DRAFT COMPREHENSIVE ENVIRONMENTAL EVALUATION

Construction and Operation of the Jang Bogo Antarctic Research Station, Terra Nova Bay, Antarctica

February 2011

Korea Polar Research Institute

Korea Environment Institute

(INTENTIONALLY LEFT BLANK)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Non-technical Summary

I. Introduction

This draft Comprehensive Environmental Evaluation (CEE) report aims to establish a plan that will minimize the adverse impact of the construction and operation of a new Korean research station in Antarctica. Comprehensive analyses on the environmental impact have been carried out in order to ensure that the station can be operated in a sustainable manner with minimal impact on the environment.

Considering the research programs including international collaboration, convenience of logistics, and its impact on the local environment, the site of Jang Bogo Antarctic Research Station (74°37.4′S / 164°13.7′E) was chosen through an evaluation process of six candidate sites in the Antarctic region from 2007 to early 2010. The proposed site is located near Cape Möbius, the coastal area of Terra Nova Bay in Northern Victoria Land along the Ross Sea.

The main purpose of Korean Antarctic research is parallel to the international efforts on predicting global climate change process through multidisciplinary research. As an independent station that will operate year-round, the Jang Bogo Station will develop the West Antarctic observatory network with Korea’s King Sejong Station and the icebreaker *ARAON*.

The key scientific programs based on the Jang Bogo Station include:

- Climate and atmospheric chemistry

  A WMO/GAW Global Station will be installed at the Jang Bogo Station. In connection with other stations in Antarctica, this large-scale monitoring of atmospheric components will cover the entire Antarctic region to strengthen the understanding of the interactions between the polar region and middle latitude of the southern hemisphere.

- Glaciology and snow chemistry

  Studies of snow and glaciers along the coast of West Antarctica will be conducted at the Jang Bogo Station as well as supported by the icebreaker *ARAON*, contributing to restoring the paleo-climate and paleo-environmental changes of the Pacific margin of Antarctica.

- Tectonics and geophysics

As various forms of glaciers developed near the proposed site, long-term monitoring of movement and mass balance of glaciers will be carried out in order to comprehend the relationship between tectonics and glacial changes. In addition, seismic, geomagnetic and GPS observation systems will be installed at the Jang Bogo Station as a part of the Polar Earth Observing Network (POLENET).

- Long-term monitoring for ocean and ecosystem

The Jang Bogo Station will accommodate year-round monitoring and research of the long-term impacts of climate change to ecosystem of the surrounding areas. A long-term monitoring program will be established in order to identify the major oceanographic and atmospheric parameters that are responsible for the rapid freshening in the Ross Sea.

II. Description of the Proposed Activity

The proposed site for the Jang Bogo Station is located on a small cape approximately 1.2km NNE of the Cape Möbius where Germany's Gondwana Station is located.

The main activities dealt with in the draft CEE include: construction, operation, and dismantlement of the station; installation and use of temporary facilities during the construction; and transportation of supplies and personnel to the station. The construction is planned to start in December 2012 and continue for two years during the Antarctic summer season. The station will begin to operate early 2014.

The station includes the main building, research facilities, and maintenance and operation facilities with a building area of 3,826.9m^2. The station is planned to be used for no less than 25 years. It will accommodate up to 15 personnel in the winter and up to 60 personnel in the summer.

The main building is designed to be an aerodynamic triple-arm structure elevated from the ground surface. The main building will work as the central hub, with other facilities being arranged like the spokes of a wheel. This type of layout is known to be reliable, has high functionality and efficiency, and causes minimal damages to the surrounding land. Moreover, the layout will minimize access time between buildings since all facilities will be directly accessible to the main building. The main building is designed to withstand strong winds and fire. The compartmentation in the building will help prevent fire from spreading, and the stable aerodynamic structure will provide increased resistance against strong winds. Furthermore, the combination of the elevated and slanting structures helps to minimize the amount of snow pile-up around the building.

In an effort to minimize the construction period, a modular construction system will be adopted. The modular construction system will not only shorten the construction period but also minimize the number of workers required and construction wastes. This will also facilitate future dismantlement.

The use of Combined Heat and Power (CHP), solar and wind renewable energy, and waste heat will cover 100% as energy sources, thereby reducing the use of fossil fuels while the station is in operation. A state-of-the-art comprehensive treatment system will be installed and operated in order to prevent waste and wastewater from affecting the clean Antarctic environment. The basic operation principle will be thorough management and storage of wastes, and treatment and removal them off the Antarctic. In case of incineration, a flue gas recirculation which minimizes the emission of pollutants by high temperature combustion will be used. Furthermore, the wastewater will be reused as much as possible by using the gray water reclamation and reuse system, and ultimately, will be treated and discharged with almost no pollutant.

III. Alternatives to the Proposed Activity

Various alternatives including no-action to the proposed activities have been compared and reviewed to select the best option in terms of the comparability of the site as well as for the design of the station.

Several alternatives examined to the proposed activities include:

- No-action alternative
- Six alternative locations in Antarctica (two in West Antarctica and four in East Antarctica)
- Three alternative locations in Cape Möbius region
- Three alternative designs of the main building
- Three alternative wind turbine types
- Five alternative means of transport (two for air transportation and three for marine +land transportation)

The proposed site was selected considering not only its compatibility in construction and operation, but also the research areas that Korea is planning. Minimizing any impact which the station would have on the natural environment was also considered.

For the main building, intensive triple-arm shaped design was selected because it is known to respond reliably to the extreme weather conditions of the Antarctic region, while maximizing energy efficiency, and could be operated year-round.

The vertically stacked modular type structure was selected for the final design of the wind turbine considering efficiency of power generation, noise, maintenance ease, and impacts on the ecosystem.

Marine transportation was selected over air transportation as the best means of transportation in consideration of cost, convenience, and on-time performance under uneven weather conditions.

IV. Initial Environmental Reference State of the Terra Nova Bay Region

The Terra Nova Bay region where the Jang Bogo Station will be located is one of the most biologically and ecological diverse regions in Antarctica. It is a habitat to a diverse number of species, namely bryophytes, lichens, sea birds, and invertebrates. However, the colonies and habitats of major bio-species do not exist close to the proposed site.

The wind speed at Cape Möbius region is extremely high and variable. Strong westerly wind can reach a maximum speed of 56.4m/s. According to the previous long-term observatory data produced by Italy's Mario Zucchelli Station, the annual average temperature of the regions is -14.1℃, and the annual average wind speed is 6.4m/s. According to the results of the data analysis by AWS (Automatic Weather System), northwesterly winds, together with westerly winds, develop at the proposed site predominantly due to topographical controls.

The proposed site is located in a small cape that is mainly composed of exposed bedrocks and glacial moraines. Most of the land gently slopes close to the coast.

Regional studies on flora and fauna show that only a few kinds of species inhabit the area. About 26 species of vegetation, primarily lichens and mosses, exist near the freshwater pond, approximately 1.2km north of the proposed site. A population of Weddell Seals was observed on an ice field near the proposed site and a colony of South Polar Skua was located in the east of Germany's Gondwana Station.

There are three Antarctic Specially Protected Areas (ASPA) and two Historic Sites and Monuments (HSM) in the vicinity of the Cape Möbius region.

V. Prediction of Impacts, Assessment and Mitigation Measures of the Proposed Activities

An impact assessment of the construction and operation of the station on the Antarctic environment was conducted through comprehensive analyses of the proposed activities based on the data acquired during the survey and accumulated knowledge on natural environment and weather conditions of the region provided by Italy and Germany. In addition, the environmental impacts caused by the construction and operation of the station were estimated for the major factors such as emissions of air pollutants, potential fuel and oil leakage, waste and wastewater, and noise generation, and ecosystem. Optimal mitigation measures to reduce them were established accordingly (see section II in the above).

The main environmental impacts possibly caused by the proposed activities include:

- Unavoidable atmospheric emissions involved with fuel consumption
- Possibility of fuel and oil spills during fuel transfer and refueling as well as from damaged fuel pipelines and tanks
- Generation of hazardous and non-hazardous wastes such as construction waste, domestic waste, waste oil, and food waste
- Wastewater generation during the construction and operation of the station
- Noise generated from loading and unloading activities, equipment operations and other activities
- Possibility of disturbance to the local ecosystem of both marine and land biota (e.g., colonies of Weddell Seal and South Polar Skua, and lichens and mosses)

Waste heat from CHP system will be used to reduce the emissions of air pollutants. The use of fossil fuels will be minimized by increasing renewable energy and maximizing the indoor use of natural sunlight, and recycling the waste heat.

To prevent fuel spills, fuel tanks will be double-skinned and oil impermeable bund wall will be built around the fuel tank. For prevention and clean-up of spills, appropriate equipments and supplies will be prepared in the station in accordance with the associated regulations such as the guidelines of COMNAP/SCALOP (2003), etc.

Waste will be managed according to the guidelines for waste management in the Antarctic. All wastes will be sorted, safely stored and removed out of Antarctica for recycling or disposal.

Wastewater will be treated using the comprehensive state-of-the-art treatment system. The treated water up to the most stringent level of wastewater standards will be discharged (e.g., BOD less than 5㎎/ℓ and COD less than 20㎎/ℓ) accordingly.

Even at full-capacity operation of heavy equipment during the construction, the estimated noise levels do not significantly affect the colonies of South Polar Skua and Weddell Seal, located approximately 1km away from the proposed site.

Given that there are no habitats or colonies of major bio-species close to the proposed site, the station will not cause a significant impact on the surrounding ecosystem.

Environmental impacts and mitigation measures are summarized in an impact matrix, which evaluates possibility, range, period, and importance of the impacts.

VI. Environmental Monitoring and Verification

The Jang Bogo Station will implement an environmental monitoring program to continuously monitor environmental changes caused by its operation, and prepare systematic mitigation plans to respond to environmental accidents and other emergency. Activities that adversely affect the environment will be investigated and adjusted through monitoring of air emissions, fuel leakage, wastewater treatment, waste management, and the ecosystem.

VII. Gaps in Knowledge and Uncertainties

The uncertainties and gaps in knowledge identified in the draft CEE for the construction and operation of the Jang Bogo Station are as follows:

- Distribution of sea ice around Cape Möbius and climate conditions during construction period
- Future retreat of the Campbell Glacier Tongue near the proposed site
- Long-term climate change near the construction site
- Uncertainties in the knowledge and information of natural environment near the proposed site
- Status of a few South Polar Skua nests distributed close to the proposed site
- Final design and layout of the facilities
- Minor changes in the application of various techniques and methods of construction and operation

- Items related to the future expansion of the station
- Changes in the activities of the station according to the change in future perspectives of research

VIII. Conclusion

The environmental impact of the construction and operation of the Jang Bogo Station is anticipated to be minimized by applying environmentally friendly technologies and optimal scientific mitigation measures. In addition, impacts of activities related to research and maintenance/management of the station on the ecosystem are also expected to be reduced by proper mitigation measures. The South Polar Skua colony near the proposed site is located at a safe distance from the station, and hence, the disturbance to skuas will not be significant by the construction and operation of the station.

The Jang Bogo Station will be a multidisciplinary research hub of this region. It will fulfill its role of contributing to the international and multidisciplinary research activities by providing support not only to Korean scientists, but to foreign scientists and giving opportunities cooperating on international science projects.

The result of CEE suggests that the profits of knowledge and scientific information that will be obtained from the Jang Bogo Station will grossly outweigh the “more than a minor or transitory” impact on the Antarctic environment; thus, the establishment of Jang Bogo Station is highly recommended.

(INTENTIONALLY LEFT BLANK)

1. Introduction

1.1. Purpose of the Jang Bogo Station

This draft Comprehensive Environmental Evaluation (CEE) for the construction and operation of Korea's Jang Bogo Antarctic Research Station near Cape Möbius, the Terra Nova Bay of Northern Victoria Land in the Ross Sea area, estimates and analyzes the environmental impacts as well as lays out plans to minimize such impacts of the proposed activities so that its construction and operation are environmentally sound and sustainable (Fig. 1-1).

Global-scale environmental changes that have been surfacing since the end of the 20th century seem to pose a potential threat to human survival. Such alerting presence of environmental issues propelled the formation of an expansive agreement on the need to preserve the untouched environment of Antarctica and highlighted the importance of scientific research in the region. Antarctica provides a unique vantage point for observing the very first symptoms of climate change as it regulates the global climate system through constant energy and element exchanges with other regions. Preserved conditions of the Earth's past in the polar ice caps provide important clues to understand the current climate system and to better predict its future changes. The region is also geographically ideal for astronomical and aerospace studies.

In February 1988, the Republic of Korea constructed the King Sejong Station, a permanent base on King George Island near the northern Antarctic Peninsula. This station is actively undertaking a variety of research activities. However, given the distance from the main Antarctic continent, its current location has often been assessed as limiting the extent of in-depth research and of making a greater contribution to global efforts in tackling climate change. In this context, a proposal to construct the second research station in the mainland of Antarctica was initiated in 2004 (Ministry of Maritime Affairs and Fisheries, 2005), and six candidate sites were selected (KOPRI, 2007). Field investigations and assessment on those candidate sites were conducted from 2007 to early 2010 by a group of experts, including the Korea Polar Research Institute (KOPRI), organized by the Korean government (Kim *et al.*, 2008; KOPRI *et al.*, 2010). The findings of the assessment and three open hearings in Korea led to the final selection of the site approximately 1km north of Cape Möbius, which is a part of the coastal regions of Terra Nova Bay, Northern Victoria Land near the Ross Sea (74°37.4′S / 164°13.7′E) (Fig. 1-2). In this process, factors such as the planned research activities in the station, the level of environmental impact by the station, logistical convenience, and existing international research network were all carefully considered. Later, the international procedure on the construction of the station was initiated by the submission of the Information Paper (IP) on the establishment of Jang Bogo Station to the XXXIII Antarctic Treaty Consultative Meeting (ATCM) held at Punta del Este, Uruguay in May 2010.

The official name of the base, Jang Bogo Station, was chosen through a naming contest, which was held to boost nationwide interest on the construction of the second Korean research station in Antarctica. Jang Bogo is a distinguished figure in Korean history who built the marine Silk Road to enable international exchange of goods and cultures in the 9th century, an epitome of the Korean pioneer spirit.

Major research bases located near the Ross Sea area are as follows: The U.S. McMurdo Station, which has been in operation since the late 1950s on Ross Island along the Ross Ice Shelf of Southern Victoria Land; New Zealand's Scott Base located approximately 3km from the McMurdo Station (Fig. 1-1); and Italy's Mario Zucchelli Station and Germany's Gondwana Station, both operating approximately 370km north from the McMurdo Station (Fig. 1-2).

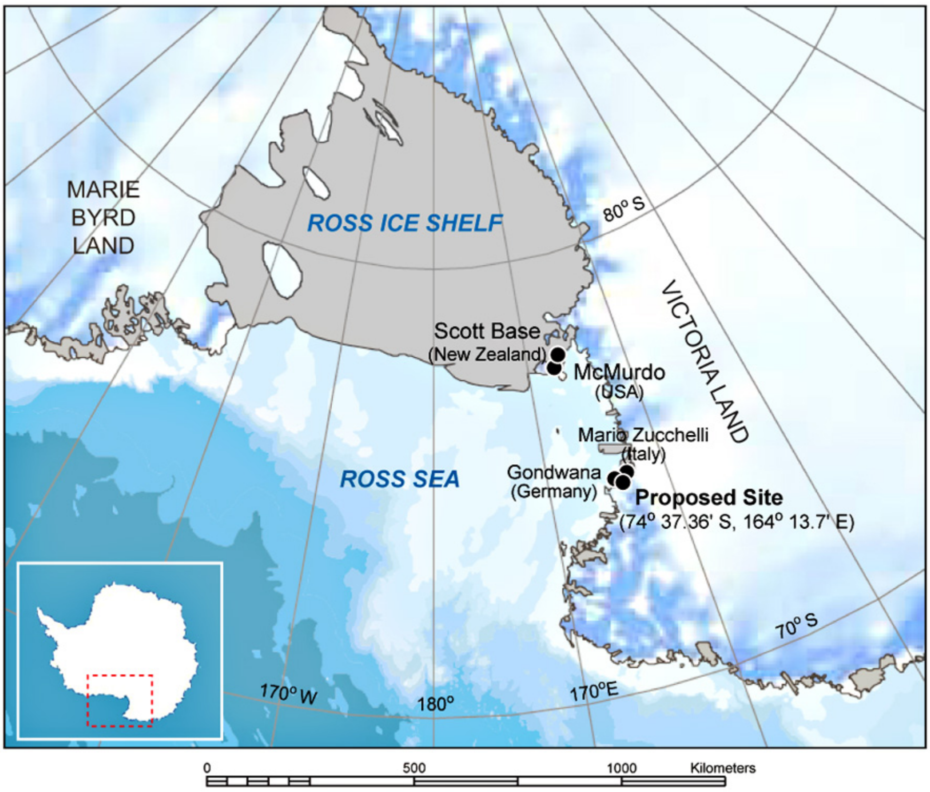


Fig. 1-1. Research bases near the Ross Sea and proposed site of the Jang Bogo Station. (Base map: adapted from Australian Antarctic Division, 2007)

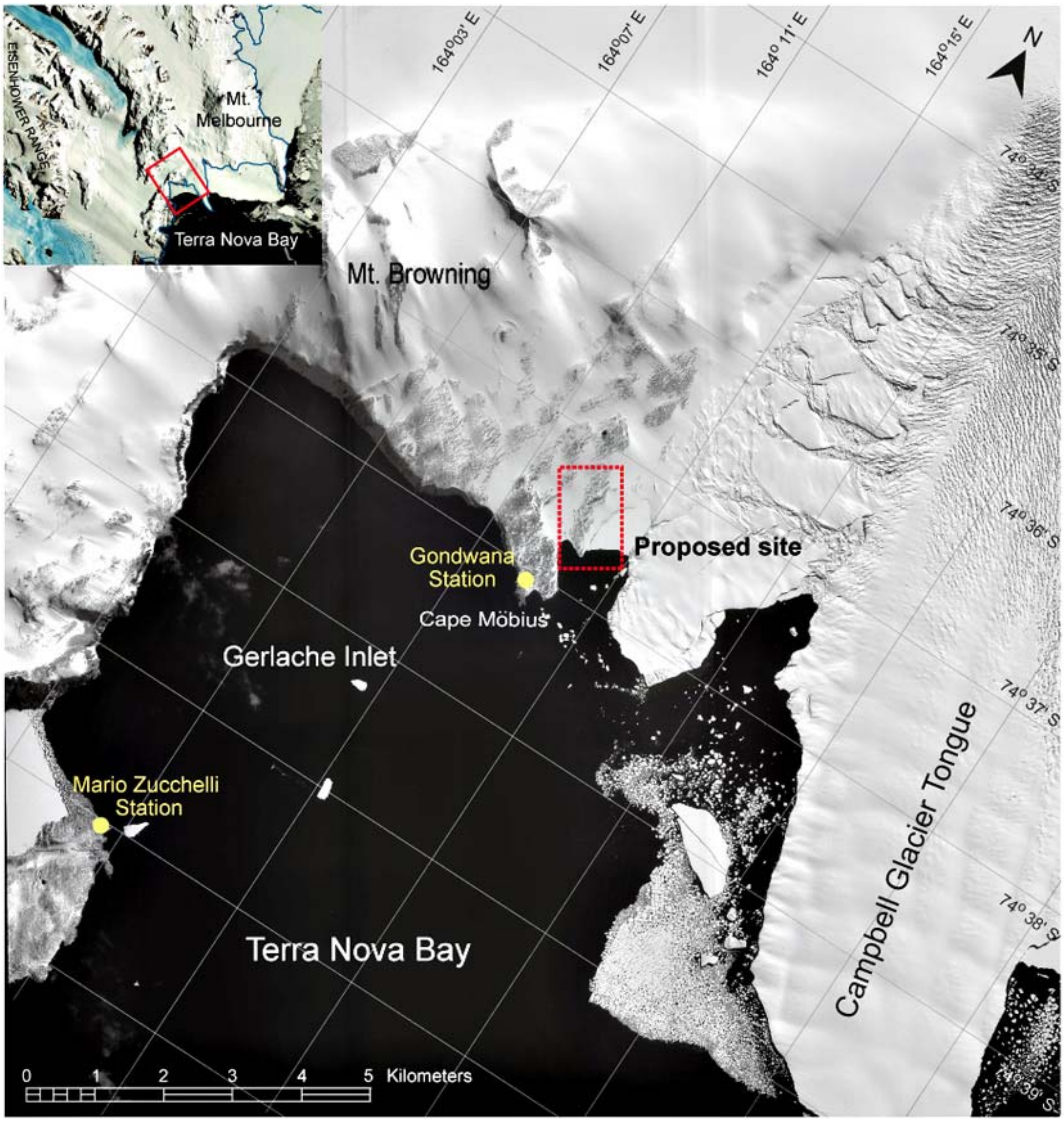


Fig. 1-2. Proposed Site of the Jang Bogo Station.

The Jang Bogo Station will be located on the boundary between East and West Antarctica. This position will allow comparative studies on climate change of both regions, filling the knowledge gap on the West Antarctic region caused by its limited accessibility. In close collaboration with the King Sejong Station (Fig. 1-3), the Jang Bogo Station will form West Antarctic observatory network using the icebreaker *ARAON*. In operation since 2009, the *ARAON* is a year-round research ship, fully equipped with various cutting-edge research equipments and uniquely designed for research and logistics support in the Polar Regions (Fig. 1-4).

Fig. 1-3. King Sejong Station in the Antarctic Peninsular (Winter 2008).

Fig. 1-4. Icebreaker *ARAON*.

The Ross Sea surrounding Terra Nova Bay, the area selected to host the Jang Bogo Station, is known to form large-scale bottom currents. Recently, as the changes in the ocean circulations observed at the Ross Sea are being noted for their ultimate impact on climate change, the importance of monitoring distribution of sea ice as well as oceanographic and climatic natures is ever growing. Furthermore, the critical role of Terra Nova Bay in the formation of polynyas augments the importance of studying its impact on the marine ecosystem. Accessibility of the proposed site to the sea makes it an optimal location to study coastal ecosystems.

The Campbell and Preistley glaciers near the proposed site continuously drift towards the sea, and separating icebergs from glaciers further facilitate the movement. Thus, observations on changes of their movement will be a direct indicator of the increase and decrease in the size of the Antarctic ice sheet. It also provides an opportunity for researchers to go beyond Mt. Browning to the plateau and conduct studies on the continental glaciers of the East Antarctic region.

Once the Jang Bogo Station is constructed at Terra Nova Bay, the provided capacity, together with icebreaker *ARAON*, to conduct independent research on the broad region of West Antarctica will make a significant contribution to the international efforts of investigating global environmental change (Fig. 1-5).

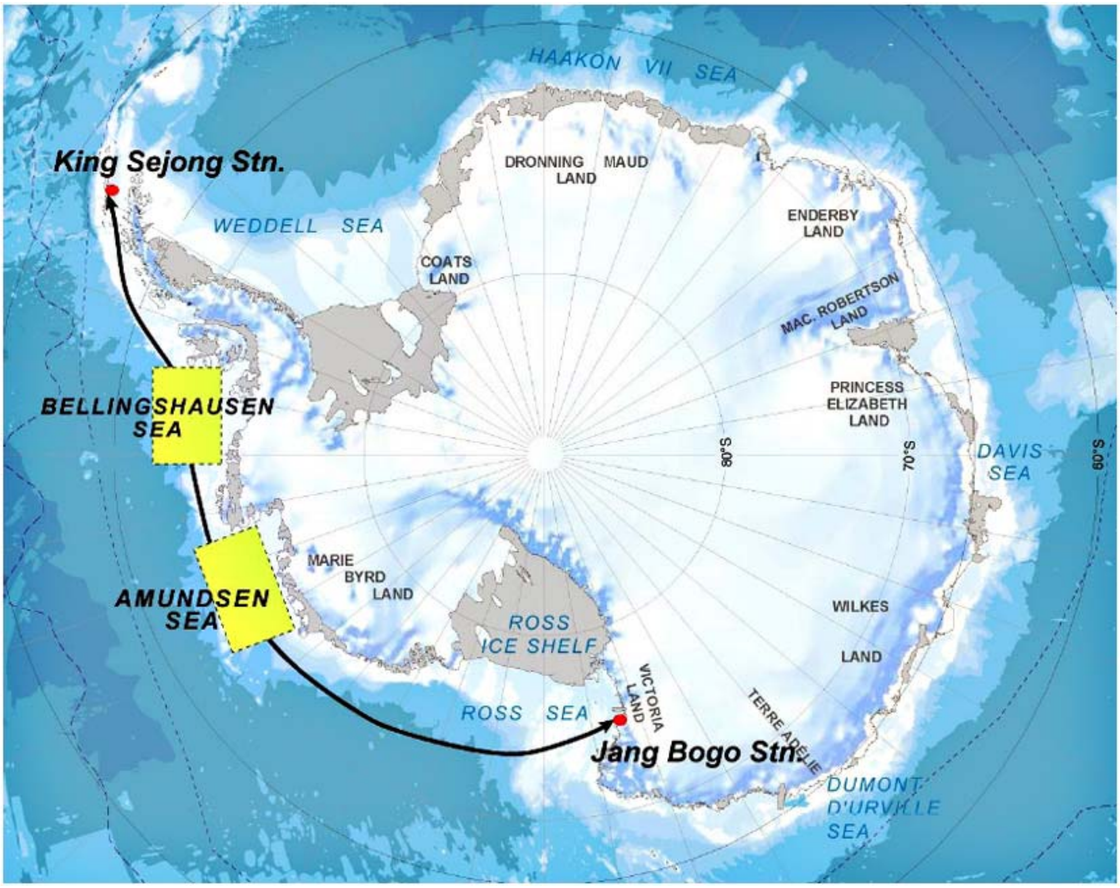


Fig. 1-5. Research sites in West Antarctica. (Base map: adapted from Australian Antarctic Division, 2007)

The Jang Bogo Station will be a sole permanent base operated throughout the year in Northern Victoria Land. It will also accommodate year-round monitoring and research of long-term impacts of climate change to ecosystem of the surrounding areas. Acting as the hub of various researches as well, the Jang Bogo Station will contribute to international collaboration and multidisciplinary studies in support of both Korean and foreign scientists.

The Jang Bogo Station is designed to minimize the impact of its construction and operation activities on the Antarctic environment. Combined Heat and Power (CHP) generation will reuse heat energy from generators and high efficient insulation panels are going to be placed. In order to minimize green house gas emission, the use of solar and wind renewable energy will contribute as much as 30% to the required energy need.

1.2. History of Korea's Antarctic Research

Recognizing the significance of the Antarctic research, Korea joined the Antarctic Treaty in 1986. Korea's history of research interest in the Antarctic reaches as far back as to 1978, when the investigation of krill in the Antarctic Ocean was initiated. However, the first step toward the full-pledged research activities in Antarctica began with the establishment of the King Sejong Station (62°13′S / 58°47′W) on King George Island, the South Shetland Islands, located northeast of the Antarctic Peninsula. The Korea Antarctic Research Program (KARP) based at the King Sejong Station has since been conducted for past 23 years on both land- and sea-sides of the South Shetland Islands, including King George Island and Bransfield Strait. The on-going program on the Antarctic Peninsula includes researches on meteorology and geology of the Antarctic Ocean and northern Antarctic Peninsula; long-term monitoring of the land and marine ecosystems in the region; and marine and benthic ecosystems of the Antarctic Ocean. These multidisciplinary studies are intended to enhance understanding of environmental changes of the Antarctic Peninsula, the most sensitive area to climate change in Antarctica.

The King Sejong Station was registered as an official weather station of the World Meteorological Organization (WMO) in 1989. The atmospheric observation system at the King Sejong Station is studying the exchange of energy between land and atmosphere, and monitoring changes of air chemistry in the polar region by analyzing aerosols.

Furthermore, in an effort to trace the paleo-climate change, studies on the geologic history of the South Shetland Islands as well as the sedimentary environments of both glacier in Bransfield Strait and inner bays are ongoing. Korea is also actively participating in EPICA

(European Project for Ice Coring in Antarctica), an international ice drilling and research program on paleo-climates and paleo-environments. It began to collect meteorites in the ice fields of the Antarctic to study early history of the solar system from 2006 as well.

1.3. Scientific Research at the Jang Bogo Station

Continued legacy of scientific achievements of the International Polar Year (IPY) 2007-2008 evidently emphasizes the importance of the Antarctic in the Earth's system and the need for continuous post-IPY research activities to overcome limited human knowledge on climate change. In solidarity with the legacy, Korea further expanded the scope of the climate change research in its Antarctic Research Program pursuing to benefit humanity beyond borders through better understandings of the global-scale issue.

The coastal area of the Ross Sea where the Jang Bogo Station will be located provides an easy access to a variety of cryosphere (e.g., ice sheet, glacier, ice shelf, ice tongue), geosphere (e.g., Transantarctic Mountains) and hydrosphere (e.g., Ross Sea), accommodating a wide range of studies. The Ross Sea continental shelf represents a unique habitat and is substantially different from other areas of the Southern Ocean because of the extreme seasonality, numerous polynyas and extensive ice shelf. Along with the Weddell Sea, it is also one of the places with extensive bottom water formation in the Antarctic. This region is experiencing rapid freshening that may result in change in the rate of bottom water formation and in turn global climate change. The long-term and winter-over research program based on the Jang Bogo Station will contribute a great deal to understand the rapid climate change in the region and the Antarctic system response to it. The Jang Bogo Station is expected to provide an ideal platform for the research on climate change over the Pacific Ocean side of Antarctica and contribute to promoting scientific research of Northern Victoria Land.

In this context, the Jang Bogo Station is expected to boost multinational and multidisciplinary research collaborations in Northern Victoria Land while its infrastructure will remain open to all international researchers who wish to study the Antarctic. Currently, the United States, New Zealand, Italy and Germany run their research stations in the Ross Sea. International cooperation with these countries in operational support and logistics is expected to increase safety and efficiency in Antarctic activities.

☐ Climate and Atmospheric Chemistry: Establishment and Operation of WMO/GAW Global Station

In order to understand and predict the process of climate change, continuous observation of changing atmospheric compositions in various regions is highly important considering their vital role in radiative forcing.

A WMO/GAW Global Station will be installed at the Jang Bogo Station. This will connect the Atlantic Ocean (Germany's Neumayer III) and the Pacific Ocean regions, being centered on the South Pole (the U.S. Amundsen-Scott Base). This large-scale monitoring of atmospheric components covers the entire Antarctic region, thereby strengthening the understanding of the interaction between the polar region and the middle latitude of the southern hemisphere. An observatory fully functional all year round is critical for such research, but there has been no such permanent observatory within the near-300km radius from the proposed Jang Bogo Station site.

☐ Glaciology and Snow Chemistry: Restoring Paleo-climate and Paleo-environment in the Antarctic

Various proxy analyses using glaciers and snow samples in East Antarctica that will be conducted at the Jang Bogo Station are expected to restore the past climatic change record of the last hundreds of thousands of years and those of more recent decades, enabling a more complete understanding of the climate changes of the region. Furthermore, the Jang Bogo Station will undertake studies of snow and glaciers along the coast of West Antarctica, on which climate change study has been relatively rare. Supported by the icebreaker *ARAON*, these studies will contribute to restoring the paleo-climate and environmental changes of the Pacific margin of Antarctica. In the future, it is also expected for the Jang Bogo Station supporting a new drilling program planned in Northern Victoria Land as part of the global efforts to restore paleo-climate changes in the Antarctic region. For the drilling program, a separate environmental impact assessment will be carried out to see how the drilling activity will affect the local environment.

☐ Tectonics and Geophysics

Various forms of cryosphere are located near the proposed site, such as Aviator Glacier, Campbell Glacier, Priestley Glacier, Nansen Glacier, David Glacier and

Drygalski ice tongue. This geographical set-up makes the site well qualified for monitoring the stability of ice sheet and tectonic evolution of the Antarctic. David Glacier, in particular, is known to be one of the fastest moving glaciers in the Antarctic region. Icequakes caused by this speedy motion have been observed while the low-velocity layer beneath the glacier indicates relatively high geothermal heat. Thus, long-term monitoring of movement and mass balance of the David Glacier will be carried out, and the moving mechanism of the terrestrial glaciers will be studied in order to comprehend the relationship between tectonics and glacial changes. Three-dimensional monitoring will be conducted employing ground, marine, and satellite data.

Installations of seismic, geomagnetic and GPS observation systems at the Jang Bogo Station are planned as part of the Polar Earth Observing Network (POLENET), an international geophysical network working in the Antarctic area.

☐ Long-term Monitoring for ocean and ecosystem

The food web in the Ross Sea continental shelf is substantially different from those in the other areas of the Southern Ocean because of its extreme seasonality, numerous polynyas and extensive ice shelf. This ecosystem is also subject to all physiochemical changes occurring in the area.

For rapid freshening in the Ross Sea, it is of a great importance to identify major oceanographic and atmospheric parameters that are responsible for the freshening and to monitor the variability in the rate of bottom water formation. The observation of sea ice extent and physical processes is also important topics that need to be addressed collectively in a timely manner. As these physiochemical changes of the ocean can alter diversity of the marine ecosystem, its food web and functions, a long-term monitoring in this area is warranted.

In addition, the Jang Bogo Station will assist the observation of ionosphere using Dynasonde antenna; the exploration of meteorite in Northern Victoria Land; and the paleo-climate study of the Ross Sea using marine sediments.

