Draft Comprehensive Environmental Evaluation of New Indian Research Base at Larsemann Hills, Antarctica

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DRAFT COMPREHENSIVE ENVIRONMENTAL EVALUATION

OF NEW INDIAN RESEARCH BASE AT LARSEMANN HILLS,

ANTARCTICA

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NON-TECHNICAL SUMMARY

INTRODUCTION

This draft Comprehensive Environmental Evaluation (CEE) has been carried out by the National Centre for Antarctic and Ocean Research (NCAOR), an R&D wing of Ministry of Earth Sciences, Government of India, which is mandated to coordinate and manage all the activities of India in the Antarctic region. The CEE has been prepared for the establishment of the proposed new Indian research base in the Larsemann Hills of the East Antarctica (69°24' to 69^0 25'S latitude and 76°10' to $76^0$13'E longitude) at an unnamed promontory also referred in some journals as Grovnes. The document has been prepared in accordance with Annex I of the Protocol on Environmental Protection to the Antarctic Treaty (The Madrid Protocol 1991) and the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 4, XXVIII ATCM, 2005). This document deals with the following:

- History of Indian Antarctic programme and scientific activities planned at new base
- Description and need of the proposed activity
- Design and construction criteria
- Alternatives to proposed activity
- Initial environmental reference
- Identification and prediction of impacts
- Mitigation measures to control proposed activity
- Gaps in knowledge and uncertainty to define activity or impacts.

This CEE is based on a conceptual design of the station which will be built using the latest technology to minimize the environmental impact of the structures and planned scientific and logistic activities.

DESCRIPTION OF THE PROPOSED ACTIVITY

The proposed station, which is to be built on an unnamed promontory between Stornes and Broknes peninsula in the Larsemann Hills area (69°24'-69^0 25'S latitude and 76°10'-$76^0$13'E longitude) is an ice-free coastal oasis fringing the Prydz Bay. It is located approximately midway between the eastern extremity of the Amery Ice Shelf and the southern boundary of the Vestfold Hills.

The proposed location is of interest on account of scientific and logistic reasons, the ice-free terrain and the easy access from the sea. This area including the islands and promontories offers an excellent scope for extensive studies on geological structures and tectonics with special reference to Gondwanaland, palaeoclimatology, solid earth geophysics, spaceweather and meteorology, oceanography, marine biology, microbiology, environmental science etc.

The proposed research base is planned to have a life span of 25 years. It shall accommodate 25 people during summer and 15 people during winter. Design of the station will withstand extreme environmental conditions prevailing at Larsemann Hills, meeting the environmental standards as provided under the Madrid Protocol. Emphasis will be on use of alternative energy i.e. wind and solar power to reduce the fossil fuel consumptions.

STATION DESIGN AND CONSTRUCTION CRITERIA

The Station is being designed as an ergonomic entity in harmony with the prevailing environment at the Larsemann Hills. It is proposed to build a self-contained double-storey structure on stilts capable of accommodating a maximum of 25 persons. To facilitate the planned scientific studies including environmental monitoring, the base will have state-of-the-art laboratory facilities.

The conceptual design of the station has been obtained through global tenders for innovative ideas. Overall 32 design proposals were received from around the world out of which four entries were short listed for providing a detailed concept on design and construction of the station. The architect/consultants were selected based on their experience to build environmental friendly stations in Antarctica by a committee of experts, drawn from the national organizations and academic institutions involved in building design, construction and environmental engineering.

The selected conceptual design meets the Madrid Protocol requirement. Once the approvals of the CEP and ATCM are obtained, the construction of the station will be initiated during the subsequent austral summer. The station is expected to be commissioned in two years time from the initiation of construction activity. The scientific activities and work for collection of base data, which was started in the austral summer of 2003-04, when the first Task Force landed at Larsemann Hills, will however continue to gather more information on the gap areas and to improve upon the design parameters and further reduce the environmental impact.

SITE SELECTION AND ALTERNATIVES

Initially three regions in Antarctica were recommended to the Government of India by an expert committee in 1996, for more comprehensive research by the Indian scientists by establishing an additional research base in Antarctica. The probable areas were:

a) Antarctic Peninsula,

b) Filchner Ice Shelf and

c) Amery Ice shelf – Prydz Bay area

The site for the new Indian base at the Larsemann hills was selected after a thorough consideration of various options available along the East Antarctic coast.

