental Management Plan is under development, supported by a suite of specialised management plans, including but not limited to waste management, contaminated land remediation and biosecurity control.

Monitoring programmes
Antarctica New Zealand has established a monitoring programme that commenced in advance of, and will continue throughout and beyond the Scott Base Redevelopment, made of three components:

- The monitoring programme established as part of this draft CEE;
- Monitoring of construction activities, defined through the Construction Environmental Management Plan and topic-specific management plans; and
- Monitoring through the existing environmental and carbon management systems as part of the Antarctica New Zealand's Environmental Management System.

Gaps in the knowledge
The scope and timeline of the proposed activities are based on funding being granted in its entirety in the 2021/22 Financial Year. Should the project's funding be deferred, or partially granted, this draft CEE would be reviewed and updated as necessary.

This draft CEE was prepared using the design information known at the time of drafting. The temporary base and the Ross Island Wind Energy network replacement were at a feasibility stage only. While significant departures from the proposed activities described and assessed in this draft CEE are not anticipated, minor changes to the final design and delivery of the activities may occur.

The proposed construction and logistics strategies rely on a large vessel being able to berth at Pram Point. There is a high degree of confidence in the suitability of the location, with final confirmation expected in early 2021, after the finalisation of this draft CEE.

Conclusions
Following the comprehensive assessment of the proposed activities and associated mitigation measures, it is concluded that the proposed activities are likely to have **more than a minor or transitory impact on the Antarctic environment**. This draft CEE concludes that the proposed activities should proceed on the basis that the positive impacts in terms of improvements to safety, environmental protection and ability to support science are greater overall than the negative impacts associated with the proposed activities.

1. Introduction

Antarctica New Zealand has prepared this draft Comprehensive Environmental Evaluation (CEE) to assess the potential environmental impacts associated with the Scott Base Redevelopment. The project has two main components: the design and build of a new station and the replacement of the windfarm. The proposed activities are required because the current Scott Base buildings, facilities and associated infrastructure and the wind farm are reaching the end of their functional life, and health and safety and environmental risks are escalating. The base is also becoming increasingly expensive to operate and maintain, and almost infeasible to incrementally renew or upgrade.

1.1 Antarctica New Zealand

Antarctica New Zealand is a Crown Entity, established on 1 July 1996 by the New Zealand Antarctic Institute Act 1996. Antarctica New Zealand's functions as set out in the Act are:

- To develop, manage and execute New Zealand's activities in Antarctica and the Southern Ocean;
- To maintain and enhance the quality of Antarctic scientific research; and
- To co-operate with other institutions and organisations both within and outside New Zealand that have similar objectives.

Key activities of Antarctica New Zealand include facilitating scientific research, protecting the natural Antarctic environment and raising public awareness of the global significance of the Antarctic continent and surrounding Southern Ocean (Antarctica New Zealand's 2019-2023 Statement of Intent).

Antarctica New Zealand's vision is:
Antarctica and the Southern Ocean: Valued, Protected and Understood.

Antarctica New Zealand's main office is located in Christchurch, New Zealand. It is responsible for the management of Scott Base, New Zealand's permanent research station in the Ross Sea region, Antarctica (Figure 1). Scott Base is approximately 3,800km south of Christchurch and 1,350km from the South Pole (Figure 2) and has operated year-round since 1957 on Pram Point, Ross Island.

Figure 1: Scott Base on Pram Point, Ross Island, McMurdo Sound (© Anthony Powell, 2017).

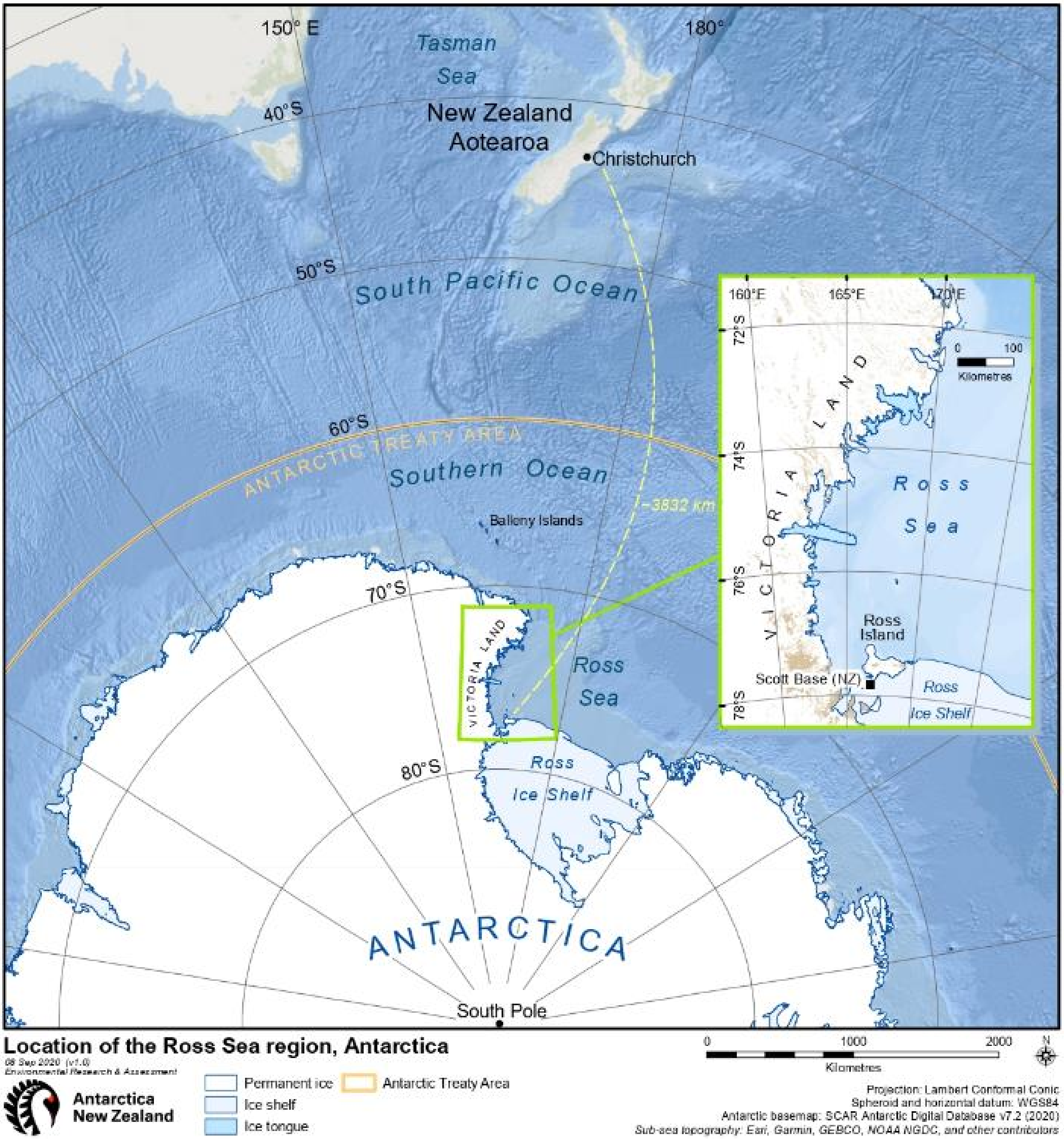

Figure 2: New Zealand in relation to Antarctica and Scott Base.

1.2 Scott Base

Scott Base is located on Pram Point, at the southern tip of Hut Point Peninsula on Ross Island, McMurdo Sound (77° 55'S 166° 46 E), approximately 3km from the United States Antarctic Program (USAP) McMurdo Station (Figure 3, Figure 4).

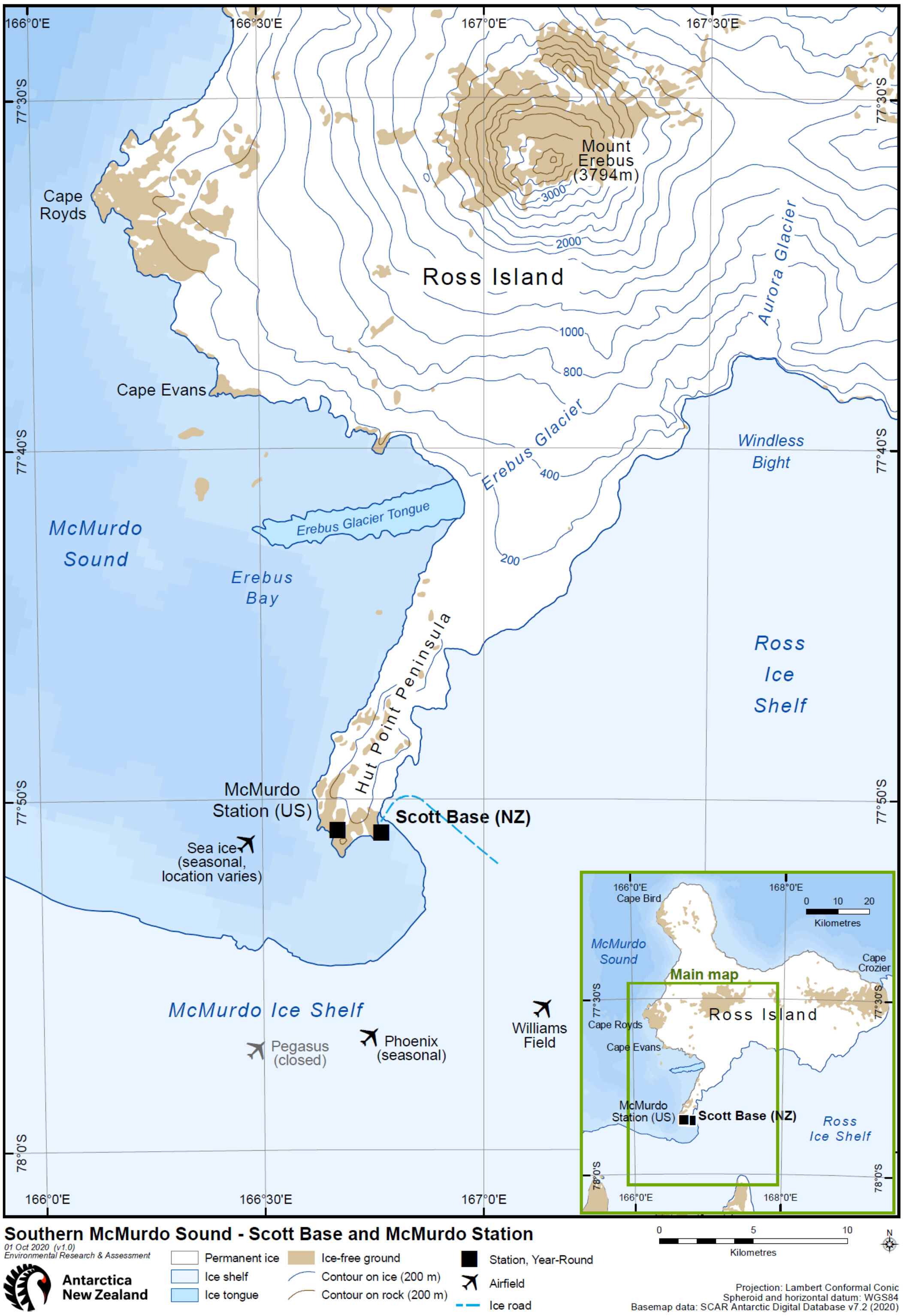

Figure 3: Southern McMurdo Sound, Scott Base and McMurdo Station.

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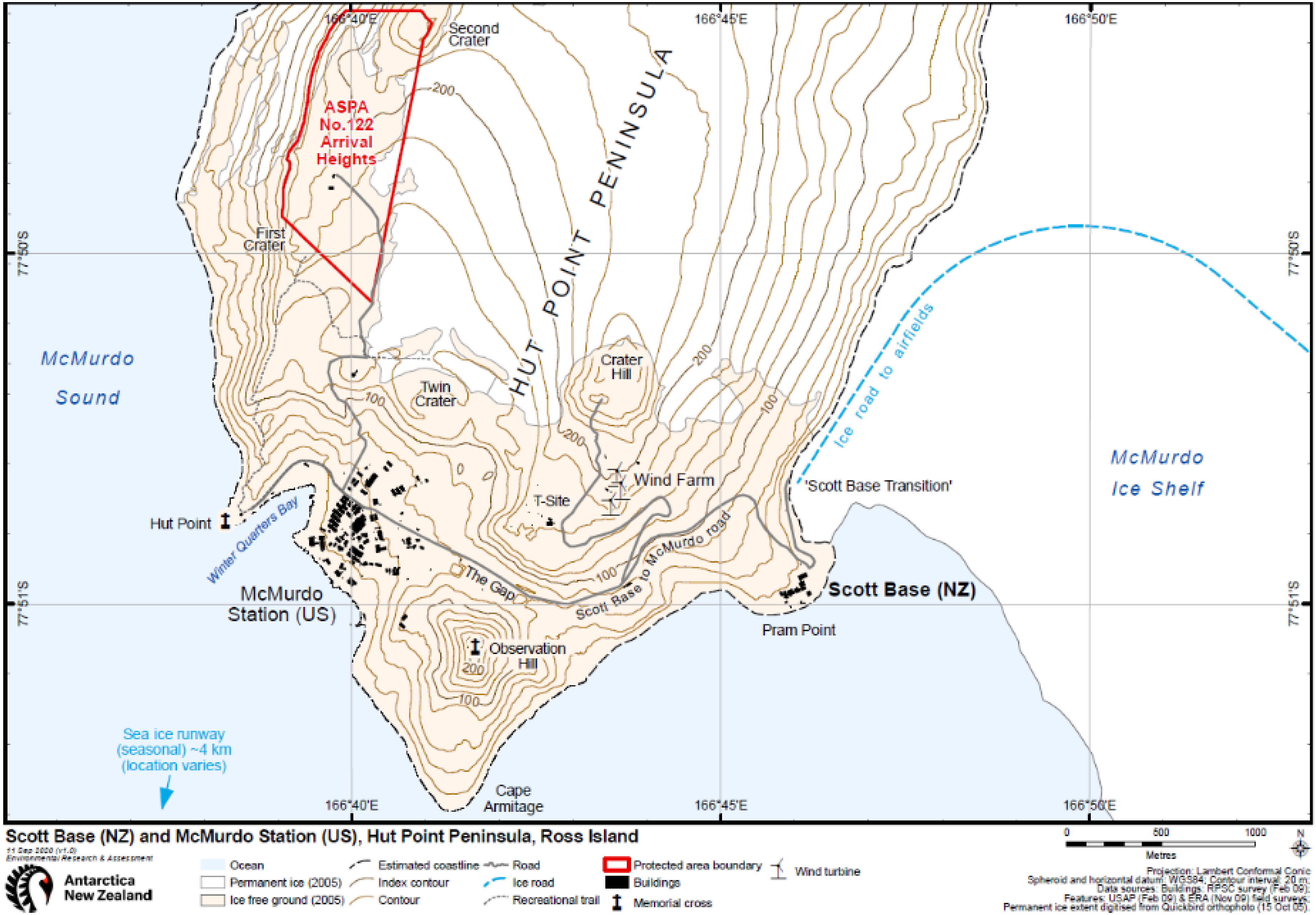

Figure 4: Scott Base and McMurdo Station, Ross Island.

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Scott Base was established in the summer of 1956/57, with the support of the New Zealand government, to plan and oversee New Zealand's involvement in the Commonwealth Trans-Antarctic Expedition (TAE) (1955-1958) and the International Geophysical Year (IGY) (1957-1958). Ground and aerial reconnaissance of the initial proposed site, a rocky spur adjacent to Butter Point on the western side of McMurdo Sound, proved unsuitable. After discussion with Rear Admiral George Dufek, United States Navy (USN), Commanding Officer for Naval Support Force, Operation Deep Freeze 2, Captain Gerald Ketchum USN and Captain John Wiis USN, Pram Point on Ross Island was identified as a suitable location for Scott Base (Harrowfield, 2007). Pram Point provided broad rock terraces, access from the sea ice and ideal aircraft landing locations nearby. Scott Base was officially opened on 20 January 1957 (Figure 5).

The IGY began in July 1957, and the winter-over team of five scientists carried out observations on the ionosphere, geomagnetism, aurora, seismology, gravity and Very Low Frequency (VLF) signals and meteorology. In October 1957, several survey parties left Scott Base to carry out scientific field observations. Simultaneously and independent of the TAE and IGY, and with the United States supported logistics, New Zealand's first geological expedition worked in the Tucker Glacier region of North Victoria Land.

The TAE was a Commonwealth expedition, sponsored by the governments of the United Kingdom, New Zealand, United States, Australia and South Africa. The expedition completed the first overland crossing of Antarctica via the South Pole. It was the first expedition to reach the South Pole overland since both Amundsen and Scott's expeditions in 1911 and 1912. The goal of the New Zealand Ross Sea support team, led by Sir Edmund Hillary, was to establish a base and to lay supply depots from the Ross Sea to the South Pole to support Dr. Vivian Fuchs, leader of the TAE, who was crossing the continent from the Weddell Sea. The overland party arrived at Scott Base on 2 March 1958, successfully completing the historic crossing.

In the same month, the New Zealand government took over Scott Base from the TAE. It announced the appointment of a Ross Dependency Research Committee responsible to the Minister in charge of the Department of Science and Industrial Research, to coordinate and supervise New Zealand's continuation of science and research activities in Antarctica (Templeton, 2000). The decision resulted in Scott Base becoming New Zealand's permanent research station in Antarctica.

Figure 5: Raising of the Flag ceremony at the opening of Scott Base 20 January 1957.

The original Scott Base consisted of six buildings connected by covered walkways designated Building A - F, including a main hut with the mess, galley, radio room and leaders' office (Hut A), scientific hut (Hut B), sleeping hut (Hut C), additional accommodation and medical room (Hut D), ablutions and generators (Hut E) and a workshop (Hut F). The station was only intended to be temporary and designed to last for the period of the IGY. Therefore, an extensive building and maintenance programme was undertaken and by the summer of 1962, Scott Base was a permanent station consisting of 11 interconnected buildings and five separate dedicated science buildings. In 1965, the original orange and yellow and corrugated iron buildings were repainted to the now green colour of the present-day Scott Base.

The huts and buildings underwent a systematic rebuilding process starting in 1976 with completion in 1988. Recently, Antarctica New Zealand commissioned a two-storey, 1,800 square metre heated warm store at Scott Base, the Hillary Field Centre (HFC), which became operational in the 2005/06 season and was upgraded in 2017 to improve science support facilities. Figure 6 shows the various station iterations and approximate building locations over time since 1957.

There are only three of the original 1957 buildings remaining today. These are Hut A, also known as the TAE Hut (designated Historic Site and Monument No. 75), and Huts G and H, known as the magnetic huts. These three huts are still maintained and in use. In the 2016/17 season, Hut A underwent a significant restoration and conservation project with the work completed in time to mark the 60th anniversary of Scott Base (Watson, 2018) (Figure 7).

Today, Scott Base consists of 11 buildings connected by link ways (Figure 8). There are alos several outbuildings in the vicinity of Scott Base, as well as others on Hut Point such as the New Zealand research facility at Antarctic Specially Protected Area (ASPA) No. 122 Arrival Heights and the wind farm buildings, which are maintained by Antarctica New Zealand (Figure 4). Scott Base can currently accommodate up to 86 people with temporary accommodation for a further 12 people.

Antarctica New Zealand employs a summer team of approximately 35 staff between September to February and a smaller (11-13 person) winter-over team between February to September. The role of the teams is to ensure that the station facilities and services are maintained year-round and to support Antarctic science and environmental protection work.

Figure 6: Evolution of Scott Base buildings over time.

Figure 7: TAE Hut following restoration to original colours.

Figure 8: Scott Base today, TAE Hut in foreground.

1.3 New Zealand Antarctic research

New Zealand has been conducting scientific research in the Ross Sea region of Antarctica for more than 60 years. New Zealand's Antarctic research programme is supported by several government agencies (including Crown Research Institutes, Universities and central government Ministries), which provide funding for science. Antarctica New Zealand provides logistical support with funding from the Ministry of Foreign Affairs and Trade.

New Zealand's Antarctic research programme is multidisciplinary and focuses on a broad range of scientific endeavours to better understand Antarctica and its role in whole-earth systems. Research teams operating from Scott Base work in a wide variety of locations throughout the Ross Sea region, from Cape Adare at the northern extent of the Ross Sea, to the Siple Coast on the southern side of the Ross Ice Shelf – a distance of nearly 2,000km (Figure 9).

Scott Base also supports several Long-Term Science (LTS) programmes. These include measurements of atmospheric ozone and greenhouse gas concentrations, the strength and direction of Earth's magnetic field, gravity and sea level, lightning activity and associated energy inputs to the upper atmosphere, Adélie penguin numbers, toothfish abundance, and weather and soil climate. These longstanding programmes provide important time-series from which we can detect, attribute and monitor changes to the ocean, atmosphere, climate, and ecosystems. These programmes represent some of the longest-running Antarctic datasets of their type (Table 1).

Table 1: Long-term monitoring programmes supported at or from Scott Base.

Monitoring Programme	Year established	Description (location)
Magnetic measurements	1911 (Cape Evans) 1974 (Lake Vanda, McMurdo Dry Valleys)	Measurements of the strength and direction of Earth's magnetic field (Cape Evans, Lake Vanda, McMurdo Dry Valleys).
Absolute gravity and sea level	1957	Combined measurements of gravity and sea level, which assist with monitoring sea-level rise (Scott Base; Cape Roberts).
Climate measurements	1957	Daily weather recordings (Scott Base).
Adélie penguin census	1981	Penguin abundance measured using high-resolution aerial photography (at multiple colonies throughout the Ross Sea region).
Middle atmosphere	1982	Remote sensing measurements made using medium frequency radar and satellite data to understand how the middle atmosphere affects ozone (Scott Base).
Atmospheric composition	1982	Measurement of changes and trends in greenhouse gases and the evolution of the ozone hole (Arrival Heights).
Soil climate stations	1999	Soil temperature and climate data collected from a network of soil climate stations and boreholes to understand the impacts of a warming climate on permafrost stability (McMurdo Dry Valleys).
Space weather	2008	Data collected to determine how the Sun and space impact the environment and technological systems (Scott Base).
Ross Sea toothfish survey	2012	Annual long-line survey of toothfish in the Southern Ross Sea (onboard commercial fishing vessels).

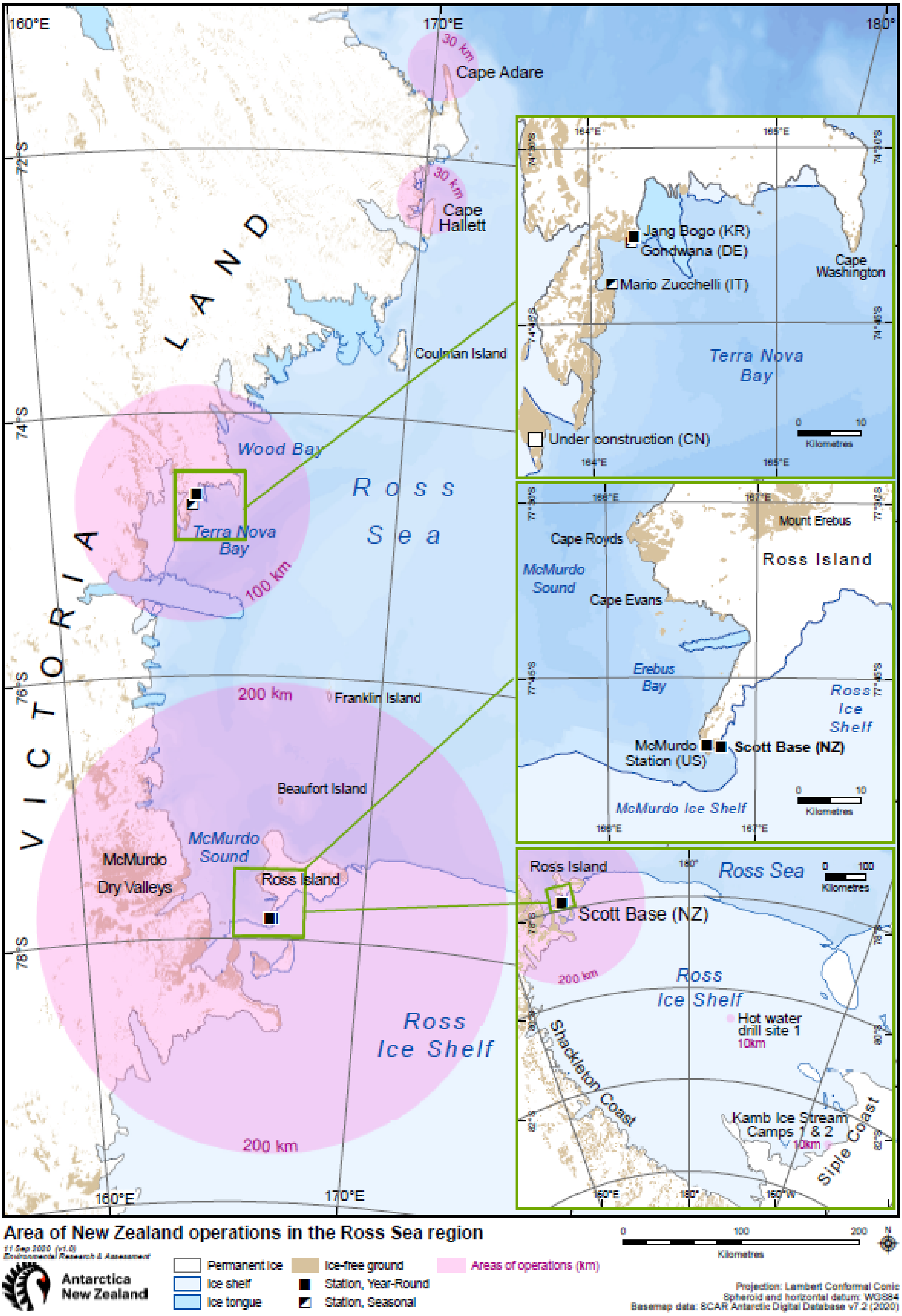


Figure 9: Antarctica New Zealand area of operation.

Since the 1960s, research in the McMurdo Dry Valleys has been a major focus for New Zealand with significant contributions made to understanding the region's geology (Webb & McKelvey, 1959; Cox, et al., 2000), pedology (Campbell & Claridge, 1987), microbiology (Cary, et al., 2010) and aquatic systems (Chinn, 1993; Vincent, 1981; Howard-Williams & Hawes, 2007) of the region. New Zealand researchers continue a long-standing participation in the United States' McMurdo Dry Valleys Long Term Ecological Research Program which has supported inter-disciplinary science in the Dry Valleys since 1992.

New Zealand has played a leading role in the development of remote geological and glaciological scientific drilling technology. This began through New Zealand's involvement in the Dry Valleys Drilling Project, which had the aim of reconstructing Antarctic geological history using direct shallow drilling techniques that traditional surface or near-surface studies alone could not achieve (McGinnis, 1981). Support for research and logistics was coordinated among groups from Japan, New Zealand, and the United States. In total, 15 boreholes ranging in depth from 4 to 381m were drilled between 1971 and 1975 enabling a more detailed reconstruction of the late Miocene through Pleistocene glacial and climatic history of the McMurdo Sound/Dry Valleys area.

The success of the Dry Valleys Drilling Project provided the basis for subsequent multi-national offshore and subglacial geological drilling programmes in the Ross Sea region including the Cenozoic Investigations of the western Ross Sea (CIROS), Cape Roberts Project and ANDRILL programmes, in which New Zealand played a leading role, in cooperation with scientists from Australia, Germany, Italy, the United Kingdom and the United States. In 1986, the CIROS-1 core was drilled 702m into the sea floor, under McMurdo Sound sea ice, in the Ross Sea. It was the first to extend as far back as the Eocene (~36 Million years ago) and the first to record the inception of Antarctic glaciation at the pivotal Eocene-Oligocene transition (~34 Million years ago) (Hambrey, et al., 1989). In the 1990s, three sites cored in McMurdo Sound by the Cape Roberts Project (Davey, et al., 2001) provided the first evidence of the response of Antarctic glaciers to orbital forcing in the Oligocene and Miocene (~23 Million years ago) (Naish, et al., 2001).

The Cape Roberts Project was succeeded by the ANDRILL McMurdo Ice Shelf (Naish, et al., 2007) and Southern McMurdo Sound projects (Harwood, et al., 2009) in 2006/07, which drilled cores extending from the Oligocene into the Pleistocene (~33 to 1 Million years ago), temporally overlapping ice core records at the younger end and Cape Robert Project cores at the older end, thus providing a complete paleoclimate record for the Cenozoic in Antarctica. Notable results from ANDRILL include the first Antarctic record of the Mid-Miocene Climatic Optimum and evidence of open-water conditions in the Ross Embayment during the Pliocene (Florindo & Lurcock, 2017). The Mid-Miocene Climatic Optimum (~17 to 15 Million years ago) is a period of global warmth and relatively high CO_2 atmospheric concentrations and is thought to be associated with a significant retreat of the Antarctic Ice Sheet (Foster, et al., 2012). The period is viewed as good analogues to climate change under present CO_2 emission scenarios. ANDRILL was led by research teams from New Zealand, Italy, Germany and the United States.

In addition to geologic drilling, New Zealand researchers have also made notable contributions to ice core research. Through the International Trans-Antarctic Scientific Expedition, a series of intermediate length (<500m) ice cores from the Ross Sea region were recovered from remote locations, including Roosevelt Island on the eastern side of the Ross Ice Shelf. Data obtained from these coastal ice cores demonstrated that the El Niño Southern Oscillation forcing, primarily in the form of El Niño events, governs temperature variability in the Ross Sea region (Bertler, et al., 2004).

Beginning in the austral summer of 2003/04, New Zealand coordinated the Latitudinal Gradient Programme (LGP) a decade-long programme under which several collaborative research projects were undertaken by New Zealand, Italy and the United States. A total of 18 LGP projects studied terrestrial, marine, and freshwater ecosystems along the Victoria Land coast from Cape Hallett in the north (72˚S) to the La Gorce Mountains in the south (86˚S). The LGP was a significant project of the Scientific Committee on Antarctic Research (SCAR) Biology Evolution and Biodiversity programme with outcomes published in special editions of the journal *Antarctic Science*. (Howard-Williams & Peterson, 2006; Howard-Williams, et al., 2010). Key findings include recognition that some species of terrestrial invertebrates have survived multiple glacial cycles over millions of years in isolated refugia. Similarly, this research programme identified microclimate rather than latitude as the key factor in controlling species distribution and the extent to which they can succeed in Antarctica.

New Zealand also contributes to the Polar Earth Observing Network (POLENET). The project primarily focuses on collecting GPS and seismic data from autonomous systems that together provide a means to answer critical questions about ice sheet behaviour in a warming world. Complementary geophysical observations include magnetics, tide gauge, and gravity measurements (POLENET, 2020). Magnetics measurements contribute to the World Magnetic Model, the standard model used for navigation, attitude and heading referencing systems.

Historically, New Zealand has played a leading role in Antarctic research through a series of research programmes, often involving international collaboration. In addition to Scott Base, a joint United States and New Zealand station was established in 1956 at Cape Hallett as part of the IGY. It operated continuously until 1973 supporting a range of science including ecology, biology, and meteorology. In 1984, the United States and New Zealand collaborated on a joint clean-up effort to remove the station and associated infrastructure. The site was progressively remediated with the last remaining substantial items removed in January 2010 with logistics support from the Italian National Antarctic Programme. Vanda Station, established by New Zealand in the McMurdo Dry Valleys in the late 1960s, also supported a range of meteorological, hydrological, seismological and magnetics research initiatives, some of which continue today. The station also supported a series of studies on Lake Vanda itself – some of the earliest research on inland aquatic environments to be undertaken in Antarctica. Most of the Vanda Station buildings were removed in the 1990s.

Today, New Zealand's Antarctic research focus is underpinned by a unifying theme of global change. This focus is guided by the New Zealand Antarctic Science Strategy outlined in the New Zealand Antarctic and Southern Ocean Science: Directions and Priorities 2010-2020 (currently under review). The science strategy identifies three high-level areas of research (Table 2).

Table 2: New Zealand Science Strategy strategic research areas.

Outcome	Objective
Climate, cryosphere, atmosphere and lithosphere	Improved understanding of the past and current state of Antarctica, its significance, and implications of the role of Antarctica in global change and implications of global change for Antarctica.
Inland and coastal ecosystems	Improved understanding of inland and coastal ecosystems of the Ross Sea region leading to enhanced knowledge, conservation and protection priorities in Antarctica.
Marine systems	Improved conservation and resource management of the Antarctic marine environment.

In 2018, the Antarctic Science Platform was established through a Strategic Science Investment Fund to conduct excellent science and to understand Antarctica's impact on the global Earth system and how this might change in a +2°C (Paris Agreement) world. The Platform is hosted by Antarctica New Zealand and research undertaken by the Platform is centred on two programmes that investigate: 1) the Antarctic ice-ocean-atmosphere system and; 2) the Ross Sea region ecosystem dynamics in a warming world. Four core projects address key questions that contribute to these major programmes

(Table 3).

Table 3: Antarctic Science Platform priorities.

Research Programme	Project	Description
Antarctic Ice-Ocean-Atmosphere Dynamics	1. Antarctic ice dynamics, past, present and future	Understanding the response of the West Antarctic Ice Sheet to projected warming.
	2. Antarctic ocean atmosphere coupling	Understanding the Ross Sea ocean-atmosphere system, with a focus on processes that influence the import of warm waters to Antarctica.
Ross Sea region ecosystem dynamics in a changing world	3. Ross Sea region ecosystem dynamics	Understanding the sensitivity of the Ross Sea region's ecosystems to warming.
	4. Sea ice and carbon cycle feedbacks	Understanding Antarctic sea ice behaviour to predict its and its role in the global climate system.

The Ross Sea Region Research and Monitoring Programme (Ross-RAMP), launched in 2018, is a five-year research programme aimed at evaluating the effectiveness of the Ross Sea Marine Protected Area (MPA). Ross-RAMP and the New Zealand Antarctic Science Platform work together to anticipate the effects of climate change in the Ross Sea region and help inform appropriate monitoring and management strategies.

1.4 International collaboration and cooperation

New Zealand has a long history of Antarctic engagement. Early exploration of the continent saw many expeditions using New Zealand as a stepping stone on the journey to "the ice". As part of the 1893-1895 Norwegian Sydishavet Expedition, a New Zealander Alexander von Tunzelmann was possibly one of the first people to set foot on the continent when they landed at Cape Adare on 24 January, 1895. The heroic era expeditions of Carsten Borchgrevink (1899-1900 British Antarctic Southern Cross Expedition), Captain Robert Falcon Scott (1901-1904 National Antarctic Discovery Expedition and the 1910-1913 British Antarctica Terra Nova Expedition) and Sir Ernest Shackleton (1907-1909 British Antarctic Nimrod Expedition) all used New Zealand as a departure point and included New Zealanders amongst the crew. As part of the TAE, Sir Edmund Hillary led the third team ever to reach the South Pole overland.

To date, Christchurch is used as a gateway city by several National Antarctic Programmes, including those of the United States, Italy, Korea and China. Other countries also use the air-bridge or Lyttelton Port as a departure point towards the Ross Sea region. Antarctica New Zealand and the Christchurch City Council (through the Christchurch Antarctic Network) continually seek to find ways of supporting other National Antarctic Programmes to operate through Christchurch.

As an original signatory to the Antarctic Treaty, New Zealand has been involved in negotiations of all the instruments of the Antarctic Treaty System[1] and has made significant contributions to Antarctic research since the establishment of Scott Base. Environmentally, New Zealand has had significant achievements such as producing the first state of the environment report (2001) for the Ross Sea region, co-sponsoring with the United States and Italy the first Antarctic Specially Managed Area (ASMA), the McMurdo Dry Valleys, supporting the conservation of the heroic era historic huts in the Ross Sea region, project management of the development of the Antarctic Environments Portal and co-sponsoring with the United States the Ross Sea region MPA. New Zealanders have held leadership

[1] New Zealand has not ratified the Convention for the Conservation of Antarctic Seals as it does not conduct sealing activities.

positions with the Antarctic Treaty Consultative Meetings (ATCM), the Committee for Environmental Protection (CEP) and SCAR.

International collaboration has been a crucial element of the New Zealand Antarctic Programme since its establishment in the late 1950s. New Zealand has cooperated particularly closely with the United States on both logistics and science activities since McMurdo Station, Scott Base and Hallett Station were all established during the IGY in 1957. The road that links McMurdo Station and Scott Base was completed in 1966/67 season and is used daily in the summer to this day. The United States/New Zealand Joint Logistics Pool (JLP) has provided the basis for running logistical collaborations and delivers greater operational efficiency and resilience for both programmes. The JLP includes cooperation both in Antarctica and in Christchurch.

Intercontinental flights and intracontinental helicopter and fixed wing resources are shared under the JLP. The United States provide the shipping for annual resupply of McMurdo Station and Scott Base, including fuel for both stations. Search and Rescue operations are also conducted jointly. More generally, both programmes work closely together on a daily basis and have forged strong relationships over 60 years of collaboration.

New Zealand has been effective in establishing enduring relationships with National Antarctic Programmes and researchers from other Antarctic Treaty Parties, in particular those with established stations in the Ross Sea region including China, Italy, the Republic of Korea and Germany. Personnel regularly transit through or work out of one another’s stations, share resources for fieldwork and collaborate on research projects. For example, the Republic of Korea has hosted New Zealand scientists at Jang Bogo Station, supplied them with logistical support for their fieldwork and scientists have worked collaboratively at Cape Hallett. China has supported New Zealand historical hut conservation activities at Cape Adare over two summer seasons and Italy has hosted New Zealand scientists working in the region at Mario Zucchelli Station. The Scott Base Redevelopment offers an opportunity to continue and enhance those relationships.

1.5 The case for the Scott Base Redevelopment

Scott Base continues to support the New Zealand Antarctic research programme. However, the last complete redevelopment of the station was nearly 40 years ago in the 1980s, before the implementation of the Protocol. As such, no construction or refurbishment activities of Scott Base have been subject to an EIA to date, except for the Hillary Field Centre (HFC) and the Ross Island Wind Energy network (RIWE). The base has served New Zealand well – and longer than ever expected – but many of the structures have reached the end of their effective life and their environmental performance falls short of today's standards.

The current Scott Base faces many issues with ageing buildings and functionality. The outdated buildings, facilities and life support systems are deteriorating and no longer functioning as designed. The station is becoming harder to maintain, impacting on operational efficiency and the buildings do not comply with some areas of the New Zealand safety legislation and other requirements. In addition, past building practices and decommissioning resulted in ground contamination around the station that requires attention.

In short, Scott Base has deteriorated to a point where there are increasing risks to health, safety and the environment. The base is also becoming increasingly expensive to operate and maintain and it is becoming practically unfeasible to incrementally renew or upgrade the existing infrastructure.

1.5.1 Building structure and operation

A Condition Assessment was recently conducted at Scott Base to assess individual buildings for architectural and structural integrity, fire safety and overall compliance with the New Zealand Building Code. The rating for buildings could range from "Very Good" (1) to "Very Poor" (5) (Table 4). Buildings that rated as "Moderate" (3) or higher require full replacement within ten years to preserve the safety of the station's occupants. The assessment highlighted that 10 of the 11 existing Scott Base buildings are in "Poor" (4) condition and one is in "Moderate" (3) condition (Figure 10). The Condition Assessment Report concluded that the current Scott Base is in a poor state and is continuing to deteriorate.

The effort (cost and difficulty) required to resolve issues and upgrade the buildings was also assessed as part of the report. The "effort to resolve" rating evaluates the degree of effort required to upgrade and the urgency to replace existing buildings to achieve compliance with the New Zealand Building Code. Overall, the Scott Base buildings were found to be difficult to maintain and unable to achieve or maintain compliance without a full rebuild.

Table 4: Building condition rating scale from the Condition Assessment Report.

5	Very Poor	Asset fails to meet performance requirements and is of immediate concern
4	Poor	Asset performance is poor with a moderate to high compliance risk
3	Moderate	Asset performance is marginal with a low to moderate compliance risk
2	Good	Asset generally meets performance requirements but maintenance due soon
1	Very Good	Asset fully meets both performance and durability requirements as if new

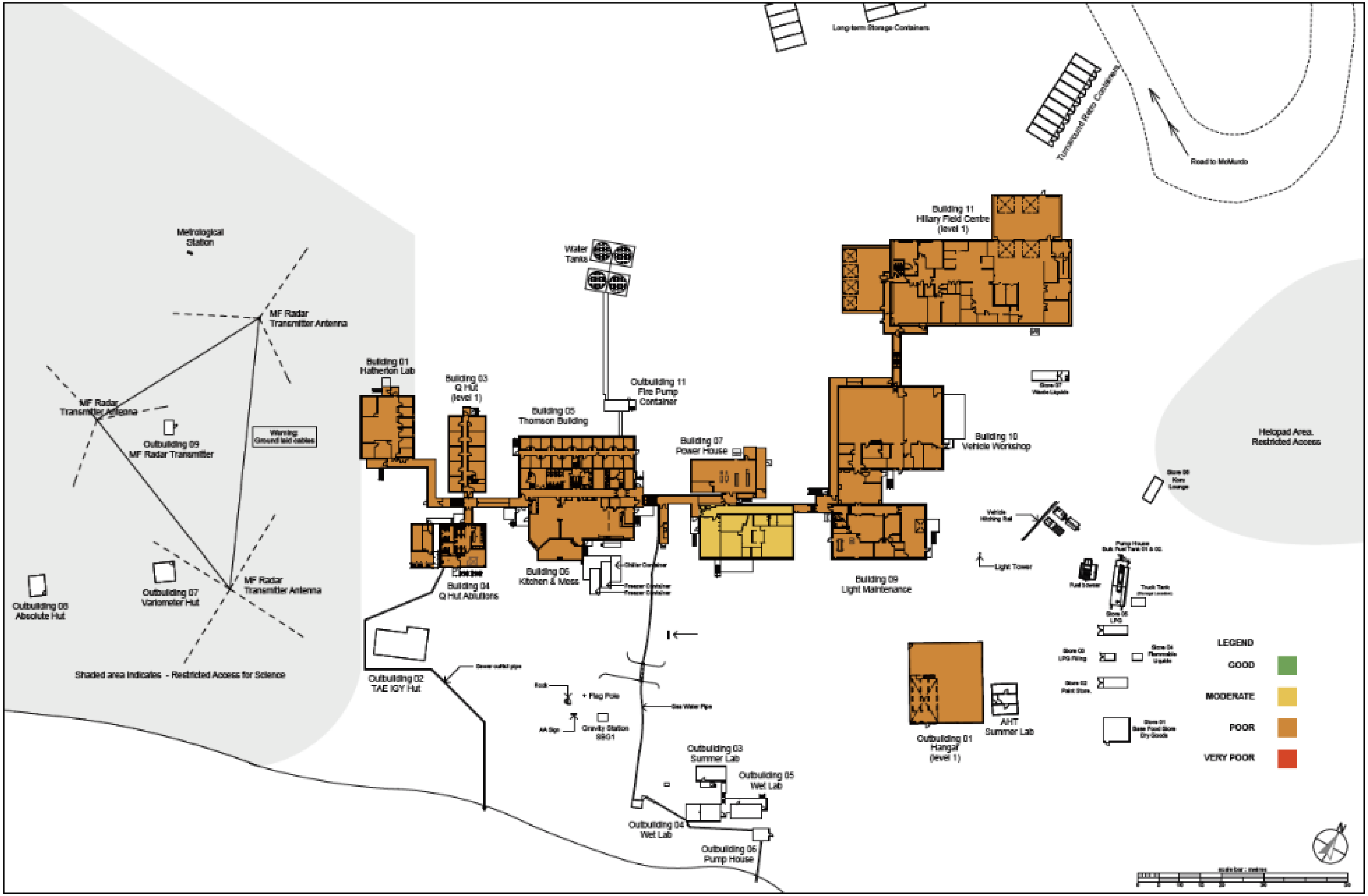


Figure 10: Existing Scott Base site plan with building condition rating.

Some specific structural and operational challenges with the current station include:

- Building cladding is old and is leaking, which creates a hazard and increases demand for heating and fuel reserves;
- The extreme cold and dryness of the environment has caused ageing building materials to shrink and warp, resulting in snow and water ingress inside the station;
- The level of passive fire protection within the existing Scott Base buildings has been assessed as inadequate by Fire and Emergency New Zealand and independent experts. The ageing electrical systems also increase the fire risk[2];
- Cables and pipes are housed under the floor. The confined area makes them difficult and time-consuming to access for maintenance and repairs;
- The majority of engineering and life-support systems (the provision of heat, power, water and sanitation services) are now operating beyond their intended lifespan. There are many single points of failure that would have significant impacts on Antarctica New Zealand's ability to provide safe living conditions at Scott Base, including:
  - There is no back-up in case of failure of one of the life-support systems. A failure would require costly and time-consuming repairs that would take priority over supporting scientific research.
  - The reverse osmosis water supply system is 20 years beyond its design life and has started to fail.
  - The water intake was ripped from its foundations on the shoreline in a storm in the 2013/14 season and remains vulnerable. The wastewater outfall is impacted by shoreline erosion.
  - Critical water storage tanks suffered major leaks in the winter of 2018.
  - The wastewater treatment plant (WWTP) requires constant maintenance and repairs to function. The plant is fragile and its failure would result in significant health, safety and environmental risks.
  - Maintaining equipment is a constant challenge as systems become increasingly obsolete. Spare parts are difficult or impossible to source and have to be fabricated in New Zealand or abroad before being brought to Scott Base.
- The sprawling layout of the station requires intensive snow management to maintain safe access to buildings. Snow clearance requires the use of heavy machinery, therefore fossil fuels, and significant staff time; and
- Access to roofs is difficult to achieve consistently in a safe manner.

Figure 11 and Figure 12 provide examples of the operational and infrastructure problems with Scott Base.

[2] Interim action taken in response includes remediation to mitigate failings in the fire protection system where feasible and Antarctica New Zealand maintains active control systems and responses through the 24/7 presence on station of a fully-trained fire crew.

Figure 11: Example of snow management required at Scott Base.

Figure 12: Examples of maintenance and infrastructure issues at Scott Base.

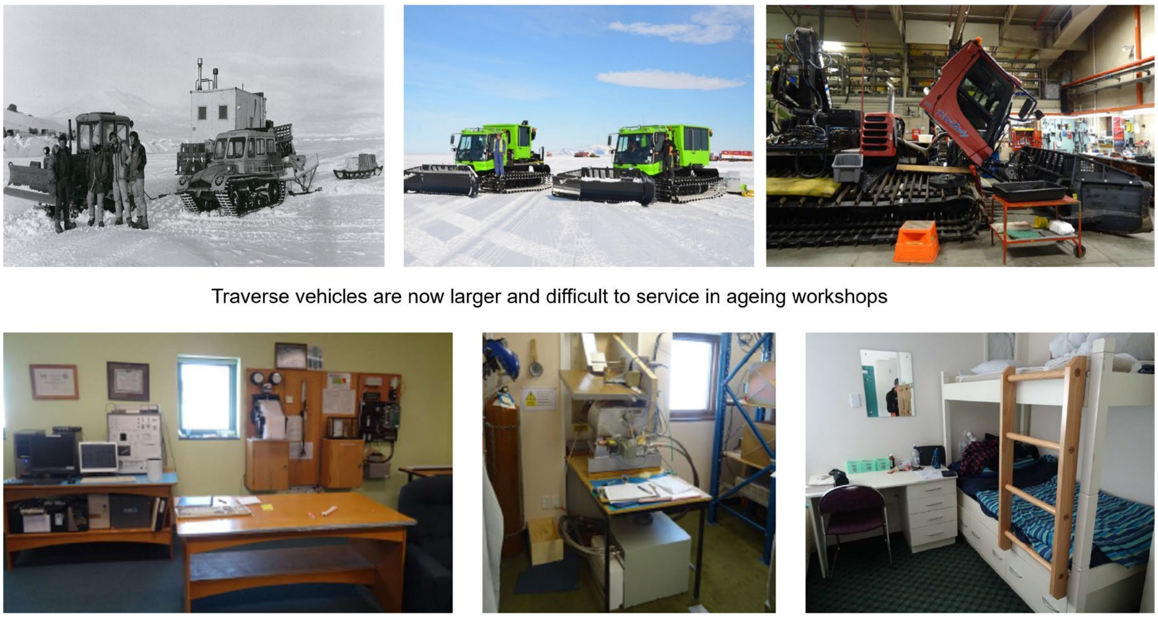
1.5.2 Building functionality

In addition to the structural and operational challenges, the functionality of the existing station is no longer fit for purpose. Scott Base has been modified many times to suit changing requirements and the layout is now inefficient.

Specific problems with functionality of the current station include:

- Housing people in small multiple occupancy bedrooms (bunk rooms) with poor noise separation makes sleeping difficult, increasing fatigue;
- The station population can exceed the maximum number of beds available (86) at peak times of the season or when travel back to New Zealand is delayed. Up to 100 people may need to be accommodated, leading to overcrowding of common areas and to some occupants having to sleep outside in modified shipping containers for a few nights;
- Scott Base was built and then upgraded when vehicles and machinery were smaller. Maintenance workshops are no longer large enough or suitably configured for the current vehicle fleet;
- The science facilities are increasingly unsuitable for supporting current research requirements.
  - Some instruments are located in places that are no longer suitable, such as the Hatherton lab that doubles up as a movie room and public computer space. Datasets and instruments are at risk of being accidentally compromised.
  - Other science facilities such as the marine lab (shown as Outbuildings 3-5, Figure 10) are dated and unable to support specific marine research needs.
  - Different science disciplines often share the same lab and preparation spaces, which is becoming unsustainable.

Figure 13 shows some examples of functionality issues.



Traverse vehicles are now larger and difficult to service in ageing workshops

Instruments are housed in multiple-use spaces | CLOE instrument | Accommodation is cramped

Figure 13: Examples where Scott Base is no longer functional.

1.5.3 Historical ground contamination

A land contamination assessment undertaken in the 2017/18 season confirmed the widespread presence of asbestos-containing material (ACM) fragments on the ground surface, as well as asbestos fibres in the soils, with concentrations above human health standard guidelines (Ministry for the Environment, 2011) in some areas surrounding Scott Base (Figure 14). The presence of asbestos is the result of the demolition of old Scott Base buildings, in particular during the 1970s and 1980s upgrades, when waste management practices were not as well considered as they are today. Several years of earth movement and wind erosion have spread the fibres over a large area (Figure 15). The legacy of these practices is a risk to human health from the inhalation of asbestos fibres. Remediation works took place in the 2018/19 season to encapsulate the highest concentrations of ACMs (found within the footprint of the old buildings) and to manage the lower concentration areas, and remove visible ACM fragments.

The land contamination assessment also found several isolated areas of hydrocarbon contamination in the surface soil layers, associated with past fuel and chemical storage sites and spills (Figure 15). The concentrations present an acceptably low risk to human health, in line with the criteria for commercial and industrial land use (Ministry for the Environment, 2011). The risk to the environment is considered low, given the generally low concentrations and limited mobility in the soils.

Additionally, human waste frozen into the ground near a known historical wastewater outfall was recently discovered during geotechnical investigations, and part of the operational area contains stockpiles of scoria contaminated with timber and metal debris from the Lake Vanda Station clean-up[3] and other past practices. Sixty years of human activity, the storage and use of fuels, inadequate decommissioning of old buildings and waste management practices, have resulted in the contamination of soils across the Scott Base operational area. The Scott Base Redevelopment will be used as an opportunity to address this legacy and remediate these areas of contamination, in accordance with Article 1(5) of Annex III to the Protocol.

[3] The summer station located in the McMurdo Dry Valleys was removed in 1994/95. The site became at risk of flooding from the rising lake level.

Visible ACM fragments under the Administration building

Hydrocarbon staining in parking area

Scoria stockpile with timber and metal debris

Figure 14: Examples of historical and recent contamination.

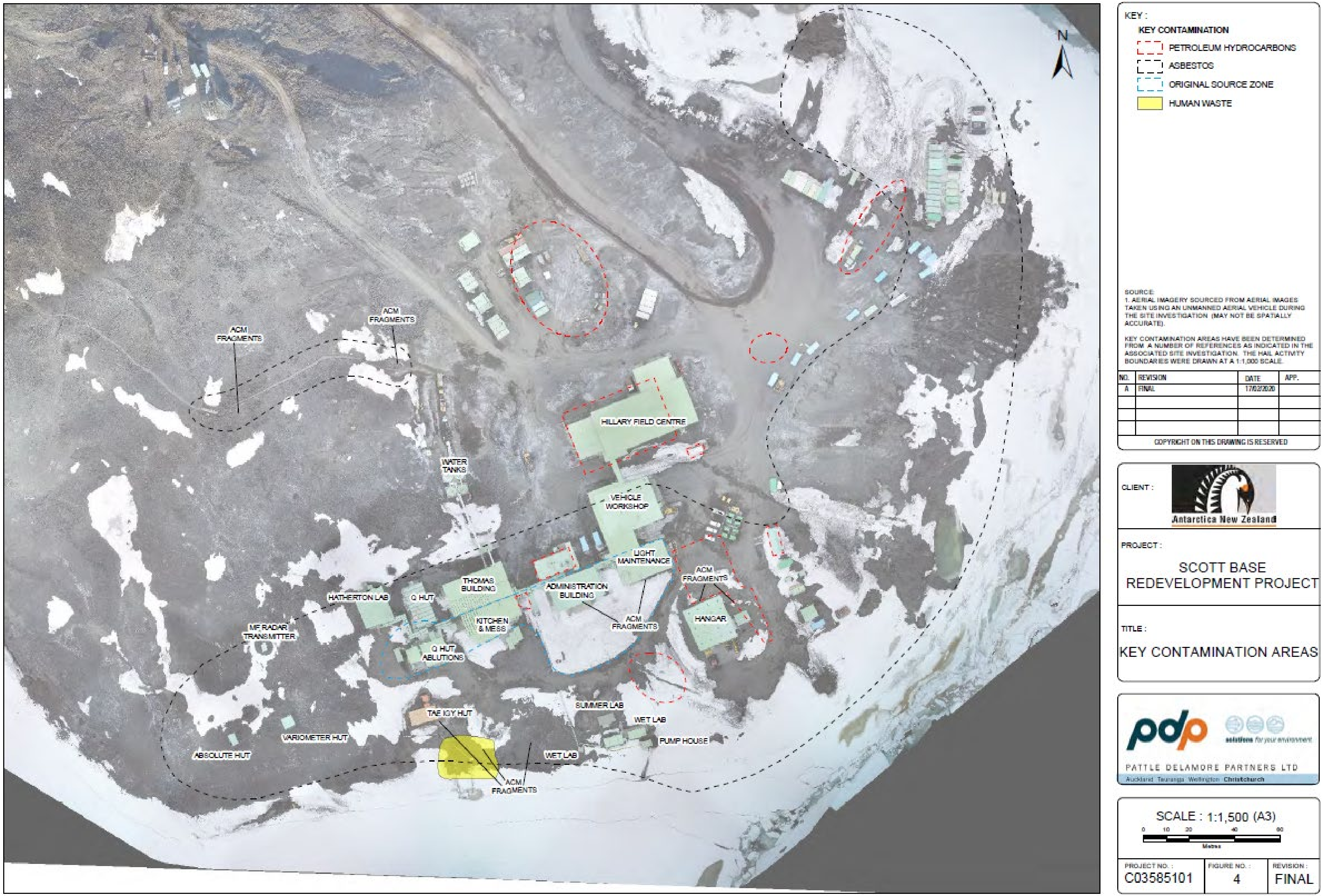


Figure 15: Known contamination areas of the Scott Base operational area, 2020.

1.5.4 The Ross Island Wind Energy network replacement

RIWE was constructed during the 2008/09 and 2009/10 austral summer seasons and was commissioned in January 2010. It is designed to operate until 2030. The wind farm is located on Crater Hill, between McMurdo Station and Scott Base (Figure 4 and Figure 16) and consists of three 330kW Enercon E33 Turbines (Figure 17). The design capacity of the wind farm is 990kW of power.

RIWE was implemented in order to:

- Reduce diesel fuel consumption on Ross Island and to reduce both New Zealand and the United States' environmental impact in Antarctica;
- Develop and test a fully integrated wind farm "proof of concept" on Ross Island; and
- Contribute to the shared Joint Logistics Pool (JLP) with the United States.

The project was the first such joint initiative between two national programmes to date, and the first of its kind in Antarctica, as it links Antarctic stations from two different countries into a common electrical network. The commissioning of RIWE was the culmination of five years of commitment from Antarctica New Zealand and USAP and the success of the project is a testament to the power of collaboration and cooperation between the two programmes. The environmental impact assessment for the project was conducted by New Zealand as an IEE in 2008.

RIWE was a serious investment in renewable energy technology and energy management equipment. The project is described in further detail in "Ross Island Wind Energy Project: Sustainability through collaboration" (ATCM XXXIII, IP 37 (2010)).

The Ross Island integrated electrical grid is fed by electricity generated by the wind farm and generators at both Scott Base and McMurdo Station. This mixture of generation provides significant potential for generation efficiency because the grid is designed to constantly seek out the optimum mix of generating assets, in order to fulfil the electricity demand from both stations at any one time. The stations each retain the ability to function independently and do not exclusively rely on each other for access to electricity.

At full capacity, RIWE can provide up to 80% of the electrical load requirements for Scott Base and 20% for McMurdo Station. Based on the modelled output, RIWE is estimated to substitute 22% of the total fuel burned for electricity generation across both stations. This equates to approximately 900,000 litres of diesel per year or 2,480 tonnes of avoided CO_2 emissions.

The current RIWE met its aim of reducing fossil fuel demand for New Zealand and the United States and delivered the "proof of concept" for a wind farm on Ross Island.

The three wind turbines are expected to reach the end of their design life by 2030. RIWE was developed to accommodate existing infrastructure and has served its purpose for the current version of the Ross Island grid. It is timely and appropriate to address the replacement of RIWE in conjunction with the Scott Base Redevelopment to optimise the logistics and construction resources required for the proposed activities.

Figure 16: RIWE on Crater Hill.

Figure 17: Wind turbines with Observation Hill, McMurdo Sound and Mount Discovery in the distance.

1.6 The establishment of the Scott Base Redevelopment project

With the Scott Base buildings, facilities and associated infrastructure and the windfarm reaching the end of their functional life, Antarctica New Zealand presented an Indicative Business Case to the New Zealand government in 2016 to seek funds to develop a case for investing in a redevelopment project. Five investment options were considered (Table 5) including:

- Investment Option 1: Repair (Do nothing)
- Investment Option 2: Replace (Like for like replacement)
- Investment Option 3: Upgrade (Like for like replacement with minimal upgrades)
- Investment Option 4: Enhance (Partial rebuild with significant upgrades[4])
- Investment Option 5: Rebuild (Aspirational)

Option 5: Rebuild was ultimately selected as the basis for the proposed activities. However, different options were initially shortlisted. The selection process is described here.

Option 3: Upgrade and Option 4: Enhance were initially shortlisted and funding was provided to progress with the project. A consultant design team was appointed and a formal project was established, structured around the New Zealand Construction Industry Council Guidelines, which were used to guide the design process.

During the Concept Design phase, four concepts for a building design were developed and assessed against a number of criteria including staging, impact on science, buildability, efficiency of operation, impact on engineering design, environmental impact, future adaptability, welcome and wellness, aesthetics, and safety in design.

A number of site constraints and challenges needed to be considered when developing the four concepts. These included limited land availability for construction, the sloping topography of the site, predominant wind direction and snow drift deposition, consideration of the coast line and potential sea level rise, minimising disturbance to the flora and fauna to the north of the existing operational area, historical ground contamination, traffic to and from McMurdo Station and onto the ice shelf, the location of long-term science experiments, and consideration of heritage and cultural sites.

As noted in Section 1.5, the Condition Assessment Report indicated that the Scott Base infrastructure had deteriorated so much that the recommendation was for all buildings to be replaced. The recommendation triggered a review of the Indicative Business Case, in which the three rejected options were reassessed. Noting the state of disrepair of the station, Investment Option 3: Upgrade was rejected and Investment Option 5: Full Rebuild was reinstated as a viable alternative alongside Option 4: Enhance.

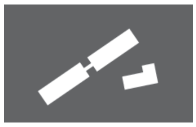
[4] Partial rebuild is used because some buildings like the HFC would be kept instead of being replaced.

Table 5: Investment options for investing in a safe and fit for purpose permanent facility in Antarctica.

Investment Options	Description	Advantages	Disadvantages/risks
1.Repair Do nothing	Under this option nothing new will be done and plant and infrastructure will be repaired as far as possible until they fail.		Repairs will only be possible for a short time before building and equipment failure will prevent Scott Base from operating.
2.Replace Like for like	Under this option the core services will be delivered, with any replacement or upgrade being delayed as long as possible.	It is less expensive than enhancing it or rebuilding (but more expensive than upgrading it). It will address some of the basic age-related issues (e.g. delamination of external walls).	All the risks and failings of the current Scott Base design remain e.g. health and safety issues, does not support what is needed currently, will not support future needs, is not resilient (still single points of failure) Operations and science support will be compromised for much of the project as building work takes place.
3.Upgrade Like for like with minimal upgrades	Under this option core and some extended services will be delivered by replacing or refurbishing assets like for like. Some upgrades to improve functional design issues of the facility will be made.	Least expensive option. Some issues will be fixed	As above, although some current risks will be mitigated through improvements and upgrades. The overall design risks and single points of failure remain.
4.Enhance Partial rebuild with significant upgrade	Under this option core and extended services will be delivered by a partial rebuild to improve functional design and infrastructure services to enhance the existing capability of Scott Base. These will address the issues set out above.	Addresses the key issues in a timely way whilst keeping the costs and disruption down. Allows new functionality to come on line sooner.	Operations and science support will only be marginally compromised as the rebuild will take place alongside the current Scott Base.
5.Aspirational Rebuild	Under this option core and extended services will be delivered by a full rebuild of Scott Base with a completely new modern facility. A greenfield approach to the build would be taken.	Have the opportunity to do something quite innovative. Will deliver all requirements and possibly more.	Rebuild costs are based on known technologies. The current investment in the HFC is lost. It is the most expensive option.

Four concept options were presented to the New Zealand Government in a Detailed Business Case (Table 6). The four concept options provided varying improvements in science support, accommodation and personal wellbeing, resilience and environmental protection. A multi-criteria decision analysis was applied to the four concept options (including criteria on the projects objectives and requirements). 2B was identified as a preferred option and approved in principle, subject to environmental approval and final costs, and progressed through to design.

Table 6: Overview of the concept options for a redeveloped Scott Base.

Investment Option	Concept Options	Description	Decision	Layout
Investment Option 4: Enhance	1	Involves upgrading one building (HFC) and demolishing and replacing all the other buildings. Minimal service level improvements (science support and resilience) to Scott Base as it stands. Unknowns of renovating and integrating new buildings with old buildings introduces risk. Minimal improvement in environmental performance. It is the cheapest option.	Rejected – does not address the issues of the current base, particularly how fit for purpose it is to support science and it does not address the issues with the wellbeing of occupants.	
Investment Option 5: Rebuild	2A	Involves a full rebuild. Enables improvement in accommodation and living areas, better bedrooms, areas to exercise, read, relax, eat and live. Minimal improvements to science-support capabilities. Life support systems will have built-in multiple redundancy so that operations can continue in the event of a single system failure. Improved environmental performance.	Rejected – science support is a core function of the base and must be improved over current levels.	
Investment Option 5: Rebuild	2B	Involves a full rebuild. Offers the same improvements as 2A and adds capability to support and deliver Antarctic science through modern work spaces, adequate areas to prepare for deep field traverses, marine labs and data centres. New capabilities to support future science include preparation areas for gliders and drones. Improved wellbeing of personnel such as single bedrooms.	Selected – the full rebuild design with enhancements in accommodation and living and design to attract and enable high-quality science for the next 50 years.	
Investment Option 5: Rebuild	2C	Involves a full rebuild. Offers similar improvements as 2B with marginal gain in sustainable design. The completed working and living areas will be inspirational, and limit the impact of seasonal affective disorder.	Rejected – it is the most expensive option and only provides marginal gain against a significant cost increase over Option 2B.	

In addition to agreeing in principle to the preferred option 2B, the New Zealand government requested that options be considered for funding the RIWE replacement in conjunction with the Scott Base Redevelopment. Coordinating the activities would optimise the logistics and construction resources required for the proposed project.

In 2020, Antarctica New Zealand commissioned Hydro-Electric Corporation (trading as Entura) to conduct a feasibility and options study on replacing and upgrading RIWE. Antarctica New Zealand defined three general options for investigation:

1. Do nothing option: Decommissioning the existing wind farm and running the redeveloped Scott Base on diesel only;

2. Meeting no less than 80% of the redeveloped Scott Base's energy demand with renewable energy; and
3. Meeting 100% of the redeveloped Scott Base's energy demand with renewable energy.

At the time of preparing this draft CEE, the Scott Base Redevelopment design is at a stage where the scope of all major elements, materials, finishes and floor area of the proposed new station is clearly defined and drawn to scale with supporting documentation and specifications. Temporary works (i.e. earthworks such as road realignments and logistic and construction plans, etc.) required to construct the buildings have been designed and specified. The final and remaining stage of design for the Scott Base Redevelopment is to confirm the construction detailing and fabrication drawings and to get approval from government to proceed, subject to environmental impact assessment approval. If funding is approved, the design process for the RIWE replacement will be initiated and further integrated into the Scott Base Redevelopment.

1.7 Scope of the draft CEE

The scope of this draft CEE **includes** all activities in the Antarctic Treaty Area associated with the Scott Base Redevelopment. This includes two main components of the project.

1.7.1 Scott Base Redevelopment

The proposed Scott Base Redevelopment includes all activities associated with the design and operation of the new station, the deconstruction of the existing station, civil and foundation works, enabling works, logistics and shipping, and the installation and commissioning of the new station.

1.7.2 RIWE replacement

The RIWE replacement includes feasibility options on the turbine design, the deconstruction of the current RIWE, civil and foundation works, construction and logistics, and the installation and commissioning of the new RIWE.

The temporal scope of the assessment for the proposed Scott Base Redevelopment and RIWE replacement is expected to begin in the austral summer of 2021/22, with practical completion in the 2026/27 season.

The scope of this CEE **excludes** all activities undertaken in New Zealand or otherwise outside of the Antarctic Treaty Area. Where relevant, information about these activities is provided for clarity and completeness, such as the construction and prefabrication work undertaken in New Zealand, logistics north of 60°S latitude, and enabling works completed at Scott Base outside of the temporal scope of this draft CEE.

1.8 Approach to the environmental impact assessment

This draft CEE has been prepared in accordance with the applicable requirements of Article 3, Annex I to The Protocol on Environmental Protection to the Antarctic Treaty, and the Guidelines for Environmental Impact Assessments in Antarctica (Resolution 1 (2016)). It has also taken into consideration New Zealand legal requirements and other Antarctic Treaty System requirements.

1.8.1 The Protocol on Environmental Protection to the Antarctic Treaty

Article 8 of the Protocol requires any activities in the Antarctic Treaty area to be subject to an assessment, under Annex I to the Protocol. Under Article 3, activities should be planned and conducted on the basis of 'information sufficient to allow prior assessments of, and informed judgements about, their possible impacts on the Antarctic environment.

Annex I to the Protocol sets out the detailed requirements for Environmental Impact Assessment (EIA) in Antarctica and establishes a three-stage process based on different levels of predicted impact. The assessment levels are:

- Preliminary Stage;
- Initial Environmental Evaluation (IEE); and
- Comprehensive Environmental Evaluation (CEE).

If an activity is determined as having **"less than a minor or transitory impact"**, it may proceed. An IEE must be prepared if it is determined that an activity will have **"no more than minor or transitory"** impacts. A CEE is for activities that are likely to have **"more than a minor or transitory impact"** on the Antarctic environment.

Following the EIA process defined in Annex I, New Zealand concluded that the appropriate level of assessment for the proposed Scott Base and RIWE replacement is a CEE.

This draft CEE was publicly notified by a notice in a daily newspaper in the cities of Auckland, Wellington, Christchurch, and Dunedin. It is available on the Antarctica New Zealand website and any person may comment on the draft CEE for a period of 90 days following notification. This draft CEE has been circulated to the Antarctic Treaty Consultative Parties through the Committee for Environmental Protection at least 120 days before ATCM XLIII, 2021.

1.8.2 New Zealand statutory requirements

New Zealand implements the requirements of the Protocol through the New Zealand Antarctica (Environmental Protection) Act (1994), which is administered by the Ministry of Foreign Affairs and Trade. The Act requires persons planning or carrying out activities in Antarctica to act in a manner consistent with the environmental principles set out in Article 3 of the Protocol. Additionally, the Act sets out the domestic consultation process for CEEs. Following the Act, this draft CEE has been publicly notified in New Zealand for at least 90 days, during which any person may consult and comment on the draft CEE.

Further New Zealand legislation applies to the proposed activities, such as the Health and Safety at Work Act (2015) and its relevant regulations on, for example, asbestos and hazardous substance management. The proposed activities seek to achieve full compliance with all applicable New Zealand legislation, to the extent possible in the Antarctic environment.

1.8.3 ATCM/CCAMLR measures applicable to the proposed activities

There are several Recommendations, Resolutions or Measures that relate to environmental protection, operational, and logistical activities adopted by the ATCM and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), which are relevant to the proposed activities. These are highlighted here for completeness and have been considered in this environmental impact assessment and in the planning for the operation of the proposed Scott Base and RIWE.

Relevant ATCM Recommendations and Resolutions:

- Recommendation XV-5 (1989) – Environmental Monitoring Activities
- Resolution 2 (2005) – Guidelines for Environmental Monitoring
- Resolution 3 (2007) – Long-Term Monitoring
- Resolution 3 (2012) – Improving Cooperation in Antarctica
- Resolution 4 (2013) – Improved Collaboration on Search and Rescue in Antarctica
- Resolution 2 (2013) – Antarctic Clean-Up Manual
- Resolution 1 (2014) –- Fuel Storage and Handling
- Resolution 1 (2016) – Revised Guidelines for Environmental Impact Assessment in Antarctica
- Resolution 4 (2016) – Non-Native Species Manual
- Resolution 1 (2019) – Revised Antarctic Clean-Up Manual
- Resolution 5 (2019) – Reducing Plastic Pollution in Antarctica and the Southern Ocean

CCAMLR through its Commission agrees a set of conservation measures that determine the use of marine living resources in Antarctica. A Measure relevant to the proposed activities is Conservation Measure 91-05 (2016) Ross Sea region MPA.

1.8.4 Additional guidance material

The Council of Managers of National Antarctic Programs (COMNAP) fosters cooperation among National Antarctic Programs. COMNAP has developed guidance material that is also relevant to the proposed activities, including the COMNAP Fuel Manual and the Checklists for Supply Chain Managers for the Reduction of Risks of Introduction of Non-Native Species.

This draft CEE was prepared within New Zealand's EIA framework for activities in Antarctica. The EIAs relevant to this draft CEE are:

- Initial Environmental Evaluations for Antarctica New Zealand operations for the periods 2015-2019 and 2019-2023; and
- Initial Environmental Evaluation for the Installation of Wind Turbines, Crater Hill, McMurdo Sound 2008.

International and New Zealand best practice EIA references were also referred to in the preparation of this draft CEE. CEEs and IEEs published on the EIA database of the Antarctic Treaty System website were consulted as sources of information on the assessment and mitigation of potential environmental impacts of activities within Antarctica.

1.9 Summary

In summary, Scott Base is reaching the end of its functional life. RIWE is integral to New Zealand's commitment to managing its impacts in Antarctica and its replacement is necessary to continue to supply Ross Island with renewable energy. The proposed Scott Base will provide facilities that are purpose-built to support New Zealand's current and future science needs, operate more efficiently, with fewer maintenance requirements, supported by a modern on-site renewable energy system. Following an assessment at the preliminary and initial environmental evaluation levels, it is considered that the proposed activities are likely to have **'more than a minor or transitory impact'** on the Antarctic environment, provided proposed mitigation measures are implemented. After consultation with New Zealand's Ministry of Foreign Affairs and Trade, it was concluded that an environmental impact assessment at the CEE level was the appropriate level of EIA for the environmental impacts associated with the proposed activities. This CEE provides relevant information in sufficient detail with 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.

2. The Scott Base Redevelopment

2.1 Introduction

Article 3(2)(a) of Annex I to the Protocol requires that CEEs include a description of the proposed activity including its purpose, location, duration and intensity.

The Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1 (2016)) specify that an activity is an event or process resulting from (or associated with) the presence of humans in the Antarctic, and/or which may lead to the presence of humans in Antarctica. An activity should be analysed by considering all actions involved over all of its phases.

This chapter describes the activities associated with the Scott Base Redevelopment including the design and operation of the proposed station, the deconstruction of the existing station, civil and foundation works, enabling works, logistics and shipping, and the installation and commissioning of the new station. It also considers the design, construction and operation of a temporary Scott Base. The proposed RIWE replacement is described in Chapter 3.

All activities are described to the extent known at the time of writing this draft CEE.

2.2 Timeline

The high-level proposed timeline for the Scott Base Redevelopment covers the austral summer of 2021/22 to the end of the 2027/28 season (Figure 18). Annual activities are shown in detail in Appendix 1 and include:

Season 0 (2021/22) – Pile/foundation testing and completion of LTS relocation;

Season 1 (2022/23) – Shipping and staging of equipment and plant, temporary base site preparations, prepare staging areas, commencing construction of new buildings in New Zealand;

Season 2 (2023/24) – Construction of temporary base, Scott Base to McMurdo road realignment, water and wastewater intake and outlet structure installation, bulk fuel tank platform establishment and the preparation and piling for a temporary wharf, construction of new buildings in New Zealand;

Season 3 (2024/25) – Existing Scott Base decommissioning and deconstruction, bulk earthworks, piling/foundations, establishment of a haul road from temporary wharf to building site, temporary wharf bollard installation and first new wind turbine installation, construction of new buildings in New Zealand;

Season 4 (2025/26) – Finalise bulk earthworks and haul road, piling/foundations, decommission existing windfarm, install remaining turbines and commission new windfarm, install fenders on temporary wharf, ship new building modules to Pram Point, install new building modules on foundations, fit out and recommission new buildings over winter 2026;

Season 5 (2026/27) – Occupy proposed Scott Base, deconstruct temporary Scott Base and remaining structures, final earthworks to finish building access ramps, demobilise plant and containers back to New Zealand.

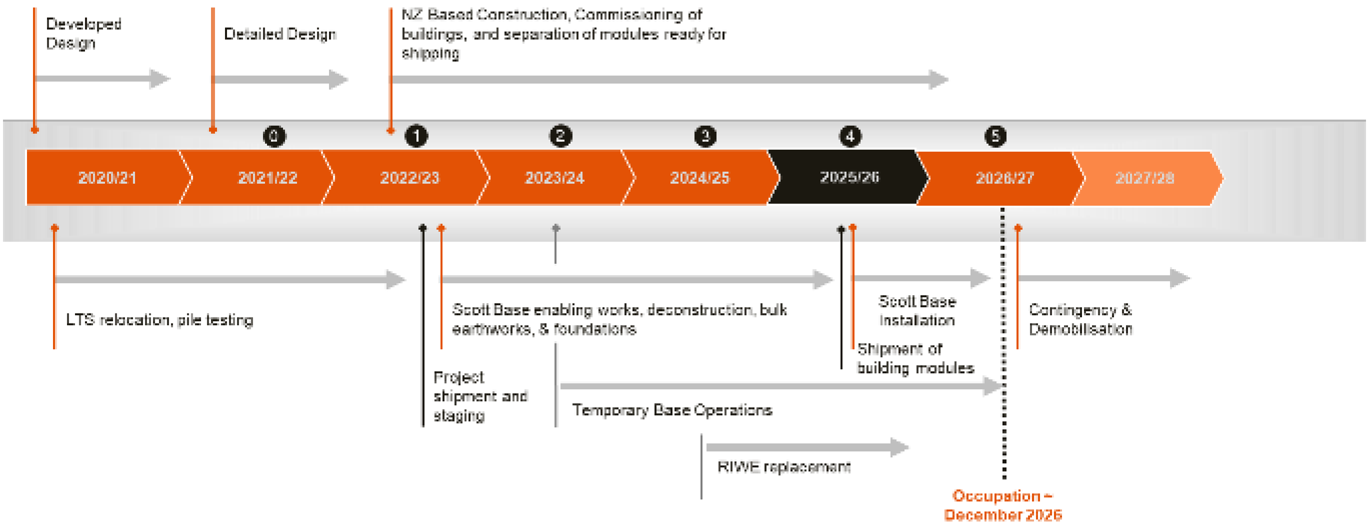


Figure 18: High-level proposed timeline for the Scott Base Redevelopment.

2.3 Description of the proposed Scott Base

2.3.1 Design of the proposed Scott Base

The proposed Scott Base aims to deliver the following strategic objectives:

- Provide a modern, safe and healthy environment for people while living and working at Scott Base for the next fifty years;
- Enable effective logistics support to maintain and enhance high quality science at Scott Base;
- Protect the Antarctic environment.

The design used some key principles to address the structural, operational and functionality issues of the existing Scott Base. They are:

- A design which promotes health and safety and a culture of wellbeing for staff and visitors;
- To support scientific excellence on base and in the field;
- To be environmentally sustainable, by developing a base that minimise energy use and reduces the physical impact on the site by consolidating the buildings and operational infrastructure into an efficient footprint;
- To develop a base which can be built, managed and operated safely;
- To enhance operational flows around base and minimise the extent of ground works;
- Aerodynamic buildings that are inter-connected, offset and elevated above the ground to minimise snow accumulation and snow management;
- Buildings designed with a repeating structural grid to allow for modularisation to assist the construction process and long-term maintenance;
- Resilience in the layout and services to eliminate single points of failure and ensure safe and continued operation in a range of scenarios; and
- An exterior design with enhanced performance to suit the cold climate.

The location for the proposed Scott Base is on Pram Point. It overlaps the footprint of the existing Scott Base (Figure 19). The Scott Base Redevelopment aims to reuse the current modified and operational area as far as possible. Pram Point is a useful location to access the sea ice, the ice shelf and existing essential supporting infrastructure which enables ongoing efficient logistics to support New Zealand Antarctic science activities.

The proposed station is made up of three connected, aerodynamically shaped, two-storey buildings (Buildings A, B, and C). The buildings step down the hillside of Pram Point. The three buildings are offset from each other to minimise the risk of snowdrift between them and are connected with enclosed linkways (Figure 20). The lower level of the upper building connects to the upper level of the lower building. All the buildings are elevated above the ground to encourage wind to flow underneath, thereby minimising snow accumulation under the buildings.

Each building is made up of a six-metre repeating structural steel grid. This makes it straightforward to reconfigure space should it be needed in the future, because the structure is regularly spaced with large clear span zones between.

The key design features (Figure 21) of the three buildings are described below and a floor plan is provided in Appendix 2.

Building A is 78m long and 26m wide. It contains the living accommodation and is the primary point of entrance into the station. The upper level contains a mix of single, twin and four-person bedrooms, ablution blocks and living spaces to support a summer population of 100 people and a winter crew of 15. Rooms for longer stay residents have views to the landscape. Rooms for those staying over shorter periods look into a double-height circulation zone illuminated by glazed roof lights. The dining room and bar include panoramic windows with views towards Mount Erebus and Mount Terror. The lower level contains the medical facilities, laundry, recreational space, food storage, shop, locker room, a welcome lounge, and mechanical plant spaces, with a level access via bridge link to the upper level of Building B.

Building B is 42m long and 26m wide and contains science laboratories, training rooms and offices on the upper level. The lower level is for the staging and preparation of field science expeditions, with level access via a bridge link to the field stores in the upper level of Building C. The open plan arrangement provides safe and functional cargo flows in and out of the building. Spaces around the perimeter of the staging area allow scientists to calibrate electronics and other equipment in a clean environment. The field return area includes biosecurity facilities, a wash-down area, human field waste disposal facility, field laundry, a drying room, and the field equipment maintenance space. Building B has one vehicle ramp for access into the staging area.

Building C is 78m long and 26m wide and contains the engineering office, central stores, field stores, and a gymnasium on the upper floor. The lower level includes the intercontinental cargo bay, waste management facilities, engineering stores, and technical workshops. The vehicle workshop has two bays, each of which is wide enough to suit the largest vehicles in the current Antarctica New Zealand fleet. Water production and wastewater treatment facilities are also located on the lower level of Building C. Two vehicle ramps provide access into the cargo bay and vehicle workshop.

Linkways between Buildings A, B and C are 3m wide to enable efficient transport of goods and equipment. The wide circulation areas, together with minimal changes in level, are designed to increase efficiency and reduce manual handling.

The interior design fosters a strong sense of wellbeing and minimises the need for maintenance. Warm finishes provide durability, comfort and wellbeing. The design seeks to reflect New Zealand’s cultural and natural landscapes, by conveying indigenous Māori values and reflecting New Zealand’s history of involvement in Antarctica. Central to Māori values is a sense of shared responsibility for the mauri, or life force, of the environment, and for the health and wellbeing of all people who depend upon it for their survival. This connectivity is a key feature of the interior design. Windows are carefully placed to make the most of natural light and reinforce connections with the Antarctic landscape.

Figure 19: The location of the proposed Scott Base on Pram Point.

Figure 20: Aerial render of the proposed Scott Base.