1.4. Preparation and Implementation of the CEE for the Jang Bogo Station

The CEE of the construction and operation of the Jang Bogo Station has been carried out in accordance with the domestic law, "Act on Activities and Preservation of the Antarctic Region," and internationally the Article 8 and Annex I (Environmental Impact Assessment) of the Protocol on Environmental Protection to the Antarctic Treaty.

A survey team composed of environment and construction experts led by KOPRI conducted a preliminary field study for the proposed site of Cape Möbius at Terra Nova Bay in February 2010, to be followed by a more detailed field investigation in February 2011 to confirm the validity of collected data on major bio-species as well as to strengthen hydrographic data on sea currents near the proposed site.

The CEE was completed based on the results of the field study and data analysis as well as predictions and assessment of environmental impacts. A draft CEE written in Korean was submitted to the Korean Ministry of Foreign Affairs and Trade in December 2010 and circulated to relevant ministries including the Ministry of Environment. Currently, it is open to public for opinions on the environmental validity of the project.

The Korean Ministry of Foreign Affairs and Trade will submit the draft CEE (English version) at the Antarctic Treaty 120 days prior to the XXXIV ATCM and XIV CEP (Committee for Environmental Protection) to be held in Buenos Aires, Argentina from June 20, 2011. The final CEE will be submitted to the ATCM once domestic and international processes on the CEE are completed, and before starting the proposed activities.

1.5. Regulations, Standards and Guidelines

In principle, the CEE of Jang Bogo Station follows the essential instructions of Article 8 and Annex I of the Protocol on Environmental Protection to the Antarctic Treaty. In this regard, the draft CEE has been prepared in accordance with the Guideline for Environmental Impact Assessment in Antarctica, which is a sub-guideline to the Principle of Antarctic Environment Protection, prescribed in Article 3 (Environmental Principles) Clause 2(c) of that Protocol (COMNAP, 2005a). In terms of transportation, oil spill countermeasures, waste management and contingency plans, the CEE is prepared following the guidelines for construction and operation of a station, suggested by COMNAP (Table 1-1).

Table 1-1. COMNAP and ATCM guidelines.

Operational Guidelines	
COMNAP Guidelines for oil spill contingency planning	1992
COMNAP Guidelines for the reporting of oil spill incidents which occur in Antarctica	1993
COMNAP Guidelines for Environmental Impact Assessment in Antarctica	2005
COMNAP Papers to Antarctic Treaty Meetings	
XXVII ATCM (IP012)-COMNAP's framework and guidelines for emergency response and contingency planning in Antarctica	2004
XXVII ATCM (WP010)-Guidelines for the operation of aircraft near concentrations of birds in Antarctica	2004
XXVIII ATCM (WP026)-Practical guidelines for developing and designing environmental monitoring programmes in Antarctica	2005
XXIX ATCM (IP088)-Practical biological indicators of human impacts in Antarctica	2006
XXX ATCM (IP0998)-Waste management	2007
XXX ATCM (WP035)-Energy	2007
XXXI ATCM (IP098)-Survey on existing procedures concerning introduction of non native species in Antarctica	2008
XXXI ATCM (IP091)-The COMNAP Fuel manual, incorporating revised guidelines for fuel handling and storage in Antarctica	2008

Korea enacted the Act on Activities and Preservation of the Antarctic Region in 2004 based on the Protocol on Environmental Protection to the Antarctic Treaty. This Act aims to contribute to the protection of the Antarctic environment and advancement in science technology in Antarctica by declaring the principles of activities in the region. Those who wish to commit to activities in Antarctica must consult with the Ministry of Environment and obtain approval from the Minister of Foreign Affairs. The entire process of preparation, consultation, and approval of the CEE will comply with the enforcement ordinances and regulations under the Act.

For air quality, water quality and noise, domestic environmental standards were applied. The domestic environmental standards will be applied to the Initial Environmental Evaluation (IEE) for supplementary field investigations as well as to the CEE. The domestic environmental standards are considered as strict criteria of ecosystem and human health protection and well qualified for application to the Antarctic environment.

1.6. Project Management System

Once the Jang Bogo Station is constructed, KOPRI, the national operator of Antarctic activities, will coordinate the operation of the station and be in charge of Korea's overall research activities in Antarctica including the operation of the King Sejong Station and the icebreaker *ARAON*.

Under the supervision of the Ministry of Land, Transport and Maritime Affairs, KOPRI is responsible for the overall project for the establishment of Jang Bogo Station. Two other national research institutes, Korea Environment Institute (KEI) and Korea Institute of Construction Technology (KICT) were assigned to lead the generation of CEE and the construction master plan, respectively. Universities and private companies were also invited to participate in digital mapping, satellite image analysis, and other activities associated with the establishment of the station. In November 2010, a consortium led by Hyundai Engineering & Construction Co. was awarded the construction contract of the station. The company will be in charge of construction of the entire station, including designing and planning the facilities.

The construction for the Jang Bogo Station is expected to start at the end of 2012 once the proposed activities are agreed by ATCM as well as approved by the Korean Government. The construction will proceed for two Antarctic summers, and the station is expected to begin to operate early 2014. The design of the main station building should provide convenience, safety and energy efficiency. Renewable energy will be used in the station as much as possible. To ensure the best possible outcome in the planning and construction of the Jang Bogo Station, a group of consulting experts in environmental assessment, safety management, construction technology, and other associated areas will be summoned and provide necessary assistance to move the project forward.

2. Description of the Proposed Activity

2.1. Regional Overview

The Terra Nova Bay region is bordered by Cape Washington to the northeast and Inexpressible Island to the southwest in the western Ross Sea of East Antarctica (Fig. 2-1). Italy's Mario Zucchelli Station is located in the Northern Foothills in the west. The station mainly operates as a summer station, where quality research on various fields such as oceanography, geology and ecology is conducted. Cape Möbius lies approximately 7km northeast of the Mario Zucchelli Station, and the Germany's Gondwana Station is situated at the southern end of this cape. The station is a base that undertakes research in geology and geophysics only during the summer.

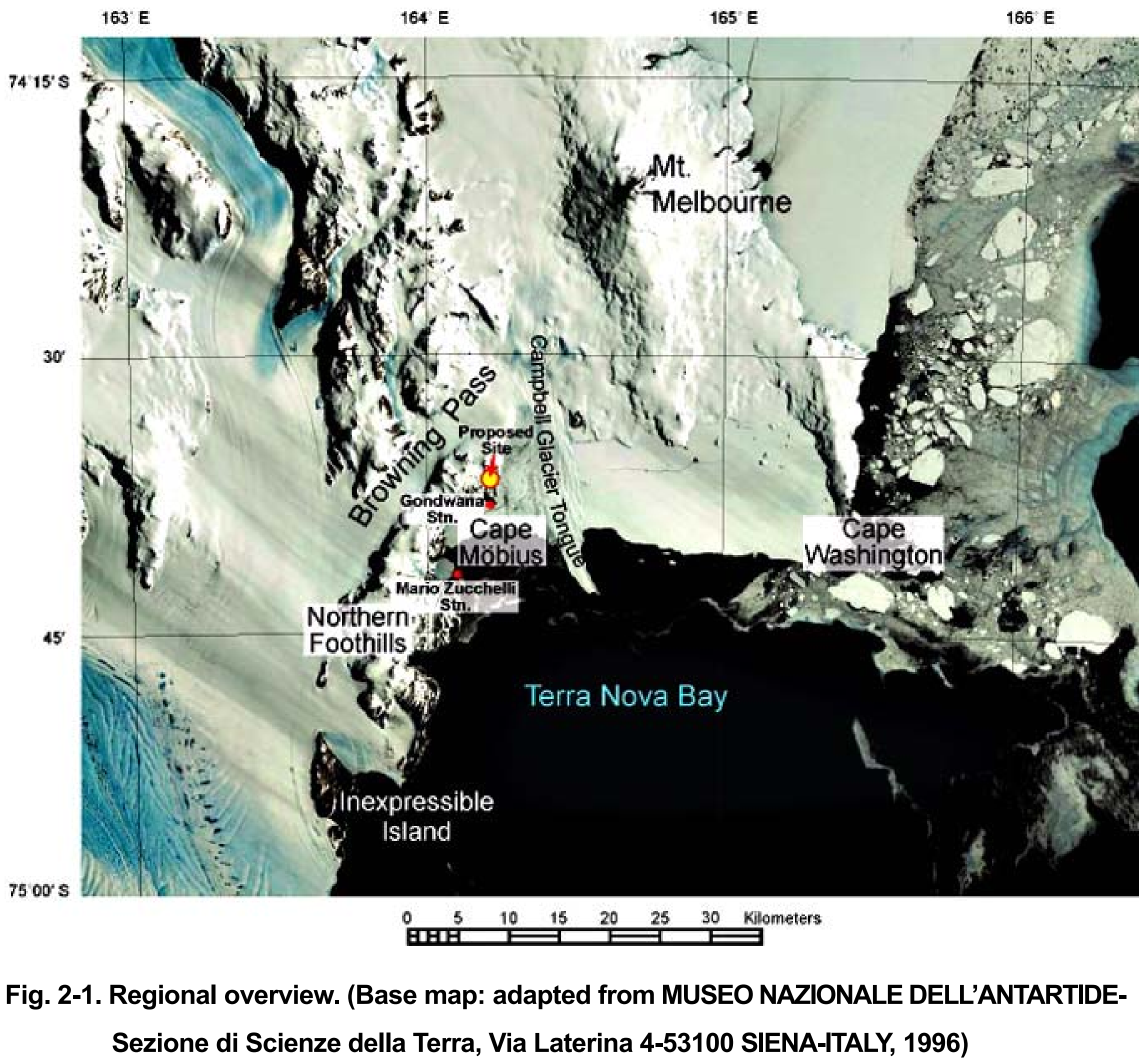


Fig. 2-1. Regional overview. (Base map: adapted from MUSEO NAZIONALE DELL'ANTARTIDE-Sezione di Scienze della Terra, Via Laterina 4-53100 SIENA-ITALY, 1996)

The proposed site for the Jang Bogo Station is located on the flat ground of a small bay 1.2km to the NNE of the Gondwana Station (74°37.4′S, 164°13.7′E, Fig. 2-1). Mt. Browning of NE-SW direction stands in the northwest rear of the proposed site, over which the 3km wide Browning Pass Glacier is developed in parallel. This ice valley is used as a runway by Italy. To the east of the small cape of the proposed site, the Campbell Glacier Tongue, which stretches from north to south, flows to the sea. About 30km NNE from the proposed site lays Mt. Melbourne.

A large colony of more than 150 South Polar Skuas resides in the eastern hills of Cape Möbius, but no penguin colonies were found in the region. There are two Adèlie penguin colonies near the Mario Zucchelli Station and a colony of Emperor penguins near Cape Washington approximately 20km to the east from the proposed site.

2.2. Proposed Activities

2.2.1. Main Activities

Main activities mentioned in the CEE include construction, operation and dismantling of the Jang Bogo Station and logistics to the station. The construction of the station is expected to commence in December 2012 and continue until April 2014 on during two consecutive Antarctic summer seasons. In principle, all activities related to the construction and operation of the station will adhere to the Protocol on Environment Protection to the Antarctic Treaty, and the impact of such activities on the environment has been planned to be restricted to a minimum level.

2.2.2. General Specification of the Jang Bogo Station

The station is planned to be in use at a minimum of 25 years. For the year-round operation of the Jang Bogo Station, it is planned that there will be 15 staff members in the winter, and up to 60 personnel, including additional researchers and visitors in the summer (Table 2-1). The number of winter-over staff doubles during the overlap in summer.

Table 2-1. Personnel for operating the Jang Bogo Station.

Type	Personnel	
	Winter	Summer
Staff	11	24
Researchers	4	Max. 36
Total	15	60

The station consists of the main building, power plant, maintenance facility, storage, and emergency shelter with a building area of 3,826.9m^2. Other facilities such as scientific observatories, antennas, fuel tank and heliports will additionally be installed (Appendix 1).

The design of the station includes a triple-arm shaped central main building, which connects to individual facilities such as the maintenance and power facilities in radial arrangement. As a result, all facilities will be placed close to each other. This station layout is intended not only to give the safety, functionality and efficiency that the operation of the station requires, but also to limit the land usage and minimize potential intrusion to the environment. Furthermore, as all facilities will be directly connected to the main building, the indoor traffic and associated energy loss will be minimized.

An aerodynamic design will be used for the main building in order to enhance its resistance against strong winds. Fire protection will be implemented with compartmentation in the building. The building will be elevated from the ground surface and be built with slanting walls and roofs to minimize snowdrift piling up around the building. Light shelves will bring in natural light from outside and double-layer walls and five-time glazed windows will maximize the energy efficiency.

Each facility will be in harmony with the natural landscape. The current design of the building foundation does not require driving piles or anchors into the ground, and hence, will not only shorten the construction period but also minimize the noise generated in the process. Modular construction system will be applied to most of the buildings in order to further shorten the overall construction period.

In order to minimize the use of fossil fuels required in the operation of the station, CHP system will be mainly used and the generators will fully utilize the waste heat. Solar and wind renewable energy system will be co-operated with at least 30% of the 320kW CHP capacity.

A comprehensive state-of-the-art treatment system will be used to treat wastes and wastewater during the operation of the station. All wastes generated by the station will be stored and treated accordingly with the regulation before being transported out of Antarctica. If incinerating is required, high temperature combustion method with flue gas recirculation will be used.

Using the gray water reclamation and reuse system, most wastewater will be reused, and the small amount of discharge water is expected to be near pollutant-free.

It is expected that activities related to logistics and transportation can be expanded depending on the changes of the station's operation plan, including cooperation with other stations and future research.

An environmental monitoring plan will be implemented in order to regularly monitor the environmental changes caused by the activities at the station. A systematic emergency plan will also be established.

2.2.3. Transport and Logistics

All supplies for the station will be surface-shipped from Busan, Korea to Terra Nova Bay, via Christchurch, New Zealand. On the other hand, all personnel will be traveling by air from Incheon, Korea to Christchurch, arriving at Terra Nova Bay using the icebreaker *ARAON* (Fig. 2-2).

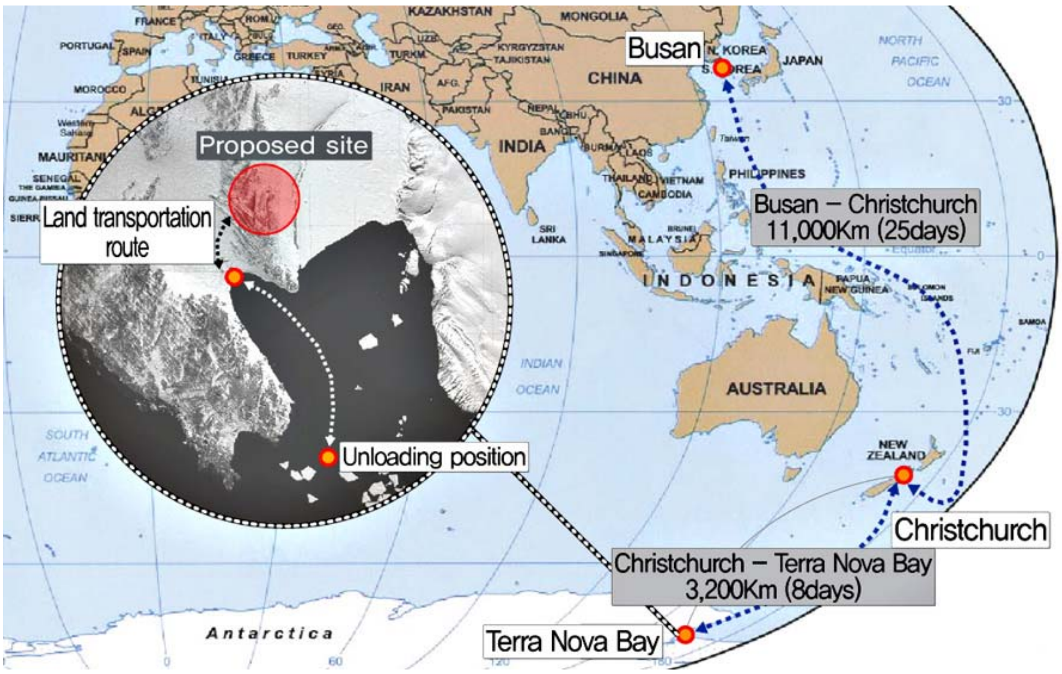


Fig. 2-2. Transportation route for shipping.

Given the geographical features of the proposed site, and the fact that there is no additional supply base in the area, the icebreaker *ARAON* will be providing main logistics support to transport supplies including the maximum 6,000kg food once each austral summer.

For the transportation of cargos and workers associated with the construction of the station, the *ARAON* and a chartered ice-strengthened cargo ship will be used. After they anchor near the proposed site, barge ships and helicopters will carry the workers and cargos from the ships to the land. Tracked vehicles will be needed for the additional 200m ground transport from the unloading point to the proposed site (see section 3.6 for more detail).

2.3. Station Design

The main demands for the design of the Jang Bogo Station were maximum energy efficiency and endurance to extreme weather conditions of the Antarctic region for the year-round operation of the station. Such demands prompted an aerodynamic triple-arm structure protective of strong winds in all directions (Fig. 2-3).

The concentrated radial positioning of facilities around the main building is intended to reduce the overall area usage of the station, thereby minimizing any possible intrusion into the surrounding environment. In order to reduce interferences between different programs in the station and to enhance functionality and efficiency in maintenance and management, each section of the building is clearly separated by its function in the design.

Energy plans of the station during the summer include installing light shelf and duct systems, and solar energy, which will encourage the highest level of activities by the largest number of personnel, to be engaged in during the long daylight hours. Furthermore, the double-layer walls of the building will minimize energy loss by using the state-of-the-art insulations.

Fig. 2-3. Aeroview of the Jang Bogo Station.

☐ Station Layout Plan

The layout of the facilities in the station aims to provide the safety, functionality and efficiency required for the operation of the station. The facilities will be grouped into relevant sections and each section will be placed at the location that can provide optimal routes to other sections considering the inter-connectivity with minimal functional interference. With the main building acting as the pivot, facilities that will be used for similar comparable programs will be located within the same arm of the triple-arm structure. More specifically, most of the maintenance facilities and an emergency shelter will be located in the southern part, separated from the main building and the research facilities to minimize the noise disturbance. Research facilities for atmospheric science and geophysics will be located at a safe distance from the main building within the northwest and northeast arms, respectively, minimizing potential interferences by equipments in one facility on those in the other facility (Fig. 2-4(a)).

With the radial arrangement with the main building in the center, the layout plan provides direct access to the facilities from the main building. Major facilities include research facilities, power plant, maintenance and storage buildings, waste treatment facility, communication antennas and observatories. For renewable energy, wind turbine towers will be installed and solar panels will be mounted on the walls of buildings (Fig. 2-4(b)).

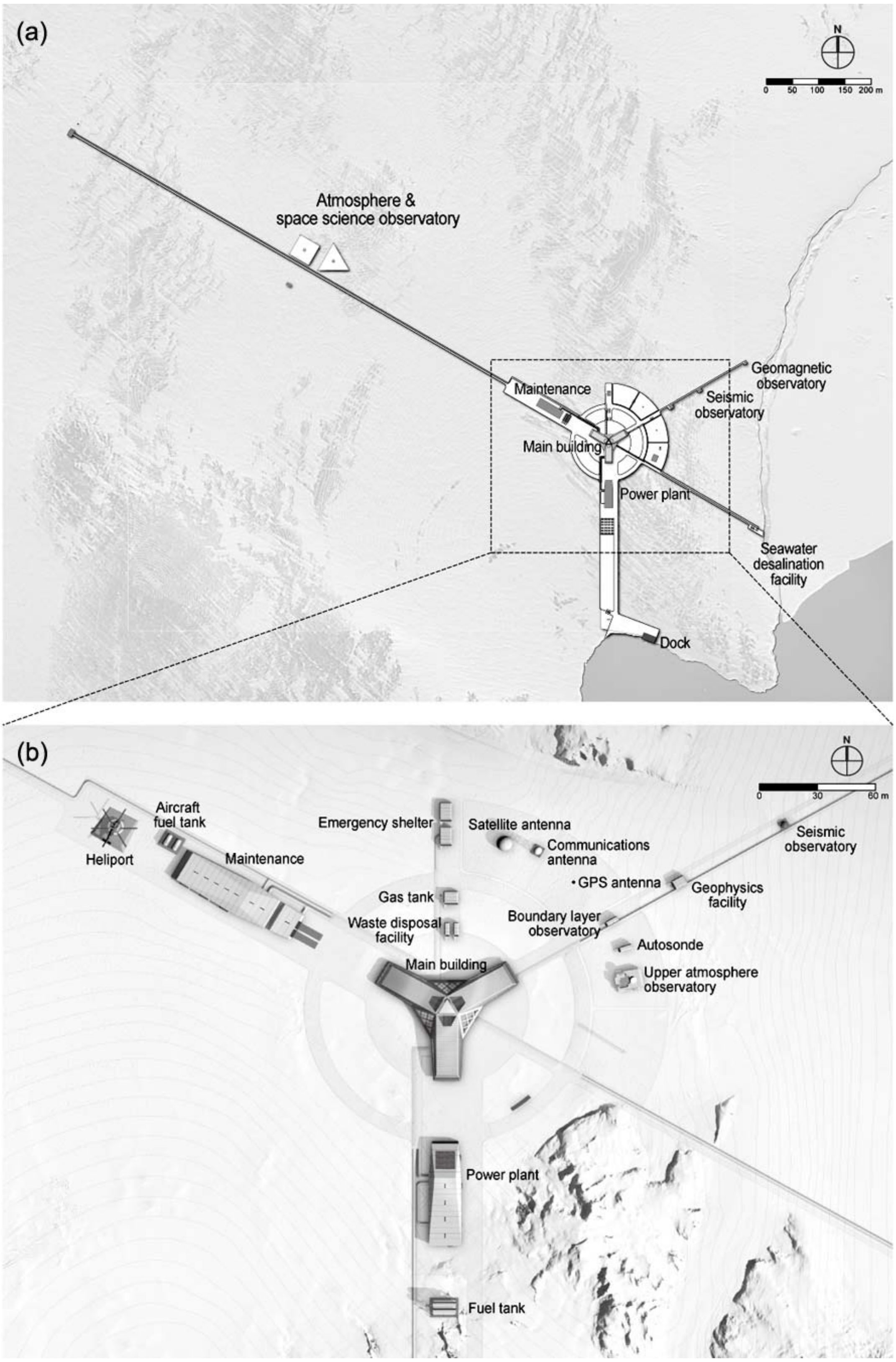


Fig. 2-4. Layout of the Jang Bogo Station. (a) Layout plan based on activities, (b) Arrangement of facilities.

☐ Main Building

The main building is designed to be an aerodynamic triple-arm structure elevated from the ground considering the strong winds and heavy snow in the region. Three main sectors of research labs, sleeping areas and residence supporting facilities are located on the elevated first floor of the main building. These sectors are laid out in the triple-arm structure, allowing each sector to be independent, at the same time making it secure, functional and efficient. The layout of the other floors in the building includes an Air Handling Unit (AHU) and emergency equipments on the ground floor, an office and meeting room on the second floor, and a communication room and observatory on the top floor (Fig. 2-5).

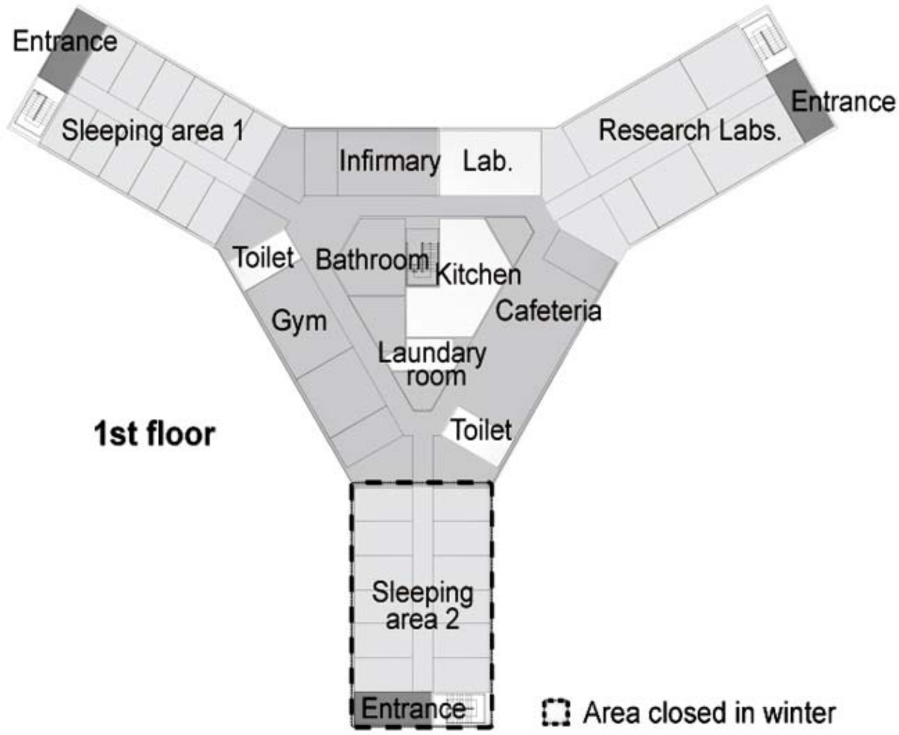


Fig. 2-5. Main building program.

Residence supporting facilities will have tall windows that allow as much natural light as possible into the facilities. A three-dimensional space plan has been devised for each floor and function area (Fig. 2-6).

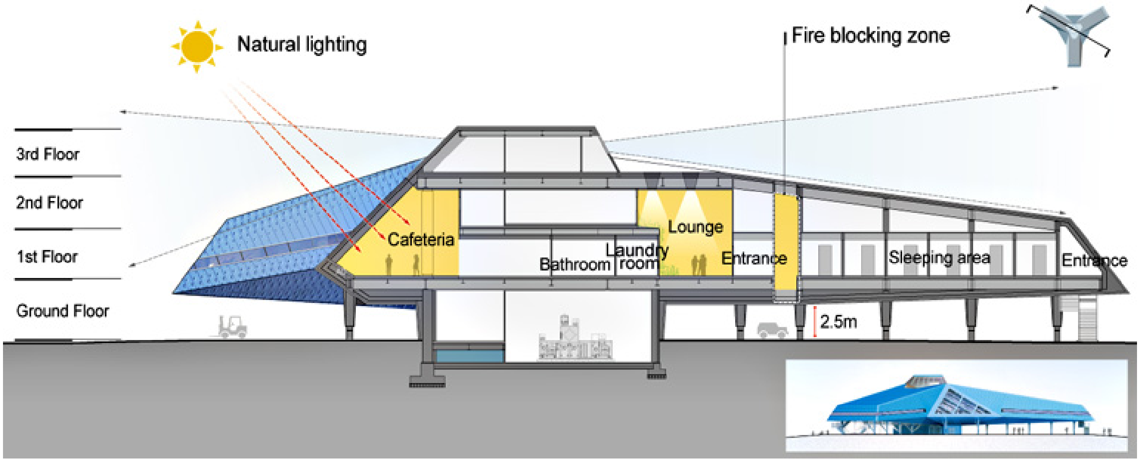


Fig. 2-6. Sectional view of the main building.

Furthermore, the working space and residence area will be separated through a division of both horizontal and vertical space. Facilities that may generate excessive noise will be grouped together, and separated from the sleeping areas and research labs with noise buffer zones to manage internally generated noise problems (Fig. 2-7).

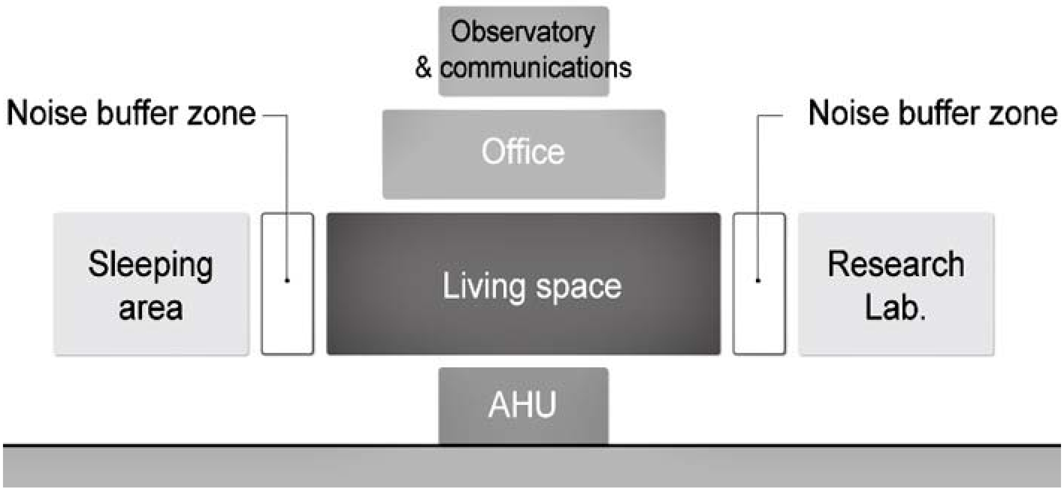
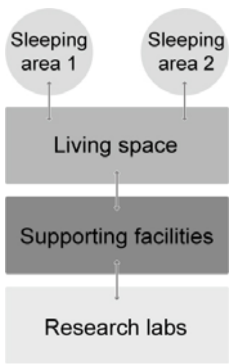
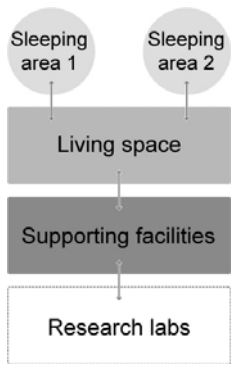
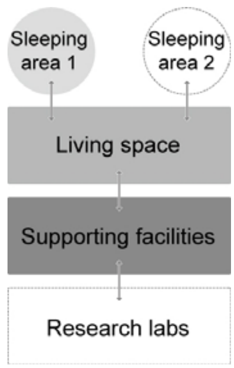
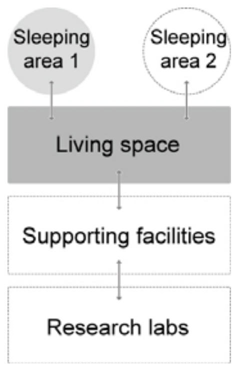


Fig. 2-7. Schematic diagram of noise buffer zone.

Also, an energy savings and efficiency plan was developed to plan sectioning of the main building into different operating areas by daily and seasonal changes in number of staff and facilities in operation. One of the residence areas and some research labs, for instance, will be closed during the winter to reduce the base operation down to 42% (Table 2-2). Meanwhile, cafeteria and convenience facilities will be installed with removable wall panels to be able to accommodate seasonally varying number of people they serve.

Table 2-2. Daily and seasonal operation plan of the main building.

Time	Summer day	Summer night	Winter day	Winter night
Personnel	60		15	
Main facilities in operation				
Operation ratio	100%	76%	65%	42%

The access passages for residential and research activities will be situated in close proximity to one another for both safety and accessibility reasons (Fig. 2-8(a)). In contrast, the access passages for vehicle, unloading, emergency and evacuation will be installed at locations to cause minimal disturbances to the passages for residential and research activities, and connected to the equipment facilities. The access passages for vehicle and unloading will also be connected to the dock facilities (Fig. 2-8(b)).