The Antarctic Peninsula being overcrowded by the existing stations did not find much favor. The Filchner Ice Shelf poses logistics constraints in maintaining a research facility. The third option emerged as the most favorable choice, after a thorough consideration of various options available along the East Antarctic coast, since it offered enormous scope for initiating long term scientific experiments in Antarctica and the Indian Ocean region between India and Antarctica.

In the Amery Ice shelf-Prydz Bay area, many sites were visited to find a suitable location. Considering various environmental factors and avoiding areas of wildlife concentration and critical natural values, the Larsemann Hill region was found most suitable. In Larsemann Hills, three locations were visited but finally the present site was selected based on:

- the availability of a flat terrain for station construction
- the relative ease of cargo discharge operations,
- the availability of freshwater lakes, and
- the open sea approach to the site.

As bathymetry of Prydz Bay along the approach route was not available, a detailed multibeam bathymetry survey was carried out during the austral summer of 2006 to identify a suitable channel for ship/barge movement. The route is found deep enough for vessel movement and will provide a safe sea access to the station site.

The information on the selection of the new site was provided to the ATCM through IP 80 at XXVIII ATCM in Stockholm and in the WP 20 at XXIX ATCM in Edinburgh.

DESCRIPTION OF THE AREA AND ENVIRONMENT

The Larsemann Hills area is marked by persistent, strong katabatic winds that blow from east to southeast during austral summer. Daytime air temperatures from December to February at times exceed 4˚C, with the mean monthly temperature a little above 0˚C. Extreme minimum temperature recorded in the region so for is -40^0 C (Turner and Pendlebury, 2004). Annual mean wind speed of 7 m/s and maximum wind speed 50 m/s is recorded at the nearby Zhongshan station. Annual mean gale days are about 171 (47%). Precipitation occurs as snow and is unlikely to exceed 250 mm water equivalent annually (Hogdson et al., 2001) Pack ice is extensive in north-eastern side throughout the summer and the fjords and embayment are rarely ice-free. Snow cover is generally thicker and more persistent on Stornes Peninsula than on Broknes Peninsula. The sea ice grows steadily during March – September, with maximum growth in April – June.

Lakes present in the Larsemann Hills area are mostly saline in nature (Gillieson et al, 1990) and are characterized by low microbial diversity (Burgess and Kaup, 1997). However the promontory supporting the proposed site has small fresh water lakes and a saline lake at upper reaches. The area adjoining the proposed site does not support any population of breeding penguins or seals.

IMPACT ASSESSMENT AND MITIGATION MEASURES

Assessment of the impact of the proposed station has been carried out keeping in view various activities pertaining to the logistics of transportation, construction and subsequent operation of the proposed station. Experience of about 25 years in maintaining Dakshin Gangotri and Maitri stations in Antarctica has been the main strength of the Indian scientists and engineers in assessing the environmental impacts and taking mitigation measures in the proposed CEE.

A matrix was prepared to identify the impacts and define appropriate practical mitigation measures. The main environmental disturbances during construction and operational phases pertain to:

- air pollution due to emissions from the vehicles, vessels, aircrafts, generators and incinerators
- ground impact due to vehicular and human movement
- noise pollution
- disposal of treated wastewater and solid waste
- accidental oil spill

The environmental impact assessment matrix indicates by and large of low to medium category impacts. Proper preventive and mitigation measures have been proposed for strict implementation during the construction and operation phases. Solid waste treatment shall be carried out and wastewater will be discharged in sea after proper treatment. Electromagnetic disturbance due to operation of the electrical equipment and vehicles is not ruled out, but all the equipment placed in the area will meet Electro Magnetic Compatibility standards. To reduce the fossil fuel consumption, renewable energy (solar and wind) shall supplement fuel based power generation. The thermal energy from the water cooled generators will be used for station heating purposes.

Since the mitigation measures are defined and all construction and operational activities at the proposed station shall comply with the provisions contained in Madrid Protocol using appropriate technology, the environmental impact will be kept at minimum and close to the existing parameters.