Key Design Features

1. Short term accommodation is provided as four person bunk rooms, with bunks having a "pod" type design for improved privacy. Twin and single rooms plus two accessible en-suite rooms complete the total provision of 100 full size beds.
2. Where appropriate, spaces are designed for flexible, multi-functional use. A variety of social and working spaces cater to individual needs and preferences.
3. Support for science includes clean workspaces and an external deck for testing equipment or preparing samples for shipment, as well as laboratories for on-base analysis.
4. All workspaces benefit from access to views and daylight.
5. Two bridges - with clearance for snow clearing vehicles to pass beneath - connect the three buildings into a continuous internal environment.
6. Windows at key positions around the new base's circulation routes ensure awareness of current weather conditions as well as helping to orientate users and improve their connection to the Antarctic environment.
7. High density storage systems facilitate the internal storage of all food, field equipment, base supplies and engineering spares and tools.
8. The external cladding mostly comprises high performance insulation with metal facings. FRP (fibre-reinforced plastic) panels are incorporated in strategic locations where local wind conditions demand complex, curved geometry, and enhanced surface durability. The entire envelope is designed for airtightness, resisting water and spindrift ingress under the extreme wind pressures on Ross Island, as well as meeting all appropriate fire safety standards. All components are designed to facilitate either future repair or replacement, with a design life of 50 years with 25 years to the first major maintenance.
9. Windows are triple-glazed with thermally broken aluminium frames. Blinds are incorporated into reveals to reduce glare (in workspaces) or achieve blackout (in bedrooms).
10. Vehicle entrances are segregated from pedestrian entrances for safety. Open grate bridges allow the wind to pass through, reducing snow clearance requirements around doors.
11. Photovoltaic panels contribute to energy supply during the busy summer season.
12. External vents are strategically located and shrouded to minimise snow entry and resulting maintenance.
13. Fuel 'day tanks' provide resilience for generator and boiler operation in an emergency. This is one of many resilience strategies in place, ensuring continued life support in a wide variety of scenarios.

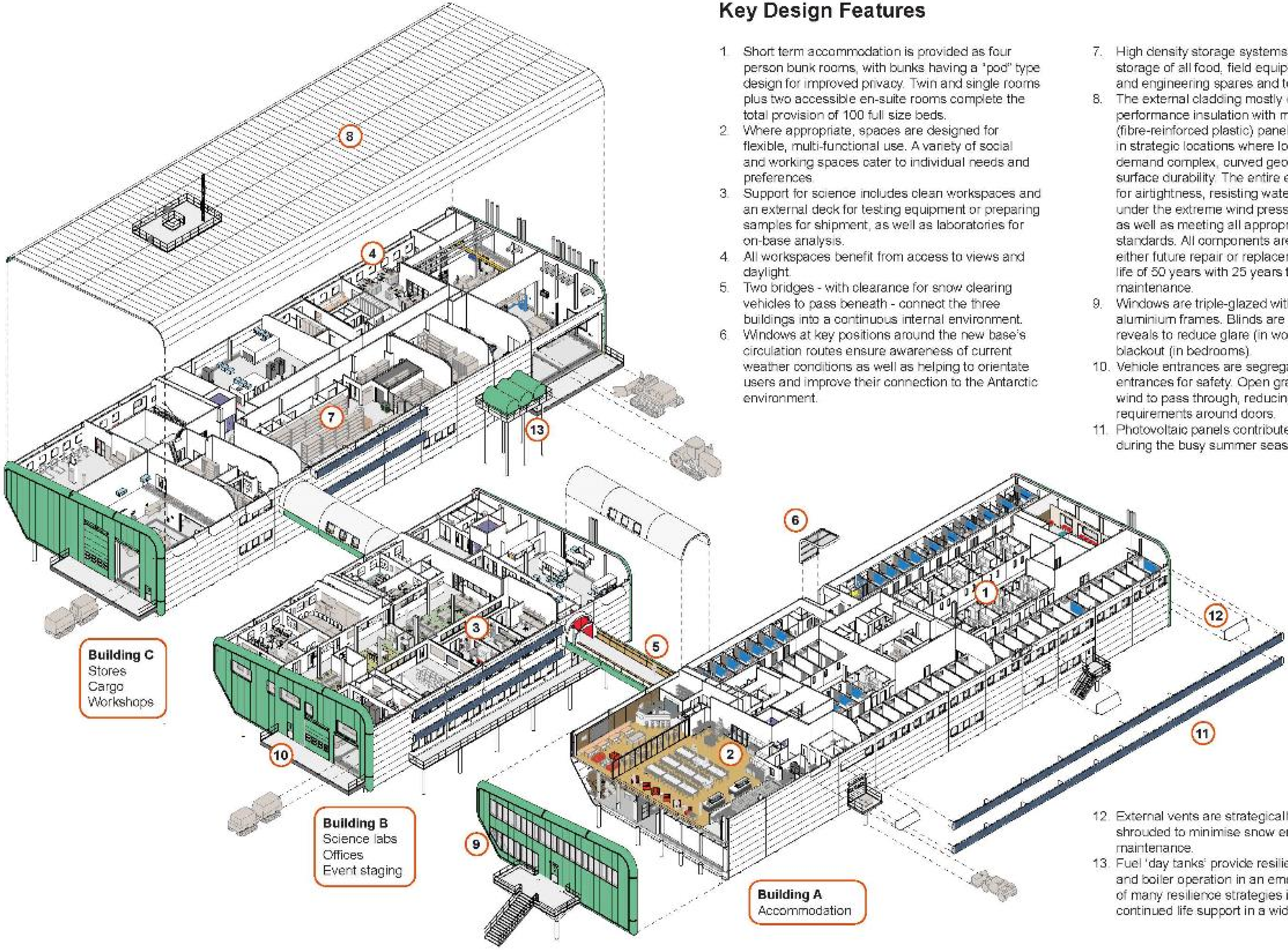


Figure 21: 3D rendering of the proposed Scott Base looking from Building A (uphill, bottom right) through to Building C (downhill, top left).

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2.3.2 Size of the proposed Scott Base

The size of the proposed Scott Base is estimated at 9,404.5m^2. This consists of 8122.5m^2 gross internal floor area (GIFA) (Table 7) and 1,122m^2 for the building envelope[5], 107m^2 for the retained summer and wet labs and 53m^2 for the electrical substation. By comparison, the size of the current Scott Base is 6,182m^2 (consisting of 5,148m^2 GIFA, 567m^2 for the envelope; 360m^2 of operational containers; and 107m^2 summer and wet labs).

Shipping containers used in the annual ship resupply are not included in the building size descriptions. They are expected to be transient and comparable to current volumes.

Table 7: Gross Internal Floor Area for the proposed Scott Base.

Building area	**Zone Area (m²)**
A Lower	1533.5
A Upper	1636.5
B Lower	891.5
B Upper	1001
C Lower	1552
C Upper	1329.5
Link A-B	89.5
Link B-C	89.5
Grand total	8122.5

The increase in the size of the station resulted from several design requirements, summarised as follows:

- Increasing the number of beds from 86 to 100 with single and double bedrooms provided;
- Increasing the number of ablutions;
- Improving resilience of critical services by increasing the number of plant rooms across the station;
- Removing the risk of confined spaces by having all services that require regular maintenance in dedicated reticulation spaces;
- Improving inventory and storage with internal centralised stores and reductions in external storage areas, containers and outbuildings where possible;
- Internal, centralised food storage – the current station has food storage in numerous locations, including three external refrigerated containers;
- Increasing circulation areas (hallways, mezzanine areas) to make movement of equipment easier, in particular by pallet trolley;
- Improving people wellbeing by providing more and enhanced amenity spaces;
- Increasing science lab space (type and number) to better support science in Antarctica;
- Providing dedicated biosecurity containment and cleaning areas in each building;
- Providing internal waste sorting and staging;
- Providing separate intercontinental and intracontinental cargo-handling areas;
- Increasing the capacity of the vehicle and engineering workshop for maintenance and servicing of the current and future vehicle fleet; and
- Providing improved medical facilities.

[5] The building envelope includes voids for services reticulation, insulation and the cladding of the buildings.

2.3.3 Site layout

The key features of the proposed site layout (Figure 22) include:

- **Improved ground profile and reduced snow build up**: A slightly stepped ground profile, with a flatter area on the landward side of each building over ten meters to facilitate vehicle movements and a slightly steeper slope profile in between buildings (Figure 23). This profile provides suitable building platforms and external circulation areas. The ground profile, along with the shape of the windward aspect of the buildings, will facilitate a wind-tunnelling and scouring effect to prevent snow drifting under the buildings. The offset buildings also prevent snow build up.

- **Improved meltwater drainage paths**: Meltwater run-off has previously run through the station site and under buildings before draining into the sea. Ice builds up in the shade or in colder temperatures and can accumulate under buildings. A cut-off drainage channel is proposed above Building A to intercept and divert meltwater into existing overland flow paths and to the road drainage channel. Within the proposed site, drainage channels will be positioned on the uphill side of each building, to capture meltwater from the roofs and the ground surface between each building. Solid edge protection will allow the channels to be cleared of ice and snow by digger, without causing scouring and erosion in the channel.

- **Improved separation of pedestrian and vehicle routes**: The realigned Scott Base to McMurdo road separates the main entrance to the station from roading activities. A wide flat area to the north west of Building A provides for vehicle circulation around the station and vehicle movement is one-way and segregated from main pedestrian routes. Three ramps to allow vehicles to enter Buildings B and C have been included with a bridge link to prevent snow drift.

- **Provision of a dedicated LTS area**: All LTS installations will be moved to a dedicated site to minimise interference from the proposed buildings and allow for safe year-round maintenance and data collection.

- **Consolidated and reduced external storage**: The increase in internal storage areas reduces the need for extensive short-term storage outside. This consolidates the operational area and allows for safer winter operations.

- **Improved resilience of station infrastructure:** The water intake and wastewater outfall stay in the same locations and their structures are upgraded. A bulk fuel facility will be developed with internal bunding and fuel spill prevention procedures. The existing road transitions from land onto the sea ice and the ice shelf do not change.

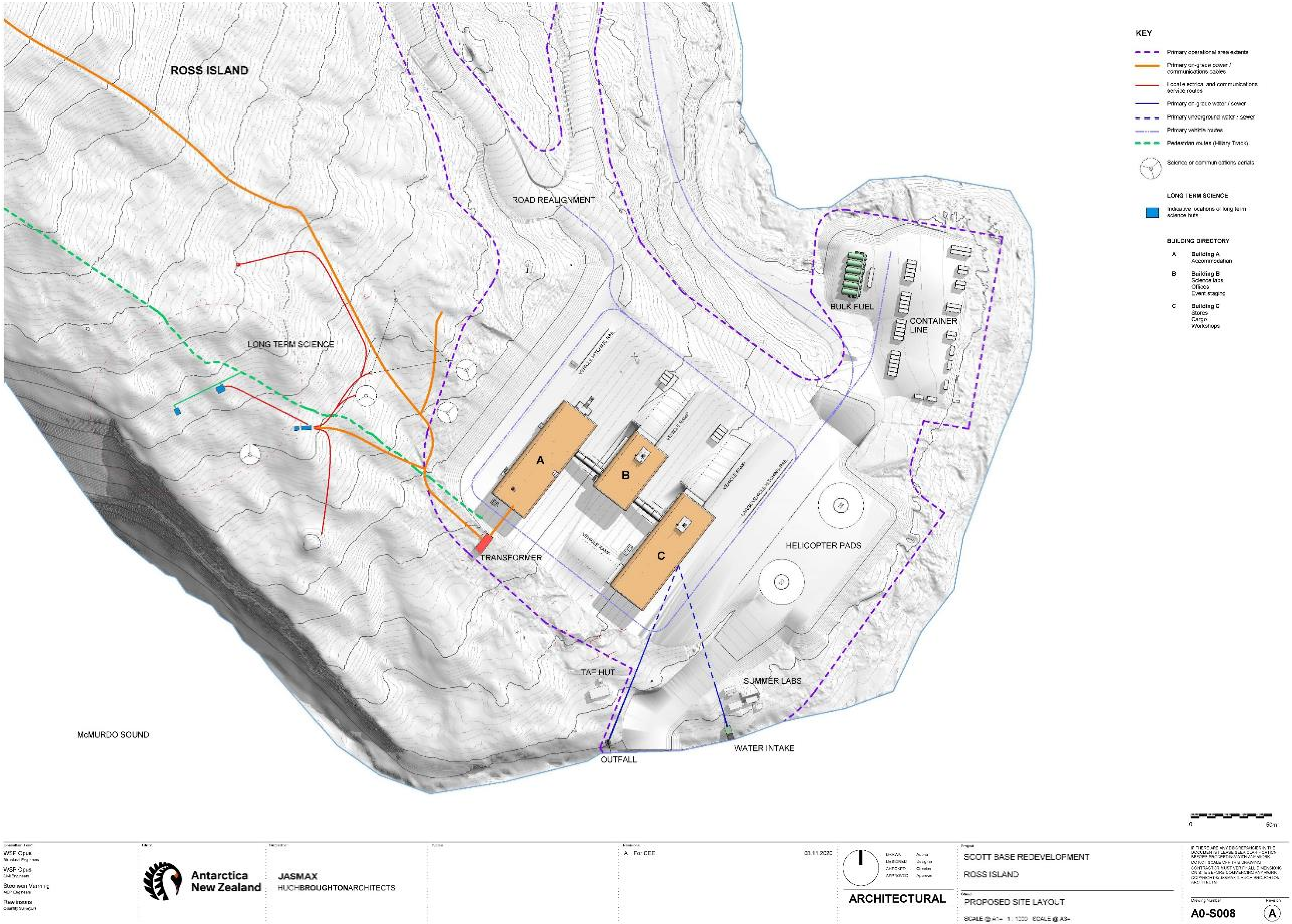

Figure 22: Proposed site layout at Pram Point.

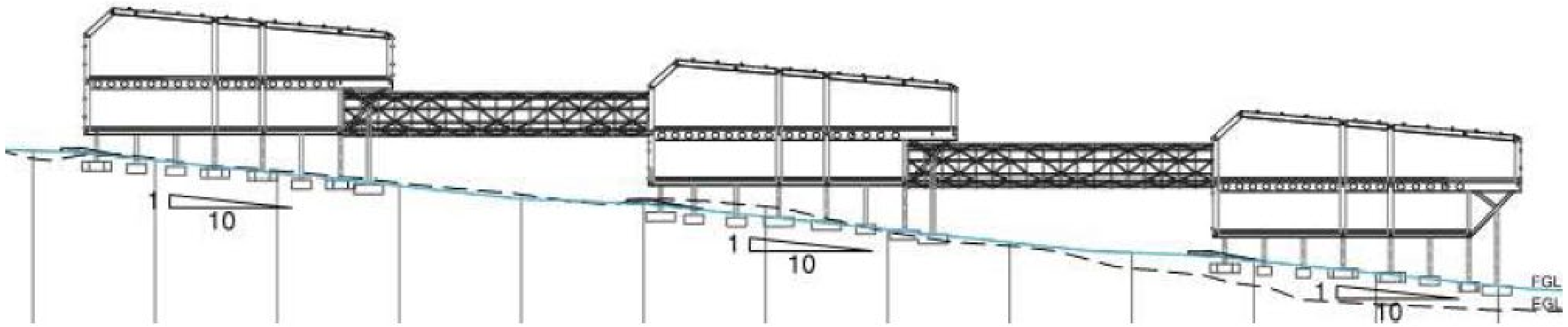

Figure 23: Proposed ground profile (blue line).

2.4 Climate change and natural hazards mitigation

During the design process, Antarctica New Zealand commissioned studies into the impacts posed by climate change, specifically a rise in sea level and permafrost stability. Snow loading on the building was considered as part of the design. In addition, the studies on two natural hazard, tsunami and volcanic eruptions, were also commissioned.

2.4.1 Sea level rise

Sea level modelling results indicate that under various climate change scenarios, and utilising various models, sea level may rise by ~140cm or fall by ~90cm by 2100. Sea level falls are possible in proximity to ice sheets in Antarctica and Greenland, while the global sea level is predicted to rise as a result of climate change. The design response was to ensure the main buildings and critical services are both above the predicted maximum sea-level rise line, and set back from the coast to mitigate coastal erosion via inundation and wave action. To accommodate a fall in sea level, the water intake is designed with a suitably deep intake.

2.4.2 Permafrost stability

The potential for an increased active layer depth, increased permafrost melting and uneven settlement was considered in the foundation decision analysis and design. Two foundation types were considered (Section 4.6.2). The proposed solution mitigates the risk of permafrost becoming unstable through the use of deep (4-6m) piles, end-bearing on mainly bedrock or permafrost deep below the active layer.

2.4.3 Tsunami

Detailed modelling of tsunami risk indicated that the Central American subduction plate boundary presented the most risk to Ross Island, with a modelled wave amplitude of 1.4m. Allowing for uncertainties and a conservative approach, a wave height and inundation elevation of 4.2m and 8m were adopted respectively. Critical infrastructure, including the three main buildings, substation and fuel storage facility are located above this 8m inundation line.

2.4.4 Volcanic eruption

Mount Erebus is an active volcano located 38km from Scott Base. It presents a volcanic risk to the operation of the station and air traffic in the Ross Sea region. The primary risk is that of ashfall from an explosive eruption. The predicted return period for an explosive eruption is 1000 years. Modelling suggests that, under the right wind conditions, ash from a large explosive eruption from Mount Erebus may reach Scott Base and affect the function of building systems. Air intakes have been designed for the snow conditions to minimise intake of blowing snow. As part of the design review, ashfall hazards were considered and mitigated through the intake design. Further ashfall modelling is planned.

2.5 Environmental and sustainability requirements

Antarctica New Zealand's Environmental Management System (EMS) implements the requirements of the Protocol into New Zealand's operations in Antarctica[6]. However, with Scott Base mainly pre-dating the implementation of the Protocol, the proposed activities identified opportunities for improvements to operations, buildings and systems. These improvements are proposed to embed the Protocol requirements and to adopt best practice in environmental protection wherever practicable.

The following environmental and sustainability priorities were identified to avoid and minimise environmental impacts in the operation of the proposed station:

- Reduce fossil fuel consumption;
- Maximise the utilisation of renewable energy;
- Minimise the quantity and improve the quality of discharged wastewater;
- Reduce the amount of waste generated and returned to New Zealand;
- Improve biosecurity and containment capability;
- Achieve a Green Star 5 Star 'Design' and 'As-Built' sustainability rating; and
- Provide a modern, safe and healthy environment for people.

The project aims to create a Scott Base that:

- Defines excellence in sustainability for Antarctica New Zealand's activities in Antarctica;
- Minimises impact on the Antarctic environment;
- Supports the health and wellbeing of people working and visiting Scott Base;
- Minimises the life-cycle environmental footprint of the facilities and operations; and
- Encourages sustainable behaviour.

2.5.1 Green Star sustainability rating tool

Antarctica New Zealand is using a third-party sustainability rating tool to inform the design and construction of the proposed Scott Base. The tool will enable Antarctica New Zealand to credibly demonstrate the Scott Base Redevelopment's sustainability performance against externally verified standards. Due to the unique environment and logistical constraints associated with building in Antarctica and informed by the experience of other Antarctic Treaty Parties, Antarctica New Zealand commissioned a custom sustainability rating tool specific to the Antarctic built environment from the New Zealand Green Building Council. The "Green Star Antarctica New Zealand Custom Tool" was created, using the existing Green Star framework and incorporating the requirements of the Protocol, including EIA, waste management and protection of flora and fauna. Green Star is an internationally recognised rating system that delivers independent verification of sustainable outcomes throughout the life-cycle of the built environment.

The Green Star Custom Tool identifies sustainability best practice standards and initiatives that are broadly applicable to all developments in Antarctica. The Green Star Custom Tool is available to the Antarctic Treaty Parties and it is hoped that it will be useful for future projects in Antarctica. The objective of Green Star is to "lead the sustainable transformation of the built environment". Green Star aims to achieve this by encouraging practices that:

- Reduce the impact of climate change;
- Enhance the health and quality of life of inhabitants and the sustainability of the built environment;
- Restore and protect the planet's biodiversity and ecosystems;

[6] The EMS is described further in Section 6.5.2.1

- Ensure the ongoing optimum operational performance of buildings; and
- Contribute to market transformation and a sustainable economy[7].

The Green Star Custom Tool will be used to assess the sustainability of the Scott Base Redevelopment during the design and construction phases of the project, resulting in both an initial 'Design' rating and an 'As-Built' rating for the project. Ratings range from 4 to 6 Stars and correspond to "Best Practice" (4 Stars), "Excellence" (5 Stars) and "World Leadership" (6 Stars) (Table 8).

Scoring in Green Star is based on 100 base points and an additional 10 'innovation' points. Points are awarded by demonstrating that the design and/or build exceeds prescribed standards. The categories and credits to which the points relate are detailed in Appendix 3. A rating is calculated on the number of base points achieved as a percentage of the available base points, plus any innovation points achieved. A project with 55% of the base points achieved, plus six innovation points will earn a score of 61 and a 5 Star rating.

Table 8: Green Star rating scale[8].

Rating	Description	Score based on % of base points achieved plus innovation points
0 Star	Assessed	< 10
1 Star	Minimum Practice	10-19
2 Star	Average Practice	20-29
3 Star	Good Practice	30-44
4 Star	Best Practice	45-59
5 Star	Excellence	60-74
6 Star	World Leadership	75+

The Scott Base Redevelopment is targeting a 5 Star "Excellence" rating. A 5 Star rating offers the highest sustainability benefits for the available project budget. The Scott Base Redevelopment is required to score between 60-74 points to achieve a 5 Star rating. Antarctica New Zealand will submit evidence for a 'Design' rating in mid-2021 and a final 'As-Built' rating will be sought after practical completion of the project.

2.5.2 Life-Cycle Assessment modelling

A Life-Cycle Assessment (LCA) is a methodology for assessing environmental impacts associated with all stages of the life-cycle of a commercial product, process, or service. An LCA was undertaken for the Scott Base Redevelopment both as part of the Green Star requirements and as a method for identifying improvements in the embodied and operational impacts of the design. Environmental impacts are assessed for each major product from raw material extraction and processing, through the product's manufacture, distribution and use, to the recycling or final disposal of the materials composing it. The operational energy saved through the inclusion of a product, such as insulation, is included in such calculations. Impact categories assessed in this LCA are presented in Table 9.

[7] Market transformation is the early adoption of innovative sustainable technology to improve market exposure and uptake.
[8] New Zealand Green Building Council only certifies projects that achieve a rating of 4 Star or higher.

Table 9: Impact categories for LCA in the design phase of the proposed Scott Base.

Primary impact categories	**Unit**
Climate change	kg CO_2 equivalent
Stratospheric ozone depletion potential	kg CFC-11 equivalent
Acidification potential of land and water	kg SO_2 equivalent
Eutrophication potential	kg PO_4^{3-} equivalent
Photochemical ozone creation potential	kg C_2H_4 equivalent
Mineral depletion (Abiotic Depletion Potential)[9]	kg Sb equivalent
Fossil fuel depletion (Abiotic Depletion Potential)[10]	MJ net calorific value
Secondary impact categories	**Unit**
Human toxicity	Comparative Toxicity Unit for humans (CTUh)
Land use	Land Transformation m^2
Resource depletion - water	m^3 water use related to local scarcity of water
Ionising radiation	kq U-235 equivalent
Particulate matter	kg PM2.5 equivalent

The LCA methodology is based on the requirements of the EN15978:2011 standard which measures the environmental sustainability of buildings and was developed by the European Committee for Standardisation. This methodology includes a comparison to a standard reference building and the calculation of the cumulative impact reduction.

Results for the Scott Base Redevelopment design shows a performance improvement of the proposed design against a standard reference building in six of the seven primary environmental impact categories (Table 10). Larger improvements in life-cycle impacts were gained through implementing the following strategies:

1. Adopting generators that can cogenerate energy and heat;
2. Ventilation savings through winterisation of parts of the station;
3. Use of motion sensors and light level adjustment lighting;
4. Installation of a solar photovoltaic system;
5. Increased insulation efficiency; and
6. CO_2 monitoring for ventilation efficiency.

Additional design improvements and iterations of the LCA are proposed throughout the design stages.

[9] Includes all non-renewable, abiotic material resources (except fossil fuel resources).
[10] Includes all fossil fuel resources.

Table 10: Preliminary results of the LCA for the proposed Scott Base. Improvements represent a percentage reduction in the environmental impact per indicator.

Primary Impact Category	Unit	Benchmark Design	Proposed Design	Improvements
Climate change	kg CO_2 equivalent	9.15×10^7	4.85×10^7	+47%
Stratospheric ozone depletion potential	kg CFC-11 equivalent	16.1	8.03	+50%
Acidification potential of land and water	kg SO_2 equivalent	2.73×10^5	1.53×10^5	+44%
Eutrophication potential	kg PO_4^{3-} equivalent	6.53×10^4	4.20×10^4	+36%
Photochemical ozone creation potential	kg C_2H_4 equivalent	1.9×10^4	1.18×10^4	+40%
Mineral depletion (abiotic depletion potential)	kg Sb equivalent	1.13×10^3	1.13×10^3	0%
Fossil fuel depletion (abiotic depletion potential)	MJ net calorific value	1.36×10^9	0.72×10^9	+47%

2.5.3 Resilience

The proposed Scott Base is designed to minimise single points of failure, assist with the resilience and maintainability of building services systems and ensure that systems are not over-engineered. Continued operation in a range of situations is critical to ensure the health and safety of people and New Zealand's ability to support science and environmental protection at all times.

Critical services, such as power generation, high voltage switch gear, communications and water storage are proposed to be divided between Buildings A, B, and C. Redundancy is designed into key services so that if the plant in one building fails, one or both of the other buildings can support it.

2.5.4 Wellbeing

Enhanced wellbeing for people living at Scott Base is a key objective of the Scott Base Redevelopment. The proposed station will provide an environment that keeps people safe and healthy, leading to an improved work performance and better quality of life. The main initiative that will support the health and wellbeing of people at Scott Base is the provision of single and twin occupancy bedrooms for longer-term stays. Good quality sleep is an important component of wellbeing that can be compromised during the summer months of constant daylight and high occupancy. The new bedroom layout, with better acoustic design, will reduce disturbance and enhance privacy.

Other wellbeing initiatives include:

- Creating clear separation of working and non-working spaces;
- Minimising exposure to static electricity in selected areas through a combination of humidification and custom floor surface treatments/finishes;
- Carpeted floors and insulated walls in the bedrooms and bedroom corridors, lounges and office areas to reduce noise and disturbance;
- Incorporating a design that reflects New Zealand's cultural and natural landscape;
- Allowing for the control of natural light and lighting designed to promote natural circadian rhythms; and the
- Provision of an improved lounge, library, gymnasium, and recreational facilities.

2.6 Operation of the proposed Scott Base

2.6.1 Energy generation

Energy modelling was undertaken during the design process to understand the total load, predictive energy use and the greenhouse gas (GHG) emissions for the proposed Scott Base. This energy modelling supported an iterative design improvement process for energy efficiency and for the Green Star accreditation process. Energy and GHG emissions contribute considerably to the final Green Star rating. The outcome of this process is that the proposed Scott Base will deliver improved management of energy and will reduce GHG emissions compared to the current station.

2.6.1.1 Energy generation and heating

There are three means of energy generation:

- Wind energy from RIWE;
- Diesel (AN8[11]) generators; and
- Solar energy with a photovoltaic array located on the buildings' façade.

A Battery Energy Storage System (BESS) is proposed to complement the generation of renewable energy on Ross Island. It is described in Chapter 3. There are three modes of energy generation[12] to meet Scott Base's energy and heating demand:

1. **All-electric mode**: The all-electric mode runs when the output from RIWE and battery storage is sufficient to meet the electrical and heating load of Scott Base. During this mode of operation, all heating is sourced from the electric boiler located in each building. This mode is modelled to provide for approximately 98% of the energy demand, assuming the four wind turbines option described in Chapter 3.
2. **All AN8 mode**: During periods of insufficient output from RIWE and battery storage, all heating and power at Scott Base can be sourced from AN8 boilers and generators through combined heat and power (CHP) cogeneration (i.e. utilising waste heat from power generation).
3. **Hybrid approach**: During periods of lower electrical output from RIWE and lower battery storage, a hybrid approach using both electric boilers and CHP cogeneration will be used.

The three proposed AN8 generators are of 725 kVA capacity each. One generator is located within Building A and two are in Building C. Each generator will have a day-tank outside the building and a 100L fuel tank within each generator room. Exhaust discharges for generator combustion fumes are proposed for Buildings A and C. All discharges are designed as elevated stack discharges between 1 to 2m above the roofline on the southwest elevation.

In addition to the proposed RIWE renewable energy output and the three new AN8 generators, approximately 62kW of solar photovoltaic panels (PV) are proposed to be installed along the northern façade of the three buildings (Figure 21). Preliminary energy modelling indicate that the installed capacity could contribute up to 1.3% of the total load of Scott Base. This energy contribution has not been included in Table 11, as the two energy sources have not yet been modelled together and the solar PV contribution is comparatively small.

A new containerised high-voltage substation will be installed adjacent to the proposed Scott Base to facilitate the delivery of renewable energy from RIWE. This is proposed to be two 40-foot containers located at the services entrance to the west of Building A.

[11] AN8 is an aviation kerosene used as low temperature diesel.
[12] Note that these modes of operation are for Scott Base load only. The generators may operate outside of these modes to contribute to the Ross Island grid demand.

2.6.1.2 Energy efficiency

All proposed systems are designed to minimise energy consumption, from lighting to heating and water production. Energy modelling indicates that the total Scott Base energy load will be approximately 3,265 MWh/year and that the wind energy usable by Scott Base will be approximately 3,200 MWh/year, increasing the renewable energy proportion from approximately 24% to 97% (Table 11).

Table 11: Modelled wind energy with 4-turbine RIWE replacement option, compared against new and current Scott Base energy usage.

	Energy (MWh/year)
Total new wind-generated electricity balance	
Wind generated electricity	9,900
Direct usable wind generated electricity	3,200
Exportable wind generated electricity to McMurdo Station	3,900
Spilt wind energy	2,800
Proposed Scott Base energy balance	
Total energy load	3,265
Direct usable wind generated electricity	3,200
Wind fraction of total load	97%
Estimated AN8[13] fuel use	18,000L
GHG emissions estimate	47.781 tCO2e
Current Scott Base energy balance	
Total energy load	2,895
Wind generated electricity used	700
Wind fraction of total load	24%
Estimated AN8 fuel use	600,000L
GHG emissions average	1,572.524 tCO2e

Winterisation of parts of the base is part of the base operational energy strategy. The sizing and zoning of systems through winterisation of non-essential areas of the base allows for lower energy use. Winterised areas would be maintained at approximately 10°C to prevent damage to systems.

2.6.2 Fuel storage and delivery

The proposed Scott Base fuel facility will consist of up to 3 x 100,000L bulk storage tanks containing two internal tanks each (Figure 22), compared with the approximately 60,000L of AN8 currently held at Scott Base, which are delivered by road tankers by the USAP. The proposed tanks will be located on raised ground to prevent any accidental vehicle collision. The tanks are internally bunded to contain any potential leaks from either inner tank. The tanks are sized to provide two months of fuel to run the station at 100% AN8.

Fuel will be supplied from McMurdo Station fuel facility by road tanker and pumped into the Scott Base tanks via the tanker's on-board pump. Fuel will be delivered as needed to ensure that a two-month supply is maintained at all times. With the increased supply of renewable energy from the proposed wind farm, it is expected that the fuel reserves will be used infrequently and will not require frequent refilling.
The current Antarctica New Zealand Spill Prevention and Response Plan will be reviewed and updated

[13] Based on the conversion factor of 1 litre AN8 equating 3.67kWh, and assuming no down time on renewable energy.

to support the proposed operations. The Plan allows for spill response training, the provision of spill response equipment and includes the requirement that only trained and competent staff can perform fuel-handling operations.

Fuel for Buildings A and C plant rooms (generators and boilers) will be supplied by a dedicated pump which will dispense fuel via a loop pipeline system to each day-tank.

The fuel pipeline between the fuel facility and the buildings will be double-walled to contain any leaks. The pipelines will be located above the ground, with buried sections under vehicle and people traffic paths.

The day-tanks for Buildings A and C will be fire-rated and double-walled. The tanks will be located outside the buildings, adjacent to the service rooms and supported on elevated steel structures. Building A will be provided with one 5,000L day-tank. Building C will be provided with two 5,000L day-tanks. The capacity of each tank allows for a minimum 24 hours supply of fuel for one generator and one boiler at full load.

A dedicated bowser pump will deliver fuel for vehicles at the Scott Base fuel facility. A single hose with a trigger nozzle will dispense fuel. Appropriate bunding and procedures are proposed to mitigate the risk of spills through user handling.

Other hazardous substances are proposed to be stored both inside Building C (e.g. paints, white spirits, science chemicals, batteries, gases, e.g. O_2, CO_2, argon, liquid nitrogen, engineering chemicals for plant maintenance and servicing and waste) and outside in dedicated containers (e.g. LPG bottles, fuel in jerry cans and/or drums and bulk quantities of any other hazardous substances) depending on the class of substance. Smaller quantities of hazardous substances for daily to weekly use are kept in dangerous goods cabinets located throughout the buildings.

2.6.3 Water

2.6.3.1 Water production

Water production is proposed via a reverse osmosis seawater desalination system located in Building C. The major benefits of this system include:

- Lower energy demand compared to the existing plant due to modernised technology;
- Compact footprint requiring less building space; and
- Common technology with no special training or maintenance requirements.

A new intake will be constructed to extract seawater. The intake will consist of a well, dug to 2m below the sea ice (approximately 4m below sea level) and stabilised by rock and piles. A heat-traced pipe will draw water from the bottom of the well and pump it to the RO plant. The brine by-product will be returned to sea via a heat-traced pipe adjacent to the intake well. The brine discharge characteristics are provided in Table 12.

The RO plant will be capable of producing 16,500L of water per day. The production rate is higher than the anticipated maximum daily consumption to provide redundancy in the system. The maximum daily consumption is calculated by analysing:

- Historical water consumption data;
- Water-saving systems and equipment; and
- Behavioural assumptions of the Scott Base population.

Table 12: Characteristics of discharged brine from the proposed RO plant.

Volume	Approximately 75% of intake volume – up to 49,500 L/day
Maximum Rate	Up to 34 L/minute
Salinity	Approximately 25% greater than intake

Water will be stored inside Buildings A and C. Water storage will be for both potable and firefighting use. Stored potable water is calculated based on the maximum occupancy for 10 days at 100 L/person/day, which equates to 100,000L of potable water storage. Additional storage for firefighting water is also included in the design.

2.6.3.2 Water efficiency

Water use at Scott Base is currently around 130L/person/day (the New Zealand average is 227L/person/day). As water production is energy intensive and storage takes up valuable space, water efficiency in design and user behaviour is essential. Water use efficiency targets are also set within the Green Star accreditation process, through the development of environmental performance targets and the inclusion of efficient fittings and fixtures.

The proposed Scott Base will seek a reduction in water use to approximately 75-80L/person/day (while the design production allows for 150L/person/day). Water efficiency strategies for the Scott Base Redevelopment include (in litres equivalent/person/day):

- Reduction of flushing water from 36L to 6L based on vacuum toilet technology;
- Reducing shower use from 45L to 30L based on reducing nozzle flow from 9L to 6L/minute; and
- Efficient laundries resulting in reductions from 11.5L to 4.3L.

Other operational strategies and leak/flow detection systems in the Building Management System are included to identify abnormal flows and manage supply and demand.

2.6.4 Wastewater management

Wastewater will be treated through a membrane bioreactor (MBR) WWTP with tertiary treatment. The WWTP may include UV treatment as well though this was unconfirmed at the time of preparing this draft CEE. MBR technology has been recently installed at the Australian Antarctic Division’s Casey and Davis Stations, the British Antarctic Survey’s Halley VI, and Belgium’s Princess Elisabeth Station among others. The plant is designed to treat an estimated 15,000L per day at peak load, with treated effluent discharged to McMurdo Sound via an elevated piped ocean outfall.

The MBR plant is designed to also treat two other major waste streams currently returned to New Zealand: food waste and solid human field waste (Section 2.6.5). These two waste streams will be macerated and injected into the MBR plant along with wastewater for treatment. Poultry waste will continue to be excluded from the wastewater stream to prevent the potential spread of avian disease to penguins.

A by-product of MBR technology is the sludge separated from the final effluent. The MBR plant will contain a dewatering unit to dry the sludge before returning it to New Zealand for disposal.

MBR technology is considered best practice for wastewater treatment and with future minor additional treatment stages, the effluent could be recycled into potable water. The level of treatment exceeds the requirements of the Protocol, the International Maritime Organization's (IMO) Marine Environmental Protection Committee's (MEPC) guidelines and the Green Star targets (Table 13). The final filtration stage in MBR technology is microfiltration of between 0.1-0.4μm, which is effective at filtering most bacterial pathogens (0.5-5μm) and microplastics (1μm- 5mm). MBR filtration is ineffective at filtering viruses.

Table 13: Comparison of standards and targets for wastewater treatment alongside the MBR technology capabilities. Percent reductions are based on the raw wastewater being treated.

Parameter	Unit	IMO MEPC Standard	Green Star Target	MBR Technology	Current WWTP Plant[14]
Total Suspended Solids (TSS)	mg/L	35[15]		1	
Biochemical Oxygen Demand (BOD5)	mg/L	35		1.1	
Chemical Oxygen Demand (COD)	mg/L	35	95% reduction	18.4	83
pH		6 - 8.5		6.5 - 7.7	
Coliforms	per 100ml	100	95% reduction	1	3075
Total Nitrogen	mg/L	20 or 70% reduction	75% reduction	5.3 or 95% reduction	
Total Phosphorus	mg/L	1 or 80% reduction	80% reduction	0.26 or 99.7% reduction	

2.6.5 Waste management

Proposed design improvements and new technologies to minimise waste generation at Scott Base include:

- Standardising equipment, fittings, fixtures and engineering requirements;
- Technological improvements in cargo and stores management;
- Elimination of some waste streams so far returned to New Zealand (approximately 25% of waste by weight):
  - Food wastes treated through the wastewater plant, eliminating approximately 6,600kg annually;
  - Drying and compaction of wastewater solid by-products, eliminating approximately 4,400kg annually; and
  - Human field waste treated through the wastewater plant;
- Provision of a specialised waste handling and sorting facility to improve process efficiency.

Updated operational policies and procedures are proposed to avoid the generation of waste and increase the reuse and recycling of wastes where possible. Some waste streams will be managed in a similar method to current operations. Recyclable materials and non-recyclable will continue to be separated at Scott Base and returned to New Zealand by ship for local recycling, treatment and/or disposal in landfill.

Hazardous wastes, including bio-hazard, medical and wastewater solids, oils, oil-contaminated materials, fuels, batteries and electronic componentry, and miscellaneous laboratory and science-derived wastes (minimal quantities) will be stored and returned to New Zealand following best practice and New Zealand compliance requirements.

[14] 2015-2016 average, not all parameters have been measured.
[15] IMO standard 227(64) also includes a dilution factor to be considered in wastewater discharge quality parameters. The standard applies to ship-based discharges. As no applicable discharge standards exist, the IMO standard was used as a quality baseline.

2.6.6 Biosecurity

Biosecurity is a key consideration for the design, construction and operation of Scott Base. Biosecurity design requirements were developed using the CEP's Non-Native Species Manual and in consultation with New Zealand's Ministry for Primary Industries Biosecurity team.

The key pathways for the transfer of non-native species are the intercontinental and intracontinental movement of people and cargo. The design provides for the separation of intercontinental and intracontinental cargo arriving and leaving the station. Dedicated biosecurity spaces are key components of the proposed Scott Base and new operational biosecurity procedures will accompany the new facilities. These include:

- Building A contains a dedicated space for the receiving and storage of food as well as facilities for boot washing and bag checks adjacent to the locker room;
- Building B contains the staging area for fieldwork and movements within Antarctica. Inward and outward movements are separated into different pathways. The outward movement pathway contains space for cleaning and checking equipment. The inward pathway includes a fully contained room to clean and check equipment; and
- Building C contains the intercontinental cargo bay. This area is fitted with biosecurity checking, cleaning and containment equipment to ensure that any non-native species that may arrive in Antarctica can be contained.

2.6.7 Science capability

2.6.7.1 Science at Scott Base

New Zealand's approach towards conducting science in Antarctica emphasises fieldwork and data collection. The majority of data processing and analysis is completed on return to New Zealand. As such, the science capability of the proposed Scott Base includes spaces for the staging of field science events, some laboratories and support for the LTS installations. The proposed facilities were developed in collaboration with the New Zealand Antarctic science community to support current and future needs.

Building B contains the majority of the proposed science facilities including:

- Two containment labs and a clean lab;
- Collaborative workspaces and shared meeting spaces;
- Two clean workspaces for electronic equipment setup and repair;
- Walk-in fridge and freezer for sample storage;
- Staging area for all science field events, including storage cages and a drive-in staging zone; and
- External roof deck for the placement of monitoring equipment.

2.6.7.2 Long-Term Science Installations

The provisions for LTS include inside space with an electrical/mechanical workshop and offices for science technicians for the servicing of long-term science. A rooftop observation deck allows for the installation of further experiments.

The existing external LTS installations are retained as their continued datasets are an important contribution to science. The locations of the installations will change as the new station will cause interference that may affect the data. The relocation of the LTS experiments is described in Section

2.9.1. Preparatory works including a range of surveys and tests began in the austral summer of 2020/21 to ensure an appropriate overlap and continuity in data collection. The activities were assessed and permitted under Antarctica New Zealand's Initial Environmental Evaluation 2019-23.

2.6.8 Resources for the operation of the proposed Scott Base

The proposed Scott Base offers improvements in efficiencies in operational efficiencies, the standardisation of all plant and equipment and materials and finishes that are long-lasting and easier to clean. This results in staffing requirements that are proportionally lower than for the current Scott Base, which requires approximately 35 personnel for summer operations. The proposed Scott Base is expected to require approximately 39 people.

The number of specialist personnel required to visit each year, for example for maintenance, inspection and certification of compliance of plant and services, is anticipated to fall from 17 to 13 people per year. This will result in increased bed capacity to host scientific personnel.

2.7 Deconstruction of the existing Scott Base

The existing Scott Base buildings need to be removed to prepare the site for the new station. The removal will occur in two stages because some of the existing buildings will be used during the Scott Base Redevelopment as accommodation for the main contractor's teams. The buildings that will be retained are Buildings 1 to 4 (Figure 24). Buildings 5 to 11 will be deconstructed before starting the construction activities in Antarctica.

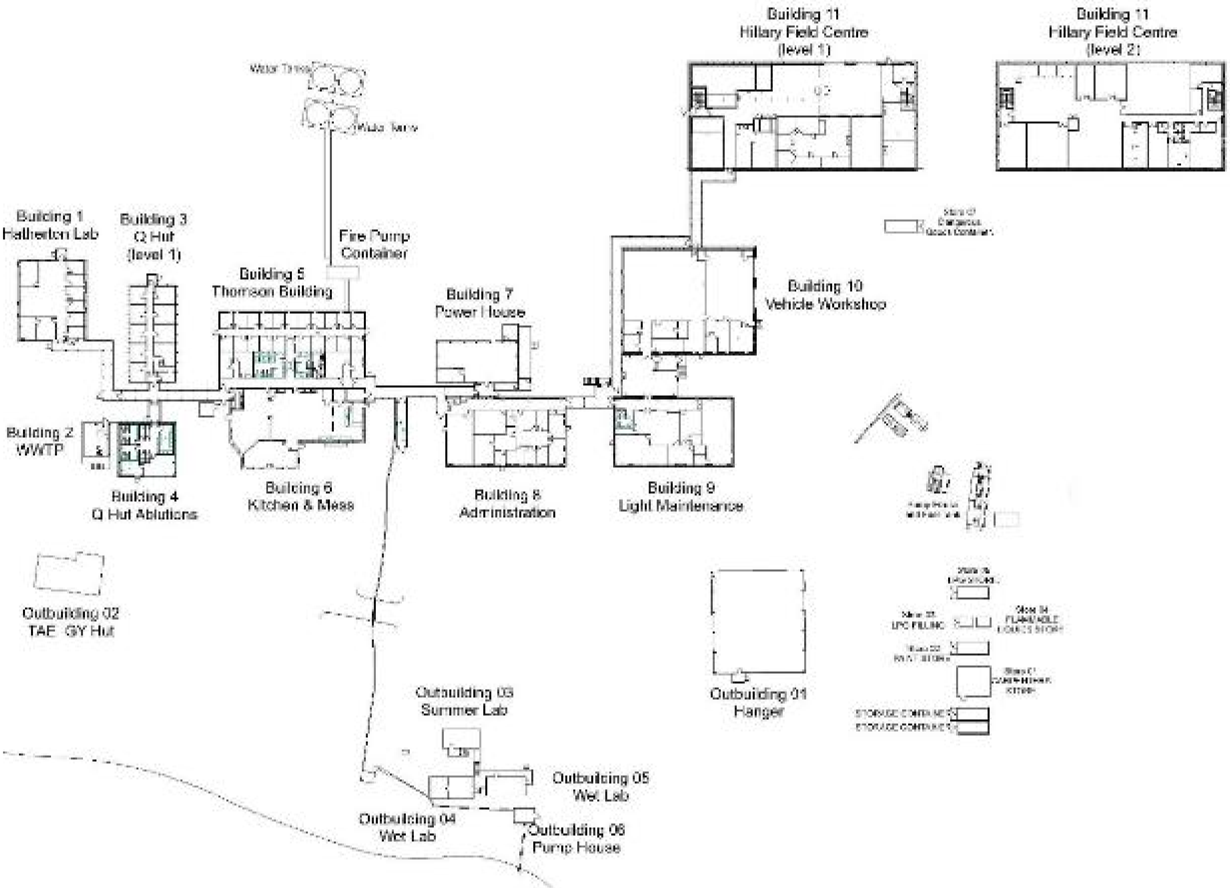

Figure 24: Current Scott Base building layouts for reference in the deconstruction methodology.

All of the Scott Base buildings will be fully deconstructed on site. The first stage of deconstruction will be the HFC (Building 11). The internal deconstruction is proposed for the winter of 2024, with the remainder of the deconstruction to occur over the 2024/25 season. This follows the establishment and commissioning of a temporary base in the 2023/24 austral summer season (Section 2.9 and Appendix 1). All waste material will be sorted on site and containerised for return to New Zealand. The contractor's accommodation buildings and associated infrastructure will be deconstructed following the completion of the proposed Scott Base in the 2026/27 season.

The method for deconstruction for both stages is:

1. Remove all retaining walls, external services and infrastructure;
2. Drain plant fluids into double-skinned drums;
3. Isolate and strip services and remove building interiors;
4. Remove exterior claddings. The cladding sheets are proposed to be removed whole and without cutting;
5. Deconstruct steel super structure using gas torches as necessary to cut sections;
6. Remove floor slabs;
7. Remove foundations. Any bearers that have been in contact with asbestos-contaminated ground will be treated as hazardous waste and handled as per the method in Section 2.8.3;
8. All remaining wastes or contaminated ground will be removed.

Local controls to divert meltwater from going through the work site will be used to prevent run-off. Depending on the site conditions, it may include snow removal or the diversion of meltwater with solid barriers.

2.8 Civil and foundation works

The civil engineering methodology and foundation design were developed in response to the following constraints:

- **Ground profile:** Ground conditions vary across the site according to the depth of the underlying bedrock. This is overtopped by varying layers of loose scoria and man-made gravel deposits. Ice lenses are present in insignificant quantities according to site investigations.
- **Bedrock:** The material strength indicated that the ground can support multiple foundation options.
- **Permafrost:** The Pram Point soils comprise a seasonally thawed active layer of soil material over permafrost. The depth to permafrost soils vary across the site with depth to bedrock in the range of 0-1m on undisturbed land and up to 2m on disturbed land.
- **Natural hazards:** The risk of earthquakes, volcanic eruption and tsunami were considered. The tsunami run-up line lies at approximately 8m above sea level.
- **Climate change:** Predicted impacts at Pram Point are longer periods of open water, resulting in more frequent storm-induced erosion events of the shoreline; sea-level rise; more frequent snow events; increase in humidity and deepening of the permafrost active layer.

2.8.1 Earthworks requirements

Bulk earthworks are proposed to:

- Realign the Scott Base to McMurdo road;
- Prepare the building platforms for both the proposed Scott Base and the temporary base sites;
- Remediate ground contamination;
- Level the foreshore for the temporary wharf;
- Build haul roads for the transport of the building modules;
- Level a small staging area at the Gap (shown in Figure 4); and
- Install the water intake and outfall structures and bulk fuel storage tanks.

Part of the area requiring earthworks either overlay the current station footprint, or is in an area of known asbestos contamination. The works will be staged from top to bottom (north to south), in line with the removal of the current Scott Base.

The Scott Base to McMurdo road links both stations and leads to the airfields via the “Scott Base transition” from land to the ice shelf. The road passes just outside Scott Base in a very tight hairpin bend, on a slope to the east of the Scott Base buildings (Figure 25). This bend is difficult to negotiate for the large vehicles and plant that use the road daily during the summer months. The gradient of the slope also causes a risk of brake failure and in summer, the frequent traffic and winds cause dust issues for Scott Base.

The proximity of the road to the proposed activities increases the risks of conflicts between normal road traffic and the Scott Base Redevelopment activities. Dust, vibration and noise from the road are issues that would affect both the project and the completed proposed Scott Base.

The Scott Base Redevelopment proposes to address these issues through the realignment of the road. This will provide better access to and from the ice shelf, as well as better separation between Scott Base activities and road traffic. The impacts of dust and noise on Scott Base will be reduced and both traffic and station operations will be safer.

The proposed realignment involves constructing approximately 383m of new road, starting from an elevation of 6.5m to 43m above sea level (Figure 25, Figure 26, Figure 27). Starting at the land to ice shelf transition, the realigned road section will depart from the existing road to a new intersection to provide access to Scott Base. This access is proposed to be a 10m-wide by 60m-long road section.

The realigned road continues through a 160-degree sweeping bend and widens from 10 to 15m to accommodate the turning circle of the USAP Kress vehicle that transports passengers from Ross Island to the airfields. The realigned road then re-joins the existing Scott Base to McMurdo road (Figure 27). Roadside v-channel drains approximately 1.5 to 2m wide will be formed on both sides of the proposed road to replace the current meltwater channels towards the coastline. A 20m-long culvert will convey meltwater beneath the road towards the coastline.

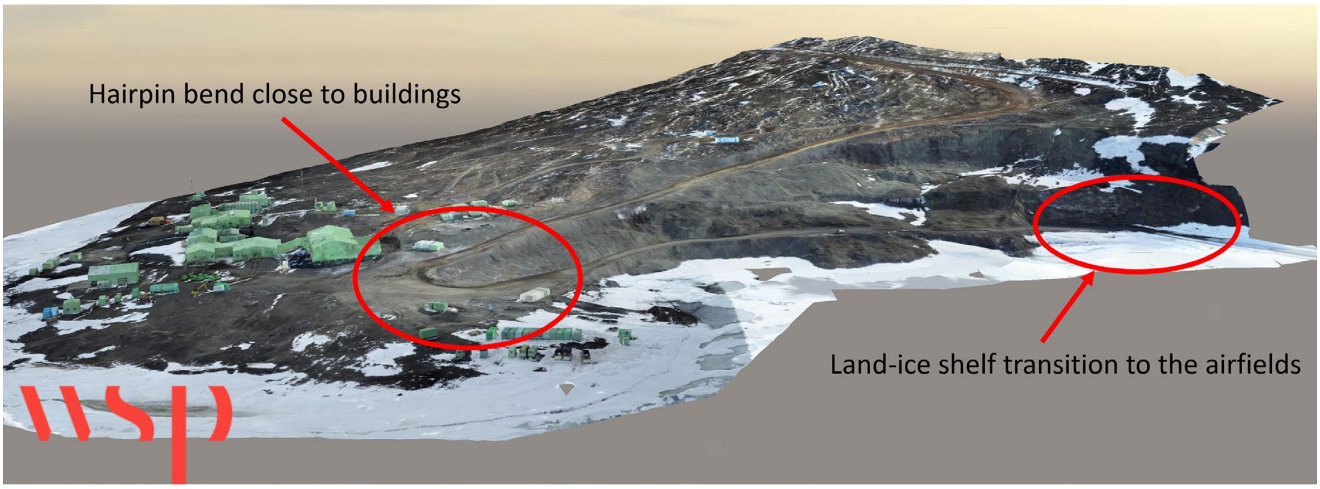

Figure 25: The Scott Base to McMurdo road is very close to Scott Base. (Base image: WSP, 2020)

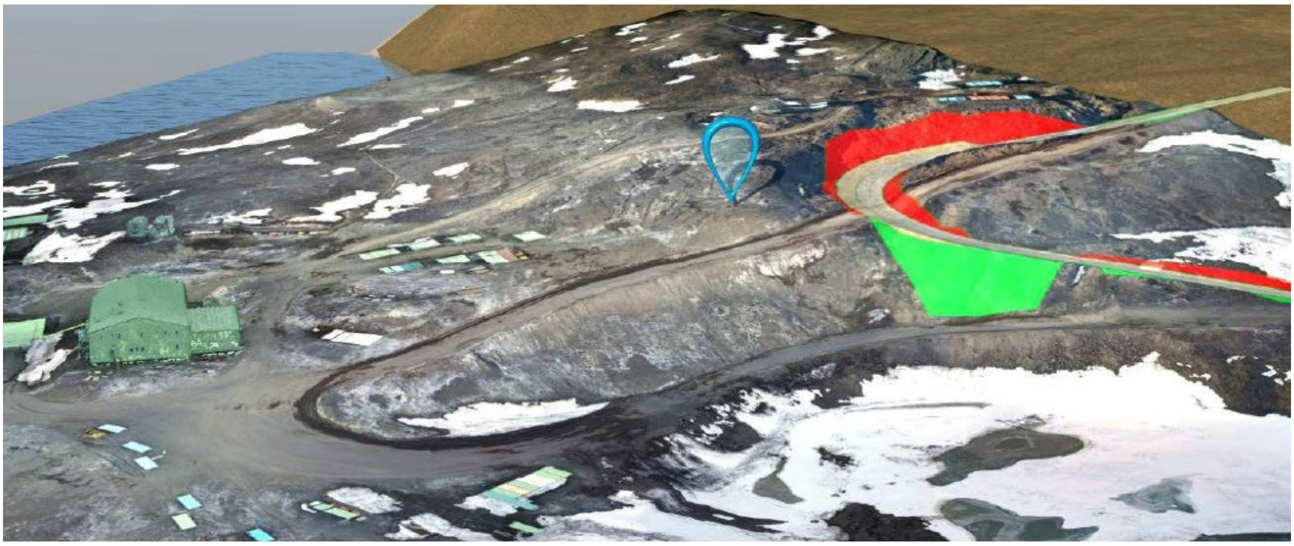

Figure 26: Proposed road realignment at the Scott Base transition.

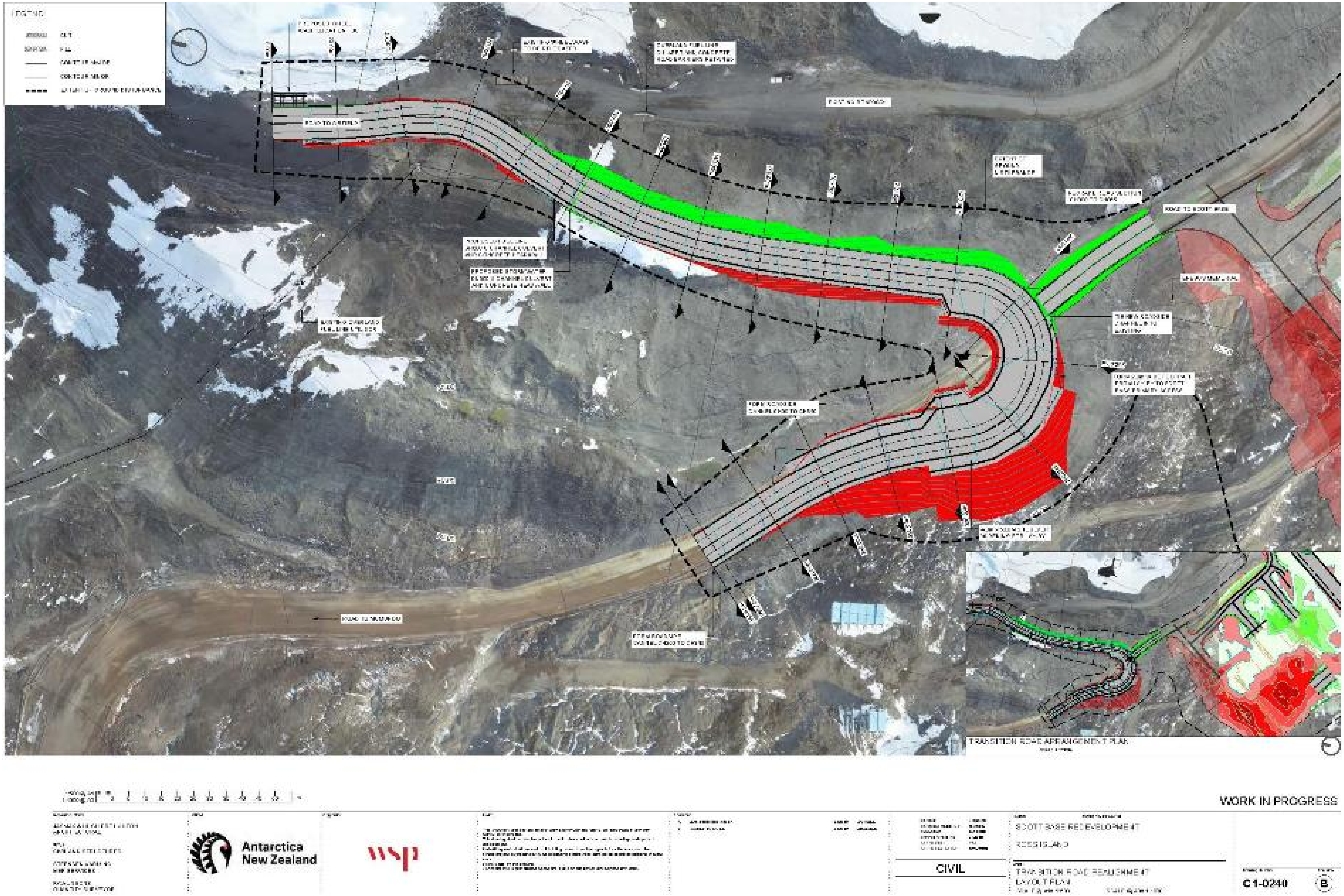

Figure 27: Scott Base to McMurdo road realignment layout plan with (inset) the wider site plan for earthworks. Note north is to the top left on the plan.

2.8.2 Earthworks methodology

The proposed earthworks area is 60,350m^2 and is detailed in Figure 28 to Figure 31[16]. The cut volume for the total civil works is estimated at 60,000-70,000m^3. The building site is to be formed by a process of 'cut to fill', to achieve an earthworks balance where all the cut, or excavated material is reused in the various fill platforms of the site.

The proposed methodology for earthworks is to drill and blast. At the current stage of design, no specific blast patterns have been determined. However, assuming the use of 76mm diameter hole production drill rigs, drilling blast holes of 1.25 – 5.75m deep at 2.0 – 3.5m spacing, the total range of blast pattern drill holes is 1,000 – 3,000. This results in the order of 3,700 – 10,100 lineal metres of drill holes. The total weight of explosives required for the activities is estimated in the range of 72,000 – 84,000kg. Supporting activities such as loading, shot firing, load-out, screening/crushing and civil earthworks would be appropriately scaled to match drilling rates.

Blasted material will be processed by a rock jaw and crusher/screener to produce AP65 sized engineered fill. The fill material is proposed to be carted directly from processing to its final location. This is to avoid extensive stockpiling and therefore freezing of the material, which would result in double-handling.

The majority of the earthworks will be conducted over two seasons (2023/24 and 2024/25), with minor earthworks in 2025/26. The earthworks are proposed to be undertaken in shifts throughout the austral summer season, with activities planned in detail to the seasonal conditions.

2.8.3 Contaminated ground remediation

The options for contaminated ground remediation (see Section 4.6.3.) included consideration of the risk of other adverse impacts arising from the clean-up activity, as well as feasibility, available technology, practicality,the safety of personnel and cost-effectiveness.

Asbestos-contaminated soil exists across Pram Point due to construction materials used in former buildings of Scott Base and past methods of deconstruction (see Section 1.5.3). Testing determined the extent of asbestos contamination in the soil at Pram Point, presented in Figure 32. The extent and volume of asbestos-contaminated material requiring remediation will be determined once the temporary and permanent works plans are developed in detail. As a result, the exact volume of contamination cannot be fully quantified at this stage of the project.

The proposed asbestos management approach uses two treatments:

- Where asbestos-contaminated soil can be adequately capped by the cut and fill plan, it will be left in situ and encapsulated. This method includes the placement of bidim cloth over the contaminated soils and a minimum of 300mm of fill placed on top to immobilise the materials. The current earthworks plan indicates that the majority of the asbestos-contaminated soils will be encapsulated in situ.
- Where asbestos-contaminated soil is exposed or cannot be adequately capped in situ by the cut and fill plan, it will be removed to a suitable disposal facility in New Zealand. The method of removal will be to excavate the soil, place it into lined containerised bins and remove to New Zealand. Due to the high cost and potential impacts of removing soils from Antarctica, this method is the least desirable and is proposed as a last resort.

[16] The figures show 6m of fill for the temporary wharf. This was correct at the time of issuing the figures but is no longer accurate thanks to the proposed design of a cantilevered structure as described in Section 2.9.3.

Hydrocarbon contamination has been measured in discrete areas around the current Scott Base. In all instances, samples were found to be below both New Zealand guidelines for the protection of nearby water bodies and the lowest-observed-effect concentration for Antarctic mosses (refer Section 5.3.2.5 for detail). The proposed methodology for remediation will be on a case by case basis, as discovered on-site, where:

- Historically contaminated soil approaching and exceeding guideline values, and all fresh spills during the project will be manually removed for disposal in New Zealand; and
- Historically contaminated soils at lower concentrations will be left in situ for natural attenuation.

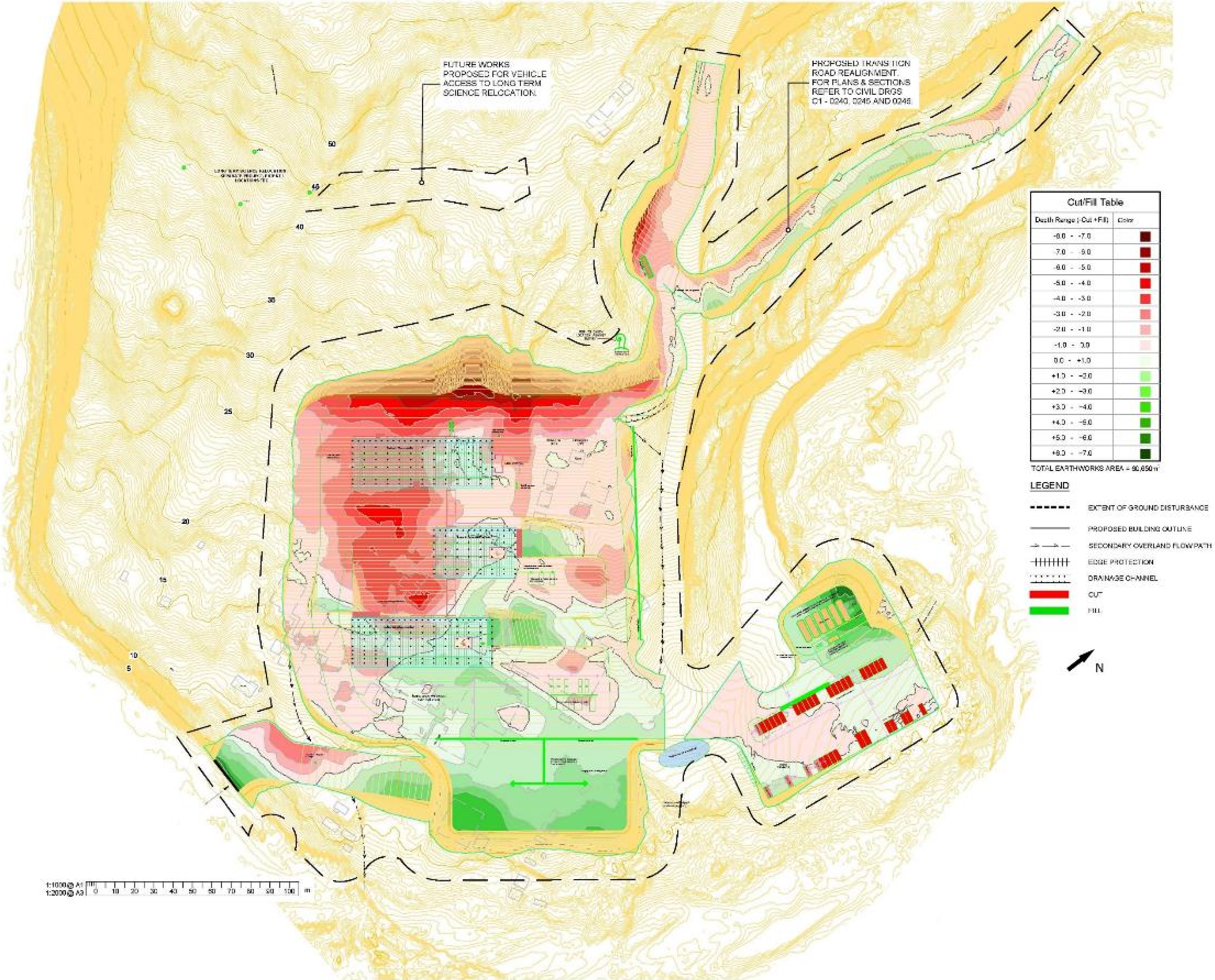

Figure 28: Bulk earthworks plan for the Scott Base Redevelopment with proposed locations of the three buildings, all associated infrastructure and relative locations of the current facilities (WSP, 2020).

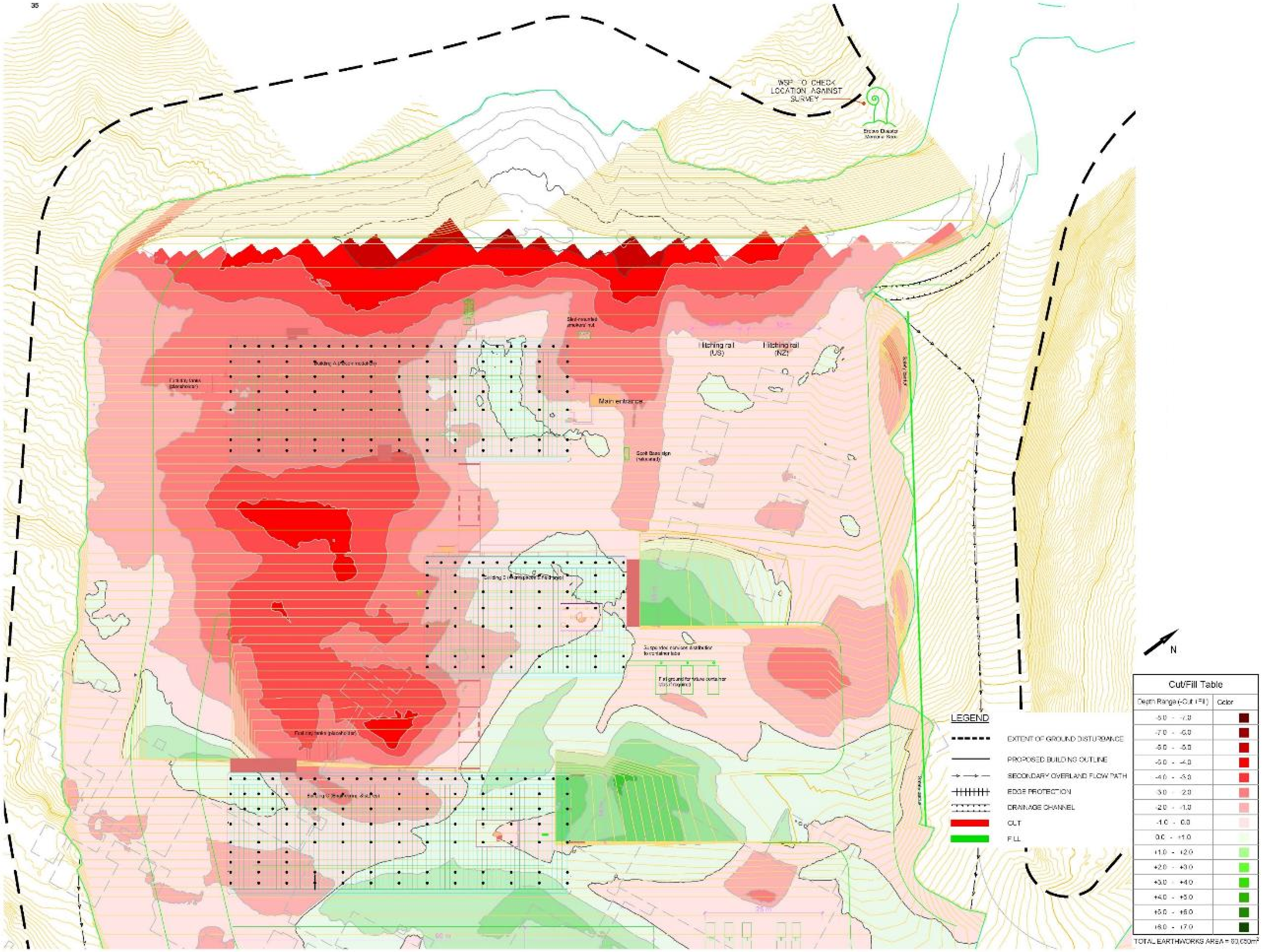

Figure 29: Detail of bulk earthworks plan with pile locations for the proposed Scott Base buildings (WSP, 2020).

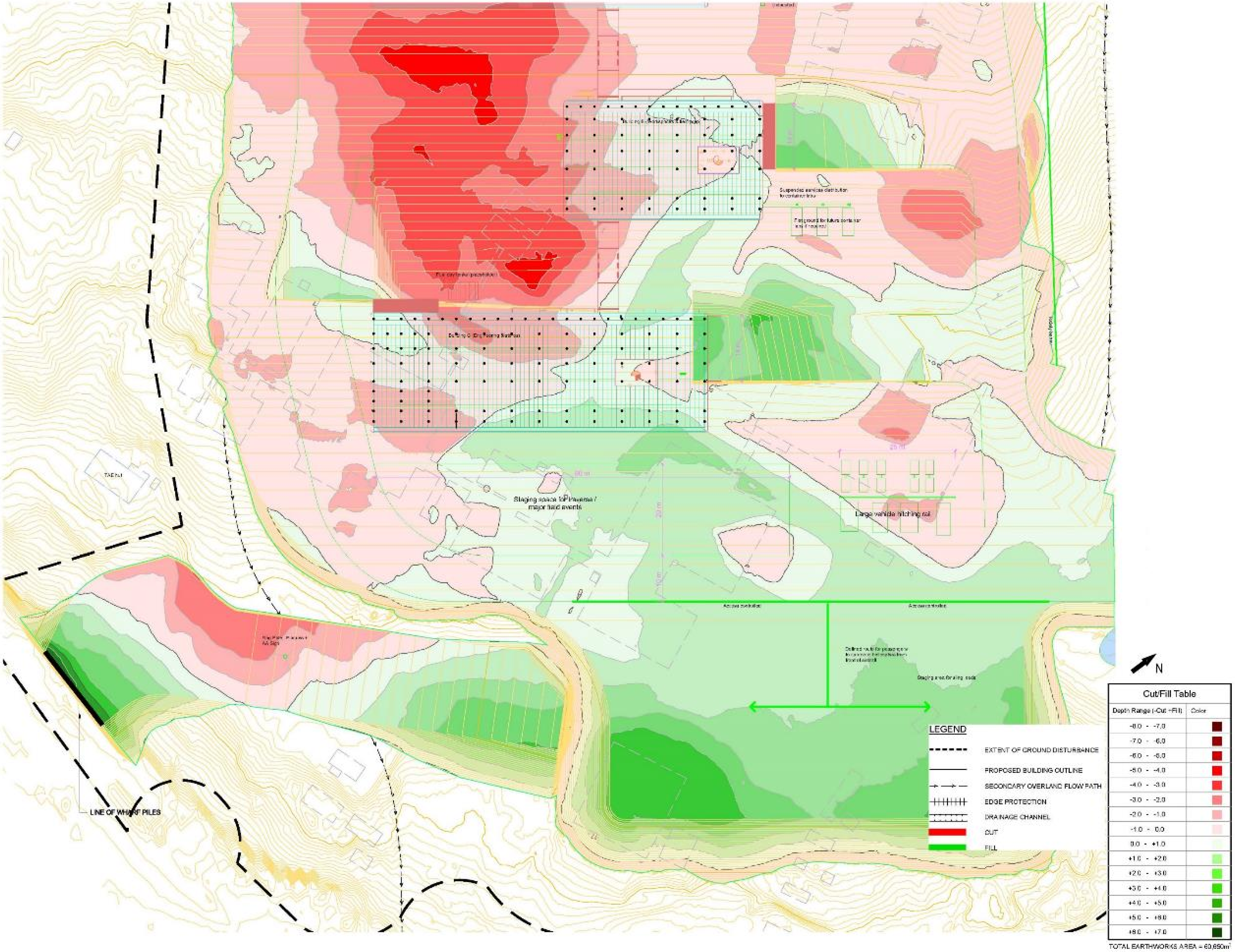

Figure 30: Detail of bulk earthworks with location of the wharf and the piling locations for Buildings B and C (WSP, 2020).

Figure 31: Detail of bulk earthworks with location of the proposed container line and bulk fuel storage. This is also the proposed staging location for construction equipment and the current buildings for removal (WSP, 2020).

Figure 32: Plan showing the cut (red) and fill (green) profile with contamination areas both known and inferred superimposed (WSP, 2020).

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2.8.4 Foundations

The proposed foundations are end-bearing piles (Figure 33). Piles will be formed by coring rock sockets of 500mm in diameter and a depth of 4-6m into the bedrock. Where engineered fill overlays the bedrock, the coring will extend through the fill to create the rock socket in the underlying bedrock.

Closed-end, steel piles of approximately 400mm diameter will be placed in the rock socket and bear the weight of the buildings on a c.100mm cement grout pad. The piles will then be frozen in place with either water or a sand/water mix. Pile numbers for the buildings and ancillary structures are provided in Table 14 and Figure 29.

Piles and bollards for the temporary wharf and the water outlet structure follow the same methodology.

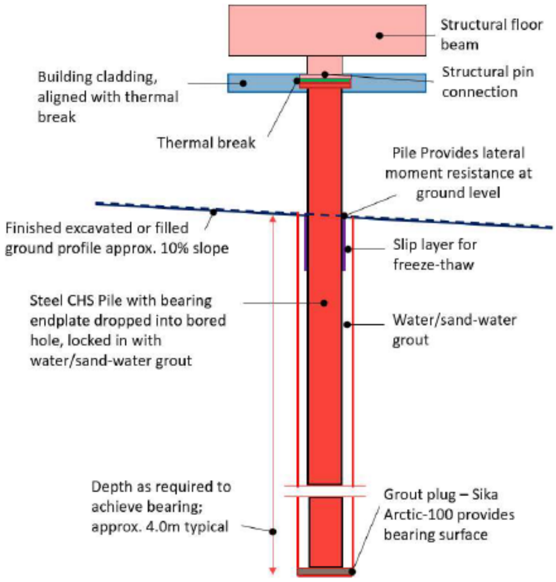

Figure 33: Sketch of the proposed end-bearing pile.

Table 14: Piles required for the Scott Base Redevelopment proposed buildings and ancillary structures.

Structure	Pile numbers
Building A	103
Building B	63
Building C	113
Wharf structure	58
Mooring bollards	12
Water outlet structure	4

2.9 Enabling works

2.9.1 Long-Term Science relocation

The LTS experiments will be moved approximately 100m uphill from their current location (Figure 34). The works will involve the construction of new masts, the installation of four container-based buildings to house some instruments, laying of services and tracking. On-ground precast concrete foundation blocks and small steel piles will be required for the new structures, and minor (less than $100m^2$) earthworks for the formation of the container platforms will take place. The old LTS instruments will run for one to three years in parallel with the new instruments to ensure an appropriate overlap in data collection. After this overlap period, the old LTS instrumentation will be removed.

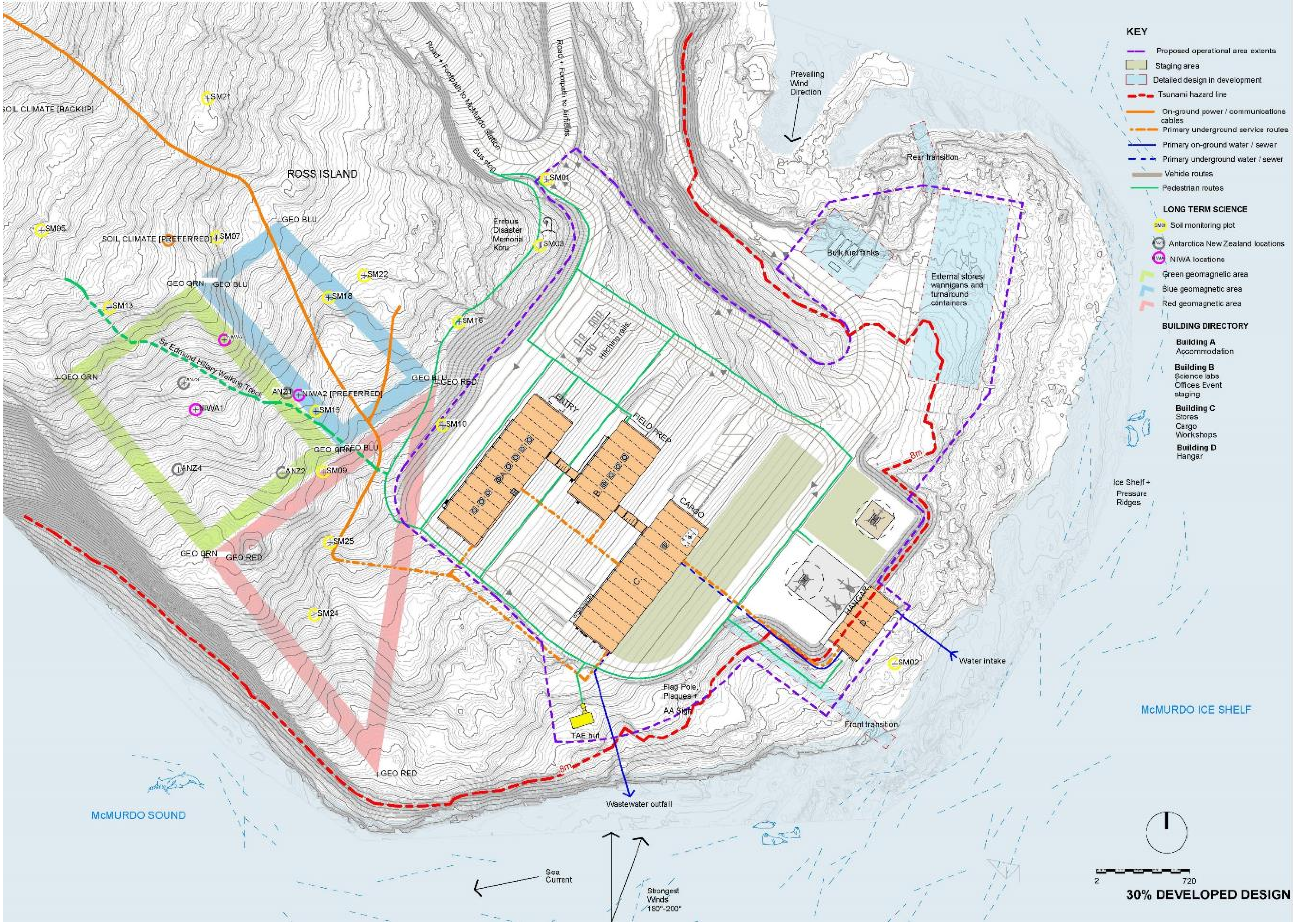

Figure 34: Indicative locations for LTS experiments. Note: hangar is out of the project scope. Original map by Jasmax.

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2.9.2 Water intake and wastewater outlet construction

A new water intake well, and a wastewater outlet structure will be constructed to replace the existing structures. The wastewater outlet structure will be similar to the current on in location and design.

The water inlet structure is a wet well. It will be constructed on the shore edge, allowing water to be drawn in from approximately 4m below sea level to supply the reverse osmosis plant. This structure, in concept design, is proposed to be a narrow V-channel cut into the foreshore in which a pipe will be placed. The well will be formed through drilling and blasting to create the well, inserting the piping, and backfilling with a larger uniform fill to protect it from sea ice pressure and icebergs. A small hut will be placed on top to house the pumps (Figure 35).

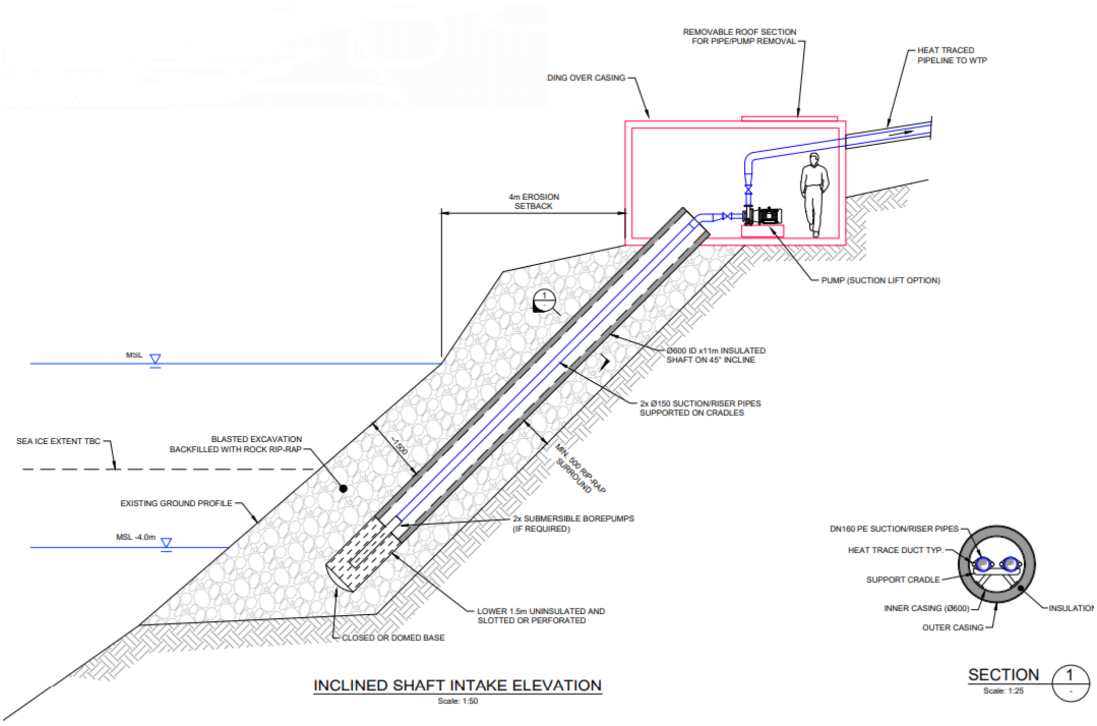


Figure 35: Concept view of water intake showing the cut channel, pipe lay and pump hut.