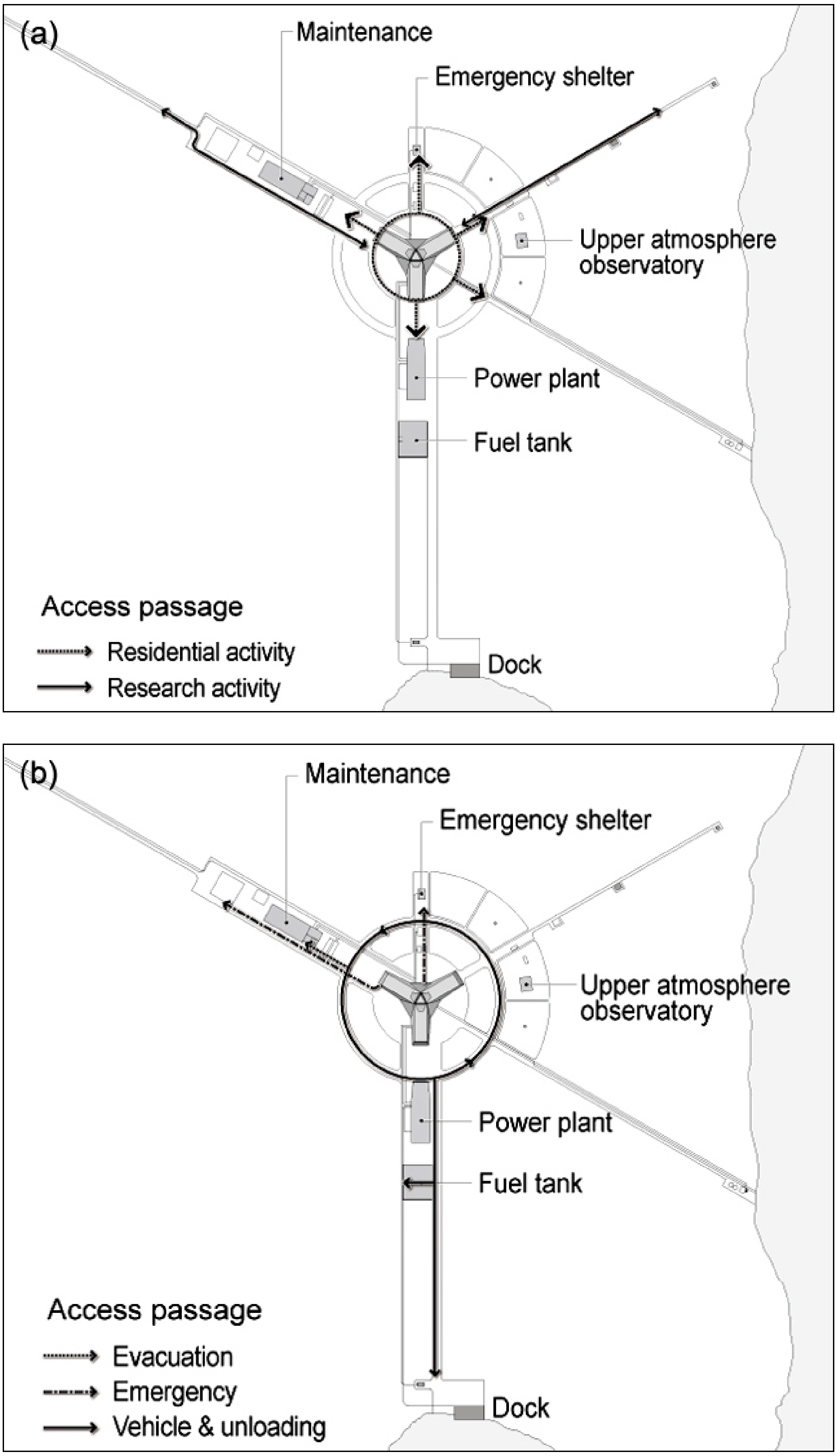


Fig. 2-8. Major access passages. (a) Residential and research activities, (b) Evacuation, emergency and vehicle.

□ Fire Prevention Plan

The division of the main building into discrete fire zones may offer the most effective means of limiting fire damage. Fire blocking zones divide the residence support and research facilities in order to prevent the spread of smoke and flames in the event of a fire (Fig. 2-9). In the event of a fire or emergency, all facilities will have two-way escape routes (Fig. 2-10) and the emergency shelter located on the opposite side of prevailing wind direction will minimize the impact of flames and smoke caused by wind during escape.

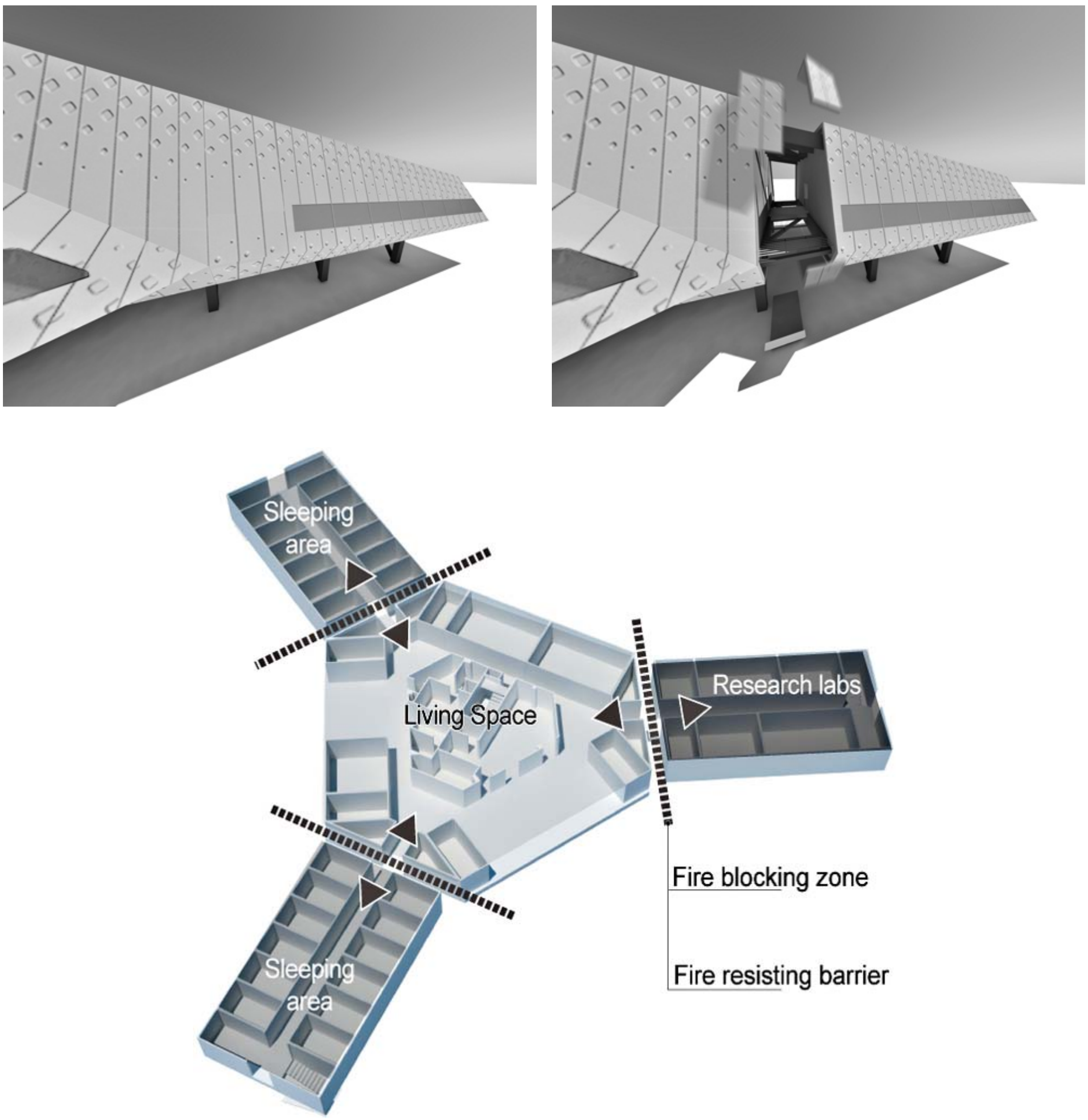


Fig. 2-9. Installation of fire blocking zone.

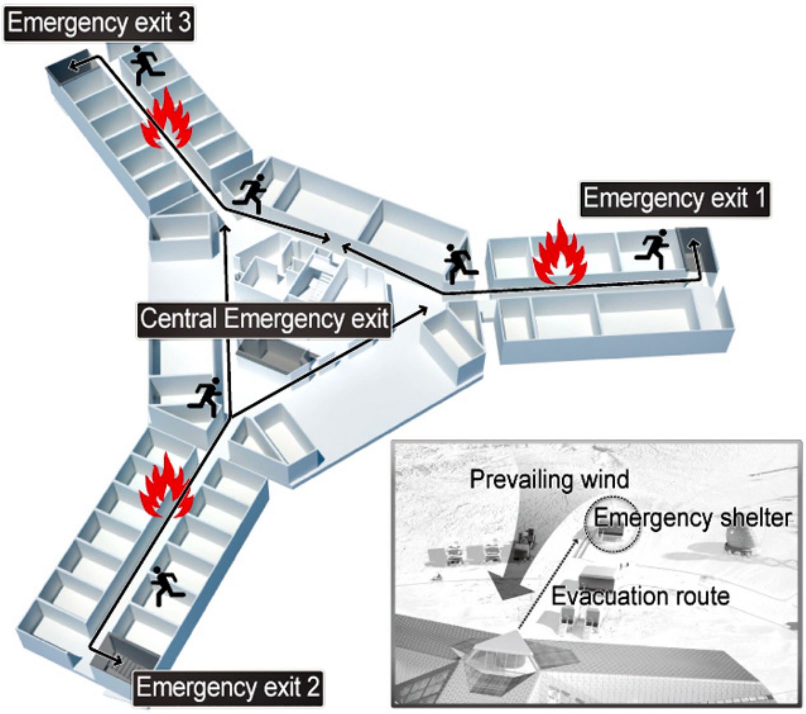


Fig. 2-10. Emergency evacuation plan.

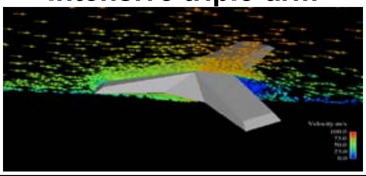
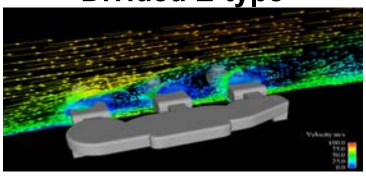
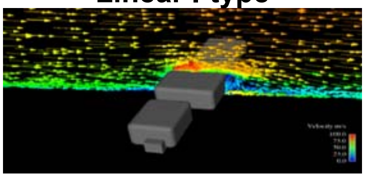
☐ Safety from Winds and Snow

Some stations in the Antarctic region are suffering from snow pile-up that incurs considerable management costs of snow removal for accessibility and structure maintenances. A solution to this issue is the establishment of an optimal building layout plan based on an assessment of the changing patterns of wind speed and snow drift at the time of design and construction. Accordingly, a Computational Fluid Dynamics (CFD) numerical simulation on the hydrodynamics was conducted in order to evaluate the most appropriate design required to minimize the impact by the wind and snow pile-up.

First, the wind pressure indices of three different building designs, the intensive triple-arm design, divided E-type design and the linear I-type design, were compared to see how they respond to the strong winds. After calculating the basic wind speed using the data of weather conditions, wind pressure indices of construction standards were calculated with the CFD simulations. The wind pressure index of the intensive triple-arm design was 0.47, which showed that it is the least affected by strong winds as the indices for the E-type and the I-type structures were 1.14 and 1.26, respectively.

Therefore, the intensive triple-arm design was evaluated as the most structurally sound design to withstand the impact of snowdrifts (Table 2-3).

Table 2-3. CFD simulations of three different types of building designs based on wind pressure index.

Type	Category	Drag Index	Lift Index
Intensive triple-arm 	Wind pressure index	0.47	0.04
Divided E-type 	Wind pressure index	1.14	0.29
	D	2.4	7.3
Linear I-type 	Wind pressure index	1.26	0.20
	L	2.7	5.0

Note) D and L: increasing/decreasing ratio of wind pressure index relative to intensive triple-arm type

Snowdrift damage caused by blizzards occurs due to the eddy flow at the rear of the structure. Drifted snow can accumulate up to more than five meters, causing extra work of clearing the snow.

Sometimes, the weight of the snowdrift may deform the structure. Combined with an elevated slanting structure, design of outer wall surface adopting the dimple effect can help minimize the damages of snowdrift. The elevated slanting structure enables the wind to circulate in the space between the structure and the ground, minimizing the exchange of heat between the relatively warmer building and the permafrost. Furthermore, the slanted design shades less area than the rectangular design, and hence, the ice formations near the main building will be also reduced (Fig. 2-11).

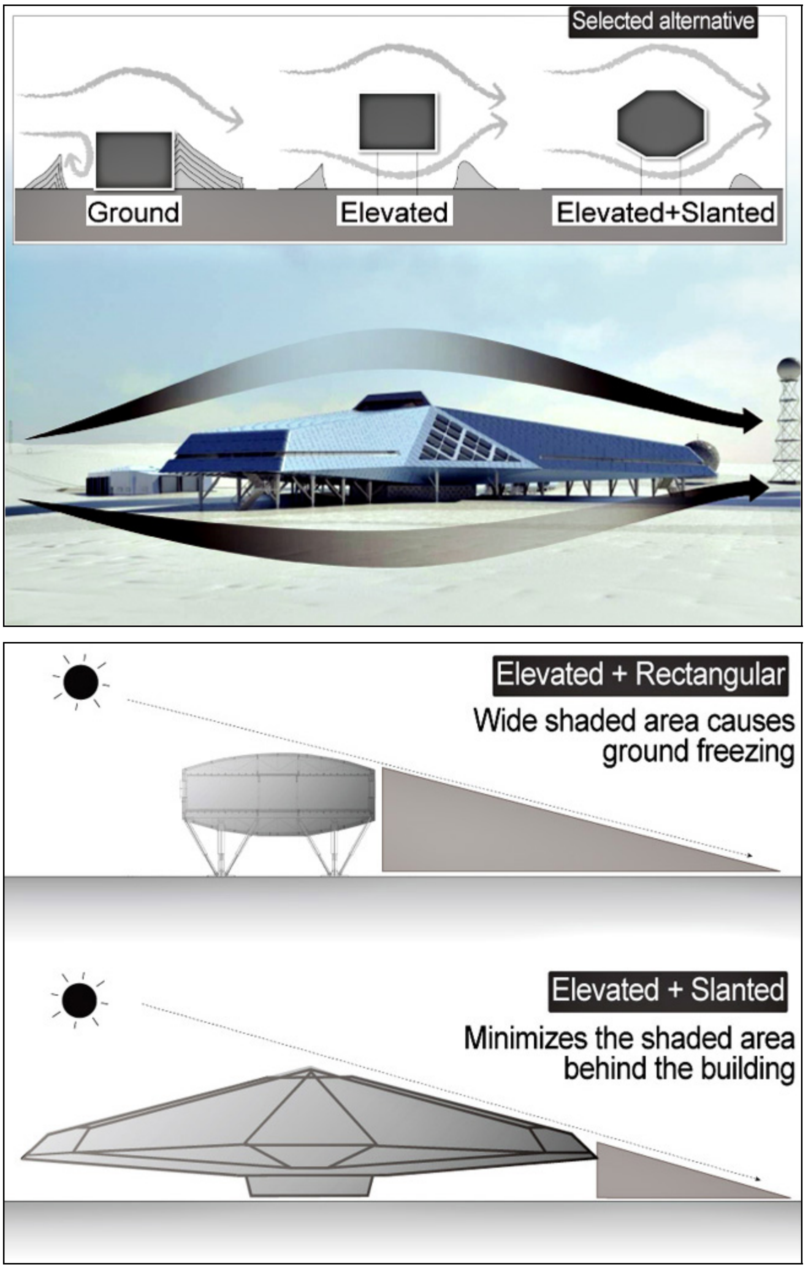


Fig. 2-11. Minimization of snowdrift and shading by adopting elevated and slanted design.

The result of the simulation on the main building elevated more than 2.5m above the ground surface indicates that there will be little snow pile-up in the surrounding area with the triple-arm design. Only a small pile of snow was created near the slipstream in the simulation (Fig. 2-12).

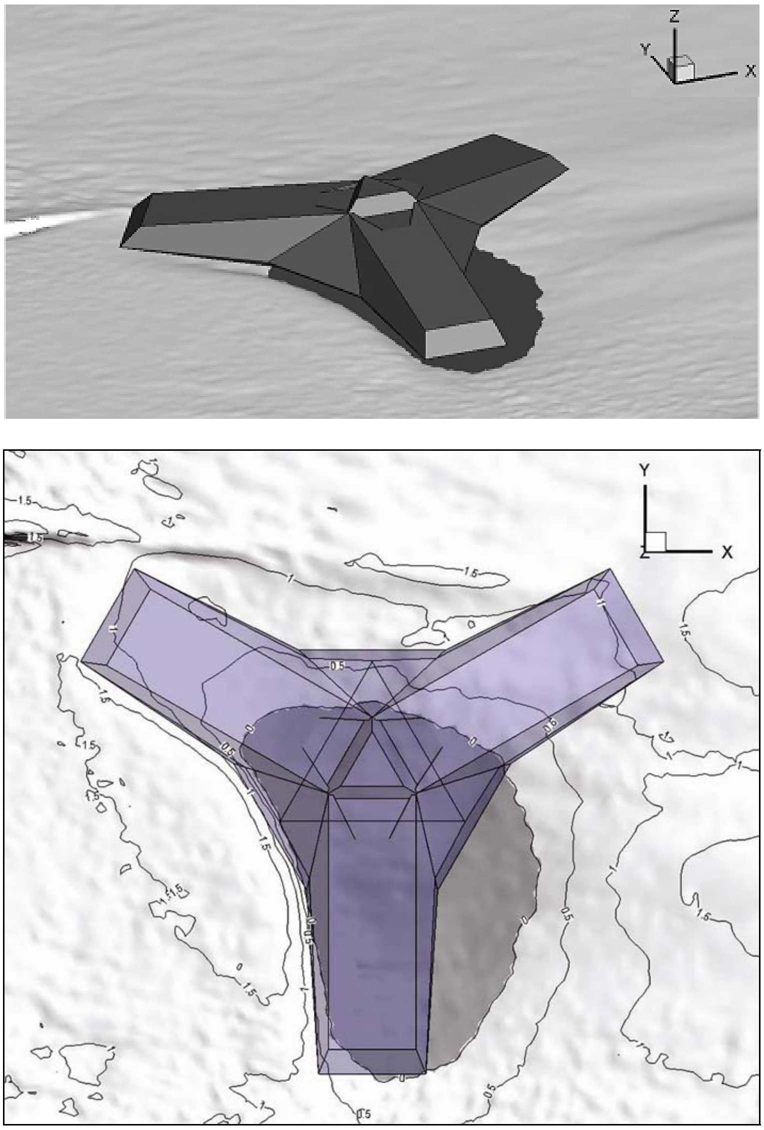


Fig. 2-12. Simulation of snow-piling up for the main building.

☐ Foundation type

For the foundation of the main building and facilities, the Precast Concrete (PC) and mat foundations were selected. Since these types of foundation do not require pile or anchor driving into the ground, it will greatly reduce field work and construction time. Mat foundation for power plant, maintenance building and satellite antennas will be also advantageous as it minimizes differential settlement and acquires bearing capacity (Table 2-4).

Table 2-4. Type of foundation.

Parameter	PC Foundation	Mat Foundation
Type		
Feature	- No pile and anchor needed - Precast concretes	- High bearing capacity - Minimizes the effect of differential settlement
Application	Foundation of main building	Foundation of power plant, maintenance building and satellite antenna

☐ Dock

A dock is indispensible for the construction as well as operation of the station. In order to minimize its impact on the marine environment, the Gravity Wall type technique will be applied. This technique is one of the most secure structural methods as it can minimize resistance of external force and pack ice. By not using piles or anchors, it can minimize any impact to the natural landscape of the coast compared to other techniques (Fig. 2-13).

Furthermore, a layout plan will be developed to be less exposed to pack ice and strong wave and the secure and durable stainless steel box will be used to minimize the impact on the marine environment. The stainless steel box will be prepared in advance in Korea and later assembled on the field so that it can shorten the construction period.

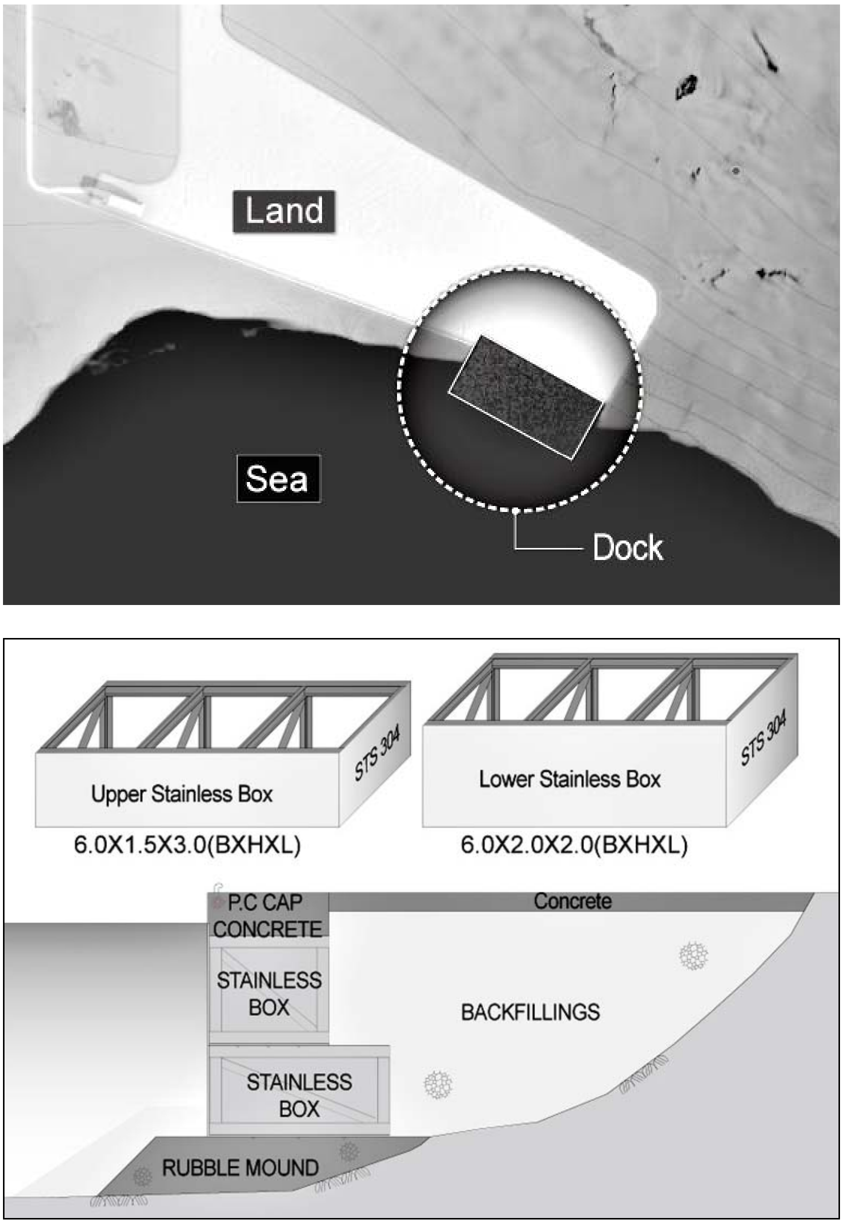


Fig. 2-13. Dock construction.

2.4. Construction of the Jang Bogo Station

2.4.1. Time Schedule and Duration

The construction of the Jang Bogo Station will commence in December 2012 to be completed by April 2014. It will be carried out in two phases over two consecutive Antarctic summer periods. If the cargo unloading or construction is obscured due to regional weather conditions, the construction period may be longer than initially planned.

The construction of the most of the major facilities surface grading and structures will be completed during the first phase. During the second phase, a step-by-step construction is scheduled for the supplementary facilities and installation of renewable energy equipments, and pilot operation of the station. Most of the major facilities will be assembled using modular units on site in the first phase (Fig. 2-14).

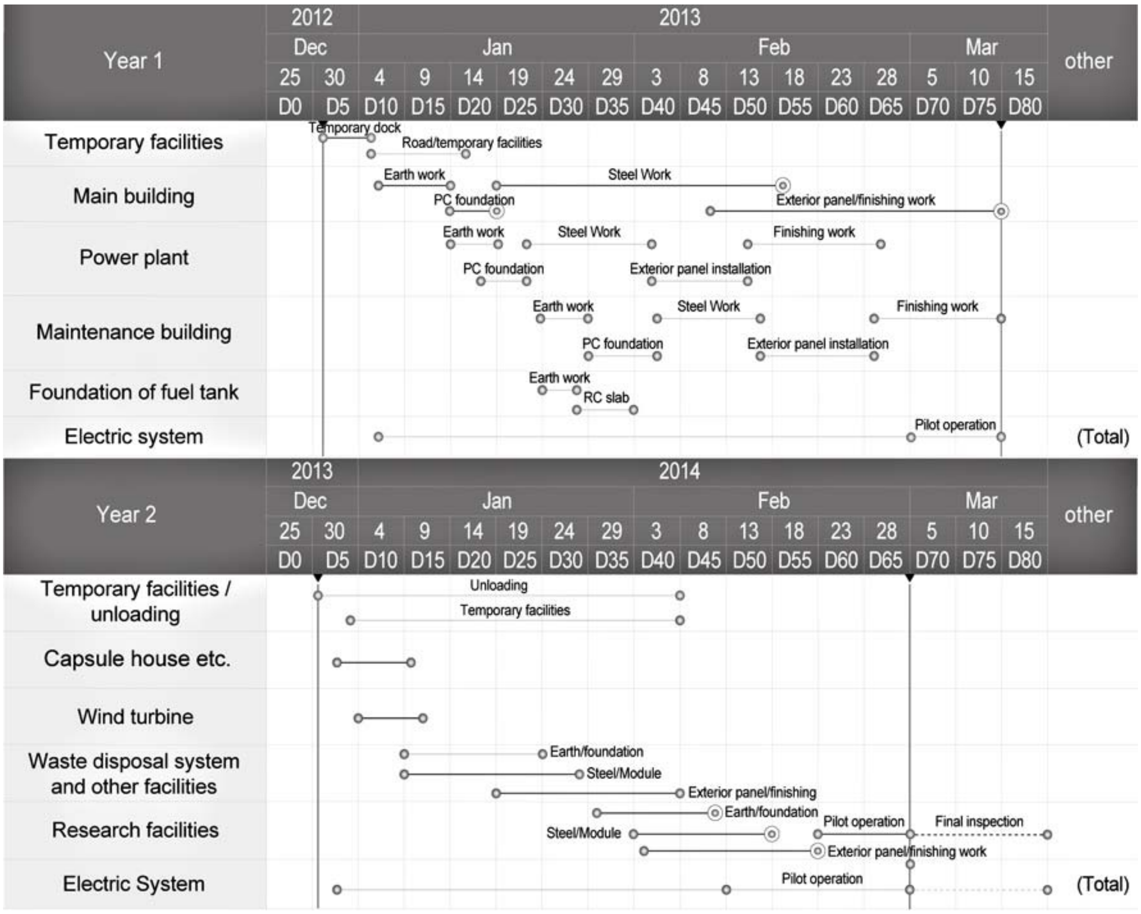


Fig. 2-14. Timeline of the construction phases.

2.4.2. Construction Workers and Accommodation

A total of 205 construction workers are expected to be required on a phase-by-phase basis (Table 2-5).

Table 2-5. Construction workers.

Phase	Personnel	Working period
Year 1	110	Dec. 2012 - Mar. 2013
Year 2	95	Dec. 2013 - Apr. 2014

Given the number of workers required in each phase, 29 containers (2.43m×6.09m×2.58m) will serve as temporary accommodations for them. The total area of the accommodations is 429m^2. A total of 110 workers will use the facility in the first construction year, and 95 workers in the second construction year. The containers will be removed from the Antarctic region after the completion of construction.

Two 250kW power generators will be rotated as the main energy supply for the operation of accommodations and facilities during the construction period (Table 2-6).

Table 2-6. Plan of energy use during construction.

<table>
<tr><th>System</th><th>Purposes</th><th>Energy supply</th></tr>
<tr><td>Heating</td><td>Electric heating</td><td rowspan="4">Generators for electric power (2×250kW in rotation)</td></tr>
<tr><td>Sewage & wastewater</td><td>Sewage & wastewater disposal equipments (22ton)</td></tr>
<tr><td>Water supply (desalination system)</td><td>Desalination equipments (7×4.5ton ea.)</td></tr>
<tr><td>Kitchen</td><td>Electric kitchen equipments</td></tr>
<tr><td>Waste disposal</td><td>Recycling and treatment of wastes</td><td>-</td></tr>
</table>

The food required during the construction will be shipped from Korea and stored using two refrigerators and two freezers. An emergency shelter for the workers will also be installed.

The wastewater generated during construction will be treated at the wastewater treatment facility that will be installed in the temporary machine unit. Solid wastes produced during construction will be stored and treated in an appropriate manner based on a waste management plan pursuant to the Protocol on Environment Protection to the Antarctic Treaty. All solid wastes including construction materials will eventually be removed from the Antarctic after construction. Food wastes will be dried and compacted using a disposal equipment to minimize volume, which will then be stored in a separate place before the off-site removal.

2.4.3. Shipping

A transportation plan has been devised based on the estimated shipping needs for the materials, equipments and workers required for the construction of the station.

Estimated 6,966ton of construction cargo and personnel will be transported to the proposed site for the first construction year, while estimated 7,057ton of construction cargo will be shipped for the second year (Table 2-7).

Table 2-7. Transport by ship during construction.

Phase	Construction cargos
Year 1	6,966ton
Year 2	7,057ton

Note) Remove all wastes from the Antarctic region at the end of each construction phase.

Two 200-ton non-powered barges and a tugboat will be used to unload cargos safely from the ship. Furthermore, a total of 36 heavy equipment will be transported including a 30-ton bulldozer, and two 20-ton trailers for transporting cargos from the unloading site to the proposed site.

2.4.4. On-site Assembly of Facilities

In an effort to minimize the construction period, a modular construction system has been established through which unit modules will be pre-produced in Korea, and later assembled on site. This modular construction system will help streamlining the construction process, by minimizing the construction period, the number of on-site workers, and construction wastes. The system will also facilitate dismantlement of the station in the future.

The size of the container for the unit modular was determined to be 3.0m×6.0m×3.1m by considering the overall volume capacity of the crane, and the working conditions at the site.

2.5. Operation of the Jang Bogo Station

2.5.1. Energy Management

The energy supply strategy during the station operation is to minimize energy loss and maximize energy efficiency. A CHP system will provide electrical power and heat for the platforms in the most efficient manner possible to minimize waste energy and, therefore, reduce fossil fuel consumption. Furthermore, the solar and wind renewable energy will be used in order to minimize CO_2 emissions.

☐ Energy use

Three types of utilities will be used for the operation of the station: electricity, waste heat and gas. The estimated total energy consumption includes an annual 1,603MWh of electric energy for the operation of research and residence facilities, waste disposal and wastewater treatment; 830MWh of waste heat energy for heating and hot water of main building; and 40.5Gcal of gas for the kitchens (Table 2-8).

Table 2-8. Estimated annual energy consumption in the Jang Bogo Station.

Source	Energy consumption
Electric power (CHP, Renewable Energy)	1,603MWh/year
Waste heat (CHP)	830MWh/year
Gas (Kitchen)	40.5Gcal/year

☐ Energy Supply Facility

Three 320kW CHP systems will be installed out of which two will alternate to be used as regular generators and one as a spare generator. Furthermore, another 320kW generator will be installed separately in the emergency shelter so that it will provide energy in emergency.

Solar and wind renewable energy will take up at least 30% (96kW) of the total capacity. A detailed installation plan of renewable energy system will be decided based on the factors such as the acquisition of a system that is durable in extreme conditions, efficiency, installation environment and the appropriateness of size. Renewable energy can be used to provide the emergency power supply to the major facilities in case all four generators fail.

☐ Renewable Energy

– Solar energy

Considering that the region's maximum solar elevation angle is 39.1° (*cf.*, NASA, 2008; Tin *et al.*, 2010), solar panels will be installed with the latest technology. The solar panels will be installed on the wall of the building to prevent damages from strong wind and blizzard as well as consider the solar elevation angle in this region.

– Wind energy

For wind turbine, 20kW vertically stacked modular type structures, each composed of four 5kW small capacity turbines, will be installed. The stacked-type design is space saving, convenient for transportation, construction and maintenance, while minimizing the noise generated by the turbine. The location of the wind turbine towers will be included in the final design.

– CO_2 reduction

When applying the equipment capacity for solar and wind energy as 60kW and 36kW, respectively, the total generation of renewable energy is expected to be 218,482kWh/yr, which will contribute to reducing fossil fuel by 66,576ℓ/yr. The use of renewable energy will eventually help to lower CO_2 emissions by a total of 97.2TCO_2/yr, of which 83.0TCO_2/yr will be reduced by wind energy and 14.2TCO_2/yr by solar energy (Table 2-9). These values, however, will be variable depending on the ratio of solar and wind energy.

Table 2-9. Fuel and carbon dioxide reduction by using renewable energy.

Source	Energy generation (kWh/yr)	Fuel reduction (ℓ/yr)	Carbon dioxide reduction[1] (TCO_2/yr)
Wind energy	186,624	66,576	83.0
Solar energy	31,858		14.2
Total	218,482		97.2

1) Carbon dioxide emission factor for power: 0.4448TCO_2/MWh (Korea Energy Management Corporation, 2009)
- Assuming solar and wind energy capacities, 36kW and 60kW, respectively

2.5.2. Water Generation

The seawater desalination facility will be installed to produce freshwater and the seawater storage tank will be double-skinned. Two 20-ton seawater desalination tanks and one 65-ton freshwater tank will be installed.

Snow melting device will be installed in addition to the seawater desalination facility. The capacity of the snow melting tank is 20-tons and will be operated by waste heat from the CHP plant.

The water supply required was calculated to be 150ℓ/day per person, which includes water needed for cooking, washing and personal hygiene. The tank will have sufficient water storage capacity for 7days. In addition, a 14-ton water tank will also be installed in the emergency shelter, and an electric-based snow melting facility will be installed to cope with emergency situations.

The eastern coast, which is the shortest distance from the water supply facility, has been selected as the intake point in order to minimize the energy required for the transfer of seawater (Fig. 2-15). The water pipes will be installed more than 1.2m above ground with heating wires and insulation to prevent freezing.