GAPS IN KNOWLEDGE AND UNCERTAINTIES

Gaps and uncertainties in this draft CEE report include:

- Uncertainty of sea ice extent during the period January-March each year.
- The exact berthing spot of the ship close to the landing site is not known.
- The CEE is based on the conceptual design of the station. There may be some modifications based on the site requirements, practical difficulties etc.
- Impact matrix and evaluation have been done according to expert judgment which is based on the predicted values and are subject to change depending on the environmental conditions.
- During the long life span of the station, the need-based scientific activities and the energy scenario may change with the developments in the technologies.

CONCLUSIONS

India plans to have a new research base in the Larsemann Hills of East Antarctica for carrying out long-term research in various domains of polar, ocean and atmospheric sciences for complementing the existing studies at Maitri and adjoining areas from an additional location. India considers that construction and operation activity of the proposed Indian research base shall have more than minor or transitory impact on the Antarctic Environment. Suitable mitigation measures have been proposed based on impact assessment matrix to minimize the impact.

The Report is submitted for consideration by the Committee for Environmental Protection (CEP X) at the forthcoming Antarctic Treaty Consultative Meeting (ATCM) to be held from 30th April – 11th May 2007 in New Delhi, India. We welcome further comments and suggestions on the draft CEE.

FURTHER INFORMATION

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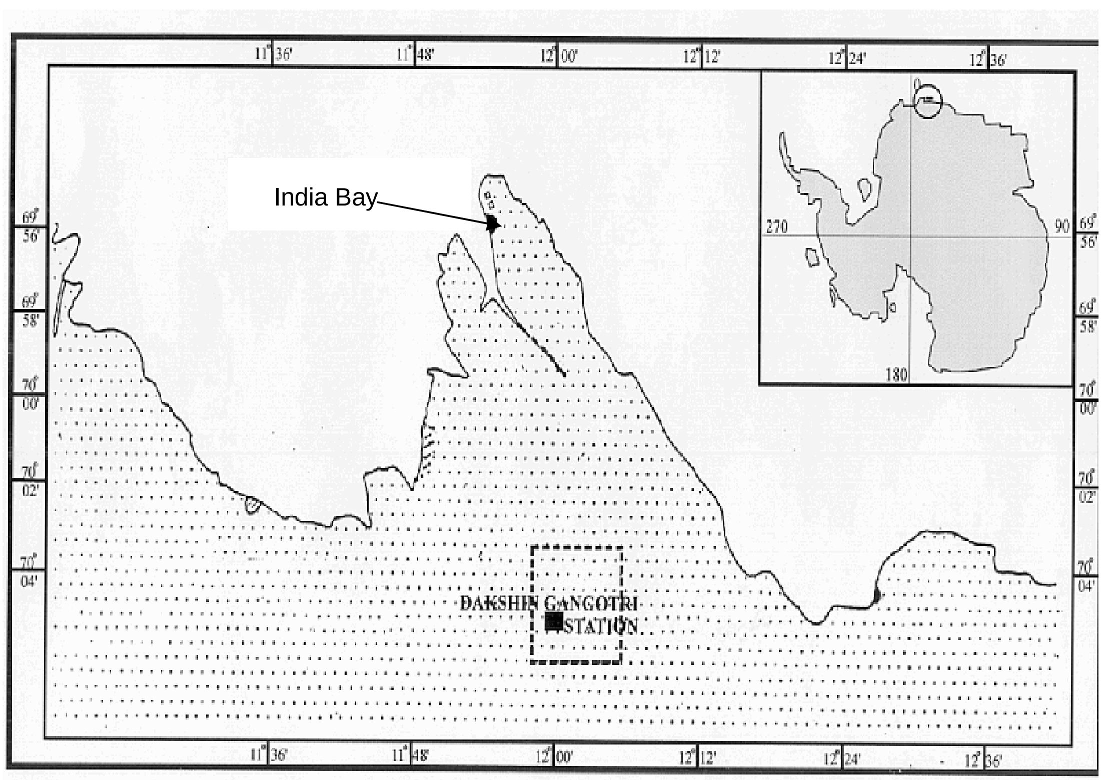
1. INTRODUCTION