2.9.3 Temporary wharf construction

Pram Point is not currently used as a ship berthing or offload location. A temporary “wharf” will need to be constructed near the current wastewater outlet (Figure 30). This wharf will allow the vessel to berth as close to the shore as possible to minimise the gap between land and ship (Figure 36).

The wharf will be constructed without any physical works in the water. The land at the wharf location will be levelled to 5m above mean sea level. Fifty-eight piles will be installed on the shore in two lines and steel frames will be cantilevered off the piles (Figure 36). These will act as fenders for the ship to moor against (Figure 36), with the inner two frames providing structural support for the offload of building modules. Two sea anchors will also be deployed from the ship’s bow to stabilise the vessel (Figure 37). An additional 12 piles to be used as bollards will be installed following the method detailed in Section 2.8.4. The steel frames are designed to be unbolted and craned off after use, with the piles designed to be removed in accordance with the method in Section 2.8.4.

2.9.4 Haul road

A haul road will be constructed (detailed in Figure 30) to manoeuvre the building modules into place from the wharf to the final location. Following the delivery of the modules, the haul road will be incorporated into the proposed helipads, vehicle tracks and hitching rails where possible. Additional fill used to form the surface of the haul road will be repositioned for use in final surface shaping and the vehicle access ramps to the buildings where required.

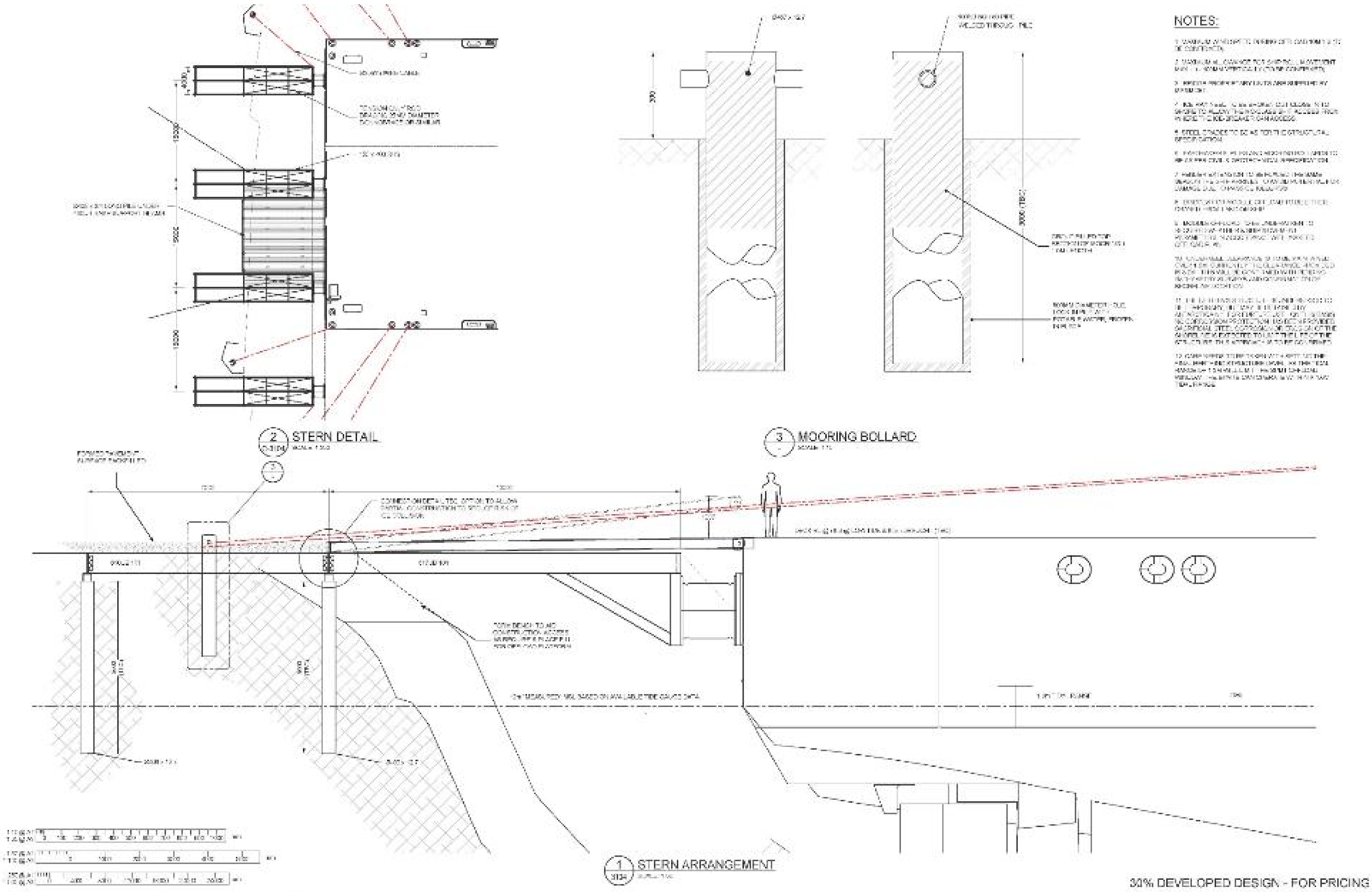
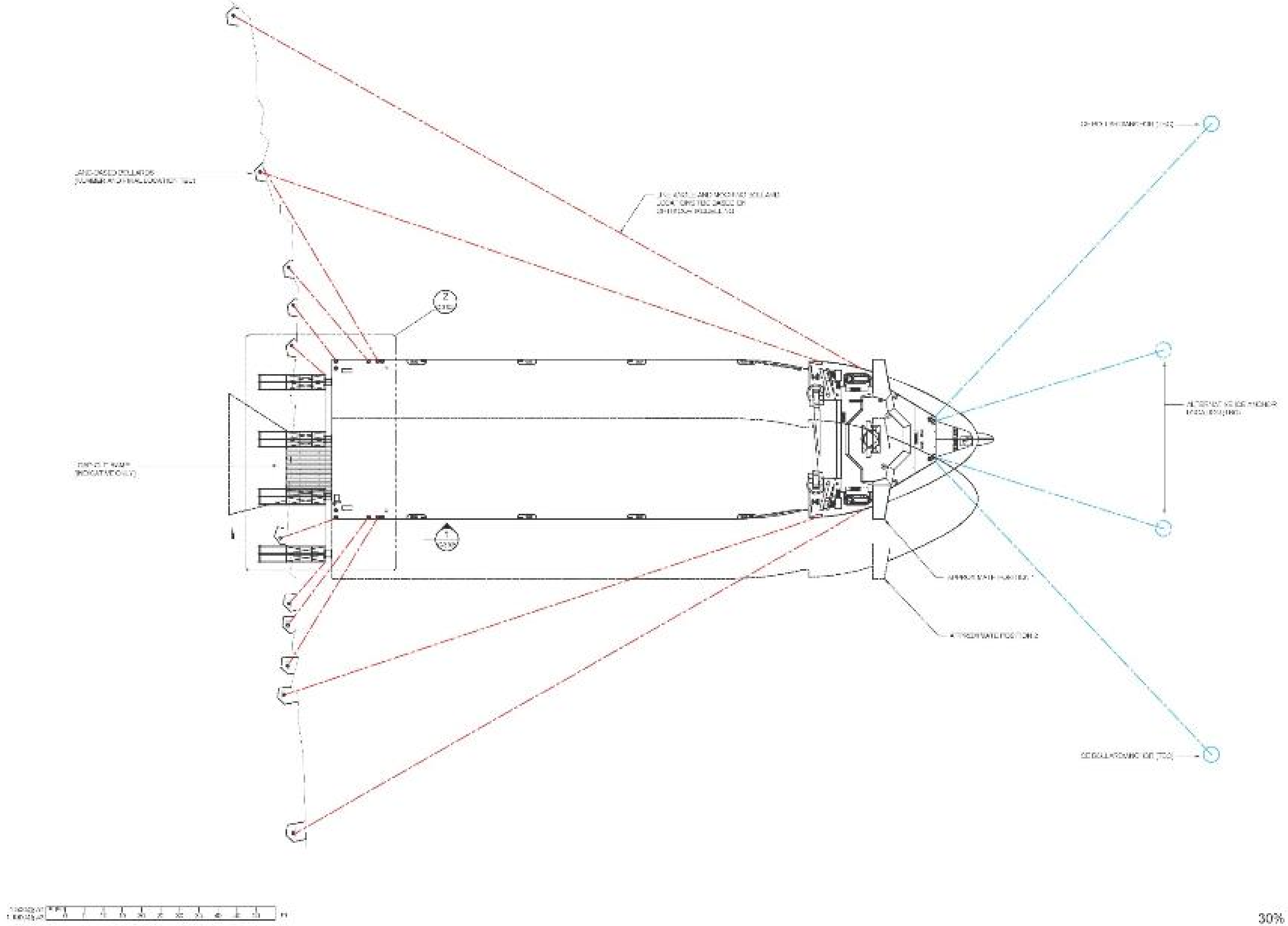


Figure 36: Plan view of the temporary wharf (top left), foundation pile and bollard detail (top right) and side view indicating the piles, cantilevered wharf, fender and ship.



30% DEVELOPED DESIGN -

Figure 37: Detail of the mooring location and two ship docking positions. Mooring lines and bollards are detailed.

2.10 Temporary Scott Base

A temporary base is required to house base staff, science teams and construction crews for the duration of the proposed activities. This is because the current Scott Base needs to be removed to make way for the new station. Construction of the temporary base is proposed in the 2022/23 and 2023/24 seasons, to be operated year-round until the proposed Scott Base is ready for occupation in 2026/27. The design for the temporary base was in a feasibility stage during the preparation of this draft CEE.

2.10.1 Temporary base location

The location for the temporary base is on Pram Point, across three sites, shown in Figure 38:

- The current long-term container storage yard, Area A;
- The current short-term container storage yard, Area B;
- Buildings 1-4 of the current Scott Base, Area C.

The proposed sites seek to reuse the current modified and operational area as much as possible. This ensures the temporary base can utilise existing infrastructure, allowing for efficient construction of the Scott Base Redevelopment.

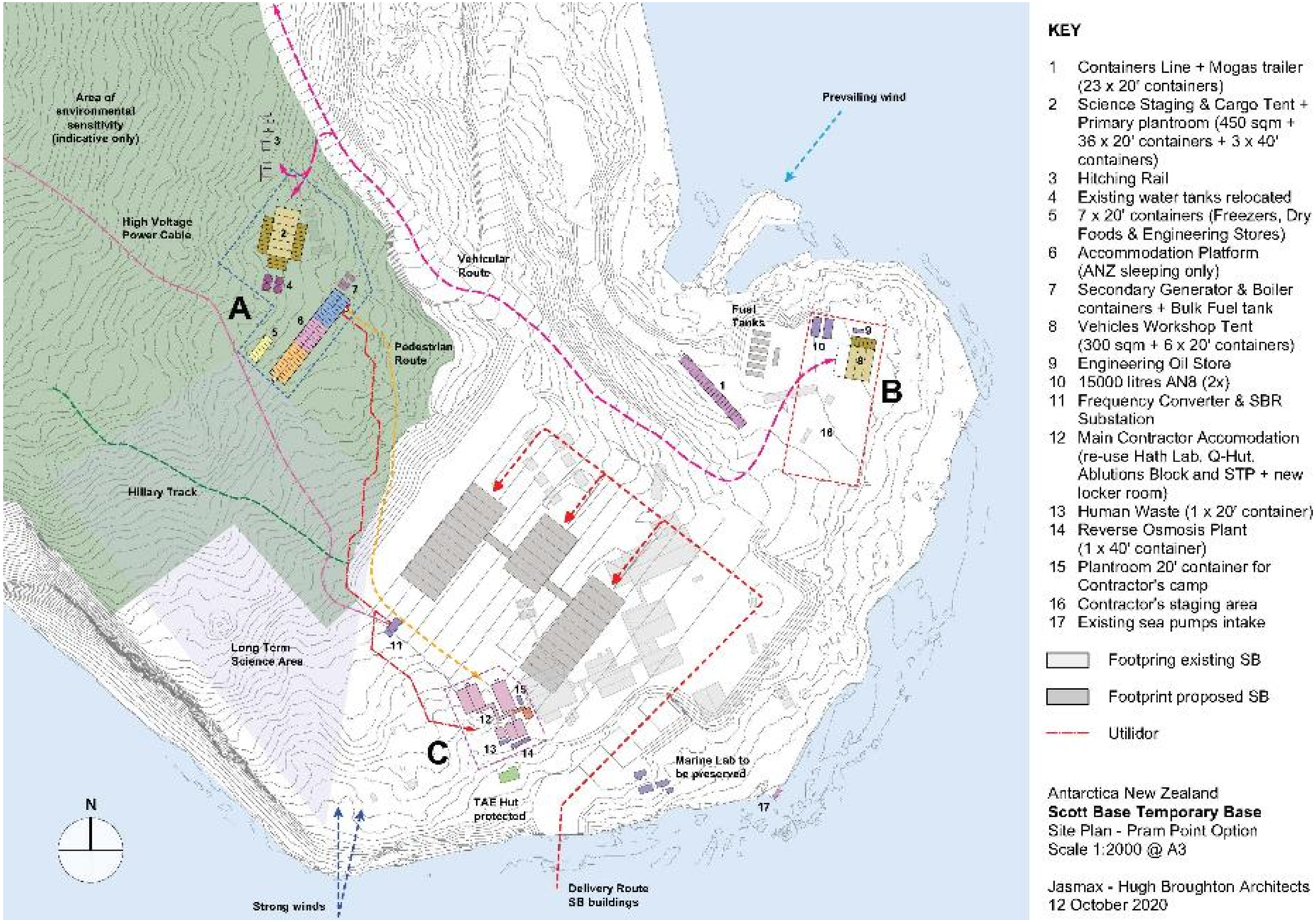


Figure 38: Site plan indicating the current, proposed station and temporary base location.

2.10.2 Temporary base design

The temporary base will have three building types:

- **Hard-sided buildings** can be formed in a variety of methods, from standard 20-foot shipping containers to flat-pack units that can be quickly assembled on-site in many different configurations. Containers can be put together to form the primary accommodation block, or individual units can be used to provide ancillary facilities (e.g. storage or plant containers).
- **Insulated fabric structures** generally comprise a lightweight insulated fabric 'stretched' over a traditional steel frame structure. They can be erected quickly and are used to form larger scale, climate-controlled spaces, for vehicle maintenance, cargo handling or science event staging.
- **Re-use of existing buildings** for Buildings 1-4. Reusing these buildings allows the temporary base to use the existing WWTP. The Hatherton Lab and Q-hut will be reconfigured to provide contractor accommodation.

The proposed design is presented in Figure 39 and Figure 40, with the current and proposed Scott Base shown respectively. All services between Area A and Area C will be run via an above-ground utilidor made of shallow steel piles (Figure 38). The structures at Area B are not proposed to have reticulated water and wastewater.

The temporary base capacity is 160 people. The average summer population is expected to be around 120 people, allowing for normal operations during the majority of the Scott Base Redevelopment. The extra capacity allows for years with a larger number of construction staff, science and operations. Nonetheless, careful planning of occupancy numbers will be required to balance normal operations and construction activities.

2.10.3 Temporary Scott Base operation

The benefit of operating the temporary base on Pram Point is the ability to use current infrastructure. The temporary base is designed to reuse the existing WWTP, energy from RIWE and containerised generators, relocated fuel storage and water tanks from the current Scott Base, containerised water production and the same methodology for waste management.

- **Energy generation:** Some of the current generators, the transformers and the frequency converter are proposed to be reused from the current Scott Base. A new permanent substation will be installed to allow the temporary base to use renewable energy from RIWE. Additional electrical energy will be provided by containerised generators located at Areas A and B. Electricity is proposed to be reticulated between Areas A and C via the above-ground utilidor.
- **Fuel storage and delivery:** Fuel storage will utilise the existing 56,000L tank. This is proposed to be relocated to Area A for use in the main plant for generation and heating. Two 15,000L containerised tanks currently on Pram Point will be used for vehicle refuelling at Area B. The proposed bulk fuel storage facility described in Section 2.6.2 is proposed to fuel the buildings of Area As and C. Fuel delivery is proposed to be the same as current, with fuel tanker deliveries from the bulk fuel storage at McMurdo.
- **Water production and storage**: Water production is proposed via a containerised reverse osmosis plant located at Area C. Freshwater will be pumped to the relocated storage tanks in Area A through the utilidor. The inlet for seawater supply is proposed to be the permanent inlet described in Section 2.9.2.
- **Wastewater treatment**: Wastewater is proposed to be treated via the existing WWTP. This plant provides tertiary treatment with ozone treatment before disposal via an ocean outfall.

The proposed increase in personnel during some seasons will likely strain the current plant, leading to lower quality of treatment. The proposed minimum standard of treatment is primary treatment (solids removal and settling) during high occupation and tertiary (full treatment with ozone disinfection) during all other periods.

- **Waste**: Waste management is the same as current operations, with minimisation as the key focus. All waste will be sorted into the same streams as current with storage in containers for removal to New Zealand.
- **Biosecurity**: Biosecurity is proposed to be managed the same as current operations, with an emphasis on cleaning and checking of cargo in New Zealand. Procedures for cargo checking and containment will be developed and implemented for the temporary Scott Base's operation.

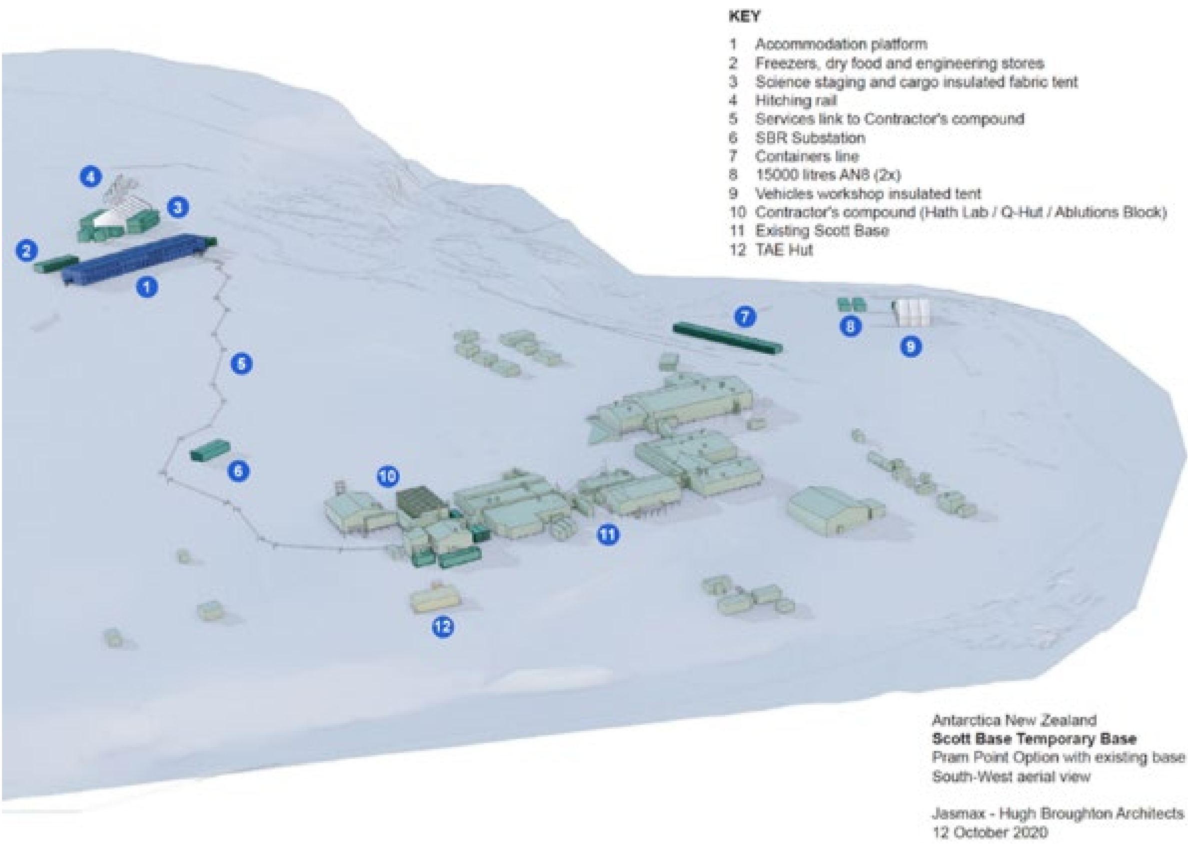


Figure 39: Temporary base design and location in relation to the current Scott Base.

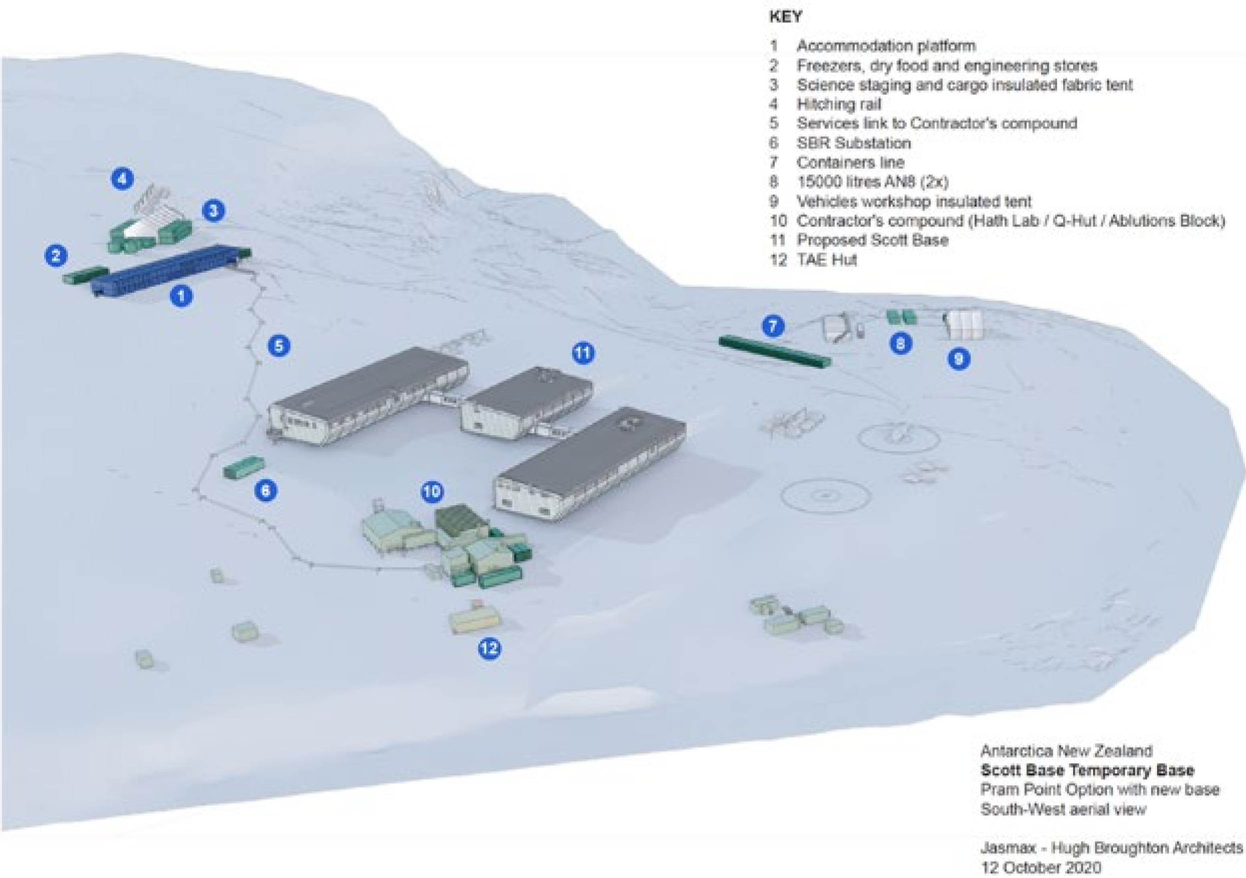


Figure 40: Temporary base design and location in relation to the proposed Scott Base.

2.10.4 Civil and foundation works

The preliminary civil design indicates that approximately 1500m^3 of earthworks is required for Area A (Figure 41). The earthworks are mostly limited to previously impacted sites, with minimal overlap onto previously unimpacted land. The method for earthworks is the same as described in Section 2.8.2 and is proposed for the 2022/23 season. Area B is included in the Scott Base Redevelopment civil works plan outlined in Section 2.8.1. These works will form part of the final platforms for the new buildings.

Foundations required for the temporary base are proposed to be precast concrete footings placed on grade with a grouted anchor rod drilled approximately to 1.5 - 2m depth. These foundations are similar to those of the current Scott Base buildings (Figure 42).

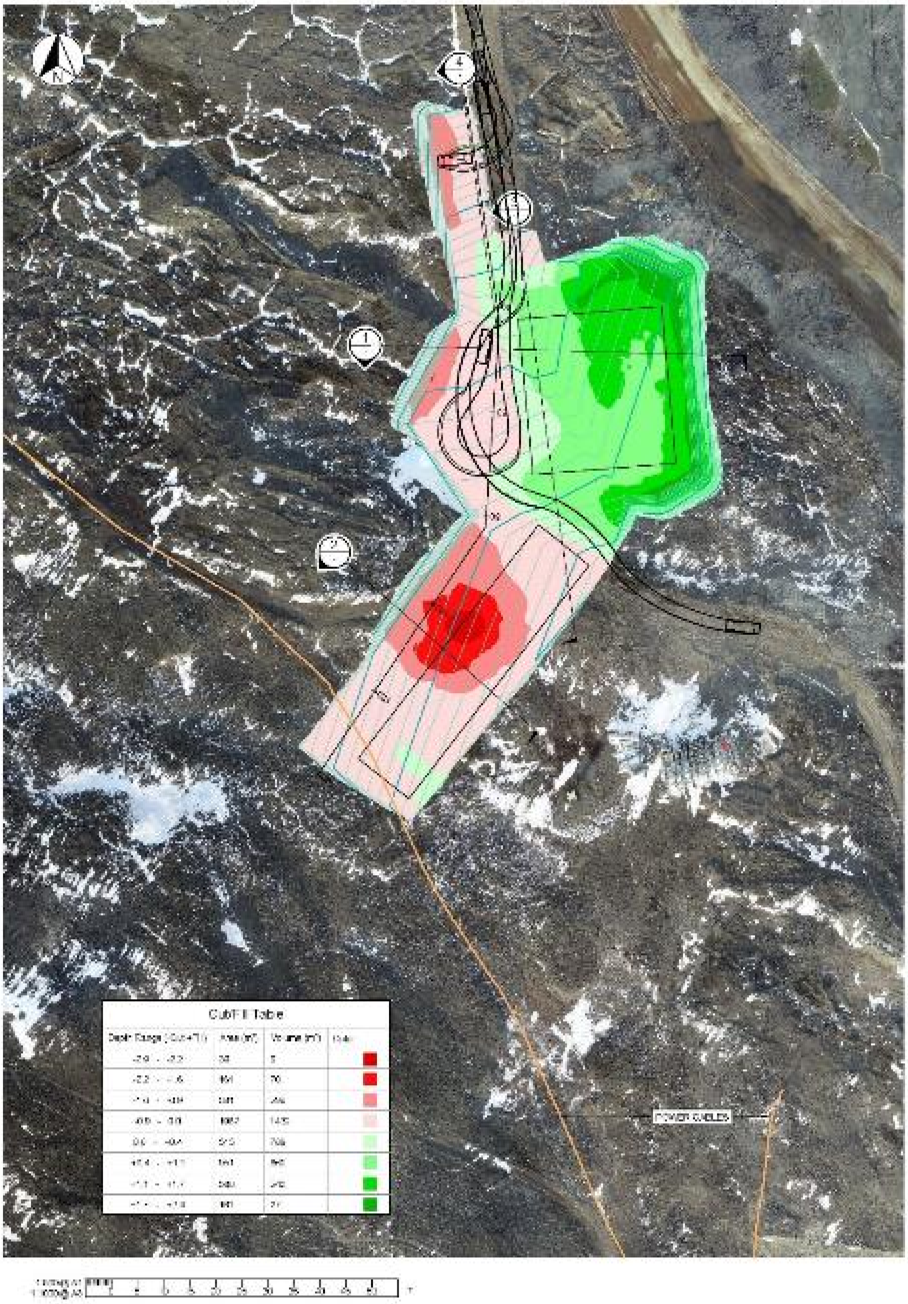


Figure 41: Preliminary temporary Scott Base Area A earthworks requirements.

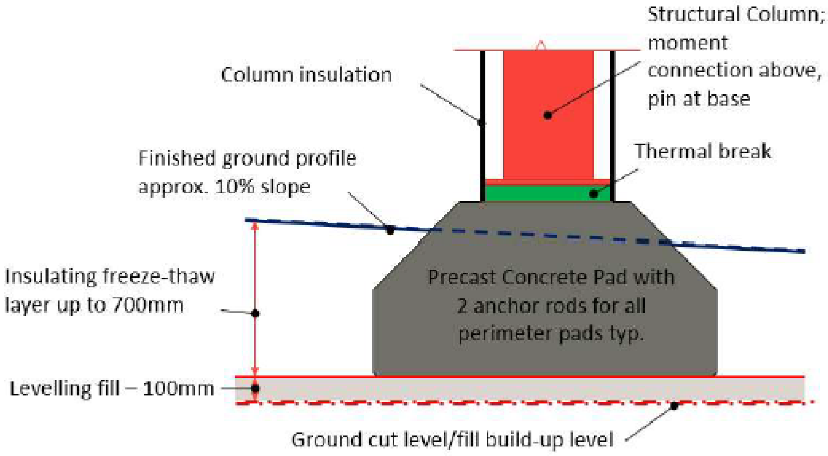


Figure 42: Pad foundations proposed for the temporary base buildings.

2.10.5 Construction and logistics

Approximately 125 x 20-foot containers are required for shipping the foundation blocks, containerised building modules, materials for the insulated fabric structures and materials for the re-fit of Buildings 1 – 4. These containers are proposed to be shipped in January 2023 and staged at Area B for construction of the temporary base in the 2022/23 and 2023/24 seasons.

Three different construction methods are required for the three buildings types within the temporary base:

- **Hard-sided buildings** are proposed to be placed directly onto the precast concrete footings and fastened together. The modules are completely pre-fitted and will clip together with only minor external finishes required to seal them together. Services will be laid between buildings including power, water and wastewater.
- **Insulated fabric structures** will be constructed using the same foundation types as the hard-sided buildings. They comprise of two parallel lines of containerised modules with a steel frame erected between forming a large enclosed open space. The enclosed open space is proposed to have a precast concrete slab across the entire area. A lightweight insulated fabric solution will be stretched over the frame structure, with insulated panels added under the fabric. External works to connect services such as power, water and wastewater will be undertaken at Area A.
- **Re-use of existing buildings** is proposed for Buildings 1-4. These buildings will require an internal remodel, with all internal linings and fixtures removed and returned to New Zealand as deconstruction waste. New interior fittings will include the provision of accommodation, kitchen and dining, contractors' office and recreation and a new locker room and cold porch as the entrance to the building. The WWTP is proposed to remain as is and the containerised water treatment plant is proposed to be located adjacent to these buildings.

2.10.6 Decommissioning

Decommissioning of the temporary base will involve reshaping the ground to the original contour. The temporary base buildings are designed to be readily mobilised on-site, so that the end of life will involve the uncoupling of buildings, flat-packing or shipping directly as containers and returning to New Zealand. All temporary overland services will be removed and containerised for return to New Zealand. The temporary foundations will be removed. The buildings in Area C are proposed to be deconstructed following the method in Section 2.7.

2.11 Scott Base delivery, installation and commissioning

The construction strategy is to construct the proposed buildings entirely in New Zealand, including completing all necessary commissioning activities. The buildings will then be separated into a series of large modules and transported to Antarctica in one season. A large ship, supported by an icebreaker, will transport the modules to Pram Point from New Zealand. Three Self-Propelled Modular Transporters (SPMTs) will transport the modules on and off the ship over the preconstructed wharf, up the haul road and lower them into place on the piles. The SPMTs are 18-axle trailers and will use AN8 as fuel while in Antarctica.

2.11.1 Transport to Pram Point

The building modules will be lifted from the construction site in New Zealand on SPMTs and rolled on to a large flat deck vessel (MC Class).

The external cladding of the modules will be exposed to the elements. It was designed with exposure to sea conditions in mind, noting that the modules will be constructed by the sea in New Zealand and that Pram Point is a coastal site. The ends of the modules will be closed with temporary cladding to protect the internal spaces during the voyage.

The footing of each building module will be welded to the deck of the vessel. The SPMTs will travel on the vessel under the last loaded (first off) building module. The SPMTs will return to New Zealand on the MC Class vessel return voyage. The deck of the proposed vessel measures 125m x 42m, allowing all proposed buildings to be loaded onto one vessel (Figure 43).

The voyage is scheduled for January 2026 for the best sailing conditions. An icebreaker will support it into Pram Point. The exact timing is dependent on the icebreaker cutting the channel to Pram Point.

The MC Class vessel was chosen because:

- It is fitted with a fully redundant propulsion system;
- The vessel has a high volume, high speed ballast system allowing ballast to be quickly pumped around the vessel to maintain stability without discharging water into the ocean;
- The vessel has a ballast water treatment system;
- Multiple systems allow detailed monitoring of weather conditions and facilitate voyage planning to optimise weather windows; and
- The MC-Class vessel has an implemented Polar Water Operational Manual enabling it to hold a Polar Code certificate.

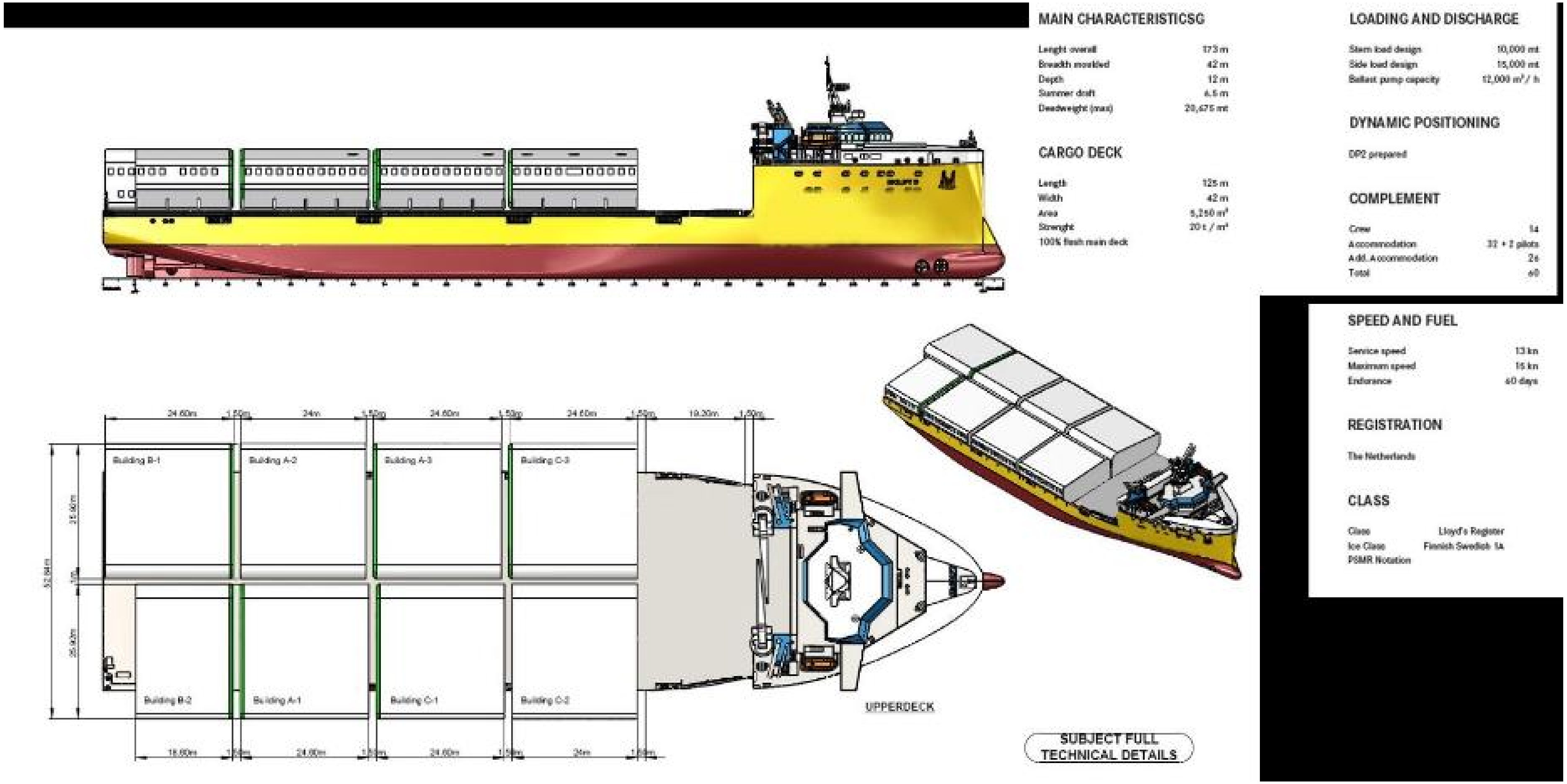


Figure 43: Preliminary loading arrangement and characteristics of the proposed MC Class vessel for the delivery of the building modules[17].

[17] Note the ordering and sequencing of modules is subject to revision.

2.11.2 Offload from ship to land

Once moored at Pram Point (Figure 44, Figure 45), bridges will be craned over the gap between the temporary wharf and the ship. The gap is expected to be between 6-10m. The vessel will be held in place by mooring lines to bollards and the fenders installed against the wharf.

Temporary elevated platforms will be constructed at each building location to create level access for the SPMTs. The temporary platform construction is not yet confirmed at the time of drafting. All temporary platform materials will be returned to New Zealand.

The building modules will be rolled off the vessel onto Pram Point on the SPMTs (Figure 46). The SPMTs will then transition the modules up the site and into position on their pre-placed piles (Figure 47).

Building B's modules will be off-loaded first (Figure 43). Temporary end cladding will be removed from the module when in its final position. As soon as the first module is positioned, the temporary platform will be removed and placed for the next module. The process will be repeated for the next module until Building B is complete.

Following Building B modules delivery, the modules for Building C will be off-loaded using the same methodology. During this time, the haul road between Building A and B will be re-graded to facilitate a smooth transition for the SPMTs delivering Building A's modules at the top of the site.

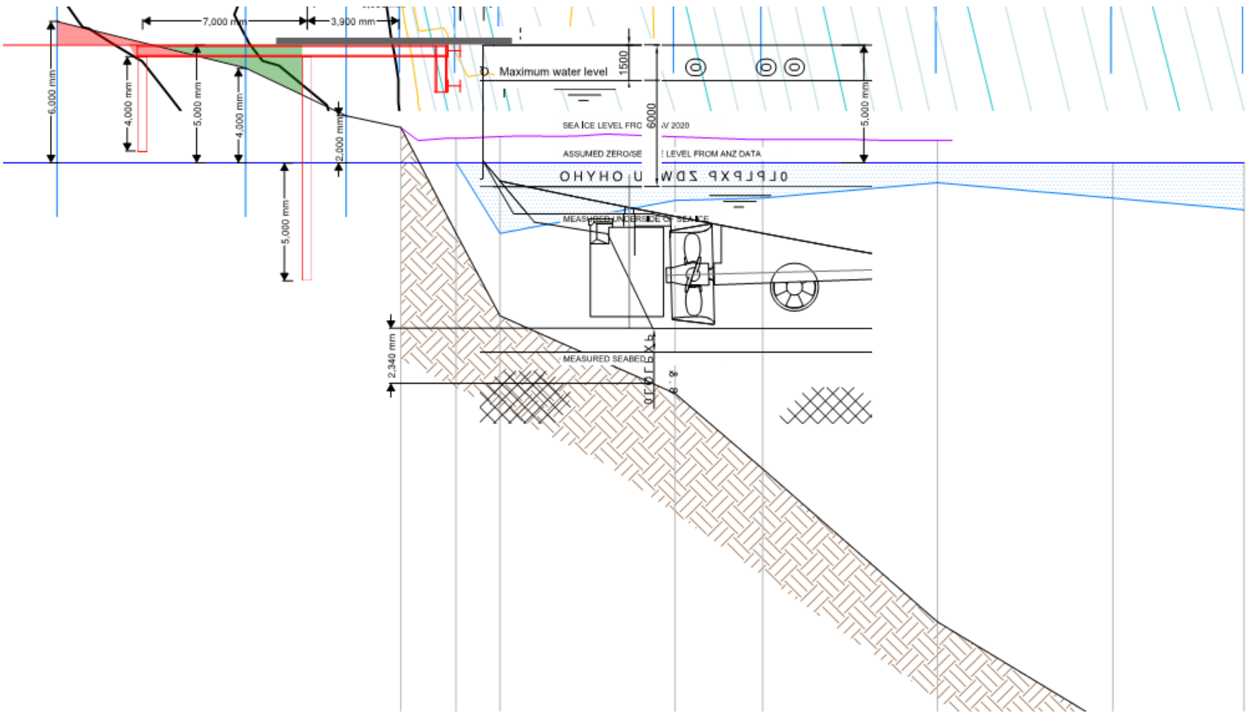


Figure 44: Side elevation of the berthing arrangement at Pram Point for offload of the modules.

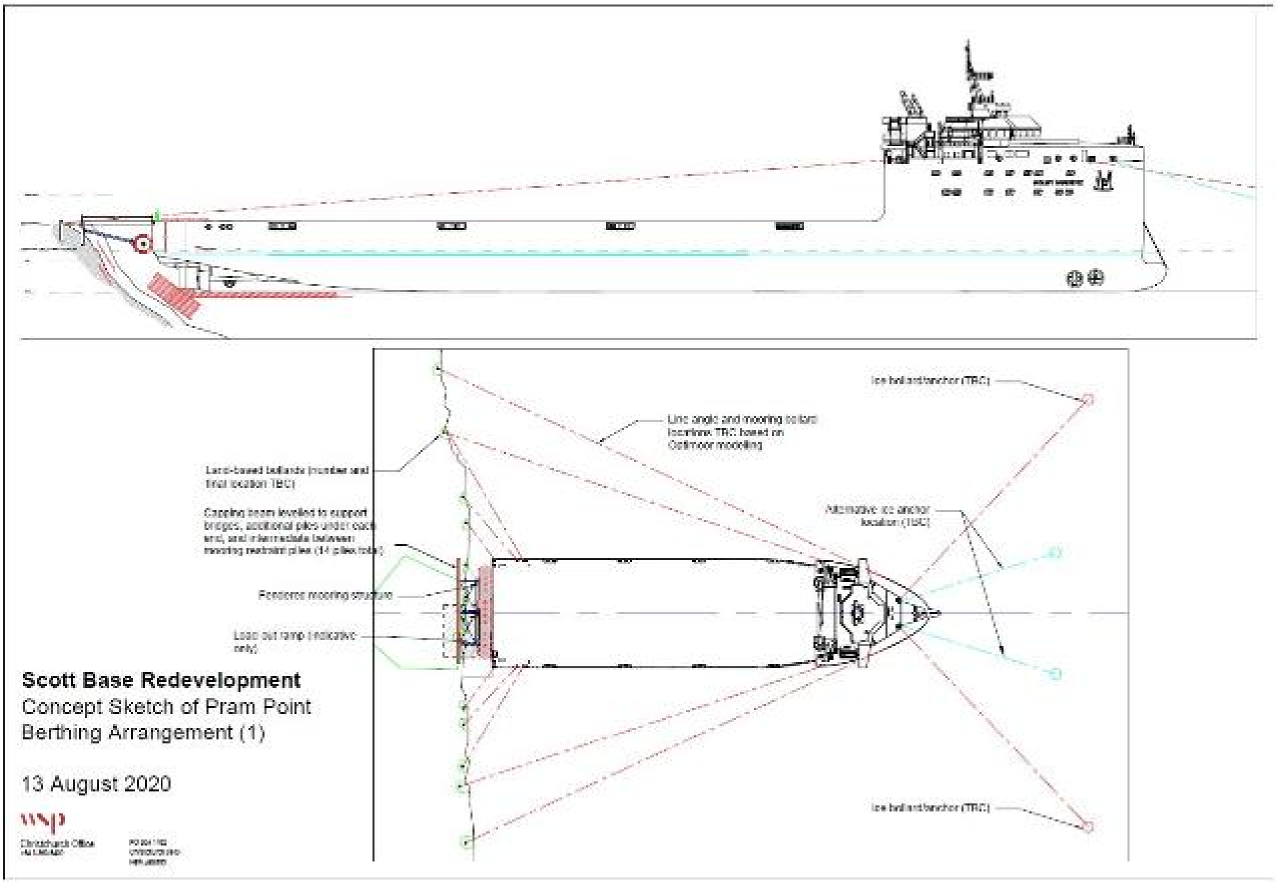


Figure 45: Plan and elevation view of the berthing arrangement.

Figure 46: Example of SPMT crossing from ship to shore.

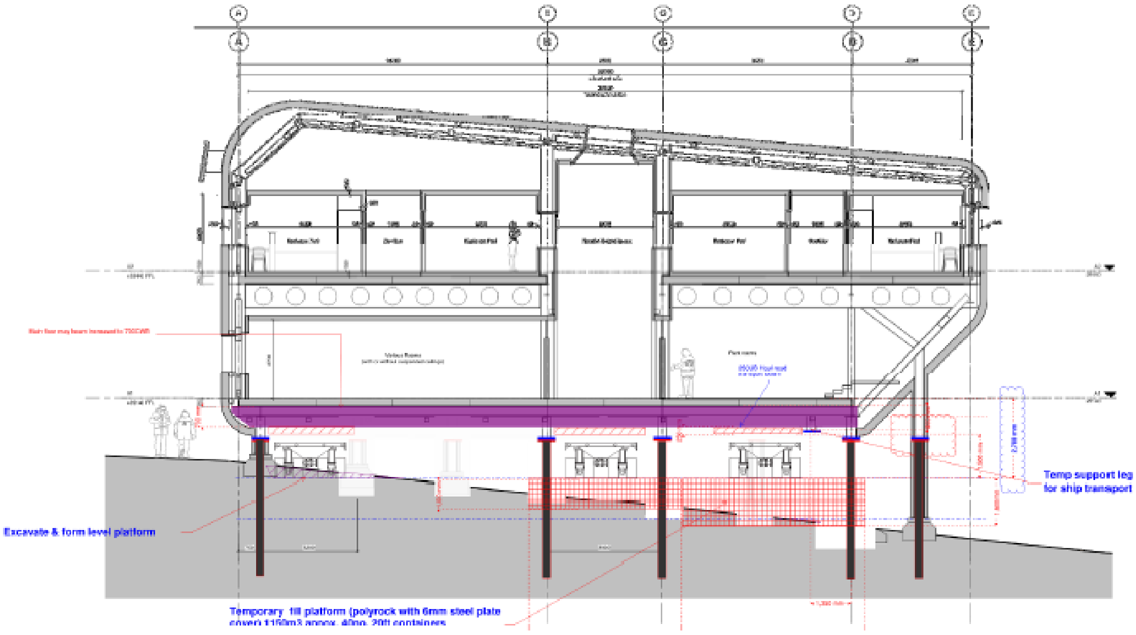


Figure 47: Side view of SPMTs delivering a building module to site. Red hash denotes the temporary platform due to gradient differences across the building platform.

2.11.3 Icebreaker support

An icebreaker is required to cut a channel from Winter Quarters Bay to Pram Point in January 2026 (Figure 48). This will be an extension of the annual channel cut by USAP to allow the annual shipping evolution to the McMurdo pier. An icebreaker will be required to maintain the channel for the period of the offload, ensuring the MC Class vessel can safely exit from McMurdo Sound.

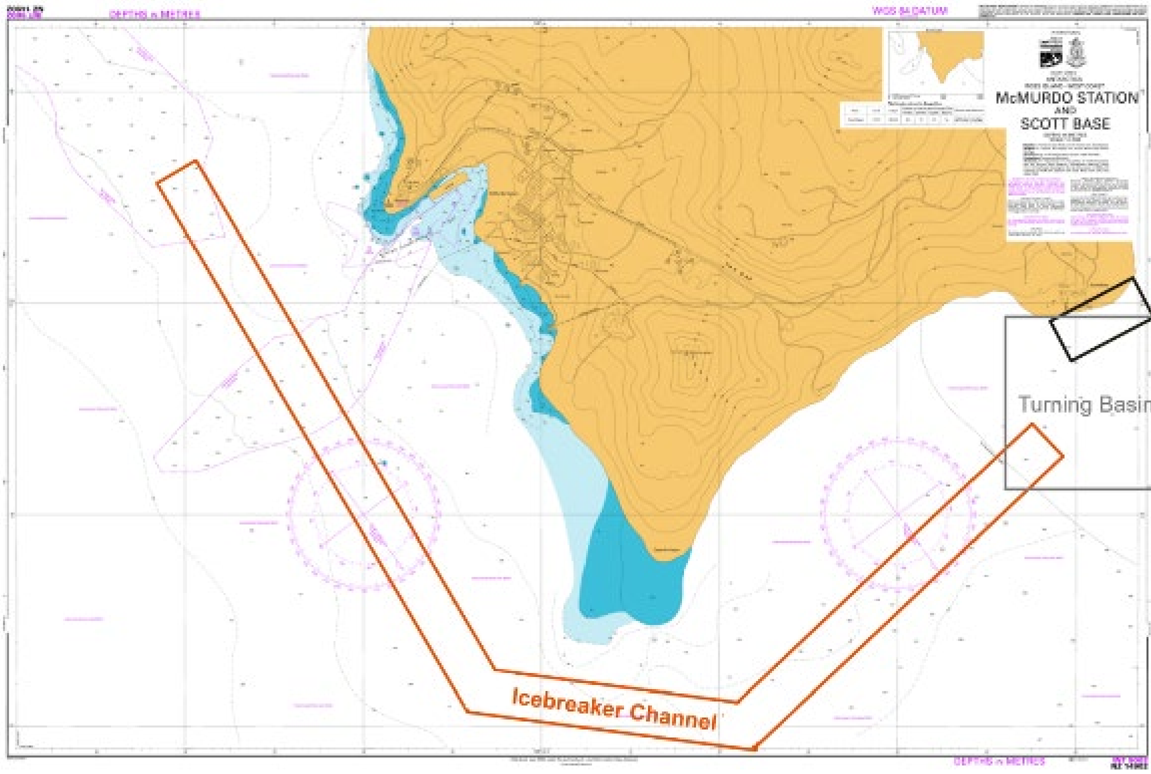


Figure 48: Indicative location of the additional icebreaker channel required to reach Pram Point.

2.11.4 Installation and commissioning

As the modules are positioned into their final location, they will be lowered onto the foundation piles. The modules will be bolted to the foundation piles using pre-aligned splices. The joints between the building modules will be re-attached structurally and sealed by reinstalling the adjoining cladding panels. The foundation piles will be clad and all joins sealed. Internally, services will be reconnected between the modules and internal fit-out at the module joins will be finished. During the final fit-out, recommissioning and tuning of all services will occur. Externally, ramps to the vehicle access points will be formed with previously stockpiled material and the required retaining walls will be installed. All remaining external services, including the vehicle hitching rails and services runs will be commissioned.

2.12 Cargo, break-bulk and waste logistics

Further logistics activities will support the Scott Base Redevelopment in addition to the shipping of the building modules. These include the movements of plant and machinery, materials and waste shipped from New Zealand to Antarctica and back to New Zealand throughout the life of the project.

The majority of the Scott Base Redevelopment cargo movements are to be delivered by sea. Air cargo channels would only be used where absolutely necessary or for smaller and light-weight cargo, if capacity is available at the time.

Containers and break-bulk cargo (cargo that does not fit in containers e.g. crane) will be shipped through existing logistics channels. Cargo shipping capacity will be sourced in collaboration with another National Antarctic Programme, if possible. Cargo will be delivered to the USAP McMurdo pier according to existing practice. Additional personnel and equipment may be required to handle the extra Scott Base Redevelopment cargo in the generally short ship offload timeframe.

Two cargo staging sites have been identified, one at Pram Point near the proposed container line and another in the Gap (Figure 4). Minor earthworks will be required to level the Gap site for container staging. This area has been used for staging and has had operational earthworks impacts by both the New Zealand Antarctic programme and USAP.

The materials resulting from the deconstruction of the existing Scott Base will be returned to New Zealand for appropriate disposal, including recycling, resale, landfill, etc. A total of 310 x 20-foot equivalent units (TEU) is estimated for the deconstruction component of returned containers (Table 15).

The deconstruction of Scott Base requires a staging area for approximately 118 x 20-foot and 96 x 40-foot containers for material storage, with return to New Zealand predominately in the 2024/25 season shipping evolution in January 2025 (Table 15).

An additional 27 x 20-foot and 4 x 40-foot containers will be required for the deconstruction of Area C of the temporary base in 2027/28 (Figure 38). These containers will be returned to New Zealand in 2027. The staging area for containers is proposed to be in the Gap between Scott Base and McMurdo Station and at the container storage area at Pram Point.

Table 15: Containers and plant shipping schedule, and approximate number of containers staged over winters.

		2022/23		2023/24		2024/25		2025/26		2026/27		2026/27	
		South	**North**	**South**	**North**	**South**	**North**	**South**	**North**	**South**	**North**	**South**	**North**
Temporary Base	**TEU**	171	-	-	-	-	-	-	-	-	171	-	-
Plant and Equipment	**Items**	25	-	13	-	-	-	-	9	-	29	-	-
Containers	**TEU**	30	-	270	50	50	200	50	100	-	30	-	20
Winter Staging	**TEU**	-	30		250		80		30		-	-	

2.13 Resources

2.13.1 Plant requirements

All major plant required for the deconstruction, civil, foundation and enabling works, and the delivery and installation of the proposed Scott Base is outlined in Table 16. All plant is proposed to be used for all activities for the Scott Base Redevelopment and the RIWE replacement project described in Chapter 3. Shipping of plant south to Antarctica occurs in the 2022/23 season and returns north to New Zealand at the end of the 2026/27 season.

Table 16: Plant requirements for the Scott Base Redevelopment project indicated in the shaded cells[18].

Plant	Staged at Pram Point				
	2022/23	2023/24	2024/25	2025/26	2026/27
Container transporter					
70t crane					
150t crane					
30t excavator	2	2	2	2	2
20t excavator					
60t excavator					
80t excavator					
D155 40t bulldozer					
Grader					
20t loader					
30t dump truck		2	2	2	2
12t roller					
Cone crusher		2	2	2	2
Jaw crusher		2	2	2	2
Tracked power screen					
Bucket crusher					
Rock breaker attachment for excavator					
500kg plate compactor					
Refuelling trailer					
20ft container for plant spares x 5					
30t drill rig		2	2	2	2
Compressor		2	2	2	2
Rock drill		2	2	2	2
Knuckle boom					
Scissor lifts		2	2	2	2
Scaffold towers					
MC Class vessel					
SPMT					3
70t crane for ship offload					

[18] All numbers for plant are one unit unless specified.

2.13.2 People requirements

The construction methodology minimises the number of construction personnel that will be required to travel to and from Antarctica, when compared to a traditional on-site build. Up to 45 construction staff will be required each season (Table 17). All logistics requirements for Scott Base Redevelopment personnel are proposed to be managed through the normal Antarctica New Zealand logistics channels, including flights, accompanied cargo, and cold-weather clothing.

Table 17: Estimated number of people for the delivery of the Scott Base Redevelopment[19].

Estimated Numbers	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28
Summer personnel	21	29	56	78	72	32	45
Winter personnel	0	0		0	15	0	0
Summer bed nights	1200	2100	6400	9600	6050	3500	6105
Winter bed nights	0	0	0	0	3200	0	0

2.13.3 Fuel requirements

Fuel will be provided to the Scott Base Redevelopment project through the JLP. Fuel is proposed to be stored for the project in existing infrastructure relocated for the temporary base and the proposed bulk fuel storage facility – to be commissioned early in the project. The total volume of AN8 required for the delivery of the project is expected to be approximately 3.3 million litres and an additional 55,200 litres for the SPMTs. Fuel for the shipping of building modules will be provided at a port facility in New Zealand. No additional refuelling is required in Antarctica.

2.14 Deconstruction methodology for the proposed Scott Base

Deconstruction of the new Scott Base is anticipated to be within 50 years of its commissioning, which is planned for 2027. Deconstruction may therefore occur from 2070s onwards. The basis of the strategy is the reverse of the delivery method. The buildings will be internally decommissioned and disconnected from services, connections between modules will be exposed and disconnected. The modules will be detached from the pile foundations and transported to a ship for return to New Zealand for deconstruction. The pile foundations are designed so that they can be removed by melting the water-based grout. All services and ancillary structures are proposed to be removed via containerised means and the site cleaned of any remaining wastes and contamination. A more specific methodology for the deconstruction will be developed in the planning stages of the activity. It is anticipated that a new EIA will be developed for the deconstruction of the new Scott Base.

[19] Note this does not include the number of people at Scott Base for any other activities.

3. The Ross Island Wind Energy replacement project

3.1 Introduction

The current RIWE consists of three 330kW Enercon E33 turbines and the design capacity of the wind farm is 990kW of power. RIWE was developed to accommodate existing infrastructure and has served its purpose. Energy modelling for the Scott Base Redevelopment has indicated that the total energy load of the proposed Scott Base will be approximately 3,265 MWh/year. This is significantly higher than the current Scott Base energy load at 2,895 MWh/year and reflects the shift from heavy reliance on fossil fuel to electricity.

While the design life of the current wind farm is 2030, a replacement in conjunction with the Scott Base Redevelopment to optimise the logistics and construction resources required for the proposed activities is sensible. It also allows for the proposed station to be powered by wind energy immediately. A feasibility and options study on replacing and upgrading RIWE was completed in 2020 to coincide with the Scott Base Redevelopment (see Chapter 1, Section 1.6). The scope of the RIWE replacement project includes the:

- Proposed design options for the RIWE replacement;
- Decommissioning of the current RIWE;
- Preparation of the site and installation of foundations;
- Installation of new wind turbines and balance of plant; and
- Decommissioning of proposed wind farm at end of life.

3.2 Proposed design

At the time of writing, the design for the replacement of the wind farm is in a feasibility stage. However, Antarctica New Zealand has defined three general scenarios to be evaluated as options (Do nothing, meet 80%, and meet 97% of the proposed Scott Base's energy demand with renewable energy). It was determined that both of the 80% and 97% options could be achieved with a combination of Enercon E44 900kW wind turbines and associated BESS.

The two options are:

1. 3 x E44 900kW turbines with a 2MW / 4MWh BESS. Estimated to provide 80% of the proposed Scott Base energy demand with renewable energy.
2. 4 x E44 900kW turbines with a 2MW / 10MWh BESS. Estimated to provide approximately 97% of the proposed Scott Base energy demand with renewable energy.

The preferred option is to achieve 97% of the proposed Scott Base energy demand. However, both options are presented in this Chapter.

The concept for the overall system design assumed at this stage of the feasibility study is similar to the current system. Currently, energy generated from RIWE is fed into the network grid system and the power is shared between both Scott Base and McMurdo Station using the best configuration of energy generation and distribution (Figure 49, Figure 50). Generator size and energy demand from the two stations differ and the system works to find the optimal configurations with the balance of plant to use the energy efficiently and reduce fuel consumption.

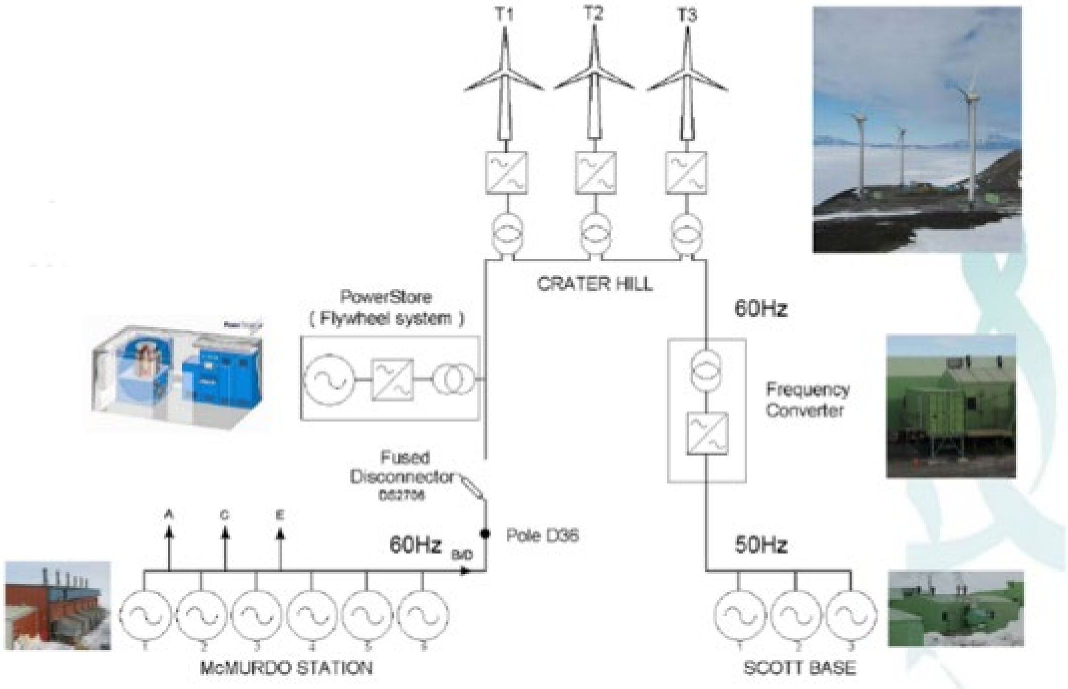


Figure 49: Current RIWE system design.

The RIWE replacement project is designed to increase the renewable generation capacity on Ross Island. Details on the energy system for the proposed Scott Base and savings on fuel use are described in Section 2.5.1.

The proposed design will see the existing system components replaced in full, including:

- Wind turbines at Crater Hill and the turbine transformers; and
- Balance of plant equipment, including:
  - Switchgear at McMurdo and Scott Base
  - Electrical substation housing transformer at Scott Base (4,160/400V)
  - Frequency converter (with increased capacity) at Scott Base
  - High voltage cabling.

The RIWE replacement is designed for a new operating strategy for the RIWE network (Figure 50). The key details of the operating strategy are:

- Renewable energy generated by the wind farm is used in the following order of priority:
  1. Scott Base electrical load and electric heating;
  2. Charging the BESS;
  3. McMurdo electrical load; and
  4. Curtailed generation (i.e. output is deliberately reduced).
- The Scott Base diesel generators are switched off when there is sufficient renewable energy or energy from the BESS to meet the Scott Base load;
- Scott Base and McMurdo diesel generators are used in the most efficient combination to reduce power wastage across Ross Island; and
- The system can regulate voltage and frequency through the use of:
  - McMurdo generators;
  - A new large grid forming BESS; and
  - Scott Base generators.

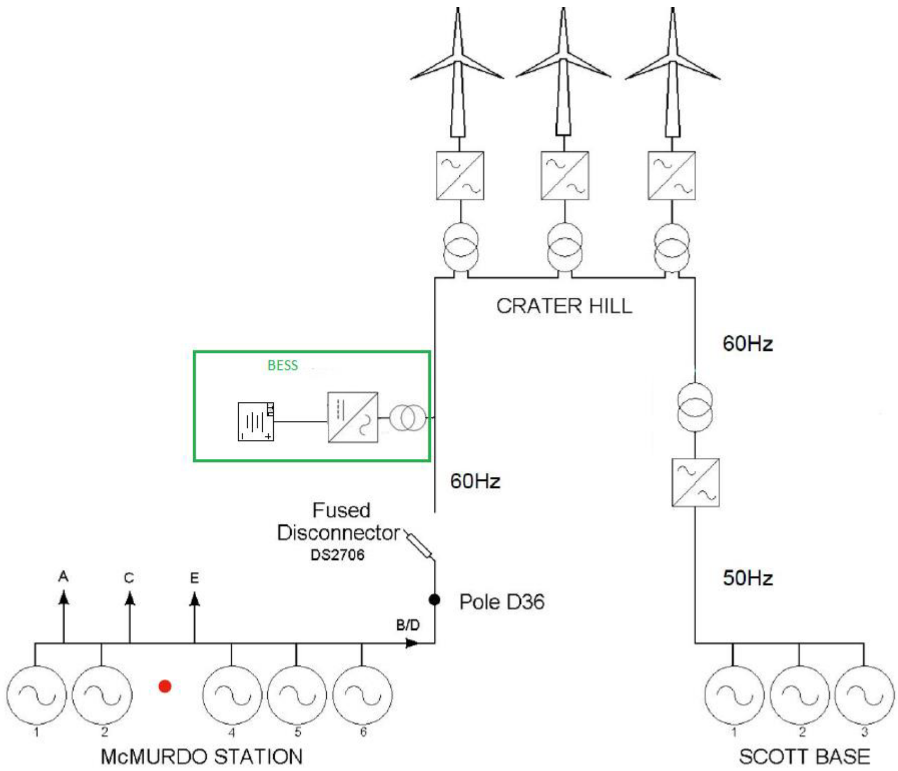


Figure 50: Power system concept design indicating from left to right, the McMurdo generators and distribution, the proposed BESS, proposed turbines, frequency converter, and Scott Base generators.

3.2.1 Location

The proposed location for the RIWE replacement is the existing Crater Hill site (Figure 51). The site is approximately 1.1km from Scott Base and 1.6km from the McMurdo Station power plant building.

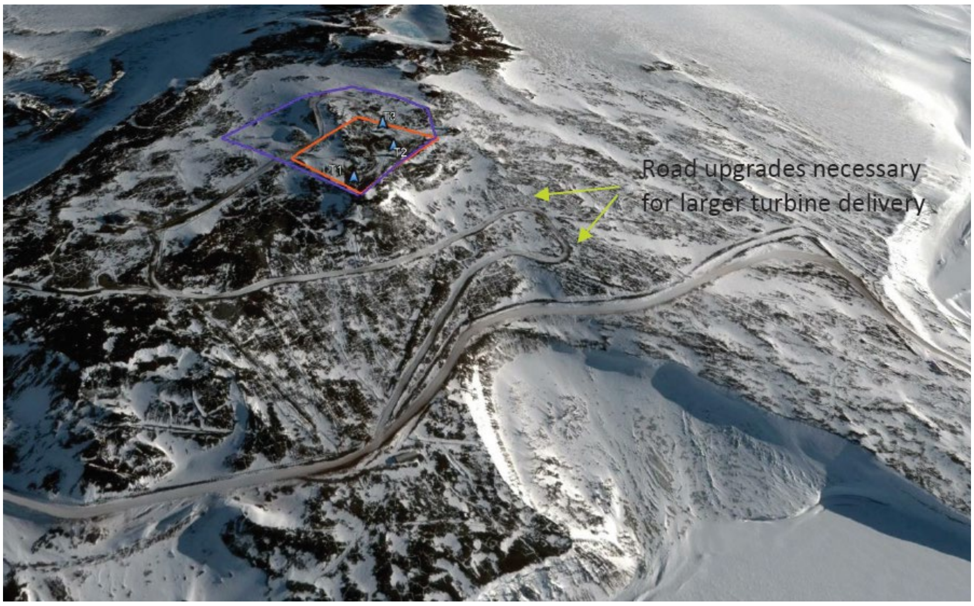


Figure 51: Aerial image of RIWE on Crater Hill, Scott Base in bottom right, McMurdo Station on the left.

3.2.2 Turbine options

The available wind resource at Crater Hill is very good and requires a wind turbine that is certified to International Electrotechnical Commission (IEC) Class I wind conditions; a high-wind class wind turbine. However, logistics and site constraints limit the size of turbines that may be installed at Crater Hill, including the access road from the pier to the turbine site, weight limits at the McMurdo pier and the size of a crane that can access the site and operate safely.

Three turbine options were considered as concepts for the RIWE replacement:

- Enercon E44 - 900 kW;
- Enercon E82 - 2.3 MW; and
- Enercon E115 - 3 MW.

The E44 type is the preferred option presented because the other two options would require extensive enabling works to allow for the components to be delivered to site, due to their significantly larger size.

Enercon E44 wind turbines are robust, proven, medium-sized turbines and as such meet the project constraints. The proposed turbine type is larger than the current E33 (Figure 52) but is the smallest suitable turbine currently on the market. Enercon turbines are proposed as they are direct-drive meaning there are no gearboxes, which typically do not perform well in cold environments. The turbines are also tested and are known to work well in Antarctica. With the E44 option, either three or four turbines are proposed allowing for a total installed capacity of between 2,700 – 3,600kW (Table 18).

The technical specifications for the E44 turbine are presented in Table 18.

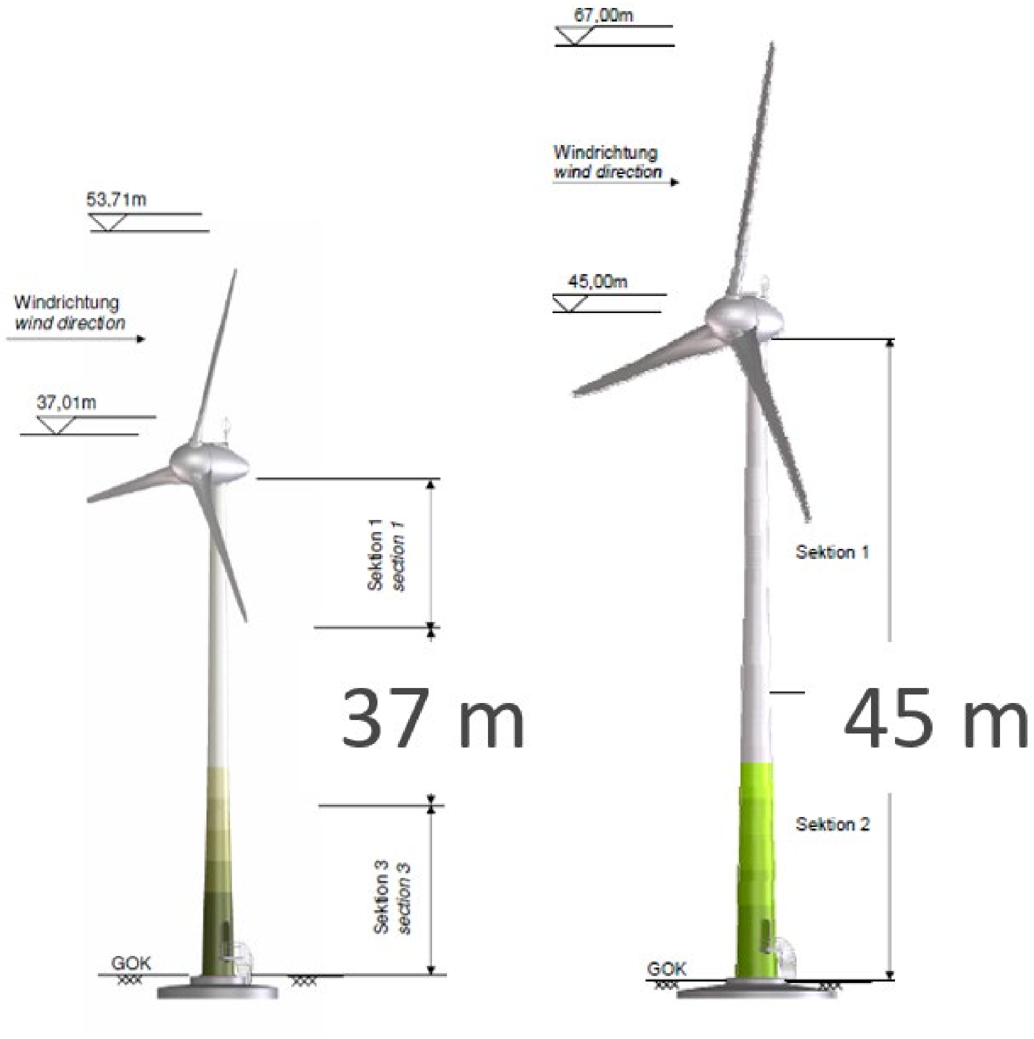


Figure 52: Relative size of the current E33 wind turbines (left) and the proposed E44 wind turbines (right).

Table 18: Technical specifications of the proposed wind turbine option.

Specification	**Enercon E44**
Proposed number	3 or 4
Rated power	900kW
Rotor diameter	44m
Rotor sweep	1,521m^2
Hub height options (m)[20]	45 / 55
Cut in wind speed	3m/s
Cut out wind speed	34m/s
Gear box	None – direct drive
Wind zone	WZ 4 GK I
Wind class	IEC IA
Low temperature operation	-30°C

[20] Hub height options are the various tower heights that the turbine can be constructed at.

3.2.3 Battery energy storage system description and options

A BESS is proposed for the provision of short-term power support and long-term energy shifting. A BESS allows for continuous renewable power output when the wind is insufficient to generate the required power. The proposed BESS option is a lithium titanate battery module with an inverter housed in a shipping container. A lithium titanate BESS has a very small footprint, high power-to-weight ratio, high power-to-energy ratio, is fully recyclable, has very high thermal stability (low fire risk) and retains approximately 80% of its capacity at -30°C. A system comprising 2 MWh of lithium titanate modules would fit within a 40-foot shipping container, with room for an inverter and switchgear.

Short term power support smooths the output of the turbines to provide power through short fluctuations in renewable energy generation. This may avoid the need for a diesel generator to respond to temporary drops in renewable output, or to allow sufficient time for a diesel generator to be started and connected into the system, which can take up to 10 minutes. BESS solutions for short term storage require a large inverter and can store enough energy for a shorter period of time (less than one hour).

Long term energy shifting is a large BESS solution which accumulates energy during an abundance of renewable energy generation and discharges it during low renewable energy generation. It usually consists of a similar inverter to short term storage, but it has significantly larger capacity to store energy. A large BESS is necessary for achieving prolonged periods of 100% renewable energy operation and limiting the need for diesel generators. A longtterm energy shifting BESS can also provide the smoothing functions of a short-term BESS.

There are two sizes proposed for the BESS, both having a 2MW output capacity, with the difference in the overall capacity. A 4MWh (80% renewable option) and 10MWh (100% renewable option) BESS are the two proposed options. Both proposed options provide the short-term power support and long-term energy-shifting functions.

3.3 Deconstruction of the current wind farm

The concept for decommissioning works is a controlled deconstruction of the turbines. This method is proposed to minimise environmental impacts and effectively manage waste, whereas standard practice in wind turbine removal is a controlled implosion to level the towers. The method of deconstruction will allow either on-selling of the turbine parts or scrap metal. The proposed decommissioning works are:

- The turbines will be de-energised and disconnected from the electrical grid;
- Oil will be drained from the turbine into bunded double-skinned barrels for transport to New Zealand. Batteries will be removed from the turbine;
- A 300-tonne crawler crane will be used to progressively lower the blades, hub, nacelle, and tower sections to ground level;
- The hub, blades and nacelle will be transported back to New Zealand whole, to remove the risk of composite fibres being released into the environment;
- Tower components are proposed to either be transported whole or cut to manageable sections using gas axes and thermic lances;
- Waste material will be moved directly into containers for shipment to New Zealand;
- Foundations blocks will be excavated and returned to New Zealand;
- Steel anchors which are embedded in grouted anchor holes are proposed to be removed utilising hydraulic jacks. If this method proves unfeasible, they may ultimately need to be cut below ground level and covered; and
- HV cabling and remainder of electrical equipment will be transferred into containers for shipment to New Zealand.

3.4 Civil and foundation requirements

The extent of civil works for the RIWE replacement is limited as the existing site and general locations of the wind turbines will be reused. Minor civil works only will be needed to upgrade the access road to the Crater Hill site as the proposed turbine components are similar in size to the current E33 turbines. This will consist of some widening and surface improvements along portions of the road corridor (Figure 51).

The current three E33 turbines are based on a steel spider frame atop eight footings that are partially buried in the ground and secured by grouted anchor rods (Figure 53 and Figure 54). The proposed foundation is similar in design to the existing, however scaled up appropriately for a larger turbine.

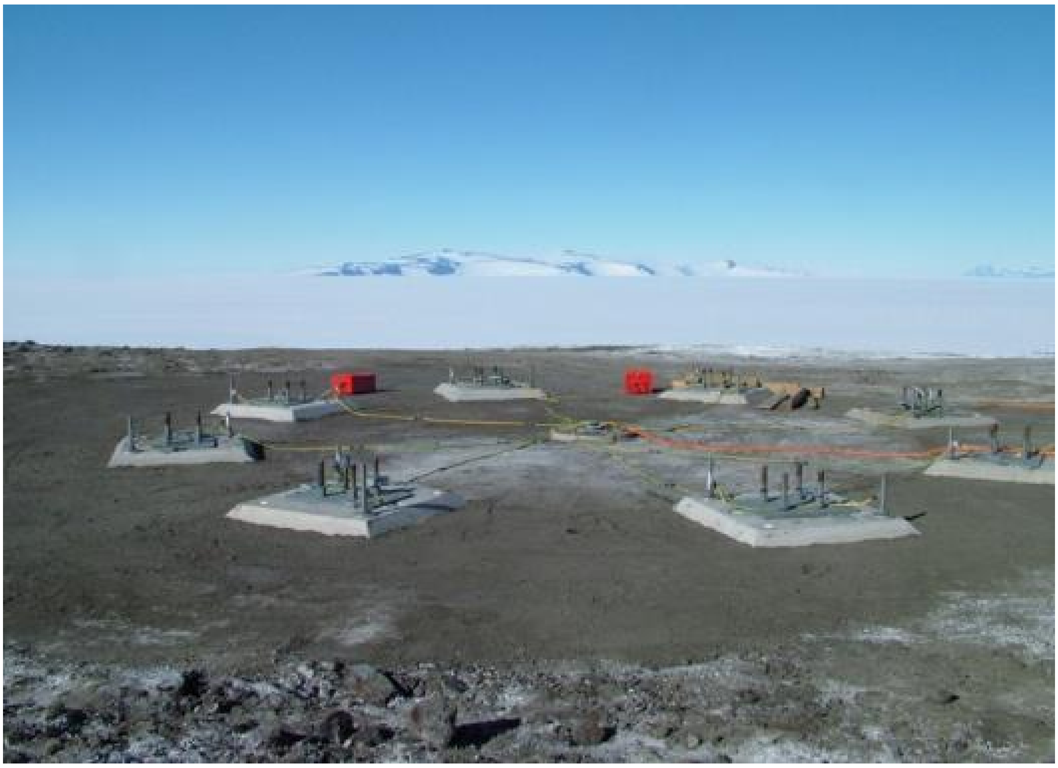


Figure 53: Pre-cast concrete foundation footings backfilled so only the top is visible.