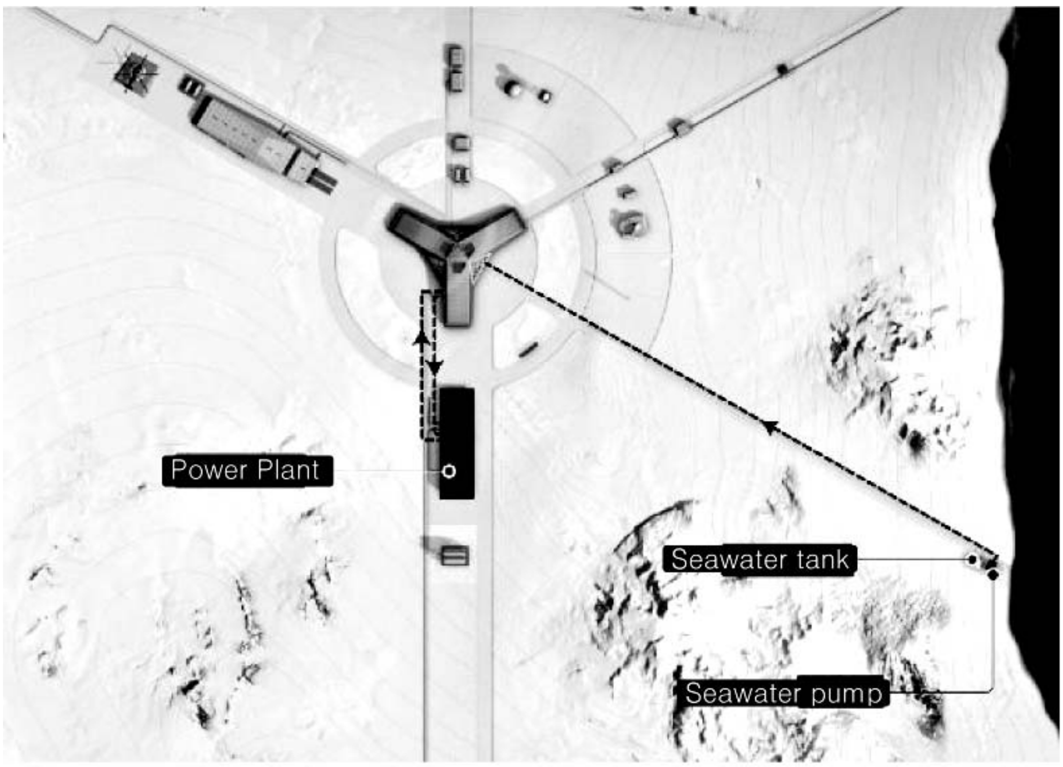


Fig. 2-15. Layout of seawater use system.

2.5.3. Fuels

The Antarctic Diesel required to operate the power generator, vehicles and incinerator is expected to be a total of 395,068ℓ per year. The use of helicopters will require approximately 31,250ℓ of fuel, and the kitchens will require LPG of a total of 2,778Nm^3 per year (Table 2-10). Six 110-ton fuel tanks and two 25-ton aircraft fuel tanks will be installed, and the LPG will be stored in a gas storage tank. At least two-year supply of fuel will be stored as the emergency fuel supply plan.

As a ship can approach up to approximately 700m to the coast, fuels will be transported using floating oil hoses to a pumping facility at the coast to be fed into the fuel tanks at the station through a pipeline.

Table 2-10. Fuel use (per year).

Fuel type	Facilities	Annual consumption	Total
Antarctic Diesel	Generator	244,579kg	395,068ℓ
	Vehicles	18,400kg	
	Incinerator	53,075kg	
Aircraft fuel	Helicopter	25,000kg	31,250ℓ
LPG	Kitchen	2,778Nm^3	2,778Nm^3

Note) Specific gravity: 0.8 for Antarctic Diesel, 0.8 for aircraft fuel

2.5.4. Waste Management

Waste generated from the station will be handled and stored according to the Antarctic Waste Management Manual (KOPRI, 2009b). The BAS Waste Management Handbook will also be used as an additional reference to manage waste (BAS, 2010). Waste materials will be classified into more than six types to minimize their environmental impact while maximizing recycling of them. A garbage compressor and a hydro-extractor will also be installed to reduce the volume of waste.

An incinerator will be installed on the waste platform for the food waste and sewage sludge. The location of the incinerator has been selected considering the wind directions, and it will be located at the farthest possible location form the main building. A maximum operation temperature of the primary chamber of the incinerator is 1,100℃. The secondary chamber has a maximum operating temperature of 1,400℃ for near perfect combustion. A multi-filtration in the incinerator will prevent pollutants from being emitted into the air. Moreover, incineration residues including sludge will be stored and then transported outside the Antarctic.

2.5.5. Wastewater Management

The comprehensive treatment system will be applied to treat wastewater to prevent any impact on the Antarctic environment. Wastewater generated in the station from various sources will be treated by an Internal Circulation in a Sequence Batch Reactor (IC-SBR). The basic concept of the IC-SBR is to maximize the reuse of water and discharge relatively clean water through a high-level treatment. The discharge point will be located as far as possible from the intake point. The optimal discharge point will be determined based on the results of the additional field investigation that will be conducted in February 2011.

2.5.6. Operation Manual and Training

The following items will be included in an operation guideline for effective management and maintenance/repair of the station.

- ☐ Guidelines for environmental protection including waste management, flora and fauna, protected areas, etc.
- ☐ Safety guidelines for fuel handling and contingency plan for fuel and oil spills
- ☐ A detailed guideline and step-by-step checklist about the usage of all major equipment and facilities
- ☐ A detailed information on procedures and step-by-step checklists for major maintenance and repair
- ☐ Tests devised from recommendations of the manufacturers who produce major equipment and systems
- ☐ A periodical inspection plan and guideline based on the maintenance/management and repairs
- ☐ A list of the standard specifications of spare parts
- ☐ A list of people responsible for the management and maintenance and of the manufacturers of the equipment and facilities and their contacting information

2.6. Range of Impacts

The general range of impact, produced by the construction and operation of the Jang Bogo Station, encompasses the areas that will be covered by the major facilities, wind turbines and unloading routes. The area is approximately 1.5km^2 and may increase if limited access to the temporary pool in the north is required (Fig. 2-16). The area may further be expanded if the spatial range should include the route to the Browning Pass. The routes toward the colonies of South Polar Skua and Weddell Seal shall be restricted for scientific purposes only. Therefore, the range of spatial impact of the station will be limited to buildings, research facilities, wind turbines, heliport, unloading routes and surrounding regions.

The spatial range of scientific activities outside the station during the summer is expected to expand due to frequent activities within a several kilometer radius of the station through the Browning Pass to the north which may increase up to a several hundred kilometer radius at occasions.

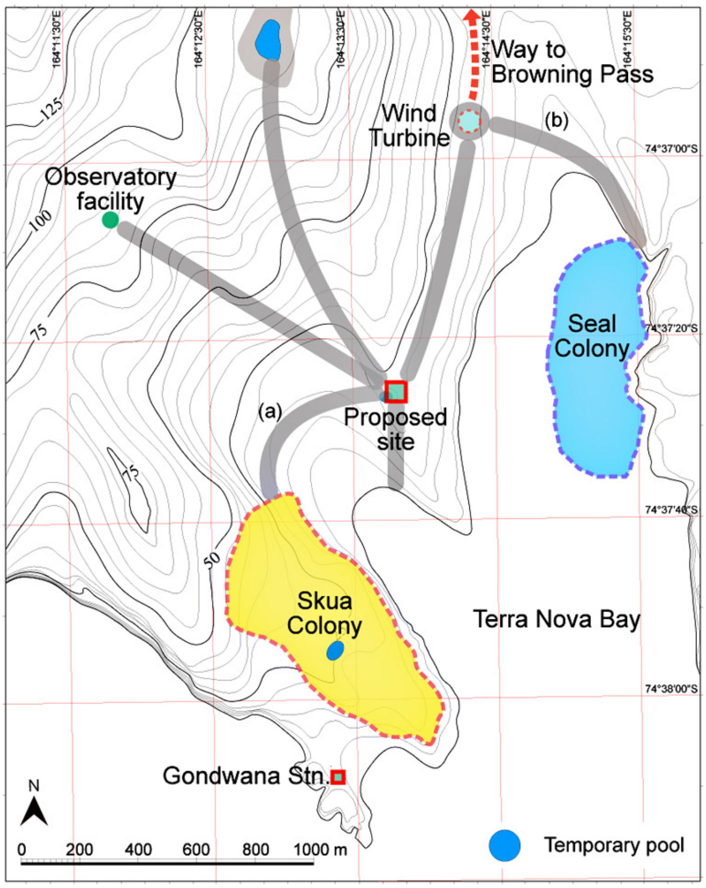


Fig. 2-16. The range of impact caused by construction and operation of the Jang Bogo Station. Visiting routes for (a) skua colony and (b) seal colony.

The temporal impact on the region caused by the construction of the station is expected to at least three months each year during the two construction years. The temporal impact of the operation of the station is expected to be at least 25 years.

3. Alternatives to the Proposed Activity

3.1. No-action Alternative

Without the proposed activities at the Jang Bogo Station, the realization of the Korean commitment toward active Antarctic research is unlikely, and the demands for more information on the changes in the Antarctic environment by both Korean and foreign researchers will remain unmet. International collaborations in Northern Victoria Land with nearby research stations operated by countries such as the United States, New Zealand, Italy, and Germany are expected significantly synergistic for the Antarctic research.

Near the proposed site are Italy's Mario Zucchelli Station and Germany's Gondwana Station. However, Mario Zucchelli Station is being operated only in the summer and Gondwana Station, a relatively small-scale facility, every other summer. As such, they cannot provide sufficient support for the various Antarctic scientific research activities that Korea is planning to undertake.

Indeed the no-action alternative, being void of the temporary and cumulative impacts caused by the construction and operation of a base, guarantees full prevention of the Antarctic environment. However, advantages that the Jang Bogo Station would bring were assessed to prevail over the negative impacts on the Antarctic environment by the station, which will be minimized with the proposed construction and operational design of the station that highlights energy optimization. The Jang Bogo Station will provide comprehensive, in-depth understanding of the role of Antarctica in global environmental changes and enhance Korea's contribution to the conservation of the Antarctic environment as a member state of the Antarctic Treaty. Therefore, the establishment of the Jang Bogo Station is highly recommended.

3.2. Alternative Locations in Antarctica

In light of climate change as the main focus of Korea's future research on the Antarctic, Korea conducted preliminary surveys and evaluated six candidate regions for a new station in Antarctica for climate change research from 2007 to early 2010. Six candidate regions include: the Amundsen Sea coastal region including the Pine Island Bay and Cape Burks of Marie Byrd Land where Russia's Russkaya Station is located (both in West Antarctica);

Terra Nova Bay near the Ross Sea, the vicinity of Russia's Leningradskaya Station on Oates Coast, Ingrid Christensen Coast where China's Zhongshan Station is located, and Mawson Coast where Australia's Mawson Station is situated (all in East Antarctica) (Fig. 3-1).

Situated on the Canisteo Peninsula of the Amundsen Sea, Lindsey Island, the location recommended by many member states of the Antarctic Treaty, holds favorable physiographic conditions for constructing a new station. However, there is a large habitat of Adèlie penguins on the island as well as various colonies of sea mammals densely distributed nearby. This creates concerns about the impact of the construction on the environment, in particular natural habitats, requiring careful review of the various aspects of the construction and operation of the station.

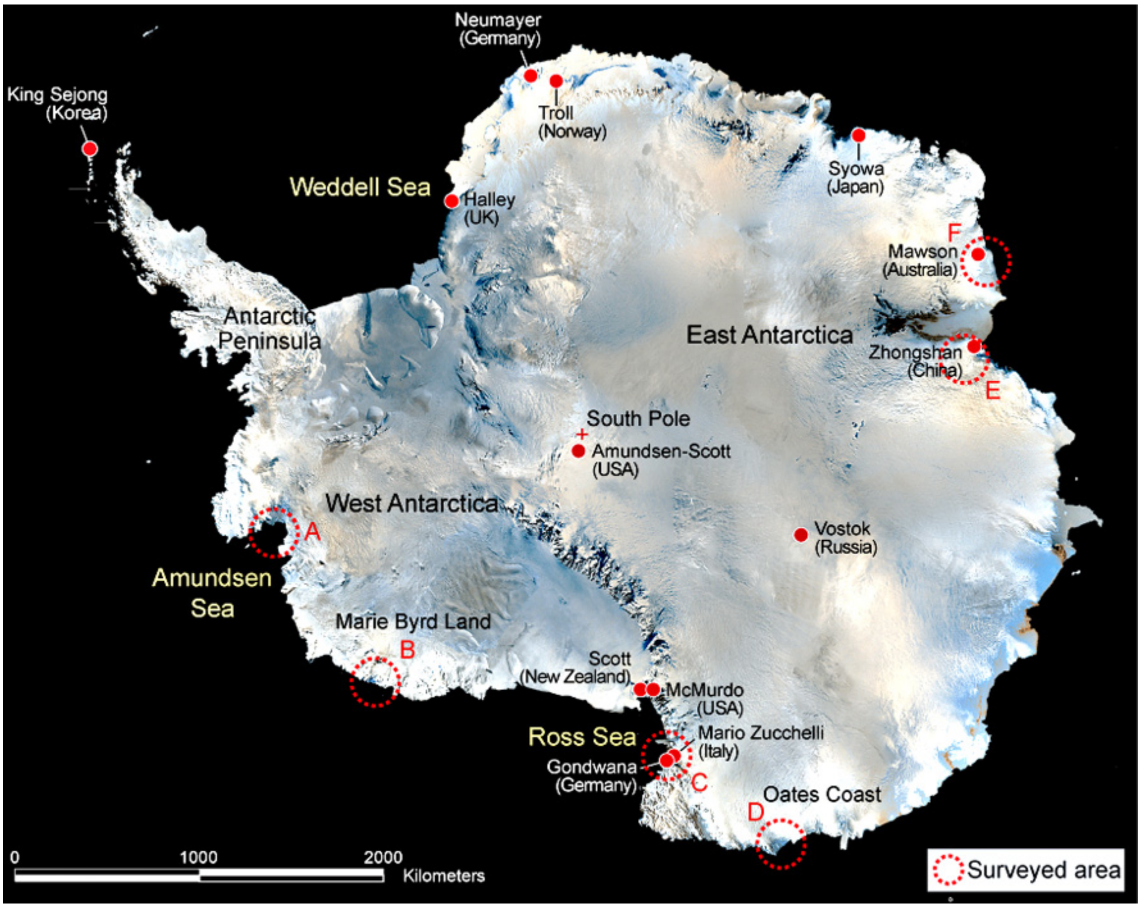


Fig. 3-1. Overview of alternative sites in Antarctica. A: Amundsen Sea, B: Cape Burks, C: Terra Nova Bay, D: Oates Coast, E: Ingrid Christensen Coast, F: Mawson Coast. (Base map: adapted from USGS, 1998)

The Mt. Hudson Nunatak located inland near the Amundsen Sea is a basaltic volcano within the active volcanic region with a record of recent eruptions. This raises concerns about the safety and stable operations of the station. Furthermore, the station would be located a considerable distance from the coast, limiting its accessibility and restricting the construction and operation of the station as well as its research activities (Fig. 3-1. Region A).

The location of Russkaya Station, Cape Bucks is a good potential site in terms of gaining access into the West Antarctic ice field. Operating an independent station in this area could contribute to the research on climate change in the West Antarctic region. However, the distribution of exposed areas is limited, diminishing opportunities for research activities in the future. In addition, the coastal topography of the region with steep slopes and unstable ice cliff would cause difficulties for approaching the coast for unloading, compounded further by the extremely harsh weather conditions developed by the geographical features. Large colonies of Adèlie penguins along the northern coast also suggest possibilities of severe impacts on the ecosystem. Prompt responses to emergency situations would be very difficult as only long-range aircrafts can gain access to the site with a runway built on ice (Fig. 3-1. Region B).

Located in the Oates Coast region in East Antarctica, the area nearby Leningradskaya Station has distinctively uneven terrains, posing challenges to air and marine transportation required for an independent station operation. Finding a new inland route is also expected to be difficult (Fig. 3-1. Region D).

The Larsemann Hills region near the Zhongshan Station and the area near the Mawson Station in East Antarctica present favorable conditions for land and air transportation. This will enable future cooperation with nearby stations when necessary, but various research activities are already being performed at the existing stations in this area. Thus, Korea’s contribution to the Antarctic research is likely to be much less here than in other potential areas. Besides, these areas feature some geographical disadvantages for providing full support to research activities in the Amundsen Sea using the icebreaker *ARAON* (Fig. 3-1. Regions E and F).

The five alternative locations mentioned above were ultimately evaluated inadequate on various decision factors for constructing the station and accommodating its research activities, such as accessibility, weather conditions, safety, logistics, and impacts on the ecosystem.

In contrast, the region surrounding Cape Möbius of Terra Nova Bay seems appropriate for the new station as it provides ample space for construction and relatively easy logistics with the absence of major flora and fauna colonies. The demand for a permanent station for year-round monitoring and research activities is also high in this region as two existing stations only operate during the summer. Therefore, the Jang Bogo Station, in cooperation with nearby stations, can play a key role providing the study of climate change in the Pacific region of the Antarctic (Fig. 3-1. Region C).

3.3. Alternative Locations in Cape Möbius Region

In the selection of the site, not only the effectiveness in construction and operation of the station, but also environmental impacts on natural environment including the habitat and breeding place of the avifauna in the area were taken into consideration. Three sites satisfying area requirements in the Cape Möbius region were considered: small gentle hill along the NW-SE axis just northeast of the Gondwana Station; an area near the access route to Browning Pass up north; and a southward small cape in the northeast, separated by a small bay. However, the first of these sites has proven to be unsuitable owing to a dense colony of South Polar Skuas. The option near the access route to Browning Pass is also unfavorable for the station because it is too far from the coast. As a result, the small cape about 600m to the northeast of the skua colony was selected as the best site for the new station. The region has only a few nests of skua and a low distribution of lichens and mosses, hence, an area of minimal potential impacts on its ecosystem.

As the coast of the small cape is mostly covered with bedrock outcrops, the construction of a base, especially grading, near the coast may extensively disturb the aesthetics of the coastal landscape. The proposed site, therefore, is located about 200m inland in flat terrain composed of glacial moraines.

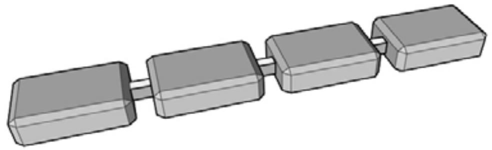
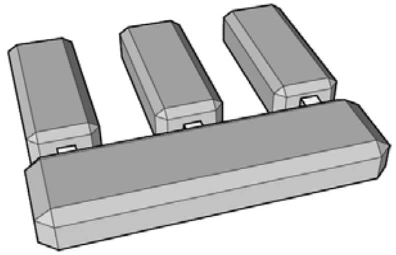
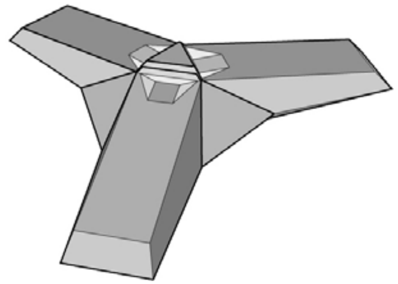
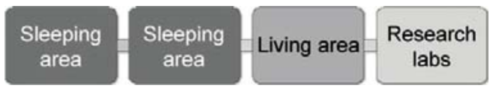
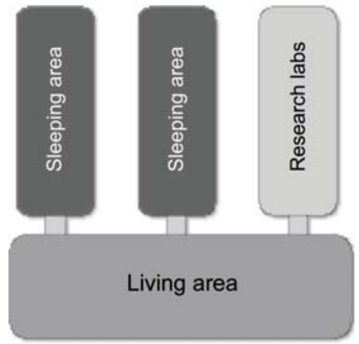
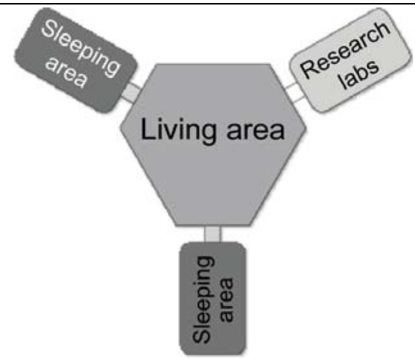
3.4. Alternative Designs

The main building of the station was designed not only to provide for the proposed scientific activities, but also to minimize environment impacts as well as to increase efficiency during the construction and operation of the station. In addition, the design paid full attention to the extreme weather conditions of Antarctica accompanied by high unpredictability, aiming to provide structural stability against all directions of wind at the same time minimizing energy requirements and increasing efficiency in staff and equipment traffic.

These considerations suggested three design options: linear I-shape, divided E-shape, and intensive triple-arm shape (Table 3-1). The first two shapes were evaluated to be too weak to withstand wind loads in some directions, too distant between facilities, and too high in energy demand with the large number of external panels required in the design. In contrast, the triple-arm shaped design was shown to provide good resistance to all directions of wind, provide better spatial efficiency through short inter-facility accesses, and energy efficiency through minimizing areas of the outer wall surface.

Consequently, the triple-arm shaped design was selected as the most appropriate and suited for the year-round operation of the station. This design incorporates Korea's accumulated knowledge on the green building strategies such as double-layer walls, five-time glazed windows, and maximizes the penetration and use of natural sunlight.

Table 3-1. Design alternatives of main building.

Parameter	Linear I-shape	Divided E-shape	Triple-arm shape (Selected)
Type			
Division of the building			
Safety of structure	Low wind-resistance perpendicular to long axis	Low resistance to all wind directions	High resistance to all wind directions
Energy efficiency	Large surface area, High energy loss	Large surface area, high energy loss	Smaller surface area Low energy loss
Accessibility between activity areas	Low	Intermediate	High

3.5. Alternative Wind Turbine Types

Three different types of wind turbines, the well-known horizontal and vertical types, and the vertically stacked modular type as a modified vertical type were evaluated and compared. Major parameters considered were efficiency of power generation, torque, noise, maintenance ease in extreme weather conditions, and impacts on the ecosystem.

Compared to the horizontal model, the vertical model has been proven to be easier to transport, construct, and maintain. Also, it can obtain high level of power generation efficiency in all directions. In particular, the low speed rotation of the vertical type is advantageous as it generates less low frequency noise when compared to the horizontal model, thus minimally affecting people and the surrounding ecosystem including the skuas.

The third option of the vertically stacked modular structure comes with all the advantages of the vertical model and more. This stack of 4 modules, each carrying relatively low power generation capacity of 5kW, can provide undisturbed power supply even in the case of failure of one of the modules, as the remaining three stacks can still generate as much as other two types. Moreover, this modular structure demands less space in the installation and dramatically lowers noise (Table 3-2). Based on these advantages, the vertically stacked modular structure was selected as the final design of the wind turbine.

Table 3-2. Comparison of wind turbine types.

Type	Horizontal		Vertical		Vertically stacked modular (selected)	
		20kW		20kW	 5kW	20kW (4×5kW modules)
Efficiency	- Stable and high efficiency in power generation - Maximum efficiency only to a limited wind direction		- Efficient in all directions of wind - Not working under the low wind speed		- Efficient in all directions of wind - Continuous power generation in the event of one turbine failure	
Torque Maintenance	- Fluctuation of torque according to wind directions - Difficult to maintain in bad weather conditions		- Constant torque for all directions of wind - More convenient maintenance compared with the horizontal type in bad weather conditions		- Constant torque for all directions of wind - A low capacity turbine is easier to maintain in bad weather conditions	
Impacts on ecosystem	- Higher chance of bird strike - High level of noise produced		- Reduced chance of bird strike thanks to a smaller radius of rotation - Lower speed turbine with reduced noise		- Little chance of bird strike due to the visibility of tower shape - Lower speed turbine with reduced noise	

3.6. Alternative Transport

People and cargos for the construction will be transported by airplanes and ships from Korea to the proposed site via Christchurch, New Zealand. Two alternatives were considered and compared as means of local transportation.

☐ Aircrafts

In case of air transportation, the glacier runway at Browning Pass and the sea ice runway of Gerlache Inlet north of Mario Zucchelli Station can be used (Fig. 3-2(a)).

– Air transportation to Browning Pass

- Browning Pass can be used as a runway throughout the year.
- Only aircraft models with skis can be used, and access by large cargo planes is restricted.
- Snowmobiles and sleds will be needed for additional transport from the runway to the proposed site, involving approximately 10km of land transportation via east side of Mt. Browning.

– Air transportation route to Gerlache Inlet north of Mario Zucchelli Station

- When frozen layer in Gerlache Inlet is thick, large-size airplanes such as C130 can land as well. However, this is limited to the freezing season, not the whole summer.
- People and cargos are needed to be carried by snowmobiles and sleds for about 5km to the proposed site. If the sea ice does not extend to the proposed site, a means of marine transportation such as barge is additionally needed to be used.
- According to the currently available data, thick sea ice rarely forms in this region during the austral summer when most of the transportation will be made.

☐ Marine Transportation

According to the expedition report of the icebreaker *ARAON* in February 2010, ships can approach up to 1km near the coast of the proposed site. The ships may then be anchored at appropriate distances from the coast, and barges can be hired to relay the cargos and equipments to land vehicles for the final hundred meters to the site.

Three land transport routes from the unloading position were considered as shown in

Fig. 3-2(b) from the perspective of ease of access. However, both route A, in which the unloading position is right next to Gondwana Station, and route C, in which the unloading position is nearest to the east coast of the proposed site, seem to have a potential to cause negative environmental impacts because they are near the colonies of South Polar Skua (route A) or of Weddell Seal (route C). Therefore, route B is considered to be the most appropriate option.

☐ Evaluation of means of Transportation Alternatives

Disadvantages of people and cargos being transported by aircraft in this region during the summer time include aforementioned limitations of sizes and types of aircraft depending on the conditions of the runway as well as the limitations on takeoff and landing time on sea ice runways. Furthermore, uneven weather conditions of the Antarctic region increase the uncertainties of scheduling, causing aircraft delays.

Besides, small cargo capacities of aircrafts may not be suitable in carrying heavy equipment such as cranes. Aircrafts are also not as cost effective as ships. Therefore, marine transportation was selected over air transportation in consideration of cost, convenience, and on-time performance under uneven weather conditions.

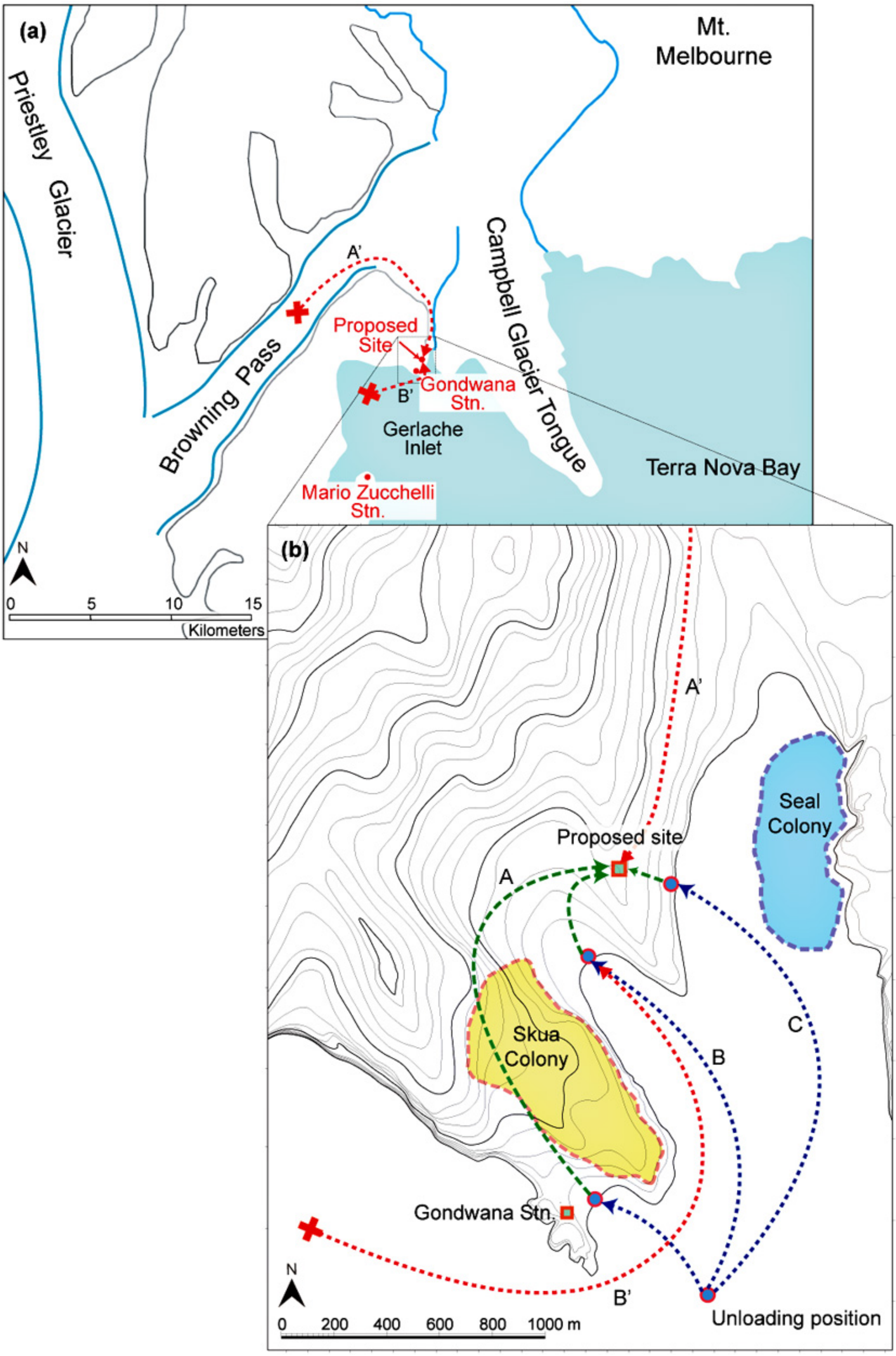


Fig. 3-2. Transport alternatives by (a) aircrafts (A' and B') and (b) ships (A, B and C).

4. Initial Environmental Reference State of the Terra Nova Bay Region

4.1. Location

In the northwestern region of Terra Nova Bay, the proposed site is located in one of the two ridges along the NW-SE direction that originate from Mt. Browning (Fig. 4-1).

The two ridges correspond to Cape 1 and Cape 2 of Fig. 4-1, respectively. A small bay is placed between the two capes and a relatively flat ground of less than 100m in altitude is extended up to 1km from the coast toward the inland. Most of the area investigated including the proposed site has gentle slopes of less than 10 degrees (Figs. 4-2, 4-3).

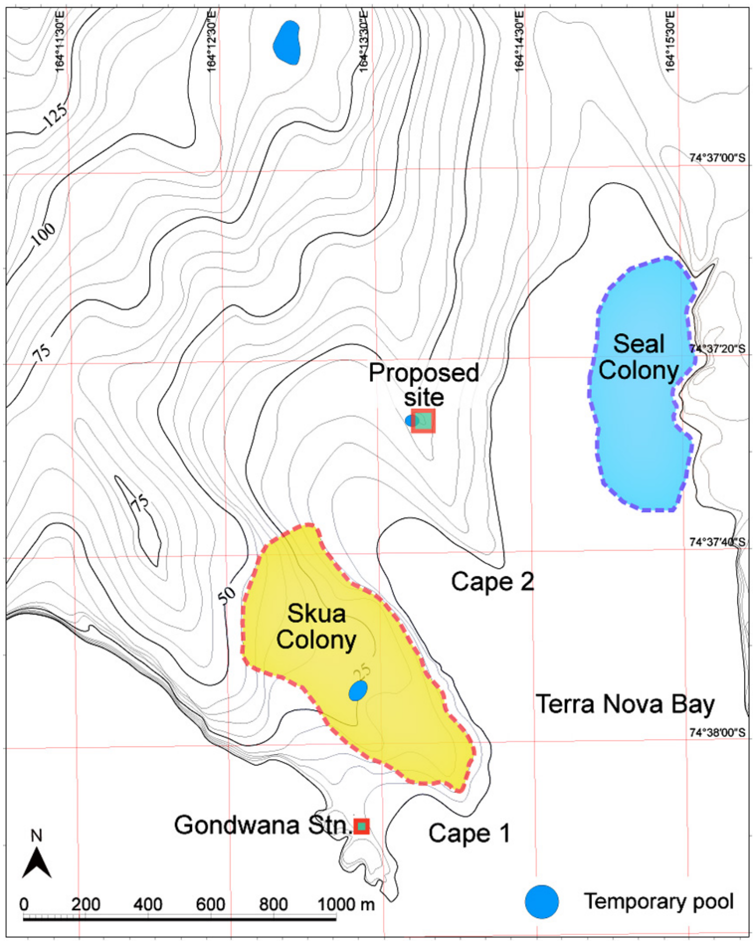


Fig. 4-1. Proposed site and surroundings.