1.1 History of Indian Antarctic Research

1.1.1 Dakshin Gangotri

The importance of Antarctica as a pedestal for front-ranking scientific research was recognized by India in 1981, when the first Indian Antarctic Expedition was launched. Since then, India has made great strides both in Polar Sciences and related logistics, through a judicious and harmonious blend of multi-institutional expertise, brought together under the umbrella of the Ministry of Earth Sciences (earlier Department of Ocean Development). This has paved the way for the country to sustain its scientific endeavor in the icy continent on year-round basis ever since 1983, when the first permanent Indian Antarctic Base “Dakshin Gangotri” (70^{O} 5’ 37”S: 12^{O} E) was commissioned on the ice shelf, off the Princess Astrid coast in Central Dronning Maud Land (Figure 1).

Figure 1 : Location of Dakshin Gangotri Station and India Bay



The station made of wood huts and built in the record time of an austral summer, continued to host the members of Indian expeditions to Antarctica till 1989, when it had to be decommissioned due to excessive snow accumulation (Figure 2). The area has since been designated as historical site, HSM 44.

Figure 2 : Dakshin Gangotri Station

(In 1983)

(In 1990)

1.1.2 Maitri

In the year 1988 an ice free, rocky area on the Schirmacher oasis was selected to build the Second Research Station "Maitri (70^o45'52"S: 11^o44'03"E). The building (Figure 3) was erected on steel stilts, and has since stood the test of time. The infrastructure available at the station has enabled the scientists to conduct research in various disciplines such as Atmospheric Sciences & Meteorology, Earth Sciences including Glaciology, Human Biology & Medicine, Biology & Environmental Sciences etc. Maitri also serves as a gateway to one of the largest mountain chains in central Dronning Maud land, located south of Schirmacher. About 20,000 sq. km. area in Wohlthat, Orvin, and Muhlig Hoffmann Ranges have been geologically mapped by Indian scientists, making Maitri as their base Station. Several research programs initiated by India in the Schirmacher oasis and its environs have also contributed directly to global experiments mounted under the aegis of the Scientific Committee on Antarctic Research (SCAR). Maitri has also provided a platform for collaborative studies with some Antarctic Treaty nations i.e. Germany, Italy, France, Poland and the United States of America. It has also facilitated scientists from Malaysia, Columbia, Peru and Mauritius to work in Antarctica. A collaborative research is also being planned with Norway and AFOPS member countries.

Figure 3: Maitri Station at Schirmacher Oasis, East Antarctica

1.1.3 Scientific Studies in Antarctica

Ever since 1981, the Indian endeavors in the icy continent have continued uninterrupted and annual scientific expeditions to Antarctica have remained one of the high priority scientific activities of the country. Till date, twenty-six expeditions have been successfully launched. In addition to these, four special expeditions to the Southern Oceans and Antarctic waters have also been undertaken. These expeditions have provided an avenue for over 1600 scientists and logistics personnel from more than 60 national laboratories, universities, and research institutes to conduct experiments/studies in some of the frontier areas of polar sciences. The studies have contributed significantly to a better understanding of the state of the Antarctic environment in general and of the central Dronning Maud land in particular. Many of the scientific studies have continued uninterruptedly since 1985 and have produced important results and a substantial database

Salient highlights of the Indian scientific activity in Antarctica are as follows:

Earth Science

Indian geologists have systematically mapped about 20,000 sq km of the area in central Dronning Maud land on 1:50,000 scale. Three geological maps of Schirmacher Oasis, Wohlthat and Orvin Mountains (GSI, 1991,1999,2006) and a geomorphological map of Schirmacher Oasis (GSI, 2006) have been released so far. Monitoring of glacier snout and the continental ice margin, on a regular basis has revealed significant retreat of the ice margin in last two decades (Chaturvedi & Ravindra 2001).