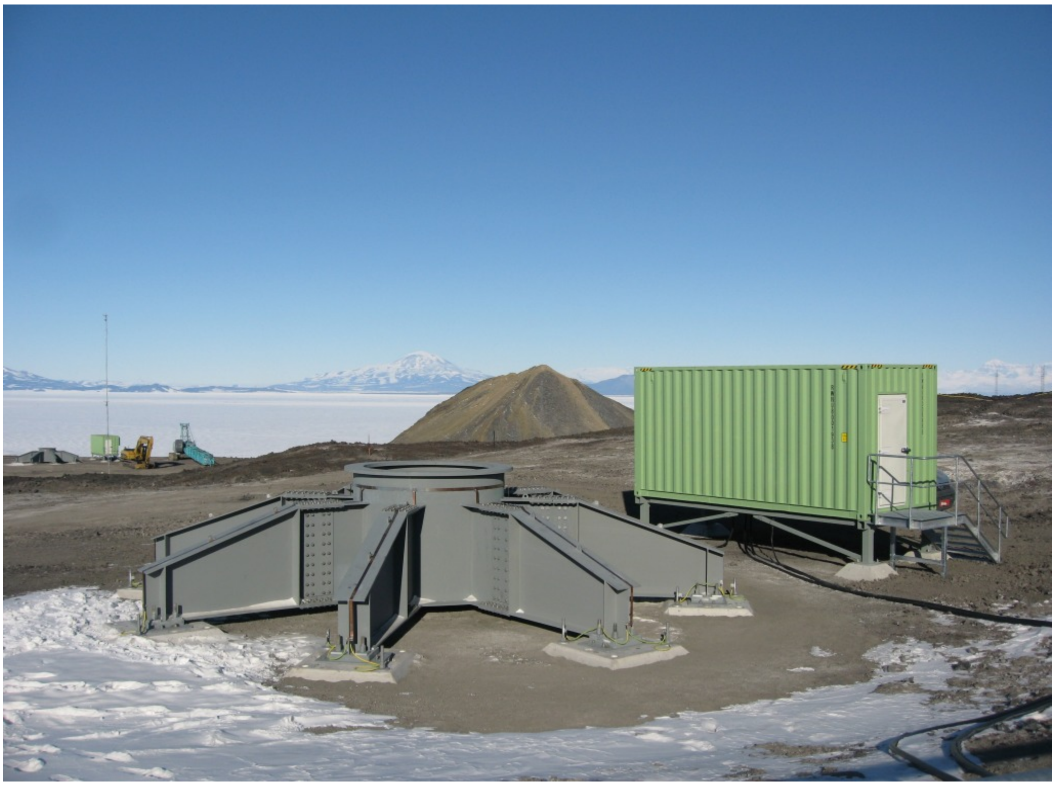


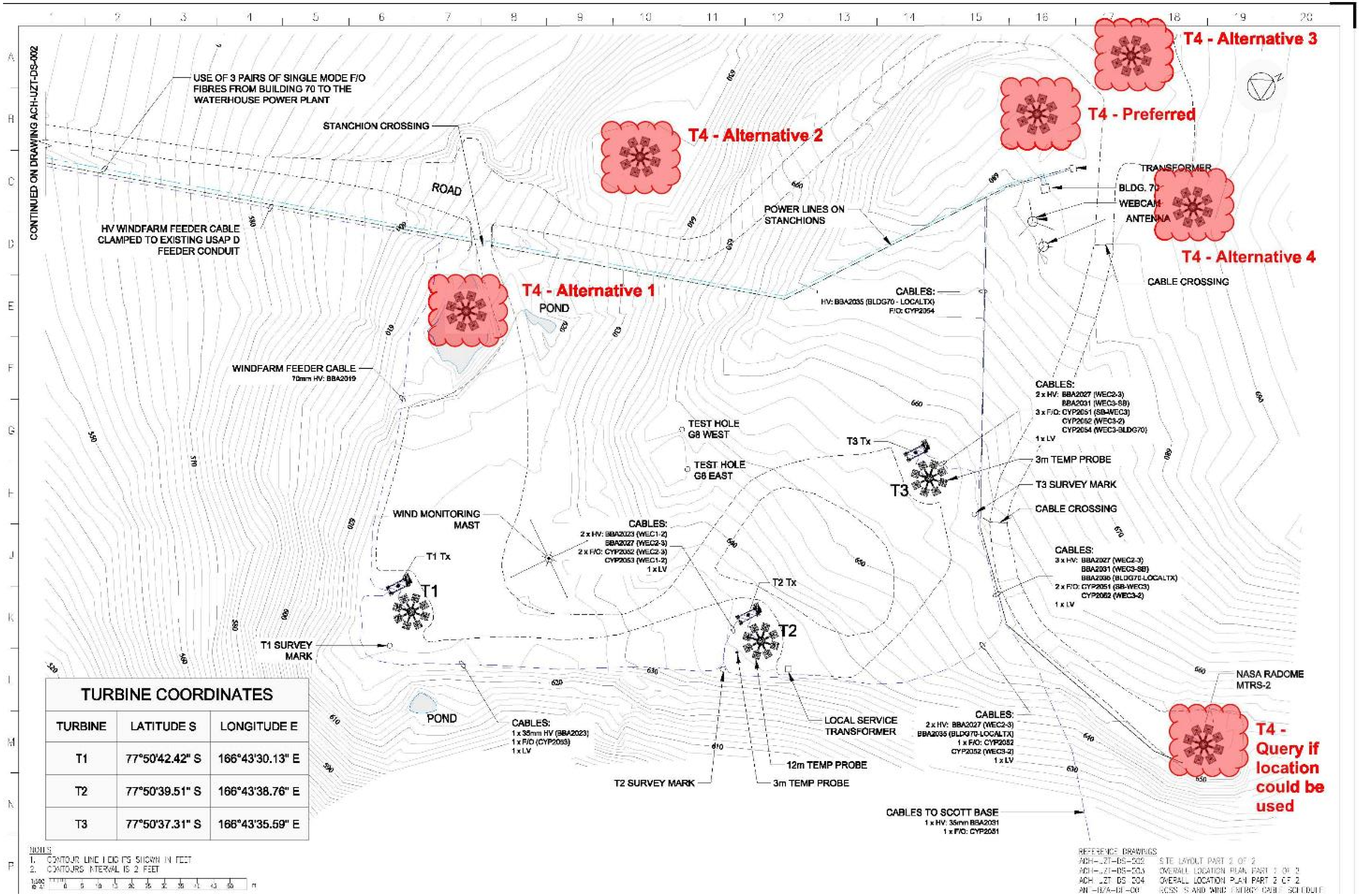
Figure 54: Steel spider framework bolted to the concrete foundation blocks.

It is proposed to reuse the locations of the existing turbines as near as possible, to avoid additional civil works and geotechnical investigations. Depending on the option selected, either three or four turbines will be installed. The location options for a fourth turbine are at sites T1, T2, T3, and "T4 Preferred" (Figure 55). For the three-turbine option, three of these four locations will be used. It is proposed that "T4 Preferred" location will be used to install the first tower before the decommissioning of the current turbines to allow continuous renewable energy generation.

The proposed earthworks require the use of dynamite for blasting. The exact amount required will depend on the depth of the foundation pit, which will be defined during detailed design. However, around 2,000kg of explosives were used for the three original RIWE turbines. It is expected that the amount required to create foundations for the slightly larger and heavier wind turbines would be in the order of 2,500-4,000kg of explosives.

The drill and blast method is the most practicable excavation solution for frozen ground. It minimises the use of earthmoving equipment, and disturbance to surrounding areas. Careful design and siting will ensure that excavations and use of explosives is kept to a minimum. Details on the method for drill and blast is included in Chapter 2.

Precast concrete pads will be placed on a bed of engineered fill and be held in place with grouted tensioned anchor rods. The foundation anchors are proposed to be grouted with an ice-bentonite mixture. The pads will be backfilled and a steel spider frame bolted to the top. The tower structure will rise from this frame.



TURBINE COORDINATES

TURBINE	LATITUDE S	LONGITUDE E
T1	77°50'42.42" S	166°43'30.13" E
T2	77°50'39.51" S	166°43'38.76" E
T3	77°50'37.31" S	166°43'35.59" E

Figure 55: Current RIWE turbine locations (T1, T2 and T3) with alternative option for a fourth location (T4).

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3.5 Construction and logistics

The indicative work program and logistics considerations developed at the time of preparing this draft CEE are described below. Cargo is proposed to be delivered via the annual shipping evolution into Winter Quarters Bay at McMurdo Station. All three options are proposed to be delivered over two shipments. The shipping requirements of each concept option are presented in Table 19.

Materials are proposed to be staged in two locations on Ross Island. One is the Gap (described in Chapter 2), where some materials and equipment would also be staged for the Scott Base Redevelopment. The other site is the RIWE operational area on Crater Hill.

Table 19: Shipping volume estimates for each concept option and for returning the current wind turbines to New Zealand.

Component	Shipping Volume (m^3)		
	3 x E33 (Waste material)	3 x E44	4 x E44
Wind Turbine Generator	600	1,065	1,424
Tower	390	1,206	1,608
Foundations – Pads	156	202	270
Foundations – Steel	600	780	1,040
BESS and Frequency Converter	0	385	385
Electrical Auxiliary Plant	304	380	380
Crane	0	612	612
Blade Trailers	0	480	480
Sub Total	2,050	5,110	6,199
+15% allowance (excluding decommissioning)	2,050	5,876	7,128

The indicative work programme is outlined below and detailed alongside the Scott Base Redevelopment work programme in Appendix 1.

- November 2023 – January 2024
    - Ship one turbine, 3 or 4 foundations and balance of plant to Ross Island;
    - Upgrade road and hard stand if/as required, excavate new foundation at one of the T4 sites; and
    - Install foundations for one new turbine, and footings for all auxiliary plant.
- November 2024 – February 2025
    - Install one turbine and commission;
    - Deconstruct all existing turbines and auxiliary plant;
    - Install remainder of new turbine foundations; and
    - Ship remaining turbines, install and commission all auxiliary plant, frequency converter and BESS.
- November 2025 – January 2026
    - Install and commission remaining new wind turbine generators.

Resource requirements on site will be on average ten persons for the two summer seasons, with a peak of approximately 19 to allow for the commissioning of the turbines. No personnel are proposed to winter-over for the purposes of this project.

Plant requirements for the deconstruction, civil works and installation of the new turbines is proposed to be shared with the Scott Base Redevelopment, with no specialist plant requirements outside of those described in Chapter 2.

3.6 Decommissioning and end of life

The design life of the new RIWE is estimated at 22 years. Decommissioning activities would therefore be expected to take place around 2050. The current proposed end-of-life decommissioning works are the same as the proposed decommissioning of the current turbines, with a controlled deconstruction. The decommissioning activities will be reassessed closer to the time so that they are fit for purpose. It is expected a specific EIA will be prepared.

4. Assessment of alternatives

4.1 Introduction

Article 3(2)(a) of Annex I to the Protocol requires CEEs to consider possible alternatives to the proposed activities, including the alternative of not proceeding and the consequences of those alternatives.

The Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1 (2016)) specify that both the proposed activity and possible alternatives should be examined in concert so that a decision can more easily compare the potential impacts on the Antarctic environment and dependent and associated ecosystems. Under Article 3 of the Protocol, this should include consideration of impacts on the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research.

This chapter presents alternatives considered throughout the design phases of the Scott Base Redevelopment and the RIWE replacement.

4.2 Do not proceed

New Zealand remains committed to supporting high-quality Antarctic scientific research of global relevance, strengthening protection of the Antarctic environment, and the Antarctic Treaty System. This work is delivered through Scott Base, New Zealand's only research station in Antarctica.

The alternative of not proceeding with the Scott Base Redevelopment was considered at the initiation of the project in the Indicative Business Case (Section 1.6). The alternative was discounted because it would result in the closure of Scott Base as critical infrastructure is at the end of its life and Antarctica New Zealand is facing increasing challenges to maintain a safe and resilient station. Under a "do not proceed" scenario, Scott Base would become unmaintainable, unsafe and opportunities to improve environmental and health and safety performance would not be realised. New Zealand would become unable to support its science and environmental protection programmes.

4.3 Alternative concept designs

Four different concept designs were developed, each with opportunities and constraints. The four concept designs are discussed below. To develop the four concept designs, the design team explored many ideas (Figure 56), undertook site visits and held a series of workshops covering cold climate design considerations, Antarctic construction, sustainable design, biosecurity, logistics and design considerations for living and working in a remote facility. Up to 185 individual spatial requirements were identified and considered within the design. Architectural solutions such as building form (shape and layout), the number of individual buildings and the bulk and location of the new buildings were also considered.

In addition to the physical building and infrastructure requirements, several other areas needed to be assessed to ensure that the final solution met the objectives of the project, including:

- The extent of sustainable design and construction principles;
- The use of renewable energy sources;
- The level of resilience against failure of the building systems;
- How autonomous the control systems should be (i.e. balancing a reliance on technology with manual intervention by base staff);
- The level of impact the construction activities could have on science delivery;
- The level of reliance on external parties to manage the logistics; and
- The ease and feasibility of construction.

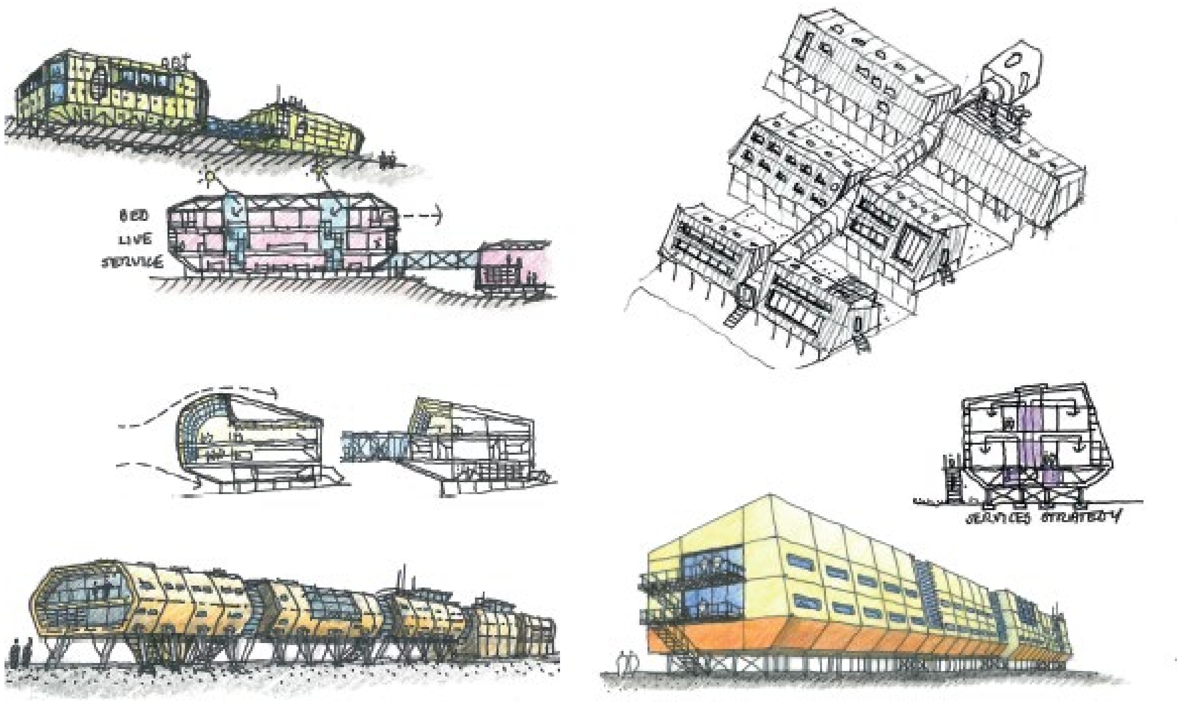

Figure 56: Concept sketches prepared during the early stage of design.

4.3.1 Concept Design A

This concept combines new construction with the refurbishment and extension of some existing structures. Accommodation, some science support activities and mechanical plant would be housed in a new two-storey building. The existing HFC would continue to support science and field operations. The HFC and garage would be fully refurbished with a new layout and linked together while the new block would not be connected to the existing structures (Figure 57). As this concept retained two existing buildings, it did not resolve the critical problems of the existing base and was therefore not progressed beyond concept design.

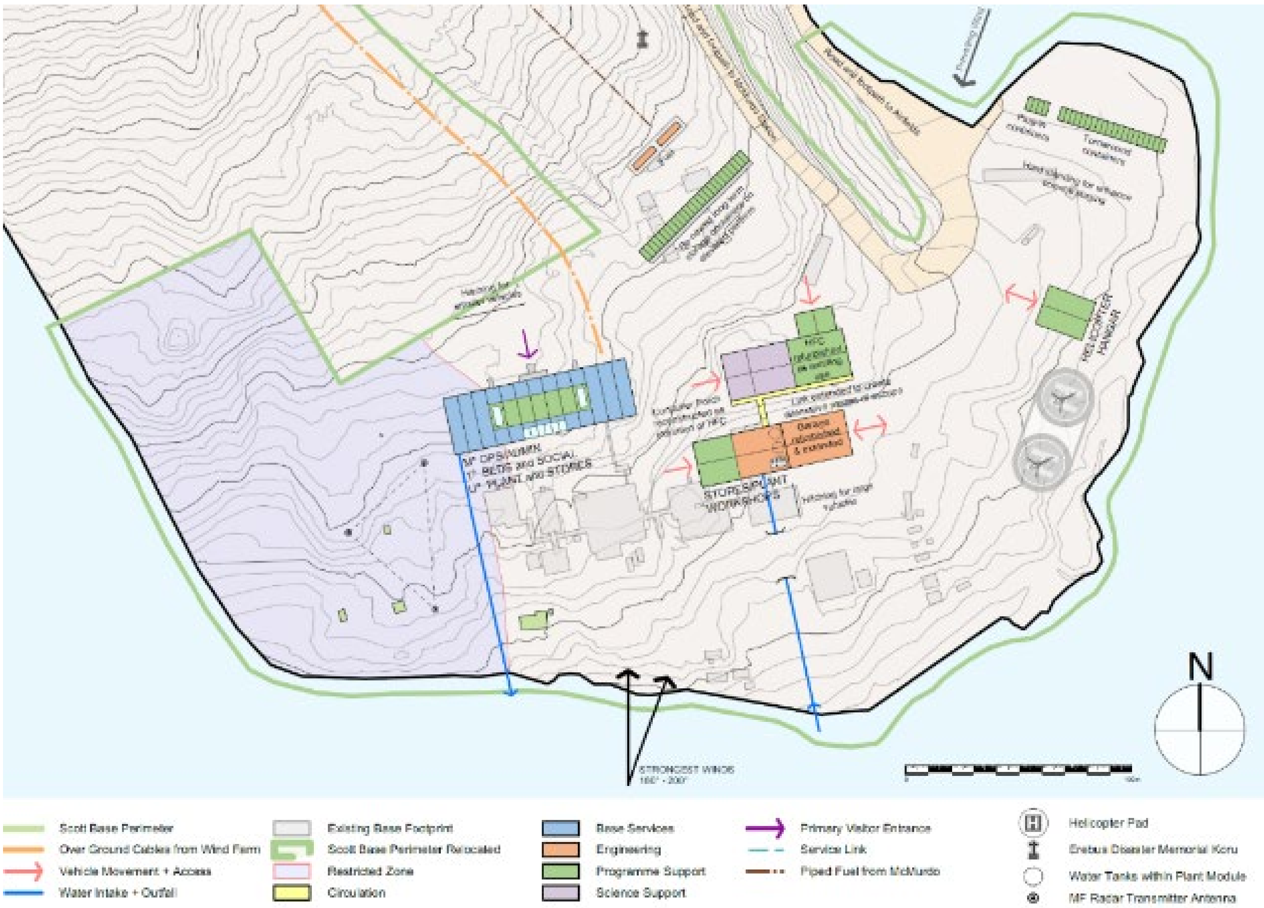

Figure 57: Concept Design A - plan view.

4.3.2 Concept Design B

Concept Design B combines new construction with refurbishment and an extension of the HFC. Two new two-storey buildings are arranged in a line along the 20-metre contour (Figure 58). The west building would contain accommodation on the upper level with plant, storage and lockers on the lower level. The eastern building would include science, office areas and workshops. The buildings would be linked at the lower level. The HFC would provide space for storage, cargo handling, science event preparation and plant. It would be fully refurbished and reorganised to improve efficiency and safety. This concept could be constructed with minimal impact on the existing station. However, some existing operational issues would remain and the ground-level link between the new blocks presented snow management issues. Concept Design B was presented as an option to government but was discounted.

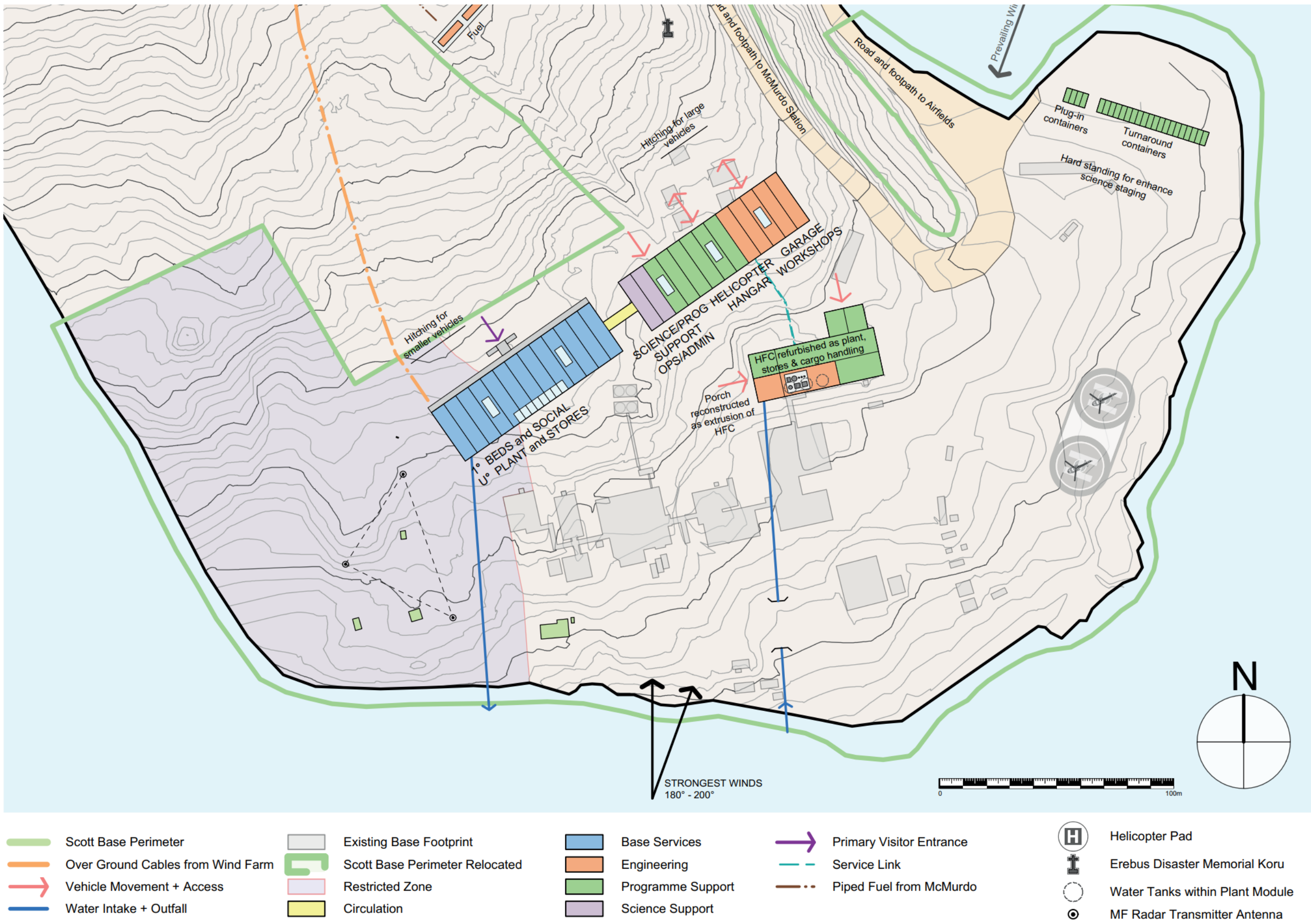

Figure 58: Concept Design B - plan view.

4.3.3 Concept Design C

Concept Design C is a full replacement of all facilities with three new two-storey buildings. The three buildings are arranged in parallel on tiered terraces that follow the site contours (Figure 59). They are connected by link bridges creating a circulation spine in the new station. The lower level of the upper building connects via the link bridge to the upper level of the lower building. The buildings are arranged with accommodation in the upper building, science, field and administration in the middle building, and engineering, cargo, and stores in the lower building. Preliminary snow modelling indicated that this design was the most effective in minimising snow build-up. Concept Design C was presented as an option to government and was the preferred option.

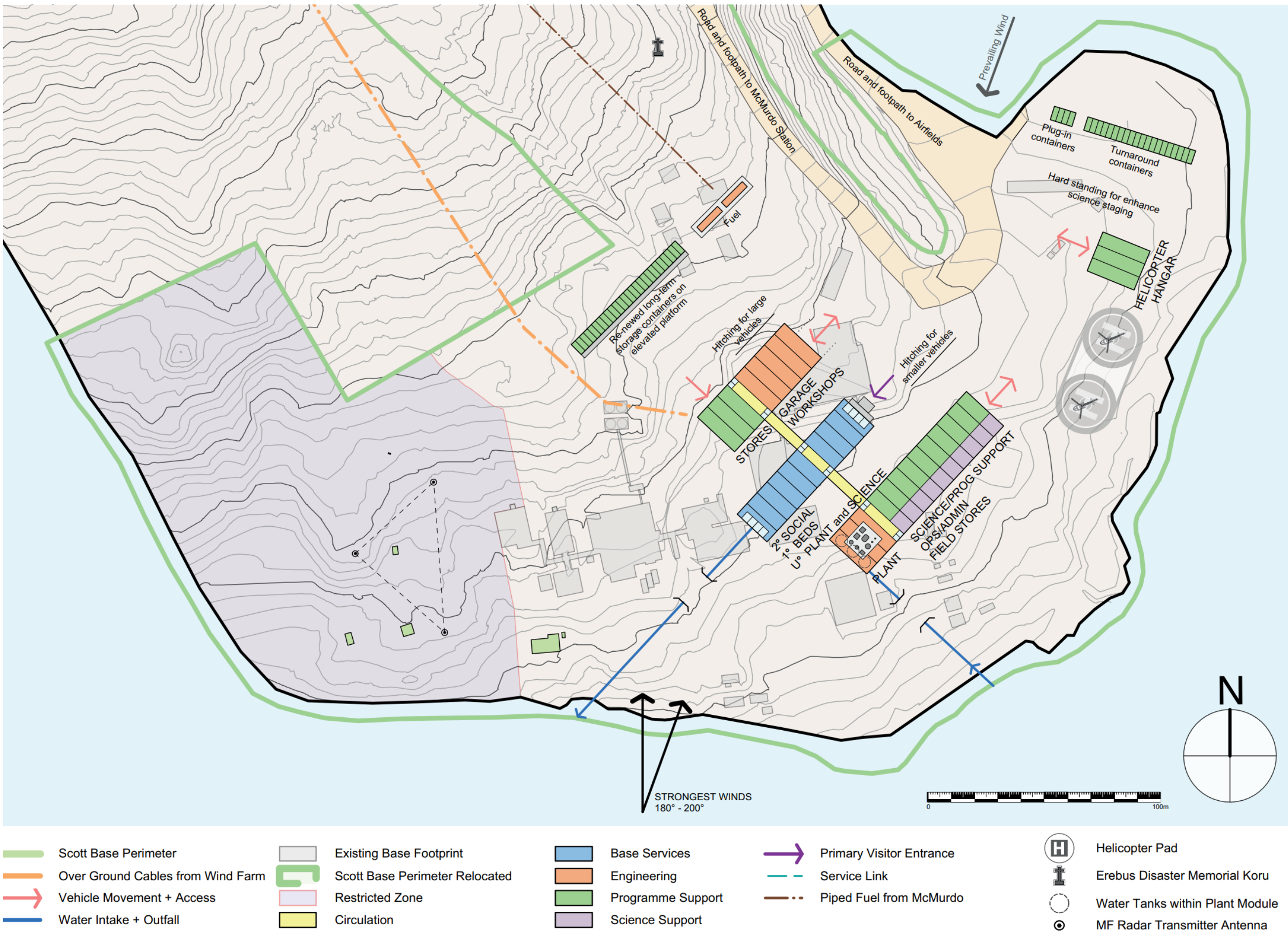

Figure 59: Concept Design C - plan view.

4.3.4 Concept Design D

Concept Design D is a full replacement of all facilities with three 25m-wide buildings with chamfered aerodynamic corners (Figure 60). Link bridges connected opposite corners of each building. Due to the topography of the site, the links included ramps to deal with changes in level. Accommodation is provided in one three-storey building. Workshops, stores, plant and science facilities are housed in two-storey blocks. The wider buildings proposed in this concept made it compact and efficient. However, the ramps created issues with snow accumulation and the corner link bridges were not practical to construct or operate. As a result, Concept Design D was not progressed into the next stage of design.

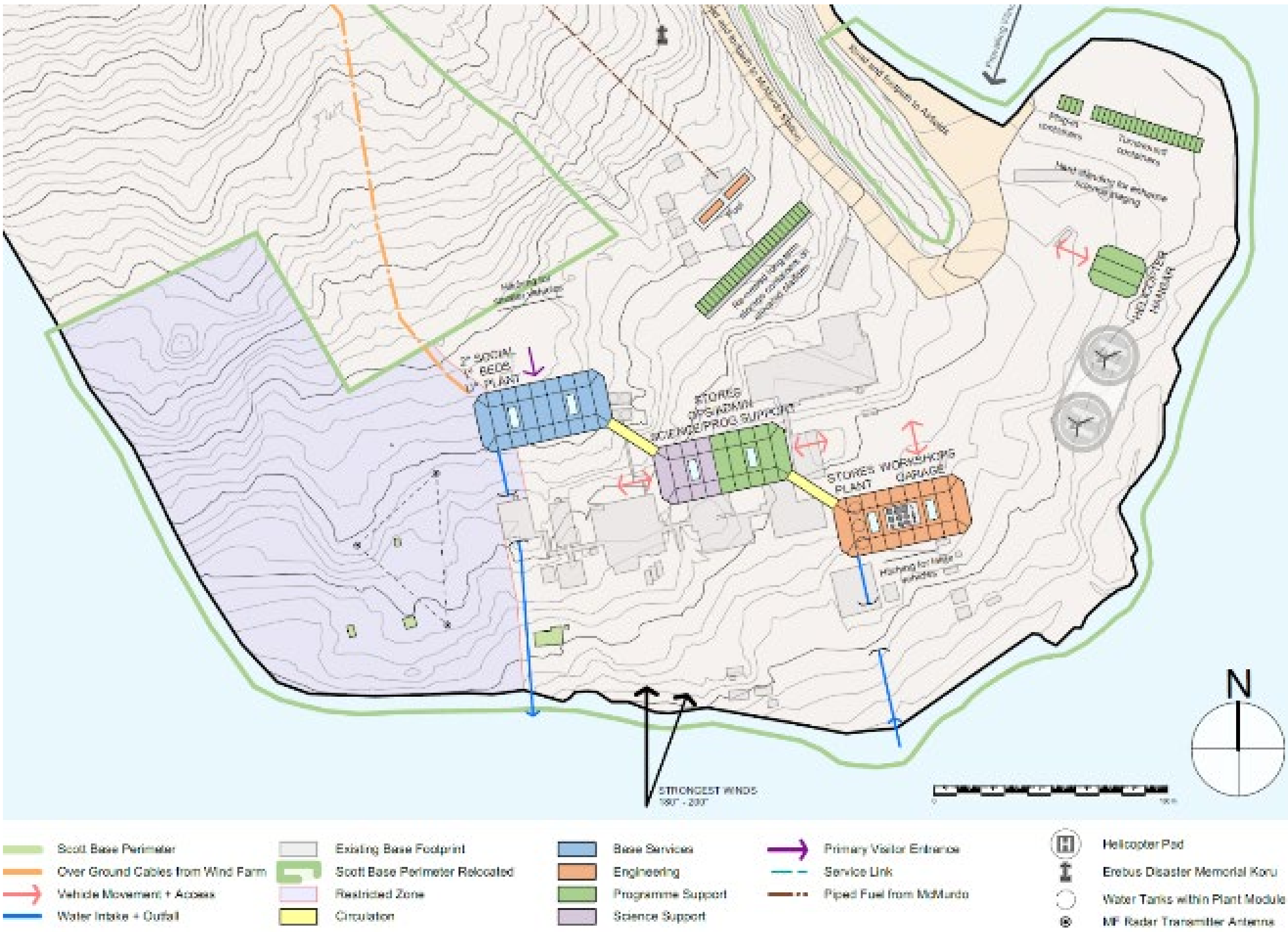

Figure 60: Concept Design D - plan view.

4.4 Alternative Locations

4.4.1 Location of Scott Base

The relocation of Scott Base to a site other than Pram Point was discounted early. Pram Point has been modified by human activity over the past 60 years and keeping Scott Base there contributes to controlling the extent of the potential impacts associated with New Zealand's activities in Antarctica. Pram Point's proximity to infrastructure such as Williams and Phoenix airfields, McMurdo Station and access to the sea ice and the ice shelf provide logistical efficiencies that would be near impossible to replicate at a different site.

Pram Point has several physical and environmental constraints and the final location of the building is linked to the logistics and construction methodology and earthwork requirements.

The site constraints include:

- The area to the west of the existing base is used for long-term science data collection;
- The area above the site hosts flora and fauna which disturbance needs to be minimised;
- The sloping topography of the site has a significant impact on the planning of the new base. To minimise the extent of earthworks, new buildings need to be arranged at different levels;
- New buildings need to be carefully positioned relative to predominant and strong winds to reduce snow accumulation;
- The station needs to avoid disturbing areas of contamination or consider remediation opportunities before the construction of the new buildings;
- Staging space is needed around the station for storing trailers, sledges, large rolls of cable, cargo and waste containers;
- The hairpin bend in the road to the airfields can become congested. Traffic movements around the base should be separated from the vehicular circulation on the road and buildings need to be as far from the road as possible to avoid dust impacts on the station;
- Any construction activities must minimise impacts on the TAE Hut (HSM 75).

Three options were considered:

1. The existing building footprint with a temporary base elsewhere to continue operations;
2. The existing building footprint but with a staged approach to building and demolition; and
3. Relocation further up the slope behind the existing Scott Base to allow continued operation of the existing station throughout the activities.

The location of the building significantly impacts on the volume of earthworks required to prepare the site and consideration was given to maintaining and managing a construction site while continuing operations. The preferred location was the existing building footprint with a temporary base elsewhere to continue operations.

4.4.2 Location of temporary base

Two options for the location of the temporary base were considered; Pram Point (preferred option) and the McMurdo Ice Shelf (discarded). The Pram Point location was preferred as there are existing services, access to renewable energy and it is an already impacted site.

Table 20: Summary of the two temporary base locations.

Consideration	Pram Point	McMurdo Ice Shelf
Pros		
Design and Construction	• Ability to prefabricate buildings • Flexibility in design • Easy and quick build • Reuse of existing plant and utilities • More resilience in design • Reuse potential of modules	• No earthworks required • Ability to prefabricate buildings • Reuse potential of modules
Maintenance	• Simple winterisation of portions of base • Safer location than ice shelf • Connection to construction site • Allows for operational efficiency	• Deconflicted from construction site
Environmental Impact	• Connection to renewable energy • No duplication of bulk fuel storage • Wastewater treatment through existing plant • Full reuse of building modules • Selected sites already impacted	• No terrestrial ecological impact • No remediation of terrestrial environments required • Full reuse of building modules
Health and Wellbeing	• General wellbeing enhanced being on land	• No construction noise or vibration impacts • Deconflicted from potential 24hour operations • Deconflicted from all potential construction hazards
Cons		
Design and Construction	• Earthworks required • Foundation design complicated on permafrost	• Little flexibility in design • Duplication of services • No reuse potential of existing plant or utilities
Maintenance	• Potential conflict with construction activities	• Difficult snow management • Difficult to winterise modules • Movement of personnel between ice shelf and Pram Point • Safety and inefficiencies in operations
Environmental Impact	• More earthworks and potential terrestrial impacts	• High energy demand, fossil fuel powered • No connection to renewable energy • Limited technology for wastewater treatment • Duplication of bulk fuel storage
Health and Wellbeing	• Impacts from construction noise • Potential exposure to construction hazards	• Isolation on ice shelf • Limited access to Hut Point walking trails and McMurdo Station

4.4.3 Location of long-term science experiments

The siting options of the proposed new buildings all have some degree of impact on the LTS area (Figure 61). The relocation of some, if not all, of the LTS experiments became necessary to preserve the integrity of the datasets. Three options were assessed (Table 21). The preferred option to 'Move some experiments' is described in Chapter 2.

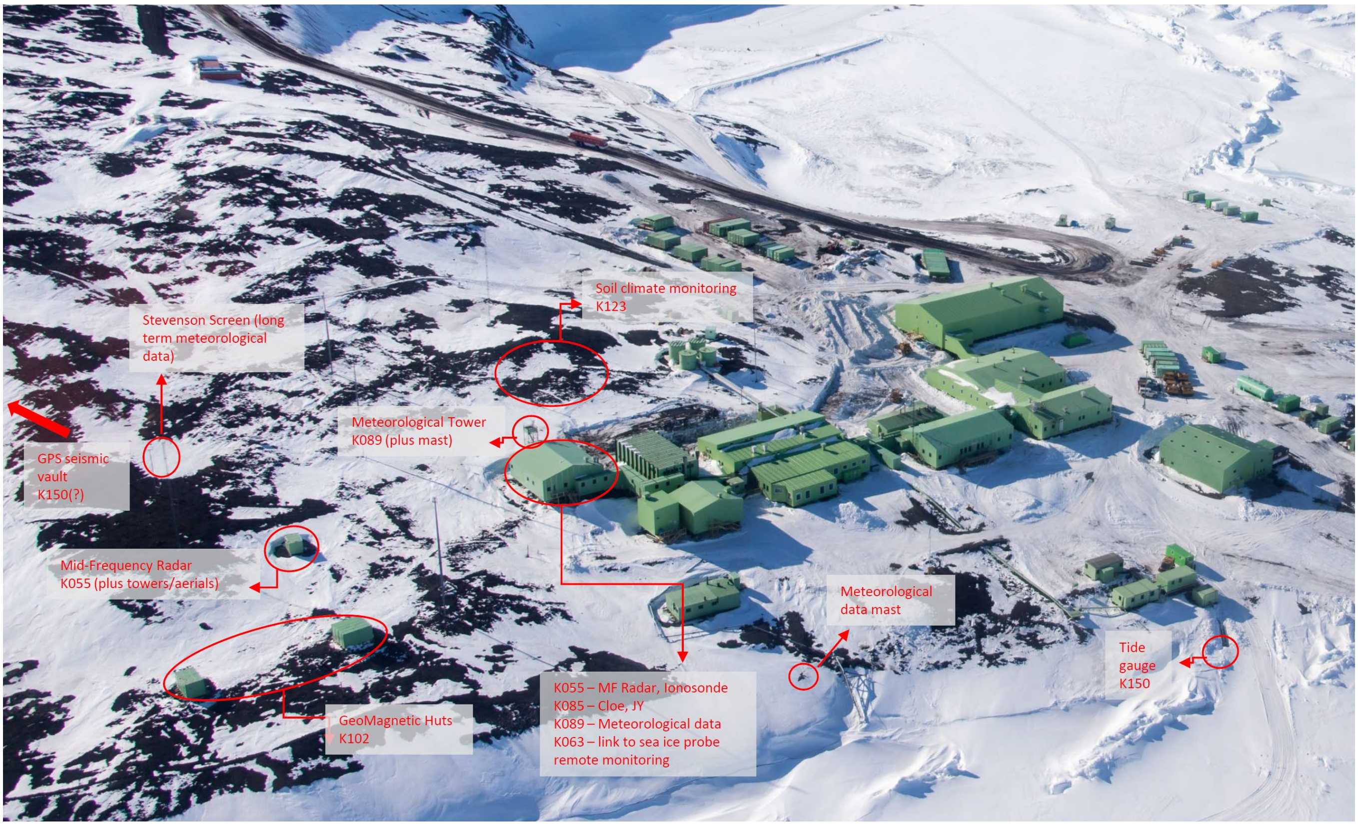

Figure 61: The location of long-term science experiments at Scott Base.

Table 21: Options for the relocation of long-term science experiments.

Options	Pros	Cons
Option 1: Move no experiments	• No further disturbance in the LTS area	• Certain interruption to LTS experiments during construction • An alternative location for the base is needed and will not be the optimal site • Possible additional earthworks • Possible environmental impacts on native flora • Additional cost • Lost opportunity to use current base as temporary camp • Lost opportunity to upgrade current LTS experiments • Lost opportunity to remove some of the manual data collection and equipment maintenance by automating the experiments • All experiments will require repairs and maintenance • Additional work for Science Support staff to maintain • Possible disturbance to LTS experiments from construction activities regardless of alternative site chosen
Option 2: Move some experiments	• Possibility of moving some science experiments to Arrival Heights, • Possibility of moving some science experiments to a new fit for purpose facility • Deconflicts LTS from new buildings • Opportunity to upgrade some experiments to the latest technology. • Limited environmental impact in the LTS area • Limited additional support needed from base staff • Release more area in the vicinity of Scott Base for natural ground rehabilitation • More site flexibility • Existing assets are in increasingly deteriorating condition and the supporting infrastructure could be renewed so that it's safe and fit for purpose for the future. • May provide additional laydown areas • Some experiments are best placed outside a designated LTS area	• Leaving some experiments where they are may lead to constraints around building locations. • Risk of interrupting long-term datasets • The remaining experiments will require repairs and maintenance to bring them up to code / just keep it going which comes at an expense • Additional work for base staff to maintain and collect data measurements on the remaining Experiments • Possible disturbance to LTS experiments from construction activities regardless • Multiple sites to maintain which may require travel away from base
Option 3: Move all experiments	• Removes one siting constraint at the west of the base • Opens up the opportunity to automate and/or upgrade many LTS experiments • May reduce project timeline as construction is unimpeded • Will likely reduce the amount of earthwork • New base could be built while retaining parts of the existing one • Contaminated land could be more easily remediated • Only one science site to maintain in future • Opportunity to create a brand-new site free of disruption for the next 50 years	• Extra cost to the project • The requirement for data overlap may impact the start date for the project • Risk of interrupting long-term datasets • Possible environmental impacts. Whilst the LTS area cannot be considered pristine as it has already been disturbed by LTS events, there has been significantly less disturbance than the area currently proposed. • Unlikely that one site will meet all LTS requirements • Position of the LTS area – consideration will need to be made to cable run lengths for power, data, etc. between event equipment and the LTS area. • Possibly significant additional support needed from base staff.

4.5 Alternative mechanical and services engineering solutions

4.5.1 Energy generation

The maximum energy demand of the proposed Scott Base was projected to be in the range of 292kW to 342kW. Identified power supply sources were:

- On-site power generation via diesel generator or micro-turbines;
- Electricity supply from the existing wind farm;
- Electricity supply from McMurdo Station; and
- Electricity supply from local alternative sources.

The main objective of energy generation was to provide a system without a 'single point' of failure. Various power supply configurations were considered and ultimately a combination of electricity supply from local diesel generators, electricity supply from the wind farm and from local alternative sources was incorporated into the design. Multiple local alternative sources of electricity were investigated (Table 22) with supply from PV as the preferred alternative. The technologies progressed for the new station provide the lowest cost per kW of generation as well as the critical resilience needed for the project.

Table 22: Summary of alternative energy generation technologies.

Technology	Pros	Cons
Storage options		
Lithium-Ion batteries	• Can increase efficiency of existing wind turbine systems by evening out daily peak power demands • Can increase efficiency for future PV-systems • Can function as short uninterruptible power supply to recover from blackouts due to wind turbine failures or service • Large scale redox flow batteries are cost effective and can store more energy for use in longer wind turbine down periods • Flow battery systems have an expected life-span of more than 20 years	• Expensive technology • Heavy and space demanding • Contain environmentally hazardous substances (depending on type) • Efficiency is temperature dependent (depending on type)
Fuel Cells	• Can increase efficiency for large PV – systems and wind power production by seasonal storage of energy • Converts surplus electricity to demand-controlled power and heat production • Extension of wind farm is possible in combination with fuel cell technology • Can function as a long-term electricity supply system • Large-scale plants can be utilised as heating supply system • Low noise pollution • By-products are water and waste heat, which are environmentally acceptable and/or can be utilized • High efficiency of energy conversion when waste heat is utilised.	• High investment costs and not off the shelf technology • Hydrogen storage tanks may constitute a danger • Generates heat during conversion to/from hydrogen • Need clean water for operation • Hydrogen in storage tanks should be compressed • Produces DC power that may be converted to AC

Technology	Pros	Cons
Energy Production Technologies		
PV cells – Electric Energy	• Silent and clean electricity production • Can be integrated into building and serve as façade/roofing material • Electricity produced at same time as electrical appliances are used • Well-known and reliable technology	• Electricity is not produced in winter time (from April to September) • Risk of high wind speeds damaging PV arrays • Risk of snow accumulating on low angled PV arrays • Produces DC power that may be converted to AC • Solar trackers are fragile
Thermoelectric generator – Electric Energy	• Utilises excess heat • Utilises cold outside temperatures • Silent operation • Robust technology, no moving parts	• Low efficiency • Expensive • Dependent on excess heat • Produces DC power that may be converted to AC
Solar thermal systems – Heat Energy	• Renewable during summer season • Can be combined with heat pump systems • Easy to transport and maintain	• Energy cannot be stored effectively for long periods • Produces low quality energy • Heat losses during transportation • High glycol content reduces efficiency • Snow and frost accumulation issues
Drain Water Heat Recovery Systems – Heat energy	• Facilities in Scott Base such as showers, dishwashing and clothes washing may have a high potential from drain-water heat recovery • Heat recovery efficiency depend son system water flow and water temperatures • Based on low-tech technology by use of heat exchangers • Low running costs and potential for a short payback time	• Additional service for maintaining the systems should be expected • The system should be accessible to staff for service
Seawater heat pump – Heat Energy	• Efficient • Can utilise local heat source – seawater • Short payback period	• Antarctic conditions add complexity to design • Permafrost prevents the use of boreholes • Certain refrigerants are harmful to the environment
Anaerobic digesters	• Reduces waste streams and produces biogas • Biogas can be utilised for producing heat, electricity or fuel for vehicles • Reduces shipping of waste back to NZ	• Process is temperature dependent 35-40 °C • Increased temperatures needed to help sterilise the digestate • High investment costs • Not enough waste generated
Small-scale waste incinerator	• Reduces shipping of waste back to NZ • Waste streams can be exploited to generate heat and electricity • Low operational costs • Low value waste replaces high value fossil fuels (AN8)	• Emits flue gases • High investment costs • Waste handling and waste storage required near plant • Problems with odours may occur • Unlikely to meet a large portion of the electrical load

Technology	Pros	Cons
Internal combustions generators	• CHP technology generates electricity and utilises waste heat. • On-site-produced biogas (produced by other technologies) may be used as a fuel (biogas is often mixed with natural gas for better performance). • Demand-controlled technology and can be used as a backup system in absence of uncontrollable renewables (such as wind and PV-systems).	• Natural gas is a fossil fuel that has to be transported to the camp. • Gas (natural gas and biogas) constitutes a safety risk in terms of leakage risks and risk of explosion.
Small scale horizontal wind turbines	• Produces electricity asynchrony with PV-systems, at night and in wintertime • Small wind turbines are highly transportable and relatively easy to install • A cluster of smaller wind turbines has lower down time (e.g. due to service) than a few large wind mills • Small wind turbines have a simple design, fewer parts and easier to service	• Location is essential to efficiency and safety risks • Ice shedding from rotor and blade throw is a safety risk • Noise and reflections due to low sun angle may be unwanted in the camp • Wind turbulence in low height and near camp reduces efficiency
Small scale vertical wind turbines	• Increased safety and durability • Very high stability and operates even at very high wind speeds (above 100 mph) • Suitable for temperatures below minus 50 °C • Produces electricity asynchrony with PV-systems, at night and in wintertime. 15 W at wind speed 20 m/s. • Captures wind from any direction. • Not affected by turbulence and changing wind directions. • Small and silent device 5 dB n 5 m distance.	• Small-scale energy electricity production • Reduced efficiency • Battery is needed for utilising the produced energy

4.5.2 Fuel storage and delivery

Bulk fuel on Ross Island is transported and maintained by the USAP, with transfers of fuel from the bulk storage facility at McMurdo Station to a bulk fuel tank at Scott Base. As part of the design, the Scott Base Redevelopment aimed to increase redundancy and to consider implications of not having deliveries in the winter. The requirement was to provide storage for a 2 to 6-month supply, without consideration of wind farm contributions.

Two sites for a bulk fuel facility at Scott Base were considered. To the east of the station adjacent to the buildings and located with the external storage and container area, or uphill of the proposed Scott Base with a pipeline running downhill to the three buildings (Figure 62). The uphill site option was rejected in the design due to health and safety risks of refuelling on a hill, the environmental risks of potential spills running under the proposed station and issues with snow build-up.

Alternative mechanisms for the delivery of fuel from the bulk storage facility at McMurdo Station were considered (Table 23) with the preferred option of truck-based deliveries selected.

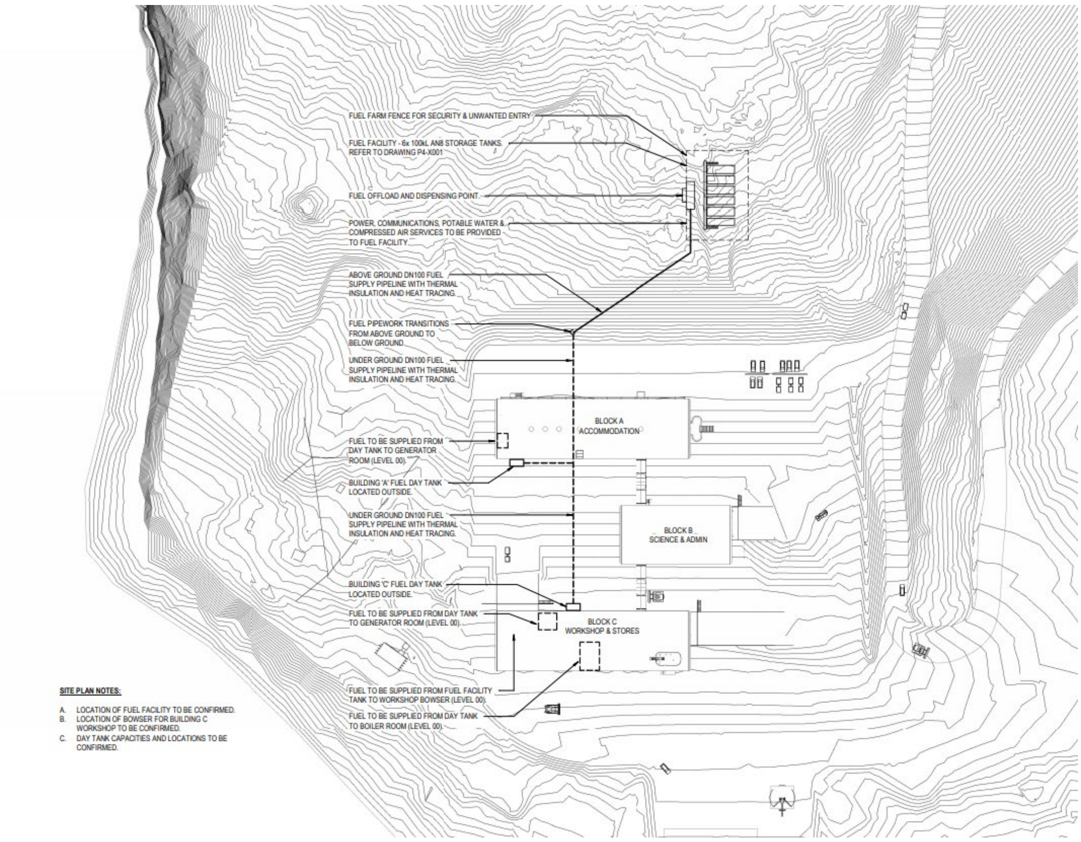

Figure 62: Alternative location of bulk fuel considered in design.

Table 23: Fuel delivery options.

Considerations	Truck deliveries	Branch off existing pipeline	New small-bore pipeline
Summer operation	Possible – acceptable safety level	Timed during airfield refuelling	Possible
Winter operation	Possible – safety a concern	Not possible, pipeline is empty	Not possible
Redundancy and emergency provisions	Poor	Moderate – back up by tanker deliveries	Moderate – back up by tanker deliveries
Risk of a significant spill	Minor	Significant if pumping fails	Moderate if pumping fails
Long term maintenance requirements	Minor	Minor	Significant
Future flexibility in terms of tank or base layout alterations or increase in fuel consumption	Good	Moderate, limited by pipe location and tank capacity	Moderate, limited by pipe location and tank capacity
Reliance on McMurdo	Dependence on tanker deliveries	Dependence on pipeline charging	Dependence on new infrastructure tie-in
Cost	Nil	Low	Significant

4.5.3 Water production

Water production is an energy-intensive process. Three potential sources of water were identified:

- Seawater, drawn from below the sea ice as per existing;
- Snow, harvested from areas adjacent to the station;
- Recycled water produced from the recycled water plant.

Several water production technologies were investigated that ranged in intensity, environmental impact and cost (Table 24). They were assessed against a set of criteria (Table 25) and the preferred option was a reverse osmosis plant due to its proven reliability, simplicity and environmental impact, amongst other reasons.

Table 24: Water production technologies options.

Option	Title	Water Source	Example Technology	Description
A	Existing RO plant	Seawater	MMF / RO / Cl / UV	Upgrades as required to enable the existing treatment plant to be re-used
B	Snow melt system	Snow	Fuel or electric MMF / UF / Cl	Harvesting and thermal melting of snow from areas adjacent to the base. Catchment protection is recommended to minimise contamination. Solids reduction and disinfection of the melted snow before use.
C	Thermal desalination	Seawater	MMF / UF / Cl	Solids reduction followed by thermal desalination of seawater using fuel or electric thermal desalination. Condenser / cooler to precipitate product and disinfection before use.
D	New RO plant	Seawater	MMF / UF / RO / Cl	Similar to existing with contemporary upgrades to all systems. Need for UV to be assessed
E	Option D + high recovery system	Seawater	Option D + additional stage of RO or equivalent	Maximises the recovery of raw seawater to treated water
F	Direct potable reuse	Recycled water	Recycled Water Plant / Advanced treatment (RO / Advanced oxidation / Cl)	Processes recycled water which would otherwise be discharged into treated water suitable for human consumption.
NOTES: MMF = Multimedia Filter / RO = Reverse Osmosis / UV = UV Disinfection / Cl = Chlorine Disinfection / UF = Ultrafiltration				

Table 25: Multi-criteria decisional analysis matrix for the water production options.

Criteria/Option	A	B	C	D	E	F
Operational reliability	✓	x	x	✓✓✓	✓	x
Simplicity	✓✓✓	x	x	✓✓✓	x	x
Landform impact	✓	x	✓	✓	✓	✓
Energy / fuel efficiency	✓	x	x	✓✓	✓	✓✓
Waste discharge quality	x	✓✓	x	x	✓	x
Robustness	✓	x	x	✓✓	✓	xx
Operator involvement	x	x	x	✓	x	x
Environmental stewardship	✓✓	✓	x	✓✓	✓	✓
Capital cost	✓✓✓	✓	✓	✓	x	xxx
Operational cost	✓	✓	✓	✓✓	✓	xx

4.5.4 Wastewater management

Management of wastewater is critical to the ongoing operation and environmental sustainability of Scott Base. Several treatment options were identified that ranged in complexity, environmental impact and cost (Table 26). They were assessed against a set of criteria (Table 27) and the preferred options, a basic wastewater treatment plan and advanced WWTP were progressed. These were selected due to their very high standard of treatment, success in other recent polar installations and other criteria considered in Table 27. Both options provide a greater level of treatment compared to the current plant.

Table 26: Wastewater treatment options.

Option	Title	Example Technology	Description
A	Existing treatment plant	-FBBR / Ozone -Sludge dewatering	Maintenance and minimal modification of existing treatment plant.
B	Maceration + discharge	Maceration	All wastewater macerated to reduce size of solids. The macerated wastewater then discharged to the ocean untreated.
C	Basic WWTP	-MBR -Sludge dewatering	Suitable treatment required to reduce the effluent nutrient for ocean disposal. No disinfection. Solids + sludge dewatered and sent to NZ for disposal.
D	Advanced WWTP	-MBR / UV -Sludge dewatering	Wastewater treated to a suitable standard for discharge into the environment with minimal environmental impact. High level of nutrient removal and disinfection. Solids + sludge dewatered and sent to NZ for disposal.
E	Recycled water plant	-MBR / UV / Cl -Sludge dewatering	Wastewater treated to a suitable standard for re-use in toilets, washing machines. Excess discharged to ocean. Solids + sludge dewatered and sent to NZ for disposal.
F	Zero discharge	-MBR / UV / Cl / RO / Evap -Solids digester + dewatering + incineration	Wastewater treated to a suitable standard for re-use in toilets, washing machines. Excess recycled water treated to allow evaporation. Solids + sludge digested + dewatered and dried / incinerated.
G	Direct potable reuse (DPR)	-MBR / RO / Advanced oxidation / Cl -Solids digester + dewatering	All wastewater treated to a very high standard suitable for reuse as potable water. Brine would be discharged to the ocean and solids returned to NZ for disposal.
NOTES: FBBR = Fixed Bed Bioreactor / MBR = Membrane Bioreactor / RO = Reverse Osmosis / UV = UV Disinfection / Cl = Chlorine Disinfection			

Table 27: Multi-criteria decision analysis on wastewater treatment options.

Criteria	Option A	Option B	Option C	Option D	Option E	Option F	Option G
Low operational risk	xx	✓✓	✓✓	✓✓	✓✓	xxx	xxx
Simple constructability	✓	✓✓✓	✓	✓	✓	xxx	xxx
Waste solids transport minimisation	x	✓✓✓	✓	✓	✓	✓✓✓	✓✓
Food waste treatment	xx	✓✓✓	xx	xx	xx	✓✓	✓✓
Reuse potential (recycled water)	✓	xxx	xx	xx	xx	✓✓✓	✓✓✓
Operational robustness	xx	✓	✓✓	✓✓	✓✓	xx	xxx
Minimal operator involvement	xx	✓	✓✓	✓✓	✓✓	xxx	xxx
Environmental stewardship	x	xxx	✓	✓✓	✓✓	x	✓
Capital cost	✓✓	✓✓	✓✓	✓✓	✓✓	xxx	xxx
Operating cost	✓	✓✓✓	✓✓	✓✓	✓✓	xxx	xxx

4.5.5 Waste management

All waste generated at Scott Base is transported via shipping containers on the return voyage of the annual resupply vessel and disposed of in New Zealand, either through recycling or landfilling. The process is costly, time consuming and inefficient. In addition to measures to avoid, reduce, reuse and recycle waste, option for treatment on site before return to New Zealand were investigated. Several treatment options were identified that ranged in their ability to treat the different waste streams, air quality emissions and recovery of energy/fuel (Table 28). These options were not deemed feasible for the limited quantities and types of waste generated by Scott Base, as the energy expended would not have been offset by that recovered. The current mode of operations was therefore retained, with improvements in design of the waste management area and operational procedures.

Table 28: Waste management technology options.

Technology	Pros	Cons
Small-scale waste incineration	• Suitable for almost all types of wastes. • Well established technology • Reduces the original volume of waste by 80-95% • Does not require continuous operation • Potential for energy and heat recovery	• Emits flue gases that include water vapour, nitrogen, oxygen and carbon dioxide. Smaller amounts of carbon monoxide, hydrogen chloride, sulphur oxides and nitrogen oxides may also be produced • Potential high investment costs and air pollution control costs • Ash collected from the flue gases contains hazardous compounds and needs to be disposed of • Potential for odours
Pyrolysis and plasma gasification	• Small scale • Syngas can be used to fuel a steam turbine or gas engine • Fewer emissions to the atmosphere • Clean alternative to incineration • Can process a broad range of wastes, that may also include hazardous and food waste • Potential for heat recovery at lower waste quantities than waste to energy incineration	• New technologies, limited demonstration and track record for range of waste types • High investment and operational costs • Maintaining high temperatures for gasification is expensive • Plasma gasification has limited commercial scale operations, therefore uncertainty on technical performance and ability to meet emission limits
Anaerobic digestion	• Reduces organic waste that is considered hazardous once imported to New Zealand • Biogas can be used to produce heat, electricity or fuel for vehicles • Reduces the volume of waste by 60% • Proven technology	• Needs careful control and regular supply of consistent feedstock • Only manages food waste and sewage sludge • High investment costs • To ensure a sufficient supply of feed, the treatment of waste from the McMurdo Station may be required • Unsuitable for seasonal variation • Process is sensitive to contaminants • High process residence time (biomass conversion typically takes up to 14-20 days)

4.6 Alternative civil and foundation works

4.6.1 Alternative earthwork methodologies

Geotechnical investigation confirmed that digging and ripping are not viable options for the Scott Base Redevelopment earthworks as the rock strength of Pram Point is too high. Two methods for earthworks were then considered. Drilling and blasting and using a milling machine (i.e. a surface miner or terrain leveller). The plant and personnel requirements for each method were broadly comparable and did not significantly influence the decision-making process.

Drilling and blasting is a proven method at Scott Base to undertake earthworks projects. The use of milling machines is common in the mining industry, though it is untested in cold climates. Drilling and blasting was chosen as the proposed method early in design. It is a proven method and the experience with New Zealand contractors.

4.6.2 Foundations

Two foundation options were analysed in detail through the design stages for their suitability to the proposed Scott Base. The options were precast concrete pads with tension anchors and end-bearing piled foundation as described in Section 2.8.4. Precast pads were discounted early in the design process due to their warming effect on the permafrost and their potential for causing subsidence. These characteristics were also considered undesirable as they would increase the expected impacts of climate change on Pram Point, which include warming and subsidence of the permafrost. Pile foundations were chosen due to their higher bearing capacity and the reduction in the volume of earthworks required to install.

Pad foundations:
The pad option is a precast concrete pad, founded below the freeze-thaw layer to ensure that there is sufficient insulating material to prevent thawing of the ground below (Figure 63). The bearing surface would either be on bedrock with a thin layer of levelling fill, or on the final engineered site fill that builds up the final slope. Excavation requirements are high for this option and excavated material must be left to settle for one season. The tension anchors used in pad foundations are permanent as they cannot be removed at the end of life.

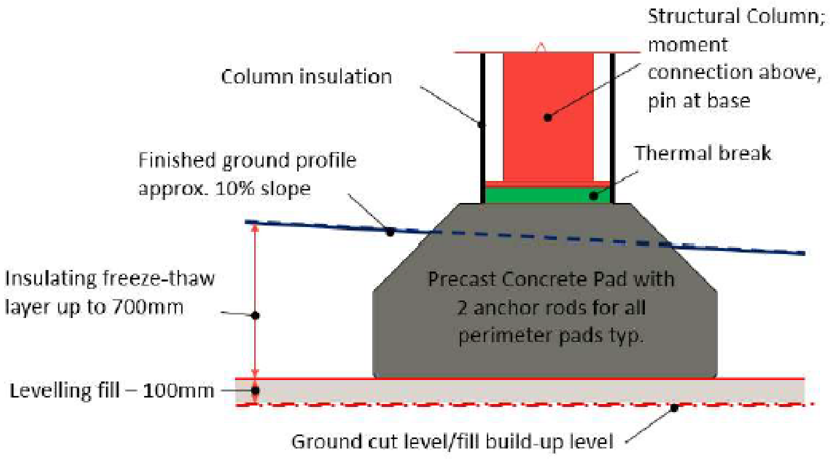

Figure 63: Diagram illustrating the proposed pad foundation option.

4.6.3 Contaminated ground remediation

Three options for the management of asbestos contaminated soil were considered in the earthworks design for the proposed Scott Base Redevelopment. These options are presented in Table 29, with in situ encapsulation considered the most appropriate for cost, environmental, and schedule reasons. The three options were:

- **Excavate offsite and dispose in New Zealand**: Excavation and removal of the asbestos impacted material within the redevelopment boundary and transportation back to New Zealand for disposal. This would include removal of all asbestos impacted soils in the redevelopment boundary or selective removal from areas with identified elevated asbestos concentrations above human health guidelines only.
- **Containment cell**: Removal of the asbestos impacted material and placement within a dedicated containment cell. This would include removal of all asbestos impacted soils in the redevelopment boundary or selective removal from areas with identified elevated asbestos concentrations above human health guidelines only.
- **Encapsulate**: Leave the asbestos impacted material in-situ and encapsulate it beneath a geotextile/warning layer and 'clean' surface material. This would include the encapsulation of all asbestos impacted soils in the redevelopment boundary or selective areas with identified elevated asbestos concentrations above human health guidelines only.

Table 29: Summary of alternative asbestos remediation options.

Description	Pros	Cons
Excavate off site and dispose in New Zealand	• Removal of source material (i.e. contamination removal from Antarctica) • Depending on the level of asbestos removal undertaken (i.e. partial or full), it would either lower or eliminate the ongoing liability or legacy issues within the redevelopment boundary • Lowering the risk profile for future users/visitors to the Base (noting some asbestos impacts would still be present outside of the redevelopment boundary regardless of full or partial removal) • Once removed there would be no restrictions on the milling or drill and blast techniques for the soil disturbance/bulk earthworks within the remediated areas • Future routine tasks like ongoing ice/snow scraping and clearing around the proposed base within the remediated areas could be undertaken without ongoing management controls • No future ongoing monitoring, maintenance or mitigation costs post-redevelopment	• High costs to transport material back to New Zealand for disposal • Will require extensive disturbance and excavation of highly contaminated material, therefore creating increased risk to site workers and other base users at the time of the work • Vertical and exact lateral extent of the impacted material not fully known so difficult to determine the total volume requiring removal (may require further soil sampling to determine extent of impacts) • Possible permafrost constraints meaning removal of all material may be difficult • Time period to remove all asbestos impacted soils could result in remedial works being undertaken over several seasons • Material present beneath existing buildings so would require demolition in the first instance and undertaken in stages • Validation soil sampling required following removal of the impacted material • Logistical issues with temporarily storing the impacted material in suitable waste bins/containers and also transporting the material via ship back to New Zealand • It is undesirable to remove large volumes of soils from Antarctica • The importation of foreign soils is a potential biosecurity risk to New Zealand's environment

Description	Pros	Cons
Containment Cell	• Removal of source material from the future operational area • Lowering the risk profile for future base users (noting some asbestos impacts would still be present outside of the redevelopment boundary regardless of full or partial removal) • Lower cost than shipping material back to New Zealand for disposal • Once removed there would be no restrictions on the milling or drill and blast techniques for the soil disturbance/bulk earthworks within the remediated areas • Future routine tasks like ongoing ice/snow scraping and clearing around the proposed base within the remediated areas could be undertaken without ongoing management controls • Reduction in future ongoing monitoring, maintenance or mitigation costs post-redevelopment	• Will require extensive disturbance and excavation of highly contaminated material (both for the excavation of the impacted material in situ and during the placement within the cell), therefore creating increased risk to site workers and base users at the time of the work • Vertical and exact lateral extent of the impacted material not fully known so difficult to determine the total volume requiring removal and placement within the cell (may require further soil sampling to determine extent of impacts) • Possible permafrost constraints meaning removal of all material may be difficult • Time period to remove all asbestos impacted soils could result in remedial works being undertaken over several seasons • Material present beneath existing buildings so would require demolition in the first instance and undertaken in stages • Validation soil sampling required following removal of the impacted material • Identifying a suitable area for construction of the dedicated containment cell(s) • Would place restrictions on the future redevelopment, use and excavations in the vicinity of the containment cell(s) • Approval may be required to dispose of waste to ground (e.g. requirements and compliance under the Antarctic Treaty) • Additional excavation works to construct the containment cell(s) • Long-term monitoring and maintenance of the cell to ensure asbestos remains contained • Reputational issues for leaving known contaminated materials within the base and environmental considerations with using/importing geotextile material to Antarctica

Description	Pros	Cons
Encapsulate	• Minimal ground disturbance required and therefore less risk to site workers undertaking works, also other base users at the time of the work • Have successfully undertaken this type of remedial works onsite already (i.e. it works) • Could be used as interim measure to enable access to restricted areas for demolition of site buildings • Lowering the risk profile for base users by eliminating exposure to high risk areas • Can involve simple techniques and will take immediate effect • Shorter time frames to complete the works • Lower costs than removal/disposal to New Zealand • No/minimal additional soil sampling required to determine extent of impacts • No validation soil sampling required	• Asbestos material still in-situ and the asbestos risk remains to future base users • Would require careful ongoing management and long-term monitoring and maintenance of the encapsulation to ensure asbestos remains suitably encapsulated • Restrictions on the milling or drill and blast techniques for the soil disturbance/bulk earthworks within the asbestos impacted areas • Geotechnical issues and foundation design limitations/restrictions with leaving material in situ (could therefore still require impacted material to be excavated and removed during the redevelopment works) • Costs associated with geotextile and other material used to construct the encapsulation • Obtaining sufficient 'clean' material to place over the geotextile barrier • Reputational issues for leaving known contaminated materials within the base and environmental considerations with using/importing geotextile material to Antarctica

4.6.4 Road realignment

An alternative to the road realignment is to do nothing. This option was considered in the options analysis for the final exact location of the proposed Scott Base and the delivery method of the building modules.

The "do nothing" alternative was discounted as there would be an unacceptable risk to traffic on the road and no buffer to construction activities. Additionally, realigning the road allows for the earthwork volumes required in the Scott Base Redevelopment to be reduced through efficient use of space and reuse of fill from the realignment.

4.7 Alternative deconstruction methodology for the existing buildings

The alternative deconstruction method proposed was a whole building removal with smaller sections of deconstruction. The whole removal process, described below, would have allowed for more control over reducing the risk of contaminant release into the environment. This method was discounted due to additional plant and personnel requirements, larger staging area requirements and limited time to back load the proposed MC Class vessel following the delivery of the building modules. The risk of releasing wastes to the environment would have been lesser than with the proposed methodology, however, the duration, intensity (plant and personnel) and extent (staging area) of other impacts such as emissions to air and ground disturbance would have been greater.

The method for whole removal for each of these buildings would have entailed:

1. Remove retaining walls and external services;
2. Drain plant fluids into double skinned drums for removal to New Zealand;
3. Remove connection to and demolish adjoining linkways;
4. Remove external accessways, decks, any external fixtures;
5. Cut through floor to isolate and remove trusses from piles;
6. Lift buildings on hydraulic jacks onto a moving truck and relocate to a staging area;
7. Stage building in staging area located in the current cargo storage area at the north east edge of Pram Point;
8. Place buildings on levelling blocks, enclose the buildings with temporary walls and tie down buildings to endure 3-4 years unoccupied in a staging area (Figure 64); and
9. Move buildings onto the ship used for the delivery of the proposed Scott Base to site, load ship and tie down for return journey to New Zealand.

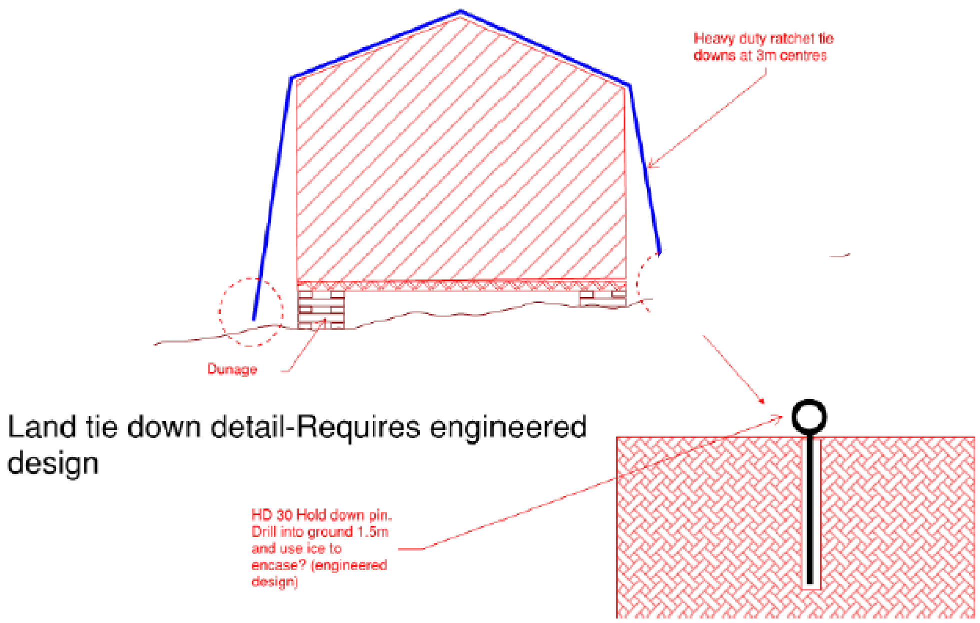

Figure 64: Land tie down detail for whole buildings stages for removal on ship.

4.8 Alternative timelines, logistics and installation of the proposed station

Two alternative modes of logistics and installation of the proposed station were considered: a full build in New Zealand with modular delivery roll-on-roll-off (RORO) delivery, and a traditional build with materials and supplies shipped in containers and a full build on-site (containerised) (Figure 65).

All of these options result in different timelines (Figure 66). The various options were assessed against a set of criteria (Table 30) and the preferred option was to conduct a full build in New Zealand with modular delivery (RORO) to Pram Point and to establish a temporary station to operate from during the project. The preferred option was much faster than the other alternatives.

For either of these modes of logistics and installation, there were three options for accommodating people throughout the project including:

1. **Temporary base**
   Some form of temporary base/station is constructed, either at Pram Point and/or elsewhere, which is occupied for some or all of the duration of the project, to allow the existing Scott Base to be demolished so the new base foundations can be constructed.
2. **Build uphill**
   In this option the new base location is located uphill of the current base footprint, allowing the existing Scott Base to be occupied during construction of the proposed base. Once the new base is commissioned and occupied, the old base is demolished and shipped back to New Zealand for disposal.
3. **Staged occupancy**
   In this option, the existing base remains occupied and the new base buildings are constructed in stages. The new buildings are located partially off the existing base footprint. When the first buildings are completed, they are temporarily commissioned and occupied before the demolition of the existing Scott Base, after which the third building is shipped, joined and the three buildings fully commissioned together.

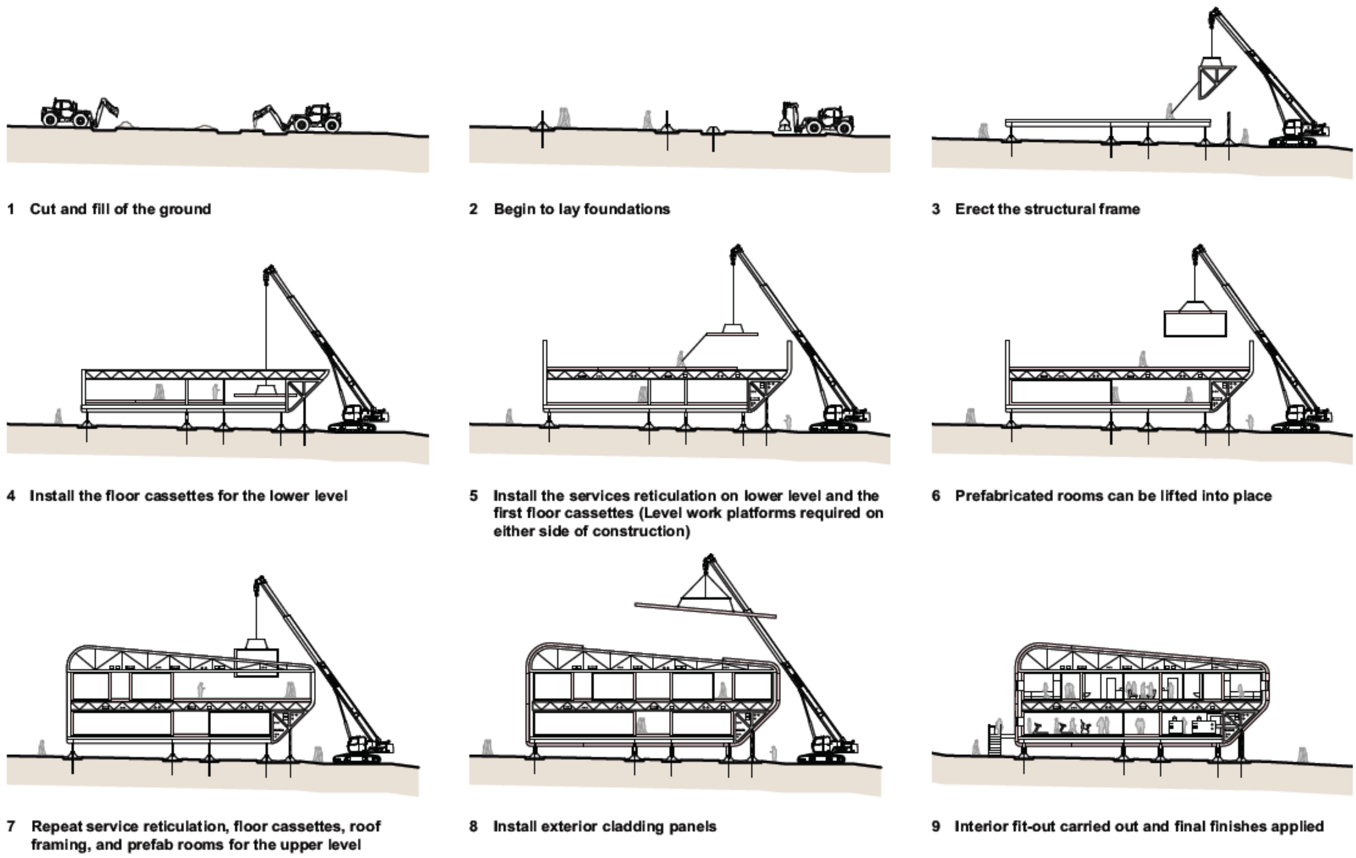

Figure 65: Construction sequencing for a traditional build on site.

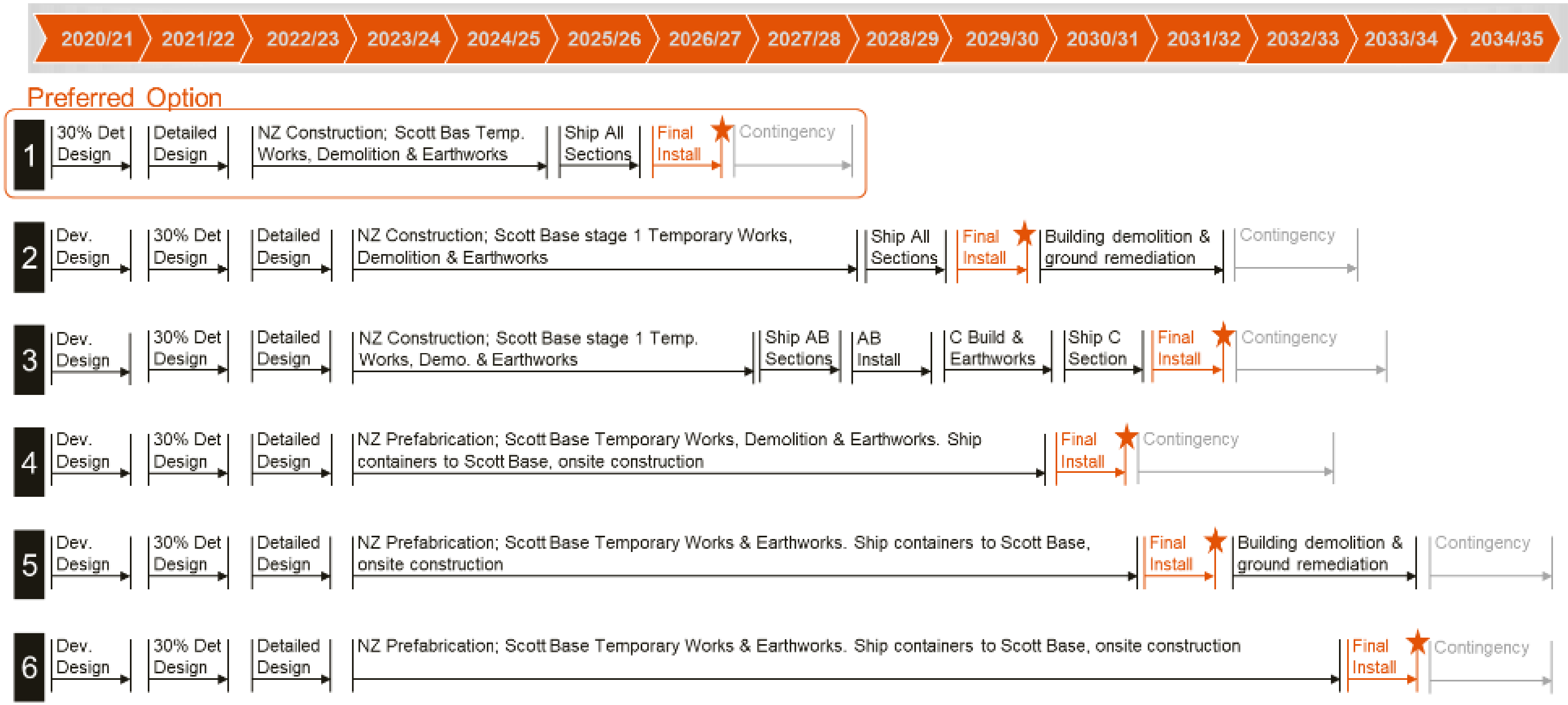

Figure 66: High level proposed timelines for the six logistics and installation options.

Table 30: Multi-criteria decision analysis matrix for the logistics and installation options.