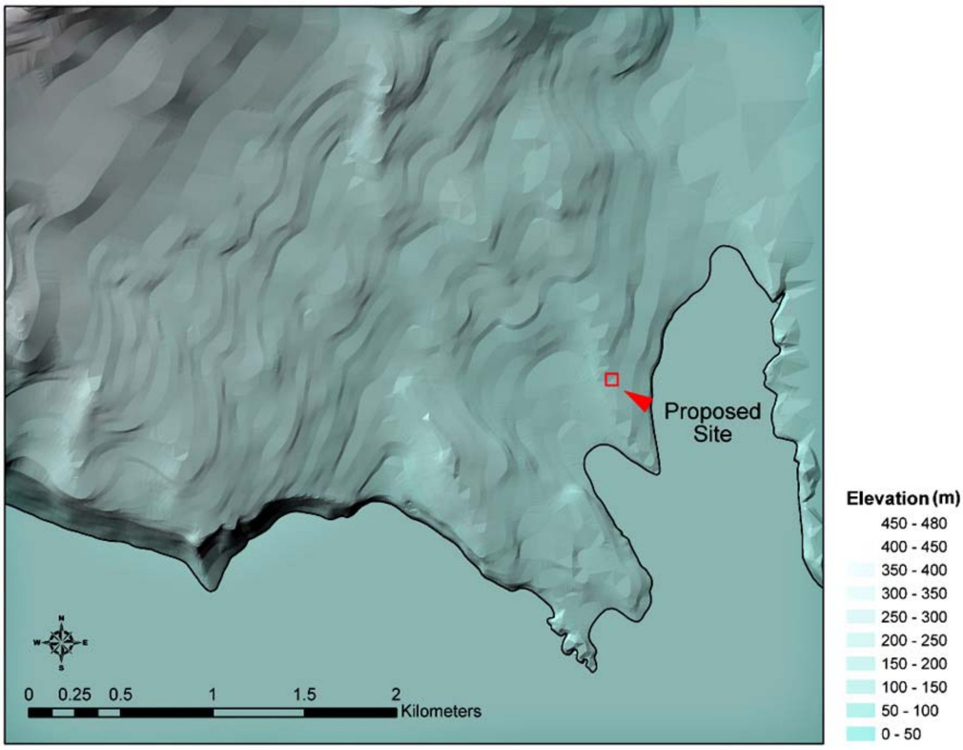


Fig. 4-2. Elevation analysis of Cape Möbius area.

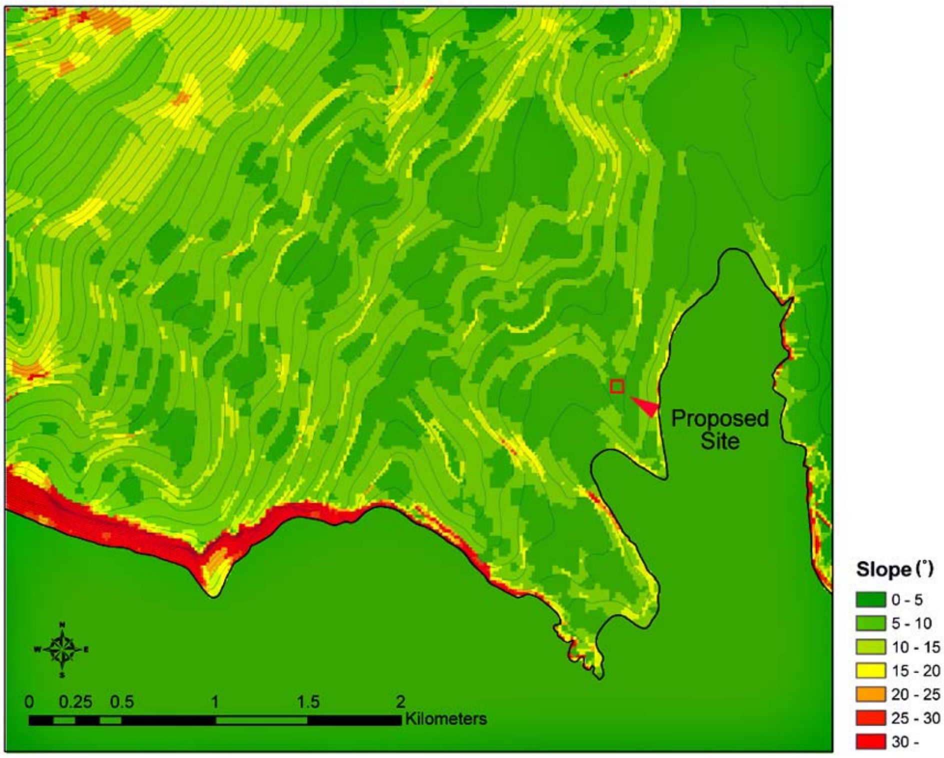


Fig. 4-3. Slope analysis of Cape Möbius area.

The Terra Nova Bay region is home to a wide range of living creatures, for example bryophytes, lichens, marine birds, mammals and invertebrates. Located in Antarctica, it is one of the regions with the highest levels of diversity in terms of biology and ecology.

Colonies of birds and seals are distributed across Edmonson Point, Adèlie Cove, and Inexpressible Island, and Emperor penguin colonies are dispersed across the Cape Washington region approximately 20km from the proposed site.

Weddell Seal can be easily observed in this region. South Polar Skuas also inhabit the area, with their largest colony located in Victoria Land. Marine birds such as Snow Petrels and Wilson's Strom Petrels can also be seen in this region. At least 7 species of bryophytes and 30 species of lichens were discovered at Edmonson Point, and more than 120 kinds of algae and cyanobacteria were identified, according to a literature review. In addition to the 24 species of lichens, various unidentified species were also found in the area (Cormaci *et al*., 2000).

Three temporary pools, formed with the thawing of ice, were found during the 2010 survey. They were located on the bedrock east of the Gondwana Station, near the proposed site for the station, and 1.2km north from the proposed site, respectively (Fig. 4-1). The temporary pool near the Gondwana Station has an area of 25m×12m, with an average depth of 20cm.

The largest temporary pool located to the north of the proposed site covers an area of 110m×72m, with an average depth of 50cm (75cm at most), and is estimated to hold about three thousand tons of water (Fig. 4-4). The pool was formed with ice melt during the summer. The bottom of the pool may be frozen during the winter due to its shallow depth.

Fig. 4-4. Temporary pool located approximately 1km to the north of the proposed site.

Biota is scarce in the region of 2-3m in depth in the tidal zone of Terra Nova Bay due to the influence of floating ice. Thus, blue green algae, diatom, and amphipod, such as *Paramoera walkeri* have been often reported in the region (Cattaneo-Vietti *et al*., 2000). However, marine algal colonies formed a distinct belt and Rhodophyta, consisting of shade-adapted species such as *Iridaea cordata, Phyllophora antarctica* and *Clathromorphum lemoineanum* is dominant at depths ranging from 2-4m to 70m (Cormaci *et al*., 2000). The marine algae provide food sources as well as shelters for various and abundant vagile fauna such as *Sterechinus neumayeri*, a species of sea urchin, and *Odontaster validus*, a species of starfish inhabiting this region.

It has been reported that both sponge and coral colonies are present abundantly in biomass and show a high species richness on the hard bottom at 70-120m in depth. Distinguishing colonies of piolychaetes and bivalve such as *Latenula elliptica, Yoldia eightsi,* and *Adamussium colbecki* (Cattaneo-Vietti *et al*., 2000) were found on the soft bottom which commonly starts from 20-30m in depth and is composed of coarse sand and gravel.

4.2. Topography and Geology

Located in the northern quadrant of Terra Nova Bay, Cape Möbius is mainly composed of exposed bedrock crops and forms the shape of a small peninsula. Most of the land close to the coast has a relatively gentle slope of less than 5º. The glacial deposits, bedrock crops, and other geological features govern the topographical characteristics of the area. In about 3km inland in the northwesterly direction, Mt. Browning (700m) lies along the NE-SW axis (Fig. 4-5).

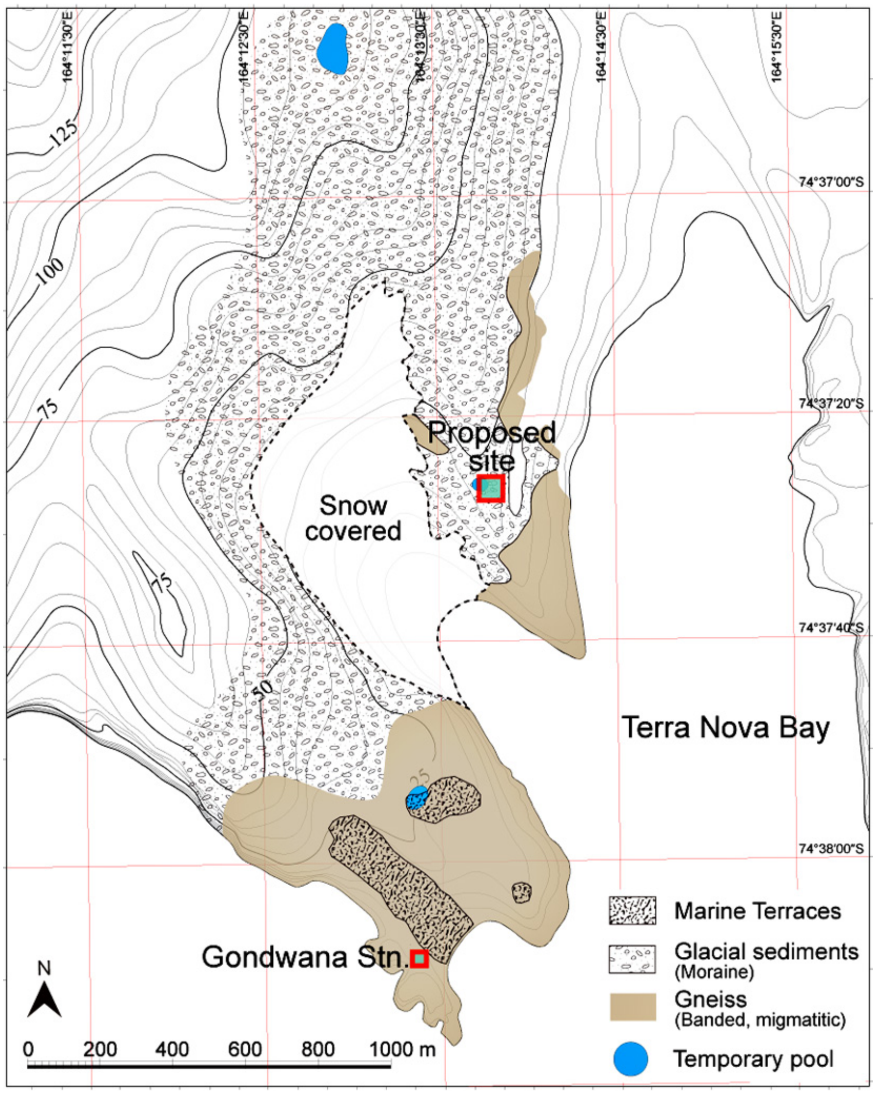


Fig. 4-5. Geological map of Cape Möbius area. (data from field survey and Kantor (1993))

The topography near the altitude of 80m along the southern part of Mt. Browning is very gentle all the way down to the coast. From the mountain, two parallel sets of gentle hills along the NW-SE direction extend to form small cape-shaped topography (Fig. 4-2). The major hill in the southwest is 600m wide and 1.5km long, while the other hill in the northeast is of a smaller size, 300m wide and 1km long. A small bay exists between the two capes. The proposed site for the Jang Bogo Station is in the center of the eastern cape (Fig. 4-6).

Fig. 4-6. Aerial image showing the proposed site.

In the west, Cape Möbius abuts Campbell Glacier, which is slowly moving from north to south, and in the west, coastal cliffs exist along the E-W direction corresponding to geologic fault scarp (Fig. 1-2).

The bedrock of the Cape Möbius region is predominantly composed of Precambrian gneiss. It is locally overlain by horizontal sedimentary layers of glacial moraine. The sedimentary layer forms glacial terraces at intervals of 1m to 2m in thickness (Fig. 4-7). Moraines are mainly composed of bedrock debris ranging in size from a few centimeters to tens of centimeters with intermediate roundness and poor sorting (Fig. 4-8).

Glacial deposits are weakly developed in the western cape where the Gondwana Station and the skua colony are located (Cape 1 in Fig. 4-1). However, the small cape where the proposed site is located is mostly covered by glacial deposits (Cape 2 in Fig. 4-1) except for along the coast. The glacial deposits were identified up to 100m in altitude. The temporary pool located in about 1km north of the proposed site is also overlaid by glacial deposits combined with thin layers of fine-grained soil (Fig. 4-4).

Fig. 4-7. Layered structure of glacial moraines.

Fig. 4-8. Moraines composed of bedrock debris.

Gneiss shows either banded or massive texture with NW-SE trending foliations. The foliations usually dip with an angle of higher than 70º to SW and NE repeatedly (Fig. 4-9). Because of the disturbance by migmatitic metamorphism, it is not easy to define the overall structural features of the gneiss, mostly quartzofeldspathic in composition.

In outcrops of gneiss, fold structures are observed with a near-horizontal fold axis (Fig. 4-10). The dominant joint set is parallel to the foliation of the gneiss at a 10-50cm interval. Perpendicular to the first one, a vertical joint set is also well developed at a 0.5-1m interval.

The coastal cliffs observed in this region are controlled by large-scale geological structures such as fault. About 30km NNE of the proposed site is Mount Melbourne, estimated to have developed in the Cenozoic era. Its activation has been stopped, but intermittent steam disgorging has been reported (Fig. 2-1).

Unconsolidated layers are only locally found and seem to be related to the formation of glacial deposits, being composed of various sizes of particles from fine to coarse. However, it is difficult to identify typical soil types in regional scale.

Fig. 4-9. Banded gneiss.

Fig. 4-10. Migmatitic gneiss.

4.3. Sea Ice

Stretching approximately 64km along the coast between Cape Washington and Drygalski Ice Tongue, the Terra Nova Bay region is a part of the Ross Sea. Frequently the melting sea ice creates a large polynya in the Ross Sea throughout the year, which develops from the rim of the Ross Ice Shelf and extends to the north (Franda *et al*., 2000). The formation of large polynya in the region is extremely significant in terms of Antarctic coastal environment and ecology as it reveals the unique environmental and ecological features formed by highly variable sea ice dynamics.

The sea ice covers Terra Nova Bay from September to October with a thickness of 2-2.5m (Stocchino and Lusetti, 1988 and 1990). Utilizing the Gerlache Inlet sea ice of Terra Nova Bay, Italy operates an ice field runway from October to early December. During the 2010 investigation, the area was completely free from sea ice in the early February, and only small area of fast ice connected to the land remained. According to the estimated data released by the Italian researchers, the ocean currents in the region slowed down and generally flowed from north to south during the summer.

According to a recent study, sea ice has been repeatedly generated and disappeared in Terra Nova Bay due to the katabatic wind blowing from the continent, the reason behind the inconsistency and variety of the distribution of polynyas (Fig. 4-11).

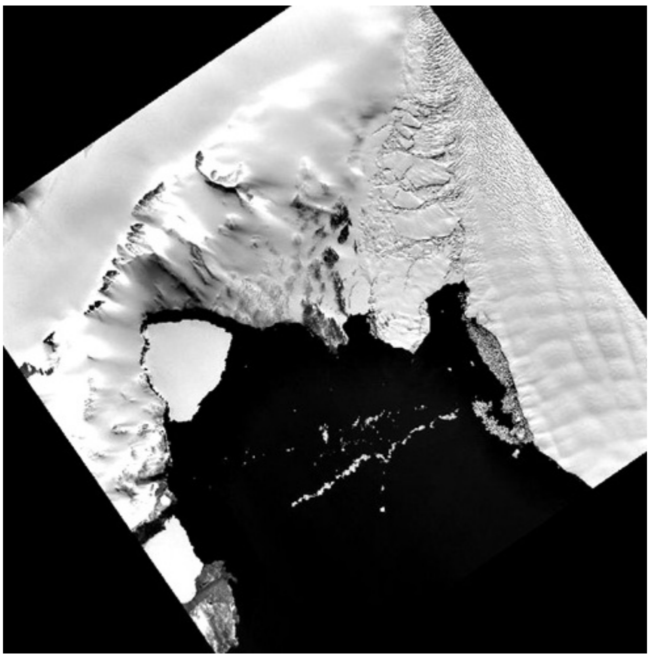


Fig. 4-11. Satellite image showing the distribution of sea ice in Terra Nova Bay.

4.4. Glaciology

Three sets of large-sized glaciers with NW-SE trending are situated in Northern Victoria Land. The Reeves Glacier, Priestley Glacier, and Campbell Glacier are located parallel to each other. The Reeves Glacier and Priestley Glacier merge together with the Nansen Ice Sheet to the west of Mario Zucchelli Station (Fig. 4-12).

The Cape Möbius region is on the edge of the Deep Freeze Range located between the Priestley Glacier and the Campbell Glacier. Northwest of this region, a relatively stable and small-sized Browning Pass Glacier stretches from northeast to southwest. The Campbell Glacier extends over 100km to the north, and covers an area of 4,000km^2, including the névé of the Southern Cross Mountains and Deep Freeze Range. The glacier flows into the sea in the south and creates a glacier tongue stretching out to many kilometers across.

The flow velocity of the glacier tongue was estimated between 140±20 m/year and 240±20 m/year (comparative analysis results of SPOT 1 XS images of December 19, 1988 and December 2, 1989, Frezzotti, 1992). The amount of ice falling off into an iceberg is almost consistently compensated by the filling of glacier flow, and the extended area of the glacier tongue from 1963 and 1989 was also reported to be almost consistent.

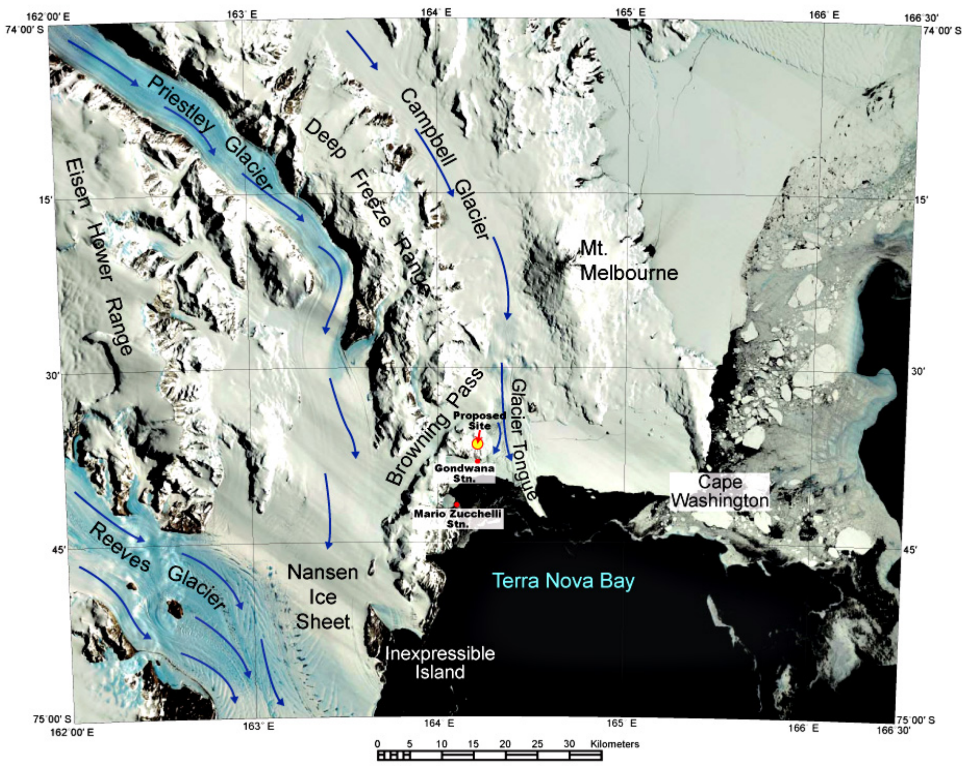


Fig. 4-12. Glaciological map. Arrows mean glacier flows. (Base map: adapted from MUSEO NAZIONALE DELL'ANTARTIDE-Sezione di Scienze della Terra, Via Laterina 4-53100 SIENA-ITALY, 1996)

4.5. Climate

Katabatic winds dominate in Terra Nova Bay due to steep topography from the inland to the coast, with increasing intensity toward the coast with the combination of channel flows from several glacial valleys. In this geography, a strong horizontal and vertical wind shear is developed, imposing severe limitations on aircraft operation. The strong wind in Terra Nova Bay will be one of the most defining climate factors in the operation of the proposed station. The wind speed is known to be highly variable even within short distances and the maximum wind speed has been measured as high as 56.4m/s with the influence of katabatic winds.

According to the analysis of the observed data over twenty years (1989-2009) at Mario Zucchelli Station, the annual mean temperature was -14.1°C, the annual mean wind speed was 6.4m/s, and prevailing wind direction was westerly. The temperature will have no impact on the operation of the station which will be the most active during Antarctic summer. With the wind chill, temperature may be felt as low as -50°C, and diurnal temperature variations reach as high as 15°C in clear sky conditions, particularly in October and February. From November to January the maximum daily temperatures are well above 0°C, having been recorded as high as 7-9°C, and daily variations decrease to 4-8°C (Turner and Pendlebury, 2004). According to the AWS data of the proposed site in operation since February 2010, the prevailing wind direction at the proposed site was westerly or northwesterly, and the range of wind direction varied more than at Mario Zucchelli Station. This difference may stem from the different topographical conditions of the two locations. The monthly mean wind speed of the proposed site has been measured relatively low compared to that of Mario Zucchelli Station, whereas the temperature and pressure were mostly within their annual ranges at Mario Zucchelli Station (Figs. 4-13, 4-14, Appendix 2).

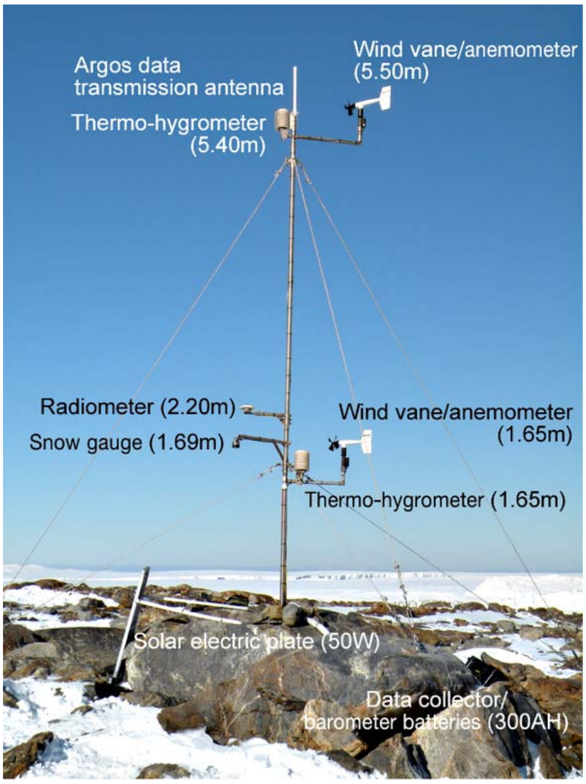


Fig. 4-13. Automatic Weather System installed at the proposed site.

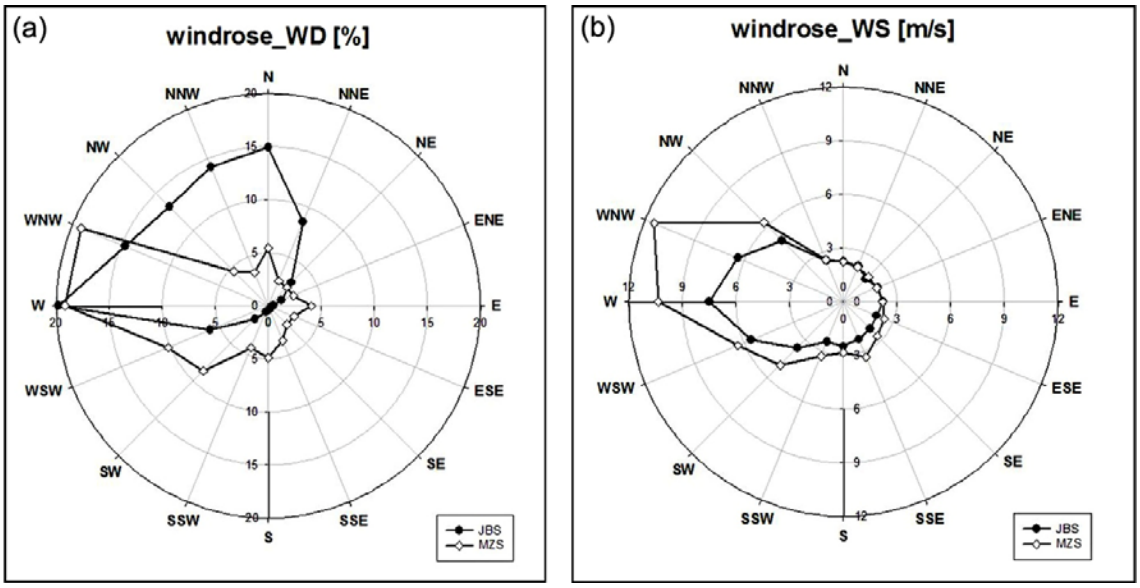


Fig. 4-14. Windroses of Mario Zucchelli Station and the proposed site. (a) Wind direction, (b) Wind speed.

4.6. Flora and Fauna

According to a study of the flora and fauna at the proposed site and nearby regions, there are not many living creatures that inhabit the area.

About 26 species of lichens and mosses including *Buellia* sp. and *Umbilicaria* sp. were found, and based on Kantor (1993), some 35 species of flora have been confirmed to be distributed across the region. Lichens and mosses showed the highest density near the largest temporary pool located about 1.2km to the north of the proposed site, but lower density in other regions.

As for marine mammals, a colony of Weddell Seal was found on the fast ice east of the proposed site. A breeding place of South Polar Skuas is located in the eastern hill of the Gondwana Station, and a couple of Adèlie penguins were also found on the ice field.

4.6.1. Flora

The proposed site and surrounding regions correspond to coastal areas. Due to low temperatures, humidity is relatively low and little vegetation is found in the area (Kantor, 1993). The area shows topography composed of diverse moraines, and vegetation can be observed mainly in the northern side of the bedrock outcrops between cracks or underneath the rocks where soil layers have been developed.

Lichens are the key vegetation, among which crustose lichen adhering tightly to the rocks are most common. In particular, foliose lichens are abundant nearby the temporary pools, as the areas surrounding the pools are relatively rich in moisture with supply of snowmelt runoff (Fig. 4-15). The largest temporary pool in the north has relatively rich vegetation. The main types that dominate the area are *Umblicaria* spp. and *Buellia* spp. *Bryum* spp. is distributed mostly in places where moist soil layer exists, but its biomass is small.

In the environmental impact analysis for the construction of Germany's Gondwana Station in 1988/89, 22 species of lichens were reported (Kantor, 1993). During the 2010 investigation, 26 species of lichens were found. The proposed site and surrounding regions have been confirmed to have a total of 35 species of vegetation, including 30 species of lichens, 4 species of mosses and one species of freshwater algae (Appendix 3).

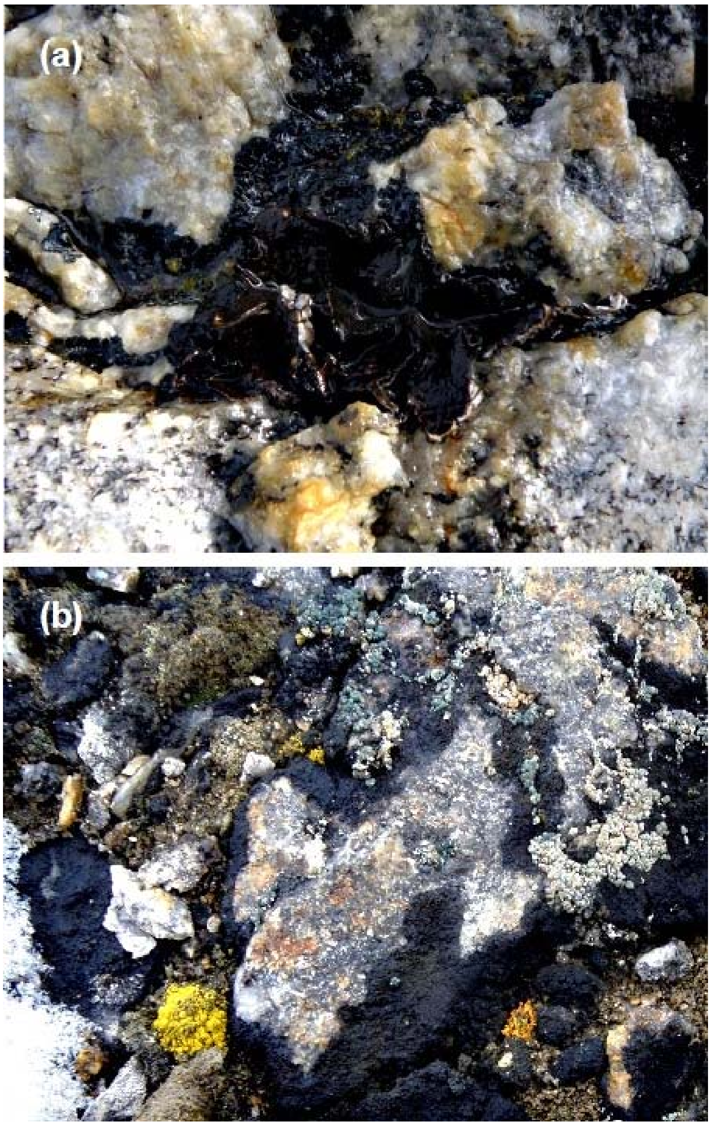


Fig. 4-15. (a) *Umblicaria antarctica*, (b) *Buellia* spp. *Candelariella flava*, *Rhizoplaca* sp. *Bryum argenteum.*

4.6.2. Fauna

A couple of Adèlie penguins have been observed resting and feeding on the ice field in the west coast of Gondwana Station. Two habitats of Adèlie penguins were also reported near the Mario Zucchelli Station, but no such habitat has been discovered near the proposed site.

A habitat of Emperor penguins is known to exist near Cape Washington, more than 20km away from the proposed site.

South Polar Skuas represent the largest portion of the bird population that was found near the proposed site. The main habitat was found on the eastern hill of Gondwana Station (Fig. 4-16).

The area of the habitat was measured approximately 800m×400m, and during the on-site investigation, 147 skua individuals, including 64 pairs and 19 chicks, were counted. Considering that chicks often hide between cracks in rocks, the number of skua inhabiting the area may be more than 200 individuals. Some skua nests were found scattered outside of this habitat. Five skua nests were spotted near the proposed site, inhabited by pairs and chicks (Fig. 4-17).

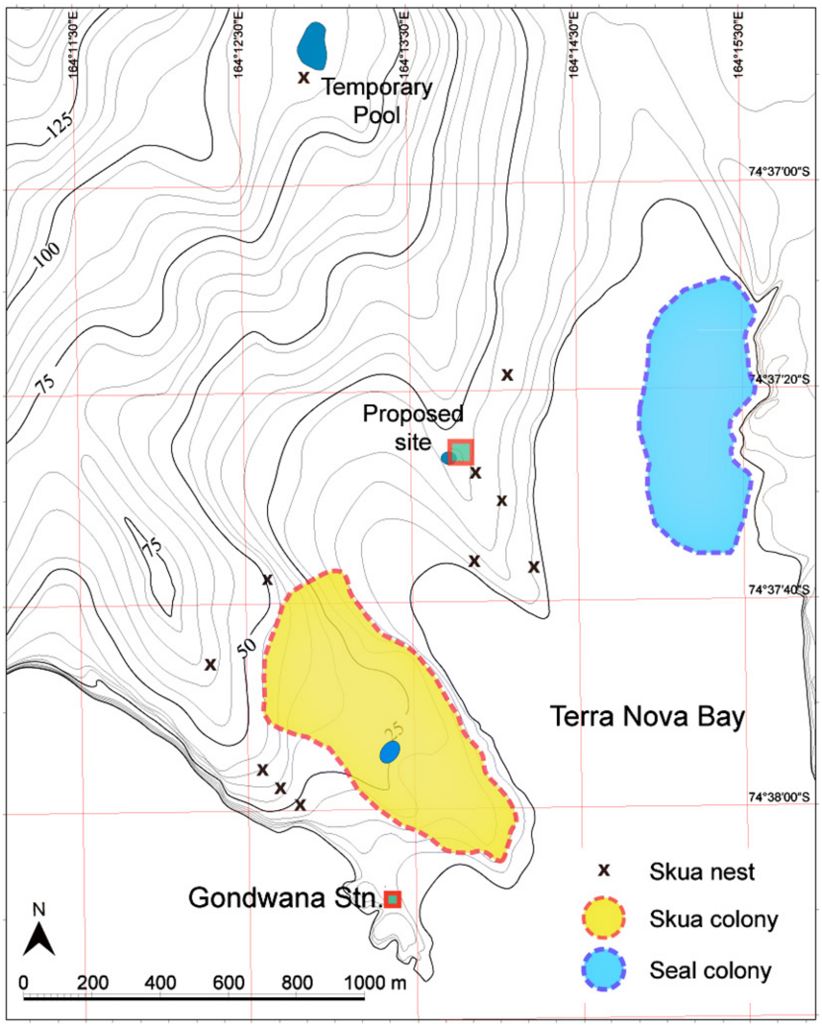


Fig. 4-16. Distribution of fauna near the proposed site.

Another five skua nests were observed on the rocky area in the west coast of Gondwana Station and one nest near the largest temporary pool north of the proposed site.

Weddell Seals were observed during the on-site investigation. Three groups of the seal were observed resting on the fast ice in the east side of the proposed site. More than 85 seals in the fast ice were counted. Considering hidden individuals resting in the ice cracks, there could have been more than 100 seals inhabiting the area at the time of the investigation (Fig. 4-18).

Fig. 4-17. South Polar Skuas.

Fig. 4-18. Weddell Seals.

4.7. Human Activities

In 1985, Italy constructed Mario Zucchelli Station on the exposed land about 8km southwest from the proposed site across the Gerlache Inlet. The station has been actively conducting researches on biodiversity, changes in the ecosystem, geophysics, atmospheric science, and astronautics in the Ross Sea region. In particular, their marine ecology research has been focusing on understanding the marine communities in Terra Nova Bay. Based on the data accumulated through the research activities over the past 25 years, Italy recently proposed to designate the region across the Terra Nova Bay toward the northern Wood Bay as Marine Protected Area (MPA) in order to assure continued scientific research activities in the area while preserving ecological values of the area at IP 45 of the XXXIII ATCM (ATCM, 2010). In addition, the New Zealand-led Latitudinal Gradient Project (LGP) has been steadily promoted since the 2000s to understand the marine, land, and freshwater ecosystems of the coastal region of Victoria Land in the Ross Sea.

At Terra Nova Bay, research activities of Mario Zucchelli Station in conjunction with supply and transport activities are being vigorously conducted from November to February every year. Intercontinental and inner air flight routes connect from Christchurch, New Zealand to both McMurdo Station and Mario Zucchelli Station. The air routes are used to supply goods as well as to transport research and operating personnel. Furthermore, Italy's PNRA (Programma Nazionale Ricerche in Antartide) provides supplies and assists research activities using Italy's icebreaker *Italica.*

The Federal Institute for Geosciences and Natural Resources of Germany (BGR) began a research program titled GANOVEX (German Antarctic North Victoria Land Expedition) based in Terra Nova Bay in 1979. Under the program, being operated with two- to three-year interval projects (in 2009/10, the project GANOVEX X was completed), studies on the geology and geophysics of Northern Victoria Land have been conducted. BGR constructed the Gondwana Station right next to Cape Möbius in 1988/89 and has been operating the station temporarily only in the summer every two or three years. BGR cooperates with the programs of Italy, New Zealand, and the U.S. in order to provide assistance to the activities of Gondwana Station. It also undertakes joint researches with Alfred Wegener Institute of Polar and Marine Research (AWI).

Antarctic tourist ships visit Terra Nova Bay to observe Cape Washington for a habitat of Emperor penguins, Inexpressible Island, and Mario Zucchelli Station. According to IAATO (International Association of Antarctic Tour Operation), the number of tourists that visited Cape Washington was the highest in 2005/06 registering 525 people. From 2003/04 to 2009/10, approximately 1,800 people visited the area. Cape Washington is the most popular destination for tourism in Terra Nova Bay, with 237 people visiting the region in 2009/10. During the same periods (2003/04 to 2009/10), a total of 1,144 people visited Mario Zucchelli Station.

4.8. Protected Areas, Historic Sites and Monuments

There are three ASPAs (Antarctic Specially Protected Areas) and two HSMs (Historic Sites and Monuments) in the vicinity of the Cape Möbius region.

☐ ASPA 118 (Summit of Mt. Melbourne, Northern Victoria Land)

ASPA (74°21′S, 164°42′E) proposed by New Zealand to protect the unique flora in a volcanic region (31.9km from the proposed site).

☐ ASPA 161 (Terra Nova Bay, Ross Sea)

ASPA (74°45′S, 164°10′E) proposed by Italy for preservation of coastal regions and long-term scientific research (15.7km from the proposed site).

☐ ASPA 165 (Edmonson Point, Wood Bay, Ross Sea)

ASPA (74°20′S, 165°08′E) proposed by Italy to protect diversity of the freshwater system and rich vegetation (40.9km from the proposed site).

☐ HSM 14 (An ice cave located on Inexpressible Island in Terra Nova Bay)

During the British expedition into the Antarctic from 1910 to 1913, Victor Campbell's northern exploration team created the ice cave in March 1912. They spent the winter of 1912 in this very cave, leaving signs, boards, and seal bones which still remain (74°54′S, 163°43′E). It was proposed by New Zealand and has been jointly managed by Italy and the U.K. (35.6km from the proposed site).

☐ HSM 68 (Location of storage on the moraine Hells Gate in Terra Nova Bay)

This emergency storage room was built in the form of a sled equipped with supplies and equipment on January 25, 1913 by the British expedition of the Antarctic from 1910 to 1913 (74°52′S, 163°50′E). It was proposed by New Zealand, Norway, and the U.K., and has been jointly managed by New Zealand and the U.K. (31.0km from the proposed site).

As mentioned previously, at the XXXIII ATCM held in May 2010, Italy submitted a proposal to designate the Terra Nova Bay-Wood Bay region as a Marine Protected Area (MPA). This region covers an area of 6,000km^2 and includes the area south-southwestward from Kay Island (74°05′S), across Terra Nova Bay to Inexpressible Island (75°00′S), thus including the coastal region as well as part of the terrestrial land of 166°30′E and the entire coastal maritime land (ATCM, 2010).

The proposed site for the Jang Bogo Station is located within Terra Nova Bay, but is excluded from the proposed MPA (Fig. 4-19).

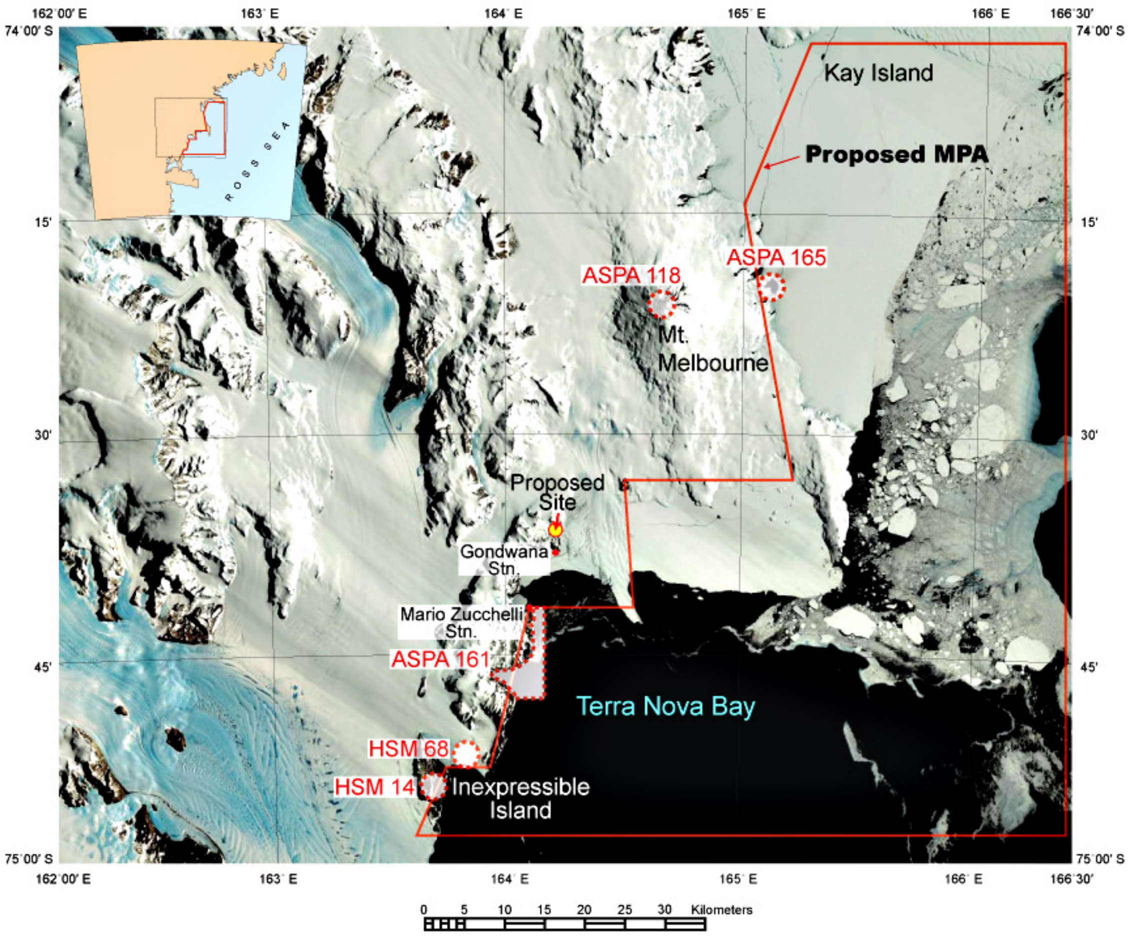


Fig. 4-19. Antarctic Specially Protected Areas (ASPA) and Historic Sites and Monuments (HSM) in Terra Nova Bay region. The red boundary indicates a proposed MPA by Italy. (Base map: adapted from MUSEO NAZIONALE DELL'ANTARTIDE-Sezione di Scienze della Terra, Via Laterina 4-53100 SIENA-ITALY, 1996)

4.9. Prediction of the Future Environmental Reference State in the Absence of the Proposed Activity

The proposed site of Jang Bogo Station is located on the way to Browning Pass from Mario Zucchelli Station and Gondwana Station. The environment of the proposed site is assessed free from any significant disturbances that may have been caused by past human activities.

Without the proposed activities being carried out, the current undisturbed environmental status will be preserved and the natural landscape will remain unchanged. In addition, there will be no topography change associated with the base construction. Individual nests of South Polar Skua will also be preserved as they are.

No impacts of the proposed activities on the environment, caused by either pollutants (such as noise, atmospheric pollutants and waste) or human interferences, will occur. If no dock for unloading is constructed along the coast, there will be little influence on marine environment either.

5. Prediction of Impacts, Assessment and Mitigation Measures of the Proposed Activities

5.1. Methodologies and Data

An Environmental Impact Assessment comprises three major phases: estimation of the current status of the environment, prediction of impacts, and suggestion of further assessment and mitigation measures. This draft CEE for the construction and operation of the Jan Bogo Station is prepared in this phased process.

The preparation of the launch of the Jang Bogo Station is largely based on the Korea's experience of operating the King Sejong Station for more than two decades as well as the data acquired in Antarctica during the same period. It is also based on the knowledge on natural environment and weather conditions of the region accumulated by Italy and Germany. The data published by Italy and Germany (Faranda *et al*., 1999; Kantor, 1993; Orombelli, 1987) were particularly useful to better understand the environment and weather conditions at and near the proposed Jang Bogo Station site.

A detailed survey was conducted as part of the 23rd KARP for the proposed site in February 2010 using the icebreaker *ARAON*. This survey provided data on the current environmental conditions at the proposed site, primarily the regional weather and ecosystem. The overall environmental impacts were assessed through comparison of the collected site survey data with the Italian and German data.

During this period, an AWS was installed at the proposed site to obtain continuous weather data. Thus, real-time data on the temperature, wind speed, wind direction, atmospheric pressure and snow fall have been accumulated since February 2010.

The intensity of a potential impact on Antarctic environmental media (atmosphere, glacier, sea, flora and fauna, etc.) can be classified into five different levels for each of its four different aspects: probability, extent, duration and importance of impact. The criteria of classification are based on whether the potential impact is direct/indirect, cumulative/temporary and inevitable/avoidable. A comprehensive impact assessment for the proposed activities associated with the establishment of the Jang Bogo Station was performed with the impact matrix provided by the EIA guidelines for Antarctic activities (e.g., COMNAP, 2005a, etc.).

5.2. Air quality

For the prediction of unavoidable atmospheric emissions involved with the construction and operation of the station, the ISCST3 model, a Gaussian Dispersion Model, was applied as the proposed site features flat topography with the slope less than 10˚. The ISCST3 model predicted the impact on air quality based on topography and meteorology data collected between February and June 2010, measured by the AWS. With respect to the results of impact prediction, mitigation measures were prepared for the construction and operation phases per each source of the emissions.

5.2.1. During Construction

(1) Estimation of Emissions

The amount of atmospheric emissions is estimated based on the transportation plan per construction phase. The primary sources of the emissions during the construction are transportation, activities of the construction team, operations of temporary facilities, and the combustion of fuel by the construction equipments.

As shown in Appendix 4 and summarized in Table 5-1, total emissions from the construction were estimated at 13.83ton of CO, 40.52ton of NOx, 300.27ton of SO_2, 3.19ton of PM10, and 8,533.29ton of CO_2.

Table 5-1. Predicted atmospheric emissions during construction. (unit: ton)

Source \ Emission	CO	NO_x	SO_2	PM10	CO_2
Transportation (Ships & aircraft)	7.32	29.96	293.71	2.48	7,797.0
Construction camp & service facilities	0.02	0.34	0.02	0.03	14.11
Construction equipments	6.49	10.22	6.54	0.68	722.18
Total emissions	13.83	40.52	300.27	3.19	8,533.29

(2) Impact on Air Quality

The model-predicted 1-hour average PM10 concentration is 40㎍/㎥ and 24-hour average PM10 concentration 10㎍/㎥, which indicates that construction activities will have a minimal impact on air quality (Figs. 5-1, 5-2). Meanwhile, the emissions may partially contaminate snow, ice or rock surface causing adverse impacts on biota living in the rock cracks.

Most of the emissions will be originated from marine transportation except for during the anchoring periods. These emissions will rapidly disperse over wide areas.

Therefore, their impacts will be limited, but they may contribute cumulatively to the air quality of Antarctica.

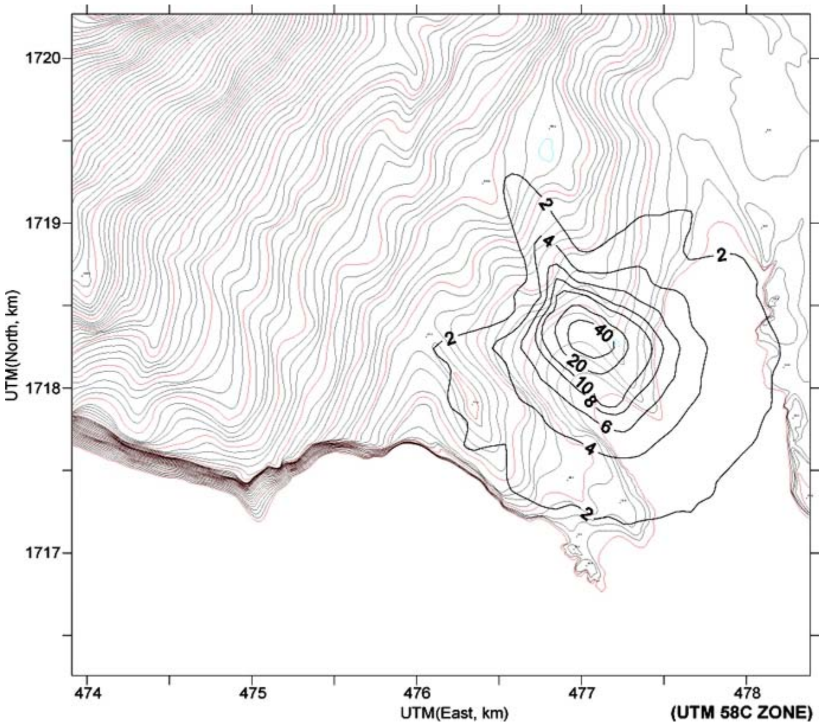


Fig. 5-1. Predicted 1-hour average PM10 concentration during construction. (㎍/㎥)

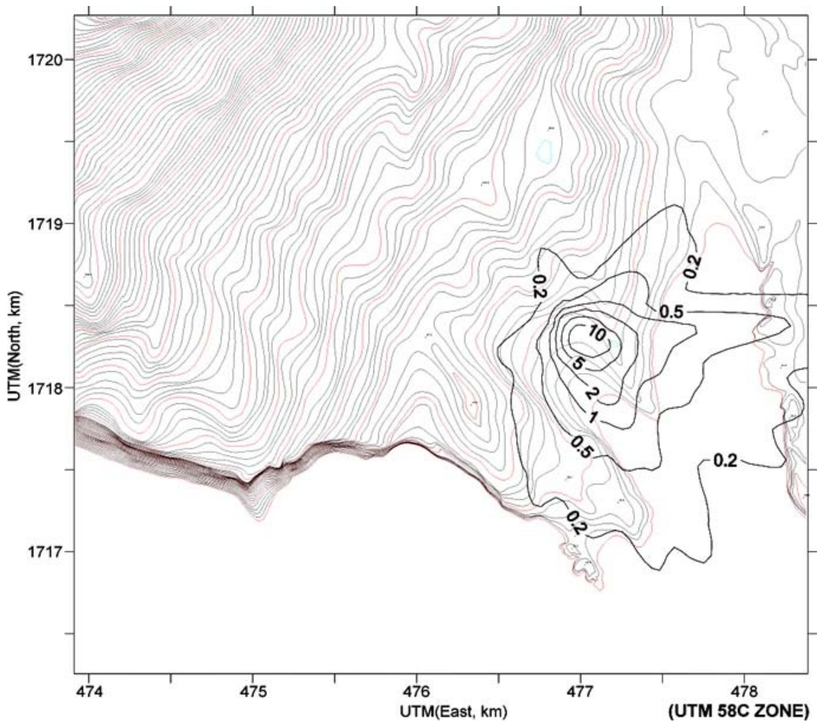


Fig. 5-2. Predicted 24-hour average PM10 concentration during construction. (㎍/㎥)

(3) Mitigation Measures

All ships in the area will be recommended to use high refined fuel such as Marine Gas Oil (MGO) with low-sulfur (lower than the 4.5% regulation by the MARPOL 73/78 if possible).

Equipments will be properly maintained to high standards to minimize atmospheric emissions. Equipment will not be left idling unless necessary and the operator will be advised to follow the routes selected for minimum fuel consumption.

Temporary facilities for construction workers are designed to use high quality insulation materials and maximum sealing to minimize energy loss.

5.2.2. During Operation

(1) Estimation of Emissions

Annual emissions coming from fuel consumption during operation of the station were estimated to be 1.13ton of CO, 10.08ton of NOx, 0.38ton of SO_2, 1.13ton of PM10, and 1,067.93ton of CO_2 as shown in Table 5-2 (see Appendix 4 for more details).

Table 5-2. Predicted annual atmospheric emission during operation. (unit: ton)

Source \ Emission	CO	NOx	SO_2	PM10	CO_2
Heating facilities	0.25	3.58	0.23	0.31	801.96
Vehicles	0.01	0.34	0.01	0.00	60.33
Incinerator	0.01	0.10	0.09	0.67	174.03
Helicopter	0.30	0.00	0.02	0.01	21.48
Kitchen facilities	0.56	6.06	0.03	0.14	10.13
Total annual emissions	1.13	10.08	0.38	1.13	1,067.93

(2) Impact on Air Quality

A simulation was conducted using the ISCST3 model to assess the air quality around the station in its operation phase, and the result indicates that there will be little impact on air quality due to the operation of the station. The result shows the maximum concentration of 15ppb for 1-hour average NOx near the station and average of 0.3ppb during the summer, which are much lower than standard levels of both the National Ambient Air Quality and the WHO standard (Figs. 5-3, 5-4, 5-5).

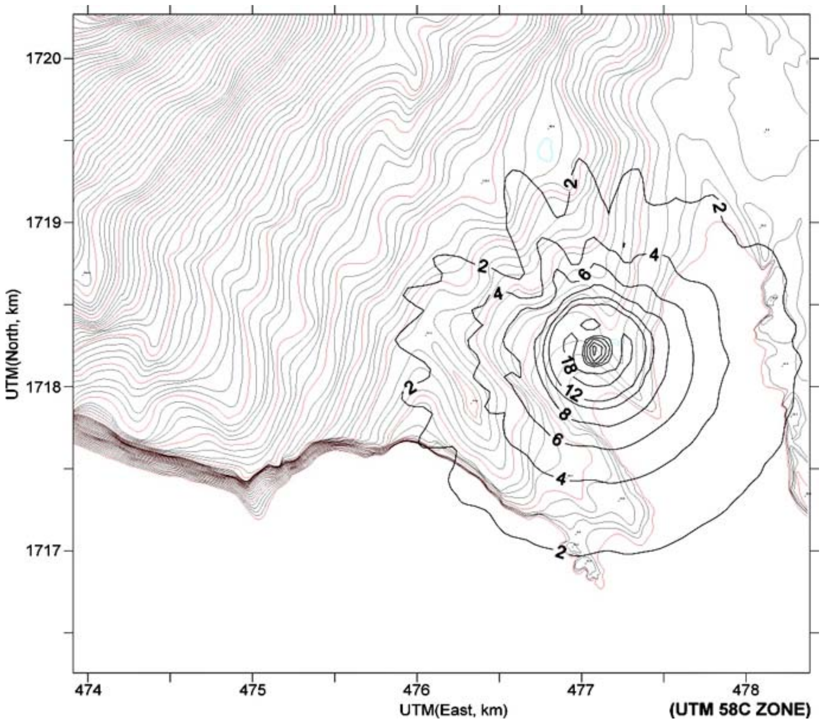


Fig. 5-3. Predicted 1-hour average NOx concentration during operation. (ppb)

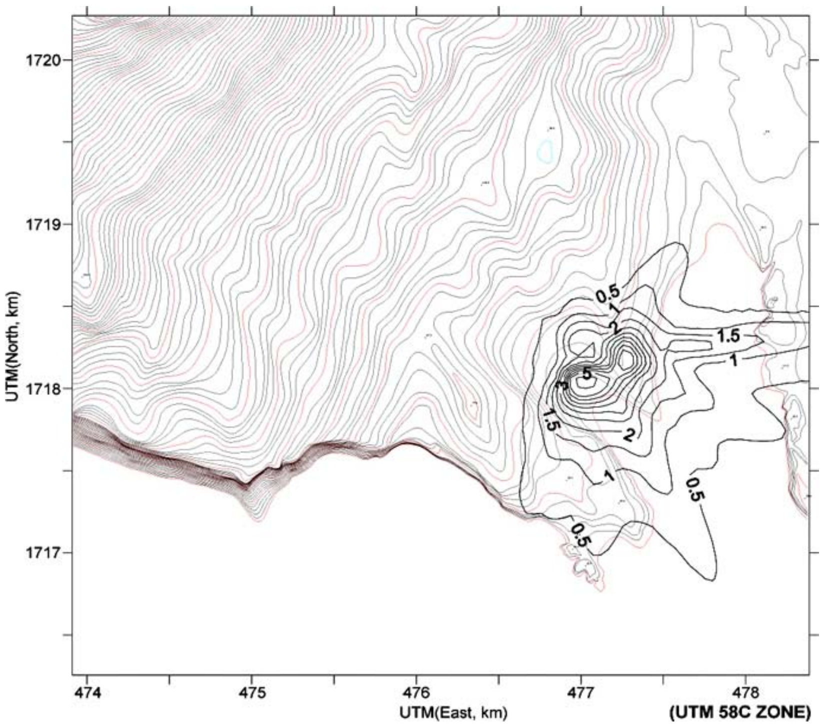


Fig. 5-4. Predicted 24-hour average NOx concentration during operation. (ppb)

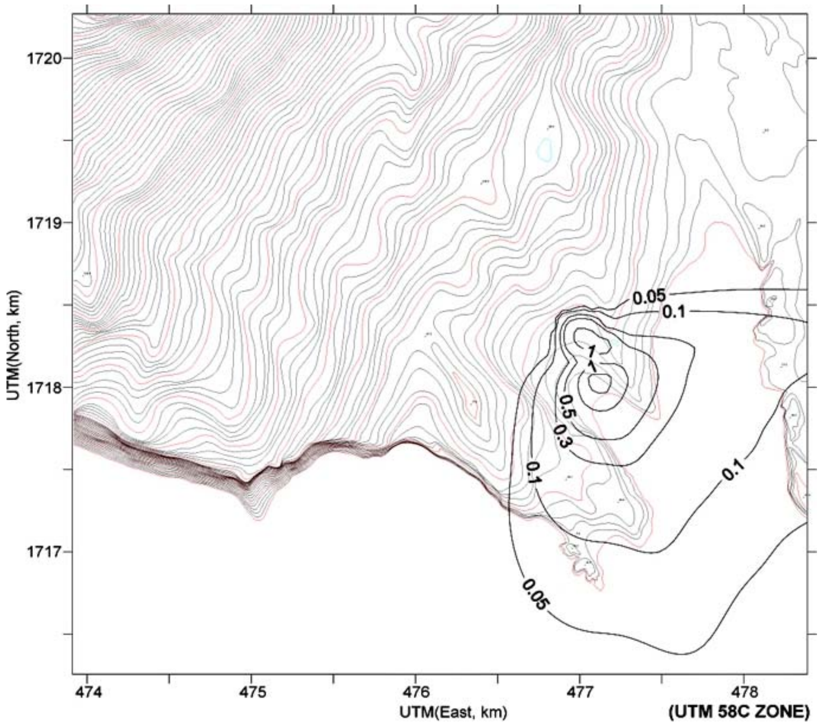


Fig. 5-5. Predicted average NOx concentration during operation during the summer. (ppb)

(3) Mitigation Measures

Waste heat from CHP plant will be used to reduce heat loss and to minimize the use of fossil fuels and the emissions of air pollutants. Solar and wind renewable energy sources will be used to minimize the use of fuels, too. Waste will be incinerated at high temperature for near perfect combustion. A state-of-the-art multi-filtering system will be installed in the incinerator to reduce to achieve near-zero emissions of air pollutants, especially PM10 and NOx. The use of fossil fuels and associated carbon emissions can be minimized by increasing the use of solar and wind renewable energy, maximizing the indoor use of natural sunlight, and recycling the waste heat (Table 5-3).

Table 5-3. Estimated reduction of carbon emissions resulted from limit in use of fossil fuels.

Category	Annual reduction of CO_2			
	Solar energy	Wind energy	Natural sunlight	Recycled waste heat
Amount of electric power saved (kWh)	31,858	186,624	13,715	1,693,440
Annual carbon emissions reduction[1] (TCO_2)	14.2	83.0	6.1	753.2

1) Carbon emissions factor of electric power applied is 0.4448TCO_2/MWh (Korea Energy Management Corporation, 2009)
- Assuming solar and wind energy capacities, 36kW and 60kW, respectively

5.3. Fuel and Oil Spills

5.3.1. Possibility of Fuel and Oil Spills and Impacts

Various fuels and lubricants will be used during the construction and operation of the station.

Fuel and oil spills may occur during the processes of unloading construction materials and equipments, and fuel transfer procedures between transit and fuel tanks. Fuel spills may also occur during refueling aircraft, vehicles and generators. Cracked fuel pipelines and damaged fuel tanks are also potential sources of fuel spill, but the possibility of leakage from them is very limited. Ocean fuel spills can occur if a ship is stranded or collides with sea ice, but the probability of such occurrences is also very low.

Fuel or oil spills can seriously affect the environment. Spills, if occur in the station, are expected to be confined at the site. Besides, most of the fuel used in the station is relatively volatile and expected to vaporize quickly in case of spills, but a waxy residue may remain.

However, fuel spills may permeate through rock cracks or pore spaces of moraines. If permeated fuel spills do reach the sea, it will have an adverse impact on marine environment. Furthermore, inland fuel spills may contaminate the soil and also adversely affect the flora living in the cracks between rocks.

Spills during construction may indirectly affect the scientific values of the area and contribute the cumulative effects of the station in the future.

5.3.2. Prevention of Fuel and Oil Spills

The primary method of managing fuel and oil spills is the prevention of spills, thus the use of fuel and oil will be strictly managed during the construction and operation of the station. A contingency plan will be prepared to take immediate measures for unexpected oil spills.

To prevent fuel spills, fuel tanks will be double-skinned, suitable absorbent mats will be used to underlay the pipelines, and oil impermeable bund wall will be built around the fuel tank (Fig. 5-6). Fuel pipelines for generators will be designed double-skinned to minimize the possibility of oil leakage.

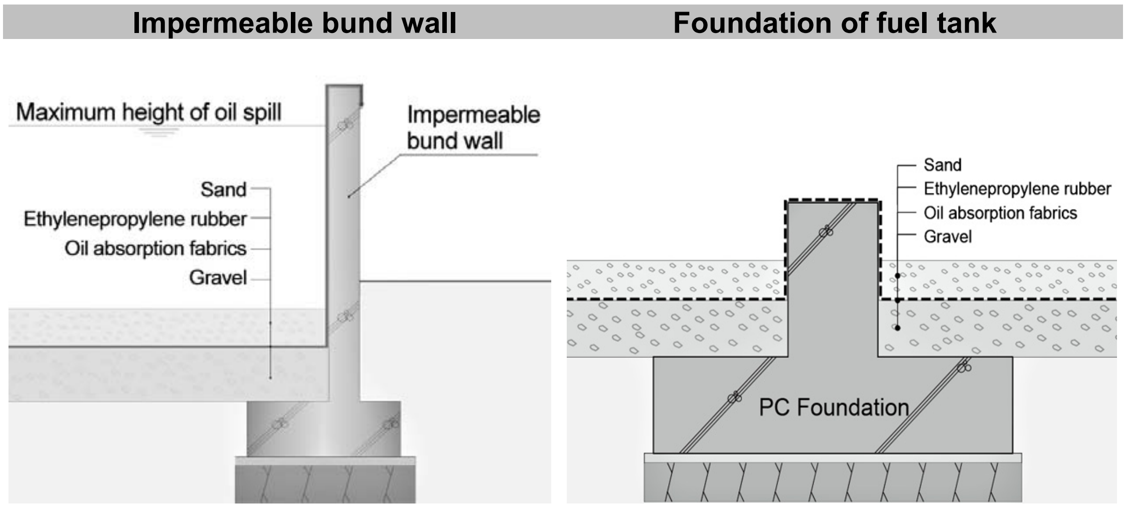


Fig. 5-6. Cross section of oil spill prevention facility.

The guidelines of COMNAP/SCALOP (2003), which describe actions to be taken in the event of different kinds of oil spills, will be strictly followed. Any incident, whether it involves casualties or any environmental damages, will be reported to the relevant authorities including the Ministry of Environment, the Ministry of Land, Transport and Maritime Affairs, and the KOPRI.

Most of the oil spills are likely to be minor, but oil tank damages can create greater harm. For such rare but potentially catastrophic events, emergency equipments and supplies against large amount of oil spills as well as comprehensive plans against marine accidents will be prepared. The station will also be provided with appropriate equipments and supplies for prevention and clean-up of spills in accordance with the associated regulations.

Furthermore, clean-up material and equipment at the station will be properly maintained for immediate emergency response. The maintenances will be scheduled at least once a year.

All staff members will be trained and refreshed once a year regarding immediate and appropriate response actions on the contingency action plan. The oil spill prevention and emergency response program will be regularly audited.

5.4. Waste

5.4.1. During Construction

(1) Waste Generation

The proposed construction activities are expected to mostly generate non-hazardous solid waste such as packaging materials, metal, plastic and wood. Some hazardous waste, including batteries, solvents and waste oil will also be produced.

The waste oil from construction equipments was calculated to be maximum 96.2ℓ/day. The domestic waste has been estimated to be less than 55kg/day based on the data collected from the recently renovated King Sejong Station (KOPRI, 2009a; Appendix 5).

Total amount of construction waste is expected to be contained in five 20-feet high containers when the modular construction method is applied, 90% less than the expected amount with a conventional construction method being applied.

If not securely contained, waste materials may be blown away by strong winds, buried under snow or scavenged by skua. Not properly managed waste may have other adverse biological effects on the fauna in the region. Waste may also have indirect effects on the future scientific value of the area.

(2) Mitigation Measures

All wastes, other than sewage and grey water, will be carefully packaged, labeled, secured to prevent dispersal, and eventually transported off from Antarctica, in accordance with the Antarctic Waste Management Manual (KOPRI, 2009b). The BAS Waste Management Handbook (BAS, 2010) will be referenced in management of waste.

The modular construction method will work to reduce substantial quantities of construction waste.

Storage of materials and waste will be carefully conducted in order to prevent wind dispersal or scavenging by skua.

Waste oil will be stored in storage facility. Night soil will be packaged and stored until being transported out of Antarctica.

Construction and domestic wastes will be separately collected for recycling and reuse if possible. All construction wastes will be properly stored, carefully managed and also removed permanently from Antarctica.

5.4.2. During Operation

(1) Waste Generation

Operation of research, residential and maintenance facilities will generate hazardous and non-hazardous solid waste. If not properly stored and managed, some waste may be scattered by strong winds or buried by snowfall. Food waste could be scavenged by skua or contaminate exposed rock surfaces and flora if not thoroughly contained.

Total domestic waste including noncombustible, recycled and incinerated waste (bottom ash) may reach as much as 7.76kg/day during the winter and 31.05kg/day during the summer. Food waste as much as 4.52kg/day during the winter and 18.06kg/day during the summer are expected according to the daily food waste unit published by the Ministry of Environment of Korea (Appendix 5). However, given the living conditions in the Antarctic, the amount of food waste produced is expected to be significantly lower than the predicted value.

(2) Mitigation Measures

Waste will be managed according to Antarctic Waste Management Manual (KOPRI, 2009b) as well as the BAS Waste Management Handbook (BAS, 2010). Appropriate training and guidance on waste management for staff members will be provided.

All wastes will be sorted, compacted if possible, safely stored and removed from the station for reuse, recycling or disposal.

An incinerator will be installed for food waste and sewage sludge, and all bottom ashes will be collected and transported out of Antarctica. Fly ashes will be filtered out in a dust filtration facility.