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
	RORO Temporary Base	**RORO Build Uphill**	**RORO Staged Occupancy**	**Containerised Temporary Base**	**Containerised Build Uphill**	**Containerised Staged Occupancy**
Temporary base	Required for 120 people	Not required Some additional accommodation required to support construction workers - 40 people	Not required Some additional accommodation required to support construction workers - 40 people	Required for 120 people	Significant additional accommodation required to support large number construction workers - 120 people	Significant additional accommodation required to support large number construction workers - 120 people
Noise during construction	No issues – temporary base located away from activities	Drilling, blasting, excavation, and crushing within 100m of living and working areas	Drilling, blasting, excavation, and crushing within 100m of living and working areas	No issues – temporary base located away from activities	Drilling, blasting, excavation, and crushing within 100m of living and working areas	Drilling, blasting, excavation, and crushing within 100m of living and working areas
Impacts on science programme	Impacted winter science seasons in 2024, 2027. Impacted summer science seasons in 23/24-27/28. Most flexibility on amount of science supported	Impacted winter science seasons in 2024, 2029, 2030. Impacted summer science seasons in 24/25-31/32. If additional accommodation not provided (space limited) science support will be reduced	Impacted winter science seasons in 2024, 2028, 2029, 2031. Impacted summer science seasons in 24/25-31/32. If additional accommodation not provided (space limited) science support will be reduced	Impacted winter science seasons in 2025, 2027-30. Impacted summer science seasons in 24/25-30/31. More flexibility on amount of science supported	Impacted winter science seasons in 2024, 2028-32 Impacted summer science seasons in 24/25-33/34 Unlikely to be enough space to provide accommodation to support science (as well as construction) at Pram Point	Impacted winter science seasons in 2024, 2027-29, 2033. Impacted summer science seasons in 24/25-33/34. Unlikely to be enough space to provide accommodation to support science (as well as construction) at Pram Point
Demolition of old base	Majority back-loaded on MC-class ship	Containerised and shipped	Back loaded on second MC-class ship	Containerised and shipped	Containerised and shipped	Containerised and shipped
Snow clearing	Design optimised for snow clearing	Poor - will require steep slope above building A	Design optimised for snow clearing	Design optimised for snow clearing	Poor - will require steep slope above building A	Design optimised for snow clearing
Temporary construction works	Haul road works shortest due to clear site. Pier at Pram Point required	Haul Road longest due to base located further from offload point and have to work around the current Scott Base. Pier at Pram Point required	Haul Road to remain in place longest due to two MC-class shipments. Pier at Pram Point required for multiple seasons	Large staging area for containers required	Large staging area for containers required	Large staging area for containers required
Location	Less visual impact on environment. Minimise base footprint. Location connected to key historic features	Higher visual impact on environment. Increased base operational footprint. Further from key historic features. Further from coastline	Less visual impact on environment. Minimise base footprint. Location connected to key historic features	Less visual impact on environment. Minimise base footprint. Location connected to key historic features	Higher visual impact on environment. Increased base operational footprint. Further from key historic features. Further from coastline	Less visual impact on environment. Minimise base footprint. Location connected to key historic features
Construction productivity	Most productive due to clear site allowing direct cut to fill, direct contaminated material capping, higher production blasting and allows 24-hour operations (if required)	Less productive due to inability to cut direct to fill, increased earthworks volume, inability to treat/cap contaminated material until new base complete and old base demolished (double handling of fill), reduction in blasting size due to proximity to operational base and inability to undertake 24-hour operations (if required).	Less productive due to inability to cut direct to fill, inability to treat/cap contaminated material until new base complete and old base demolished (double handling of fill), reduction in blasting size due to proximity to operational base and inability to undertake 24-hour operations (if required)	More productive for first stage due to clear site allowing direct cut to fill, direct contaminated material capping, higher production blasting and allows 24-hour operations (if required). Much less productive for second stage due to larger volume of works to be completed in Antarctica.	Least productive due to inability to cut direct to fill, increased earthworks volume, inability to treat/cap contaminated material until new base complete and old base demolished, reduction in blasting size due to proximity to operational base, inability to undertake 24-hour operations (if required) and much larger volume of works to be completed in Antarctica.	Less productive due to inability to cut direct to fill, inability to treat/cap contaminated material until new base complete and old base demolished, reduction in blasting size due to proximity to operational base, inability to undertake 24-hour operations (if required) and much larger volume of works to be completed in Antarctica.
Operations	Duplication of services between temporary base and construction site. Majority of operations able to be run separate from construction site (less conflict)	No duplication of services. Conflict between base operations and construction activities.	Significant amount of temporary services (water, wastewater, power, workshops etc) required to commission buildings A & B early for occupation while existing base demolished and building C constructed Conflict between base operations and construction activities	Duplication of services between temporary base and construction site. Majority of operations able to be run separate from construction site (less conflict)	No duplication of services. Conflict between base operations and construction activities	Significant amount of temporary services (water, wastewater, power, workshops etc.) required to commission buildings A & B early for occupation while existing base demolished and building C constructed. Conflict between base operations and construction activities
Logistics	Single shipment of building modules, plus 424 20-foot containers equivalent.	Single shipment of building modules, plus 424 20-foot containers equivalent.	Double shipment of building modules, plus 424 20-foot containers equivalent.	Shipping and staging of 1650 20-foot containers equivalent	Shipping and staging of 1650 20-foot containers equivalent	Shipping and staging of 1650 20-foot containers equivalent

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4.9 Alternatives to the Ross Island Wind Energy replacement

4.9.1 Do nothing

The alternative of not upgrading the wind farm was considered. RIWE is expected to reach the end of its life in 2030 and “do nothing” would result in the wind farm being decommissioned after 2030. As a result, the RIWE grid that supplies McMurdo Station and Scott Base would rely entirely on fossil fuels. The alternative of not replacing the wind farm was discounted because it goes against New Zealand’s commitment to manage its environmental impacts in Antarctica, would increase Antarctica New Zealand’s contribution to climate change and reduce New Zealand’s input to the JLP.

4.9.2 Extension of RIWE’s operational period

While most wind turbines are certified to a 20-year design life, it may be possible to extend their operational life. This period of extended operation where a wind turbine can be safely operated, is referred to as “lifetime extension”. Lifetime extension requires each wind turbine component to be assessed against their design limits for site-specific fatigue damage. If the fatigue damage is less than the anticipated design limits, the wind turbines may continue to be used for many years. Given the extreme site conditions, it was considered unlikely that RIWE would have suffered less fatigue damage than the design limits allow. Lifetime extension also carries an increased risk of failure for the wind turbines as well as significant costs and is not a long-term solution. This option would have delayed the provision of more renewable energy to the Ross Island grid and increased the use of fossil fuels when compared to the preferred option. The alternative to extend the lifetime of the existing RIWE was therefore not pursued.

4.9.3 Like-for-like replacement of the wind turbines

The option of replacing the three currently installed Enercon E-33 wind turbines with similar turbines was assessed. The Enercon E-33 is no longer in production and therefore a direct replacement was not possible. The nearest alternative of similar capacity was a single Enercon E-44 900 kW wind turbine. This like-for-like capacity replacement would have required the replacement of all components including the foundations, with a full decommissioning and deconstruction of the current wind turbines. This alternative was discounted because a like-for-like replacement would not meet Ross Island’s long-term energy needs, resulting in increased burning of fossil fuels to make up the shortfall.

4.9.4 Alternative turbine options

Two alternative turbine options were considered early in the concept design stage of the RIWE replacement project. These options were for significantly larger turbines and are presented in Figure 52 and Table 18. During this design process, it was confirmed that the logistical considerations of constructing a wind farm of Enercon E44s on Ross Island will be similar to the considerations faced when constructing the current E33s and that installation is achievable. Construction of E82s or E115s on Ross Island would be more challenging and would include a major upgrade to the roads and the McMurdo pier to deliver the components. With a revised energy model for the proposed Scott Base indicating a reduced load, there remained little justification to further consider these options.

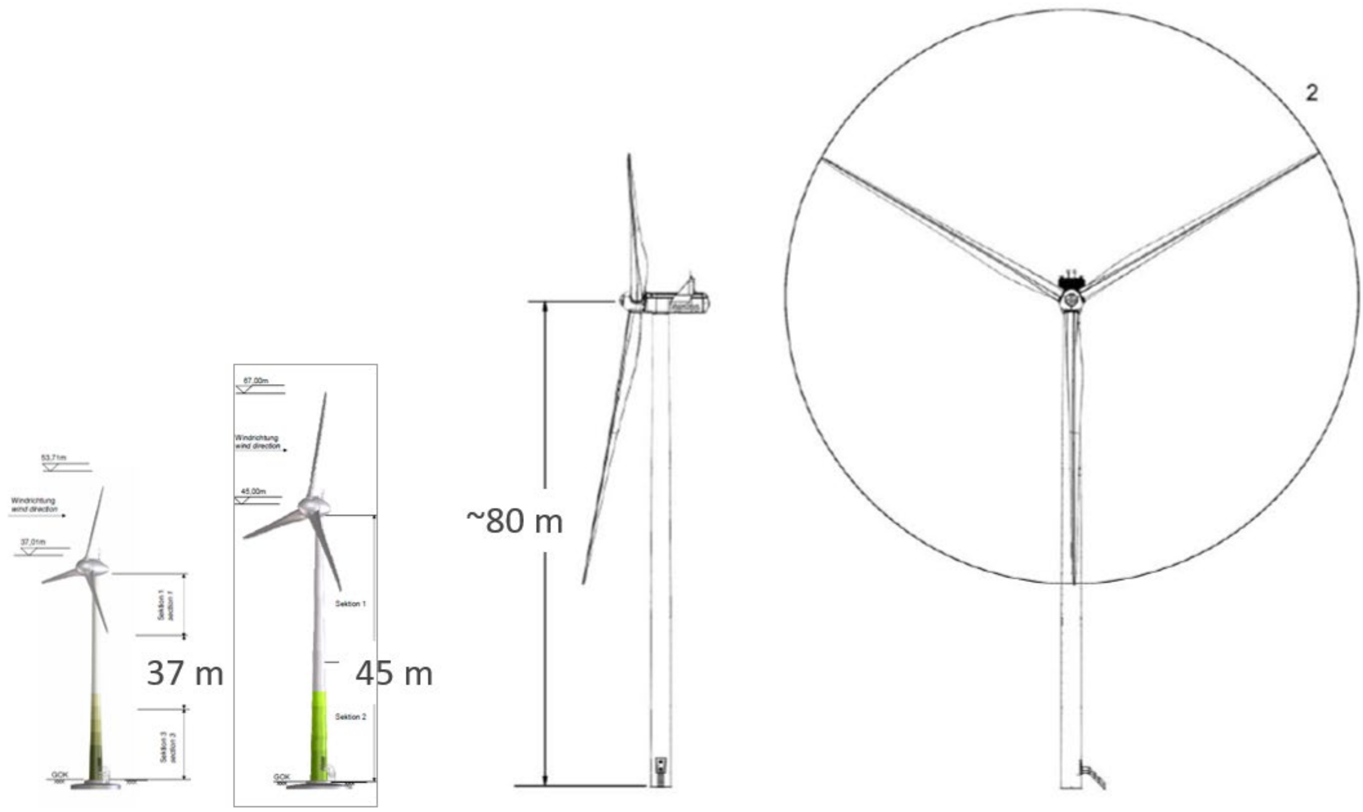


Figure 67: Relative size of wind turbines. From left, current E33, E44, E115.

Table 31: Technical specifications of the three proposed wind turbine options.

Specification	**Enercon E44**	**Enercon E82**	**Enercon E115**
Proposed number	3 or 4	2	1 or 2
Rated Power	900kW	2,000kW-2,300kW	3,000kW
Rotor Diameter	44m	82m	115.7m
Rotor Sweep	1521m^2	3,281m^2	10,515m^2
Hub height options (m)[21]	45 / 55	78 / 84 / 85 / 98 / 108 / 138	80 / 92 / 122 / 135 / 149
Cut in wind speed	3m/s	3m/s	3m/s
Cut out wind speed	34m/s	28-34m/s	28-34m/s
Gear box	None – direct drive	None – direct drive	None – direct drive
Wind zone	WZ 4 GK I	WZ 4 GK I	WZ II
Wind class	IEC IA	IEC IIA	IEC IIA
Low temperature operation (^{o}C)	-30	-30	-30

Logistics associated with the turbine options including the proposed E44 are presented in Table 32. There are significant increases in the volume of shipping materials with the discounted options, partly leading to the proposed solution of E44.

[21] Hub height options are the various tower heights that each model can be constructed at. More numbers mean there are more construction options.

Table 32: Shipping volume estimates for each concept option. This also includes the estimate for backloading the current wind turbines to New Zealand.

Component	**Shipping Volume (m^3)**				
	1 x E115	**2 x E115**	**2 x E82**	**4 x E44**	**3 x E44**
Wind turbine generator	2,891	5,782	3,196	1,424	1,065
Tower	1,298	2,596	2,154	1,608	1,206
Foundations – pads	156	312	208	270	202
Foundations – steel	600	1,200	800	1,040	780
BESS and frequency converter	385	385	385	385	385
Electrical auxiliary plant	380	380	380	380	380
Crane	792	792	756	612	612
Blade trailers	960	960	720	480	480
Sub total	6,117	11,062	7,494	6,199	5,110
+15% allowance	7,035	12,721	8,618	7,128	5,876

5. Description of the Environmental Reference State

5.1 Introduction

Article 3(2) (a) and (b) of the Protocol requires that activities in the Antarctic Treaty area shall be planned and conducted so as to limit adverse impacts on the Antarctic environment and dependent and associated ecosystems and to avoid:

- Adverse effects on climate or weather patterns;
- Significant adverse effects on air or water quality;
- Significant changes in the atmospheric, terrestrial (including aquatic), glacial or marine environments;
- Detrimental changes in the distribution, abundance or productivity of species or populations of species of fauna and flora;
- Further jeopardy to endangered or threatened species or populations of such species; or
- Degradation of, or substantial risk to, areas of biological, scientific, historical, aesthetic or wilderness significance.

The Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1, (2016)) specify that a thorough understanding of the pre-activity state of the environment is an essential basis for predicting and evaluating impacts, and for identifying relevant and effective mitigation measures. The guidelines also note that this pre-activity consideration should include the characterisation of all relevant physical, biological, chemical and anthropogenic values or resources in the area where the activity is proposed.

This chapter describes the existing environmental reference state for Pram Point, Crater Hill and the nearshore marine environment adjacent to Pram Point, before the commencement of the Scott Base Redevelopment. The information presented in this chapter is drawn from published scientific literature and the results of the Scott Base Redevelopment environmental monitoring programme (Chapter 9).

5.2 Climate

Climate observations are needed for characterising the local and global climate and state of the environment, identifying climate variations and changes, and in research on climate-sensitive processes and ecosystems. Climate observations (wind speed and direction, air temperature, global solar radiation, diffuse solar radiation and direct solar radiation) have been recorded daily at Scott Base since 1957. It is one of the longest continuous records in Antarctica. Wind speed and direction, air temperature, relative humidity and global solar radiation have also been recorded at Arrival Heights since 1999. There is no climate station on Crater Hill, but a wind monitoring tower was installed between 2005-2007 to collect 10-minute average data from wind speed and direction sensors at 10m and 20m height to support the RIWE feasibility study.

The lowest temperature ever recorded at Scott Base was -57˚C, in September 1968, with a mean average lowest temperature range between -14.5°C to -48.7°C from January to December (Table 33). The highest ever recorded temperature at Scott Base was 7.5˚C, in January 2002, with a mean average highest temperature range between 3.6°C to -11.3°C from January to December (Table 33). Average temperatures between January and December range between -4.7°C to -29.9°C with a mean annual temperature of -19.8˚C (Table 33).

The 2019 climate observations, when compared with the 1957-2018 average (Table 33) have the following features:

- The mean monthly temperature was consistently higher than the long-term average for almost every month, with mean temperatures particularly warmer than the long-term average during late winter;
- The extreme maximum temperatures did not show a lot of deviation from the long-term averages for much of the time, however July was markedly higher than the long-term average (9°C higher);
- Generally, 2019 extreme minimums were higher than the long-term averages, however there was some variability during the winter months;
- 2019 monthly averages were close to the long-term monthly averages; and
- Generally, monthly wind run totals were greater than the long-term average indicating that 2019 was a windy year. The exception was December which was lower than the long-term average.

The prevailing wind direction at Pram Point is from the northeast (Figure 68) and the mean wind speed is 17.9 km/hr. In general, the strongest winds and storm events typically come from a southerly direction and are the main cause of snow accumulation on Pram Point. On average, Hut Point Peninsula has between two and five days of precipitation (in the form of snow) each month.

For the period 1957 to 2019 the mean monthly solar radiation was 9.5 Mj/m^2, with the highest solar radiation levels occurring in December (30.1 Mj/m^2) and the lowest during periods of full darkness (May, June and July).

As a proxy for Crater Hill, climate observation at Arrival Heights shows a mean average lowest temperature range between -13.0°C to -40.8°C from January to December (Table 34). The mean average highest temperature range between 3.2°C to -12.6°C from January to December (Table 34). Average temperatures between January and December range between -4.7°C to -27.1°C with a mean annual temperature of -18.3˚C (Table 34).

The prevailing wind direction at Arrival Heights is from the northwest and east, with strong winds from the east (Figure 69). In general, the strongest winds come from an easterly direction. For the period 1999 to 2018 the mean monthly solar radiation was 9.6 Mj/m^2, with the highest solar radiation levels occurring in December (30.6 Mj/m^2) and the lowest during periods of full darkness (May, June and July).

Table 33: Scott Base climate observations between 1957-2019 (NIWA).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2019 mean temperature (°C)	-4.8	-9.8	-18.4	-23.6	-21.1	-26.4	-24.1	-25.8	-24.7	-20.4	-9.4	-3.6	-17.7
Average (1957 – 2018)	-4.7	-11.2	-20.4	-24.3	-26.1	-26.2	-29.0	-29.9	-27.6	-21.3	-11.5	-4.9	-19.8
2019 extreme maximum temperature (°C)	2.0	-1.9	-4.3	-7.1	-8.8	-6.2	-2.3	-10.7	-10.5	-9.3	1.0	2.9	-4.6
Average (1957 – 2018)	3.6	-0.6	-6.5	-8.2	-8.7	-9.7	-11.3	-11.2	-10.7	-7.1	-1.1	3.3	-5.7
2019 extreme minimum temperature (°C)	-15.7	-20.2	-33.3	-45.6	-37.1	-46.2	-42.4	-49.9	-40.0	-34.3	-22.9	-13.1	-33.4
Average (1957 – 2018)	-14.5	-24.5	-36.2	-41.8	-44.5	-44.0	-47.3	-48.7	-46.3	-38.3	-25.5	-15.0	-35.6
2019 mean solar radiation (MJ m^{-2})	27.1	13.8	4.6	1.0	0.0	0.0	0.0	0.6	3.2	12.4	24.1	30.1	
Average (1957 – 2017)	25.8	14.1	4.8	0.5	0.0	0.0	0.0	0.1	2.7	11.7	24.0	30.1	
2019 average daily wind run (km)	375.9	415.2	519.8	450.2	475.3	556.3	502.1	533.6	478.6	462.4	402.9	334.3	458.9
Average (1997[22] – 2018)	350.1	416.6	441.5	428.4	444.9	473.8	437.2	446.0	467.9	437.4	401.4	366.6	426.0

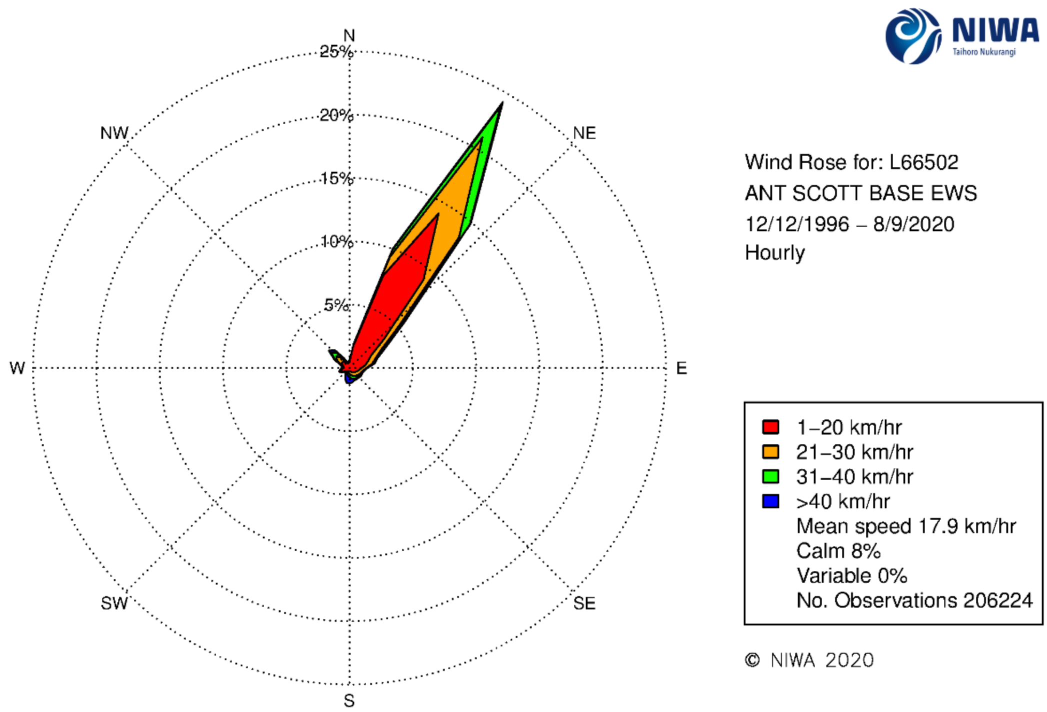


Figure 68: Predominant wind direction at Scott Base (data provided by NIWA).

[22] Wind run has only been calculated since 1997

Table 34: Arrival Heights climate observations between 1999-2019 (NIWA).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2019 mean temperature (°C)	-4.9	-9.8	-17.9	-21.8	-19.8	-25.3	-22.8	-24.7	-23.7	-19.3	-8.9	-3.8	-16.9
Average (1999 – 2018)	-4.7	-10.9	-19.0	-23.3	-23.6	-24.7	-27.1	-27.1	-24.6	-19.2	-10.7	-4.7	-18.3
2019 extreme maximum temperature (°C)	1.8	-2.0	-5.6	-8.6	-10.3	-7.7	-3.7	-11.9	-12.5	-9.6	-0.8	1.5	-5.8
Average (1999 – 2018)	2.7	-1.1	-6.9	-9.9	-9.1	-10.6	-12.6	-12.4	-10.9	-8.2	-1.1	3.2	-6.4
2019 extreme minimum temperature (°C)	-14.8	-20.4	-29.4	-36.4	-37.6	-42.2	-38.2	-43.6	-37.4	-29.7	-20.8	-10.6	-30.1
Average (1999 – 2018)	-13.0	-21.7	-31.2	-35.1	-36.7	-37.8	-40.8	-40.2	-38.7	-32.2	-23.1	-13.1	-30.3
2019 mean solar radiation (MJ m^{-2})	25.7	12.7	4.2	0.6	0.0	0.0	0.0	0.1	2.8	11.6	23.5	28.8	
Average (1999 – 2018)	25.9	14.6	5.0	0.5	0.0	0.0	0.0	0.1	3.0	11.8	24.2	30.6	
2019 average daily wind run (km)	602.1	726.5	871.6	683.8	778.1	785.1	699.9	749.5	675.6	676.6	655.3	484.4	699.0
Average (1999 – 2018)	542.0	685.0	668.9	604.4	640.9	702.3	659.6	659.1	687.9	663.3	632.4	540.7	640.5

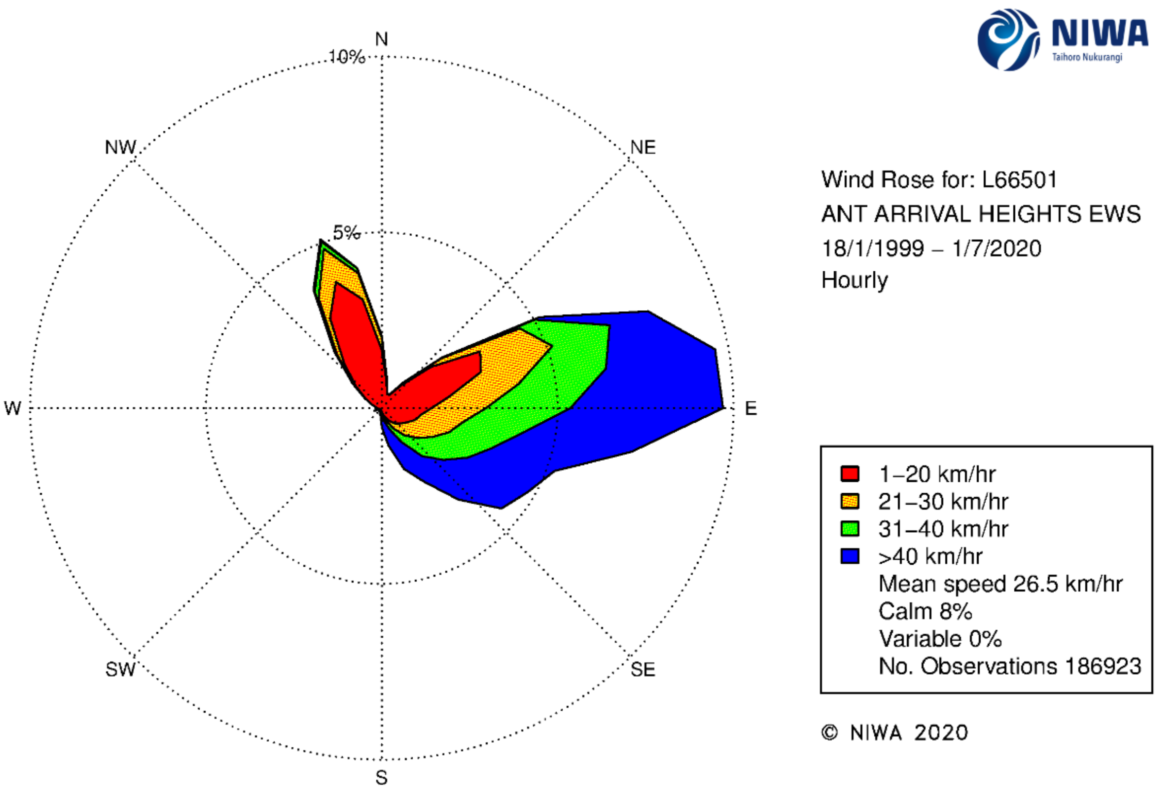


Figure 69: Predominant wind direction at Arrival Heights (data provided by NIWA).

The wind monitoring tower that was installed on Crater Hill between 2005 and 2007 was correlated with long-term data from the Arrival Heights climate station. It found that the mean wind speeds at Crater Hill are between 18 and 36 km/h, with a maximum recorded as 126 km/h. The prevailing wind is from the northeast (Figure 70).

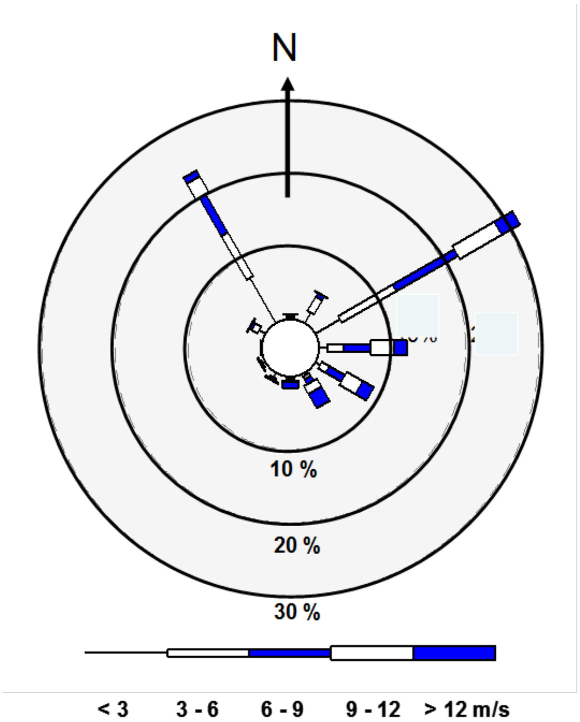


Figure 70: Predominant wind direction at Crater Hill (New Zealand, 2008)

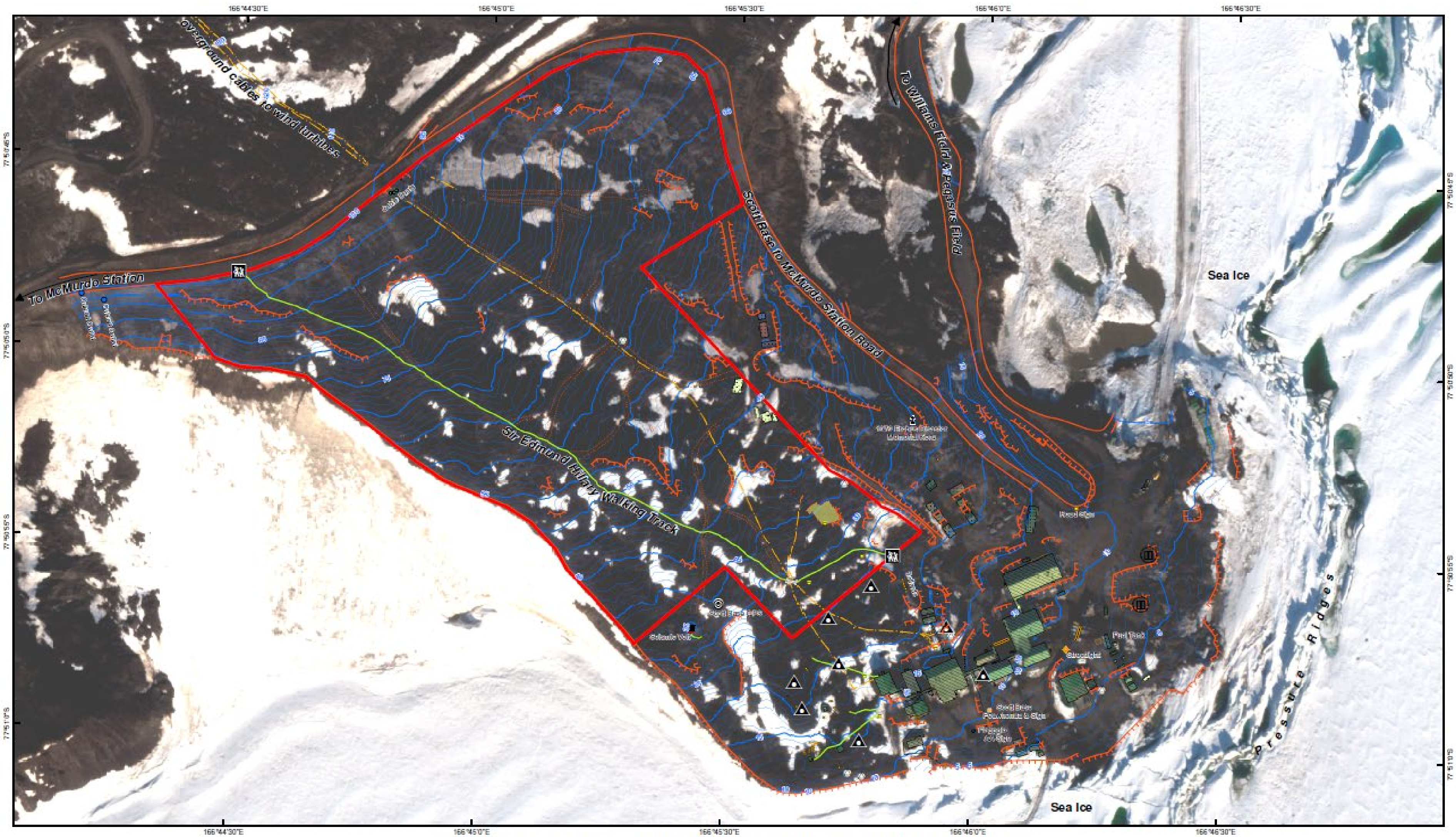
5.3 Terrestrial environment of Pram Point and Crater Hill

5.3.1 Topography

Pram Point is on the southern tip of Hut Point Peninsula on Ross Island. The overall topography of Pram Point slopes gently southwards towards the sea (Figure 71). The wind farm is located on Crater Hill, also on Hut Point Peninsula and situated above Pram Point (Figure 4). Crater Hill is approximately 1.1km from Scott Base, at an elevation of approximately 190m.

Pram Point and Crater Hill are representative of an ice-free environment that has been the receptor of significant and ongoing human impacts for more than 60 years. A site survey, completed in 2014 to map human impacts (Figure 72), found extensive evidence of ground disturbance and historical waste across the site (see Section 5.3.2.4). Figure 73 shows Crater Hill both before (2009) and after the installation of the wind farm (2010) and demonstrates the significant ground disturbance due to installation of various infrastructure.

Ice-free ground in Antarctica is rare and is estimated to represent only 0.44% (54,274 km^2) of the continent (Brooks, et al., 2019). Ice-free ground also hosts a disproportionate concentration of biodiversity, scientific value, and human activity, with 76% of all buildings found on ice-free ground within 5km of the shore (Brooks, et al., 2019). The ice-free areas of Ross Island are classified as Environment S – McMurdo-South Victoria Land geologic under the Environmental Domains Analysis of Antarctica (Resolution 3 (2008) (Morgan, et al., 2007) and Antarctic Conservation Biogeographic Region Region 9, South Victoria Land (Resolution 6 (2012) (Terauds & Lee, 2016) (Figure 74).



Scott Base Ecological Survey - Topographical Features

Map Information:
Draft Version 1.0 - 9 August 2014.
Horizontal Datum: WGS84, UTM Zone 58 Projection.
Vertical Datum: Mean Sea Level.
Survey Reference Mark: SCOTT BASE GPS (LINZ) - 166° 45' 28.8540" E; 77° 50' 56.3457" S; 35.23 m above MSL.
Units: Metres.

Data Sources:
Topographical Data: Acquired by survey performed by Land Information New Zealand January 2013.
Base Image: DigitalGlobe WorldView-2 Satellite - acquisition October 2011.

Ecological Survey Extent
Building
Storage Containers
Open Storage Area
Helicopter Pad
Antenna Mast & Guy Wires
Survey Mark
Survey Drum
Posts & Poles
Over Ground Cables
Hitching Rail
Science Experiment Site
Top of Bank
Edge of Formed Road
Historic Track
Walking Track
Contour ~ 5-metre interval
Contour ~ 1-metre interval

N

0 25 50 100
metres

Figure 71: Topography of Pram Point.

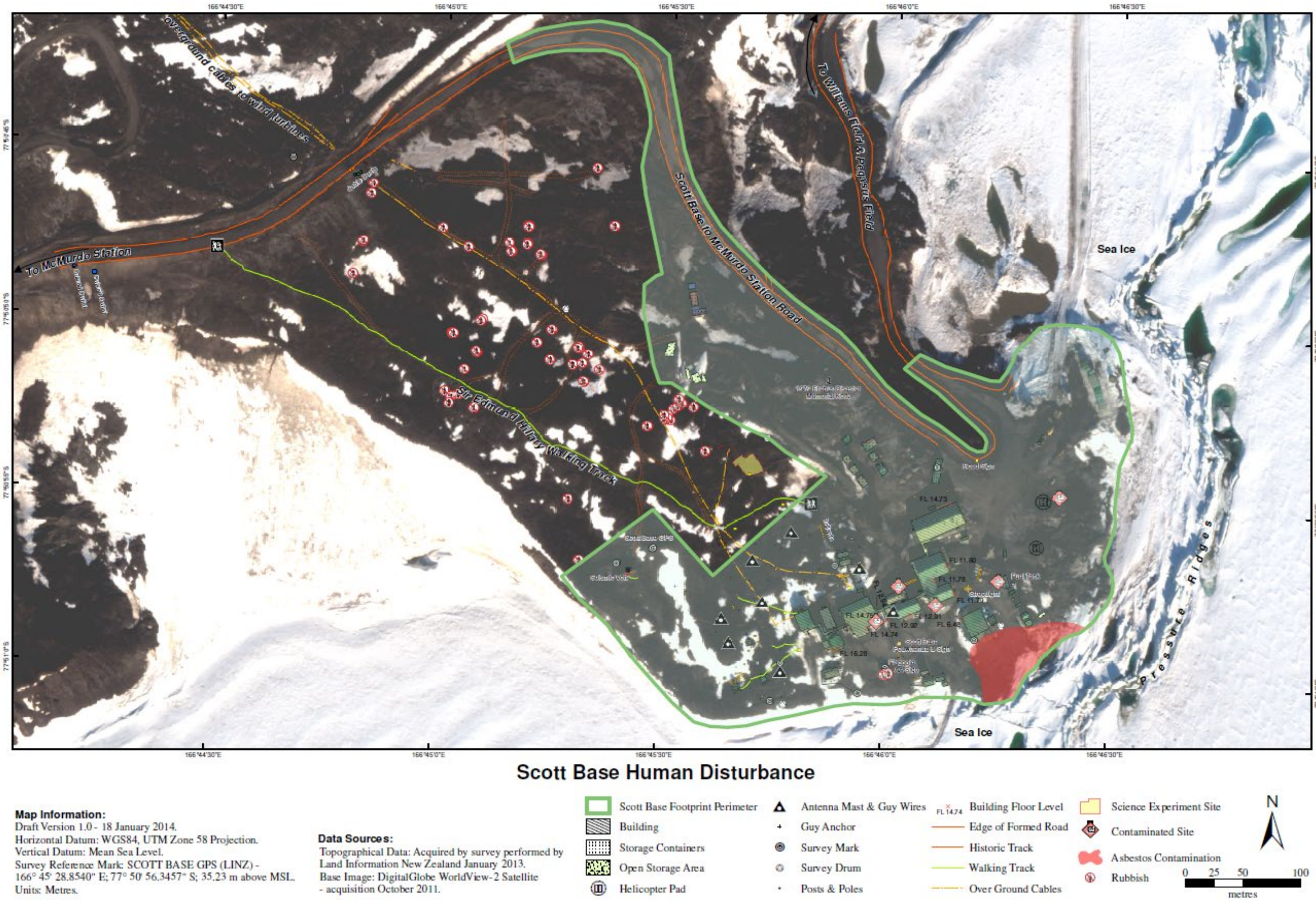


Figure 72: Visible human impacts of Pram Point from a 2014 survey[23].

[23] The extent of asbestos contamination has been updated since the survey was conducted (2014).

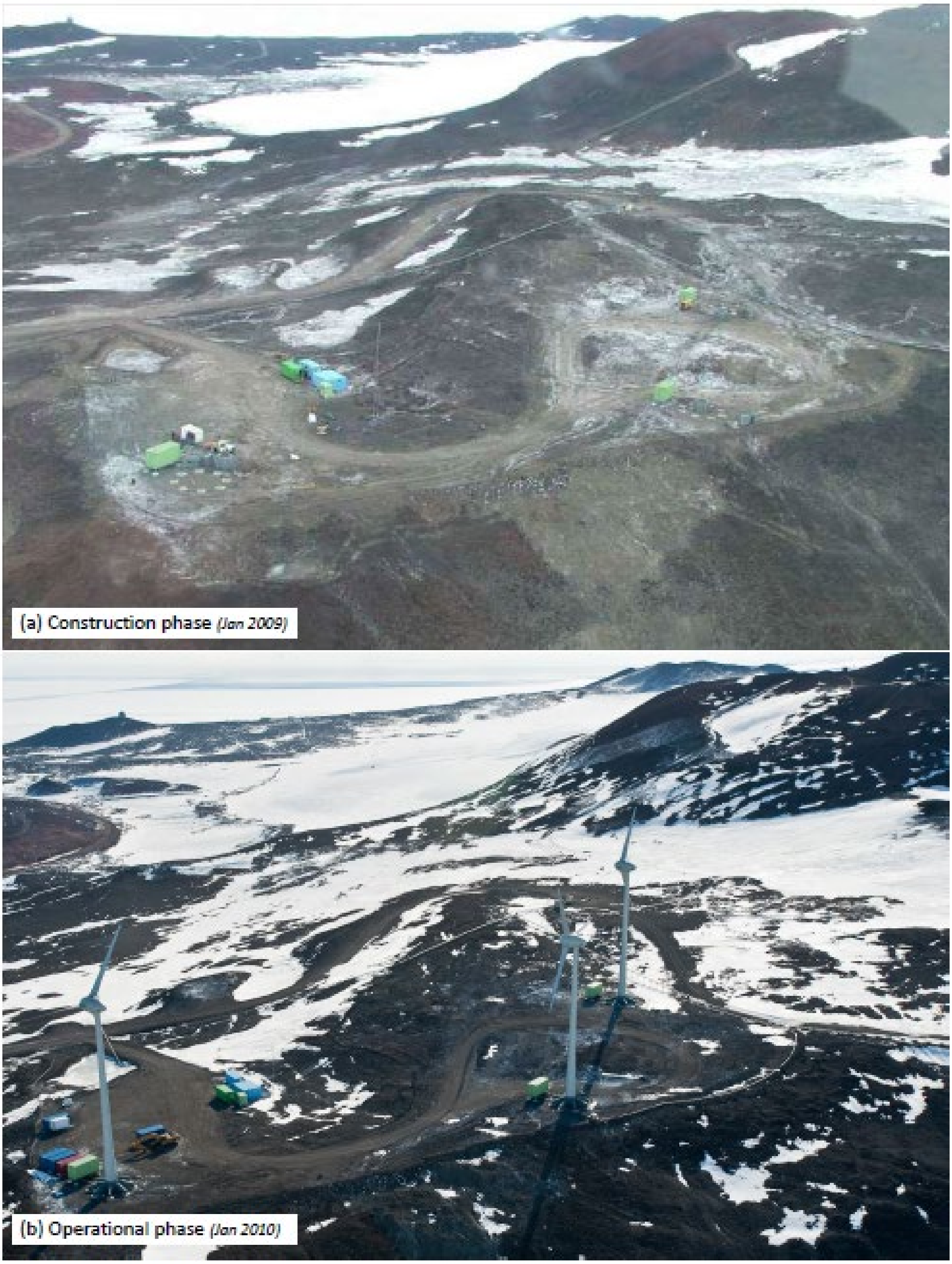


Figure 73: Aerial photo of the Crater Hill wind turbine site (New Zealand, 2008).

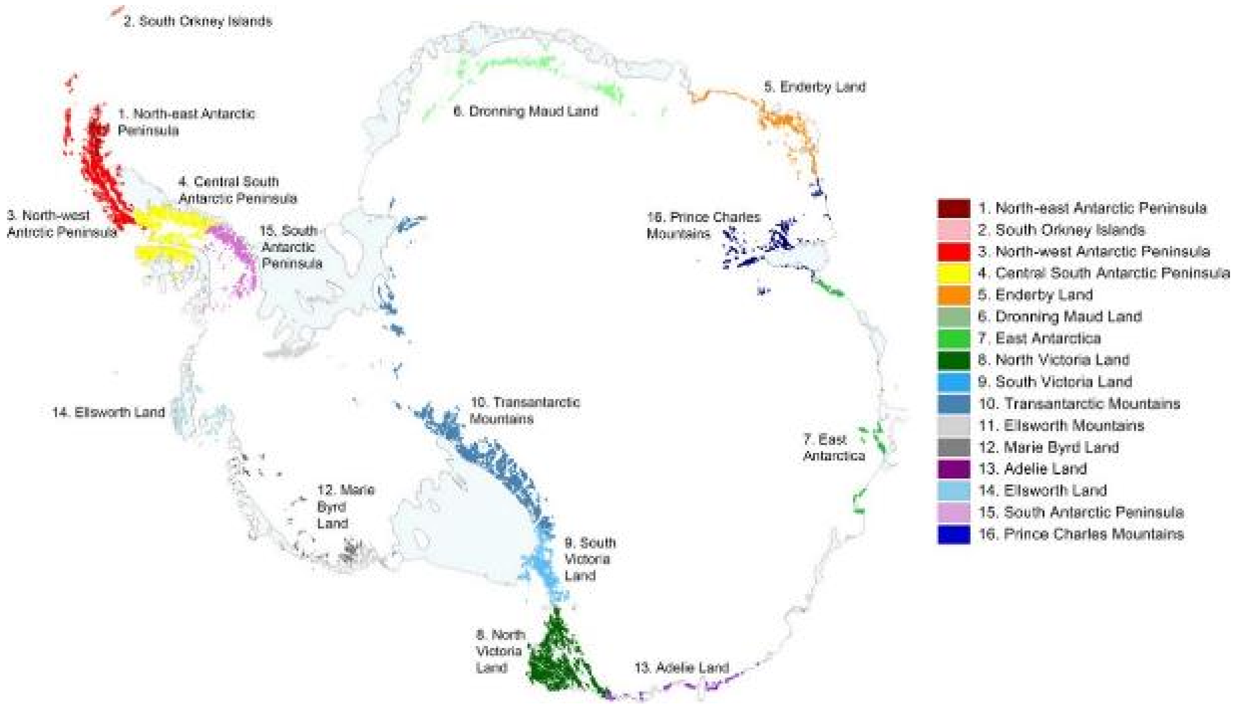


Figure 74: Antarctic Conservation Biogeographic Regions (Terauds and Lee, 2016).

5.3.2 Soils

Soils of Pram Point are formed from the gently undulating scoriaceous basaltic lava flows of the McMurdo Volcanics Formation (Kyle, et al., 1990), which have been considerably fractured by freeze-thaw processes (Sheppard, et al., 2000). The soils comprise a seasonally thawed active layer of soil material over permafrost. Chemical weathering is restricted due to cold temperatures and lack of liquid moisture. Soils are generally shallow, loose and the soil texture ranges from coarse sand to boulder gravelly sand. Armoured desert pavements exist in undisturbed areas, while elsewhere clasts have been overturned exposing the salts beneath. Sand-wedge polygons were a feature of the area but have been diminished by vehicle traffic and earthworks in areas routinely used by Antarctic operations.

Crater Hill is an extinct volcanic crater. The soils are mostly cold desert soils and have no topsoil, or accumulation of organic matter. Till deposits have not been identified, however, patterned ground movement has reworked the surface (Campbell, et al., 1994). Soils are loosely compacted consisting of a pebbly boulder surface containing variable amounts of fine particles. The Crater Hill geology sequence consists of olivine-augite basanitoid. These lavas show a moderate amount of erosion and are overlain by phonolite lavas of the Observation Hill sequence (Kyle & Treves, 1974). It is thought that some of the surface area around the wind turbine site may still be covered by sand-wedge polygons, which are ubiquitous periglacial features (Klein, et al., 2012).

5.3.2.1 Active layer and permafrost

For much of the year, Pram Point soils are at temperatures below 0°C. However, over the summer months (December – January) with 24-hour sunshine, the soils are warmed at the surface. The black basalt surface soil absorbs radiant energy and soil surface temperatures often become higher (sometimes >15°C) than the ambient air temperatures which generally remain near or below 0°C (Balks & O'Neill, 2016). Heat is conducted downwards thawing the near-surface soil and the depth to which soils thaw each summer is referred to as the active layer. Beneath the active layer is permafrost, defined as having a temperature of less than 0°C for at least two consecutive years (Grosse, et al., 2011). Ice-cemented permafrost at Pram Point typically lies around 45cm below the surface and may contain 10 to 60% moisture as ice (Sheppard, et al., 2000). Soil surfaces can dry to as little as 2% moisture over summer, but can also become saturated during summer melt periods (Sheppard, et al., 2000).

Baseline surveys recorded that depth to ice-cement ranged from 5cm to 36cm across Pram Point. In moist environments, a significantly greater active layer depth was recorded. This was expected as the thermal conductivity of moist soil is greater than dry soil (Ikard, et al., 2009; Gooseff, et al., 2013). All soil monitoring sites have a similar low albedo due to the black basaltic parent material absorbing heat, so their active layer depth would be comparable in this regard (Balks, et al., 2002). The shallowest active layer depths occur in highly disturbed and often recently disturbed sites and the active layer depths tended to increase the further uphill and away from Scott Base. Some of the deepest active layers are found at the highest elevations close to the Scott Base to McMurdo Station road where less human impact and disturbance has occurred.

Permafrost depth at Crater Hill is understood to generally occur at 4.5cm (Waterhouse, 1996).

5.3.2.2 Soil moisture and meltwater

Soil water controls plant growth and influences a variety of soil processes, including erosion, chemical exchange, microbial activity (presence, abundance and diversity of terrestrial biota), transport of solutes and water and pedogenesis (Seybold, et al., 2010). Hut Point Peninsula does receive some precipitation in the form of snow, and subsequently moisture from melting snow. Down-slope flow provides limited moisture to soil (Sheppard, et al., 2000; Balks & O'Neill, 2016). Seybold et al. (2010) showed over a 10-year monitoring period at a Scott Base soil climate station site, there was generally about one to four wetting events per summer season that extended to at least 20cm in depth. The site does receive subsurface flow of water from upslope (snow melt) along the ice-cemented permafrost. Past excavation work has revealed evidence of sub-surface channels. These meltwater flows are a mode of dispersal for soil contaminants. Vehicle and helicopter operations increase dust mobilisation, which causes greater thaw of snow surfaces leading to excess water flows, stream channelling and sediment discharges (Campbell & Balks, 2001).

The soil moistening effect tends to be brief as it takes about two weeks for the near-surface (0-10cm depth) soil to dry again. Because of the low humidity, a large portion of the snow is lost directly to the atmosphere by sublimation and thus the water is never available to the soil. There are areas of Pram Point where run-off from snow melt occurs for a large portion of the summer months. Here the soil will be saturated and ephemeral streams form. The water conducts heat into the soil and can harbour high levels of vegetation and biodiversity.

Using a remotely piloted aircraft across Pram Point, a catchment model was run to identify areas of water accumulation and run-off (see Chapter 7). The model identified seven possible catchment areas for Pram Point (Figure 75).

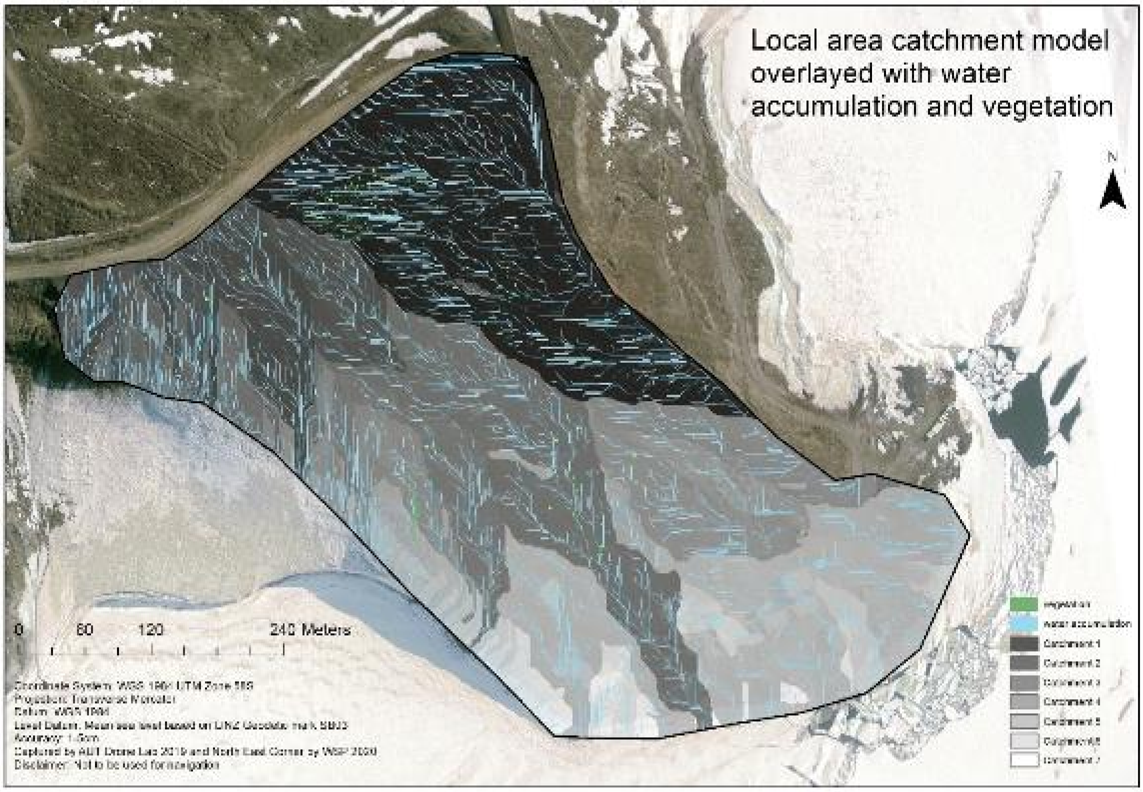


Figure 75: Local area catchment model overlaid with water accumulation and vegetation.

Meltwater samples were taken from three sites in the vicinity of Scott Base:

1. Near the HFC cold porch from a melt pond;
2. North-west corner near the TAE Hut from running water; and
3. Near the Front Transition (FT) from running water which had lots of fine sediment.

Samples were analysed in New Zealand for a range of contaminants and compared to the Australian New Zealand Guidelines for Fresh and Marine Water Quality protection guideline for 99% of species in both freshwater and marine environments (ANZECC & ARMCANZ, 2000) (Table 35).

pH levels were relatively neutral and ranged from 6.6 to 7.7. Electrical conductivities ranged from 384μS/cm to 1,930μS/cm and largely reflected distance to coast and salt influence. Alkalinity ranged from 60 to 90mg/L and suspended solids ranged from 73 to 256mg/L. Total solids ranged from 507 to 1192mg/L. Suspended and total solids are physical stressors for marine species, however, no appropriate guideline exists (ANZECC & ARMCANZ, 2000).

Total recoverable arsenic, chromium, copper, lead, and zinc generally exceeded the freshwater and marine standards for the protection of 99% of species in pristine environments. This is similar to previous measurements by Sheppard et al. (1997) which showed high concentrations of metals including silver (attributed to historical dumping of photographic solutions), cadmium, chromium, copper, zinc and lead (all associated with drains, leaded petrol, building materials) and mercury (historical drains), in the vicinity of Scott Base. Sheppard et al. (1997) attributed high metals in Scott Base meltwater to the low absorbance capacities of soils and thus concluded that metals were highly mobile if water was passed through contaminated soils. Metals can also be deposited as particulate matter from the atmosphere (e.g. lead and zinc from long-range or local sources), or via natural processes such as weathering of the rock material from which soil is formed. At disturbed sites such as those found at Scott Base, there is a likely relationship with proximity to road, buildings, and high vehicle-use areas.

Table 35: Total recoverable concentration of trace metals, hardness, pH, total solids, suspended solids and electrical conductivity of Scott Base meltwaters (in **µg** /L unless specified)[24].

Meltwater contaminants	Scott Base sampling sites			MAV	
	HFC	TAE	FT	ANZECC (2000) freshwater quality standard	ANZECC (2000) marine water quality standard
	(µg/L)			(µg/L)	
pH	7.7	6.6	7.0	-	-
EC (µS/cm)	852	384	1,930	-	-
Antimony	<LOD	0.12	0.22	-	-
Arsenic	1.4	2.6	3.2	0.01	50
Cadmium	0.041	0.29	0.044	0.06	0.7
Chromium	3.5	4.9	2.3	0.01	0.14
Copper	7.8	19	7.2	1	0.3
Lead	2.1	10.3	2.2	1	2.2
Mercury	<LOD	<LOD	<LOD	0.06	0.1
Nickel	6.3	8.4	3.5	8	7
Silver	-	-	-	0.02	0.8
Zinc	23	104	12	2.4	7
Alkalinity ($CaCO_3$)	90×10^3	73.3×10^3	60×10^3	-	-
Total solids (mg/L)	699	507	1,192	-	-
Suspended solids (mg/L)	79	256	73	-	-

5.3.2.3 Soil chemical analysis

Like other dry environments, salts accumulate where evaporation exceeds precipitation. At Pram Point they occur as encrustations on rocks, as efflorescence on the soil surface, or precipitate as calcite on the underside of stones (Claridge, 1965; McCraw, 1967; O'Neill, et al., 2012). Because of the low clay and low organic matter contents, the soils have a low pH buffering capacity and therefore the salts that accumulate have a strong effect on soil pH. Consequently, salinity is highest at the surface and soils are alkaline and range from about pH 8 to 10 (Campbell & Claridge, 1987; Campbell, et al., 1998; O'Neill, 2013).

Soil pH and electrical conductivity (EC), a measure of salt content, were measured at two depths across Pram Point. In samples taken from the top 0-2cm, pH ranged from 8.22 to 10.14 and at 2-5cm depth, from 8.56 to 9.96. EC varied across Pram Point, but was always highest in the top 2cm, ranging from 135.5 to 5,400.0 µS/cm in the 0-2cm samples, and 36.0 to 5,180.3 µS/cm in the 2-5cm depth soil samples (Table 36). EC tends to be higher in the more disturbed sites and closer to the road.

[24] HFC = HFC/Cold porch pond site, TAE = TAE meltwater stream, FT = Front transition meltwater stream. Guideline values presented are for the protection of 99% of species in a pristine environment (ANZECC & ARMCANZ, 2000).

Table 36: Soil pH and electrical conductivity measurements at two depths at each monitoring site.

Monitoring Site no.	Soil sample 0-2 cm		Soil sample 2-5 cm	
	EC (µS/cm)	pH	EC (µS/cm)	pH
SM01	3,020.5	9.06	702.0	9.46
SM02	786.5	10.05	163.3	9.80
SM03	5,400.0	9.08	5,180.3	8.79
SM04	457.0	9.27	120.1	9.15
SM05	312.0	10.14	122.4	9.22
SM06	3,550.0	8.22	1,209.5	8.56
SM07	201.9	9.14	52.5	9.22
SM08	1,268.5	9.29	628.5	9.96
SM09	210.3	9.67	117.8	9.63
SM10	542.5	9.46	227.8	9.83
SM11	204.3	9.24	36.0	8.73
SM12	947.5	9.04	218.6	9.73
SM13	285.0	9.76	93.5	9.71
SM14	1,208.5	9.16	208.3	9.85
SM15	152.0	9.64	114.3	9.38
SM16	234.1	9.72	89.7	9.44
SM17	135.5	9.24	60.7	9.01
SM18	2,489.5	8.51	215.4	9.15
SM19	255.2	9.73	222.7	9.54
SM20	678.0	8.67	137.5	9.03
SM21	675.5	9.66	158.4	9.81
SM22	1,657.5	9.53	200.3	9.48
SM23	206.4	9.78	230.5	9.49
SM24	255.3	9.38	185.5	9.19
SM25	238.6	9.42	43.0	9.11

5.3.2.4 Ground disturbance

Pram Point has been the site of New Zealand's Antarctic station since the 1950s and has been extensively and permanently impacted by operations. Repeated scraping and earthworks have resulted in soil surface disturbances, permafrost retreat, land subsidence, and salinisation (Campbell, et al., 1998). These disturbances have spread dust widely over snow-covered surfaces, causing changes in albedo, and in turn, have caused snowfield retreat and accelerated water and sediment runoff (e.g. land between Pram Point and Observation Hill).

Over 60 years of human activity at Scott Base has caused significant reductions in snow, moss, and lichen cover, along with soil slumping and melting of permafrost caused by earthworks (Sheppard, et al., 2000). Physical disturbance changes the biology, physical features, thermal conditions, moisture, and salinity of soil (Waterhouse, 2001). Salts are observed to form on soils where surface removal has led to the thawing of lower soil layers (and depending on the severity of the disturbance, potentially down to the underlying permafrost) and to the mobilisation of the salts contained in them (Sheppard, et al., 2000). In addition to salts, naturally occurring metals such as iron, aluminium, nickel, chromium and manganese are thought to be released during earthworks due to a combination of mechanical action and melting of permafrost, which mobilise the metal particles in alkaline solutions. Dust created by station operations settles on snow and ice surfaces and increases melt, which further exacerbates the mobilisation of salts, metals and contaminants.

The immediate vicinity of the Scott Base buildings is highly impacted, with regular vehicle movements and minor earthworks in the operational area such as snow clearing (Figure 72). Nonetheless, much of Pram Point remains free of measurable compaction or earthworks, particularly the area north of the buildings (Figure 76). While historical tractor tracks are still visible on the slopes above the station, the corridors currently used to move between the Scott Base buildings and the long-term storage areas, to the north-east, show the greatest amounts of disturbance (Figure 76). The areas of disturbance match the extent of the current operational area, introduced in Section 1.5.3.

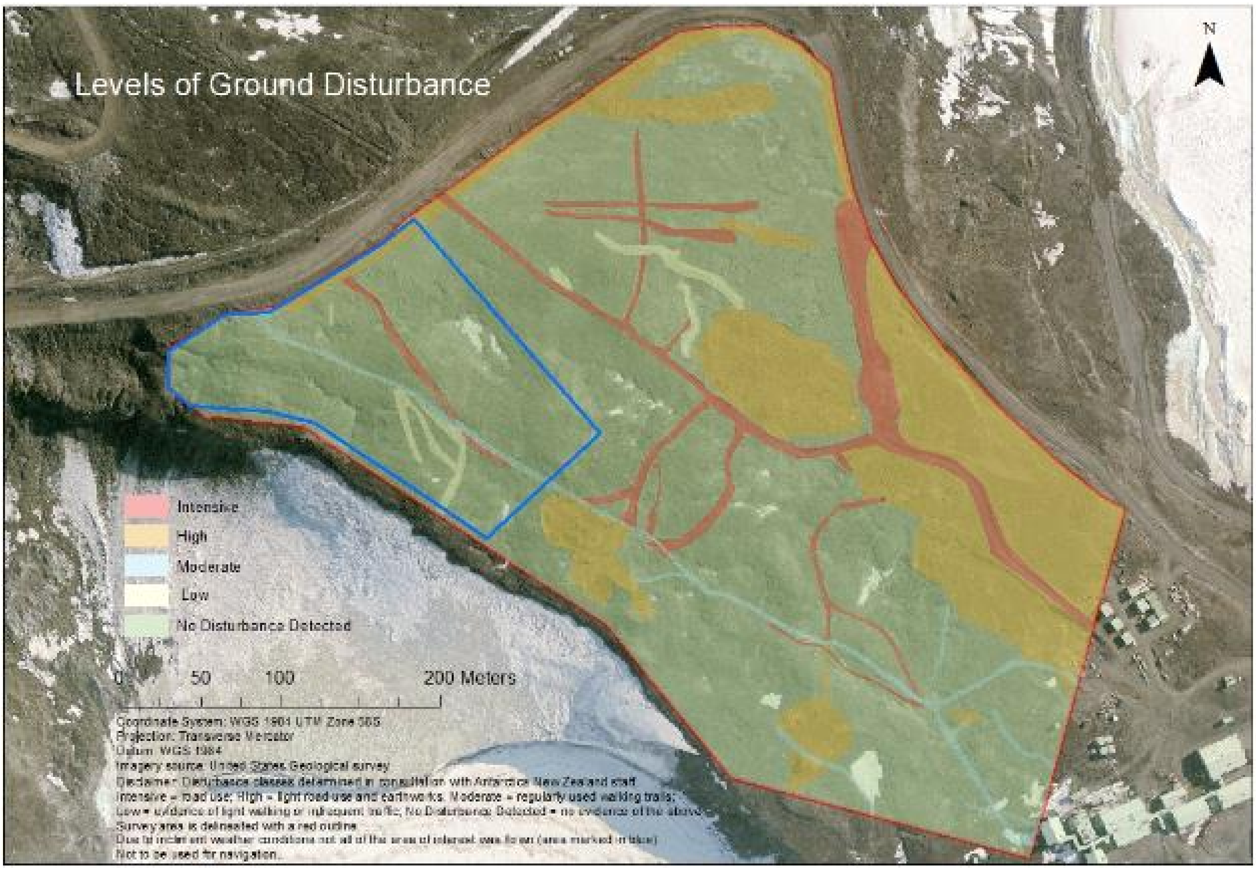


Figure 76: Levels of ground disturbance in the Scott Base area.

In the 2018/19 season, a Visual Site Assessment method (VSA) (Campbell, et al., 1993) was used to assess the present-day visual impacts across Pram Point. The VSA method is a rapid visual evaluation of terrestrial impacts and rates the extent of surface disturbance against impact assessment criteria, such as extent of disturbed surface stones, evidence of boot imprints, and evidence of foreign objects, as a means of comparing disturbance severity across different sites (see Chapter 8). Several sites were found to have evidence of low to moderate disturbance. Several sites showed elevated levels of disturbance and included those located within the operational area, close to walking trails or the power cable connecting the wind farm to Scott Base.

Crater Hill has also been impacted for 60 years by both historical and current vehicle traffic and earthworks associated with infrastructure supporting McMurdo Station and Scott Base operations (Figure 73) including radio transmitters and repeater stations and more recently the wind farm. Access to the site has been via at least three different paths and the remains of the abandoned roadways are still visible today. Vehicle tracks and evidence of surface scraping to collect fine material for roading and construction are clearly visible. Studies in the early 1990s undertaken by United States researchers characterised the area of Crater Hill as showing evidence of disturbance (Kennicutt, et al., 1998), which was further impacted by the construction of the current wind farm at Crater Hill (New Zealand, 2008).

5.3.2.5 Soil contamination

A continuous human presence since the 1950s is responsible for the introduction of a wide range of organic and inorganic wastes, fuel spills, rubbish and debris, which have all impacted the base surrounds to some extent, including areas where hotspots of total petroleum hydrocarbons (TPH) and asbestos are found, heavy metals and other changes in the chemical and organic content of soils. Emissions to air from generator operation and incineration (from the 1970s to 1990s) have also been deposited on soils (Sheppard, et al., 2000).

Past studies found measurable silver, arsenic, cadmium, copper, lead and zinc contamination around Scott Base, particularly where materials have historically been dumped or stored. Contaminants are also found in surface waters overlying the soil contamination (Sheppard, et al., 2000) and are transported downhill of the site of contamination by surface waters. However, analysis of Scott Base soils for heavy metals in 2018 found very low concentrations across the station area, including those containing historical demolition debris. The concentrations of metals are thought to be typical of background levels and all results were below relevant standards for human health and water pollution.

Wood fragments and other materials remain in soils under the footprint of now-demolished buildings and old waste dumping sites along the foreshore. Old demolition works also released asbestos fibres into the environment and these have been further dispersed by snow-clearing activity and wind. Asbestos is harmful to humans if inhaled, but otherwise has no known ecological consequences. Lead-based paint on wood fragments could have ecological impacts. However, the 2018 survey did not show elevated levels of lead in soil samples, even from areas containing debris.

Antarctica New Zealand's EMS monitoring records show that at least 4,000 litres of mostly hydrocarbon products have been spilt or leaked in the last 20 years. The records estimate that almost 3,000 litres have been recovered via sorbent materials and removal of contaminated snow and soil. The most significant spill events were associated with bulk fuel storage facilities and underground fuel lines (Figure 77). Analysis in 2018 detected hydrocarbons in the majority of soil samples from these known areas, ranging from 59mg/kg to 5,935mg/kg TPH (PDP, 2018). The highest results were for AN8 spills associated with an old 9,500L fuel tank, while low levels of heavier oils were found around old workshop areas. The highest levels were below New Zealand soil acceptance criteria for the protection of nearby water bodies (Ministry for the Environment, 2011). The standard was identified as relevant due to the potential for ecological impacts of meltwater flowing into McMurdo Sound.

Behind Scott Base, TPH concentrations in surface soils (0-2cm) and at depth (2-10cm) were measured at each of the soil monitoring sites during the 2018/19 season. The results found that the area between Scott Base and the road is generally less contaminated than the Scott Base operational area, with just a few locations showing contamination (Figure 78).

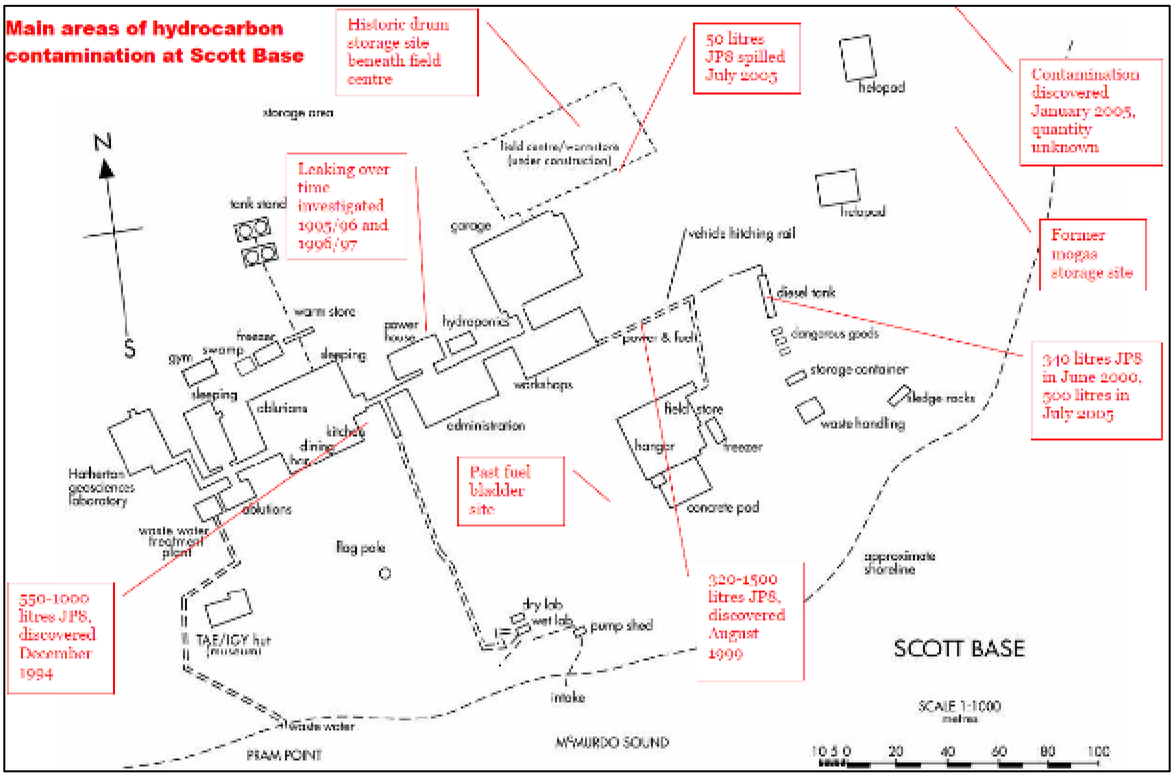


Figure 77: Known past contamination events within the Scott Base operational area.

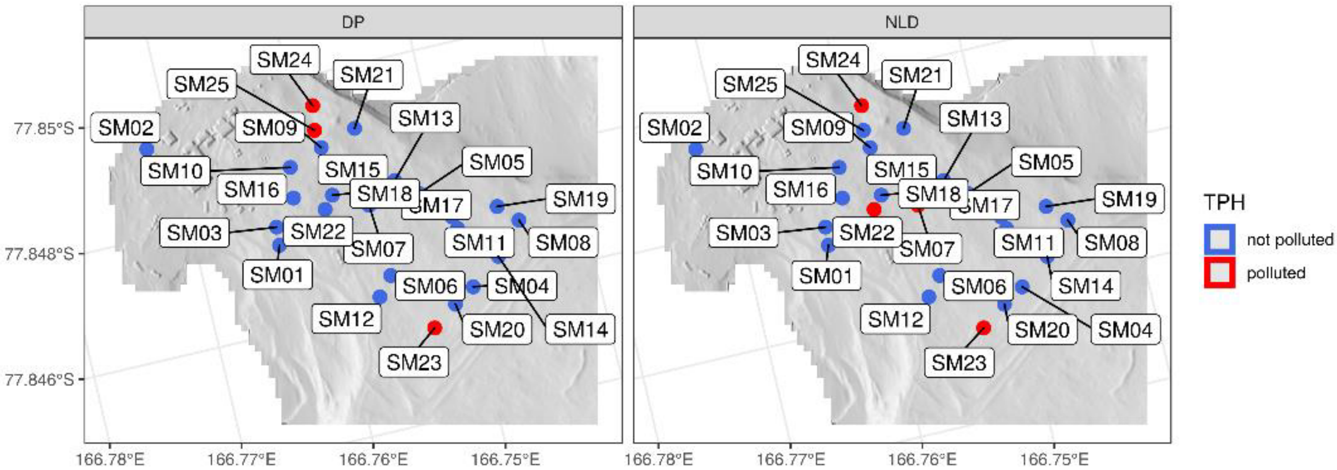


Figure 78: Estimated TPH contamination in surface soils (0-2cm) and soils at depth (2-10cm) at each of the soil monitoring sites above Scott Base.

Soil contamination investigations at Crater Hill were conducted as part of the United States' McMurdo Station Long Term Monitoring Programme. TPH concentration from some samples collected at Crater Hill, on the road and at the turbine site was above 30ppm, particularly the east-facing slope leading down from the turbine site toward Scott Base (Klein, et al., 2012). These are thought to indicate isolated patches of elevated TPH. Small areas of the turbine site on Crater Hill were found to have elevated lead as well as cadmium, mercury and zinc which appear to be associated with small historical landfills. Small landfills are indeed visible in aerial photographs through the early 2000s and when examined were found to contain a variety of materials including cans, batteries, insulators and other metal debris (Klein, et al., n.d.).

5.3.3 Emissions to air

The primary source of airborne pollution at Pram Point is exhaust gases from vehicles and generators run on AN8. AN8 combustion emits fine particulates, carbon monoxide, carbon dioxide, nitric oxides, sulphur dioxide, and hydrocarbons. Between 2008/09 and 2015/16, the total fuel use at Scott Base, which includes fuel used in the field away from Scott Base, produced on average 756.33 tonnes of carbon dioxide equivalent (tCO_2e) per annum. Little air quality work has been done at Scott Base.

Air quality at Pram Point is affected by natural as well as human sources. The active volcano Mount Erebus is the largest source of many chemicals, which affect air quality including sulphur dioxide, particulates, heavy metals, fluoride, hydrogen sulphide and nitrous oxides (Fisher, 2001). It is estimated that 1,000 times more sulphur dioxide comes from Mount Erebus than from Scott Base and McMurdo Station combined and airflows pass from Mount Erebus directly over Hut Point Peninsula (Godfrey & Clarkson, 1998).

Ambient air monitoring has identified an anthropogenic increase in the toxic metal composition of suspended particles (Kennicutt, et al., 1998). Comparison of contaminant levels in Pram Point soils with background levels suggests accumulation, with arsenic attributed to generator emissions and lead to vehicle exhausts (Sheppard, et al., 2000). These penetrate the soil and are further dispersed by freeze-thaw, water flow, and wind. However, the impact of emissions from stations is considered to be highly localised and to have “extremely minor” effects on air quality (Fisher, 2001).

5.3.4 Terrestrial flora and microfauna

5.3.4.1 Vegetation diversity and abundance

Pram Point has had extensive disturbance through the mechanical action of the ground from vehicles and construction activities. Nevertheless, moss, lichen and algae are found around Scott Base and the wider Pram Point area. In 2014, a ground-based survey undertaken by Antarctica New Zealand identified that vegetation was present across the area between the Scott Base operational area and the Scott Base to McMurdo road (Figure 79). This area is thought to contain the most extensive vegetation on Hut Point Peninsula and to be very easily disturbed (Roman Türk Personal Comments, 2009). As a result, an operational area was defined (Figure 80) and local management controls were established outside this area to minimise impacts on areas of known vegetation cover.

A more detailed investigation of the flora and microfauna undertaken in the 2018/19 and 2019/20 seasons, found vegetation absent within the operational area (SM01, SM02 and SM03 in Figure 81) with lichen relatively common across most of Pram Point. The most common lichen observed were *Caloplaca* sp. which are an orange/yellow colour and often appeared as small flecks on the surface of rocks. Other lichen species found on rocks include *Lecidea sp*. and *Rhizoplaca melanophthalmo*, and those found on moss include *Caloplaca citrina, Lecanora expectans* and *Caloplaca sp.* Lichen more frequently occur in drier areas, particularly *Caloplaca sp*. (Figure 82).

Mosses were relatively common across most of Pram Point, although they were frequently observed to be inactive (i.e. brown, suggesting a lack of photosynthesis). They were most abundant in drainage cracks and under snow packs. Mosses were absent from the highly impacted sites in the operational area, which were physically disturbed and exposed to high levels of dust from the road (which can suffocate mosses). However, mosses were also observed inhabiting old tractor paths, indicating an ability to recover over time (Beet & Lee, 2020).

Overall there was a complete lack of hypoliths and cryptoendoliths, likely due to the predominant scoria substrate, with hypoliths more often found on the underside of quartz rocks (Cary, et al., 2010). *Cyanobacteria*l/algal mats were frequently observed (Figure 81 and Figure 82), although they were often in a desiccated inactive state except for those present at one site which had running water present. Moss and lichen were not identified at the control site, Cape Evans, where only algae were found (Figure 81).

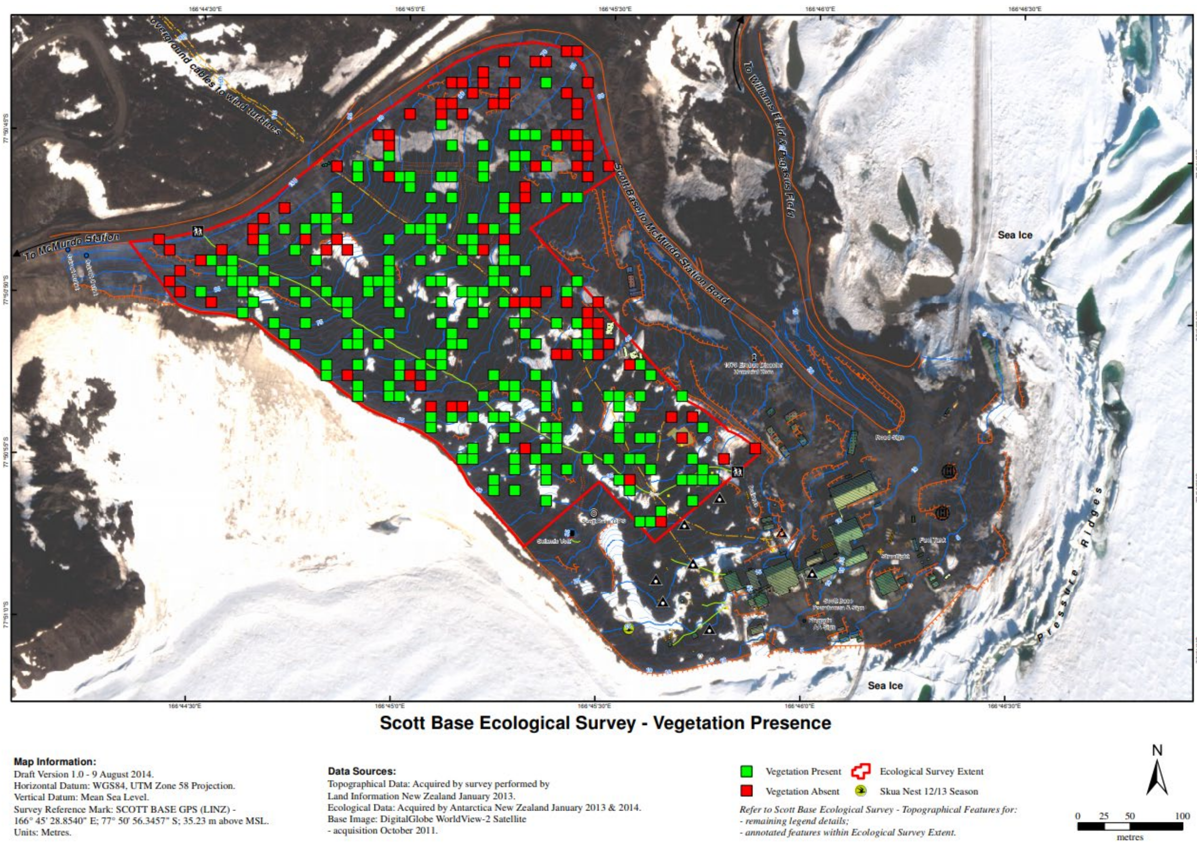


Figure 79: Vegetation presence at Scott Base, 2014.

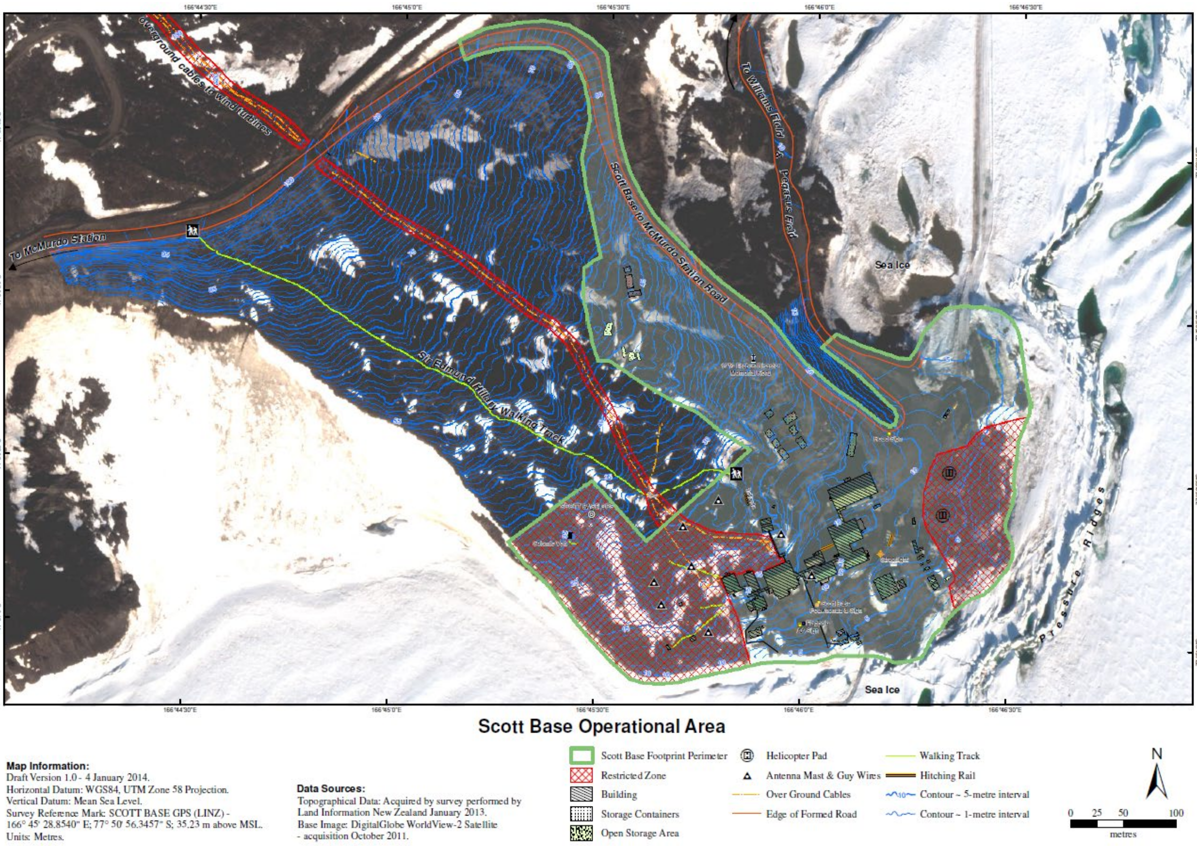


Figure 80: The Scott Base operational area.