Special care will be taken for the storage of food waste as any food waste items left outside may be scavenged by skua.

Hazardous waste produced from laboratories and waste oil will be stored separately and eventually transported out of Antarctica.

5.5. Wastewater

5.5.1. During Construction

(1) Wastewater Generation

The wastewater will be generated as much as 22.0㎥/day during the first construction year, and 19.0㎥/day during the second construction year (Appendix 6). These are calculated based on the wastewater generation units provided by the Ministry of Environment of Korea. However, wastewater is actually expected to be less than the calculated amounts given the energy and resource-conscious life style in Antarctica.

The direct on-site disposal of untreated wastewater may cause contamination of the marine environment as well as the land biota such as lichens and birds inhabiting the region.

(2) Mitigation Measures

Wastewater generated during construction will be discharged after treatment using a state-of-the-art treatment system.

5.5.2. During Operation

(1) Wastewater Generation

Wastewater will be generated from activities such as food preparation and washing during the operation phase of the station. A conservative estimation of the wastewater that will be generated is up to 2.14㎥/day in the winter and 8.55㎥/day in the summer.

If the wastewater is discharged without proper treatment or in case of a failure of the treatment system, it could adversely affect the marine environment and the flora and fauna inhabiting the coastal region. In addition, if such discharge continues for a long time, cumulative impact on marine biota may occur.

There are also certain environmental concerns that must be addressed related to desalination of seawater. The disposal of concentrated residual brine into the sea may cause some environmental impacts on the marine ecosystem in nearby areas due to the changes in salinity, oxygen levels, and possibly temperature.

(2) Mitigation Measures

Methods of wastewater treatment and disposal will be based on the Protocol on Environmental Protection to the Antarctic Treaty.

The production of wastewater will be minimized in addition to the comprehensive treatment system that will be provided. The Internal Circulation in a Sequence Batch Reactor (IC-SBR) technique will be used to treat wastewater and the gray water reclamation and reuse system to maximize the reuse of wastewater.

Wastewater will be treated and discharged based on the most stringent level in Discharged Water Quality Standard of Korea (BOD less than 5㎎/ℓ, COD less than 20 ㎎/ℓ, T-N less than 20㎎/ℓ, T-P less than 0.2㎎/ℓ), thereby minimizing the impact on the marine environment.

Wastewater produced with hazardous chemical component from laboratories will be contained, specially sealed and transported back to Korea. In addition, water-saving devices will be installed.

The final discharge location of treated wastewater will be selected among farthest possible locations to the south from the intake position. The optimal discharge location will be determined based on the additional field investigation scheduled in February 2011.

Several methods for an adequate and safe disposal of the concentrated brine produced by the desalination process will be considered to reduce the environmental impacts of desalination. Although the brine generation is expected to be relatively small, direct discharge into the sea requires selecting an optimal location where the brine can easily disperse and be diluted. Pre-discharge mixing of the brine with treated wastewater will be another alternative to reduce salt concentration.

5.6. Noise

Noise levels during construction and operation were estimated and associated mitigation measures were established.

5.6.1. During Construction

(1) Prediction of Level of Noise and Impact

Noise will be generated from loading and unloading activities, equipment operations and other construction activities.

Levels of noise during construction were estimated considering mainly the operation of equipments and other construction activities. The equation of point-sound source attenuation (Appendix 7) was used under the worst case scenario assuming full-capacity operation of heavy equipment. The calculated noise levels do not exceed 50dB except for within and the immediate proximity of the construction site, which is the most stringent daytime noise limit applied in Korea (Fig. 5-7).

Noise disturbance may influence habitats of birds and mammals. However, the estimated noise levels are conservative as the model assumes flat topography, which is known to be the most preferable condition for the propagation of noise. Therefore the colonies of South Polar Skua and Weddell Seal, located approximately 1km away from the proposed site, will not be significantly impacted by the noise generated during the construction.

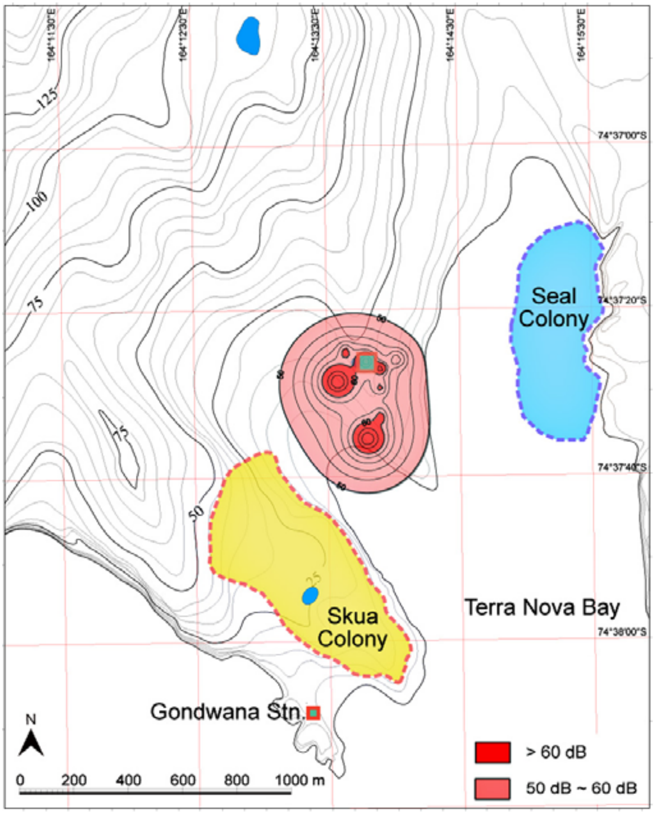


Fig. 5-7. Predicted noise level by equipment operation.

(2) Mitigation Measures

Simultaneous operation of construction equipment will be limited in order to minimize impact of noise on the colonies of skua and seal, although predicted levels of noise under the simultaneous operation condition were insignificant. In addition, construction machines of low noise and vibration-reduction technologies will be used and idling of vehicles will be minimized.

5.6.2. During Operation

(1) Prediction of Noise Level and Impact

The noise generated from the station during its operation and associated scientific activities may cause an adverse impact on fauna such as skuas and seals. The operations of ships and aircrafts will also produce inevitable noise, but their impact is temporary and limited mostly during the summer.

Power generators and radiators will produce constant noise. However, their levels are expected to be significantly lower than 35dB, the indoor noise standard applied for the station in its operation phase.

The use of vertically stacked modular type wind turbines which combines four 5kW vertical turbines is also expected to significantly lower the noise levels than the equivalent single 20kW horizontal-type turbine. One such type wind turbine is calculated to produce about 39dB of noise. As the level of noise will be attenuated logarithmically by distance, impact of noise will be almost negligible for the station, and for the colonies of skua and seal.

(2) Mitigation Measures

Noise absorbing materials will be installed in the power generator facility.

The helicopters will maintain a flying altitude recommended by the ATCM guideline for aircraft operation to minimize the impact on the ecosystem (ATCM, 2004b).

5.7. Flora and Fauna

The construction and operation of the Jang Bogo Station may not affect the surrounding ecosystem significantly because no major colonies or breeding grounds of designated species have been found at the near proximity of the proposed site.

The flora, mostly lichens and mosses, is very sporadic with low distribution density and a coverage degree of less than 1% nearby the proposed site. They are expected to be disturbed during the construction of the station, especially by grading work. However, as there are very few lichen growths on the proposed site, the disturbance to vegetation will be transitory only for the construction and thus not be so significant.

The colony of South Polar Skua located in the eastern hill of the Gondwana Station will not be directly disturbed due to the construction and operation of the station, but indirect impacts are expected considering relative proximity of the colony, the shortest distance between the colony and the site being approximately 500 meters. Besides, in 2009/10 survey, five individual skua nests have been observed within a 400m radius of the proposed site (Fig. 5-8). The distribution of individual nests, however, is expected to vary every year.

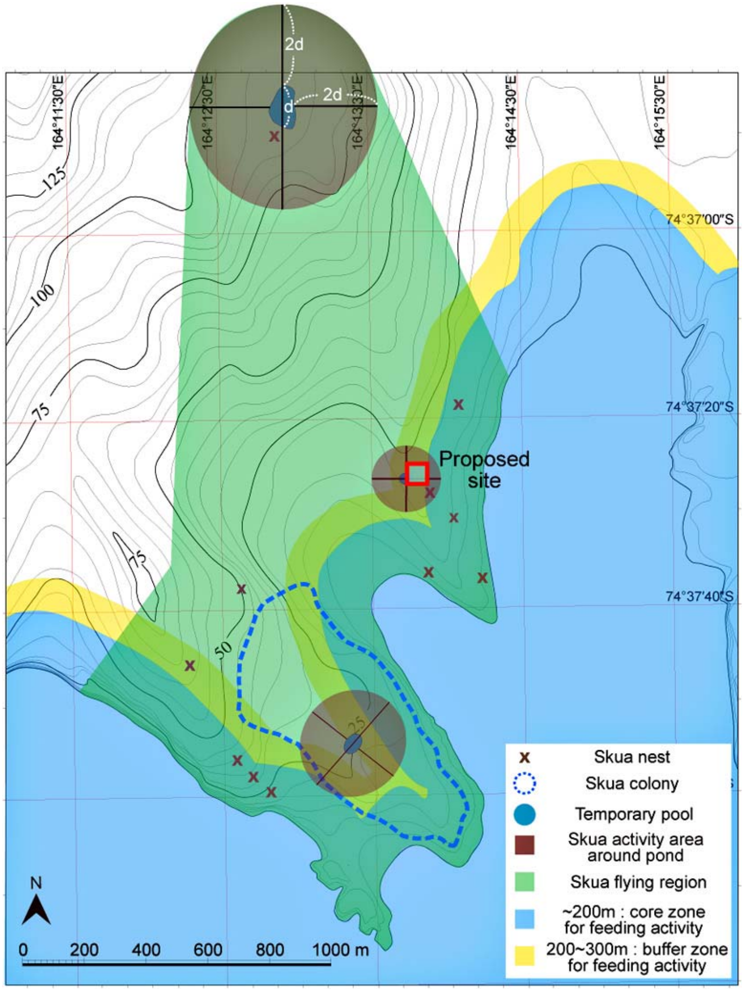


Fig. 5-8. Activity areas of South Polar Skua estimated based on the data of 2009/10 survey.

A number of Weddell Seal colonies were observed on ice fields more than 1km to the east, and hence, with little potential impacts expected on the habitats by the construction and operation of the station. The access route selected to be used for the station, one through the small bay west of the proposed site, is expected to have little impacts on the habitats of skua and seal than the other alternative routes.

5.7.1. During Construction

(1) Prediction of Impacts

1) South Polar Skua

The proposed site was selected in a location approximately 500m away from the boundary of the skua colony, approximately 1km from the center of the colony, in order to minimize any disturbances caused by the construction.

A few scattered nests in or near the proposed site are unlikely to have chance to be developed as a large colony in the future due to the lack of bedrock outcrops, which are favorable for nests. However, currently existing skua nests within the site may be distressed during construction.

2) Helicopters

When helicopters fly over the skua colonies, noise may disturb the habitats. In particular, helicopter noise increases during low-altitude flying, thus causing a significant impact, especially on the breeding colony.

3) Marine transportation and unloading

Marine transportation may disturb the marine environment and ecosystem. Especially, it is likely that unloading from a barge to land has an impact on the benthic ecosystem along the coastal line as well as on marine mammals.

4) Marine ecosystem related to construction of dock

In construction of dock, pre-manufactured stainless steel boxes will be used to shorten the construction period as well as to reduce potential impacts on the marine environment and natural coastal landscape. However, the benthic ecosystem near the shoreline may temporarily be impacted due to construction activities such as backfilling.

(2) Mitigation Measures

Impacts on the local ecosystem due to the construction and operation of the station can be reduced if mitigation measures are properly implemented.

1) South Polar Skua

For diminishing direct impacts on a few number of skua observed at the proposed site, soft measures will be taken to encourage voluntary relocation of their nest to alternative places.

To conserve the skua colony at the western area apart from the proposed site, unnecessary visiting by either construction workers or other personnel will be strictly controlled and restricted during construction period.

In addition, all personnel will be given site specific guidance on minimizing anthropogenic disturbance to the skua colony. Semiweekly monitoring on the skua colony will be taken by biologists to exam if there would be unexpected impacts occur.

2) Helicopters

In order to minimize the impact of helicopter operations on the colonies of skua and seal, a flight route which is able to minimize the impact on them will be taken into account. Moreover, guideline related to flying in the Antarctic, “Guideline for the operation of aircraft near concentrations of birds in Antarctica” will be followed (ATCM, 2004b). These guidelines will also be followed during the operation of the station.

3) Marine transportation and unloading

Impact of marine transportation on the marine ecosystem may vary depending on the alternative access routes to the station. Considering the distributions of the flora and fauna, a route through the small bay west of the proposed site, route B of Fig. 5-9, was estimated to be the best transportation route for the protection of biodiversity and the ecosystem (Table 5-4).

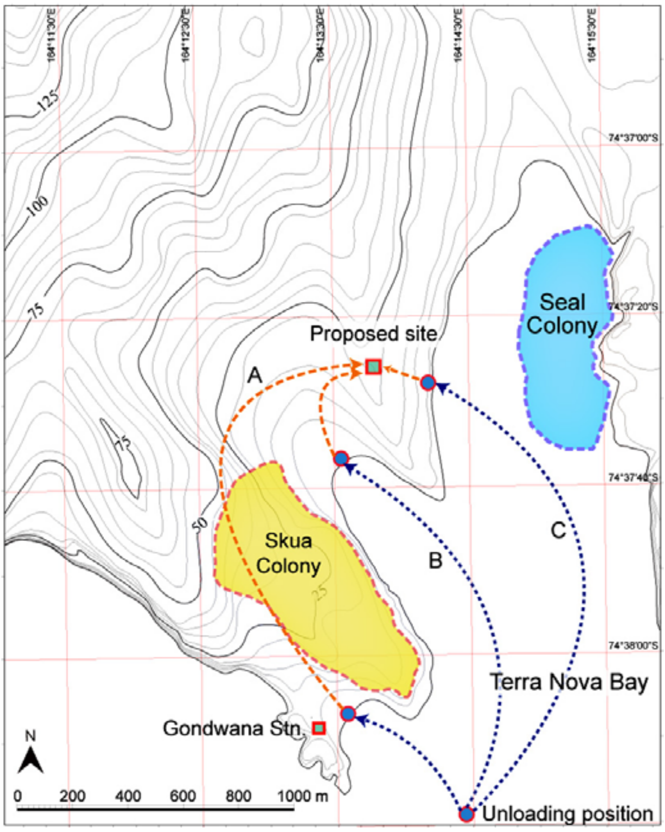


Fig. 5-9. Marine transport and unloading alternatives.

Table 5-4. Ecological impact of each transport alternative.

Category	Lichens/mosses	Birds	Marine mammals
Route A	extremely low	moderate	none
Route B	extremely low	extremely low	none
Route C	extremely low	extremely low	moderate

4) Marine ecosystem related to construction of dock

During the construction of the proposed dock, only the limited amounts of gravels and boulders, by-product of grading and excavation for the mat foundation of the building will be used for backfilling to minimize the disturbance to nature of glacial topographic features in the area. Precast concrete blocks will also be used on the top. In addition, the excavation site will be contained within a turbidity barrier that will be installed during the construction in order to avoid dispersion of suspended materials, and thus minimize impacts on the benthic ecosystem.

5.7.2. During Operation

(1) Prediction of Impacts

1) Research activities and visitors

Human disturbances can be induced by a variety of research activities and summer visitors, but the impact on lichens and mosses is almost negligible given their locations and densities of distribution. The impacts on skua and seal habitats will be indirect and minor during the operation of the station because the colonies are located at a safe distance from the proposed site.

2) Introduction of alien species

Alien species may be introduced through food items, equipment or other materials associated with personnel imports to the Antarctic. Non-native soil imports may also transfer alien species such as seeds and micro-organisms.

3) Transportation and unloading

In case of oil spill during transportation or unloading, the marine ecosystem may be subject to adverse impacts.

4) Wind turbine

The low speed rotation of vertically stacked modular type turbines is expected to generate noise less than 39dB, which will have almost no impact on the surrounding ecosystem as well as on people. It was predicted that bird strikes are highly unlikely to occur because of good visibility of tower structure as well as the small radius of rotation of the turbines (Kikuchi, 2008).

5) South Polar Skua

Although located away from the station, environmental disturbances associated with the operation of the station may cause some stress to skuas especially while breeding.

Skuas are scavengers, and therefore food or food waste left outside of the station, if skuas feed on them, may disturb their dietary habits.

6) Temporary pools

If the temporary pool, located 1.2km to the north of the proposed site, is utilized as an emergency water source, the associated installation of pipe lines and facilities may render an adverse impact on the density of lichens and mosses as well as on the skua habitat. Skuas consistently use the pool as a freshwater source and resting area. Therefore, preservation of the temporary pool undisturbed will be more beneficial than using it as an emergency water source for the station.

(2) Mitigation Measures

1) Research activities and visitors

The impacts caused by research activities and activities of the summer visitors are expected mostly insignificant on the flora and fauna of the region. In particular, the major colonies of skua and seal are not exposed to the direct impact during operation. However, as temporary indirect impacts are still expected, limits on the number and the scope of research activities and activities of the summer visitors will be planned in advance in the annual plans of operation of the station.

2) Introduction of alien species

In order to prevent the introduction or dissemination of alien species possibly transferred by people, equipment or supplies, the regulation of Annex II (Article 4) of the Protocol on Environmental Protection to the Antarctic Treaty will be strictly followed. Items such as shoes, clothes and organic matters will be thoroughly cleaned and sanitized before being imported onto Antarctica. In particular, tracked and wheeled vehicles will be carefully rinsed on the ship before unloading.

3) Transportation and unloading

For transportation and unloading, an oil spill contingency plan will be set up to protect the marine ecosystem. Prevention and treatment materials such as oil absorption fabrics and recovery equipment will be prepared for immediate responses to oil spill accidents.

4) South Polar Skua

The main population of skua inhabiting a gentle hill between the proposed site and Gondwana station will be monitored as one of possible indicators responding any kind of impacts and changes in terrestrial ecosystem. During the operation, skua population fluctuation and dynamics will also be carefully analyzed to conserve the core spot of skua's habitats as well as to conduct scientific researches. In detail, the size and distribution of skua populations around the station will be monitored annually by establishing a post-monitoring program in order to investigate any changes in the ecosystem.

In consideration of skua's dietary habit as a scavenger, food and food wastes will be managed and treated according to a proper management plan.

All personnel including visitors will be given guidance on minimizing disturbance to the skua colony. Helicopter will not overfly the skua colony and its operation will follow the guideline related to flying in the Antarctic, "Guideline for the operation of aircraft near concentrations of birds in Antarctica" (ATCM, 2004b).

5) Temporary pools

As the flora and fauna in the northern temporary pool are diverse compared to those in other areas, the pool will not be used as an emergency water source to preserve the biota in this area.

5.8. Changes in Topography

Partial grading is required for constructions of buildings, facilities and a temporary camp. Furthermore, the natural topographic features of the region should be modified for the unloading activities close to the coast and the installation of routes for the cargos and equipment to the proposed site.

Various activities related to the installation of wind turbines may also cause changes in the topographic features as well as the local landscape. The activities include transport of heavy equipment, construction of the foundation of the wind turbine towers, and installation of three 20m high towers. These changes will locally disturb the unconsolidated glacial sedimentary layers and bedrocks to some extent. However, it is expected that such change in topography is likely to be insignificant because the area is generally flat or only gently slopes.

5.9. Scenery and Aesthetic Natural Values

The proposed site is a region where its exposed bedrock outcrops and glacial moraines, in combination with the Campbell Glacier to the east and Mt. Browning to the northwest, command a stunning scenery.

Although horizontal glacial sedimentary layers develop relatively flat topography, the construction of buildings and routes may nevertheless result in, if minor and local, a visual disturbance of the natural landscape of the region. Installation of wind turbines may also cause a local disturbance to the scenery as well. The uncontrolled use of tracked vehicles that mark disordered tracks on snow and land surface may create an undesirable visual impact, especially from a remote view.

The station layout will be intended to have a minimum impact on landscape and maintain the aesthetics of the region. The buildings and facilities at the station will be arranged to reduce an influence on the local scenery as much as possible. Tracked vehicles will only be used on designated routes to minimize disturbances of the land surface.

5.10. Cumulative Impacts

Cumulative impact refers to the combined impacts of past, present and future activities. The direct and indirect impacts should be evaluated and the temporal and spatial ranges of individual impacts must be taken into consideration to estimate cumulative impact.

The construction of the station is limited to the comparatively short time frame, and hence, contributing insignificantly to the cumulative impact on the environment. Impacts by the operation of the Jang Bogo Station will be combined with the impacts generated by the nearby Gondwana Station. However, such impacts are expected to be insignificant because the Gondwana Station is located 1.2km away from the proposed site and, furthermore, generally operates every other year. Summer activities may increase the cumulative impact on the environment due to increased research activities and number of personnel. As possibility of direct/indirect effects from increasing summer activities cannot be overlooked, a monitoring plan to observe cumulative effects will be set up.

Cumulative impacts will stem mainly from emissions air and discharge of wastewater during the construction and operation of the station.

The emissions generated by fuel consumptions will have direct impacts on air quality, and may further affect water and snow in the long term. Emissions may cumulatively affect regional/global air quality. However, these emissions will rapidly disperse with the strong winds of the area and the amount will be trivial relative to global emissions level. Therefore, the cumulative impacts are not considered significant.

The discharge of treated wastewater may cause some marine environment risks and adversely affect the flora and fauna inhabiting the coastal region if not properly treated. However the amount of discharge water will be reduced using the gray water reclamation and reuse system. In addition, a state-of–the-art technology will be adopted to treat wastewater. Therefore the cumulative impacts on marine environment will not be significant.

5.11. Dismantling

The Jang Bogo Station will be constructed using the modular construction system. A detailed dismantling program, including plans to dismantle and reuse the station, will be established in accordance with the guidelines of the Protocol on Environment Protection to the Antarctic Treaty.

More specifically, a detailed work schedule will be planned including the time schedule of dismantling, packing and transportation of the station. For the environmental impacts estimated, relevant mitigation measures will be prepared for all tasks associated with the dismantling process.

The modules and wastes produced during dismantling will be completely transported out of the Antarctic region. A comprehensive phase-by-phase dismantling plan will be prepared.

After the dismantling is completed, the region will be monitored for a certain period of time to assure minimizing the impact of the dismantling and determine whether additional measures are needed to recover the site.

5.12. Impact Matrix

Tables 5-5 and 5-6 illustrate the predicted impacts of the construction and operation of the Jang Bogo Station. Details of the activities were itemized by their environmental stressors, predicted impacts, and the levels of probability, extent, duration and importance of each stressor and impact were independently evaluated. The results of evaluation were incorporated into the mitigation measures per each stressor.

The criteria which categorize the impacts are as follows:

☐ Probability

- Unlikely
- Low
- Medium
- High
- Certain

☐ Extent

- Area-specific: Impact near the construction site
- Local: Around 1km radius from the proposed site
- Regional: Around 10km radius from the proposed site
- Continental: Antarctic continent, including the Ross Ice Shelf
- Global: Worldwide

☐ Duration

- Very short: - days
- Short: weeks to months
- Medium: years
- Long: decades
- Very long: centuries

☐ Importance

- Very low: almost no impact
- Low: very little impact
- Medium: average impact
- High: significant impact
- Very high: serious impact

Table 5-5. Impact matrix (Construction).

Activity		Stressors	Predicted impact	Probability	Extent	Duration	Importance	Mitigation measures
SHIPS	Shipping and cargo handling	Atmospheric emissions	-Cumulative impacts on local and global air quality	High	Regional	Long	Very low	-Strictly follow IMO regulations - Use of highly refined fuel such as MGO with low-sulfur (lower than 4.5% as regulated by the MARPOL 73/78)
			-Contamination of glaciers, snow and ecosystems	Low	Regional	Long	Very low	
		Fuel spills and generation of hazardous wastes	-Local marine pollution when anchored	Medium	Area-Specific	Short	Very low	-Care and attention when refueling -Oil absorbents to be kept on site in case of local oil spills and resulting marine pollution -Establishment of oil spill contingency plan
		Generation of wastes and wastewater	-Local marine pollution	Low	Area-Specific	Short	Very low	-Wastes discharged in accordance with MARPOL requirements after storing in containers -All vehicles and equipments to be cleaned before shipping
			-Introduction of alien species and diseases	Low	Area-Specific	Short	Very low	
HELICOPTERS	Taking off, landing, and operation of helicopter	Atmospheric emissions	-Cumulative contribution to local and global atmospheric pollution	Low	Regional	Short	Very low	-Efficient operation of helicopters -Use of high energy efficient fuel
			-Contamination of glaciers, snow and ecosystems	Low	Regional	Short	Very low	
		Flight	-Cumulative impact of helicopters flying over colonies of birds and mammals repeatedly	Medium	Local	Short	Medium	-Use of detour routes from colonies -Observe ATCM (2004b) “Guideline for the operation of aircraft near concentrations of birds in Antarctica”
			-Disturbance to ecosystem -Decrease in colonies of birds and mammals	Low	Local	Short	Very low	
			-Loss of biodiversity	Low	Local	Short	Very low	

Activity		Stressors	Predicted impact	Probability	Extent	Duration	Importance	Mitigation measures
	Refueling	Fuel spills	-Cumulative pollution on snow and glaciers	Low	Area-Specific	Long	Medium	-Refrain from refueling near station -Care and attention when refueling -Oil absorbents to be kept on site in case of local oil spills -Establishment of oil contingency plan
			-Loss of scientific value	Low	Area-Specific	Long	Low	
CONSTRUCTION ACTIVITIES	Construction of dock	Construction activities	-Disturbance of benthic sediments and ecosystem near the dock	High	Area-Specific	Short	Medium	-Limit the range of construction activities -Installing turbidity barrier during construction -Prohibit oil exchange and refueling near coast to prevent marine pollution
	Construction of station	Topographic change	-Land disturbance by foundation work	Medium	Area-Specific	Very short	Very low	-Application of foundation technique which does not use piles or anchors -Minimize impact by limiting site area
			-Land disturbance by land grading work	Low	Area-Specific	Short	Low	
		Route construction	-Land disturbance by land grading work	Medium	Local	Short	Medium	-Minimize damage by considering topographic features
		Movement of equipments	-Disturbance to glacial sediment layers	High	Area-Specific	Short	Medium	-Limit expanding transfer routes of equipment
		Atmospheric emissions	-Contamination of glaciers, snow and glacial sediments	High	Regional	Short	Low	-Adopt low carbon techniques reducing the construction process (i.e., unit modular system for on-site assembling) -Consider both fuel efficiency and emission when choosing equipment -Limit operation of equipment and machineries -Use high quality heat insulating materials on temporary facilities and control the energy consumption efficiently -Lower dust generation by installing a diesel particle filter -Use of low-sulfur fuel
		Fuel spills	-Contamination of snow, soil and rock surface	Low	Area-Specific	Long	Low	-Prepare temporary oil storage and install Impermeable bund walls -Establishment of oil spill contingency plan -Care and attention when refueling -Oil absorbents to be kept on site to prevent spreading of an oil spill

Activity		Stressors	Predicted impact	Probability	Extent	Duration	Importance	Mitigation measures
		Generation of wastes and wastewater	- Contamination of snow, soil and rock surface	Low	Area-Specific	Short	Low	- Solid waste will be separately collected, reused if possible and completely removed out of Antarctica - Use toilets with suction system not requiring washing - Apply modular construction system to limit the generation of construction waste
			- Introduction of alien species	Low	Local	Short	Low	
		Generation of noise	- Decrease of colony size	Low	Local	Short	Medium	- Periodic use of equipment - Apply low noise and low vibration techniques - Installation of device to control idling while driving - Establish a monitoring plan considering reproductive and breeding seasons of birds and mammals near the station
			- Loss of biodiversity	Unlikely	Local	Medium	Very low	
		Impacts caused by construction equipments and workers	- Disturbance to soil, soil compaction and introduction of alien species	Low	Local	Short	Low	- Use cleaned construction equipment - Limit construction area and wear cleaned shoes and clothes

Table 5-6. Impact matrix (Operation).

Activity		Stressors	Predicted impact	Probability	Extent	Duration	Importance	Mitigation measures
OPERATION OF STATION	Operation of station	Atmospheric emissions	-Contamination of glaciers, snow and soil	Low	Local	Long	Low	-Minimal energy consumption by using waste heat from CHP and high efficiency lighting device -Minimum incineration by recycling of wastes -Latest technology applied to incinerator -Use of renewable energy
			-Contamination of glaciers, snow and soil specially caused by the operation of incinerator	High	Regional	Long	Medium	
		Generation of wastes and wastewater	-Contamination of snow, soil and rock surfaces	Low	Local	Long	Low	-Complete removal of incinerated ashes outside the Antarctic -Installation of recycling bins -Dry and compact food waste for incineration -Limit hazardous materials -Manage food waste not to be approached by skuas
			-Disturbance to skua's dietary Behavior	Medium	Local	Medium	Medium	
			-Behavioral change of skuas and infection of disease	Medium	Local	Short	Medium	
		Fuel storage and oil spills	-Contamination of snow, soil and rock surfaces	Medium	Area-Specific	Long	Medium	-Prepare clean up equipment and audit once a year -Develop a training program for staff -For oil spills, activate oil removal process
		Operation of wind turbines	-Disturbance to ecosystem by noise	Low	Local	Long	Low	-Installation of vertically stacked modular type turbines which reduce noise and prevent bird strike
			-Disturbance to birds' behavior	Medium	Local	Long	Low	
			-Decrease of colony size	Unlikely	Local	Medium	Very low	
			-Bird strike	Low	Area-Specific	Long	Very low	

Activity		Stressors	Predicted impact	Probability	Extent	Duration	Importance	Mitigation measures
	Research activities	Observation of flora and fauna	-Disturbance to habitat and breeding activities	Medium	Regional	Long	Medium	-Limit access to habitat -Limit activities aside from those with scientific purpose -Observe Recommendation ⅩⅧ-1 "Guidance for Visitors to the Antarctic" during operation -Prevent disturbance by conducting preliminary evaluation of the sampling plans
			-Disturbance caused by sampling	Medium	Local	Medium	Medium	
		Visitors	-Expansion of range by visitors	Medium	Regional	Long	Medium	-Observe Recommendation ⅩⅧ-1 "Guidance for Visitors to the Antarctic" during operation -Limit access to breeding site -Limit the number of visitors -Establish visiting plan and conduct visitor training -Clean clothes and shoes
			-Disturbance to breeding birds	Medium	Regional	Short	Medium	
			-Damage of vegetation	Medium	Regional	Medium	Medium	
			-Introduction of alien species	Low	Regional	Medium	Low	
USE OF TRANSPORTATION	Operation of transportation	Atmospheric emissions	-Cumulative impacts on snow, glaciers and soil caused by snowmobiles	Unlikely	Regional	Long	Very low	-Limited use of vehicles in the station -Use energy efficient vehicles
		Introduction of alien species	-Proliferation of alien species due to snowmobiles	Unlikely	Regional	Long	Very low	-Clean equipment and clothes
	Refueling	Fuel spills	-Accumulation of contaminants on snow and glaciers	Medium	Area-Specific	Long	Medium	-Refueling only in designated place -Care and attention when refueling -Prepare oil spill prevention materials -Establishment of oil spill contingency plan
			-Loss of scientific value	Unlikely	Area-Specific	Long	Low	

6. Environmental Monitoring and Verification

KOPRI will establish a monitoring program for the environmental impact of the construction and operation of the Jang Bogo Station. Data collected during the 2009/10 survey, weather data collected from the AWS installed during the same period, and the additional data collected during the 2010/11 survey will be used as baseline data. This monitoring will be continued as a part of the major scientific research after the completion of construction of the station. The program will be continuously reviewed and modified in coordination with other post-construction research activities. The COMNAP guidelines will be followed by the monitoring program (COMNAP, 2005b). Table 6-1 demonstrates the most basic items that will be included in the monitoring program. The program will be open to the public, allowing any concerned or interested parties to review the monitoring processes and results.

Table 6-1. Environmental monitoring plan during construction and operation.

Items	Environmental monitoring program
Air quality	- Check the impact of the construction and operation on air quality
Oil leakage	- Inspect for oil leakage in the oil storage facility and equipment during construction or operation of the station and establish a clean-up plan in case of oil leakage
Wastewater treatment	- Measure the quality of the wastewater discharge to sea
Waste management	- Compliance check of the disposal of waste produced during construction and operation of the station - Compliance check of recycling and disposal
Ecosystem	- Establish a plan to monitor the impact of the construction and operation of the station on the ecosystem · Changes in the ecosystems of lichens, South Polar Skuas, and Weddell Seals · Inspecting for introduction of alien species and inflow of harmful materials
Natural Environment	- Investigate any changes in the natural environment caused by the construction and operation of the station · Changes in the piling of snow and their nature · Distribution and movement of glaciers

Such monitoring program will be devised and executed to investigate the environmental impacts of human activities. Therefore, through such monitoring program, it should be possible to identify an adverse impact on the environment with enough lead time to allow establishing suitable mitigation measures and minimizing the consequences of the impact.

Especially for the construction period, a construction site supervisor as well as a manager from KOPRI will be on site throughout the whole construction period to oversee the construction process. They will send photos and other visual recordings of the construction back to Korea for stakeholders. If it is deemed that any process of construction fails to meet the environmental regulations and standards, the supervisor shall stop the construction until a mitigation measure can be set up for bring the process back into compliance.

7. Gaps in Knowledge and Uncertainties

The gaps in knowledge and uncertainties identified during the CEE on the construction and operation of Jang Bogo Station are as follows:

☐ Distribution of sea ice around Cape Möbius and climate conditions during construction period

– Associated transportation disruptions may affect the construction period.

☐ Future retreat of the Campbell Glacier Tongue near the proposed site

☐ Long-term climate change near the construction site

☐ Uncertainties in the knowledge and information of natural environment near the proposed site

– Validity of the collected data on major bio-species as well as the hydrographic data of the sea currents near the proposed site

– An additional field survey will be conducted to collect supplementary data to confirm the optimal location of the wind turbine towers as well as the final discharge location of treated wastewater to the sea.

☐ Status of a few South Polar Skua nests distributed close to the proposed site

– Location and number of nests expected to change every year

☐ Final design and layout of the facilities

– Details may partially change in the final design plan.

☐ Minor changes in the application of various techniques and methods of construction and operation

☐ Items related to the future expansion of the station

– The station may be expanded depending on future research demands, although there is no detailed present plan of the expansion.

☐ Changes in the activities of the station according to the change in future perspectives of research

8. Summary and Conclusion

The Republic of Korea plans to construct the Jang Bogo Antarctic Research Station near Cape Möbius, the northwestern coastal region of Terra Nova Bay of Northern Victoria Land in the Ross Sea area, in order to conduct more in-depth research in Antarctica, the center of attention of international scientific community as well as the general public, and to contribute to the global efforts to address and respond to climate change.

A CEE was conducted in order to establish an environmentally sound and sustainable station with construction and operation plans to minimize any adverse impacts on the environment.

The station will be accommodating up to 60 personnel during the summer with estimated life expectancy of at least 25 years. A layout radially arranging structures from the central main building was selected for the station. This layout not only ensures safety, functionality, and efficiency, but also requires minimal disturbances to the natural topography at the site. The building will be constructed as a combination of elevated and slanting structures in order to efficiently respond to the extreme weather conditions of the Antarctic. Latest energy-saving technologies for buildings will be applied to maximize energy efficiency.

As an effort to minimize the use of fossil fuels during operation of the station, all waste heat will be fully utilized by a CHP. Solar and wind renewable energy will also be used as much as possible in the station.

The location of the proposed site for Jang Bogo Station at Terra Nova Bay is a region with high levels of biodiversity. However, the colonies and habitats of major bio-species do not exist close to the proposed site, and therefore, the station is not expected to have a significant impact on the ecosystem. The South Polar Skua colony near the proposed site is located at a safe distance from the station, and the degree of direct disturbance on the skuas by the station will not be significant.

The environmental impacts of the construction and operation of Jang Bogo Station were estimated and assessed accounting for major environmental issues such as air quality, fuel and oil leakage, waste, wastewater, noise, and ecosystem. Mitigation measures corresponding to the estimated potential impacts were developed accordingly. Furthermore, an environmental monitoring program will be administered to identify any environmental changes throughout the operation of the station. A systematic emergency response plan will be established for expedient and effective management of emergency situations.

The expected level of the environmental impact of the construction and operation of Jang

Bogo Station is expected to be “more than minor or transitory.” In this regard, the Republic of Korea conducted a CEE on the proposed activities and proposed use of various cutting edge technologies and mitigation measures to minimize the potential environmental impacts that the construction and operation of the new station may have on the region.

The Jang Bogo Station will be operated year round and therefore, diverse scientific data on the surrounding environment and ecosystem will be continuously acquired at the station. It is our hope that the station will become a world leading contributor in prediction of future climate change. Furthermore, as a research hub supporting not only the activities of Korean scientists, but also partnerships with leading foreign experts on climate change in the Antarctic region, the Jang Bogo Station is expected to enable and inspire international collaboration and multidisciplinary research.

The results of CEE have led to the conclusion that the knowledge and information gained through the research activities held in the station will prove to be invaluable to the international scientific community and grossly outweigh the “more than a minor or transitory” impact on the Antarctic environment; thus, the establishment of Jang Bogo Station is highly recommended.

9. Authors and Contact Details

This draft CEE was prepared by a team of researchers from Korea Environment Institute (KEI), Chungnam National University, and Korea Polar Research institute (KOPRI). PDF download is available from either KOPRI (http://www.kopri.re.kr) or Ministry of Foreign Affairs and Trade (http://www.mofat.go.kr).

For more information on this draft CEE for the Jang Bogo Station or if you would like to comment, please contact:

Korea Environment Institute
290 Jinheung-ro, Eunpyeong-gu
Seoul, 122-706, Korea
Tel: +82 2 380 7763 Fax: +82 2 380 7744
e-mail: yjlee@kei.re.kr (or jaychoi@cnu.ac.kr)
http://www.kei.re.kr

The authors of draft CEE are:

KEI - Drs. Young-Joon Lee (CEE project manager), Nankyoung Moon, Young Han Kwon, Ji Young Kim, Tae Ho Ro, and Dong Jun Chun
Chungnam National University - Dr. Jaeyong Choi (CEP representative)
KOPRI - Drs. Yeadong Kim, Ji Hee Kim, and Joohan Lee

Overall project management for the Jang Bogo Station:

Manager: Dr. Yeadong Kim
Korea Polar Research Institute
7-50, Songdo-dong, Yeonsu-gu
Incheon, 406-840, Korea
Tel: +82 32 260 6007 Fax: +82 32 260 6079
e-mail: ydkim@kopri.re.kr
http://www.kopri.re.kr

10. Acknowledgements

The authors wish to express their gratitude to the following people and organizations for the support in preparing this Draft CEE:

- Sohee Park and Hyeyeong Choe of KEI for analyzing data, drawing and manuscript editing
- Young Soo Lee and Yun Sung Kim of KEI for their valuable comments and reviews
- Mindae Park of Dongrim Consultant Co. and Jae Goo Lee of Korea Engineering Consultants Corp. for proving emission and conversion factors as well as for technical comments on air quality, waste, and noise
- Hyundai Engineering & Construction Co. for providing information on the building design and station layout
- KICT for providing the construction master plan and comments on air quality and waste

The supports of the Ministry of Land, Transport and Maritime Affairs and the Ministry of Foreign Affairs and Trade are gratefully acknowledged.

This Draft CEE has been officially reviewed by Nature Policy Division, Ministry of Environment before submitting to ATCM.

The satellite image in Figures 2-1, 4-12 and 4-19 was used by permission of MUSEO NAZIONALE DELL'ANTARTIDE, Italy.

11. References

ATCM (2004a) COMNAP's Framework and Guidelines for Emergency Response and Contingency Planning in Antarctica (IP 012) XXVII ATCM.

ATCM (2004b) Guidelines for the Operation of Aircraft near Concentrations of Birds in Antarctica (WP010) XXVII ATCM.

ATCM (2005) Practical Guidelines for Developing and Designing Environmental Monitoring Programmes in Antarctica (WP026) XXVIII ATCM.

ATCM (2006) Practical Biological Indicators of Human Impacts in Antarctica (IP088) XXIX ATCM.

ATCM (2007a) Energy (WP035) XXX ATCM.

ATCM (2007b) Waste Management (IP0998) XXX ATCM.

ATCM (2008a) Survey on existing procedures concerning introduction of non native species in Antarctica (IP098) XXX ATCM.

ATCM (2008b) The COMNAP Fuel Manual, incorporating revised guidelines for fuel handling and storage in Antarctica (IP091) XXX ATCM.

ATCM (2010) Terra Nova Bay - Wood Bay Marine Protected Area inside a wider proposal for a Ross Sea MPA. XXXIII ATCM.

Australian Antarctic Division (2007) Antarctica and the Southern Ocean. Map No. 13438.

British Antarctic Survey (2010) Waste Management Handbook. 4th Edition, Rev 6.

Cattaneo-Vietti, R., Chiantore, M., Gambi, M.C., Albertelli, G., Cormaci, M. and Di Geronimo, I. (2000) Spatial and Vertical Distribution of Benthic Littoral Communities in Terra Nova Bay. In: Faranda, F.M., Guglielmo, L. and Ianora, A. (eds.) Ross Sea Ecology: Italian Expedition (1987-1995). Springer-Verlag, Berlin Heidelberg, 503-514.

COMNAP (1992) Guidelines for Oil Spill Contingency Planning.

COMNAP (1993) Guidelines for the Reporting of Oil Spill Incidents which Occur in Antarctica.

COMNAP (2005a) Guidelines for Environmental Impact Assessment in Antarctica.

COMNAP (2005b) Practical Guidelines for Developing and Designing Environmental Monitoring Programmes in Antarctica (WP026) XXVIII ATCM.

COMNAP/SCALOP (2003) Framework and Guidelines for Emergency Response and Contingency Planning In Antartica. Comnap XV meeting.

Cormaci, M., Furnari, G. and Scammacca, B. (2000) The Macrophytobenthos of Terra Nova Bay. In: Faranda, F.M., Guglielmo, L. and Ianora, A. (eds.) Ross Sea Ecology: Italian Expedition (1987-1995). Springer-Verlag, Berlin Heidelberg, 493-502.

Faranda, F.M., Guglielmo, L. and Ianora, A. (2000) The Italian oceanographic cruises in the Ross Sea (1987-1995): Strategy, general consideration and description of the sampling sites. In: Faranda, F.M., Guglielmo, L. and Ianora, A. (eds.) Ross Sea Ecology: Italian Expedition (1987-1995). Springer-Verlag, Berlin Heidelberg, 1-13.

Frezzotti, M. (1992) Fluctuations of ice tongues and ice shelves derived from satellite images in Terra Nova Bay area, Victoria Land, Antarctica. In: Yoshida Y et al. (eds.) Recent progress in Antarctic Earth Science. TERRAPUB, Tokyo, 733-739.

Kantor, W. (1993) Environmental Impact Analysis of the German Gondwana Station, Antarctica, and Mapping of the Substrate, Flora and Fauna. In: Damaske, D. and Fritsch, J. (eds.) German Antarctic North Victoria Land Expedition 1988/89 (GANOVEX Ⅴ). Hanover, 7-37.

Kikuchi, R. (2008) Adverse impacts of wind power generation on collision behaviour of birds and anti-predator behaviour of squirrels. Journal for Nature Conservation 16, 44-55.

Kim, J., Lee, Y. and Choi, J. (2008) A Field Survey Report for the 2008 Antarctic Expedition-Topography, Geology, and Environment. (In Korean)

Korea Energy Management Corporation (2009) Automatic calculation of TOE and tCO2, http://co2.kemco.or.kr/directory/toe.asp

Korea Institute of Construction Technology (2010) Construction Master Plan for the Second Antarctic Station. (In Korean)

Korea Polar Research Institute (2007) A Guide to developing the Comprehensive Environmental Evaluation for the Second Antarctic Station. (In Korean)

Korea Polar Research Institute (2009a) Initial Environmental Evaluation (IEE) for the eco-friendly renovation of King Sejong Station, King George Island, Antarctica. (In

Korean)

Korea Polar Research Institute (2009b) Antarctic Waste Management Manual. (In Korean)

Korea Polar Research Institute, Korea Environment Institute, Korea Institute of Construction Technology (2010) A Field Survey Report for the 23rd Korean Antarctic Research Program. (In Korean)

Ministry of Maritime Affairs and Fisheries, ROK, (2005) Feasibility Study for the Construction of the New Antarctic Station. (In Korean)

MUSEO NAZIONALE DELL'ANTARTIDE-Sezione di Scienze della Terra, Via Laterina 4-53100 SIENA-ITALY (1996) MOUNT MELBOURNE QUADRANGLE (VICTORIA LAND), ANTARCTIC GEOMORPHOLOGICAL AND GLACIOLOGICAL 1:250,000 MAP SERIES.

NASA (2008) Surface meteorology and Solar Energy Data Set, http://eosweb.larc.nasa.gov/sse/RETScreen/

Orombelli, G. (1987) Terra Nova Bay: A geographic Overview. Proceedings of the meeting Geosciences in Victoria Land, Antarctica. Siena, 2-3 September 1987. 69-75.

Stocchino, C. and Lusetti, C. (1988) Le costanti armoniche di marea di Baia Terra Nova (Mare di Ross, Antartide). F.C. 1128 Istituto Idrografico della Narina, Genova.

Stocchino, C. and Lusetti, C. (1990) Prime osservazioni sulle caratteristiche idrologiche e dinamiche di Baia Terra Nova (Mare di Ross, Antartide). F.C. 1132 Istituto Idrografico della Marina, Genova.

Tin, T., Sovacool, B.K., Blake, D., Magill, P., Naggar, S.E., Lidstrom, S., Ishizawa, K. And Berte, J. (2010) Energy efficiency and renewable energy under extreme conditions: Case studies from Antarctica. Renewable Energy 35, 1715-1723.

Turner, J. and Pendlebury, S. (2004) The International Antarctic Weather Forecasting Handbook. British Antarctic Survey.

USGS (1998) Satellite Image Map of Antarctica-Using Advanced Very High Resolution Radiometer (AVHRR) Images, http://terraweb.wr.usgs.gov/projects/Antarctica/AVHRR.html

12. Index

Acronym	Meaning
AHU	Air Handling Unit
ATCM	Antarctic Treaty Consultative Meeting
ASPA	Antarctic Specially Protected Areas
AWS	Automatic Weather System
BOD	Biochemical Oxygen Demand
CEE	Comprehensive Environmental Evaluation
CEP	Committee for Environmental Protection
CFD	Computational Fluid Dynamics
CHP	Combined Heat and Power
COMNAP	Council of Managers of National Antarctic Programs
EIA	Environmental Impact Assessment
EPICA	European Project for Ice Coring in Antarctica
GANOVEX	German Antarctic North Victoria Land Expedition
GAW	Global Atmosphere Watch
HSM	Historic Sites and Monuments
IAATO	International Association of Antarctic Tour Operation
IEE	Initial Environmental Evaluation
IMO	International Maritime Organization
IC-SBR	Internal Circulation in a Sequence Batch Reactor
IPY	International Polar Year
KARP	Korea Antarctic Research Program
KEI	Korea Environment Institute
KICT	Korea Institute of Construction Technology
KOPRI	Korea Polar Research Institute
LGP	Latitudinal Gradient Project
MARPOL	Marine Pollution
MGO	Marine Gas Oil
MPA	Marine Protected Area
NASA	National Aeronautics and Space Administration
PC	Precast Concrete
PNRA	Programma Nazionale di Ricerche in Antartide
POLENET	Polar Earth Observing Network
SCALOP	Standing Committee of Antarctic Logistics and Operations
TPLMS	Total Pollution Load Management System
WMO	World Meteorological Organization

13. Appendices

Appendix 1. Building area of the Jang Bogo Station

Facilities	Area (m^2)	Specific facilities
Main building	1,955.3	bed room, office, operating room, communication room, infirmary, laundry room, gym, lounge, storage, research labs. etc.
Power plant	850.8	maintenance room, office, storage, larder
Maintenance facility	774.8	heavy equipment maintenance room and storage, wastewater disposal system
Boat storage	191.8	boat maintenance room, storage
Emergency shelter	54.2	bed room, office, toilet, kitchen, storage
Total area	3,826.9	

Appendix 2. Data of monthly mean temperature, wind speed and pressure at the Mario Zucchelli Station and the proposed site

Site	Variables		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mario Zucchelli Station	T (°C)	Mean	-1.4	-6.5	-14.6	-19.2	-20.6	-20.1	-21.3	-21.9	-19.6	-14.9	-7.6	-1.8
		Max	0.2	-4.3	-11.4	-14.7	-15.6	-16.6	-18.1	-14.1	-15.7	-7.4	-6.0	0.0
		Min	-2.8	-8.7	-18.6	-22.6	-24.3	-25.8	-28.2	-25.8	-23.3	-18.0	-9.2	-3.5
	WS (m/s)	Mean	4.4	6.8	7.0	6.4	6.8	8.0	7.7	7.7	7.3	6.4	5.9	4.4
		Max	6.3	10.2	10.3	9.4	10.7	11.6	10.5	11.0	11.5	8.8	8.7	6.2
		Min	2.7	4.5	4.7	3.3	2.9	4.1	4.7	4.6	4.6	3.5	3.9	2.6
	P (hPa)	Mean	980.6	979.9	979.9	978.3	979.0	982.6	979.9	977.1	976.9	973.1	975.1	979.5
		Max	990.2	989.3	985.7	988.4	993.2	994.7	996.6	986.0	986.2	985.3	982.5	990.7
		Min	973.5	972.7	973.9	971.9	967.4	971.8	968.3	971.4	967.8	960.4	967.5	969.9

※ Mario Zuccheli Station: 1987.2. - 2009.11.

Site	Variables		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Proposed site	T (^{o}C)	Mean		-7.0	-12.7	-19.0	-21.5	-23.1	-24.7	-21.9	-22.7	-15.0	-6.4	
		Max		0.7	-1.1	-9.0	-10.8	-12.1	-10.4	-6.9	-12.0	-3.5	2.5	
		Min		-12.6	-26.3	-26.7	-34.0	-31.3	-33.0	-33.4	-31.9	-26.3	-14.5	
	WS (m/s)	Mean		4.8	4.0	3.6	3.9	3.9	5.5	5.5	4.5	4.2	4.9	
		Max		18.7	14.5	17.6	19.0	15.9	28.4	29.0	35.9	23.2	16.7	
		Min		0.4	0.4	0.3	0.4	0.5	0.5	0.5	0.4	0.3	0.4	
	P (hPa)	Mean		992.3	987.9	985.6	987.3	982.3	974.4	978.0	984.7	979.5	978.7	
		Max		1006.0	1002.0	999.0	1007.0	993.0	993.0	999.0	1003.0	1023.0	994.0	
		Min		972.0	965.0	972.0	964.0	971.0	955.0	951.0	949.0	958.0	956.0	

※ Proposed site: 2010.2. - 2010.11.

Appendix 3. A list of flora found in the proposed site and its vicinity

Species name	Kantor 1993 [1)]	2010. 2
Lichens		
Acarospora gwynnii	+	+
Buellia frigida	+	+
Buellia pallida	+	+
Buellia papillata		+
Caloplaca sublobulata		+
Caloplaca citrine	+	
Caloplaca sp.	+	+
Candelariella flava		+
Candelariella sp.	+	
Carbonea capsulata	+	
Lecanora cf. expectans	+	
Lecanora fuscobrunnea	+	+
Lecanora sp.	+	+
Lecidella sp.	+	+
Leproloma sp.	+	+
Physcia sp.	+	
Pleopsidium chlorophanum		+
Pseudephebe minuscula	+	+
Pseudephebe pubescens	+	+
Psoroma cf.	+	
Rhiziplaca melanopthalma	+	+
Rinodina olivaceobrunnea		+
Umbilicaria antarctica		+
Umbilicaria decussata	+	+
Umbilicaria cf. rufidula	+	
Umbilicaria sp.		+
Usnea sphacelata	+	
Xanthoria candellaria	+	
Xanthoria elegans	+	+
Xanthoria mawsonii		+
Moss		
Bryum argenteun var. argenteum		+
Bryum argenteum var. muticum		+
Bryum pseudotriquetrum		+
Syntrichia magellanica		+
Algae		
Prasiola crispa		+
Total Number	**22**	**26**

1) Kantor, W. (1993) Environmental Impact Analysis of the German Gondwana Station, Antarctica, and Mapping of the Substrate, Flora and Fauna. In: Damaske, D. and Fritsch, J. (eds.) German Antarctic North Victoria Land Expedition 1988/89 (GANOVEX V). Hanover, 7-37

Appendix 4. Estimated atmospheric emissions

<Predicted emissions produced by transportation during construction>

Source	Total fuel		Type of emission	Emission factor (g/kg)	Total Emissions (ton)
	Volume (ℓ)	Weight (kg)			
Marine transportation - Icebreaker - Cargo ship - Tugboat - Zodiac boat	10,391,927	8,781,178	CO	0.71	6.23
			NOx	3.41	29.94
			SO_2	33.44	293.64
			PM10	0.28	2.46
			*CO_2	879.0	7,718.66
Air transportation - Helicopter	114,000	91,200	CO	12.0	1.09
			NOx	0.19	0.02
			SO_2	0.72	0.07
			PM10	0.20	0.02
			*CO_2	859.0	78.34

· Source

1. Marine transportation: US EPA AP-42 (NO_2 fuel oil with uncontrolled burning)
   *CO_2: UK National Atmospheric Emission Inventory, 2008
2. Air transportation: UK National Atmospheric Emission Inventory, 2002

Note) Specific gravity: 0.845 for MGO, 0.8 for aircraft fuel

<Predicted emissions produced by operation of construction camp>

Source	Total fuel		Type of emission	Emission factor (g/kg)	Total Emissions (ton)
	Volume (ℓ)	Weight (kg)			
Generator (250kW)	28,725	22,980	CO	1.01	0.02
			NOx	14.66	0.34
			SO_2	0.93	0.02
			PM10	1.28	0.03
			*CO_2	614.0	14.11

· Source

US EPA AP-42 (electric generator from internal combustion engine, uncontrolled operation)
*CO_2: UK National Atmospheric Emission Inventory, 2008

Note) Specific gravity: 0.8 for Antarctic Diesel (generator)

<Predicted emissions produced by equipments during construction - A>

Source	Number	Average declared power (kW)	Hours	Total fuel		Type of emission	Emission factor (g/kWh)	Total emissions (ton)
				Volume (ℓ)	Weight (kg))			
Bulldozer	1	127	375	14,625	11,700	CO	2.52	0.06
						NOx	10.24	0.23
						SO_2	5.20	0.12
						PM10	0.35	0.01
						*CO_2	74,100	38.36
Wheel loader	1	153	375	2,438	1,950	CO	1.45	0.04
						NOx	8.40	0.23
						SO_2	5.20	0.14
						PM10	0.18	0.00
						*CO_2	74,100	6.40
Backhoe	2	105	960	33,984	27,187	CO	2.52	0.24
						NOx	10.24	0.99
						SO_2	5.20	0.50
						PM10	0.35	0.03
						*CO_2	74,100	89.14
C/Crane	3	226	960	36,288	29,030	CO	5.07	1.58
						NOx	5.45	1.70
						SO_2	5.08	1.59
						PM10	0.40	0.12
						*CO_2	74,100	95.19
H/Crane	1	226	960	7,488	5,990	CO	5.07	0.53
						NOx	5.45	0.57
						SO_2	5.08	0.53
						PM10	0.40	0.04
						*CO_2	74,100	19.64
Cargo Truck	1	470	960	20,256	16,205	CO	3.50	0.76
						NOx	3.50	0.76
						SO_2	5.08	1.10
						PM10	0.20	0.04
						*CO_2	74,100	53.13
D/truck	2	470	960	40,512	32,410	CO	3.50	1.52
						NOx	3.50	1.52
						SO_2	5.08	2.20
						PM10	0.20	0.09
						*CO_2	74,100	106.27

・Source

1. Korean National Emission Inventory, 2010
2. Construction estimating standard, KICT, 2010

   Total emission:

   $$E = N \times A \times k \times T \times EF$$

   Where;

   E = emissions (ton)
   N = number of equipment
   A = average declared power (kW)
   T = hours of operation (hr)
   EF = emission factors (g/kWh)
   k = constant of the average output rate, 0.48

3. For CO_2, 2006 IPCC Guidelines
   Net heating value: 35.4MJ/ℓ for Antarctic Diesel
   *: unit of emission factor: kg/TJ

<Predicted emissions produced by equipments during construction - B>

Source	Number	Hours	Total fuel		Type of emission	Emission factor (g/kg)	Total emissions (ton)
			Volume (ℓ)	Weight (kg)			
Generator (500kW)	1	300	22,980	18,384	CO	18.410	0.338
					NOx	44.100	0.811
					SO_2	3.730	0.069
					PM10	3.610	0.066
					*CO_2	74,100	60.28
Generator (250 kW)	1	750	28,725	22,980	CO	18.410	0.423
					NOx	44.100	1.013
					SO_2	3.730	0.086
					PM10	3.610	0.083
					*CO_2	74,100	75.35
Generator (100 kW)	2	450	15,660	12,528	CO	18.410	0.231
					NOx	44.100	0.552
					SO_2	3.730	0.047
					PM10	3.610	0.045
					*CO_2	74,100	41.08
Compressor (600CFM)	1	150	2,670	2,136	CO	18.410	0.039
					NOx	44.100	0.094
					SO_2	3.730	0.008
					PM10	3.610	0.008
					*CO_2	74,100	7.00
Compressor (370CFM)	1	150	1,650	1,320	CO	18.410	0.024
					NOx	44.100	0.058
					SO_2	3.730	0.005
					PM10	3.610	0.005
					*CO_2	74,100	4.33
Trailer	2	960	39,936	31,949	CO	18.410	0.588
					NOx	44.100	1.409
					SO_2	3.730	0.119
					PM10	3.610	0.115
					*CO_2	74,100	104.76
Heater	3	300	8,100	6,480	CO	18.410	0.119
					NOx	44.100	0.286
					SO_2	3.730	0.024
					PM10	3.610	0.023
					*CO_2	74,100	21.25

・Source

1. US EPA AP-42 (heavy-duty construction equipment)
2. For CO2, 2006 IPCC Guidelines
   Net heating value: 35.4MJ/ℓ for Antarctic Diesel
   *: unit of emission factor: kg/TJ

<Predicted annual emissions produced by fuel consumption during operation>

Source	Fuel consumption		Type of emission	Emission factor		Total emissions (ton)
	Volume (ℓ)	Weight (kg)				
Antarctic Diesel (generators)	305,724	244,579	CO	1.01	g/kg	0.25
			NOx	14.66	g/kg	3.58
			SO_2	0.93	g/kg	0.23
			PM10	1.28	g/kg	0.31
			*CO_2	74,100	kg/TJ	801.96
Source	**Fuel consumption**		**Type of emission**	**Emission factor**		**Total emissions (ton)**
	Volume (ℓ)	**Weight (kg)**				
Antarctic Diesel (vehicle)	23,000	18,400	CO	0.393	g/kg	0.01
			NOx	18.664	g/kg	0.34
			SO_2	0.6	g/kg	0.01
			PM10	0.062	g/kg	0.00
			*CO_2	74,100	kg/TJ	60.33
Source	**Fuel consumption**		**Type of emission**	**Emission factor**		**Total emissions (ton)**
	Volume (ℓ)	**Weight (kg)**				
Antarctic Diesel (incinerator)	66,344	53,075	CO	0.232	g/kg	0.01
			NOx	1.830	g/kg	0.10
			SO_2	1.730	g/kg	0.09
			PM10	12.600	g/kg	0.67
			*CO_2	74,100	kg/TJ	174.03
Helicopter	31,250	25,000	CO	12.0	g/kg	0.30
			NOx	0.2	g/kg	0.00
			SO_2	0.7	g/kg	0.02
			PM10	0.2	g/kg	0.01
			*CO_2	859.0	g/kg	21.48
Source	**Fuel consumption**		**Type of emission**	**Emission factor**		**Total emissions (ton)**
	Volume (Nm^3)	**Weight (kg)**				
LPG (kitchen)	2,778	-	CO	0.2	kg/kℓ	0.56
			NOx	2.18	kg/kℓ	6.06
			SO_2	0.01	kg/kℓ	0.03
			PM10	0.05	kg/kℓ	0.14
			*CO_2	63,100	kg/TJ	10.13

・Source

1. Antarctic Diesel (generators): US EPA AP-42 (electric generator from internal combustion engine, uncontrolled operation)
   *CO_2: 2006 IPCC Guidelines
2. Antarctic Diesel (vehicle): vehicle emission factors, National Institute of Environmental Research, 2006
   *CO_2: 2006 IPCC Guidelines

3. Antarctic Diesel (incinerator): US EPA AP-42 (refuse combustion, mass burn and modular excess air combustion, uncontrolled)
   *CO_2: 2006 IPCC Guidelines
4. Helicopter: UK National Atmospheric Emission Inventory, 2002
   *CO_2: UK National Atmospheric Emission Inventory, 2008
5. LPG (kitchen): National Air Pollutants Emission, Ministry of Environment, National Institute of Environmental Research, 2000
   *CO_2: 2006 IPCC Guidelines

Note) Specific gravity: 0.8 for Antarctic Diesel (generator)
Net heating value: 57.8MJ/Nm^3 for LPG

Appendix 5. Estimated wastes

<Estimated waste oil used by equipments during construction>

Equipment	Number	Capacity	Fuel consumption (ℓ/hr)	Conversion factor (%)	Waste oil (ℓ/day)
Bulldozer	1	32ton	41.6	0.016	5.3
Wheel loader	1	0.95 ㎥	6.2	0.044	2.2
Backhoe	1	1.0 ㎥	20.5	0.024	3.9
Generator	1	100kW	17.4	0.024	3.3
	2	250 kW	38.3	0.024	14.7
	2	500 kW	76.6	0.024	29.4
C/Crane	3	50ton	12.0	0.020	5.8
H/Crane	1	25ton	9.6	0.020	1.5
Forklift	2	5ton	5.7	0.037	3.4
Trailer	2	20ton	20.0	0.038	12.2
Cargo Truck	1	15ton	15.9	0.038	4.8
D/truck	2	15ton	15.9	0.038	9.7
Total	19	-	-	-	96.2

・Source

Construction estimating standard, KICT, 2010

Note) 8-hour operation per day

<Estimated domestic wastes and night soil during construction>

Type	Unit	Personnel		Total
Domestic wastes	0.5kg/day	Year 1	110	55.0kg/day
		Year 2	95	47.5kg/day
Night soil	0.3ℓ/day	Year 1	110	33.0ℓ/day
		Year 2	95	28.5ℓ/day

・Source

Initial Environmental Evaluation (IEE) for the eco-friendly renovation of King Sejong Station, King George Island, Antarctica, KOPRI, 2009

<Estimated domestic wastes during operation>

Period	Personnel	Unit (kg/person/day)	Domestic waste (kg/day)			
			Total	Combustible waste	Non-combustible waste	Recycling waste
Winter	15	1.035	15.525	9.703	1.459	4.363
Summer	60	1.035	62.100	38.813	5.838	17.450

・Source

Domestic waste generation per person in Korea, 2008

Note) Ratio of domestic wastes:
Combustible (including food waste): 62.5%, noncombustible: 9.4%, recycling: 28.1%

<Estimated incinerated ash during operation>

Period	Combustible waste (kg/day)	Conversion factor (%)	Incinerated ash (kg/day)
Winter	9.703	20	1.941
Summer	38.813	20	7.763

・Source

Disposal and recycling of incinerated ash of domestic waste, Korea Institute of Geoscience and Mineral Resources, 2004

<Final estimated domestic wastes after incineration>

Period	Noncombustible waste (kg/day)	Recycling waste (kg/day)	Incinerated ash (kg/day)	Total (kg/day)
Winter	1.459	4.363	1.941	7.763
Summer	5.838	17.450	7.763	31.051

<Estimated food waste during operation>

Period	Personnel	Unit (kg/person・day)	Volume of food waste (kg/day)
Winter	15	0.301	4.515
Summer	60	0.301	18.060

・Source

Domestic waste generation per person in Korea, 2008

Appendix 6. Estimated wastewater

<Estimated wastewater during construction>

Period	Personnel	Unit (ℓ/person·day)	Wastewater (m^3/day)
Year 1	110	200.0	22.0
Year 2	95	200.0	19.0

- Source

  Wastewater generation unit provided by the Ministry of Environment, ROK (Notification No. 2009-197)

<Estimated water usage during operation>

Period	Personnel	Consumption unit (ℓ/person·day)	Total consumption (m^3/day)
Winter	15	150	2.25
Summer	60	150	9.00

<Estimated wastewater during operation>

Period	Water consumption (m^3/day)	Conversion factor (%)	Wastewater (m^3/day)
Winter	2.25	95	2.14
Summer	9.00	95	8.55

- Source

  Guideline for Total Pollution Load Management System (TPLMS), 2006

Note) Ministry of Environment, Korea provides 0.88 for wastewater conversion factor. However, 0.95 of wastewater conversion factor was applied with an assumption of minimal leakage in Antarctica

Appendix 7. Composite noise and point-sound source attenuation

☐ **Composite noise**

$SPL = 10 \cdot \log [A \cdot 10^{(SPL1/10)} + B \cdot 10^{(SPL2/10)} + \ldots\ldots + N \cdot 10^{(SPLn/10)}]$

Here, SPL: Composite noise [dB(A)]

A,B,…,N: No. of equipment in operation

SPL1,2,…,n: Noise of each equipment [dB(A)]

☐ **Point sound source attenuation**

$SPL = SPL_0 - 20 \cdot \log(r / r_0)$

Here, SPL: Level of noise [dB(A)] r (m) away from the point-sound source

SPL_0: Level of equipment noise [dB(A)] r_0 (15m) away from the point-sound source

r : Distance from point-sound source (m)

r_0: Distance from point-sound source to measurement point (15m)

DRAFT COMPREHENSIVE ENVIRONMENTAL EVALUATION

Construction and Operation of the Jang Bogo Antarctic Research Station, Terra Nova Bay, Antarctica

Korea Polar Research Institute

Korea Environment Institute