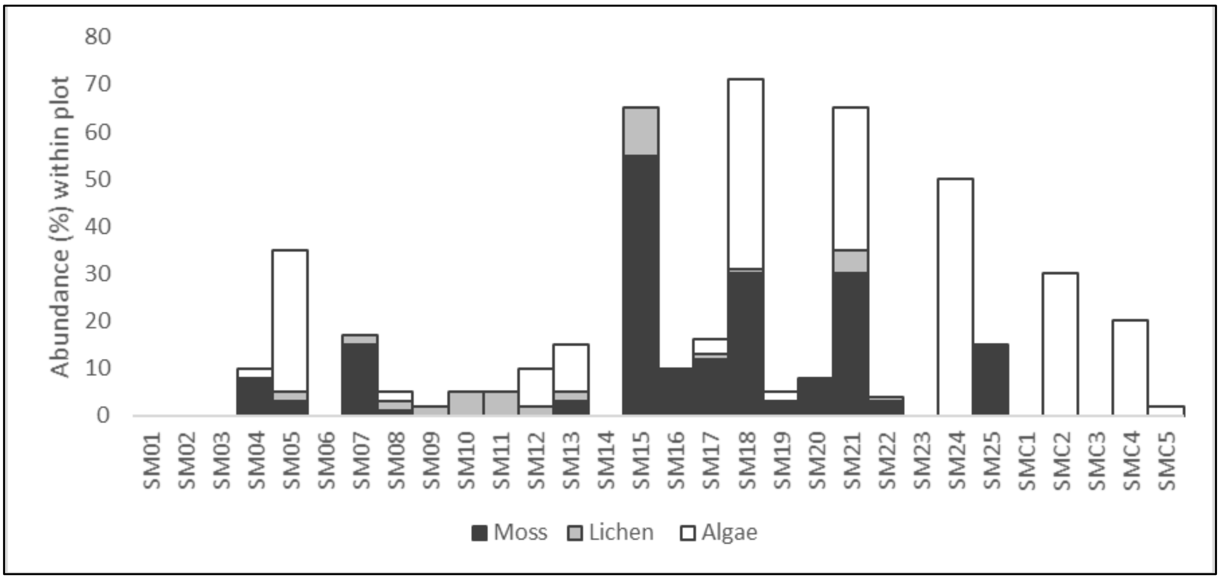


Figure 81: Vegetation abundance and composition at each of the Pram Point monitoring sites and the Cape Evans control sites.

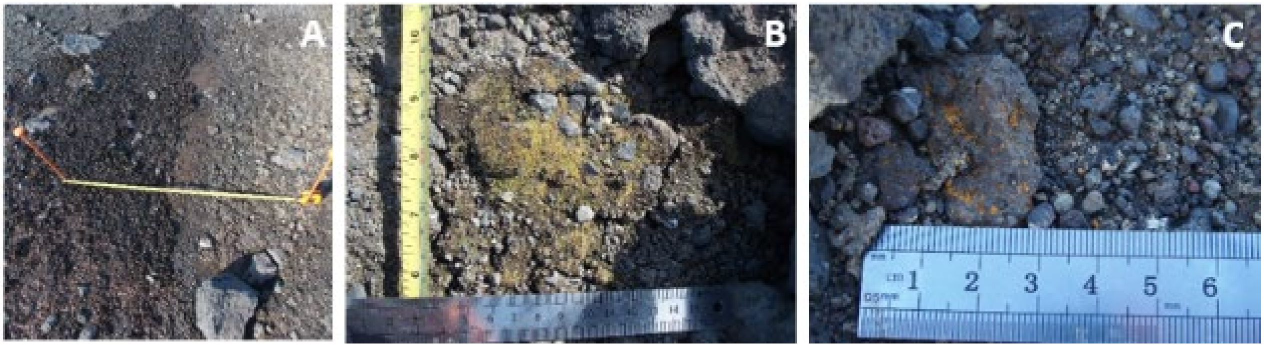


Figure 82: A - Nostoc cyanobacteria; B - Bryum *sp*. moss; C - *Caloplaca sp.* lichen (Beet and Lee, 2020).

The area above Scott Base was also remotely surveyed using drone-mounted equipment to detect vegetation (moss and algal cover, but not lichen). Figure 83 shows the vegetation density observed through a multispectral survey. When compared to the level of ground disturbance (Figure 76), it is evident that moss is largely absent from intensively impacted areas, which include heavily used tracks and historical tractor tracks. In high impact areas (where vehicle operations and minor earthworks take place), moss is absent but cyanobacterial (algal) mats still form. The multispectral survey and sampling points both showed very little vegetation in the areas where walking trails pass through.

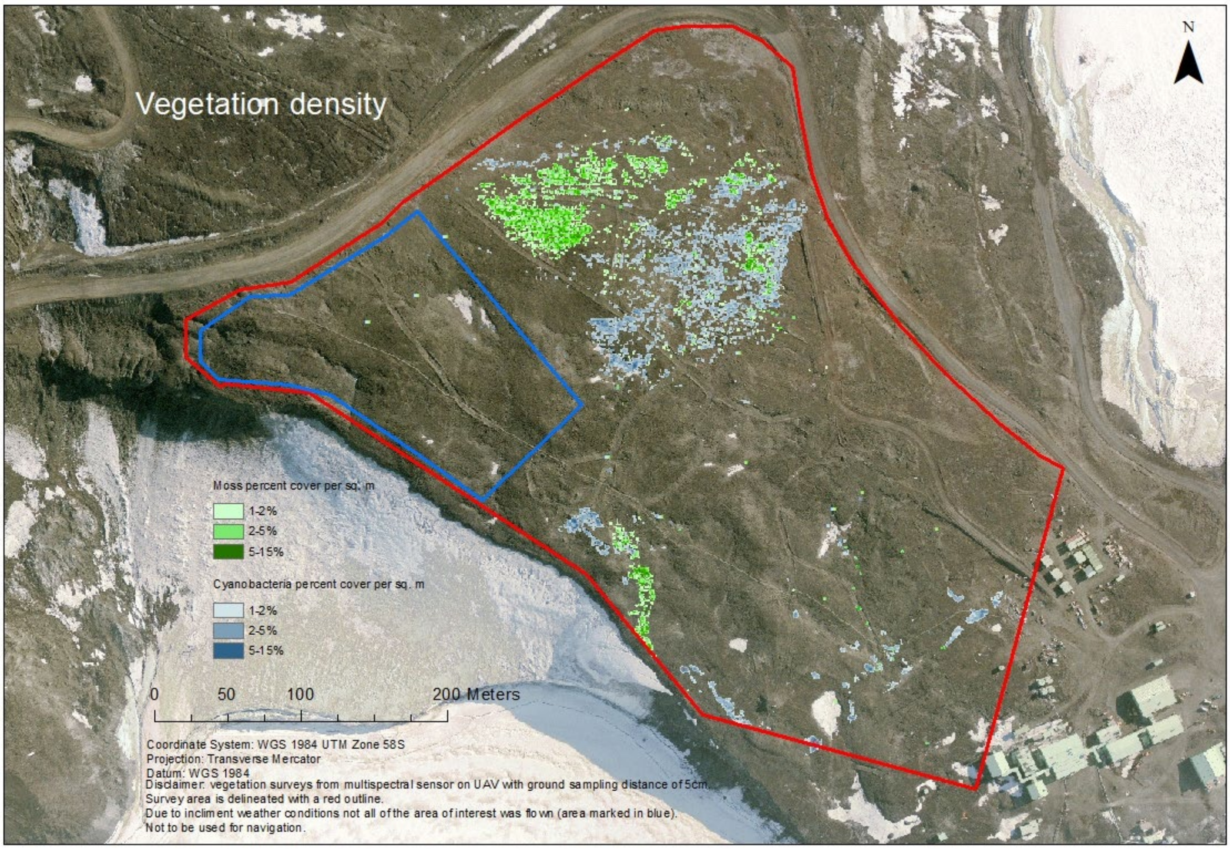


Figure 83: Vegetation cover at Scott Base from multispectral imagery (2018/19)[25].

Twenty genera of algae have previously been identified in the external environment of Scott Base. All are known to occur naturally in Antarctica. However, 14 were also identified in air samples taken in Christchurch, New Zealand, as well as in dust sampled from footwear and equipment before departure for Scott Base, and in soil samples on fresh vegetables at Scott Base (Broady & Smith, 1994). Without further analysis, it is unknown whether the strains of potential colonising algae differ from those found in the environment. Survivability experiments demonstrated that some potential colonisers can

[25] Note: Multispectral imagery was not able to be collected in the area marked in blue.

withstand Antarctic conditions, particularly those which desiccate and disperse in dry dust (*ibid.*). It is therefore possible (although not established) that algae from New Zealand have established in the Scott Base environment.

Lichens have been observed at the wind turbine site at Crater Hill, as have several nematode species (Wharton and Brown, 1989). Site investigations in November 2007 did not reveal any significant stands of vegetation, most likely due to the disturbed nature of the area. The only known other significant vegetation within several kilometres is found at a much higher elevation, northwest of Castle Rock (New Zealand, 2008).

5.3.4.2 Invertebrate diversity and abundance

Invertebrate communities can generally be divided into two groups: the macroinvertebrates (up to a few mm long), which include springtails (Collembola) and mites (Acari) and the microinvertebrates which encompass nematodes (Nematoda), rotifers (Rotifera), tardigrades (Tardigrada) and a variety of ciliates/Protozoa ((Adams, et al., 2006; Sinclair & Stevens, 2006).

Sampling to assess baseline invertebrate diversity and abundance found overall invertebrate abundance and diversity were largely associated with moisture levels and vegetation abundance (Table 37 and Table 38). There was a complete lack of invertebrates detected at three monitoring sites in both seasons (SM01, SM03 and SM06). SM02 had an overall lack of invertebrates except for rotifers (342 individuals in 2018/19) which was likely due to the presence of water from guttering overflow and nearby snowpack melt. SM01, SM02 and SM03 are in the operational area.

Scottnema lindsayae was the most abundant nematode across all sites, consistent with observations from the McMurdo Dry Valleys (Adams, et al., 2014). During 2018/19 eight sites (SM04, 05, 08, 12, 18, 19, 22, 25) had all three nematode genera present, compared to 2019/20 when only five sites had all three genera present (SM04, 13, 18, 22, 25). All three genera were also observed in control site SMC3 (the only Cape Evans control site in which nematodes were found (Table 38). This combination of species is, however, uncommon in the McMurdo Dry Valleys. Further unusual combinations of nematodes such as *S. lindsayae* and *Plectus* were observed in sites SM07, 16 and 21. It is more common to find *Scottnema lindsayae* with *Eudorylaimus* individuals as in sites SM10 and SM15 or *Eudorylaimus* and *Plectus* together (e.g. SM17 during 2018/19). These more common combinations of species are likely due to niche preferences; *Scottnema lindsayae* thrives in drier, saltier locations while *Eudorylaimus* and *Plectus* require a higher degree of moisture and organic matter (Adams, et al., 2014). The sites which had all three species could represent sites undergoing a transition. In contrast, the ones with only *Plectus* and *Scottnema lindsayae* could indicate the presence of a semi-recent disturbance in which *Plectus* has recovered/recolonised. *Eudorylaimus* has yet to do so (B.J. Adams, Personal Comments). Alternatively, these combinations could be indicative of potential biotic interactions (Caruso, et al., 2019).

Rotifers were observed in 19 out of 25 sites in 2018/19 (Table 37). In 2019/20, rotifers were found in 15 out of 25 Scott Base sites and three out of five Cape Evans control sites (SMC2, 4 and 5) (Table 38). Overall abundances were lower in 2018/19 sampling with maximal abundances of 683 individuals in SM04 followed by 277 in SM24.

Tardigrades were found in 11 sites in 2018/19 and 7 out of 25 sites in 2019/20, with abundances across all samples below 40 individuals except for SM24 in 2018/19 when 167 tardigrades were counted (Table 37 and Table 38). SMC4 was the only Cape Evans site in which tardigrades were found.

Mites were found at six Scott Base sites, and two Cape Evans control sites (SMC2 and SMC3), with the highest abundance found at SMC2 (>30 individuals). Overall, mites were more closely associated with moist, vegetated sites.

No springtails were observed in any of the Scott Base sites and have not been found in the area in recent years (Ian Hogg, Personal Comments). However, springtails were found at Cape Evans (SMC3). All of the individuals observed were the species *Gomphiocephalus hodgsoni*, the only springtail species found in the McMurdo Dry Valleys and Ross Island (Collins, et al., 2019).

Table 37: Table of invertebrate counts and environmental data (including vegetation abundance) at each of the Pram Point monitoring sites during the 2018/19 season[26]

Site	Invertebrate Counts							Environmental data	
	Scottnema	Eudorylaimus	Plectus	Rotifers	Tardigrades	Mites	Other	Soil moisture (% g/g)	Vegetation abundance (%)
SM01	0	0	0	1	0	0	0	1.8	0
SM02	0	0	0	342	0	0	0	7.5	0
SM03	0	0	0	0	0	0	0	2.2	0
SM04	306	82	32	64	0	0	1	6.6	10
SM05	478	16	57	13	0	0	2	6.6	35
SM06	0	0	0	0	0	0	0	2.7	0
SM07	144	0	112	1	12	0	0	9.5	17
SM08	488	17	12	18	0	0	0	2.2	5
SM09	131	0	0	0	0	0	0	1.5	2
SM10	300	19	0	0	0	0	0	4.3	5
SM11	77	1	0	1	3	0	0	1.3	5
SM12	33	4	4	45	1	0	0	4.3	10
SM13	56	122	0	3	12	3	7	4.7	15
SM14	272	24	0	6	0	0	4	4.1	0
SM15	409	2	0	195	0	0	0	2.4	65
SM16	555	0	109	643	12	0	1	4.5	10
SM17	0	155	27	5	0	0	48	5.4	16
SM18	322	24	200	1120	38	0	2	7.4	71
SM19	240	14	5	4	0	0	1	2.1	5
SM20	0	1	13	10	22	2	38	10.3	8
SM21	1370	0	20	106	2	11	0	5.0	65
SM22	78	2	8	0	6	6	0	3.1	1
SM23	4	0	0	3	0	0	0	1.4	0
SM24	0	0	0	146	167	17	23	17.6	50
SM25	80	94	250	32	24	4	60	7.6	15

Table 38: Table of invertebrate counts and environmental data (including vegetation abundance) at each of the Pram Point monitoring sites and Cape Evans control sites during the 2019/20 season[27]

Site	Invertebrate Counts							Environmental Data	
	Scottnema	Eudorylaimus	Plectus	Rotifers	Tardigrades	Mites	Protozoa	Soil moisture (% g/g)	Vegetation abundance (%)
SM01	0	1	0	0	0	0	0	4.3	0
SM02	0	0	0	196	0	0	0	8.3	0
SM03	0	0	0	0	0	0	0	2.6	0
SM04	283	25	22	683	6	0	1	14.2	10
SM05	363	0	11	2	0	0	0	7.6	35
SM06	0	0	0	0	0	0	0	3.3	0
SM07	57	0	133	4	2	0	0	11.5	17
SM08	156	13	0	1	0	0	0	3.7	5
SM09	416	4	0	10	0	0	1	8.3	2
SM10	226	19	0	0	0	0	0	2.7	5
SM11	57	30	0	0	0	0	0	6.7	5
SM12	48	7	0	51	0	0	2	10.8	10
SM13	82	25	1	0	2	3	0	6.0	15
SM14	226	0	0	0	0	0	0	2.7	0
SM15	412	4	0	0	0	0	0	1.6	65
SM16	921	0	8	24	0	0	1	10.2	10
SM17	129	60	0	1	0	0	1	13.4	16
SM18	414	52	66	41	14	0	1	11.0	71
SM19	540	25	0	0	0	0	1	3.4	5
SM20	0	0	1	10	20	0	5	12.7	8
SM21	997	0	24	263	0	0	4	10.6	65
SM22	32	5	8	0	0	1	0	14.8	4
SM23	17	0	0	2	0	0	0	1.5	0
SM24	2	0	0	277	1	0	3	28.7	50
SM25	149	103	11	1	29	0	4	10.2	15
SMC1	0	0	0	0	0	0	0	0.7	0
SMC2	0	0	0	192	0	5	1	8.3	30
SMC3	38	14	2	0	0	0	0	14.9	0
SMC4	0	0	0	265	16	0	35	9.6	20
SMC5	0	0	0	280	0	0	0	10.2	2

[26] Raw counts of total numbers of three genera of nematodes along with rotifer and tardigrade counts. 'Other' refers to Protozoa and mites found in samples. Numbers are raw counts of individuals found in 100g of extracted soil.
[27] Raw counts of total numbers of three genera of nematodes along with rotifer and tardigrade counts. Numbers are raw counts of individuals found in 100g of extracted soil.

5.3.4.3 Microbial diversity and abundance

Total microbial counts in Scott Base soils are high – around 100 million cells per gram of soil (dry weight) in uncontaminated samples.

The dominant phyla observed across the sites were *Bacteroides*, *Cyanobacteria*, *Acidobacteria*, *Actinobacteria* and *Proteobacteria* (Figure 84) similar to some soils found in the Dry Valleys (Cary, et al., 2010; Lee, et al., 2012). Sites SM02 and SM03 from the operational area were distinct from all other sites by their near absence of *Cyanobacteria*. Furthermore, SM02 had the highest abundance of *Proteobacteria*. *Bacteroides* almost entirely dominated SM03. In contrast, SM01 had a very high proportion of *Cyanobacteria* and appeared similar to other sites despite being a highly disturbed site. This is likely attributed to the ability of Polymerase Chain Reaction (PCR) methods to detect dried and windblown *Cyanobacteria*. Sites SM08, 09, 11, 19 and SM23 all had lower levels of *Cyanobacteria* coupled with high abundances of *Acidobacteria* and *Actinobacteria*. These sites also had low levels of soil moisture and vegetation (Table 37), which were consistent with microbial communities observed in the arid McMurdo Dry Valleys soils ((Niederberger, et al., 2015). In contrast, sites SM05, 16, 18, 20, 21 and SM25 all had very high levels of *Cyanobacteria* and moderate to high levels of soil moisture (>4.5% g/g) and vegetation (8-71%), similar to wet McMurdo Dry Valleys soils (Niederberger, et al., 2015).

Soil moisture appeared to have the comparatively largest structuring influence on microbial community composition, with distinct clusters of sites with low (<3% g/g) and very high (>10% g/g) levels of soil moisture. However, there were still high levels of variability.

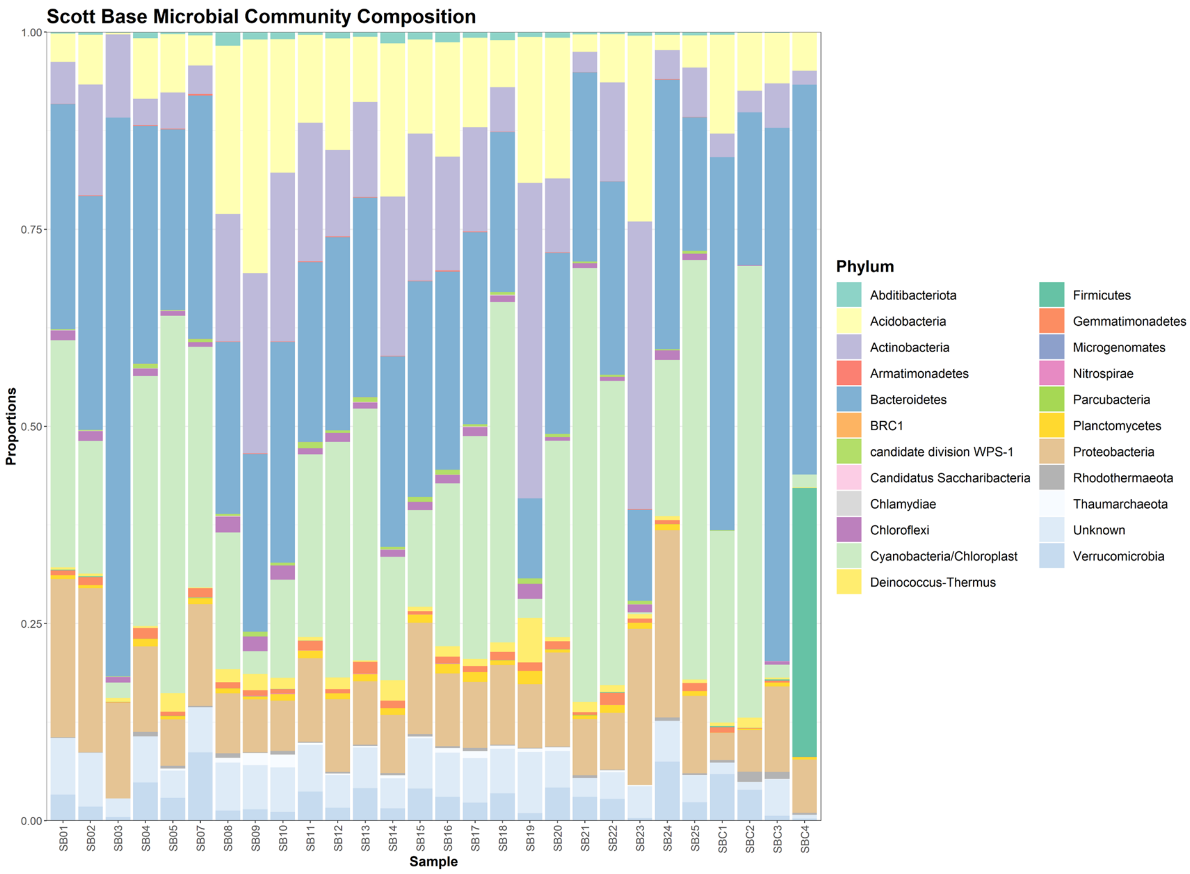


Figure 84: Plot of the average microbial community abundance at each monitoring site across 2018/19 and 2019/20, showing the relative abundance of different phyla.

Some bacterial species have been identified from samples taken at Crater Hill, including a *Streptomyces* species, which produces a soluble purple pigment and *Flavobacterium diffusum* (Boyd & Boyd, 1963).

5.3.4.4 Non-native species

During the 2018/19 and 2019/20 terrestrial surveys, no non-native species were observed at any of the terrestrial monitoring locations. Except for the possible presence of non-native algal species discussed in 5.3.3, no non-native species have been identified on Pram Point or at Crater Hill.

5.3.4.5 Dust

Dust emissions are a source of airborne pollution for terrestrial flora and fauna. Dust is mobilised primarily by vehicle movements on ice-free ground, such as the road between Scott Base and McMurdo Station. Vehicle movements and earthworks in the Scott Base area also release dust. In addition to playing a role in the dispersal of contaminants, the dust caused by vehicle movements and earthworks 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. Dust also suffocates vegetation and is linked to the distribution and density of vegetation at Pram Point. It has been estimated that 200 tonnes of wind-blown dust may result from Scott Base operations annually, compared to 2,400 tonnes from McMurdo Station (*ibid.*).

Baseline dust sampling was undertaken from 12 sites scattered across Pram Point (see Chapter 9). In general, the amount of material collected from the 12 dust samplers was low and ranged from 0.30g to 3.01g of material (Table 39). Modified Wilson and Cook (MWAC) passive dust samplers closest to the Scott Base to McMurdo Station road (i.e. SM03, SM06, SM08, SM12, SM20 and SM23) tended to have the greater volumes of dust collected (Table 39). It is important to note that the area around Scott Base is only snow-free and thawed to the surface (whereby dust can be transported) for a short time each year, and for most of the year, dust transport is unlikely to occur. Consequently, dust collected represents approximately a period of 2 to 3 months.

The average median grain size of dust ranged from 43µm (silt) to 631µm (coarse sand). Dust collectors closest to the Scott Base to McMurdo road and in the prevailing wind direction had the finest average median grain size (~45µm, silt), consistent with the fine silt seen blowing from the road onto the operational area in the summer months.

Aerosols (fine solids or liquids suspended in air) have been studied at the Cosray[28] site near Scott Base. The project focused on natural aerosols and, in screening out anthropogenic aerosols, identified short-term, local contamination events. These were attributed to site maintenance and nearby road traffic, characterised by an average duration of less than 1 h (0.5 ± 6 min), a rapid rate of concentration change (8520 ± 36 780 $cm^{-3}\,min^{-1}$), and concentrations exceeding 1000 cm^{-3} (Liu, et al., 2018).

[28] The Cosray site hosts a neutron monitor, an instrument that measures the number of high-energy particles ("cosmic rays") impacting Earth from space.

Table 39: Total quantity of dust collected from MWACs associated with soil monitoring plots (SM) around Scott Base over the 2019-2020 season (1 = lowest collector, 3 = highest collector).

Monitoring site	Collector 1	Collector 2	Collector 3	Total (g)
SM03	0.99	1.12	0.90	3.01
SM06	0.53	0.34	0.17	1.04
SM08	0.65	0.59	0.47	1.71
SM10	0.07	0.07	0.05	0.19
SM12	1.12	0.48	0.52	2.12
SM15	0.06	0.17	0.07	0.30
SM17	0.08	0.20	0.02	0.30
SM18	-	-	-	Sampler damaged
SM20	0.23	0.37	0.28	0.88
SM23	0.75	0.47	0.45	1.67
SM25	0.14	0.07	0.11	0.32
TAE Hut	0.18	0.13	0.06	0.37

5.4 Nearshore marine environment

5.4.1 Epifaunal diversity and abundance

To support the monitoring programme for the Scott Base Redevelopment, three nearshore marine monitoring sites were identified and surveyed during the 2019/20 season, including SB1 and SB3 which are close to, but on opposite sides of Pram Point and a control site located adjacent to Arrival Heights (Figure 85). SB2 was unable to be surveyed in the 2019/20 season due to sea ice conditions preventing safe operations.

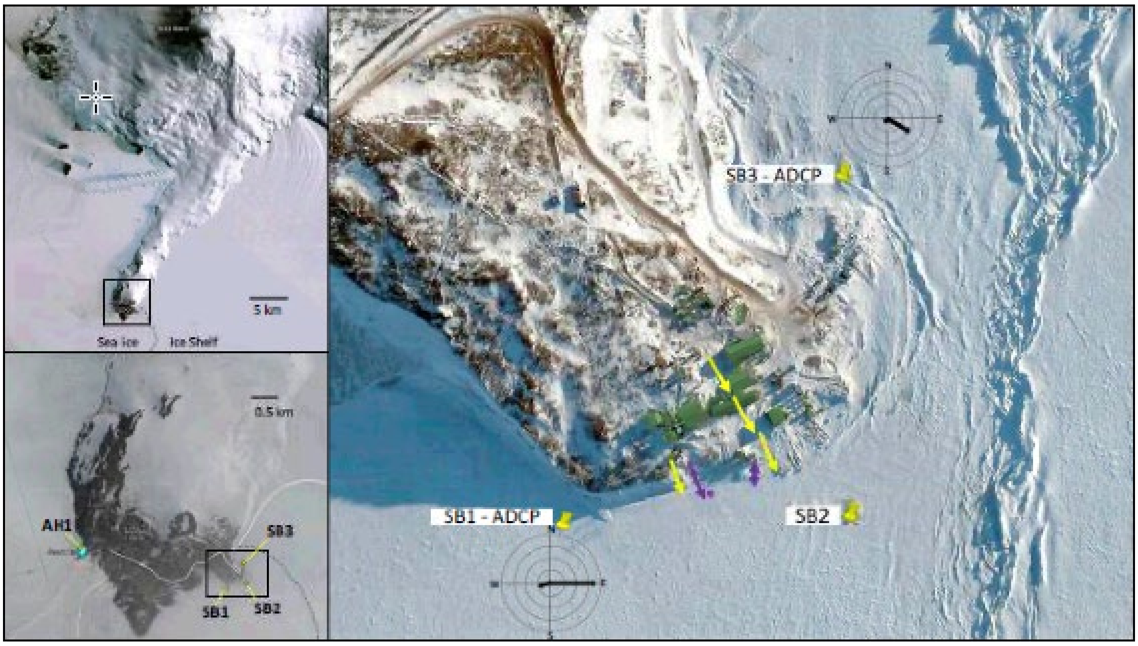


Figure 85: Study area and sites sampled during the Scott Base Redevelopment marine environmental monitoring project of 2019/20[29].

[29] The upper left panel shows the southern half of Ross Island, with Hut Point Peninsula jutting to the southwest. Lower left panel shows the southern tip of Hut Point Peninsula where McMurdo Station and Scott Base are located; control site at Arrival Heights (AH1) and the three SB sites (SB1-3) are shown. Right-hand panel is a close-up of Pram Point and Scott Base (green buildings), with information on summertime freshwater flows (yellow arrows)

The seafloor at all sites was moderately to steeply sloped and dominated by volcanic scoria substrate (boulders, rocks and cobbles with patches of gravel, sand and shell material). All sites had abundance and diverse epifaunal invertebrate life and lacked macroalgae. Sessile suspension-feeding epifauna (e.g. sponges, anemones, soft corals) were dominant. Ecological community data gathered from frame grabs of diver-collected video revealed high diversity at all three study sites and distinct differences among sites. The two Scott Base sites shared similarities more so than with Arrival Heights. The two Scott Base sites had relatively high abundances of the brittle star *Ophiacantha antarctica*, cone sponges *Polymastia invaginata*, and sea spiders (Pycnogonida), with the stoloniferous soft coral *Clavularia frankliniana* relatively rare. Although 28 individual taxa were recorded at SB3, the site with the highest average richness, evenness and diversity of taxa per frame was SB1. The control site AH1 had the lowest average richness, abundance and diversity per frame.

SB1 is a relatively steep slope (estimated to be ~40°). The seafloor substrate is a mixture of moderately unconsolidated volcanic scoria rubble and gravels with interspersed rocky outcrops. There is copious bivalve shell hash material scattered on the seafloor, predominantly empty shells of the infaunal bivalve, *Limatula hodgsoni*. The substrate is covered in many places by an unidentified filamentous fluffy turf, which is likely comprised in part from the silica spicules of sponges (Figure 86). Although the fluffy turf has a greenish-brown tint, the sediment is not coated with microphytes (e.g. settled detrital phytoplankton or under-ice algal material). No macroalgae were observed at SB1. Figure 86 shows several white cone sponges (*Polymastia invaginata*), a large anemone (*Isotealia antarctica*), a green globe sponge (*Latrunculia apicalis*), a soft coral colony (*Alcyonium antarcticum*), and a small sea star (*Odontaster validus*) on a rock on the seafloor at SB1. Note the unidentified fuzzy filamentous material in the bottom right corner of the image, likely a mixture that includes sponge spicules. The anemone is roughly 10-15 cm across.

Figure 86: Image of sloped seafloor with sessile biota and sponge spicule mat at SB1. Image: Drew Lohrer, NIWA

Epifaunal organisms are predominantly sessile filter feeders (e.g. large anemones, athecate hydroids, soft corals, and several sponge species including occasional *Sphaerotylus antarcticus* and *Homaxinella balfourensis*). The cone sponge *Polymastia invaginata* is the most common and conspicuous sponge at this site. Large pycnogonids, sabellid fan worms, several species of sea stars, brittle stars *Ophiacantha antarctica*, large tunicates *Cnemidocarpa verrucosa*, and infaunal bivalves *Laternula*

and positions of the RO intake/discharge and sewage discharge (purple arrows, with * denoting the sewage outfall). Predominant current flow directions for the two sites with ADCP current meters are also shown for reference.

elliptica are common. Nemerteans (*Parborlasia corrugatus*) and sea urchins (e.g., *Sterechinus neumayeri*) are rare to absent at this site. One large isopod (*Glyptonotus antarcticus*) and two small Antarctic scallops (*Adamussium colbecki*) were observed. There is little, if any, evidence of anthropogenic debris at this site. Dense mats of anchor ice were observed in the shallows upslope of the transect.

SB3 is also a steeply sloped site (~40°). The substrate is a mixture of moderately unconsolidated volcanic scoria rubble and gravel with interspersed rocky outcrops. Patches of sediment are slightly more common at SB3 than at SB1, and the sediment is finer. At the time of the survey in November 2019, the platelet ice layer was very thick on the under-surface of the ice close to shore but was not particularly thick near the dive hole. Anchor ice occurred on the seafloor starting at around 16m, becoming very dense and covering epifauna in the shallows (Figure 87).

Figure 87: Anchor ice covering the seafloor at approximately 12 m depth at SB3. Animals of many types and sizes were covered by anchor ice at this depth. The large sponge (~50 cm tall) is *Rossella racovitzae* (Image: Peter Marriott, NIWA).

Scattered patches of shell hash from the bivalve *Limatula hodgsoni* are common on the seafloor at SB3. Epifaunal life is rich and abundant, dominated by sessile suspension feeders. Cover of the unidentified filamentous fluffy turf and bryozoan/hydroid turf is higher at SB3 than at SB1. The bryozoan *Cellarinella sp*. is relatively common as are the brittle stars *Ophiocantha antarctica* and *Ophiolinthus sp*. Anemones (e.g. *Stompia selaginella*) are much less common at SB3 than SB1. The cone sponge *Polymastia invaginata* is very common. One of the target species for contaminants analysis collections, the sponge *Homaxinella balfourensis*, was not found at this site. The other target species (*Sphaerotylus antarcticus*, *Mycale acerata* and *Laternula elliptica*) are present at the site but are not abundant. One scallop (*Adamussium colbecki*) was recorded, nemerteans (*Parborlasia corrugatus*) and sea urchins (e.g., *Sterechinus neumayeri*) are rare to absent, and no macroalgae are present at SB3.

An important distinction at SB3 relative to SB1 is the presence of anthropogenic debris, including wood, glass bottles, bamboo flag poles, rusting metal drums, and food waste (Figure 88). The rusting and disintegration of the metal drums gives the sediment an obvious red tinge in places. Negri et al. (2006) reported that the area was once a dump site, which is consistent with the observations of strewn refuse on the seabed during the November 2019 survey.

Figure 88: Rusting metal pipe or drum on the seabed at SB3. Note the fine orange sediment-like material in the cylinder and the exterior covered with epifaunal life (Image Peter Marriot, NIWA).

5.4.2 Nearshore marine contamination

Scott Base general solid waste was dumped on land close to the sea, left on sea ice or open-burned up until the 1980s. Debris is embedded in the foreshore and on the seafloor (Webster, et al., 2006). Signs of past dumping on the foreshore are still visible during high melt periods, and ground-penetrating radar studies have identified large buried metal objects approximately 20-30m from the shoreline (Pettersson & Nobes, 2003). Snow clearing and earthworks around Scott Base over the years have resulted in soil and associated contaminants being pushed into the sea. Land-based contamination is also transported to the sea by meltwater.

Polychlorinated biphenyls (PCBs) have been detected in one composite marine sediment sample taken near to Scott Base (Negri, et al., 2006). PCBs are a pervasive and persistent global pollutant, but the extreme patchiness of results from samples near Scott Base suggests a local source; probably an individual item of equipment disposed of by being left on the sea ice to sink when the ice melted.

In the early days of Scott Base, liquid wastes were manually dumped into sea ice cracks. From about the 1960s until 2000, macerated sewage and grey water were discharged onto land approximately 13m from the shoreline. In 2000, a new, permanent outfall line releasing macerated sewage and greywater approximately 5m offshore was constructed and in 2002 a biological treatment plan for wastewater was commissioned. In 1999, the effluent “plume” (as measured by the distribution of nutrients, faecal coliforms and biochemical oxygen demand in receiving water) was found to extend up to 175m along the shore and 50m offshore (Redvers, 2000). Since the WWTP was commissioned in 2002, the general spatial extent of the plume has reduced to approximately 50m along the shore and 30m offshore. Faecal coliforms have declined to below detectable levels within the plume, while dissolved oxygen and total organic carbon concentrations in the plume have increased, and conductivity has decreased (Williams, 2012). Contamination from Scott Base does not appear to have negatively affected the marine benthic community (Williams, 2012), although it is likely to have altered the composition of bacterial and eukaryotic communities, including those associated with coral (Webster & Negri, 2006; Webster, et al., 2006).

Studies undertaken in 1994, when macerated and otherwise untreated sewage and greywater were still being discharged onto the foreshore, found elevated levels of copper, zinc, lead and nickel in the effluent, seawater and sediments near the outfall (Anderson & Chague-Goff, 1996). Sea ice conditions at the time-limited mixing of effluent with seawater and the levels of toxicants in seawater samples exceeded contemporary and current Australian and New Zealand marine water quality guidelines[30]. Copper (324ppb) and zinc (93.6ppb), were well above the levels which would now be applied to a degraded ecosystem (8μgL^{-1} for copper and 43μgL^{-1} for zinc), let alone a pristine one (0.3μgL^{-1} and 7μgL^{-1}). Concentrations in sediment near the outfall were also very high, with copper in the closest sample being 200 times higher than applicable threshold effect levels available at the time (Anderson & Chague-Goff, 1996). Seawater samples near the outfall taken in 1998 (Redvers, 2000) showed lower concentrations of metals but copper, with a maximum of 3.2μgL^{-1}, was still above 'pristine' guideline levels (i.e. the goal of no biodiversity change). Lead in seawater from the 1994 study was 7.66ppb, compared to the no-change guideline level of 2.2 μgL^{-1}.

However, in 2002 following the installation of the WWTP and offshore outfall, marine sediments near Scott Base were found to contain similar concentrations of cadmium, lead, mercury and arsenic to those reported for the comparison pristine site (Negri, et al., 2006). Metal concentrations in bivalves from Scott Base were also similar across sites. No discernible spatial patterns were detected for trace metal concentrations in sponge species. Levels of butyltins were also found to be lower than at nearby Cape Armitage and McMurdo Station (Webster, et al., 2006). In the most recent study, copper and zinc in seawater near Scott Base remained at levels above the 'pristine' guideline level (99% species protection), but below the 95% protection level (Williams, 2012).

There are several known hydrocarbon contaminated sites around Scott Base and migration with meltwater can occur. Divers in 2000/01 found the mean TPH concentration in sediments from Scott Base was 12.1 mg/kg, three times higher than the pristine comparison site, Turtle Rock (Negri, et al., 2006). However, total hydrocarbons and polyaromatic hydrocarbon levels were considered moderate compared to Cape Armitage and McMurdo Station (Webster & Negri, 2006).

As part of the Scott Base Redevelopment monitoring programme, sediment and biological samples were taken for analyses of contaminant levels.

5.4.2.1 Sediment contamination

Concentrations of all polycyclic aromatic hydrocarbon (PAH) and PCB congeners in sediments at all sites were below the detection thresholds of the analytical procedures used. Total PAH and PCB concentrations (i.e. all congeners combined) were also below detection thresholds at all sites, indicating very little existing organic contamination at the study sites in 2019.

The only exception was petroleum hydrocarbons, which, while below detection limits at SB1 and AH1 (<70 mg/kg dry weight), were present at SB3 (average 157.5 ± 52.2, range 90–300, mg/kg dry weight).

Heavy metals were detected in the sediments at all three sampling sites (Figure 89). Average concentrations of arsenic, copper, lead, zinc and cadmium were generally highest at SB3 (Figure 89). The concentration of mercury, in contrast, was highest at the AH1 control site, with all replicates at this site exceeding the indicative sediment toxicity Default Guideline Value for Mercury of 0.15 mg/kg.

High among-replicate variation in sediment heavy metal contaminant concentrations was noted at SB3. One of the four SB3 replicates had substantially higher concentrations of all metal species tested (arsenic, calcium, copper, lead, mercury and zinc), with concentrations of some metals at (copper) or above (arsenic, lead) indicative sediment toxicity guideline values (ANZECC & ARMCANZ, 2000). The lead concentration in this sample from SB3 was 100 times higher than that of the other samples at the site. Arsenic was about ten times higher in this sample, and copper, calcium and mercury were about three times higher.

[30] https://www.waterquality.gov.au/anz-guidelines

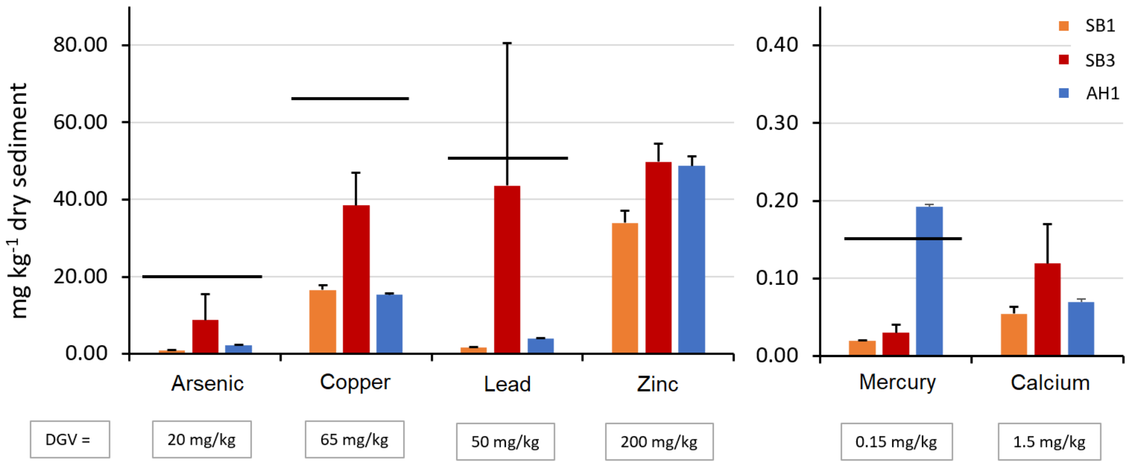


Figure 89. Sediment heavy metal contaminant concentrations at SB1, SB3 and AH1[31].

5.4.2.2 Biological contamination

Like the sediments, levels of PAH and PCB contamination in animal tissues were generally below detection limits. Some of the individual PCB congeners (PCB-52, PCB-101, PCB-118, PCB-138, PCB-149 and PCB-153) were just above the detection threshold in *Laternula elliptica* tissues sampled at AH1. However, the concentrations were still very low, with total PCBs <0.02 mg/kg in all replicates of both species at all three sites.

Heavy metal contaminants were detected in the tissues of both suspension-feeding species analysed. Cadmium, which was in very low concentrations in sediment, was relatively concentrated in the tissues of epifaunal sponges *Sphaerotylus antarcticus* and infauna bivalves *Laternula elliptica*. Across all metal species, concentrations in *Laternula elliptica* tended to be highest at SB1, intermediate at SB3, and lowest at AH1 (Figure 90). This site-related pattern was not apparent for *Sphaerotylus antarcticus*.

[31] Average concentrations for each metal species at each site (+ 1 standard error) are presented along with information on published sediment toxicity default guideline values (DGV, developed by ANZECC & ARMCANZ 2000). DGVs (horizontal black lines) “indicate the concentrations below which there is a low risk of unacceptable effects occurring, and should be used, with other lines of evidence, to protect aquatic ecosystems”. DGVs for Zn and Ca are off scale and therefore not shown.

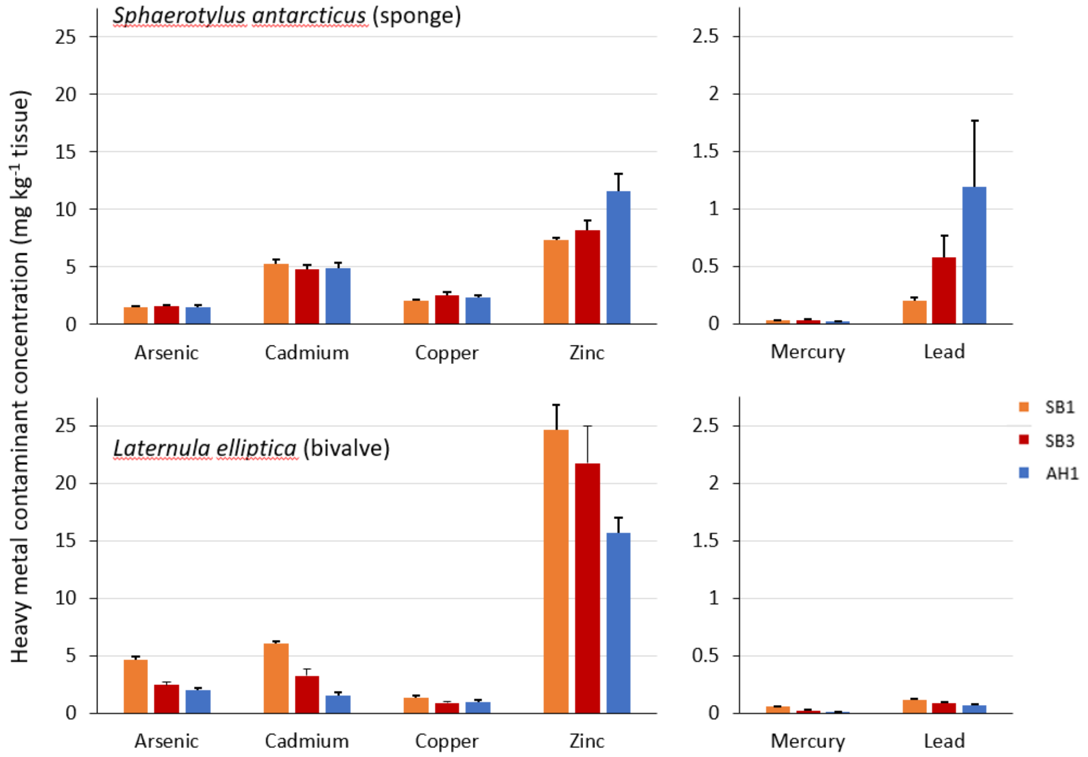


Figure 90. Heavy metal contaminant concentrations in sponge and bivalve tissue samples at SB1, SB3 and AH1[32].

5.4.3 Nearshore currents

Current profiles (velocity, direction, depth variation, etc.) were assessed at SB1 and SB3 to understand the potential for transport of sediments and contaminants introduced to the marine environment as a result of construction activities.

Currents at SB1 exhibited a strong east-west flow regime. Tidal flows usually oscillate back and forth on flooding and ebbing tides. However, at SB1, easterly flows were observed to be stronger and more frequent than westerly flows. This suggests that the general (residual) pattern of flow is from SB1 towards the Scott Base outfall, rather than vice versa (Figure 91 and Figure 92).

Current flows were relatively uniform from the surface to the seabed, with only marginally stronger currents at depth. There were brief pulses of relatively strong flow during the deployment (18-20 cm/s), although the median and mean current speeds were relatively weak (<6 cm/s).

Divers noted that tidal currents were conspicuously strong at this site, with many organisms swaying and fluttering in the current.

[32] Average concentration + 1 standard error is given for each metal at each site. Four replicate tissue samples of sessile suspension feeding taxa were analysed (epifaunal sponge *Sphaerotylus antarcticus*; infaunal bivalve *Laternula elliptica*).

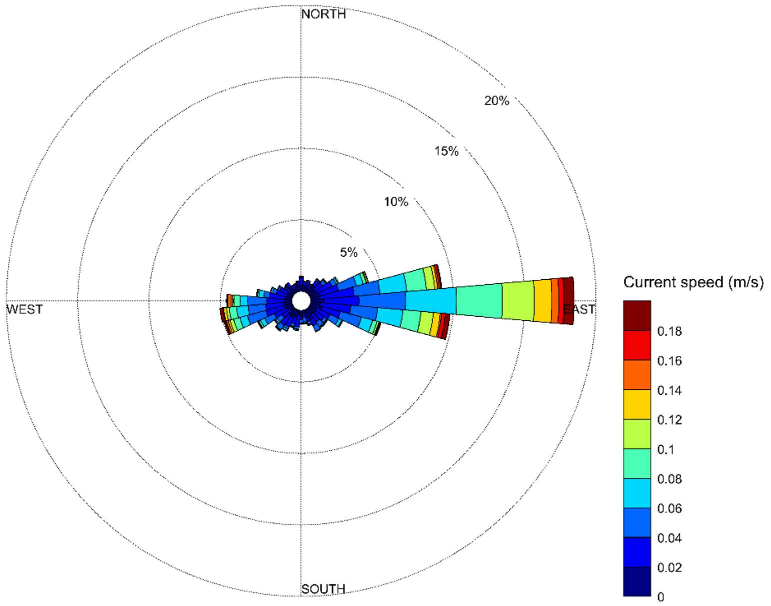


Figure 91. Current speed and direction at SB1 during November 2019. Distribution of depth-averaged current direction (degrees True) and velocity (m/s) between 28/10 and 18/11/19[33].

The currents at SB3 had a predominantly south-westerly flow direction. There was little evidence of oscillating (bi-directional) flow. The average current direction was 120° True, towards the front of Scott Base, where freshwater inputs and intake/outfall points are located (Figure 92).

Median, mean and near maximum currents were weaker during the deployment, on average, than those at SB1. The divers noticed the difference in tidal current strengths between sites. There was also more vertical structure to the current velocities at SB3, relative to SB1, with currents tending to be higher underneath the ice and slower near the bottom. Bottom water current speeds were almost half what they were at SB1.

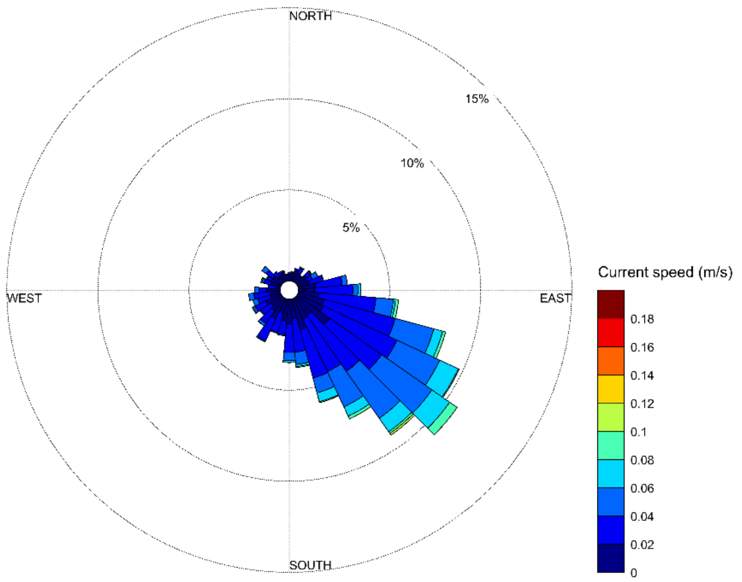


Figure 92. Current speed and direction at SB3 during November 2019. Distribution of depth-averaged current direction (degrees True) and velocity (m/s) between 28/10 and 15/11/19.

[33] The compass rose indicates the percentage of time when currents are flowing in a given direction at a given speed.

5.5 Birds and mammals

5.5.1 Marine mammals

The sea ice immediately adjacent to Scott Base hosts a recovering Weddell Seal (*Leptonychotes weddellii*) colony (Figure 93). Seals were killed between 1956/57 and the mid-1980s, when New Zealand took around 2,000 seals to feed dogs (Ainley, 2010). Between 1957/58 and 1967/68, seal numbers in the Pram Point area fluctuated between approximately 300 and 945, with between 5 and 12 pups a year (Stirling, 1971).

Figure 93: Weddell seals on the sea ice in front of Scott Base.

Due to changes of sea ice and/or the food web, it is believed the McMurdo Sound Weddell Seal population has not yet fully recovered from harvesting, sitting at around 2,000 individuals compared to 3,000 before 1957 (Ainley, 2010).

Weddell Seal observations were undertaken over two seasons (2018/19 and 2019/20) and revealed far fewer seals in the 2019/20 season than in the 2018/19 season (Table 40). This difference may be attributed to weaker sea ice in 2019/20, which resulted in the formation of holes and cracks further out in McMurdo Sound, giving the seals more access points/breathing holes and allowing them to spread out instead of being concentrated in front of Scott Base. These smaller aggregations consisted of up to c.20 individuals.

Until the 1980s, southern elephant seals (*Mirounga leonine*) foraged in the Ross Sea region and were known to haul out at Ross Island. However, the source population at Macquarie Island has now seriously decreased. Therefore, the Ross Sea shelf is missing several dozen elephant seals and several hundred Weddell seals from the summer food web (Ainley, 2010).

Blue whales (*Balaenoptera musculus*) once occurred over the Ross Sea continental shelf slope. This is where the sea floor, formed by the continental shelf, descends from 500m to 3,000m below the surface. It is a highly productive area where upwelling currents bring nutrients from deep water. Commercial whaling commenced in 1923 and by 1930 “the unrestricted slaughter of whales led to a catastrophic fall in catch figures” (Quartermain, 1971). Blue whales have never reappeared, leaving three species currently known to occur over the continental shelf of the Ross Sea: Minke whales (*Balaenoptera bonaerensis*), Ross Sea killer whales Ecotype C (*Orcinus orca*) and Arnoux’s beaked whales (*Berardius arnuxii)* (Ainley, 2010).

It is thought that Minke whales expanded into the habitat vacated by Blue whales (*ibid.*). They were hunted during the 1970s and 1980s, but appear to have recovered (*ibid.*). Scientific whaling of minke whales has been undertaken in recent years but has now ceased.

Killer whales of Ecotype A, B and C are found in the Ross Sea. The population of at least 3,400 individuals is predominantly Ecotype C, which feed on fish and particularly toothfish[34]. Commercial fishing for Antarctic toothfish commenced in the Ross Sea in the summer of 1996/97. Whales are occasionally seen off the shore of Pram Point, in front of Scott Base late in the austral season when the sea ice breaks out.

Table 40: Weddell Seal counts for the 2018/19 and 2019/20 summer seasons[35].

2018/19 Seal counts		2019/20 Seal counts	
Date	**Count**	**Date**	**Count**
20/12/18	40	21/12/19	19
27/12/18	60	28/12/19	35
03/01/19	150	04/01/20	62
10/01/19	195	11/01/20	64
17/01/19	330	18/01/20	59
24/01/19	580	25/01/20	14
31/01/19	460	01/02/20	20
07/02/19	340	08/02/20	28
14/02/19	310	15/02/20	89
21/02/19	200	22/02/20	285
25/02/19	80	29/02/20	55
		07/03/20	83
		14/03/20	49
		20/03/20	6
		27/03/20	10

5.5.2 Birds

South Polar skuas *(Catharacta maccormicki)* 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 the LTS area to the west of the buildings each season. Skuas are not known to breed at Crater Hill but are occasionally observed in the area.

Adélie (*Pygoscelis adeliae*) and Emperor (*Aptenodytes forsteri*) penguins are occasional visitors to the sea ice near Scott Base. The nearest breeding colonies are at Cape Royds for Adélie penguins and Cape Crozier for both Adélie and Emperor penguins (the southernmost emperor colony).

Over a million Snow petrels *(Pagodroma nivea)* breed in the Ross Sea region and the nearest colony is at Franklin Island approximately 120km north of Ross Island (Ainley, et al., 1984). Snow petrels disperse widely to feed in pack ice, including in the Ross Island area (*ibid.*). Two Snow petrels were found dead at the wind farm site in the 2012/13 season and one more fatality occurred in 2018/19 season, likely due to bird strike with the turbines. Snow petrels have not been seen elsewhere near Pram Point.

[34]http://www.lastocean.org/Ross-Sea/Antarctic-wildlife-animals-Adelie-penguin-Emperor-penguin-__l.2431

[35] Note: All counts were undertaken at 11am on the day shown. 2018/19 survey ended when the sea ice broke out. 2019/20 survey ended at the end of the summer operational period.

5.6 McMurdo Sound

The McMurdo Ice Shelf lies at the southern end of McMurdo Sound on the north-western side of the Ross Ice Shelf (Figure 94). The total area of the McMurdo Ice Shelf is about 4,000km^2.

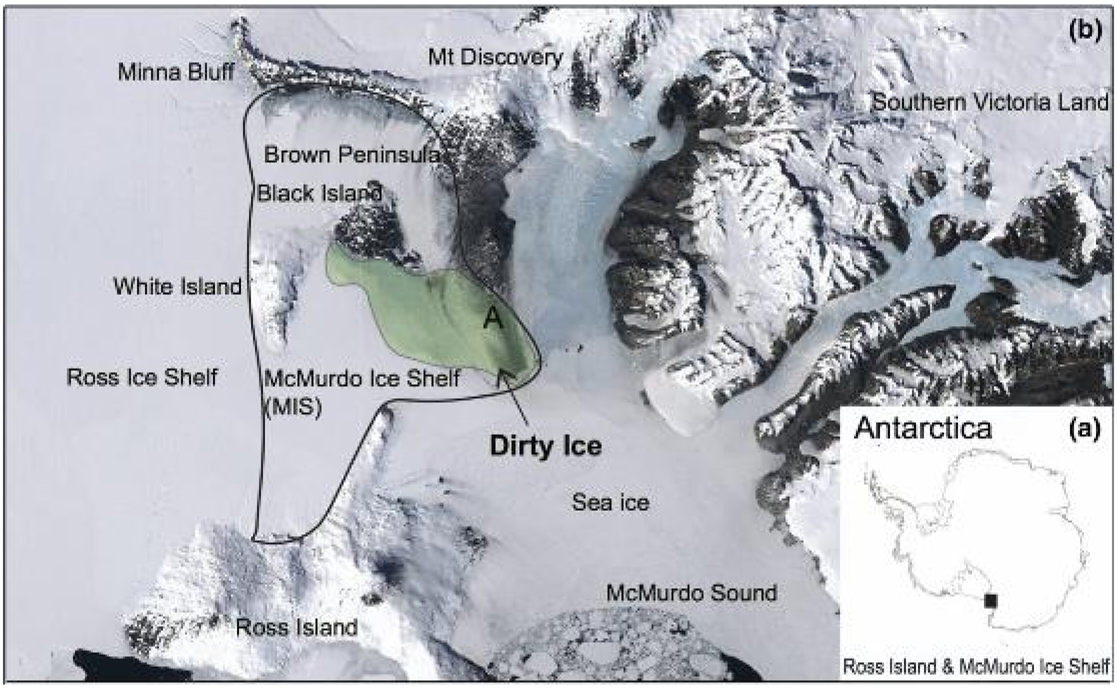


Figure 94: McMurdo Ice Shelf and Southern McMurdo Sound (Source: Hawes et al., 2018).

The McMurdo Ice Shelf is an unusual Antarctic ice shelf in that it has low thickness in places (~20m to ~50m (Rack, et al., 2013). It alos has extensive debris cover in some areas (Hawes, et al., 2018); it displays slow ice flow in an oblique direction to the ice front. Furthermore, it has an unusual oceanographic and meteorological setting, supporting strong basal freezing that balances surface ablation by summer surface melting and year-round sublimation (Glasser, et al., 2006).

Relatively warm Antarctic surface water is drawn into the ice shelf cavity during summer, causing melt at the ice shelf base (Robinson, et al., 2010). At the beginning of winter, the near-surface flow switches northward and out of the cavity and supercooled water is observed in the water column that was in contact with the ice shelf at depth (Leonard, et al., 2011; Mahoney, et al., 2011).

In the west, an apparently more persistent northward flow of near-surface supercooled water results in net freezing at the ice shelf base and the formation of a persistent and relatively thick cover of land-fast sea-ice (Robinson, et al., 2010). A persistent feature is a tongue of sub-ice platelets on the western side of the sound, which is the result of supercooled water carrying ice crystals from beneath the McMurdo Ice Shelf (Dempsey, et al., 2010). This sub-ice platelet layer is an important ingredient for the sea ice formation and morphology of sea ice in this area (Rack, et al., 2013).
Studies have discovered a diverse macrofaunal benthic community beneath the McMurdo Ice Shelf at a depth of 188m and 8km back from the ice shelf front. The general habitat at this location is fine sediment with occasional dropstones. Dominant taxa observed were polychaetes and brittle stars, with alcyonacean soft corals and anemones on hard substrates. Gelatinous animals were abundant near the seafloor, and possibly part of a food web that supports the benthic community (Kim, 2019).

The McMurdo Ice Shelf is covered in places with a large amount of debris or “dirty ice” which leads to surface ablation and the creation of numerous meltwater ponds and streams (Figure 95). These aquatic bodies vary in size, shape and physicochemical conditions, even though some are only a few metres apart (Jungblut, et al., 2005). These aquatic bodies are colonised by thick, cyanobacterium-dominated mats (de los Rios, et al., 2004) and have been postulated as providing evidence for Cryogenian biological refugia (Hawes, et al., 2018).

Figure 95: Meltwater ponds on the surface of the McMurdo Ice Shelf among the debris field.

Southern McMurdo Sound is characterised by relatively persistent, multi-year sea ice. However, this does break out sporadically allowing for some calving of ice-bergs from the front of the ice-shelf (Banwell, et al., 2017). The sea ice in front of Pram Point has been multi-year sea ice in some years. Natural sea ice break-out occurs every few years and in some years the sea ice is single year sea ice. The tidal movement causes the sea ice to flex and buckle forming pressure ridges throughout the summer season. It is through these cracks that Weddell seals haul out to pup.

The USAP operates two airfields in McMurdo Sound (COMNAP AFIM, 2020). Phoenix Airfield, located on the McMurdo Ice Shelf was commissioned in 2016 and supports wheel and ski aircraft operating from New Zealand throughout the summer season (September to February). Phoenix runway is comprised of heavily compacted snow. Williams Field, also located on the McMurdo Ice Shelf, supports ski aircraft only. It operates from December to February and is utilised by LC-130 and Twin Otter ski-equipped aircraft.

5.7 Wilderness and aesthetic values

While the Antarctic Treaty System does not formally define wilderness, the general understanding of the term is of remoteness and a relative absence of both people and indications of past and present human presence or activity (Tin, et al., 2008). The International Union for Conservation of Nature defines wilderness as “large unmodified or slightly modified areas that retain their natural character without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition” (Dudley, et al., 2013).

As such, all of Antarctica can be considered as wilderness, except for areas modified by human activity such as the construction of infrastructure (Summerson & Bishop, 2012). Hut Point Peninsula is a highly disturbed environment. The infrastructure supporting both stations and the airfields contribute to diminishing the wilderness attributes of the place. Yet, Hut Point Peninsula is located within wilderness and Scott Base’s compact and colourful appearance contrasts starkly with the surrounding vast landscape views, such as Mount Erebus, the Ross Ice Shelf and the Trans Antarctic Mountains (Figure

96).

The measurement of Pram Point and Crater Hill's aesthetic value is a qualitative exercise. Heritage values are also associated with Ross Island, Hut Point Peninsula and Pram Point and the Scott Base buildings. Operational, safety and practical requirements, rather than a focus on aesthetic values, have driven the successive construction and improvements projects at Scott Base. The original Scott Base was painted with a mixture of orange, red and yellow. In 1965, Scott Base was repainted green, in keeping with the image of the New Zealand landscape and it remains green today. Both colour schemes give the buildings high visibility in the Antarctic landscape. The assemblage of buildings, storage containers and vehicles on Pram Point and the resulting noise and dust emissions create an industrious atmosphere that contrasts highly with the wilderness of the surrounding landscape.

Looking up from Scott Base, the Crater Hill wind turbines protrude from the landscape and interrupt the line of sight. They are visible from most of Hut Point Peninsula and from the ice shelf.

Figure 96: Scott Base and the surrounding landscape, Castle Rock and Mt Erebus in background.

5.8 Value of Pram Point for scientific research

Several long-term smonitoring studies have been maintained since 1957, as a consequence of establishing Scott Base during the IGY (Section 1.4). The LTS installations found at Scott Base are clustered in a science area to the west of the station (Figure 97).

Since 1960, scientists and technical staff from Scott Base have also maintained several 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 and a certified Global Atmosphere Watch 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. Arrival Heights is designated as ASPA 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.

Figure 97: Long-term science installations at Scott Base

5.9 Areas with special values

5.9.1 Specially Protected Areas, Managed Areas and Historic Sites

Nine ASPAs have been designated on Ross Island, including two that are located within 4km of Scott Base (ASPA 122 and 158) (
Table 41, Figure 98).

One ASMA is found in the wider Ross Sea region, the McMurdo Dry Valleys (ASMA 2) (Figure 98). The Dry Valleys are the largest ice-free area in Antarctica and the ASMA covers 17,500 km^2. Four ASPAs are designated within the Dry Valleys ASMA.

There are 11 HSMS on Ross Island (Figure 99). One is found at Scott Base, HSM 75 Hut A (the TAE Hut). The other Ross Island HSMs are:

- HSM 15: Shackleton's Hut (within ASPA 157);
- HSM 17: Cross on Wind Vane Hill (within ASPA 155);
- HSM 18: Scott's Discovery Hut (within ASPA 158);
- HSM 19: George Vince's Cross;
- HSM 20: Observation Hill Cross;
- HSM 21: Wilson's Stone Igloo;
- HSM 54: Richard Byrd's Bust;
- HSM 69: Discovery's Message Post;
- HSM 73: Mount Erebus Cross (near ASPA 156); and
- HSM 85: Plaque Commemorating the PM-3A Nuclear Power Plant at McMurdo Station.

Table 41: Ross Island Antarctic Specially Protected Areas.

ASPA No.	Name	Location	Area	Description
122	Arrival Heights	Hut Point Peninsula	0.73km²	The area is a natural and electromagnetically quiet site offering ideal conditions for the installation of sensitive instruments for recording data associated with upper atmosphere research programmes. The ASPA is near the full logistic support of nearby McMurdo Station and Scott Base
158	Hut Point	Hut Point Peninsula	N/A	Hut Point is a small ice-free area protruding south-west from the Hut Point Peninsula and situated to the west of McMurdo Station. The ASPA consists solely of the structure of the hut which is situated near the south western extremity of Hut Point. The hut is one of the principal sites of the Heroic Age of Antarctic exploration, being built during the National Antarctic (Discovery) Expedition in 1901-1904, and used again by other expeditions in 1907-1909, 1910-1913, and 1914-1917
124	Cape Crozier	Cape Crozier	72.21 km²	The area supports rich bird and mammal fauna, microfauna and microflora. The ecosystem depends on a substantial mixing of marine and terrestrial elements of outstanding scientific interest. Protection is afforded to the long-term studies of the population dynamics and social behaviour of Emperor and Adélie penguin colonies; as well as skua populations and vegetation assemblages
156	Lewis Bay	Mount Erebus	14.41 km²	The Area was the site of an Air New Zealand aircraft crash on 28 November 1979 into the northern slope of Mount Erebus. The designated Area encompasses the crash zone and the surrounding glacial ice 2km above and to either side of this position. The Area is to be kept protected as a mark of respect, in remembrance of the victims of the tragedy and to protect the site's emotional values

ASPA No.	Name	Location	Area	Description
116	New College Valley	Caughley Beach, Cape Bird	0.34 km²	New College Valley is located south of Cape Bird on ice-free slopes above Caughley Beach, which lies between two Adélie penguin rookeries known as the Cape Bird Northern and Middle Rookeries. The area is the site of the most extensive and luxuriant stands of moss, algae, and lichens in southern Victoria Land; the terrestrial ecosystem within the site is the subject of long-term research. The Restricted Zone is a conservation reserve with more stringent access conditions
175	High Altitude Geotherm al site	Mount Erebus	0.265 km²	High altitude geothermal sites are vulnerable to the introduction of new species, particularly from human vectors, as they present an environment where organisms typical of more temperate regions can survive. These once isolated sites are now more frequently visited by humans for science and recreation, both of which require logistical support. Species from sites within Antarctica, and locally non-native to geothermal sites, or from regions away from Antarctica, may inadvertently be introduced to the Area through human activity. High altitude geothermal sites are also vulnerable to physical damage to the substrate from trampling and over-sampling because changes in the soil structure can affect the location and rate of steam emissions in which biological communities occur. The limited extent and fragility of these biological communities highlights the need for protection
121	Cape Royds	Cape Royds	0.62 km²	The area supports the most southerly established Adélie penguin colony known. The site was specially protected to allow the penguin population to recover and protect on-going science programmes. The colony remains of high scientific and ecological value and as such merits continued long-term special protection, especially given ongoing visits to Cape Royds from nearby stations and tourist groups
157	Backdoor Bay	Cape Royds	0.04km²	The area is one of the principal sites of the Heroic Age of Antarctic exploration and it contains historic structures and relics pertaining to this era. Some of the earliest advances in the study of earth sciences, meteorology, flora and fauna in Antarctica are associated with the 1907-1909 British Antarctic (Nimrod) Expedition which was based at this site. The hut was also used by the Ross Sea Party of the Imperial Trans-Antarctic Expedition of 1914-1917. As such, the site has high historical, cultural and scientific significance
155	Cape Evans	Cape Evans	0.06km²	The site is one of the principal sites of the Heroic Age of Antarctic exploration; it contains historic structures and relics of this era. Some of the earliest advances in Antarctic science are associated with the R.F. Scott Terra Nova Expedition, and as such, the site has considerable historical, cultural and scientific significance. It was subsequently used as a base by the Ross Sea party of Sir Ernest Shackleton's Imperial Trans-Antarctic Expedition of 1914-1917

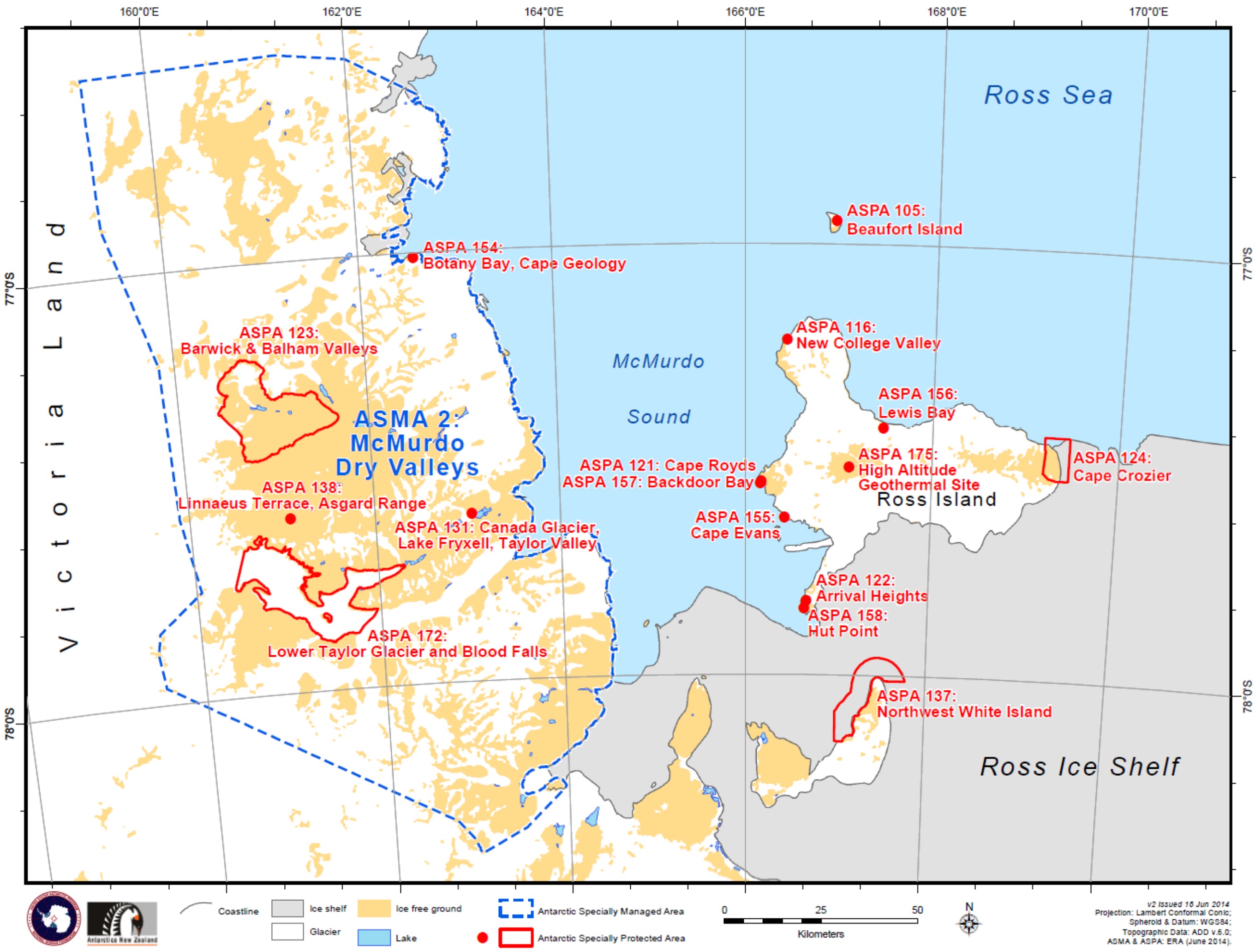


Figure 98: Antarctic Specially Protected Areas and Antarctic Specially Managed Areas in McMurdo Sound.

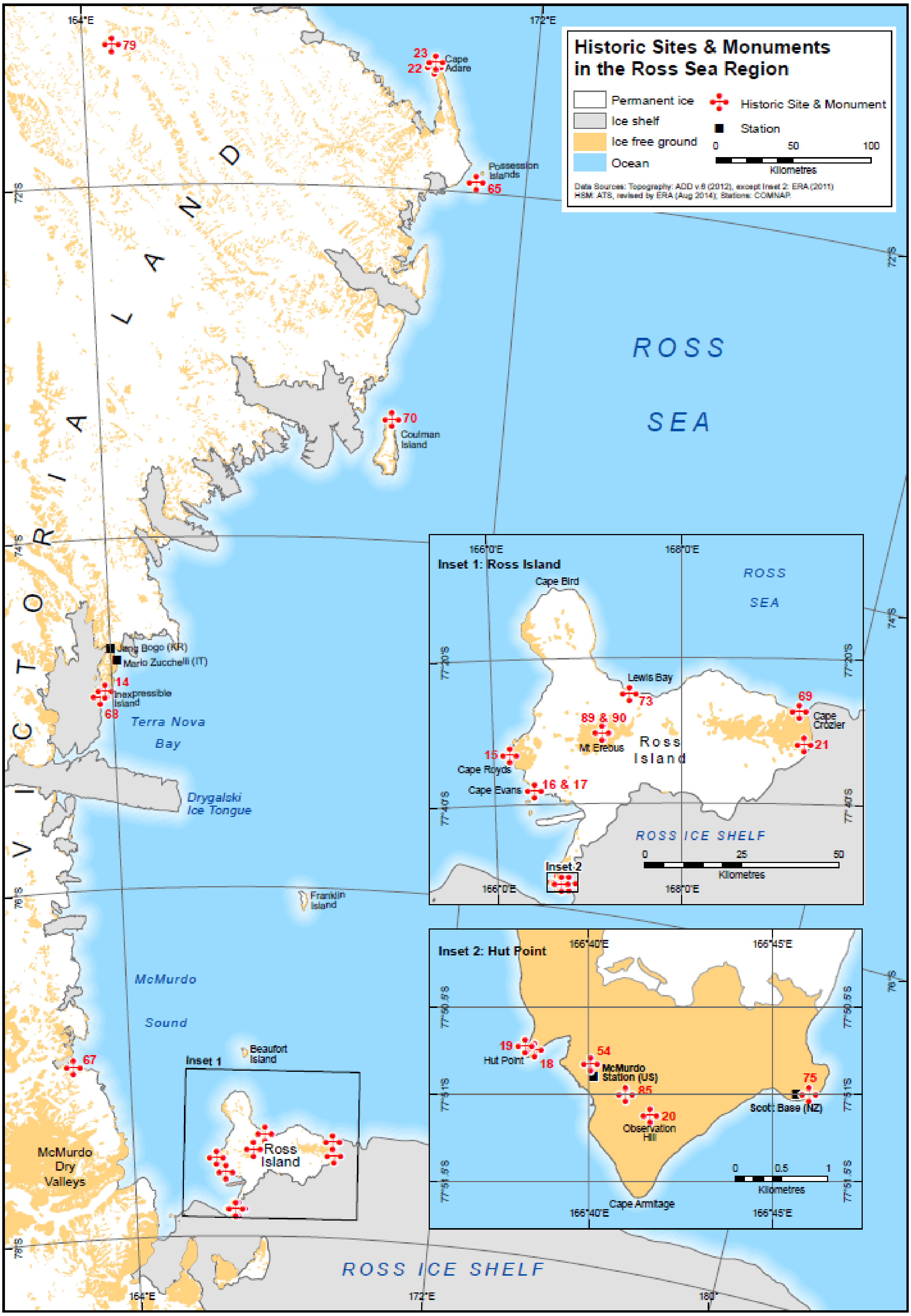


Figure 99: HSMs in the Ross Sea region.

5.9.2 Marine Protected Area

The Ross Sea is considered to be the anthropogenically least-affected stretch of ocean remaining on Earth (Ballard, et al., 2012). Most of the Ross Sea continental shelf (the largest continental shelf ecosystem south of the Antarctic Polar Front), including the productive shelf break and slope areas, is now protected by the Ross Sea MPA (Figure 100). The majority of the Area (1.12 of 1.55 million square kilometres, including key features such as the Balleny Islands and Scott Seamount), is a no-take zone (GPZ in Figure 100). Other zones provide for research fishing (KRZ and SRZ in Figure 100).

The objectives of the Ross Sea MPA are (CCAMLR, 2016):

1. to conserve natural ecological structure, dynamics and function throughout the Ross Sea region at all levels of biological organisation, by protecting habitats that are important to native mammals, birds, fishes and invertebrates;
2. to provide reference areas for monitoring natural variability and long-term change, and in particular a Special Research Zone, in which fishing is limited to better gauge the ecosystem effects of climate change and fishing, to provide other opportunities for better understanding the Antarctic marine ecosystem, to underpin the Antarctic toothfish stock assessment by contributing to a robust tagging program, and to improve understanding of toothfish distribution and movement within the Ross Sea region;
3. to promote research and other scientific activities (including monitoring) focused on marine living resources;
4. to conserve biodiversity by protecting representative portions of benthic and pelagic marine environments in areas where fewer data exist to define more specific protection objectives;
5. to protect large-scale ecosystem processes responsible for the productivity and functional integrity of the ecosystem;
6. to protect core distributions of trophically dominant pelagic prey species;
7. to protect core foraging areas for land-based top predators or those that may experience direct trophic competition from fisheries;
8. to protect coastal locations of particular ecological importance;
9. to protect areas of importance in the life cycle of Antarctic toothfish;
10. to protect known rare or vulnerable benthic habitats; and
11. to promote research and scientific understanding of krill, including in the Krill Research Zone in the north western Ross Sea region.

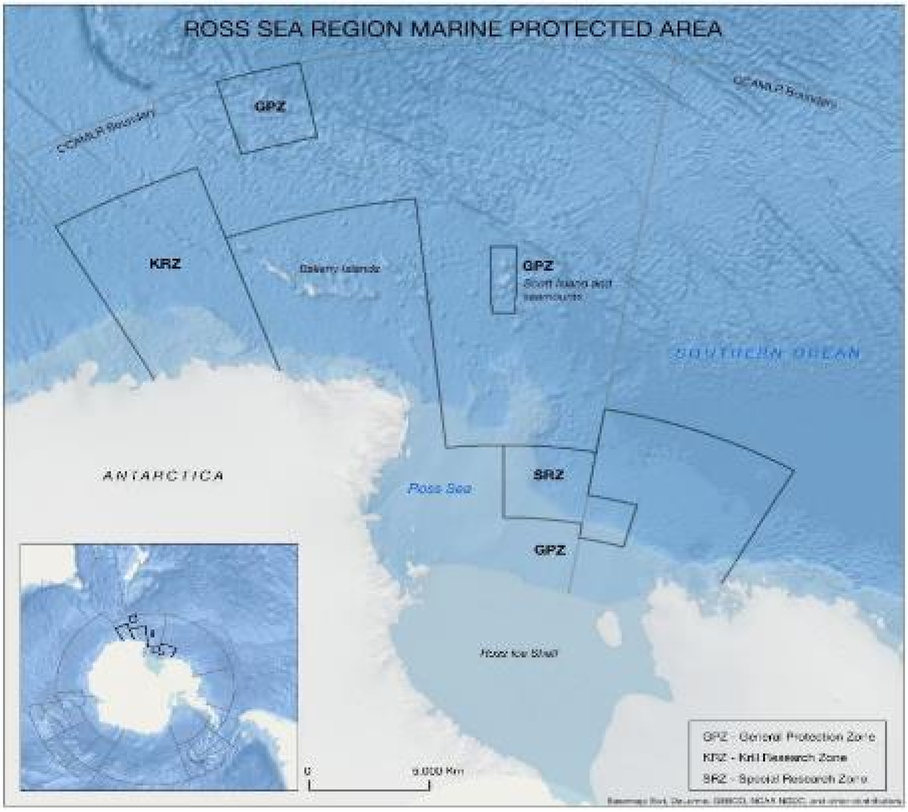


Figure 100: Ross Sea region Marine Protected Area.

5.10 Spatial and temporal variability of environmental sensitivity

In broad terms, environmental sensitivity is greater in summer, which is also the period of greatest human activity (Table 42). These times of heightened sensitivity overlap with the peak period for human activity, with regular flights and the greatest intensity of vehicle movements and outdoor activity occurring from the start of October to the end of February.

Female Weddell seals give birth in mid to late-October and pups are nursed for 5 to 8 weeks until late November to December (Eisert, et al., 2013). Non-lactating adults do not appear to have lower health when exposed to human disturbance (Mellish, et al., 2010). However, irregular pedestrian traffic has been found to increase alert responses in lactating females and pups (Van Polanen-Petel, et al., 2008). Although most seals move into pack ice north of Ross Island during the winter, some remain in McMurdo Sound including Pram Point (Testa, 1994).

Ross Island skuas lay eggs during late November and early December, with chicks hatching around mid-December and early January. The juveniles begin to fledge in early February and the last birds do not leave until early April (Wilson, et al., 2017).

During winter, soils are frozen and covered with snow. From late November or early December through to January and sometimes into early February, snow cover melts and the soil thaws. Soil temperatures at Scott Base have reached 12 degrees (at 2cm depth, recorded in 2014)[36]. At these times the soil is more vulnerable to disturbance and compaction and contaminants can be mobilised by surface or subsurface meltwater. Exposed, as opposed to snow covered, vegetation is also more susceptible to damage from foot traffic or other activity.

[36] https://www.nrcs.usda.gov/wps/portal/nrcs/research/soils/survey/climate/?code=101110116000000

Table 42: Temporal sensitivity at Scott Base.

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Summer operational period												
Seal pups born and nursed												
Skuas nesting /chicks present												
Reduced snow cover and soil thaw												

Spatial sensitivity relates to many of the same factors as temporal sensitivity: skua nesting, seal pups and exposed soils and vegetation. Skua nests occur in the restricted science area west of the buildings. Seals pup gather amongst the pressure ridges immediately offshore from Pram Point, south and east of the buildings. The specific location of sea ice openings and seal haul out sites vary from year to year. As shown in Figure 79, vegetation occurs throughout the slopes northwest of the station. As shown in Figure 76, soils in the immediate operational area are already compacted and disturbed. However, more sensitive, relatively undisturbed soils exist to the west of the buildings in the science restricted zone, up slope towards the Scott Base-McMurdo Road and from the helicopter pad restricted zone east of the station to the shoreline.

5.11 Environmental state in the absence of the activity

Pram Point has been the site of human activities for the past 60 years. In the absence of the proposed Scott Base Redevelopment, the immediate vicinity of Scott Base will remain physically impacted. Existing contamination by hydrocarbons will gradually reduce over time, as natural processes degrade them. Without the proposed activities, Scott Base operations would continue as they are now, with the addition of increased maintenance until the station must be decommissioned, or another alternative is chosen. The current impacts on the environment would therefore continue for some time. For example, levels of disturbance to skua and seals can be expected to stay the same with current National Antarctic Programme activities. Additional impacts should be expected to arise in the absence of the project. Indeed, it is likely that new spills and leaks would occur as the station infrastructure continues to degrade and fuel tanks, fuel lines and fittings are not upgraded.

Crater Hill is also a site of human activities and would remain so in the absence of the wind farm replacement. Local impacts associated with maintenance of the current wind farm would continue, until the wind farm is decommissioned and/or replaced with an alternative project. GHG emissions would increase without the wind farm replacement, as both Scott Base and McMurdo Station increase their energy demand and fossil fuel consumption.

As discussed in Chapter 4, not proceeding with the RIWE replacement would lead to increased burning of fossil fuel and an increased contribution to climate change.
Climate change would impact the environmental states of Pram Point and Crater Hill. Impacts of climate change in the absence of the proposed activities include a warming local climate, changes in permafrost depth and active layer, sea ice presence/absence and thickness, stability of ice shelves and mean sea level (Levy, et al., 2020).

6 Impact assessment

6.1 Introduction

Chapters 1 to 4 of this draft CEE described the activities of the proposed Scott Base Redevelopment and RIWE replacement including the need, purpose, location, duration, intensity, and possible alternatives (Article 3(2)(a) of Annex 1). Chapter 5 provided a summary of the initial environmental reference state of Pram Point and Crater Hill for which predicted impacts of the activities will be assessed (Article 3(2)(b) of Annex 1).

Article 3(2) (c-i) of Annex I of the Protocol requires CEEs to provide:

i. A description of the methods and data used to forecast the impacts of the proposed activity;
ii. An estimation of the nature, extent, duration, and intensity of the likely direct impacts of the proposed activity;
iii. Consideration of cumulative impacts of the proposed activity in the light of existing activities and other known planned activities;
iv. Identification of measures, including monitoring programmes, that could be taken to minimise or mitigate impacts of the proposed activity and to detect unforeseen impacts and that could provide early warning of any adverse effects of the activity as well as to deal promptly and effectively with accidents;
v. Identification of unavoidable impacts of the proposed activity; and
vi. Consideration of the effects of the proposed activity on the conduct of scientific research and on other existing uses and values.

The Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1, (2016)) provides guidance on how to identify environmental aspects, identify environmental impacts, including indirect and cumulative impacts, evaluate the significance of those impacts and identify measures to minimise or mitigate environmental impacts.

This chapter describes the methodology and undertakes an impact assessment for the proposed activities associated with the Scott Base Redevelopment and the RIWE replacement. The terms used in this chapter follow the definitions set out in the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1 (2016)).

6.2 Methodology

For the Scott Base Redevelopment and RIWE replacement project, the potential environmental impact of the proposed activities was assessed using a four-step analysis involving:

1. Identifying the **aspects**; the ways in which a proposed activity can interact with the environment, for example an output released to, or a removal from the environment, such as emissions, dust, noise, introduced species, etc.;
2. Identifying the **receptors**; the elements of the environment that may be affected, including the atmosphere, terrestrial, cryosphere, and marine environments, as well as intrinsic values, the value of Antarctica for scientific research and areas with special value;
3. Identifying the **impacts**; the change in environmental values or resources attributable to a human activity; and
4. Assessing the **significance** of the identified potential impacts by considering their spatial extent, duration, intensity and probability of occurrence – with reference to the three levels of significance identified by Article 8(1) of the Protocol (less than, no more than, or more than a minor or transitory impact).

The proposed the Scott Base Redevelopment and RIWE replacement project are described in Chapters 2 and 3. The proposed activities have been divided into project component areas to identify aspects and potentially impacted receptors. For each of these component areas, the specific high-level activities were identified (Table 43). All of the component activities include the use of plant, vehicles and generators and have therefore been listed once for brevity.

The proposed activities include:

- Deconstruction of the old station;
- Civil and foundation works;
- Enabling works; and
- Project logistics and installation of the proposed station.
- RIWE replacement

Table 43: Scott Base Redevelopment and RIWE replacement project components and high-level activities.

Project component	Activities	Seasons
All project components – listed once for brevity	Operation of vehicles, plant and generators throughout all activities on Ross Island including maintenance, refuelling, repairs	2021/22 to 2027/28
Deconstruction of the existing Scott Base Section 2.7	Deconstruction of current buildings and infrastructure and removal to New Zealand	2024/25 (Phase 1) - 2026/27 (Phase 2)
Civil and foundation works Section 2.8	Earthworks (drilling, blasting, crushing and placing of materials) in the project footprint area on Pram Point	2022/23 to 2025/26
	All foundation installations for the proposed new buildings, temporary base and temporary wharf	2023/24 to 2024/25
Enabling works Sections 2.9, 2.10, 2.13	Water intake and wastewater outlet construction	2023/24
	Temporary wharf installation	2024/25 and 2025/26
	Temporary base construction and operation	2023/24 to 2026/27
	Bulk fuel tanks installation and commissioning	2023/24
Project logistics and installation of the new station Sections 2.11-2.12	Transport by air of people and cargo from New Zealand to Antarctica	2021/22 to 2027/28
	Transport by ship of people and cargo from New Zealand to Antarctica (i.e. icebreaker, cargo ship and MC Class vessel)	2022/23 to 2026/27
	Icebreaker activities (i.e. icebreaker channel cutting from Winter Quarters Bay to Pram Point)	2025/26
	Importation of people, plant, buildings, fuel and other cargo	2021/22 to 2027/28
	Staging of cargo, break bulk and waste	2021/22 to 2027/28
	Offload of buildings from ship to land (i.e. MC Class vessel at Pram Point connected to the temporary wharf and use of SPMTs)	2025/26
	Installation and commissioning activities of the new station	2025/26 to 2026/27
RIWE replacement Chapter 3	Civil works on Crater Hill including earthworks and road improvements (drilling, blasting, crushing and placing of materials)	2023/24 to 2025/26
	Deconstruction of the old wind turbines	2024/25
	Installation of the new foundations	2024/25
	Installation of the new turbines and ancillary plant	2024/25 to 2025/26

6.2.1 Identifying the aspects

The identified potential environmental aspects expected to arise from the Scott Base Redevelopment and RIWE replacement project are summarised in Table 44. They are adapted from the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1 (2016)) to reflect the project's location and proposed activities. The potential aspects of the Scott Base Redevelopment and RIWE replacement proposed activities were considered and are presented in Table 46.

Table 44: Potential aspects expected to arise from Scott Base Redevelopment and RIWE replacement activities.

Environmental aspect	Definition
Atmospheric emissions	Discharge of emissions to the atmosphere (including GHG and particulates) from engines, generators, plant, etc.
Generation of dust	Discharge of dust from mechanical action with ice-free areas.
Noise (and vibration) emissions	Sound and vibration arising from activities in water, on land or in the air from the operation of plant (e.g. ships, small boats, aircraft, plant, equipment), from individuals or groups of people, and earthwork activities.
Interaction with ice-free ground	Direct or indirect contact with ice-free land by foot traffic, vehicles, plant, equipment, earthworks, mechanical action, etc.
Release of hazardous substances	Leaks or spills of oil or oily wastes to the environment, including the subsequent movement of such substances.
Release of waste	Release or loss of any wastes (including asbestos), sewage, chemicals, noxious substances, pollutants, equipment or presence of toxic coatings (e.g. antifouling on hulls).
Interaction with water and sea ice	Disturbance to the water column. Direct breaking of sea ice with a vessel. Altered wave action. Use of the water (i.e. water production).
Anchoring	Interaction with the seafloor or coastal mooring sites from deploying and retrieving anchors and anchor chains.
Interaction with wildlife	Direct or indirect contact with, or approach to, wildlife (i.e. marine mammals and birds).
Interaction with terrestrial flora and microfauna	Direct or indirect contact with terrestrial flora and microfauna or controls on flora and microfauna abundance (e.g. altered water availability).
Interaction with marine benthic flora and fauna	Direct or indirect contact with marine benthic flora and fauna or controls on marine flora and fauna abundance (e.g. sediment, water quality).
Transfer of non-native species	Unintended introduction to the Ross Sea region of species not native to that region, and the movement of species within Antarctica from one biogeographic region to any other.
Interaction with areas of special value	Direct or indirect contact with special places (e.g. ASPAs, ASMAs, HSMs, MPA), historic artefacts and taking of artefacts.
Interaction with scientific stations or scientific research	Direct or indirect contact with science equipment, monitoring or research sites and with station activities.
Presence	The presence of people and human-made objects in the Antarctic environment, including the interaction with intrinsic values.

6.2.2 Identifying the receptors

The environmental receptors that have the potential to be affected by the proposed Scott Base Redevelopment and RIWE replacement are summarised in Table 45.

Table 45: Environmental receptors that may be impacted by the proposed activities.

Environmental element	Environmental receptor
Atmosphere	Atmosphere
Terrestrial	Topography
	Soil quality
	Meltwater
	Flora and microfauna
	Birds
Cryosphere	Sea ice
	Ice shelf
Marine	Nearshore benthos
	Nearshore flora and fauna (i.e. epifauna)
	Marine mammals (i.e. seals and whales)
Intrinsic values	Wilderness values
	Aesthetic values
Scientific research	Scientific research support capacity
	LTS monitoring sites and instruments
Areas with special values	Special places (e.g. ASPAs, ASMAs, HSMs, MPA),

Table 47 identifies the potential interactions between aspects arising from the proposed activities and environmental receptors. Interactions have the potential to result in a change in the environmental receptor, leading to an impact.

Table 46: The potential environmental aspects of the Scott Base Redevelopment and RIWE replacement proposed activities.

Project component	Activities	Atmospheric emissions	Generation of dust	Noise/vibration emissions	Interaction with ice-free ground	Release of hazardous substances	Release of waste	Interaction with water and sea ice	Anchoring	Interaction with wildlife	Interaction with terrestrial flora and microfauna	Interaction with marine benthic flora and fauna	Transfer of non-native species	Interaction with areas with special value	Interaction with scientific stations or research	Presence
All project components – listed once for brevity	Operation of vehicles, plant and generators throughout all activities on Ross Island including maintenance, refuelling, repairs	X	X	X	X	X									X	X
Deconstruction of the existing Scott Base, Section 2.7	Deconstruction of current buildings and infrastructure and removal to New Zealand					X	X							X	X	X
Civil and foundation works Section 2.8	Earthworks (drilling, blasting, crushing and placing of materials) in the project footprint area on Pram Point		X	X	X	X					X	X		X	X	X
	All foundation installations for the proposed new buildings, temporary base and temporary wharf		X			X									X	X
Enabling works Section 2.9	Water intake and wastewater outlet construction			X				X				X		X	X	X
	Temporary wharf installation		X	X				X							X	X
	Temporary base construction and operation	X				X	X	X							X	X
	Bulk fuel tanks installation and commissioning					X									X	X
Project logistics and installation of the new station Sections 2.11-12	Transport by air of people and cargo from New Zealand to Antarctica	X													X	X
	Transport by ship of people and cargo from New Zealand to Antarctica (i.e. icebreaker, cargo ship and MC Class vessel)	X				X		X	X	X			X	X	X	X
	Icebreaker activities (i.e. icebreaker channel cutting from Winter Quarters Bay to Pram Point)			X				X		X		X			X	X
	Importation of people, plant, buildings, fuel and other cargo						X						X		X	X
	Staging of cargo, break bulk and waste				X										X	X
	Offload of buildings from ship to land (i.e. MC Class vessel at Pram Point connected to the temporary wharf and use of SPMTs)	X		X										X	X	X
	Installation and commissioning activities of the new station						X								X	X
RIWE replacement Chapter 3	Operations of vehicles, plant, generators at Crater Hill throughout the project	X			X	X								X	X	X
	Civil works on Crater Hill including earthworks and road improvements (drilling, blasting, crushing and placing of materials)				X									X	X	X
	Deconstruction of the old wind turbines					X	X							X	X	X
	Installation of the new foundations					X								X	X	X
	Installation of the new turbines													X	X	X

Table 47: The environmental receptors susceptible to the environmental aspects from the Scott Base Redevelopment and RIWE replacement activities.

Environmental Aspects	Environmental Elements/Receptors															
	Atmosphere	Terrestrial					Cryosphere		Marine			Intrinsic Values		Scientific Research		Areas with special values
	Atmosphere	Topography	Soil quality	Meltwater	Flora and microfauna	Birds	Sea ice	Ice shelf	Nearshore benthos	Nearshore flora and fauna (epifauna)	Marine mammals	Wilderness values	Aesthetic values	Scientific research support capacity	LTS monitoring sites and instruments	Specially protected areas, managed areas and historic sites
Atmospheric emissions	X		X		X							X	X		X	
Generation of dust				X	X		X	X	X	X		X	X		X	
Noise (and vibration) emissions											X	X	X		X	X
Interaction with ice-free ground		X	X	X	X				X	X		X	X		X	
Release of hazardous substances			X	X	X		X		X	X	X	X	X			X
Release of waste			X	X	X				X	X	X	X	X			X
Interaction with water and sea ice							X	X	X	X	X	X	X			X
Anchoring									X	X		X	X			
Interaction with wildlife						X					X	X	X			
Interaction with terrestrial flora and microfauna					X							X	X			
Interaction with marine benthic flora and fauna									X	X		X	X			
Transfer of non-native species					X					X		X	X			X
Interaction with areas with special value												X	X		X	X
Interaction with scientific stations or scientific research														X	X	X
Presence (including interaction with intrinsic values)												X	X	X	X	

6.2.3 Identifying the environmental impacts

The interactions between environmental aspects and environmental receptors result in the potential for environmental impacts to arise. A single environmental aspect can have several environmental impacts.

This assessment considers different types of impacts: direct, indirect and cumulative impacts. The following definitions are used to describe the different types of impact:

- A **direct impact** is a change in environmental values or resources that results from direct cause-effect consequences of interaction between an environmental receptor and an activity or action (e.g. the generation of dust landing on ice surfaces changing the albedo);
- An **indirect impact** is a change in environmental values or resources that results from interactions between the environment and other impacts - direct or indirect (e.g. dust landing on ice surfaces changes the albedo, leading to increases in meltwater runoff and the transport/deposition of soil and any contaminants to the marine environment). Indirect impacts may not be known until a direct impact occurs; and
- A **cumulative impact** is the combined impact of past, present and reasonably foreseeable future activities. Cumulative impacts may occur over time and should be assessed by looking at other human activities occurring in the proposed locations (e.g. the generation of dust from road movements causes dust to land on the soil, smothering the local flora and microfauna and changing their abundance and distribution). As with indirect impacts, cumulative impacts may not be identified until a direct impact has occurred.

The potential direct, indirect and cumulative environmental impacts that may occur as a result of the Scott Base Redevelopment and RIWE replacement proposed activities were identified following the methodology described in Section 6.2. The identified potential impacts are discussed on each of the environmental receptors are described below.

6.3 Impacts associated with the proposed activities

6.3.1 Impacts on the atmosphere

Potential Impact: Direct and Cumulative

The release of atmospheric emissions including GHG and particulates to the atmosphere is expected to occur at all stages of the Scott Base Redevelopment and RIWE replacement project. It will continue into the operational phase of the proposed Scott Base from the use of vehicles (including SPMTs), plant, and generators and from the use of aircraft and ships (including an icebreaker) for transporting people and cargo between New Zealand and Antarctica. The operation of the temporary base and continued operations throughout the project will also result in the release of emissions to the atmosphere from the use of vehicles, plant and generators.

The direct release of emissions to the atmosphere can impact on local air quality. Increased activity results in increased emissions locally.

The direct and cumulative impacts of the release of emissions to the atmosphere are a contribution to global climate change. Emissions to the air from the combustion of fossil fuels produce several GHG such as carbon dioxide (CO_2), volatile organic compounds including PAHs, particulates (such as black carbon), oxides of nitrogen (NO_X) and sulphur (SO_X). These gases all contribute to atmospheric warming in combination with all other global GHG emissions (IPCC, 2018). Since the mid-twentieth century there has been an unprecedented rapid increase in atmospheric CO_2 concentration. In February 2020, atmospheric CO_2 measure at Mauna Loa, Hawaii was 416.08 ppm, the highest concentration ever recorded. CO_2 had not been over 400ppm for several millennia. The increased level of CO_2 has resulted in a global temperature increase of 0.9˚C since the industrial revolution in the late 1800s (IPCC, 2014). Further global average temperature rises are anticipated (Brown & Caldeira, 2017), with a wide range of anticipated social, ecological, environmental and economic implications (IPCC, 2014).

The GHG emissions emitted from the proposed Scott Base Redevelopment and RIWE replacement activities will be measured by Antarctica New Zealand's carbon management system, currently accredited through the Toitū carbonreduce programme[37] whereby emissions are measured and a reduction plan is in place. The total estimated GHG emissions for the Scott Base Redevelopment and RIWE replacement project is expected to be approximately 44,557.9 tonnes of carbon dioxide equivalent (tCO_2e) (Table 48).

Table 48: Estimated GHG emissions for Scott Base Redevelopment and RIWE replacement project.

Emission source	Estimated total units	Estimated total footprint (tCO_2e)
Plant, vehicles and equipment	3.3×10^6 Litres AN8	8,669
SPMT	55,000 Litres AN8	145
Shipping cargo	1,798 TEU	11,318
Marine fuel (MC Class vessel)	1,000 tonnes	3,1560
Waste to landfill	395.44 tonnes	463
Passenger transport	348 passengers	192
Icebreaker	1 season of ice breaking	20,612
Temporary base operation	383,000 Litres AN8	1006
Total		**45,564**

6.3.2 Impacts on the terrestrial environment

Topography
Potential Impact: Direct, Indirect and Cumulative

Impacts to the topography of Pram Point and Crater Hill may occur at all stages of the proposed Scott Base Redevelopment and RIWE replacement project. These impacts would result from any interaction with ice-free ground particularly through deconstruction of the existing Scott Base, civil and foundation works, enabling works, project logistics and installation of the new station and wind turbines. Bulk earthworks are estimated to impact an area of approximately 60,350 m^2, with volumes of approximately 70,000 m^3 being excavated, processed and used to reshape the site.

The direct impact predicted is an alteration to the topography of the landscape.
Any changes to the landscape of Pram Point and Crater Hill may directly impact on the wilderness and aesthetic values of the area and any value of the area for scientific research.

Indirect impacts of changes to the topography may include changes in the soil quality and permafrost, changes to meltwater drainage channels and snow accumulation areas and resulting changes to the distribution and abundance of terrestrial flora and microfauna. Open-water conditions around Pram Point may result in erosion of the shoreline and unplanned changes in the topography.

Any impacts on the topography of Pram Point and Crater Hill are cumulative to the significant and ongoing human impacts on the landscape from more than 60 years of operations.

[37] https://www.toitu.co.nz/

Soil quality
Potential Impact: Direct and Cumulative

The operational areas around Scott Base and Crater Hill become ice and snow-free for part of the summer. Impacts on the soil quality of Pram Point and Crater Hill may occur from any interaction with the ice-free ground resulting in physical disturbance, erosion, creation of new tracks and compaction, the direct deposition of contaminants and contamination from the release of hazardous substance or waste. These impacts may occur largely throughout the proposed Scott Base Redevelopment and RIWE replacement project mainly through the deconstruction of the existing station and wind turbines, civil and foundation works, enabling works, and project logistics and installation of the new station and turbines.

The direct impact of any interaction with ice-free ground is physical changes in the soil structure which can result in land subsidence, erosion, permafrost retreat and change to the chemical composition of the soil. More local disturbances may arise from the movement of vehicles and people, the staging of cargo and the operation of the temporary base which can all contribute to changes in the soil quality, release salts and impact on the permafrost. Areas that may be locally affected include the haul road and vehicle tracks, staging areas on Pram Point, in the Gap and Areas A, B and C of the temporary base (Figure 38).

Exhaust emissions containing contaminants will occur at all stages of the project across Pram Point. With the prevailing wind direction from the northeast, exhaust emissions dissipate in a south-westerly direction across Pram Point. They may settle on ice-free ground and directly impact soil quality.

The release of hazardous substances to the environment may occur in the event of a vehicle accident, breakdown or hazardous substances handling incident. Additional fuel for vehicles and generators will be imported to Pram Point to support the proposed activities. Accidental release of fuel, oil or oily wastes to Pram Point or Crater Hill would directly impact the soil quality. The indirect impact may be on the distribution and abundance of flora and microfauna and depending on the location and volume of any accidental release. Fuel may also be transported and deposited in the nearshore marine environment with potential indirect impacts on water quality, the benthic environment, epifauna and marine mammals.

A range of waste materials will be generated throughout the various stages of the proposed activities including demolition, human, food or recyclable waste (wood, metal, cardboard, plastics, etc.) and hazardous wastes. There are also known sites with historical ground contamination (see Chapters 1 and 5). Any earthworks and ground remediation activities have the potential to uncover unknown contaminated sites and release these wastes, directly impacting the soil quality of Pram Point and Crater Hill and indirectly impacting on the distribution and abundance of flora and microfauna (Stark, et al., 2005; Tin, et al., 2014; Tin, et al., 2009; Waller, et al., 2017; Reed, et al., 2018). Any change to the soil quality may directly impact on the wilderness and aesthetic values of the area and any value of the area for scientific research.

Any impacts on the soil quality of Pram Point and Crater Hill are cumulative to the significant and ongoing human impacts on the landscape from more than 60 years of operations.

Meltwater
Potential Impact: Direct, Indirect and Cumulative

Impacts on the meltwaters of Pram Point and Crater Hill may occur from any interaction with ice-free ground, contamination from the generation of dust and the release of hazardous substances and waste. These impacts may occur largely throughout the proposed Scott Base Redevelopment and RIWE replacement project but mainly through civil and foundation works, enabling works, and project logistics and installation of the new station. Civil works may change the meltwater drainage channels and the location and extend of snow accumulation areas.

Direct impacts on the quality (i.e. contamination) of the meltwater and run-off may result from the generation of dust that settles on the land and deposits contaminants; the accidental release of hazardous substances during any fuel handling activities from draining existing plant before deconstruction, fuel deliveries to the bulk tanks, fuel handling and refuelling and maintenance of vehicles.

Indirect impacts on meltwater pathways may be on the distribution and abundance of terrestrial flora and microfauna and changes to the erosion and sediment transfer to the marine environment as a result of new drainage pathways. Further indirect impacts may be the transport and deposition of contaminants into the nearshore marine environment, potentially impacting of the marine water quality, the benthic environment, epifauna and marine mammals.

Any impacts on meltwater pathways of Pram Point are cumulative to the significant and ongoing human impacts on the landscape from several decades of operations.

Flora and microfauna
Potential Impact: Direct and Cumulative

Impacts on the terrestrial flora and microfauna of Pram Point may occur from the generation of dust, any interaction with ice-free ground, the release of hazardous substances and waste and from the introduction of non-native species. These impacts may occur largely throughout the proposed Scott Base Redevelopment but mainly through the civil and foundation works, enabling works and project logistics.

Direct impacts on the terrestrial flora and microfauna may result from any interaction with ice-free ground where this biology exists. Physical alteration of the ground or trampling may permanently remove biota or change their distribution and abundance.

Direct impacts to these communities may arise from the generation of dust which may settle on and smother the biology. Indirect impacts may occur from the alteration of meltwater pathways and soil quality as a result of changes to the topography of Pram Point, which in turn can affect their distribution and abundance.

The generation of dust and changes to the soil quality and meltwater pathways (soil moisture) are major threats to extant biological communities (flora and microfauna). Dust settling on areas of terrestrial flora has the potential to smother the vegetation, leading to reduced photosynthetic rates or in extreme cases complete burial (Convey & Peck, 2019; Bargagli, 2005; Farmer, 1993) which in turns alters the presence of microfauna. Recent observations suggest that the absence of moss species in sites close to the Scott Base to McMurdo road is likely to be a consequence of elevated deposition of dust from vehicle activity (Beet & Lee, 2020).

The siting of the new station is to occur partly within the existing operational footprint. Direct impacts to the microfauna and flora that is within the new footprint may occur. The scientific research value of the area and of any monitoring plots lost to the proposed activities may be indirectly impacted.

The area affected by the road realignment is thought not to support notable biodiversity values but has not been surveyed due to its steepness. The Crater Hill site has no record of significant vegetation, likely due to the site being subject to human activities for many years.

Microbial distribution may also be directly and indirectly affected by dust and/or deposited contaminants (Elzay, et al., 2017). Microbial communities may be impacted by large-scale changes in land-use, water availability or temperature.

The terrestrial flora and microfauna may be directly impacted from any release of hazardous substances or waste. The impacts of accidentally released fuel (or other wastes) on terrestrial biota depend several factors, including the chemical properties of the spilt substance, its bioavailability and toxicity, the health of the biota and the consequences of any previous spills to the site (Raymond, et al., 2017). Antarctic terrestrial biota demonstrate differing sensitivities to hydrocarbons. Antarctic moss and algae may experience a breakdown or inhibition of biosynthesis of chlorophyll and carotenoids reducing photosynthetic efficiency (Nydahl, et al., 2015).

Hydrocarbon pollution has different effects on Antarctic terrestrial microbial communities depending upon the history of contamination at the site. Numbers of hydrocarbon degraders are often low or below detection limits in pristine soils but can become elevated following a spill (Aislabie, et al., 2004), meaning that sites with a history of hydrocarbon contamination respond faster to spills, because hydrocarbon-degrading bacteria are already present in suitable numbers (Raymond, et al., 2017).

There are several reported examples of non-native species introductions and establishments into terrestrial Antarctic environments, almost all of which are attributed to human activity (Hughes, et al., 2015; Houghton, et al., 2016).

Most known Antarctic non-native species have been found within the Antarctic Peninsula region, but some have been reported from other areas of Antarctica (Frenot, et al., 2005; Hughes, et al., 2015). Changing climate conditions (particularly in West Antarctica) and growing human activity in the region increase the risk of further introductions and expansion of the range of already established non-native species (Chown, et al., 2012; Duffy, et al., 2017). Scientists and scientific research equipment have been identified as presenting a particularly high risk of introducing non-native species to Antarctica (Chown, et al., 2012).

The introduction and establishment of non-native species at Pram Point, if it were to occur and no response action was possible, may result in potential modifications to the local biodiversity.

Any changes to the terrestrial flora and microfauna of Pram Point and Crater Hill may directly impact on the wilderness and aesthetic values of the area and its value for scientific research.

6.3.3 Impacts on the cryosphere

Snow and ice surfaces (including land and sea ice)
Potential Impact: Direct

Impacts on the snow and ice surfaces may occur from the generation of dust from earthworks activities and the operation of vehicles and plant on ice-free ground.

Direct impacts on the sea ice may largely arise from the movement of ships breaking sea ice and generating waves. An icebreaker will extend the annual icebreaking activities from Winter Quarters Bay around Cape Armitage and directly in front of Pram Point. A large turning circle will be created to allow the MC Class vessel to manoeuvre in front of Pram Point to allow the ship to link up with the temporary wharf to offload the proposed Scott Base buildings.
The Weddell Seal colony that hauls out on the sea ice in front of Pram Point may be directly impacted

due to the loss of sea ice.

Ice shelf
Potential Impact: Indirect

Indirect impacts on the ice shelf may arise from the breaking of the sea ice in front of Pram Point and potentially, the earlier introduction of open-water conditions to the edge of the ice shelf. Localised accelerated melting of the ice shelf from exposure to relatively warm waters may occur as a result. Open-water conditions have a lower albedo than sea ice.

6.3.4 Impacts on the marine environment

Nearshore benthos
Potential Impact: Direct, Indirect and Cumulative

Impacts on the nearshore benthos may occur from the generation of dust and interaction with ice-free ground, potentially resulting in the increased loading of sediments into the marine environment. Hazardous substances and waste may accidentally be directly released into the marine environment or transported into it by meltwater run-off. A further source of impact may be interactions with the water column and benthos from ship activity and anchoring. Direct impacts may occur from specific activities during the proposed Scott Base Redevelopment and RIWE replacement project, particularly during civil and foundation works, enabling works (i.e. the installation of the water intake and wastewater outlet) and the use of ships. Indirect impacts may occur throughout the project activities.

Direct impacts on the nearshore benthos may include increased sediment loading from any increase in dust deposition and sediment run-off caused by interactions with the ice-free ground. As the topography and meltwater pathways change, sediment movement from the land to sea may change by altering current meltwater channels and increasing sediment transport to the marine environment.

The release of hazardous substances and waste in the terrestrial environment and subsequent transport to the marine environment may directly contaminate the nearshore benthic environment. Likewise, a spill in the marine environment may directly impact the nearshore benthic environment.

The discharge of wastewater into the local marine environment has the potential to introduce microbial pathogens (Hughes & Thompson, 2004a; Hughes, 2004b) with consequences for local wildlife (Smith & Riddle, 2009) as well as the release of micro-pollutants with bioaccumulation potential (Emnett, et al., 2015).

No untreated wastewater will be released directly into the Antarctic environment. The existing WWTP will continue to operate during Scott Base Redevelopment to support the temporary base. Increased volumes of wastewater are expected, in line with the increase in the temporary base population. As such, a slight decrease in effluent quality may occur, resulting in contamination of the nearshore benthos. Failure of the WWTP may require the short-term discharge of macerated effluent until the plant is repaired. There has been no failure requiring macerated effluent to be discharged in the past four years.

The movement of ships breaking sea ice and generating waves, propeller-induced turbidity and aeration in the water column, ship's wash contributing to coastal erosion, the re-suspension of sediments and ship anchoring may all directly impact on the nearshore benthos (Ellis, et al., 2005). The MC Class vessel that will be used to deliver the proposed Scott Base buildings will operate adjacent to the coast in relatively shallow water for short periods, with the potential to cause resuspension of sediments.

The forced exposure to wave action of the Pram Point coastline as a result of icebreaking activities may also result in some erosion and sediment release underwater.

Increased sediment loading in nearshore marine environments may have a range of impacts, including reduced light levels affecting algal photosynthetic ability as well as smothering of communities, with effects on benthic abundance and diversity (Miller, et al., 2002).

Nearshore flora and fauna (i.e. epifauna)
Potential Impact: Direct and Cumulative

Impacts on the nearshore flora and fauna may occur from the same environmental aspects and project activities as those for the nearshore benthos, with the addition of the introduction of non-native species.

Direct impacts on the nearshore flora and fauna may include smothering from any increased sediment loading into the marine environment. The release of hazardous substances, waste and the deposition of particulates or dust into the marine environment may directly contaminate the biota. Antarctic marine biota can take longer to respond to contaminants than related temperate biota, due to their lower metabolic rates and slower growth and development rates (Chapman, 2005). Life-cycle patterns and the life-cycle stage at which exposure occurs can also influence the impact of fuel on marine species (Raymond, et al., 2017).

Oil in Antarctic marine sediments has been demonstrated to persist for long periods of time (Powell, et al., 2010) and to influence recruitment and succession of macrofaunal (Thompson, et al., 2007) and microbial communities (Powell, et al., 2005). Significant impacts of oil on marine benthic communities adjacent to Hut Point Peninsula have been observed, including reduced diversity and dominance by tolerant species (Stark, et al., 2014).

Any interaction with the benthos from ship activities and anchoring (as described above) may directly damage the epifaunal community.

The introduction of a non-native species may indirectly impact the nearshore flora and fauna. Shipping is recognised as a major vector for the global transfer of non-native marine species. Marine species are routinely transferred through ballast water, hull fouling, in sea chests and on ancillary equipment such as launches, rescue boats, anchors, ropes etc. (Coutts & Dodgshun, 2007; Hewitt, et al., 2009).

Although invasions to high-latitude terrestrial ecosystems are now well described (Frenot, et al., 2005; Hughes, et al., 2015), the same is not true for marine systems. Recent studies have suggested some potential mechanisms for marine introductions to Antarctic coastlines, including with rafts of marine debris (Barnes & Fraser, 2003) and on vessel hulls (Lewis, et al., 2003; Lewis, et al., 2004; Hughes & Ashton, 2016). Together, these reports indicate that, despite the apparent isolation of the Southern Ocean, marine introductions can occur. To date, only a single non-native species establishment has been recorded within the Antarctic marine environment (Clayton, et al., 1997), though surveillance and monitoring of the Antarctic marine environment and marine vectors remains extremely limited (Hughes & Ashton, 2016). If marine species were introduced, the indirect impacts may include potential competition with native species, as well as a reduction in the research value at locations ‘contaminated’ with marine species that have been transferred to the region.

For vessels entering southern McMurdo Sound, the abrasive action of any ice already encountered is likely to have acted to strip away most of any fouling in deeper water, thus reducing some of the risk of introductions in shallower near-shore locations (Lewis, et al., 2004).

Cumulatively, such an occurrence would be further evidence of human-induced pressures on the Antarctic environment and Southern Ocean.

Marine mammals (i.e. seals and whales)
Potential Impact: Direct and Cumulative

There is limited wildlife in the vicinity of Pram Point, except for the Weddell seals and other marine mammals (pinnipeds and cetaceans) or birds (seabirds and penguins) that will transit through the area during periods of open water.

Impacts on marine mammals may occur from the generation of noise, the accidental release of hazardous substances and waste and any interaction with the marine environment including the water column or the sea ice. These impacts may occur largely throughout the proposed Scott Base Redevelopment and RIWE replacement project but mainly through the civil and foundation works, enabling works, ship activities and the installation of the new station.

Noise generated from sources on Pram Point potentially will propagate through either or both air and water. The generation of noise at Scott Base has the potential to directly impact the Weddell seals that haul out on the sea ice in front of Scott Base.

Noise impacts on marine mammals can be acute and chronic and include auditory impacts such as temporary or permanent hearing loss as well as non-auditory physiological effects, such as increased heart rate and respiration and general stress reaction. Behavioural effects vary greatly between species and noise characteristics but can result in, for example, abandonment of territory or reduced reproduction (National Research Council, 2003).

Human disturbance comprises anthropogenic activities that are typically non-lethal, but may cause short- and/or longer-term stress and fitness responses in wildlife (Coetzee & Chown, 2016). The visual presence of humans and vehicles (including the ice-breaking and heavy-lift vessels) may give rise to thedisturbance of wildlife.

Vertebrates at risk from fuel spilt at Pram Point include the Weddell Seals resident on the sea ice throughout the first months of the summer. Other transient marine mammals may also be exposed should a spill event occur later in the summer season, particularly if sea ice has receded and open-water conditions are present. There are very few reports of oiled wildlife in Antarctica (Ruoppolo, et al., 2013), with the most notable exception being the impacts arising from the grounding of the *Bahia Paraiso* in 1989 (Raymond, et al., 2017).

The movement of icebreakers through sea ice has been demonstrated to impact on ice-breeding seals included through the displacement and separation of mothers and pups, breakage of birth or nursery sites and vessel-seal collisions (Wilson, et al., 2017).

In general, disturbance effects on Antarctic wildlife appear to have been underestimated suggesting a more precautionary approach to activities near to wildlife is required (Coetzee & Chown, 2016).

6.3.5 Impacts on intrinsic values

Potential Impact: Direct and Cumulative

Impacts on intrinsic values may occur from all activities from the proposed Scott Base Redevelopment and RIWE replacement project. The obvious visible presence of people and human-made infrastructure has the potential to directly detract from, or reduce intrinsic Antarctic values; in particular the sense of wilderness and aesthetic appreciation of the area.

The CEP has discussed the concept of Antarctic wilderness value on several occasions (New Zealand, 2013; New Zealand, 2011), but to date a definition has not been agreed (Leihy, et al., 2020). Human activity and visible human presence in the vicinity of Pram Point dates back to 1902, when the British National Antarctic Expedition under the leadership of Captain R.F. Scott, established a hut on Hut Point. Continuous human presence and associated built infrastructure in the region has occurred since the United States established McMurdo Station in 1956 and New Zealand established Scott Base in 1957. Accordingly, the area of Hut Point Peninsula has been recorded recently as one of the more heavily visited areas in Antarctica (Leihy, et al., 2020).

The proposed Scott Base Redevelopment and the RIWE replacement, albeit on the same locations as the current infrastructure, may add to cumulative impacts from human presence in the region and the associated reduction in wilderness. The installation of the new wind turbines on Crater Hill, as well as the alteration in the topography of Pram Point and the new base facilities, all have the potential to impact on the aesthetic appreciation of the area. Studies have shown that human presence in coastal regions of Antarctica has a strong negative effect on aesthetic preferences (Summerson & Bishop, 2011).

6.3.6 Impacts on scientific research

Potential Impact: Direct and Indirect

The impacts on scientific research may occur from any Scott Base Redevelopment and RIWE replacement project activities where they interact with the ongoing New Zealand Antarctic programme and cause interference with the LTS experiments at both Pram Point and the nearby Arrival Heights (ASPA 122).

Direct impacts on the New Zealand Antarctic programme are likely to occur due to conflict for assets and resources, the constraints of undertaking a construction project and a science programme at the same location and changes to the science station and support facilities due to the deconstruction of the existing station. A temporary base will be constructed to minimise disruptions to the science programme. However, the site will be shared and construction activities may impact on normal operational activities.

In practice, some research projects may be deferred in the short term, or be supported in slightly different ways from normal operations. Overall, it is expected that scientific research will not be detrimentally affected in the medium or long-term and that the proposed activities will increase Scott Base's ability to support science.

Direct impacts were anticipated from the design and location of the proposed new station. The LTS experiments are being relocated to minimise the impact (Section 2.9.1). Nevertheless, the relocation has the potential for the disruption of the datasets and damage to the instrumentation. The bulk earthworks activities in particular have the potential to disrupt the LTS activities through the generation of noise, dust and vibration in proximity to the instruments. Indirect impacts may include a temporary reduction in the quality of datasets generated which may impact the scientific output related to the Scott Base Redevelopment time-period.

The proposed RIWE replacement and the operation of a larger wind farm have the potential to cause direct impacts to the research conducted at Arrival Heights (ASPA 122), including interference with experiments and the quality of datasets. Specific studies are required to quantify and develop appropriate mitigation measures for the impact, in collaboration with the research groups that use ASPA 122. Studies are likely to include visual assessment, noise modelling and electromagnetic radiation measurements. These will be commissioned provided that the proposed activities are granted approval and funding.

Indirect impacts on scientific research may occur where the proposed activities impact environmental receptors that are the object of research. Changes imposed on these receptors may diminish their value for scientific research.

6.3.7 Impact on areas with special value

Potential impact: Direct and cumulative

Impacts on areas with special values are possible from all activities of the proposed Scott Base Redevelopment and RIWE replacement project activities.

Shipping through the Ross Sea will transit through the Ross Sea MPA. Any accidental release of hazardous substances or waste, interactions with any wildlife or shipping incident may have a direct impact on the objectives of the MPA as described in Section 5.9.2.

As noted above, the RIWE replacement activities and operation of a new, larger wind farm has the potential to directly impact on the science experiments at the nearby Arrival Heights (ASPA 122).

Any impacts on the Ross Sea MPA and Arrival Heights may be cumulative to the ongoing human impacts on these areas from ongoing national programme and other operations.

Deconstruction of the existing station, civil and foundation works, enabling works, project logistics any future deconstruction of the new station may unintentionally directly and cumulatively impact the TAE Hut (HSM 75) which is located within the current operational area of Scott Base and cannot be relocated. Vehicle movements, the operation of excavators and other plant, as well as blasting activities in the vicinity of the TAE Hut all have the potential to cause physical or structural damage to the historic site. Damage may also occur from vibrations transmitted through the ground or the air from heavy plant traffic and blasting activities.

6.4 Impacts associated with the operation of the proposed Scott Base and RIWE

Once the proposed Scott Base Redevelopment and RIWE replacement project activities are completed, the annual operation and maintenance of Scott Base and RIWE, New Zealand Antarctic programme field infrastructure and logistic support for the science programme will be assessed as current, with periodic IEEs to account for programme-specific activities. The predicted impacts associated with the operation of the proposed Scott Base and RIWE are considered below. They are similar to those impacts as described in Antarctica New Zealand's current IEE. Similar environmental impacts are expected. A number of improvements, particularly regarding the remediation of contaminated land, improved energy efficiency and improved biosecurity and waste management practices are also expected to arise.

6.4.1 Impacts on the atmosphere

One of the design objectives of the Scott Base Redevelopment was to minimise energy use and to reduce the reliance on fossil fuels. The Green Star framework and the LCA were used to inform the energy efficiency of the design and planned operations and the upgrade of RIWE would support a reduction of the use of fossil fuels.

The proposed Scott Base is expected to use less energy per square metre compared to previous buildings. Improvements in the efficiency of water generation, lighting, heating and the contribution of RIWE will reduce the fossil fuel demand. The annual modelled emissions for the new base are between 48 and 480 tCO_2e, depending on whether RIWE can supply 80% or 98% of the electrical demand, for the all-electric mode. Over the 50-year planned lifetime of the proposed Scott Base, the total project GHG emissions are between 2,400 and 24,000 tCO_2e.

It is expected that the direct and cumulative impact of contributing to global climate change will be reduced against the current baseline.

6.4.2 Impacts on the terrestrial environment

Once the project is completed, the operational area is expected to be improved. Less materials will be stored outside, reducing the potential for the release of wastes. Fit for purpose roading, drainage channels that do not flow through the operational area, and better placement of services (e.g. cabling and fuel lines) will improve access and maintenance. Reduced snow clearance requirements and the remediation of contaminated land will reduce impacts on ice-free ground.

The frequency of incursions is expected to decrease. The station's ability to detect and contain them is expected to improve. This is thanks to the biosecurity controls for the proposed Scott Base (described in Chapter 2), specifically the separation of incoming and outgoing cargo, the provision of dedicated cleaning and inspection places and a review of operational procedures (outside the scope of the proposed activities).

The provision of a dedicated waste management facility inside the proposed station and an improved waste water treatment plant, is expected to reduce waste streams, with less waste being returned to New Zealand. Improved storage facilities reduce the potential for inadvertent waste being released to the environment.

The bulk fuel storage capacity of Scott Base is projected to increase from c.60,000L to 300,000L under the proposed design. The risk of a fuel spill will still be present and with more fuel stored on site, the intensity and extent of any potential contamination would increase. The mitigation measures include the provision of three bunded tanks, each containing two 50,000L separate inner chambers. This double-bund is intended to contain any internal leaks. Prevention of accidental contact by vehicles is provided by siting the tanks on a raised platform.

Fuel will be delivered by tanker from McMurdo Station by trained and competent operators. The Antarctica New Zealand Spill Prevention and Response Plan and the amount and type of spill response equipment will be reviewed to account for the new facilities. Spill response training will continue to be provided to Scott Base staff.

All construction activities are expected to significantly alter the local topography and soil quality and in turn impact on the local flora and microfauna. Ongoing station activities will continue to avoid encroaching on the ecological area adjacent to the operational area.

6.4.2.1 Risk of bird strike

There are no large breeding colonies of birds on or near Pram Point or Crater Hill. One or two breeding pairs of skua are occasionally observed on Pram Point. Other petrels and seabirds are not frequently seen on Pram Point or Crater Hill.

Nevertheless, the presence of larger, and up to four turbines on Crater Hill carries the potential for birds to come in contact with the turbine blades, likely resulting in death. There have been three instances of bird strike by snow petrels recorded since RIWE became operational. Occurrences of bird strike will continue to be monitored following the RIWE replacement.

6.4.3 Impacts on the cryosphere

The change in the local topography and new buildings are expected to alter the snow deposition and meltwater run-off areas. The buildings are designed to reduce the amount of snow accumulation around the station. Snow, and the subsequent meltwater support the local flora and microfauna. Changes to their distribution and abundance may occur.

It is expected that the road realignment and site layout changes should reduce the generation of dust from vehicles, reducing any potential impacts on snow, land and sea ice.

6.4.4 Impacts on the marine environment

The proposed wastewater treatment plant with MBR technology delivers best practice treatment levels that exceed the requirements of Annex 3, Article 5 to the Protocol and the Green Star targets. The final filtration stage in MBR technology is microfiltration of between 0.1-0.4μm, which is effective at filtering most bacterial pathogens (0.5-5μm) and microplastics (1μm- 5mm). These improvements against the current WWTP will enhance the quality of the discharged effluent. This will lead to reduced impacts on the nearshore marine benthos and flora and fauna (epifauna) and a reduced likelihood of the introduction of non-native species to the marine environment.

Post construction activities, it is expected the activities and noise (and vibration) levels will be similar to current, or reduced. Disturbance to local wildlife, particularly the Weddell Seal population is considered to be similar to current, or reduced.

Ongoing impacts to the marine environment are expected from ongoing wastewater effluent disposal. The water intake/brine return process for creating potable water is likely to have local impacts.

The location of the bulk fuel tanks has considered spill prevention and response. However, in the event of a significant accident or failure, resulting in a large quantity of spilt fuel, it is possible that the marine environment may be impacted due to the proximity of the tanks to the shoreline.

6.4.5 Impacts on intrinsic values

Following completion of the proposed Scott Base Redevelopment, the base will look vastly different from its previous iterations. The direct impact on intrinsic values may be a perpetuation of the alteration of wilderness and perception of aesthetic values imposed on Ross Island since the mid-1950s.

The new wind farm will have an increased visual footprint on the landscape. The impact is accepted given the reduction in fossil fuel use that the new RIWE will enable.

6.4.6 Impacts on scientific research

A benefit resulting from the project is the continuation and enhancement of New Zealand's ability to support science of global importance in Antarctica for the next 50 years. The proposed facilities, developed in collaboration with the New Zealand Antarctic science community, are expected to make scientific research at and from Scott Base more efficient, modern and reliable. The continuation of LTS experiments is testament to New Zealand's long-term commitment to scientific research at Scott Base.

6.4.7 Impacts on areas with special value

As noted, the RIWE replacement and the operation of a larger wind farm have the potential to cause direct impacts to the research conducted at Arrival Heights (ASPA 122). This includes interference with experiments and the quality of datasets. Until investigation into any impacts takes place, it is anticipated that a larger windfarm may impact on the science experiments at Arrival Heights.

Once the project is complete, no significant impacts on the TAE Hut (HSM 75) are expected.

6.5 Impact assessment

6.5.1 Methodology

The evaluation of the significance of potential impacts was assessed against four criteria: spatial extent, duration, intensity and the probability of their occurrence during the project (Article 3(2)(d), Annex I). Each activity is assigned an impact score against each impact criterion between one (Low) and four (Very High). The assessment criteria and the definition of impact are summarised in Table 49.

Table 49: Assessment criteria and definition for the evaluation of significance of environmental impacts.

Assessment Criteria	Low	Medium	High	Very High
	1	2	3	4
Spatial Extent - Area or volume where changes are likely to occur	**Site-specific**: Pram Point/Scott Base operational footprint/Crater Hill/the Gap Individuals are affected	**Local**: Hut Point Peninsula, Ross Island and the local marine environment, local ice shelf, more than one of the sites identified in "Low". Groups or colonies are affected	**Regional**: South Victoria Land (Biogeographic Conservation Region 9); Ross Sea and Ross Ice Shelf; A unique feature (e.g. HSM or ASPA) is affected Regional population affected	**Continental**: Antarctica and the Southern Ocean south of 60°S Major disturbance in community (e.g. breeding success is reduced)
Duration - Period during which changes in the environment are likely to occur	**Short term** Several weeks to one season; short compared to natural processes.	**Medium term** Several seasons up to 10 years; impacts are reversible.	**Long term** 10 years and more; impacts are reversible.	**Permanent**: Environment will suffer permanent impact.
Intensity - A measure of the amount of change imposed on the environment due to the activity	Natural functions and processes of the environment or value are minimally affected. Recovery definite	Natural functions or processes of the environment or value are affected but are not subject to long-lasting changes. Recovery likely	Natural functions or processes of the environment or value are affected or changed over the long term. Recovery slow and uncertain	Natural functions or processes of the environment or value are irreversibly and permanently disrupted. Recovery unlikely
Probability - Chance of the occurrence of the impact	Unlikely to occur under normal operation and conditions	Possible, can occur under normal operation and conditions	Likely to occur under normal circumstances	Almost certain to occur, history of regular occurrence

Impact significance is obtained by multiplying the impact score of each characteristic (e.g. 1 x 2 x 3 x 4 = 24). The overall impact score range is between 1 and 256, considering a score of all lows across each assessment criteria equal one (i.e. 1 x 1 x 1 x 1 = 1) and a score of all very high across each assessment criteria equals 256 (i.e. 4 x 4 x 4 x 4 = 256). This provides a simple means of impact comparison. The higher the number, the greater the environmental impact.

There are three impact significance levels (Low, Medium and High) which correspond to those outlined in Article 8(1) of the Protocol (Table 50):

- Low = Less than a minor or transitory impact;
- Medium = No more than a minor or transitory impact; and
- High = More than a minor or transitory impact.

Table 50: Scoring the significance of impacts.

Impact score	Impact level	Significance level (Article 8(1) of the Protocol)	Description
1 to 15	Low	Less than minor or transitory	• Impact likely to be managed through normal operating procedures Specific mitigation measures might be applied for new impacts
16 to 54	Medium	No more than minor or transitory	• Impact requires mitigation, ongoing monitoring and possible further treatment • Specific mitigation measures likely to be applied for new impacts
55 to 256	High	More than minor or transitory	• Further treatment options must be explored • Unavoidable impacts must be explained

The significance assessment of the environmental impact assessment is completed in three stages:

1. A current significance rating is calculated, which assumes normal operating conditions, including applicable Antarctica New Zealand's EMS mitigation measures;
2. The project or activity-specific mitigation measures are applied to the impact, where relevant. If an impact cannot be mitigated and is therefore accepted, this is explained; and
3. A residual significance rating is calculated following the application of the mitigation measures. The overall residual significance of all identified potential impacts informs the conclusions of this draft CEE.

6.5.2 Mitigation measures

The Guidelines for Environmental Impact Assessment in Antarctica states that an impact assessment process should consider measures to decrease, avoid, or eliminate any of the components of an impact on the environment, or on scientific research.

As part of the proposed Scott Base Redevelopment design process, the protection of the Antarctic environment has been a strategic objective of the project and consideration has been given to minimising environmental impacts throughout the process. Some specific preventative mitigation measures include:

- The existing highly impacted site was selected, rather than finding a new, less impacted, site.
- A bespoke tool to build a sustainable Antarctic station was developed by partnering with the New Zealand Green Building Council to develop a Greenstar certification rating tool;
- The options to upgrade the RIWE network to support either 80% or 100% renewable energy use by Scott Base – essentially, the station could be run on renewable energy reducing the usage and reliance on fossil fuels;
- Construction and ongoing operations, are restricted as far as possible, within the highly impacted operational area ensuring activities do not encroach into the less impacted site up the hill;
- A construction methodology was chosen that supports a build in New Zealand thereby minimising the transport of materials and waste between New Zealand and Antarctica and reducing the build time;
- Environmental evaluations, plans and requirements are being created and established with the

preferred main contractor;
- The existing operational area and some existing infrastructure will be utilised to establish a temporary base to support construction and continue operations from, to minimise impacts from the activity; and
- A full-time environmental advisor is part of the Scott Base Redevelopment project team.

The mitigation measures for the Scott Base Redevelopment and RIWE replacement project are proposed to be delivered through the existing Antarctica New Zealand's EMS and the Scott Base Redevelopment Construction Environmental Management Plan (CEMP).

6.5.2.1 Antarctica New Zealand's Environmental Management System

The planning and conduct of activities by Antarctica New Zealand closely follow the environmental principles outlined in the Protocol (1991), the Antarctica (Environmental Protection) Act (1994) and guidelines adopted by the Antarctic Treaty Parties.

Antarctica New Zealand is committed to minimising impacts on the environment. To achieve this, Antarctica New Zealand has developed an EMS. This system establishes organisational policies, objectives and targets (Figure 101) and sets out a series of processes and role-specific accountabilities to drive high environmental standards across all programme activities.

The purpose of the EMS is: *to undertake all our activities in a sustainable manner*. The EMS applies to all activities conducted 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 an EMS (ISO 14001:2015), and the provisions of the Protocol and the Antarctic Treaty System. The EMS is currently accredited under Toitū Envirocare, and preparations are underway to transition the EMS to the international standard ISO14001:2015, with certification planned for early 2021. An important component of the EMS is Antarctica New Zealand's carbon management system, which is certified under the Toitū carbonreduce programme, which means the programme has measured its carbon emissions and put measures in place to manage and reduce emissions where possible.

All Antarctica New Zealand staff working in Antarctica participate in a training programme before departure. They are introduced to the policies, procedures and guidelines used by Antarctica New Zealand.

Once in Antarctica, all personnel are required to complete Antarctic field training whereby practical demonstrations and experience is gained in minimising potential environmental impacts and operating safely in the Antarctic environment. For those visiting specially protected and managed areas, a briefing is provided to outline the provisions of the management plans for that area. The Environmental Code of Conduct (Appendix 4) is provided to all staff, workers and visitors, and it sets the requirements for managing one's impacts while in Antarctica.

The main policies, procedures and guidelines used by Antarctica New Zealand include:
- Environmental Management Policy;
- Biosecurity Policy;
- EMS Manual;
- Environmental Code of Conduct;
- Standard Operating Procedures and Guidelines (covering EIA, protected area management, interference with flora and fauna, biosecurity, and hazardous substance management);
- Manuals including: Field, Waste, and Hazardous substance and fuel spill prevention and

response manuals;

- Environmental guidelines for the operation of helicopters in the Ross Sea region;
- Antarctica New Zealand's Risk Management Framework and Reference Guides;
- Antarctica New Zealand's Critical Incident Management System manual;
- CEP guidance, procedures and ASPA/ASMA management plans; and
- SCAR Code of Conducts.

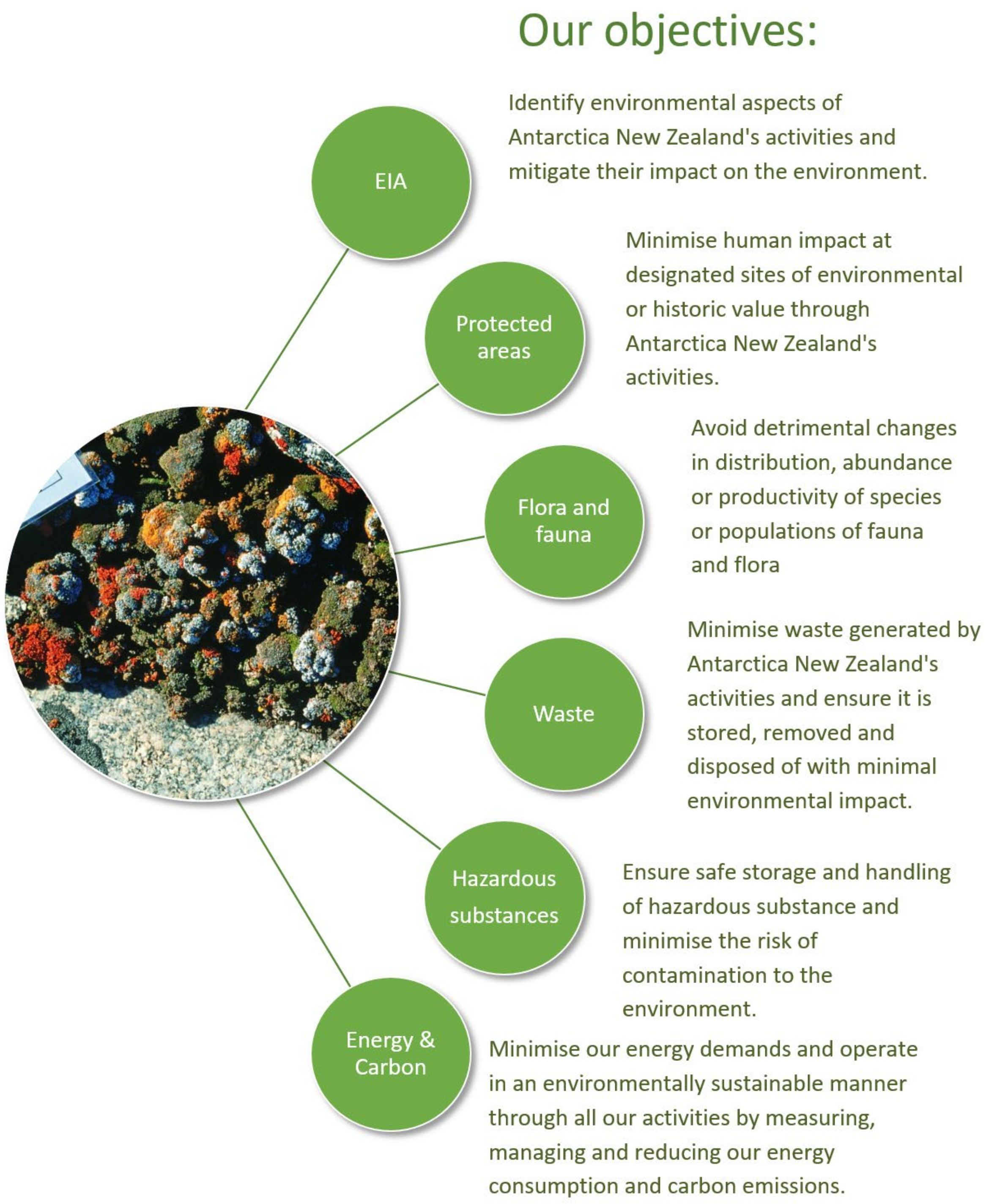


Figure 101: Antarctica New Zealand's Environmental Management System components and objectives.

6.5.2.2 Scott Base Redevelopment Construction Environmental Management Plan

For all construction activities, a CEMP is being developed by Antarctica New Zealand in collaboration with the preferred main contractor. The CEMP will be supported by several management plans which will outline the specific mechanisms for delivering the mitigation and monitoring measures. The main contractor will be required to follow the CEMP as identified in this draft CEE. The CEMP and supporting management plans were under development at the time of writing this draft CEE. Provided that funding for the proposed activities is granted, the management plans will be completed and a working paper will be presented to CEP XLIII to introduce them.

The suite of environmental management plans will include:

- Construction environmental management plan;
- Construction noise and vibration management plan;
- Biosecurity management plan;
- Erosion and sediment control plan;
- Contaminated site management plan;
- Waste management plan;
- Hazardous substances management plan;
- Wildlife management plan;
- Heritage management plan; and
- Emissions management plan.

Antarctica New Zealand will implement the CEMP, associated management plans and the CEE alongside the main contractor, shipping operator(s) and sub-contractors. Compliance with the requirements outlined in these documents will be monitored, periodically audited and reported on annually to the the Ministry of Foreign Affairs and Trade. Periodic updates will be provided to the CEP as necessary.

6.5.3 Significance assessment

The significance assessment for the proposed activities is presented in Table 51.

Table 51: Significance assessment for the proposed activities

Environmental element	Environmental receptor	Aspect	Activity	Impact description	Impact type	Extent	Duration	Intensity	Probability	Current impact significance	Mitigation measures	Extent	Duration	Intensity	Probability	Residual impact significance
Atmosphere	Atmosphere	Exhaust emissions from combustion engines	Operation of vehicles, plant and generators throughout the project, estimated 8,669 tCO_2e	Release of greenhouse gases contributing to global climate change	Direct Cumulative	2	3	2	4	48	Use of vehicles is accepted as unavoidable and no viable alternatives to fossil fuel are available yet. The Emissions Management Plan includes: • The use of vehicles, plant and generators will be minimised to the extent possible • Vehicles, plant and machinery will be serviced before shipping to Scott Base and regularly maintained once on site • New efficient models of machinery will be procured where applicable	2	3	2	4	48
			Transport of approximately 350 people and some cargo from Christchurch to Antarctica by air between 2021/22 and 2026/27, estimated 192 tCO_2e			3	3	2	4	72	There is no further mitigation available and no viable alternative to air travel for transporting project personnel to Ross Island • The proposed Scott Base has been designed to be constructed ex situ and shipped as modules. This will minimise the number of construction personnel required on site • Cargo will only be shipped by air as a last resort for emergency supplies • The number of personnel will be rationalised to minimise the number of movements	3	3	2	4	72
			Transport of cargo by ship. 8 rotations including 6 for a cargo ship, one for the MC Class vessel and one for an icebreaker between New Zealand and Ross Island, estimated 31,930 tCO_2e			3	3	2	4	72	The assessment assumes the highest impact scenario of New Zealand chartering a full ship for 5 rotations (versus shared ship with another National Antarctic Programme). One rotation is the MC Class vessel. • The proposed Scott Base has been designed to be constructed ex situ and shipped as modules to minimise shipping requirements • Combining SBR and the RIWE replacement offers shipping efficiencies • Opportunities to share shipping capacity with other National Antarctic Programmes will be explored	3	3	2	4	72
			Delivery and installation of the new buildings by SPMTs in 2025/26. Emissions of an estimated 145 tCO_2e			1	3	2	4	24	The construction methodology was chosen to minimise the duration and intensity of onsite activities • The SPMTs will be serviced before shipping them to Scott Base • Building module delivery extensively planned for minimal movements and efficiency	1	3	2	4	24
			Energy generation for the temporary base operations, from season 2023/24 to 2026/27			1	3	2	4	24	Renewable energy from the wind farm will be used where possible but it is accepted that containerised AN8 generators will provide the majority of the energy supply for the temporary base. The EMS specifies the following energy-saving measures: • Shower duration of 3 minutes maximum • Efficient use of laundry: full loads only, last load of washing is taken to New Zealand, not done at Scott Base • Vehicle use is planned and shared to minimise trips • Food waste is avoided to reduce the energy expenditure of transport, storage, preparation and disposal of food	1	3	2	4	24
Terrestrial	Pram Point Topography	Mechanical interaction with ice-free ground	Earthworks (drilling, blasting, crushing and placing of materials) in the project footprint area on Pram Point Seasons: 2022/23 to 2025/26	Changes to the physical landscape, retreat of permafrost	Direct Indirect Cumulative	2	4	4	4	128	The civil activities are confined to the minimal practical extent and concentrate on the Scott Base site which has been used for 60 years and has been subject to extensive disturbance. • Drill and blast detailed methodology will be planned to minimise overbreak requiring rework • Exposed permafrost will be covered with fill as quickly as practicable • Processing of material will be matched to the speed of the blasting to prevent rework and exposure of material • No earthworks will be permitted outside of the planned excavation area • The extent of activity will be controlled by prohibiting stockpiling or tracking of vehicles outside of the planned excavation area	2	4	4	4	128
		Increased exposure of shoreline to open water	Nearshore icebreaker activities at Pram Point, leading to exposure of the shoreline to wave action. MC Class vessel positioning and docking activities at temporary wharf. Season 2025/26	Erosion of the coastline leading to an unplanned change to the topography	Indirect	1	1	2	1	2	Icebreaking operations are confined to one season	1	1	2	1	2
	Crater Hill Topography	Mechanical interaction with ice-free ground	Civil works on Crater Hill including earthworks and road improvements (drilling, blasting, crushing and placing of materials) for the replacement of the wind turbines Season 2023/24	Changes to the physical landscape, retreat of permafrost	Direct Cumulative	1	4	4	4	64	• The activities are confined to the existing RIWE location and road to Crater Hill, which have been subject to impacts for several decades with significant disturbance • Earthworks are minimised through the use of the spider frame and foundation pad design	1	4	4	4	64
	Soil quality of Pram Point	Exhaust emissions from combustion engines	Operation of generators, plant and vehicles throughout the project	Deposition of contaminants and particulates, with loss of soil quality	Direct Cumulative	2	2	2	4	32	Use of vehicles is accepted as unavoidable and no viable alternatives to fossil fuel are available yet. • The use of vehicles, plant and machinery will be minimised to the extent possible • Vehicles, plant and machinery will be serviced before shipping to Scott Base and regularly maintained once on site • New efficient models of machinery will be procured where applicable	2	2	2	3	24
		Accidental release of hazardous substances	Refuelling of vehicles, plant, generators at the bulk fuel tanks and designated locations throughout the project	Contamination of local terrestrial environment with loss of soil quality	Direct Cumulative	2	2	2	2	16	• Requirements and guidelines in Resolution 1 (2014) - Fuel Storage and Handling and the COMNAP Fuel Manual will inform the hazardous substances management plan • Approved fuel handlers on-site will follow fuel procedures • Bunded refuelling sites will be in place for all refuelling activities • The existing Spill Prevention and Response Plan will be reviewed and updated for SBR operations • Spill response training will be provided • Spill response equipment will be available throughout the project	2	2	2	2	16
			Breakdown or crash during operation of vehicles, plant and generators throughout the project			1	2	2	2	8	• The existing Spill Prevention and Response Plan will be reviewed and updated as required for SBR operations • Spill response training will be provided • Spill response equipment will be available throughout the project • A maintenance plan will be in place for all vehicles, plant and generators	1	2	2	2	8
			Unexpected discovery of historic contamination, including hydrocarbons and asbestos during all civil and foundation works			1	2	2	3	12	The Contaminated site management plan will set out the process for the identification, containment and treatment of accidental discoveries. Removal and return to New Zealand of environmental contaminants is the preferred treatment option • Contaminated material found will be sorted and contained according to the type, human health and environmental risks • Contaminated material will be removed from the soil and returned to New Zealand if the act of doing so doesn't cause adverse environmental impacts	1	2	1	2	4
			Draining of building and plant fluids during deconstruction activities including removal of underground fuel lines			1	2	2	2	8	• Most of the draining activities will occur inside the buildings • All building and plant fluids in the deconstructed Scott Base will be decanted into appropriately lined, double-bunded containers • Removal of plant and pipework will be managed to prevent the release of fluids • Materials containing fluids will be appropriately cleaned and stored to prevent the release of material • Waste fluid barrels will be stored in a container according to hazardous types • All fluids will be returned to New Zealand for appropriate treatment or disposal	1	2	2	1	4

Environmental element	Environmental receptor	Aspect	Activity	Impact description	Impact type	Extent	Duration	Intensity	Probability	Current impact significance	Mitigation measures	Extent	Duration	Intensity	Probability	Residual impact significance
Terrestrial			Spill during the initial filling and subsequent refilling of the bulk fuel tanks			2	2	3	2	24	• Fuel will be delivered by tanker from McMurdo Station by trained and competent operators. • Fail-safe mechanisms are integrated into the refuelling point • Detailed procedures and training will be provided to the refuelling operator for the new design • A Spill Prevention and Response Plan is in place and spill training is provided. • Spill response equipment will be available and trained crew will perform tank filling. • A spill response exercise will be run before the initial tank filling.	2	2	3	1	12
			Spill in fuel reticulation system and handling operations at the temporary base			1	2	3	3	18	• Fuel will be delivered by tanker from McMurdo Station by trained and competent operators. • Detailed procedures and training will be provided to the refuelling operator for the new design • A Spill Prevention and Response Plan is in place and spill training is provided. • Spill response equipment will be available and trained crew will perform tank filling. • A spill response exercise will be run before the initial tank filling.	1	2	3	2	12
		Mechanical interaction with ice-free ground	Movement of people, vehicles and plant on ice-free ground outside of the earthwork areas All seasons	Changes to soil quality, release of salts, change to active layer of permafrost	Direct Cumulative	2	2	2	3	24	• Vehicles will be confined to designated work areas of Pram Point and to the Scott Base-McMurdo road. • Walking tracks are designated, all personnel must keep to them when outside the operational area	2	2	2	2	16
			Earthworks (drilling, blasting, crushing and placing of materials) in the project footprint area on Pram Point Seasons: 2022/23 to 2025/26			2	4	4	4	128	The civil activities are confined to the minimal practical extent and concentrate on an area which has been used for 60 years and has been subject to extensive disturbance. • Drill and blast detailed methodology will be planned to minimise overbreak requiring rework • Exposed permafrost will be covered with fill as quickly as practicable • Processing of material will be matched to the speed of the blasting to minimise rework and exposure of material • No earthworks will be permitted outside of the planned work area • No stockpiling or tracking of vehicles will be permitted outside of the planned excavation area	2	4	4	4	128
			Staging of waste and cargo for the entire project including waste materials from old station, cargo for new station, temporary base and RIWE on Pram Point and at the Gap All seasons: 2021/22 to 2027/28			2	2	2	4	32	• Staging will only take place in designated areas within previously or currently used locations (Pram Point, the Gap). • Staging areas will be maintained in a organised and tidy state • Materials will be stored in shipping containers or as bulk stores on the ground • All chemically active or hazardous material will be stored in appropriate containers	1	2	2	4	16
		Generation of waste materials with risk of release to the terrestrial environment	Deconstruction of current buildings and infrastructure Season 2024/25 (Phase 1) - Season 2026/27 (Phase 2)	Contamination of local terrestrial environment with loss of soil quality		2	2	2	4	32	• Deconstruction methodology will be controlled and progressive • The deconstruction speed will be matched to the speed of handling and storing of materials • All waste will be sorted and secured as it is generated • External deconstruction will carefully remove the cladding panels and immediately seal and stage them to prevent release of insulation material • A designated staging area will be established for wastes and materials • All waste will be carefully collected, stored and returned to New Zealand for recycling and disposal	2	2	2	2	16
			New buildings installation and commissioning activities, connection of the building modules and internal fittings of the buildings. Season 2025/26 and winter of 2026			2	2	2	3	24	• The offsite construction methodology minimises the probability of waste being released into the Antarctic environment • Temporary cladding on the building module ends will be constructed of plywood and be deconstructed to prevent the release of waste • External construction works are minimal due to the offsite construction • All remaining construction works will take place inside • The buildings will be sealed to complete the internal fit-out and prevent the accidental release of materials or waste	2	2	2	2	16
			Installation of the temporary base, Season 2023/24			2	1	2	2	8	The use of prefabricated and fabric structures minimises onsite construction activities and the probability of waste being released into the Antarctic environment. • Prefabricated modules and structures will be packaged in materials with a low risk of loss to the environment • No prohibited packaging will be used • All waste released to the environment must be recovered if safe to do so	2	1	2	2	8
			Waste handling and storage throughout the project areas, all seasons			2	2	2	3	24	All waste will be carefully collected, stored and returned to New Zealand according to the Waste management plan • All waste will be separated into streams based on type, hazards, and recycling purposes • All waste will be staged in designated locations in an ordered manner • All waste will be stored in shipping containers and returned to New Zealand • Handling and staging of waste will be conducted in a manner to prevent release • All chemically active or hazardous material will be stored in appropriate containers • All waste released to the environment must be recovered if safe to do so	2	2	1	2	8
			Spill of cement grout during pile installation Season 2024/25			1	2	1	3	6	• Grout will be produced in small batches indoors • Grout will be poured directly into the rock socket before pile installation • Any spilt grout will be recovered to the extent practicable	1	1	1	2	4
	Meltwater at Pram Point	Accidental release of hazardous substances	Draining of building and plant fluids during deconstruction activities including removal of underground fuel lines	Contamination of local meltwater streams during periods of snowmelt	Direct	1	2	2	3	12	• Most of the draining activities will occur inside the buildings • All building and plant fluids in the deconstructed Scott Base will be decanted into appropriately lined, double-bunded containers • Removal of plant and pipework will be managed to prevent the release of fluids • Materials containing fluids will be appropriately cleaned and stored to prevent the release of material • Waste fluid barrels will be stored in a container according to hazardous types • All fluids will be returned to New Zealand for appropriate treatment or disposal	1	2	2	2	8
			Refuelling of vehicles, plant, generators at the bulk fuel tanks and designated locations throughout the project			1	2	2	3	12	• Requirements and guidelines in Resolution 1 (2014) - Fuel Storage and Handling and the COMNAP Fuel Manual will inform the hazardous substances management plan • Fuel procedures will be followed by approved fuel handlers on site • Bunded refuelling sites will be in place for all refuelling activities • The existing Spill Prevention and Response Plan will be reviewed and updated for SBR operations • Spill response training will be provided • Spill response equipment will be available throughout the project	1	2	2	2	8

Environmental element	Environmental receptor	Aspect	Activity	Impact description	Impact type	Extent	Duration	Intensity	Probability	Current impact significance	Mitigation measures	Extent	Duration	Intensity	Probability	Residual impact significance
Terrestrial	Meltwater at Pram Point		Initial filling and subsequent refilling of the bulk fuel tanks			2	2	3	2	24	• Fuel will be delivered by tanker from McMurdo Station by trained and competent operators • Fail-safe mechanisms are integrated into the refuelling point • Detailed procedures and training will be provided to the refuelling operator for the new design • A Spill Prevention and Response Plan is in place and spill training is provided • Spill response equipment will be available and trained crew will perform tank filling • A spill response exercise will be run before the initial tank filling	2	2	3	1	12
			Fuel handling operations at the temporary base			1	2	3	3	18	• Fuel will be delivered by tanker from McMurdo Station by trained and competent operators • Detailed procedures and training will be provided to the refuelling operator for the new design • A Spill Prevention and Response Plan is in place and spill training is provided • Spill response equipment will be available and trained crew will perform tank filling • A spill response exercise will be run before the initial tank filling	1	2	3	2	12
		Mechanical interaction with ice-free ground	Earthworks (drilling, blasting, crushing and placing of materials) in the project footprint area on Pram Point Seasons: 2022/23 to 2025/26	Physical changes to meltwater pathways	Direct Cumulative	2	4	4	4	128	The civil activities are confined to the minimal practical extent and concentrate on the Scott Base site which has been used for 60 years and has been subject to extensive disturbance. • New water channels will be designed and constructed to prevent erosion and sediment entrainment • New water channels will discharge into existing water courses where practical • The generation of meltwater within the works site will be avoided by physical removal of snow where practical, and through the use of cut off drains above the earthworks area • Snow deposition will only occur in current operational snow deposition areas • No snow will be deposited on undisturbed land or in natural meltwater pathways	2	4	4	4	128
			Construction of drainage channels uphill of each new building			1	4	4	4	64		1	4	4	4	64
	Flora and microfauna at Pram Point	Exhaust emissions from combustion engines	Operation of generators, plant and vehicles throughout the project	Deposition of contaminants and particulates, leading to reduced photosynthetic rates, modification of local biodiversity and abundance.	Direct Cumulative	2	2	2	2	16	Use of vehicles is accepted as unavoidable and no viable alternatives to fossil fuel are available yet. • The use of vehicles, plant and machinery will be minimised to the extent possible • Vehicles, plant and machinery will be serviced before shipping to Scott Base and regularly maintained once on site • New efficient models of machinery will be procured where applicable	2	2	2	2	16
		Generation of fugitive dust	Operation of plant and vehicles throughout the project	Smothering or burial of flora and micro-fauna outside the project area, leading to reduced photosynthetic rates or burial, modification of local biodiversity and abundance.	Direct Cumulative	2	2	2	3	24	• Vehicles will be confined to designated work areas of Pram Point and to the McMurdo-Scott Base road. • Vehicle use will be minimised to the extent practicable. • Speed limits will be controlled at all times to minimise dust levels. • Haul roads and heavily tracked areas will be formed with low fines aggregate	2	2	2	2	16
			Earthworks (drilling, blasting, crushing and placing of materials) in the project footprint area on Pram Point Seasons: 2022/23 to 2025/26			2	3	3	4	72	Earthworks activities are unavoidable. They have been designed to be as minimal as practicable in volume and extent. • The drill and blast methodology will include controls to minimise dust and sediment releases, including the use of blast mats to contain the blast material • The material will be crushed, screened and placed as it is produced by blasting • Stockpiling will be avoided as far as practicable • Drop heights of aggregate will be minimised for the excavators and the loader • Equipment will be fitted with dust suppression equipment where available and practicable • Dust-generating activities will cease during high wind periods	2	3	2	3	36
		Mechanical interaction with flora and micro-fauna	Earthworks (drilling, blasting, crushing and placing of materials) in the project footprint area on Pram Point Seasons: 2022/23 to 2025/26	Physical damage or destruction, modification in the distribution, abundance or productivity of species or populations of flora and microfauna inside the project area	Direct	2	4	4	4	128	Operations are restricted to designated earthworks area. The impact has been minimised by keeping the activities on the same site, rather than relocating to a new location. However, the earthworks area does extend beyond the current operational area, into a zone that has received less disturbance in recent years • No earthworks will be permitted outside of the planned excavation area • No stockpiling or tracking of vehicles will be permitted outside of the planned excavation area • Personnel will only walk on existing tracks and in the operational area	2	4	4	4	128
		Accidental transfer of non-native species	Transport of cargo, people, personal luggage and materials from New Zealand to Antarctica by air and sea	Modification in the distribution, abundance or biodiversity of terrestrial flora and micro fauna	Indirect Cumulative	2	3	2	2	24	The Project biosecurity management plan will include: • pre-deployment inspections • pre-offload inspections • designated off-load and unpacking site • relevant personnel to be trained in biosecurity checks and incursion containment	2	3	2	1	12
	Crater Hill topography	Mechanical interaction with ice-free ground	Civil works on Crater Hill including earthworks and road improvements (drilling, blasting, crushing and placing of materials) for the replacement of the wind turbines Season 2023/24	Changes to the physical landscape, retreat of permafrost	Direct Cumulative	1	4	4	4	64	• The activities are confined to the existing RIWE location and road to Crater Hill, which have been subject to impacts for several decades with significant disturbance Earthworks are minimised through the use of the spider frame and foundation pad design	1	4	4	4	64
	Soil quality at Crater Hill	Exhaust emissions from combustion engines	Operation of generators, plant and vehicles throughout the proposed activities on Crater Hill including the road	Deposition of contaminants and particulates, with loss of soil quality	Direct Cumulative	1	2	2	3	12	Use of vehicles is accepted as unavoidable and no viable alternatives to fossil fuel are available yet • The use of vehicles, plant and machinery will be minimised to the extent possible • Vehicles, plant and machinery will be serviced before shipping to Scott Base and regularly maintained once on site • New efficient models of machinery will be procured where applicable	1	2	2	2	8
		Accidental release of hazardous substances	Refuelling of vehicles, plant, generators at the RIWE designated refuelling location throughout the project	Contamination of local terrestrial environment with loss of soil quality	Direct Cumulative	1	2	2	3	12	• Requirements and guidelines in Resolution 1 (2014) - Fuel Storage and Handling and the COMNAP Fuel Manual will inform the hazardous substances management plan • Fuel procedures will be followed by approved fuel handlers on site • Bunded refuelling sites will be in place for all refuelling activities • The existing Spill Prevention and Response Plan will be reviewed and updated for SBR operations • Spill response training will be provided • Spill response equipment will be available throughout the project	1	2	2	2	8
			Breakdown or crash during operation of vehicles, plant and generators throughout the project			2	2	1	3	12	• The existing Spill Prevention and Response Plan will be reviewed and updated as required for SBR operations • Spill response training will be provided • Spill response equipment will be available throughout the project •	2	2	1	2	8
			Draining of hydraulic oil during turbines deconstruction activities			1	2	2	3	12	• The hydraulic oil will be drained from the turbine into bunded double-skinned barrels • The barrels will be returned to New Zealand for disposal • Spill response equipment will be available during the activity, any spilt oil will be recovered to the extent practicable	1	2	2	2	8
			Spill of ice-bentonite grout during foundation anchors installation			1	2	2	2	8	• Grout will be produced in small batches in containers • Grout will not be in contact with the ground. It will be poured directly into the rock socket • Any spilt material will be recovered to the extent practicable	1	2	2	1	4

Environmental element	Environmental receptor	Aspect	Activity	Impact description	Impact type	Extent	Duration	Intensity	Probability	Current impact significance	Mitigation measures	Extent	Duration	Intensity	Probability	Residual impact significance
Terrestrial		Mechanical interaction with ice-free ground	Movement of vehicles and plant on Crater Hill's ice-free ground throughout the activities	Changes to soil quality, release of salts, change to depth to ice-cement	Direct Cumulative	1	2	3	3	18	Activities will be confined to designated work areas of Crater Hill. It is accepted that areas of previously undisturbed ground will be impacted.	1	2	3	3	18
			Civil works on Crater Hill including earthworks and road improvements (drilling, blasting, crushing and placing of materials) Season 2023/24			1	4	4	4	64	• The activities are confined to the existing RIWE location and road to Crater Hill, which have been subject to impacts for several decades with significant disturbance Earthworks are minimised through the use of the spider frame and foundation pad design					
		Generation of waste materials with risk of release to the environment	Deconstruction of the old turbines, removal of waste materials to containers Season 2024/25	Contamination of local terrestrial environment with loss of soil quality	Direct Cumulative	1	2	2	3	12	All waste will be carefully collected, stored and returned to New Zealand according to the Waste management plan. • All waste will be separated into streams based on type, hazards, and recycling purposes • All waste will be staged in designated locations in an ordered manner • All waste will be stored in shipping containers and returned to New Zealand • Handling and staging of waste will be conducted in a manner to prevent release • All chemically active or hazardous material will be stored in appropriate containers • All waste released to the environment must be recovered if safe to do so	1	2	2	2	8
	Meltwater at Crater Hill	Accidental release of hazardous substances	Draining of hydraulic oil during turbines deconstruction activities	Contamination of local meltwater streams during periods of snowmelt	Direct	1	2	2	3	12	• The hydraulic oil will be drained from the turbine into bunded double-skinned barrels • The barrels will be returned to New Zealand for disposal • Spill response equipment will be available during the activity. Any spilt oil will be recovered to the extent practicable	1	2	2	2	8
			Refuelling of vehicles, plant, generators at the RIWE designated refuelling location throughout the project			1	2	2	3	12	• Requirements and guidelines in Resolution 1 (2014) - Fuel Storage and Handling and the COMNAP Fuel Manual will inform the hazardous substances management plan • Fuel procedures will be followed by approved fuel handlers on site • Bunded refuelling sites will be in place for all refuelling activities • The existing Spill Prevention and Response Plan will be reviewed and updated for SBR operations • Spill response training will be provided; • Spill response equipment will be available throughout the project.	1	2	2	2	8
Cryosphere	Snow and ice surfaces including land ice, sea ice and ice shelf	Generation of fugitive dust	Operation of vehicles, plant and generators on ice-free ground near the shore throughout the project	Lowered albedo and increased melting of ice and snow surfaces, including sea ice	Direct	2	1	2	3	12	• Vehicles will be confined to designated work areas of Pram Point and the McMurdo-Scott Base road • Vehicle use will be minimised to the extent practicable • Speed limits will be controlled at all times to minimise dust levels • Haul roads and heavily tracked areas will be formed with low fines aggregate	2	1	2	2	8
			Earthworks (drilling, blasting, crushing and placing of materials) in the project footprint area on Pram Point Seasons: 2022/23 to 2025/26			2	2	2	3	24	Earthworks activities are unavoidable. They were designed to be as minimal as practicable in volume and extent • The drill and blast methodology will include controls to minimise dust and sediment releases, including the use of blast mats to contain the blast material • The material will be crushed, screened and placed as it is produced by blasting • Stockpiling will be avoided as far as practicable • Drop heights of aggregate will be minimised for the excavators and the loader • Equipment will be fitted with dust suppression equipment where available and practicable • Dust generating activities will cease during high wind periods	2	2	2	2	16
			Operation of machinery on engineered ground near the shoreline for the installation of the temporary wharf's frames and fenders Seasons 2024/25 and 2025/26			1	1	2	3	6	• Speed limits will be in place at all times to minimise dust levels • The activities will be stopped during high wind periods when excessive dust is generated	1	1	2	2	4
		Direct breaking of sea ice	Icebreaker activities between Winter Quarters Bay and Pram Point Season 2025/26	Artificial or early sea ice breakout	Direct Cumulative	2	1	3	4	24	Icebreaker support will be coordinated with the USAP annual shipping evolution and is therefore only assessed for the additional activities between Winter Quarters Bay and Pram Point Ice breaking operations are confined to one season	2	1	3	4	24
	Ice shelf	Direct breaking of sea ice	Icebreaker activities between Winter Quarters Bay and Pram Point Season 2025/26	Artificial exposure of the ice shelf to open water	Direct Cumulative	2	1	2	3	12	Icebreaking operations are confined to one season.	2	1	2	3	12
Marine	Nearshore benthos and benthic flora and fauna	Mechanical interaction with ice-free ground leading to release of sediment into water	Operation of vehicles, plant and generators on ice-free ground near the shore throughout the project	Contamination of the nearshore marine environment, smothering of nearshore flora and fauna, altered ecosystem performance	Direct Cumulative	2	2	2	2	16	• Vehicles will be confined to designated work areas of Pram Point and to the Scott Base- McMurdo road. • Vehicle tracks will not cross meltwater channels • Vehicle use will be minimised to the extent practicable • Speed limits will be controlled at all times to minimise dust, which may become sediment if entrained by water	2	2	1	2	8
			Earthworks activities (drilling, blasting, crushing and placing of materials) near the shore for the temporary wharf, water intake and outlet and Area B Seasons 2022/23 and 2023/24			2	3	3	3	54	Earthworks activities are unavoidable. They were designed to be as minimal as practicable in volume and extent. • The drill and blast methodology will include controls to minimise dust and sediment releases, including the use of blast mats to contain the blast material • Sediment controls will be used for work near the shore, or in meltwater pathways • Controls will be specific to the site and activities and include; sediment socks, drainage channels and bunds	2	2	3	2	24
		Accidental release of hazardous substances	Contaminated run-off resulting from spills and historical contamination on land entrained by meltwater	Contamination of the nearshore marine environment, increased toxicity, altered ecosystem performance	Indirect Cumulative	2	2	2	2	16	• Requirements and guidelines in Resolution 1 (2014) - Fuel Storage and Handling and the COMNAP Fuel Manual will inform the hazardous substances management plan • Fuel procedures will be followed by approved fuel handlers on site • Bunded refuelling sites will be in place for all refuelling activities • The existing Spill Prevention and Response Plan will be reviewed and updated for SBR operations • Spill response training will be provided • Spill response equipment will be available throughout the project.	2	2	2	1	8
			Breakdown or accident during operation of vehicles, plant and generators near the shore throughout the project		Direct Cumulative	2	2	1	2	8	• The existing Spill Prevention and Response Plan will be reviewed and updated as required for SBR operations • Spill response training will be provided • Spill response equipment will be available throughout the project	1	2	1	2	4
			Unpermitted discharges to sea from ship or icebreaker Season 2025/26			2	2	2	2	16	The shipping operators will be fully compliant with • International Marine Organisation regulations including: Polar Code which includes the Ballast Water Management Convention and Biofouling Guidelines • Antarctic Treaty System requirements including CEP Practical Guidelines for ballast water exchange in Antarctic waters	2	2	2	1	8
			Shipping incident with loss of fuel Season 2025/26			2	2	3	1	12	• Shipping operators are experienced in polar environments • Detailed shipping planning will be undertaken before voyages • All ships used will be seaworthy Weather and sea ice will be monitored throughout the activities, which may change according to the conditions	2	2	3	1	12

Environmental element	Environmental receptor	Aspect	Activity	Impact description	Impact type	Extent	Duration	Intensity	Probability	Current impact significance	Mitigation measures	Extent	Duration	Intensity	Probability	Residual impact significance
Marine	Nearshore benthos and benthic flora and fauna	Accidental release of hazardous substances	Deconstruction of current buildings and infrastructure Season 2024/25 (Phase 1) - Season 2026/27 (Phase 2)	Contamination of the nearshore marine environment, increased toxicity, altered ecosystem performance	Direct Cumulative	2	2	2	3	24	• Deconstruction methodology will be controlled and progressive • The deconstruction speed will be matched to the speed of handling and storing of materials • All waste will be sorted and secured as it is generated • External deconstruction will carefully remove the cladding panels and immediately seal and stage them to prevent the release of insulation material • A designated staging area will be established for wastes and materials • All waste will be carefully collected, stored and returned to New Zealand for recycling and disposal	2	2	2	2	16
		Generation of waste materials with potential for release to the marine environment	Waste handling and storage throughout the project areas, all seasons	Contamination of the nearshore marine environment, increased toxicity, altered ecosystem performance	Direct Cumulative	2	2	2	3	24	All waste will be carefully collected, stored and returned to New Zealand according to the Waste management plan • All waste will be separated into streams based on type, hazards, and recycling purposes • All waste will be staged in designated locations in an ordered manner • All waste will be stored in shipping containers and returned to New Zealand • Handling and staging of waste will be conducted in a manner to prevent release • All chemically active or hazardous material will be stored in appropriate containers • All waste released to the environment must be recovered if safe to do so	2	2	2	2	16
			Wastewater treatment for up to 160 occupants for up to four summer seasons and an average of 17occupants in winter seasons, leading to a decrease in the quality of the wastewater effluent, increase in discharge volumes			2	3	2	4	48	The existing WWTP plant will be used for the temporary base wastewater. The proposed minimum standard of treatment is primary treatment (solids removal and settling) during high occupation and tertiary (full treatment with ozone disinfection) during all other periods. Further options are under investigation, including using an auxiliary treatment plant to supplement the existing during the proposed activities.	2	3	2	3	36
		Interaction with water and ice	MC Class vessel positioning and anchoring at Pram Point, season 2025/25	Resuspension of sediments and increased turbidity leading to smothering of benthos	Direct	1	2	3	4	24	Ship operations at Pram Point are confined to one season.	1	2	3	4	24
		Anchoring	MC Class vessel positioning and anchoring at Pram Point, season 2025/25	Disturbance to flora and fauna, modification in the distribution, abundance or biodiversity	Direct	1	2	3	4	24	If sea ice conditions allow, sea ice anchors will be used instead of sea bed anchors.	1	2	3	4	24
		Accidental transfer of non-native species on ship hull or via unpermitted discharges	Transport of cargo by ship. 8 rotations including 6 for a cargo ship, one for the MC Class vessel and one for an icebreaker between New Zealand and Ross Island. All seasons: 2022/23 to 2026/27	Modification in the distribution, abundance or biodiversity of marine biodiversity.	Direct	4	2	2	2	32	The shipping operators will be fully compliant with: • International Marine Organisation regulations including: Polar Code which includes the Ballast Water Management Convention and Biofouling Guidelines. • Antarctic Treaty System requirements including CEP Practical Guidelines for ballast water exchange in Antarctic Waters and the CEP Non-Native Species Manual • No ballast water will be discharged in Antarctic waters	4	2	2	2	32
	Weddell seals hauled out on sea ice	Direct breaking of sea ice	Icebreaker activities between Winter Quarters Bay and Pram Point Season 2025/26	Reduction in available sea ice for hauling out, displacement of seals hauled out in the area	Direct	2	1	1	4	8	Icebreaking operations are confined to one season Ship operations will occur in late summer when the majority of seals have departed the area or have completed pupping and nursing.	2	1	1	4	8
		Generation of excessive noise	Operation of vehicles, plant and generators on ice-free ground near the shore throughout the project	Disturbance to seals hauled out on sea ice including during early season pupping and weaning stages	Direct Cumulative	2	2	2	3	24	• Antarctica New Zealand Code of Conduct requires vehicles to keep 200m away from all wildlife. • Vehicle operations will be restricted to Pram Point • Vehicles will be operated in a manner to minimise noise • Crews will be briefed on measures to avoid disturbance to seals • Regular seal observations will be undertaken to allow real-time adjustments in practice if disturbance is observed	2	2	2	2	16
			Earthworks (drilling, blasting, crushing and placing of materials) in the project footprint area on Pram Point Seasons: 2022/23 to 2025/26			2	2	2	3	24	• Blasting activities will not occur in the foreshore area during the seal pupping and nursing period • Antarctica New Zealand Code of Conduct requires vehicles to keep 200m away from all wildlife • Vehicle operations will be restricted to Pram Point, no travel on sea ice will occur • Vehicles will be operated in a manner to minimise noise • Crews will be briefed on measures to avoid disturbance to seals • Regular seal observations will be undertaken to allow real-time adjustments in practice if disturbance is observed	2	2	2	2	16
			Water intake and wastewater outlet construction Season 2023/24			2	1	2	3	12	• Antarctica New Zealand Code of Conduct requires vehicles to keep 200m away from all wildlife. • The operations are restricted to the shore, no work on sea ice or in water is planned. • 1-2 blasts only are planned for the activity • Crew will be briefed on measures to avoid disturbance to seals. • Regular seal observations will be undertaken to allow real time adjustments in practice if disturbance is observed.	2	1	2	2	8
			Temporary wharf: Installation of the temporary frames Seasons 2024/25 and 2025/26			2	2	2	3	24	• Antarctica New Zealand Code of Conduct requires vehicles to keep 200m away from all wildlife. • The operations are restricted to the shore, no work on sea ice or in water is planned. • Vehicles will be operated in a manner to minimise noise. • Crew will be briefed on measures to avoid disturbance to seals. • Regular seal observations will be undertaken to allow real time adjustments in practice if disturbance is observed.	2	2	2	2	16
		Disturbance from and direct contact with vessels	MC Class vessel and icebreaker activities (channel maintenance) between Winter Quarters Bay and Pram Point Season 2025/26	Injury or death resulting from collision between seal and vessel	Direct	1	4	4	1	16	Collision with seals will be avoided to the extent possible by adopting slow speeds to give the animals time to relocate.	1	4	4	1	16
	Marine mammals in open water conditions (Weddell seals and whales)	Generation of excessive noise	MC Class vessel and icebreaker activities (channel maintenance) between Winter Quarters Bay and Pram Point Season 2025/26	Disturbance to any marine mammals in areas of open sea	Direct Cumulative	2	1	2	4	16	Icebreaking operations are confined to one season	2	1	2	4	16
		Accidental release of hazardous substances	Unpermitted discharges to sea from ship or icebreaker Season 2025/26	Acute or chronic health effects from exposure to hazardous substances	Direct Cumulative	2	2	2	2	16	The shipping operators will be fully compliant with • International Marine Organisation regulations including: Polar Code which includes the Ballast Water Management Convention and Biofouling Guidelines • Antarctic Treaty System requirements including CEP Practical Guidelines for ballast water exchange in Antarctic waters	2	2	2	1	8
			Shipping incident with loss of fuel Season 2025/26			2	2	3	1	12	• Shipping operators are experienced in polar environments • Detailed shipping planning will be undertaken before voyages • All ships used will be seaworthy Weather and sea ice will be monitored throughout the activities, which may change according to the conditions	2	2	3	1	12

Environmental element	Environmental receptor	Aspect	Activity	Impact description	Impact type	Extent	Duration	Intensity	Probability	Current impact significance	Mitigation measures	Extent	Duration	Intensity	Probability	Residual impact significance
Intrinsic values	Wilderness and aesthetic values	Increased evidence of human presence on Ross Island	All project activities between Seasons 2021/22 and 2027/28 at Pram Point, Crater Hill on land and at sea	Diminution of wilderness and aesthetic values of Ross Island	Direct Cumulative	3	4	2	4	96	• The construction methodology was chosen to minimise the duration and intensity of on-site activities • The methodology reduces duration of on-site activities by up to five years compared to a traditional on-site build • The Scott Base Redevelopment and RIWE activities are aligned to reduce the duration of the impact	3	2	2	4	48
Areas with special values	HSM 75 TAE Hut	Physical interaction with vehicles, machinery or "rock throw"	Deconstruction of current buildings and infrastructure Season 2024/25 (Phase 1) - Season 2026/27 (Phase 2)	Physical damage to the building	Direct	3	2	2	2	24	• The Heritage Management Plan will define controls, including an exclusion zone around the HSM • Any activities undertaken near the TAE hut will be supervised by a 'spotter' to help the plant operator stay away from the building • The deconstruction sequence ends near the TAE Hut. Machinery will be able to use the cleared land to access the remaining structures, rather than operating close to the TAE Hut	3	2	2	1	12
			Earthworks (drilling, blasting, crushing and placing of materials) in the project footprint area on Pram Point Seasons: 2022/23 to 2025/26			3	2	2	3	36	• The Heritage Management Pan will define controls, including an exclusion zone around the HSM • Any activities undertaken near the TAE Hut will be supervised by a 'spotter' to help the plant operator stay away from the building • The drill and blast methodology will include the use of blast mats to prevent rock throw • Blasts near the TAE Hut will be designed to minimise disturbance. This can include smaller blasts, or specific spacing of blast locations	3	2	2	1	12
			Water intake and wastewater outlet construction Season 2023/24			3	2	2	2	24	• 1-2 blasts only are planned for the wastewater outlet. The water intake site is far enough away from the TAE Hut to present minimal risk • Drill and blast methodology will include controls to minimise risk to the TAE Hut including the use of blast mats • Blasts near the TAE Hut may be specially designed, including using smaller blasts • The Heritage Management Plan will define controls, including an exclusion zone around the HSM • An exclusion zone will be established around the TAE Hut • Any activities undertaken near the TAE Hut will be supervised by a 'spotter' to help the plant operator stay away from the building	3	2	2	1	12
			Delivery of the new station: MC Class vessel offload of the building modules and onload of cargo using SMPTs at Pram Point Season 2025/26			3	2	2	2	24	• The Heritage Management Plan will define controls, including an exclusion zone around the HSM • Any activities undertaken near the TAE Hut will be supervised by a 'spotter' to help the plant operator stay away from the building • Planning and modelling of the delivery is required and only trained and competent operators may pilot the SPMTs	3	2	2	1	12
		Generation of excessive vibrations	Delivery of the new station: MC Class vessel offload of the building modules and onload of cargo using SMPTs at Pram Point Season 2025/26			3	2	2	3	36	The Heritage Management Plan will define controls, including an exclusion zone around the HSM.	3	2	1	1	6
			Earthworks (drilling, blasting, crushing and placing of materials) in the project footprint area on Pram Point Seasons: 2022/23 to 2025/26			3	2	2	3	36	• The Heritage Management Pan will define controls, including an exclusion zone around the HSM • Any activities undertaken near the TAE Hut will be supervised by a 'spotter' to help the plant operator stay away from the building • The drill and blast methodology will include the use of blast mats to prevent rock throw • Blasts near the TAE Hut will be designed to minimise disturbance. This can include smaller blasts or specific spacing of blast locations Monitoring of vibrations will inform the need to stop or modify operations to prevent impact	3	2	1	1	6
	Ross Sea MPA	Accidental large-scale release of hazardous substances	Catastrophic shipping incident during transport of cargo by ship. 8 rotations including 6 for a cargo ship, one for the MC Class vessel and one for an icebreaker between New Zealand and Ross Island. All seasons: 2021/22 to 2027/28	Diminution of the values of the MPA	Direct	3	3	3	1	27	• Shipping operators are experienced in polar environments • Detailed shipping planning will be undertaken before voyages • All ships used will be seaworthy • Weather and sea ice will be monitored throughout the activities, which may change according to the conditions	3	3	3	1	27

6.6 Cumulative impacts

The consideration of cumulative impacts is a specific requirement for CEEs (Article 3(2)(f) of Annex I to the Protocol). Cumulative impacts occur as a result of the combined impacts of past, present and reasonably foreseeable activities. Cumulative impacts may occur over time and require an assessment to be made of other human activities occurring in the proposed locations (EIA Guidelines, 2016). This assessment considered intra-project cumulative impacts (i.e. multiple sources of impact from project-related activities on the same receptor), as well as inter-project cumulative impacts, (i.e. multiple sources of impact from the proposed Scott Base Redevelopment and other activities in the region on the same receptor).

In broad terms, past impacts on the local Pram Point terrestrial and adjacent marine environment have occurred as a result of more than 60 years of human activity following the establishment of Scott Base in 1957. Over that time, construction activities, operation of vehicles including aircraft, foot traffic, accidental fuel spills and emissions to air and water have modified the local environment from its natural state. Similar past impacts on the broader Hut Point Peninsula have occurred as a result of the combined activities of the New Zealand and United States programmes over the same period. The current state of the environment, as described in Chapter 5, has been shaped by long-term and ongoing human activities in the area.

Present impacts on Pram Point and the broader Hut Point Peninsula arise as a result of ongoing logistical and scientific activities from the New Zealand and United States' programmes and the occasional visit from a tourist vessel. Current impacts are considered to be less significant than in the past due to the higher environmental standards and controls now observed.

Future impacts, beyond known proposed and planned activities, are likely to arise from the ongoing logistical and scientific activities from the New Zealand and the United States programmes and the occasional visit from tourist vessels. Future impacts in the area are expected to be reduced compared with current levels as a result of the modernisation programmes of the two stations. For example, as a result of more efficient buildings and reduced GHG emissions. There are no other known additional major activities planned in the area.

Intra-project cumulative impacts

Based on the description of the proposed activities and the assessment of their associated potential impacts, four receptors have been identified that may be cumulatively impacted by different sources of impact within the proposed activities:

- Atmosphere: Throughout the project, there will be multiple sources of GHG emissions, including from the use of vehicles, generators, the temporary station and vessels. These emissions will combine to increase the contribution to global GHG concentrations and will exceed the contribution that would have been made from business-as-usual activities. The operational phase of the proposed Scott Base is expected to reduce GHG emissions as described in Section 6.4.1.
- Terrestrial environment: All activities of the proposed Scott Base Redevelopment and RIWE replacement that interact with ice-free areas may cumulatively impact on the terrestrial environment, changing the topography, impacting on the soil quality and permafrost, meltwater and abundance and distribution of the terrestrial flora and fauna.
    - Terrestrial flora and microfauna: The impact assessment identified multiple sources of impacts on terrestrial flora and microfauna. These include physical impact of earthworks, vehicles and foot traffic, settlement of dust, accidental spills of fuel, the

modification of watercourses and the impacts from the introduction of non-native species, were this to occur.

- Marine environment: The marine environment may be cumulatively impacted by inputs from the terrestrial environment (i.e. sediment and contamination run-off) and wastewater discharges above baseline levels.
    - Weddell seals: Disturbance to the Weddell seals may occur from construction noise (bulk earthworks, civil and foundation work, enabling works, shipping activities and installation of the new station) and loss of sea ice in the haul-out area through the operation of vessels in the area as a consequence of ice-breaking activities.
- Areas with special value: Damage to the TAE Hut (HSM 75) could arise from physical disturbance (e.g. vehicle collision) as well as from vibrations caused by blasting activity and heavy vehicle traffic close to the HSM.

Inter-project cumulative impacts (local, regional and global)

Inter-project cumulative impacts may arise from multiple sources of impact from the proposed Scott Base Redevelopment and other activities in the region on the same receptor.
The EIA database maintained by the Antarctic Treaty Secretariat[38] was reviewed to inform the identification of inter-project cumulative impacts. Activities occurring in the same area as the Scott Base Redevelopment and over the same period, for which EIAs have been submitted to the database include:

- The United States' programme of modernisation of McMurdo Station. The United States CEE for the Continuation and Modernization of McMurdo Station Area was submitted to and reviewed by CEP XXII and ATCM XLII;
- Potential tourist visits to the area by New Zealand-based tour company Heritage Expeditions for which an IEE has been submitted and approved; and
- Ongoing science support activities supported by the New Zealand Antarctic programme for which a separate IEE has been submitted and approved.

The Electronic Exchange of Information System (EIES)[39] database maintained by the Antarctic Treaty Secretariat was also consulted. No countries have submitted information for the period of the proposed activities. Pre-season information is only required to be submitted for the immediate forthcoming season and not for future seasons.

Based on the assessment provided in Section 6.6 and the information available on the impacts potentially arising from other activities on Ross Island and the wider Ross Sea region, five receptors have been identified that may be cumulatively impacted:

- Atmosphere: The additional emissions from the proposed activities will combine with the extra emissions from other activities in the wider Ross Sea region. Cumulatively these emissions will increase overall emissions in the Ross Sea region compared with 'normal' operational activities. From a global perspective, the combined emissions may be negligible, but locally could be significant.

- Terrestrial environment: The proposed Scott Base Redevelopment and RIWE replacement project is occurring on already impacted sites. However, they are occurring on ice-free areas. Ice-free ground in Antarctica is rare and is estimated to represent only 0.44% (54,274 km^2) of the continent (Brooks, et al., 2019). Ice-free ground also hosts a disproportionate concentration of biodiversity, scientific value, and human activity, with 76% of all buildings found on ice-free ground within 5km of the shore (Brooks, et al., 2019). Any interaction with ice-free areas should

[38] https://ats.aq/devAS/EP/EIAList?lang=e

[39] https://ats.aq/devAS/InformationExchange/LatestReports?lang=e

be considered in the wider Antarctic context.

- Soil and ground water quality: In the unlikely event that releases of hazardous substances and waste occur during the Scott Base Redevelopment and RIWE replacement projects and the modernisation of the McMurdo Station area, they would jointly add to the past hydrocarbon spills (Klein et al, 2012) that have occurred across the southern part of Hut Point Peninsula and provide detectable long-term evidence of human presence in the area.
- Terrestrial flora and microfauna: There is little abundance and distribution of terrestrial flora and microfauna on Hut Point Peninsula. Impacts to the receptor from both the Scott Base Redevelopment and RIWE replacement projects and the modernisation of the McMurdo Station Area have identified activities that could give rise to increased pressure on terrestrial flora and microfauna, including physical disturbance and through the generation of dust. Given the distance between the two stations, it is considered unlikely that these impacts will combine to affect the same habitats However across the southern part of Hut Point Peninsula, some parts of these communities could experience increased pressures.

- Cryosphere: Impacts on the sea ice from the icebreaker support may cumulate with impacts from other National Antarctic Programmes operating ships in the area. At the Hut Point Peninsula scale, the breaking of a channel to access Pram Point by sea in addition to the annual icebreaker and shipping rotation led by USAP may result in cumulative break out of the sea ice in Season 2025/26.

- Marine environment: Impacts on the local nearshore marine environment will be cumulative to the past 60 years of New Zealand Antarctic programme activities in the area. These impacts are also cumulative to impacts on the marine environment from activities over time at other National Antarctic Programmes and science support activities (e.g. science field camps disposing of human waste in the marine environment).
    - Weddell seals that haul out on the sea ice around Hut Point Peninsula may experience a further reduction in habitat in Season 2025/26. During this season, the project icebreaking activities may cumulate with a similar impact arising from the annual shipping rotation.

- Intrinsic values: Impacts on intrinsic values are likely to occur from any human activities in Antarctica. The proposed Scott Base Redevelopment and the RIWE replacement, albeit on the same locations as the current infrastructure, may add to cumulative impacts from human presence in the region and the associated reduction in intrinsic values. In addition, New Zealand's activities in Antarctica will be cumulative to all human activities in Antarctica including national Antarctica programme activities, tourism and fishing.

Cumulative impacts summary

This assessment identifies that cumulative impacts on key receptors may occur, both within the proposed activities and in combination with the identified impacts from other activities happening in the area. Impacts that arise over the period covered by the proposed Scott Base Redevelopment are also expected to add to the historic impacts that have occurred over the 60 years of human activities at this location.

However, in each case the proposed mitigation measures are assessed as being sufficient and it is considered that no additional measures are required.

6.7 Conclusion

The impact assessment indicates that all identified environmental receptors are expected to be subject to multiple aspects and therefore to potential impacts. The significance of the predicted impacts ranges from no more than, equal to, and more than minor or transitory. The overall conclusion of this impact assessment is that the proposed activities are likely to have a more than minor or transitory impact on the Antarctic environment.

The individual impacts with a significance expected to be more than minor or transitory are listed below. Impacts that are considered to have been mitigated against as much as practicable and are accepted as unavoidable are:

- The release of GHG contributing to global climate change;
- Changes to the physical landscape, to watercourses and meltwater pathways and disturbance of the permafrost;
- Changes to soil quality, release of salts, change to depth to ice-cement; and
- Physical damage, destruction and modification in the distribution, abundance or biodiversity of terrestrial flora and micro fauna.

Another impact with a significance expected to be more than minor or transitory is the contamination of the nearshore marine environment and smothering of nearshore biota from sediment discharges. This impact is considered avoidable with the proposed mitigation measures

It is anticipated the operation of the proposed Scott Base will result in reduced negative impacts on the Antarctic environment in the following ways:

- Reduced contribution to global climate change with contributions from the proposed RIWE;
- Reduced contamination of the local marine environment through improved wastewater treatment technology; and
- Reduced risk of transferring non-native species to Antarctica and within biogeographic regions of Antarctica with fit-for-purpose biosecurity facilities.

Further environmental benefits are expected beyond the Antarctic Treaty Area, including the elimination of two waste streams currently returned to New Zealand. This will reduce cargo ship requirements and divert waste from New Zealand landfills, resulting in reduced associated GHG emissions.

7. Monitoring

7.1 Introduction

The Protocol places significant emphasis on the importance of monitoring.

Article 3(2)(c-v) provides for activities in the Antarctic Treaty area to "be planned and conducted on the basis of information sufficient to allow prior assessments of and informed judgements about their possible impacts on the Antarctic environment and dependent and associated ecosystems and on the value of Antarctica for the conduct of scientific research; such judgement shall take account of *inter alia*, whether there exists the capacity to monitor key environmental parameters and ecosystem components so as to identify and provide early warning of any adverse effects of the activity and to provide for such modification of operating procedures as may be necessary in the light of the results of monitoring or increased knowledge of the Antarctic environment and dependent and associated ecosystems."

The Protocol requires that:

- Regular and effective monitoring shall take place to allow assessment of the impacts of ongoing activities, including the verification of predicted impacts (Article 3(2)(d);
- Regular and effective monitoring shall take place to facilitate early detection of the possible unforeseen effects of activities both within and outside the Antarctic Treaty area on the Antarctic environment and dependent and associated ecosystems (Article 3(2)(e);
- CEEs identify measures including monitoring programmes that could be taken to minimise or mitigate impacts of the proposed activity and to detect unforeseen impacts, and that could provide early warning of any adverse effects of the activity as well as to deal promptly and effectively with accidents (Article 3(2)(g) of Annex I); and
- Monitoring of key environmental indicators shall be undertaken to assess and verify the impact of an activity that proceeds following completion of a CEE (Article 5). The monitoring must be designed to provide a regular and verifiable record of the impacts of the activity in order, *inter alia*, to:
  - Enable assessments to be made of the extent to which such impacts are consistent with the Protocol; and
  - Provide information useful for minimising or mitigating impacts, and, where appropriate, information on the need for suspension, cancellation or modification of the activity.

The Protocol also provides for considering impacts on the biophysical environment of Antarctica and the region's values including wilderness, aesthetic, historic and science values. To meet these requirements, Antarctica New Zealand has established a programme of monitoring that commenced in advance of the project and will continue throughout and (for some parameters) beyond the proposed Scott Base Redevelopment.

7.2 Establishing environmental baseline conditions

The proposed Scott Base Redevelopment and the RIWE replacement will take place at locations that have been subjected to moderate to heavy levels of disturbance that are consistent with long-established Antarctic bases and stations (Brooks, 2014). Several decades of human activity have occurred at these locations including vehicle activity, landscape modification, pollution events and building construction. Nonetheless, it is important to understand the current (baseline) state of the local environment, even if modified, to be able to assess any further predicted or unforeseen impacts as a result of the planned activities, including cumulative impacts.

Baseline data was collected during the 2017/18, 2018/19 and 2019/20 seasons. This pre-activity survey work included:

- Selection and establishment of terrestrial monitoring and controls sites;
- A ground disturbance and hydrological survey of Pram Point;
- Assessment of meltwater quality;
- Assessment of soil characteristics and contamination levels;
- A survey of terrestrial flora and fauna;
- Measurement of airborne dust;
- A nearshore marine survey; and
- Establishment of cameras to record Weddell Seal behaviour.

The sampling and survey work are described below together with brief descriptions of analytical methods. The results of the baseline measurements informed the description of the environment and are reported in Chapter 5. The methods described below will be repeated during the planned monitoring programme as detailed in Section 7.3.

7.2.1 Selection and establishment of terrestrial monitoring sites

The actual or potential impacts on the terrestrial environment identified in this draft CEE are likely to occur within a spatially definable area of Pram Point. Following consultation among Antarctica New Zealand environmental specialists and research advisers, an initial region of interest for the monitoring programme on Pram Point was identified (Figure 102) and would include:

- The Scott Base operational area, excluding any place less than 5m from stairs or decks;
- Some of the restricted areas, but excluding the helicopter pads, underground pipes, and any place less than 5m from cables, pipes, or antennas; and
- The area uphill from Scott Base, but below the road that connects Scott Base and McMurdo Station.

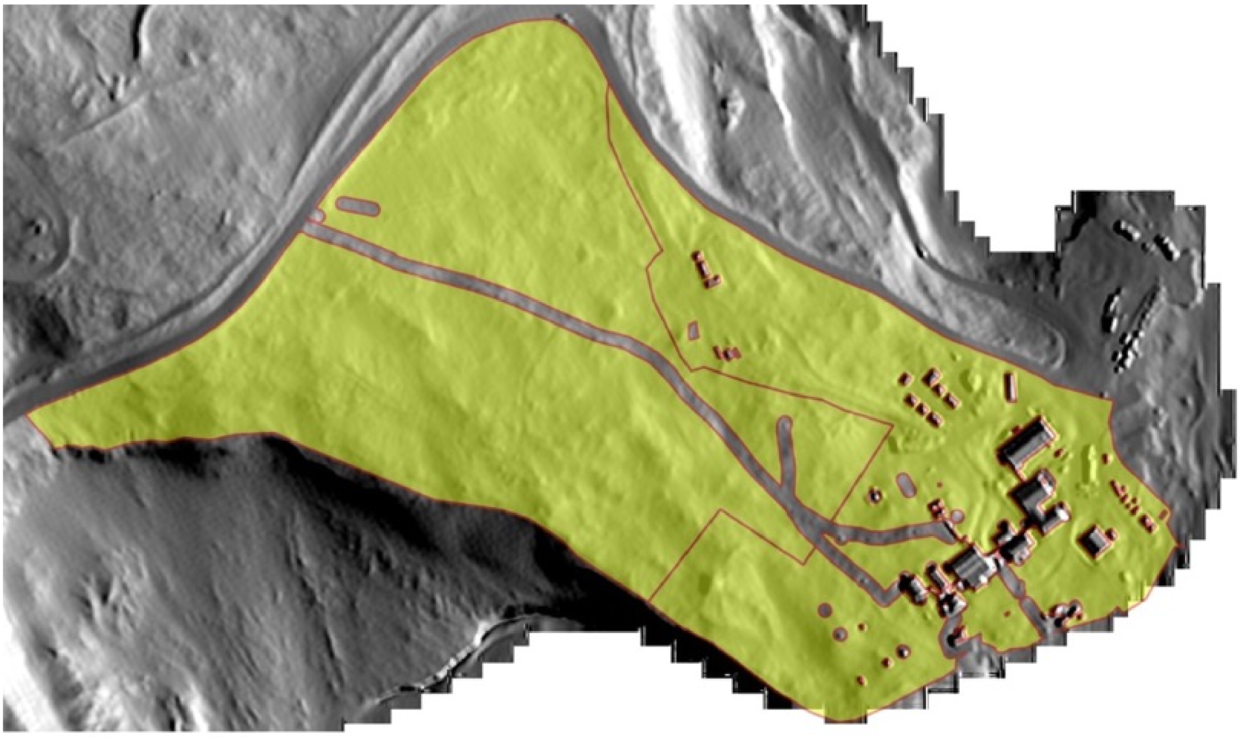


Figure 102: Identified region of interest for the baseline survey and terrestrial monitoring programme.

Five environmental covariates were selected to determine optimal sampling sites within the region of interest.

1. Distance to the road as a proxy for the major source of dust;
2. Distance to the operational area of Scott Base as a proxy for the distance from the general building operations;
3. Distance from the helicopter pads as a proxy for a major source of dust and environmental disruption;
4. The modelled global solar radiation received during summer (December to February inclusive) as a proxy for soil temperature and associated melt; and
5. A wetness index as a way to delineate areas that are likely to receive meltwater, as opposed to areas that are likely to shed meltwater.

Data layers were generated for each covariate. These were then modelled and statistically tested to derive 25 optimally-located monitoring sites (Figure 103).

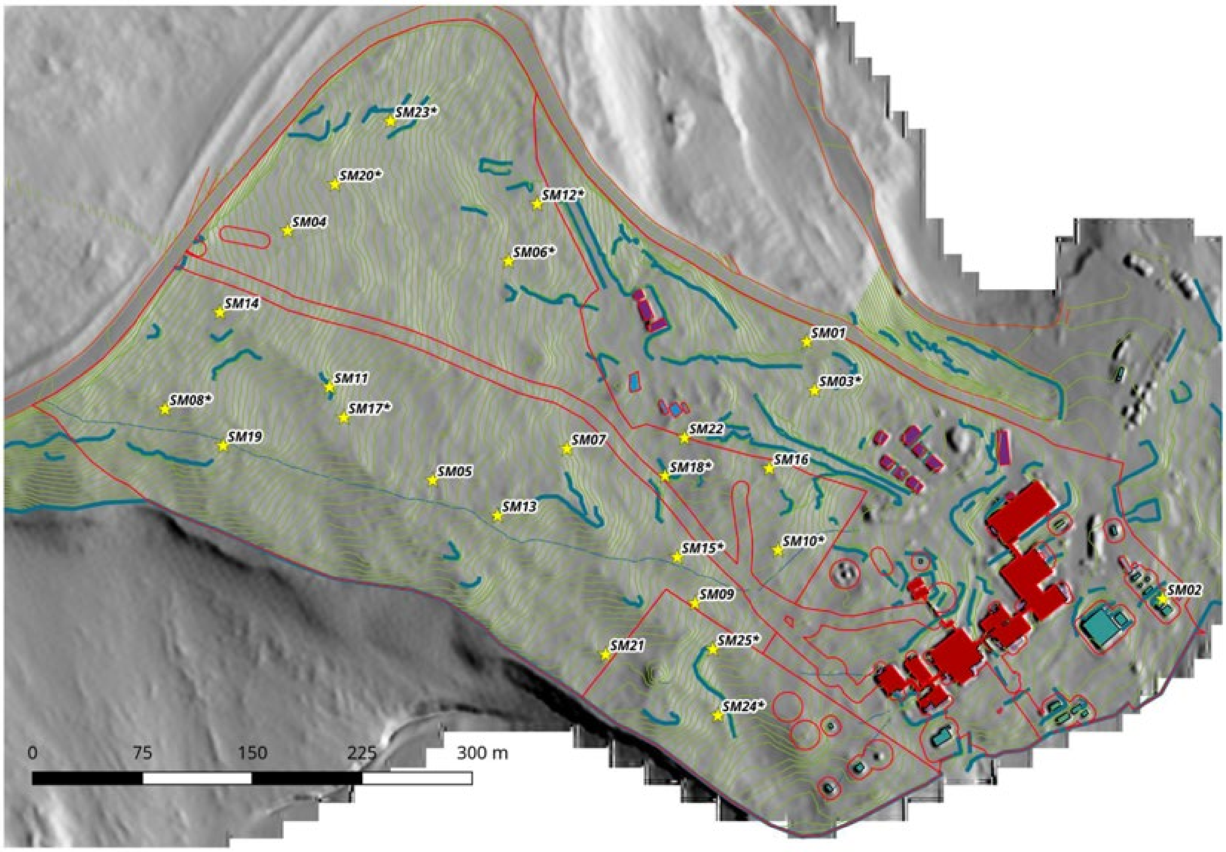


Figure 103: Map of the region of interest and the selected 25 terrestrial monitoring sites. * = MWAC dust sampler installed adjacent to the monitoring plot (see section 9.3.5). Source: (Roudier, 2019).

Each monitoring site has been marked with a GPS waypoint to support repeatable measurements for the duration of the monitoring programme.

Five sites were selected at Cape Evans (approximately 25km to the north of Pram Point on the West Coast of Ross Island) to serve as a comparatively undisturbed low-lying, coastal, control location (Figure 104). These five sites were manually chosen to incorporate vegetated/unvegetated, dry/wet soils and invertebrate presence/absence, along with sites that were near and distant from helicopter landing pads. All sites are located outside the area of Cape Evans historic hut (ASPA 155).

Figure 104: Location of the manually selected control sites at Cape Evans.

7.2.2 Ground disturbance and hydrological survey of Pram Point

During the 2017/18 and 2018/19 seasons, a survey of Pram Point was undertaken using a BMRLite Remotely Piloted Aircraft (RPA). The RPA carried a high-resolution DSLR RGB camera and a Multispectral sensor (Micasense RedEdge). Ground control points were placed throughout the area of interest and surveyed. Systematic pre-programmed waypoint surveys were conducted to ensure sufficient overlap and coverage of the area of interest. Over 20,000 multispectral images were collected from 15 January to 31 January 2019[40].

Photogrammetry software was used to interpret the images to provide an assessment of the extent of ground disturbance. A local area catchment model was also developed from the imagery to identify areas of water accumulation and run-off.

7.2.3 Meltwater quality

During the 2018/19 and 2019/20 seasons, meltwater samples were taken from three locations immediately adjacent to the shoreline in front of Scott Base to assess the water quality. The sites are shown in Figure 105 and include the Hilary Field Centre Cold Porch (top right), near the TAE Hut (bottom left), and the Front Transition (bottom middle).

Analyses undertaken included: pH; conductivity, suspended solids, total solids, alkalinity ($CaCO_3$), and metals concentrations.

[40] Heavy snowfall from 30 January 2019 prevented one section of the area of interest from being surveyed. This is marked in Figure 76 in Chapter 5.

Figure 105: Map of Scott Base showing the sites of meltwater sampling in the 2019/20 season.

7.2.4 Baseline soils assessment

During the 2018/19 and 2019/20 seasons observations were made and samples taken at each of the 25 Pram Point monitoring sites and the five Cape Evans control sites to determine baseline soil characteristics, including:

- Visual site assessments;
- Depth to ice cement measurements;
- Chemical characteristics; and
- Contaminant levels.

The monitoring methods used for each parameter are described below.

7.2.4.1 Visual site assessments

Campbell's (1993) Visual Site Assessment (VSA) method was used to assess the present-day visual impacts of a representative area at each monitoring site. The VSA method of Campbell et al. (1993) is a rapid visual evaluation of terrestrial impacts and rates the extent of surface disturbance against 11 impact assessment criteria (Table 52) as a means of comparing disturbance severity across different sites (see Campbell (1993) for full methods and illustrations). A modified version of the original VSA was used which included additional criteria to give a total of 16 impact assessment criteria. Each criterion is rated between one and four, one being no visible impact and four being the most severe (Table 52).

Table 52: Modified version of the original visual site assessment (Campbell, 1993).

Impact Assessment Criteria		Severity and Extent of Impacts (class) 1	2	3	4
A	Disturbed surface stones	none visible (0)	few (<10)	many (10–25)	abundant (>25)
B	Impressions of removed rocks	none visible	just visible	distinct	fresh
C	Boot imprints	none visible	just visible	distinct	fresh
D	Visibly disturbed area	<5 m^2	5–10 m^2	20–100 m^2	>100 m^2
E	Surface colour difference (Munsell units difference)	none visible (0)	weak contrast (-1)	moderate contrast (-2)	strong contrast (>3)
F	Walking tracks	not visible	weakly defined	moderately defined	strongly defined
G	Litter	none visible (0)	few (<10)	some (10–25)	many (>25)
H	Visible fuel spills	none visible	faintly distinguished	visible	very obvious
I	Salt deposition	none visible	faintly distinguished	visible	abundant
J	Biological disturbance	none visible	<1 m^2	1–5 m^2	>5 m^2
K	Cumulative impact	disturbance not	weakly evident	clearly visible	disturbed and very
L	Stratigraphic disturbance	negligible	within one unit	within two units	multiple units
M	Surface texture change	negligible	just evident	moderate change	very obvious
N	Rock cairns	none	rare or small	moderately common	very common
O	% change vegetation cover	none	weakly evident (loss 10-20%)	clearly visible (25-50%)	very obvious (>50%)
P	Evidence of exotic species	none	rare or small	moderately obvious	very obvious

7.2.4.2 Depth to ice-cement

Depth to ice-cement is the depth to ice-cemented ground. This depth can vary over the course of a season and between seasons and is influenced by several factors including air temperature, insulation of soil by snow, wind conditions, shelter, aspect and insolation.

Measurements of the depth to ice-cement were taken at each monitoring and control site. In the 2018/19 season, this was achieved by hammering a small stake into the ground until maximum penetration was reached. Three replicate measurements were taken immediately adjacent to each monitoring site and averaged. Measurements of depth to ice-cement were also undertaken at each of the monitoring and control sites during the 2019/20 season, though using a slightly different method. In this season, small holes were dug at each of the monitoring sites to assess the depth to ice-cemented ground.

7.2.4.3 Soil chemical analysis

Within 1m of each of the monitoring and control sites, soil samples were taken at two depths: 0-2cm and 2-5cm, using a trowel. Approximately 10 subsamples were taken and homogenised to ensure a representative bulk sample of approximately 400g from each depth and site. The samples were returned to New Zealand and analysed for pH and electrical conductivity (as a proxy for salt content) using standard methods.

7.2.4.4 Soil contamination

Using the same sampling regime for the chemical analysis noted above, samples were also collected from each monitoring site at two separate depths (0-2cm and 2-10cm) and returned to New Zealand for spectral analysis for total petroleum hydrocarbons (TPH).

A spectroscopic method was selected for assessing TPH concentrations. Any prediction of contamination using spectroscopic methods requires building a spectral library. In this approach, a pristine material is spiked with increasing concentrations of TPH. This approach has been used with success by different authors in the literature (Forrester, et al., 2010; Okparanma & Mouazen, 2013; Schwartz, et al., 2012).

For this monitoring programme, material has been used presenting a soil texture similar to conditions encountered near Scott Base (washed sand). Following the method reported by Schwartz *et al*. (2012), this sand was spiked with 13 different increasing levels (0, 200, 500, 1,000, 2,000, 4,000, 7,000, 10,000, 15,000, 25,000, 50,000, 75,000, and 100,000 ppm) of gasoline, kerosene, and diesel.

Soil spectra were recorded from the soil samples using a Tensor II HTS-XT FTIR (Bruker Pty Ltd, Germany) spectrometer with a spectral range from 7500 to 600 cm^{-1} and a spectral resolution less than 0.4 cm^{-1}.

Following statistical analysis and modelling, the probability of exceeding a pollution threshold of 1,500 ppm[41] for a single location and depth can be determined.

7.2.5 Baseline terrestrial flora and fauna survey

During the 2018/19 and 2019/20 seasons the monitoring and control sites were surveyed for:

- Vegetation diversity and abundance;
- Invertebrate diversity and abundance;
- Microbial diversity; and
- The presence of any non-native species.

7.2.5.1 Vegetation diversity and abundance

At each of the 25 monitoring sites, two orange poles were installed to mark two opposite corners of a $1m^2$ plot (Figure 106). Photographs were taken of the plot from different angles to record current levels of vegetation as well as surrounding site characteristics.

Full vegetation surveys were undertaken along a transect at eight of the monitoring sites. These sites

[41] Using New Zealand Ministry for the Environment Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand (Revised 2011).

were chosen as representative of areas with high vegetation (SM18, 21 and 24), moderate levels of vegetation (SM13, 17 and 25) and low levels of vegetation (SM08 and 20). Plot locations are shown in Figure 103. For each transect, a 20m tape was laid out (crossing the 1m^2 plot location) and photographs were taken of 1m^2 plots either side of the tape to give coverage for a total of 40m^2.

Figure 106: SM10 monitoring plot to the north of Scott Base.

7.2.5.2 Invertebrate diversity and abundance

At each monitoring and control site, the underside of rocks within the plot were searched for mites and springtails. Any macroinvertebrates found were aspirated into cryovial tubes and immediately preserved in 100% ethanol.

At each site, a 300g soil sample was collected and placed into a Whirl-pak bag for later invertebrate analysis.

Soil samples were analysed in the laboratory in Antarctica for micro-invertebrates. Soil extraction was carried out using standard dilution and filtration methods. Extracted individuals were counted under a microscope to determine the number of live and dead females, males and juveniles of each of the three groups of nematodes (*S. lindsayae*, *Plectus* sp., *Eudorylaimus* sp.) along with counts of rotifers, mites, tardigrades and ciliates present.

Soil moisture levels were also assessed for each sample (by comparing wet and dried weights) to enable the calculation of invertebrate abundance per unit weight of soil.

7.2.5.3 Microbial diversity

Microbial diversity in the soils of Pram Point was investigated to establish baseline conditions. Soil samples were taken from each monitoring site, stored and returned to New Zealand for analysis. In the laboratory, microbiome analysis was undertaken using DNA sequencing of the 16S ribosomal RNA gene following standard procedures.

7.2.5.4 Non-native terrestrial species

During the 2018/19 and 2019/20 terrestrial surveys, no non-native species were observed at any of the terrestrial monitoring or control locations.

7.2.6 Baseline dust assessment

Twelve Modified Wilson and Cooke (MWAC) dust samplers (Figure 107) were installed during the 2018/19 season adjacent to several of the established monitoring sites (those sites marked with an asterisk in Figure 103). Locations of these dust samplers were chosen to give good spatial coverage, including varying proximity to the road, both sides of the base, and proximity to vegetated areas.
The dust samplers were left in situ for one year and sampled during the 2019/20 summer season to establish baseline readings.

The material collected in the dust samplers were returned to New Zealand and analysed for particle size distribution to determine the relative amount, by mass, of particles present according to size.

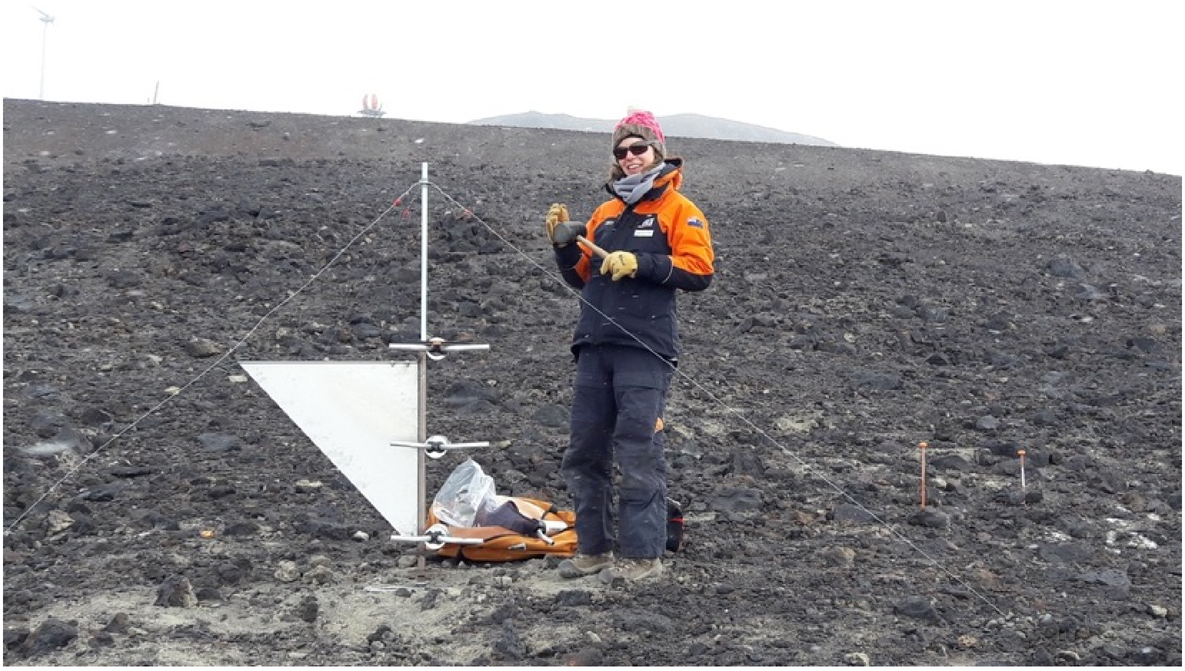


Figure 107: An MWAC dust sampler being installed at one of the monitoring sites behind the current Scott Base. Photo: O'Neill, University of Waikato.

7.2.7 Baseline marine survey

During the 2019/20 season a baseline nearshore marine survey was undertaken with the following objectives:

- Assess contaminant concentrations in four sentinel seafloor species before the start of Scott Base Redevelopment earthworks;
- Quantify seafloor biodiversity (species richness and abundance) using both diver hand-held cameras and a Remotely Operated Vehicle (ROV); and
- Measure water currents to understand sediment and contaminant transport potential (under the assumption that contaminated terrestrial soils may be introduced into the marine environment during the Scott Base Redevelopment earthworks).

Three 25m transects were established at two sites; two transects near Scott Base, and a control site away from Scott Base, as discussed in Chapter 5. A third transect near Scott Base was unable to be accessed in the 2019/20 season but plans are underway to survey the site in future seasons. Site selection and sampling was based on Negri (2006) and on where freshwater and eroded soils are anticipated to run-off during the earthworks. The transect lines have been left in place to allow for repeat observations throughout the monitoring programme.

Along the two transects, samples were taken of sediment, *Laternula* sp. (a bivalve) and three sponge species (*Homaxinella* sp., *Mycale* sp., and *Sphaerotylus* sp.). The samples were frozen and returned to New Zealand for contaminant analyses. Analyses were undertaken for: PAHs and polychlorinated biphenyl (PCB) congeners, total petroleum hydrocarbons (TPH) and heavy metals (Arsenic (As), Copper (Cu), Lead (Pb), Zinc (Zn), Mercury (Hg), and Cadmium (Cd)).

Video surveys for future assessment of species distribution and abundance were undertaken along the length of the each transect by divers and by ROV.

Three cinder blocks were deployed at each site to act as settlement structures for use in monitoring the recruitment of sessile fauna over time.

Water currents were measured using an Acoustic Doppler Current Profiler (ADCP) deployed at each site and left in place for a period of two to three weeks.

7.2.8 Baseline Weddell seals survey

There is very little baseline information available on the numbers and behaviour of the Weddell Seals that congregate on the sea ice in front of Pram Point. Therefore, there is a risk of finding spurious correlations between natural changes in seal numbers and human activity, or conversely, failing to detect significant human impacts.

Three survey cameras were mounted on the hillside behind Scott Base to record the activity and behaviour of the Weddell seals, including diurnal haul out patterns, and movements on the ice (Figure 108). The cameras were installed during the 2018/19 season and records were taken during the 2018/19 and 2019/20 austral summer seasons.

The cameras take panoramic images of the area occupied by the seals simultaneously every ten minutes. The images are processed using innovative artificial intelligence software to detect and count the seals quickly and accurately. Counts made by trained observers, either from the camera site with binoculars, or from aerial photographs, are used to validate the computer-generated counts.

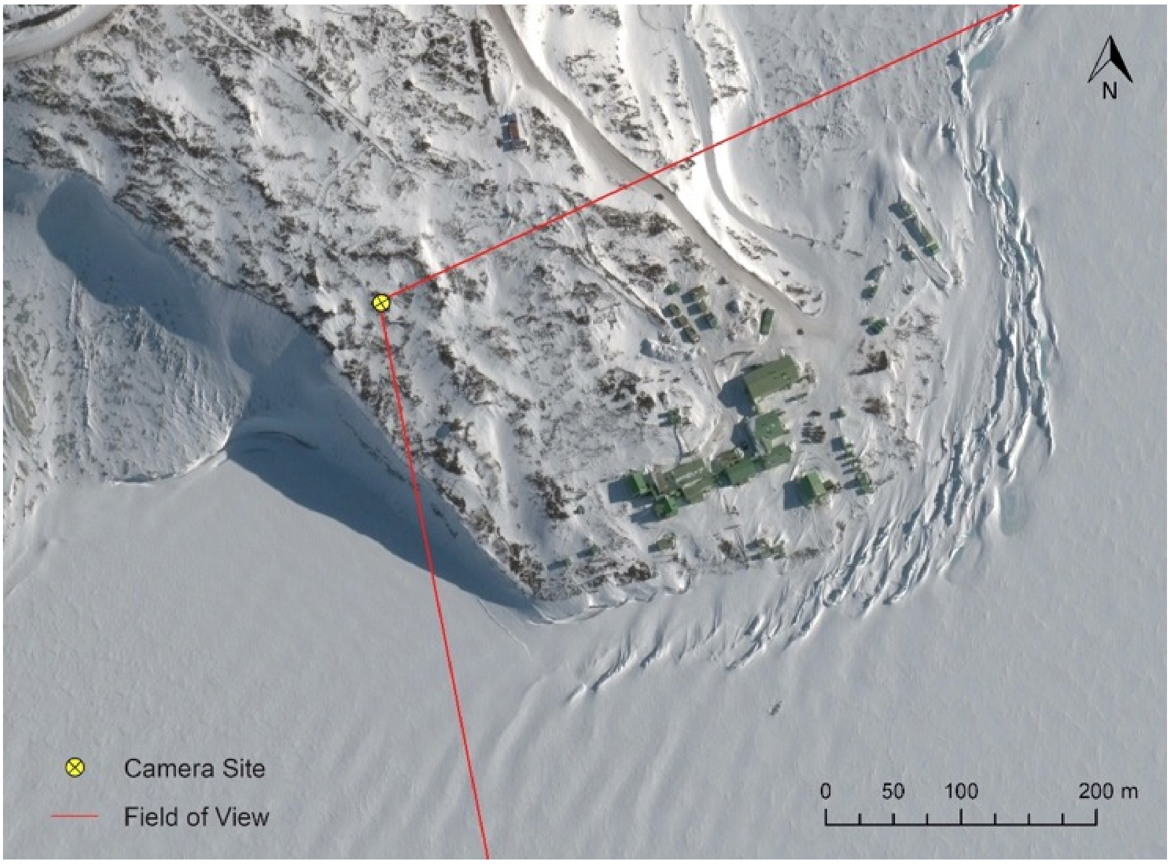


Figure 108: Location and field of view of three cameras installed to record Weddell Seal behaviour.

7.3 Monitoring programme overview

The monitoring programme that will be undertaken during the proposed Scott Base Redevelopment and the RIWE replacement will build on the baseline measurements described above and has been designed on the actual or potential impacts identified in this CEE.

The monitoring programme has been developed following the provisions of the Protocol, the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1 (2016)) and with COMNAP's Practical Guidelines for Developing and Designing Environmental Monitoring Programs in Antarctica (Resolution 2 (2005)).

7.3.1 Monitoring objectives

The objectives of the monitoring programme are to:

- Provide a comprehensive description of the environmental baseline conditions;
- Verify the accuracy of the impacts predicted through the impact assessment process, including cumulative impacts;
- Detect impacts that are more significant than predicted, and
- Provide early detection of unforeseen impacts.

Additional monitoring of selected parameters will also be undertaken in connection with the Green Star rating system that has been adopted for the proposed Scott Base Redevelopment.

7.3.2 Monitoring plan

The monitoring programme has five component parts.

1. Identification of terrestrial and marine monitoring and control sites and initial surveys and analyses to determine baseline conditions.
2. Monitoring throughout the Scott Base Redevelopment programme to verify impacts on the:
    a) Terrestrial environment;
    b) Nearshore marine environment;
    c) Cryospheric environment, and
    d) Local wildlife.
3. Assessments of the impact of the Scott Base Redevelopment programme on key values;
4. Operational monitoring associated with specific construction activities; and
5. Monitoring related to Antarctica New Zealand's environmental management and carbon reduction systems.

Scientific expertise was sought from the New Zealand Antarctic research community to assist with the development and undertaking of the planned monitoring programme. Researchers have assisted and are continuing to assist with the monitoring at terrestrial sites, conducting nearshore marine surveys, and carrying out sample analyses.

7.3.3 Spatial and temporal boundaries for the monitoring plan

The spatial focus for the monitoring programme is the southern end of Hut Point Peninsula; specifically, Pram Point, Crater Hill and southern McMurdo Sound. The majority of the impacts that have been identified in this CEE are considered likely to occur within the immediate vicinity of the key activities or a short distance away.

The aspects that may have impacts on a slightly broader spatial scale are the transport and deposition of dust that could be transported beyond the immediate areas of activity, the transmission of noise through air and water, and ice-breaking activities in southern McMurdo Sound, which may have implications for the adjacent McMurdo Ice Shelf. These factors have been considered in the design of the monitoring programme.

The temporal scale of the monitoring programme extends from the three seasons before the commencement of the planned activities, through the current Scott Base removal and earthworks activities and for a few seasons into the operational period on completion of the construction works. Broadly, monitoring commenced in the 2017/18 season and will continue through to the 2035/36 season.

Some elements of the monitoring programme will be ongoing, including the collection of data in support of Antarctica New Zealand’s environmental management and carbon reduction systems (for example, the collection of data on waste, fuel and water use and greenhouse gas emissions). An overview of the monitoring plan is provided in Table 53.

Table 53: Monitoring plan overview.

Environmental Element	Receptor	Environment Parameter	Predicted impact	Baseline Survey or Assessment	Monitoring objective	Parameters that will be measured	Frequency of measurements
Terrestrial	Geomorphology	Topography	Direct impact: Physical changes/disturbance to the landscape (e.g. mechanical action of the substrate from cut and fill, facility and ground maintenance and construction activities, building, vehicle use, installations, equipment storage, erosion, track formation, etc.)	A digital elevation model (DEM) of Pram Point has been developed to record the topography before the Scott Base Redevelopment programme.	1. To record the changes in surface topography as a consequence of the Scott Base Redevelopment programme	RPA-supported multispectral surveys and photogrammetry across Pram Point to generate 3D imagery.	Pre and post- the Scott Base Redevelopment.
			Indirect impact: Change in meltwater drainage channels or snow accumulation areas	See “meltwater” below			
		Soil quality	Direct impact: Contamination or physical alteration of the sediments (from mechanical action, windblown contamination, run-off, direct contamination, storage of equipment, movement of equipment, etc.)	Measurements of each parameter taken during 2018/19 and 2019/20 seasons.	1. To assess the extent to which the Scott Base Redevelopment programme impacts soil quality. 2. To determine the rate of recovery from any impacted locations.	At established monitoring and control sites, surface and at depth measurements of: i. Visual site assessments ii. Moisture content iii. Soil chemistry (pH & conductivity) iv. Trace elements v. Total petroleum hydrocarbons.	• 2025/26 (post earthworks) • 2028/29 (post construction) • 2035/36 (operational)
			Indirect impact: Change in the distribution and abundance of soil flora/fauna communities	See 'fauna and flora' below			
	Meltwater	Meltwater	Direct impact: Physical changes to moisture and water drainage pathways or snow accumulation areas	Multispectral survey undertaken in the 2018/19 season to record pre-activity surface flow pathways.	1. To assess how the planned earthworks (including artificial drainage channels), road realignment and new buildings alter the moisture and water drainage pathways and snow accumulation areas.	RPAS-supported multispectral surveys across Pram Point to identify: i. Surface flow pathways ii. Snow accumulation / moisture availability areas	Pre and post- the Scott Base Redevelopment.
			Indirect impacts: i. Pollution of marine environment (from fuel spills, waste disposal and other contaminants in the soil) ii. Changes to erosion and sediment transfer to the marine environment as a result of new drainage pathways	Range of analyses undertaken on meltwater (run-off) samples in the 2019/20 season.	1. To record any changes in the quality of melt water from Pram Point during and after the Scott Base Redevelopment work. 2. To assess any implications of changes in the melt water quality for the nearshore marine environment.	Melt water samples taken at key locations will be measured for: pH; conductivity; suspended solids; total solids; total alkalinity; anion/cation suite and metals concentrations.	• 2023/24 (earthworks) • 2025/26 (post earthworks) • 2028/29 (post construction) • 2035/36 (operational)
	Flora and fauna	Abundance, distribution, diversity	Direct impact: Disturbance to soil flora and fauna communities from mechanical action of the substrate from facility and ground maintenance and construction activities, vehicle use, helicopter operations, installations, equipment storage, cut and fill, erosion, track formation, contamination, etc.	Observations and sampling undertaken at established monitoring sites during the 2018/19 and 2019/20 seasons.	1. To assess the extent to which the Scott Base Redevelopment programme impacts the abundance and distribution of terrestrial fauna and flora 2. To record recovery of any impacted sites over time	At established monitoring and control sites: i. Flora type and abundance (species identification, size measurements, photographic records); ii. Fauna type and abundance (species identification and abundance measurements); iii. Molecular characterisation of bacterial communities.	• 2025/26 (post earthworks) • 2028/29 (post construction) • 2035/36 (operational)
		Non-native species	Direct impact: Introduction and establishment of non-native species leads to loss of local natural environmental value	Observations undertaken at established monitoring sites during the 2018/19 and 2019/20 seasons.	1. To identify any non-native species establishments during the Scott Base Redevelopment programme and allow for response action to be taken.	Surveillance / observation at monitoring sites for any non-native species that may have established.	• 2025/26 (post earthworks) • 2028/29 (post construction) • 2035/36 (operational)
			Indirect impact: Change in distribution or abundance of endemic flora/fauna	See 'abundance, distribution, diversity' above			

Environmental Element	Receptor	Environment Parameter	Predicted impact	Baseline Survey or Assessment	Monitoring objective	Parameters that will be measured	Frequency of measurements
	Ice-free surfaces and nearshore marine environment	Soil integrity; terrestrial biodiversity abundance; nearshore water quality	Direct impact: Loss of soil integrity leading to increased dust generation from construction related activities including earthworks and traffic. Indirect impacts: Smothering (by dust) of terrestrial flora and fauna; increased sediment loading in nearshore marine environment due to increased suspended solids in melt water.	Dust samplers installed and samples collected during the 2018/19 and 2019/20 seasons.	1. To quantify any increase in airborne dust as a consequence of the Scott Base Redevelopment programme.	At established monitoring and control sites: quantity and particle size analysis of material collected in deployed dust samplers.	Annual sampling throughout the earthworks and construction phases and repeated in the 2028/29 (post construction) and 2035/36 (operational) seasons
Marine	Nearshore benthic environment	Flora and fauna	Indirect impact: Disturbance and/or change in benthic flora and fauna communities through contamination from waste water discharges and/or contaminated run-off, or physical disturbance from vessels operating close to shore.	Surveys undertaken at selected monitoring sites during the 2019/20 season.	To assess: 1. any change in the distribution, abundance and diversity of the benthic flora and fauna that may be attributable to onshore activities 2. any change in the levels of contamination in benthic fauna that may be attributable to onshore activities.	At established monitoring and control sites: i. ROV surveys along fixed transects. ii. Diver sampling and analysis of contaminant levels in sediments and in selected species. iii. Observation of establishments on settlement plates deployed throughout the Scott Base Redevelopment programme.	ROV surveys: ・2024/25 &/or 2025/26 (earthworks) ・2026/27 (post-earthworks) ・2028/29 (post construction) Diver surveys: ・2021/22 (pre-earthworks) ・2028/29 (post construction) ・2035/36 (operational)
		Benthos	Direct impact: Contamination of the sediments from waste water discharges and/or contaminated run-off.	Sampling and analysis undertaken in the 2019/20 season. Bathymetric survey in the 2020/21 season.	1. To assess any change in benthic sediment contaminant concentrations that may attributable to the Scott Base Redevelopment programme.	At established monitoring and control sites: i. Sampling of benthic sediment and analysis of contaminant concentrations.	Diver sampling: ・2021/22 (pre-earthworks) ・2028/29 (post construction) ・2035/36 (operational)
Cryosphere	Ice environments	Permafrost	Direct impact: Disturbance to permafrost causing ground slumping (through cut and fill, ground disturbance, blasting etc.)	Measurements taken at established monitoring sites in the 2018/19 and 2019/20 seasons.	1. To identify if the work associated with the Scott Base Redevelopment programme has any effect on the permafrost layer.	At established monitoring and control sites: i. Active layer depth measurements (maximum thaw of active layer at time of sampling)	・2025/26 (post earthworks) ・2028/29 (post construction) ・2035/36 (operational)
		Sea Ice	Direct impact: Artificial removal of sea ice cover as a result of ice-breaking activity. Indirect impacts: Loss of habitat for Weddell Seal colony affecting reproduction and abundance; change in the flow, thickness or fracture of the McMurdo Ice Shelf, as a consequence of artificial removal of adjacent sea ice cover.	Review of historical records of sea ice cover in McMurdo Sound to identify any observable trends and patterns.	1. To identify any observable difference in sea ice and ice shelf behaviour that could be attributed to local ice breaking and vessel activity.	i. Satellite imagery and data; ii. GPS measurements on the sea ice before and during ice breaking activity; iii. Fixed point photographic data (from the cameras used to monitor the Weddell Seal colony).	Throughout the period of ice-breaking activity and at least two seasons post vessel activity.
Wildlife	Megafauna	Weddell Seals	Direct impact: Disturbance to individuals as a result of noise emissions, ice-breaking activity, presence of people and equipment. Indirect impact: Longer-term reduction in reproductive success in the Pram Point colony.	Photographic surveys undertaken in the 2018/19 and 2019/20 seasons.	1. To observe any change in seal behaviour and density during the Scott Base Redevelopment programme.	Automated object detection software to count seals from images taken from fixed-point survey cameras.	Throughout each summer of the Scott Base Redevelopment programme and for 3 operational seasons post-redevelopment Direct observations from the shore as required
Wilderness Values	Wilderness	The concept of wilderness at Pram Point	Changes to the perceptions of wilderness of Pram Point due to increased human activity.	There is a long history of imagery of Pram Point that will be drawn on to show change over time.	1. To record changes in levels of human activity and infrastructure on Pram Point and Crater Hill over time.	Photographic records will be maintained throughout the project and during the operational phase of the new base.	Regular photographic recording through each season of the Scott Base Redevelopment
Aesthetic Values	Aesthetic	Aesthetic appreciation	Changes to people's perception as a result of the Scott Base Redevelopment	There is a long history of imagery of Pram Point that will be drawn on to show change over time.	1. To record changes in visible human presence and alterations to the natural landscape over time.	Photographic records will be maintained throughout the project and during the operational phase of the new base.	Regular photographic recording through each season of the Scott Base Redevelopment

Environmental Element	Receptor	Environment Parameter	Predicted impact	Baseline Survey or Assessment	Monitoring objective	Parameters that will be measured	Frequency of measurements
Heritage Values	Historic and cultural sites and artefacts	TAE Hut (HSM No. 75)	Physical damage as a result of the Scott Base Redevelopment activities	The state of the TAE Hut before the Scott Base Redevelopment programme is known and recorded.	1. To record any physical damage to the TAE Hut as a consequence of the Scott Base Redevelopment programme and allow for any immediate remediation.	Physical observations and checks.	Annual monitoring and survey to be undertaken by the New Zealand Antarctic Heritage Trust
Scientific Research Values	Scientific research	Science delivery	Disruption to science delivery caused by resources being diverted to the Scott Base Redevelopment programme.	The extent of science supported before the Scott Base Redevelopment programme is known and recorded.	1. To record changes to the extent of the science programme during and after the Scott Base Redevelopment programme.	Numbers of researchers; ratio of support staff to scientists; publications.	Annually throughout the Scott Base Redevelopment programme and beyond.
		Long-term science at Scott Base	Disruption to long-term monitoring undertaken at Scott Base.	Science supported at Scott Base is known and recorded.	1. To ensure that relocated science is as uninterrupted as possible.	Support to Principal Investigators (PIs) for relocation of monitoring equipment. Confirmation with PIs that relocated science is as uninterrupted as possible.	Once only
Corporate Management Systems	Antarctic environments	Environmental aspects identified in the EMS	Environmental aspects and impacts identified within the scope of the EMS.	Operational performance data has been collected for many years to support the EMS.	1. To continually improve Antarctica New Zealand's environmental performance following the Environmental Management Policy.	As described in Antarctica New Zealand's EMS.	Annual monitoring, reporting and external auditing.
	Atmospheric environment	Contribution to climate change	Indirect impact: Release of greenhouse gases (GHG) due to burning fossil fuels contributes to acceleration of climate change.	Data has been collected to support the calculation of GHG emissions for many years.	1. To record GHG emission sources as accurately as possible, so as to support the Antarctica New Zealand Emission Management and Reduction Plan.	All 'in scope' emission sources following Antarctica New Zealand's Carbon Reduction scheme.	Annual monitoring, reporting and external auditing.

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7.4 Monitoring of construction activities

Operational monitoring will be shared by Antarctica New Zealand and the main contractor and will include maintaining records of:

- Any unplanned events, including:
    - the location, type and quantity of any fuel or other hazardous substances spills;
    - the timing and duration of any activities giving rise to significant dust;
    - the type and location of any material or equipment lost to the environment;

- The volumes / quantities of waste produced;
- The volumes / quantities of hazardous waste produced;
- The volumes / quantities of recyclable materials;
- The types and volumes of fuel used;
- The operational footprint of the proposed activities; and
- Any non-native species incursions;

The main contractor will be required to provide a summary report at the end of each season for review by Antarctica New Zealand.
Further monitoring requirements will be defined in the management plans introduced in Chapter 6.

7.5 Monitoring through the Environmental Management System

7.5.1 Environmental Management System

Antarctica New Zealand's certified EMS is designed around the requirements of the international standard for Environmental Management Systems (ISO 14001:2015).
The EMS applies to all activities undertaken by Antarctica New Zealand, in both Christchurch and Antarctica, and to all staff, contractors, visitors and event personnel operating in the Antarctic environment.

Six component areas reflect the provisions of the Protocol and the international standard for Energy Management Systems (ISO 50001:2011), with objectives and targets set for each area. These are:

- Environmental impact assessment;
- Protected areas;
- Flora and fauna;
- Waste management;
- Hazardous substances; and
- Energy and carbon management.

Data, currently collected to support the EMS, will continue to be collected throughout the proposed Scott Base Redevelopment and into the operational phase of the new station. This includes for example, protected area visits, wildlife disturbance events, non-native species incursions, waste types and volumes, hazardous substances spills, water and fuel use.

Data is collated throughout the year and an independent external audit of the EMS is undertaken annually before re-certification of the EMS can be achieved.

7.5.2 Carbon reduction system

Antarctica New Zealand has in place a certified carbon reduction system. The system ensures that greenhouse gas emissions are accurately measured and reported and that mitigation measures are established so as to manage and reduce emissions over time. The carbon reduce system is independently verified through an annual audit before re-certification.

All greenhouse gas emission sources (i.e. air travel, electricity, fuel, and water use) will continue to be measured and reported throughout the Scott Base Redevelopment programme.

7.6 Reporting

As described in Chapters 2, 3 and 4, the proposed activities span multiple seasons. Annual progress reports will be provided to the CEP. These will highlight in particular:

- Any identified unexpected or unpredicted impacts;
- Any findings from the monitoring programme resulting in modifications to the planned activities; and
- Any changes to the activity and how the environmental impacts of those changes were assessed.

On completion of the project, a full review will be undertaken following Resolution 2 (1997). This post-activity review will include an analysis of whether the activities were conducted as proposed, whether applicable mitigation measures were implemented, and whether the impacts of the activity were as predicted in the assessment.

Review findings, including any changes to the activities described in the CEE, the reasons for the changes, and the environmental consequences of those changes, will be reported to the CEP.

7.7 Independent audit

All reasonable attempts will be made to facilitate an independent audit of the proposed Scott Base Redevelopment. Representatives from one or two National Antarctic Programmes will be invited to Christchurch and Scott Base to audit the Scott Base Redevelopment activity against the findings of the CEE. Key elements of the audit will be to assess whether the mitigation measures are being applied and that the monitoring programme is effective and being undertaken as described.

The audit will also be used as an opportunity to review the effectiveness of the impact assessment process that was undertaken for the Scott Base Redevelopment project and to identify any improvements that can be made. An audit tool will be developed to assist the independent auditors. The findings of the audit will be reported to the CEP.

8. Gaps in knowledge and uncertainties

8.1 Environmental Impact Assessment feedback process

The identification and assessment of potential environmental impacts is an informed forecast, based on the bodies of knowledge available at the time of preparing the draft CEE. As such, there may be changes between the predicted and actual impacts of the proposed activities.

The implications of any such changes will be reviewed to identify any alterations to the predicted impacts and their mitigation and monitoring measures. The final version of this CEE may therefore include a revised impact assessment. Any changes occurring after the finalisation of the CEE will be evaluated and the CEE amended following the EIA feedback process and stakeholders and interested parties will be consulted as appropriate.

The areas where gaps in knowledge or uncertainties exist, which could trigger changes in the impact assessment are identified below.

8.2 Funding for the project

The scope and timeline of activities described in this document rely on the project being funded in its entirety in 2021. Should the project's funding be deferred, or partially granted, the temporal scope of the impact assessment may be affected and would be reviewed accordingly. A decision on whether the project will be funded, and to what level, is expected in early to mid-2021 after the circulation of this draft CEE.

8.3 Design

At the time of preparing this draft CEE, the Scott Base Redevelopment design is at a stage where the scope of all major elements, materials, finishes and floor area of the proposed new station is clearly defined and drawn to scale with supporting documentation and specifications. Temporary works (i.e. earthworks such as road realignments and logistic and construction plans, etc.) required to construct the buildings have been designed and specified. The temporary base and RIWE replacement are both only at the feasibility stage. While significant departures from the current design are not anticipated, minor changes in design may occur between the circulation of this draft CEE and the completion of the Detailed Design. These are not anticipated to have any material effect on the impact assessment presented here.

8.4 Construction methodology

Minor variations in the delivery of on-site activities and accompanying monitoring activities are expected as the project progresses from design to construction. These variations are not expected to materially affect the conclusions of the EIA, or the effectiveness of the mitigation and monitoring programmes. The CEMP will be the delivery tool to ensure that the proposed mitigation and monitoring measures presented in this draft CEE are effective and appropriate for the proposed activities.

8.5 Pram Point as a mooring location

The proposed project logistics methodology relies on the ability to use Pram Point as a mooring location.

There is a high degree of confidence in the suitability of the location, with confirmation expected in early 2021, after the finalisation of this draft CEE. Should Pram Point prove unsuitable, the Scott Base Redevelopment construction methodology would change from off-site construction and on-site assembly to a containerised delivery of materials and on-site construction, as described in Chapter 4. As a result, a far larger staging area for containers would be required and the timeline would significantly change.

New Zealand would assess the need to circulate a revised draft CEE if the proposed logistics and construction methodologies were not achievable.

8.6 RIWE replacement

The RIWE replacement activities described were derived from a feasibility study. The study used the modelled predictive electrical load for the proposed Scott Base Redevelopment to design the RIWE replacement options.

The preferred wind farm replacement option (four Enercon E44 900 kW turbines with 10 MWh BESS) was identified but was unable to be confirmed at the time of preparing this draft CEE. The number and size of the turbines influence the scale of RIWE replacement logistics and construction activities. These were estimated using the preferred option for this draft CEE but may need to be reviewed once the option is confirmed.

There are other uncertainties related to the RIWE replacement which are expected to be resolved as the project progresses through the design stages. These include geotechnical investigations to determine the final foundation locations for each new turbine and confirmation of the final extent of the civil works on the access road and Crater Hill site. Further impact assessments may be required for, in particular, the interaction of a new wind farm with the scientific research conducted at Arrival Heights ASPA 122, including visual and electromagnetic assessments. Noise and shadow flicker modelling and their potential impacts on operations will also be reviewed. These studies will be initiated once the funding decision for the proposed Scott Base Redevelopment and RIWE replacement has been announced.

8.7 Temporary base

The temporary base was in a feasibility stage at the time of completing this draft CEE. However, no changes to the conclusions of the EIA as a result of this are expected, given the location, duration, intensity and nature of the impacts associated with the temporary base within the overall context of the Scott Base Redevelopment and RIWE replacement projects. The final form, population, and exact location on Pram Point are still in development and any material change will be considered against the impact assessment in this CEE.

8.8 Deconstruction methodology for the proposed Scott Base

The deconstruction methodology for the Scott Base Redevelopment has been presented to the best of current knowledge about an activity that is over 50 years in the future. It is expected that a new EIA would be prepared at the time of planning for the removal of Scott Base, owing to advances in EIA practice, technology and logistics that cannot be anticipated now.

8.9 Gaps in the environmental baseline

No baseline environmental data was collected on the steep section of hillside where the Scott Base to McMurdo road realignment work is proposed. The area is too steep for safe access by foot and was not surveyed as part of the Scott Base Redevelopment monitoring programme, as the road realignment was not part of the project scope when the remote sensing surveys were undertaken (2017/18 and 2018/19). As such, the extent of biodiversity is unknown in this area but knowledge of the area suggest that it is unlikely to have significant biology.

8.10 Impacts of COVID-19 on the proposed activities

The activities are proposed in the context of the COVID-19 pandemic that has caused global disruption in 2020.

New Zealand took the precautionary approach of reducing its Antarctic operations in season 2020/21, to keep COVID-19 out of Antarctica. In future seasons, it is expected that keeping COVID-19 out of Antarctica will remain the highest priority, to prevent harm to people and wildlife. The risk of transmission of COVID-19 to wildlife is not yet fully understood. However, recent research suggests that the highest risk of transmission resides with field researchers handling animals, followed by people being in close proximity (less than 5m) to wildlife (Barbosa, et al., 2020). For the proposed activities, and in addition to ensuring that no person carrying COVID-19 enters Antarctica, no field research involving the handling of animals is proposed. All people operating under the New Zealand programme are required to stay at least 10m away from wildlife.

Ongoing implications of COVID-19 for National Antarctic Programmes globally are expected to continue in the near future, which may affect the proposed activities. A Risk Management System is in place for the project that seeks to anticipate and mitigate the potential impacts of COVID-19 on the proposed schedule, supply chain, resources, etc. with appropriate mitigation and contingency measures.

9. Conclusions

This draft CEE presented the activities associated with the proposed Scott Base Redevelopment and the RIWE replacement. The environmental impacts likely to arise from the proposed activities were assessed together with the proposed mitigation and monitoring measures.

This draft CEE concludes that the proposed activities are likely to have more than a minor or transitory impact on the environment, due to the duration, scale and intensity of the activities and their associated impacts. The most significant potential impacts expected to arise are:

- The release of GHG contributing to global climate change;
- Changes to the physical landscape, to watercourses and meltwater pathways and disturbance of the permafrost;
- Changes to soil quality, release of salts, change to depth to ice-cement;
- Physical damage, destruction and modification in the distribution, abundance or biodiversity of terrestrial flora and microfauna; and
- Contamination of the nearshore marine environment and smothering of nearshore biota from sediment discharges.

The operation of the proposed Scott Base and wind farm, on completion of the activities, is expected to result in the following environmental impacts:

- Changes to baseline intrinsic values through the changes in appearance of Scott Base and the wind farm; and
- Changes in the intensity of potential contamination of the terrestrial and marine environments from accidental releases of hazardous substances due to increased volumes of hazardous substances stored at Scott Base.

The following environmental improvements are expected to arise from the proposed Scott Base Redevelopment, through advances in energy efficiency, sustainability, operational efficiency and resilience:

- Reduced contribution to global climate change thanks to increased generation of renewable energy and greater efficiency of buildings and systems of the proposed station;
- Reduced contamination of the local marine environment through best practice wastewater treatment;
- Reduced risk of introduction of non-native species with fit-for-purpose dedicated biosecurity facilities;
- Increased ability to support scientific research through improved lab spaces and better facilities;
- Improved resilience supporting New Zealand's ability to conduct scientific research safely and efficiently; and
- Facilities that support the wellbeing, health and safety of Scott Base's occupants better than the current station.

The proposed mitigation measures, including the existing EMS and the CEMP, associated sub-plans and preventative measures incorporated into the design of the proposed station are deemed appropriate and sufficient to manage the predicted impacts.

The monitoring programme was developed in consideration of the proposed activities and environmental receptors. The monitoring programme is considered suitable to verify the accuracy of the impacts predicted, detect impacts that are more significant than predicted, and provide early detection of unforeseen impacts. The review and reporting of monitoring findings are key elements of the programme to ensure that activities and mitigation measures may be modified as required to minimise environmental impacts on an ongoing basis.

It is concluded that the proposed activities are likely to have more than a minor or transitory impact on the Antarctic environment. It is considered that the proposed activities should proceed, given the improvements in environmental performance and science support and environmental protection that they will deliver.

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