A permanent GPS station at Maitri is contributing to understanding the inter-plate motion and crustal deformation between India and Antarctica (Ravikumar and Malaimani, 2000). The station has been tied up geodetically with other ITRF reference stations. The Seismological Observatory at Maitri is a part of the Global Seismological Network and contributes the data to USGS, ISC (UK) and AnSWeR. Absolute gravity measurements too have been initiated to address the crustal deformation studies in conjunction with GPS for complementary verification, determination of geoid, glacial rebound and determination of sea level rise.

Ice cores drilled from the continental ice, south of Maitri, have been analyzed to evaluate the temporal changes in environmental characteristics during past few centuries. Results show that temperatures at the beginning of this period were about 2^0 C cooler than today Nizampurkar et al., 2002). The ice core studies also indicate that the sulfate aerosol deposition is related to the volcanic eruption (Thamban et al, 2006). The nitrate profile reveals a systematic negative shift since mid 18^{th} century, suggesting a possible change in the zonal wind transport and an apparent solar modulation of the same.

Upper Atmosphere and Astronomy

Ozone profile by Laser heteorodyne and Radio spectrometer has shown a 3% to 68% depletion in ozone concentration in the height range of 13 to 40 km. Effect of planetary wave on dynamical behaviour of the polar vortex has also been established (Jain et al, 2004). Sunphotometer, UV related studies and optical aeronomical experiments have been conducted for monitoring auroral emission. Regular monitoring of the greenhouse gases such as CO_2, CH_4 and CO is also being done at Maitri. The results have shown that there is an increase of 1.3 ppm of CO_2, whereas CH_4 concentration is relatively stable with an average value of 1.699 ppm.

During the total solar eclipse over Antarctica on 23 November, 2003, shadow-band activity resulting from the illumination of the turbulent atmospheric boundary layer was studied. The results reveal that the average width of the bands is in the range of 20-50 cm with comparable separation between bands and the speed of their movement at about 5-10 meters per second (Bagare et al., 2005).

Meteorology

Micrometeorological data is recorded hourly and transmitted on real-time basis. Indian station Maitri is included in the WMO network of synoptic stations and has been assigned the index number 89514. Ozone monitoring has been continuing since 1987.

Geomagnetism

Interaction of sun's atmosphere with earth magnetic field and magnetic storms that are produced by the solar activity, affect the technical aspects of satellite operation and communication systems. Instruments like Riometer/Flux gate Magnetometer have been installed to observe the geospace interaction. Statistical occurrence of storms and sub storms with intensification of auroral electro jet currents is being studied. It has been established that during quiet time, the Indian station occupies a sub-auroral position (Rajaram et al., 2002). Since Antarctica is recording a greater drop in the Total Magnetic Field Intensity than the global average, and Maitri falls in a 'region of Reverse magnetic Flux', continuous monitoring of 'F' values as recorded here is of significance.

Environmental Science and Biology

Psycrophilic bacteria play an important role in sub zero activity in Antarctica. So far around 125 new species have been discovered from Antarctica of which India has contributed around 20 new species. (Shivaji et al., 1989; Reddy et al., 2002a,b, 2003 a,b,c,d). Two new species, *Arthobacter Gangotriensis* and *Planococcus Maitriensis*, are named after Indian station Dakshin Gangotri and Maitri respectively (Alam et al., 2003; Gupta et al., 2004).

1.2 Planned Scientific activities at the new base

The proposed research base is expected to cater to a myriad scientific activities in some of the frontier areas of atmospheric, earth, ocean, biology and environmental sciences. The close proximity of the base to the Australian, Chinese, Romanian and Russian stations would go a long way in fostering significant collaboration and co-operation in polar science.

1.2.1 Meteorological and atmospheric studies

Meteorological data acquisition shall be with real time data transmission capability to be used worldwide for various studies. A high resolution multi-parameter AWS shall be installed to acquire the data. Other atmospheric studies to be conducted are as follows:

- Aerosol Radiative Flux estimation using Sky Radiometer
- Aerosol size distribution using multi-channel sun-photometer for solar terrestrial effects and transportation of aerosols.
- Establishment of a geomagnetic observatory and installation of instruments like DFM, DIM, PPM.

1.2.2 Earth Science studies

The Prydz Bay is considered as a key in the India-Antarctica link during Gondwanaland, as the area of Prydz Bay of Antarctica and the Eastern Ghat Mobile belt of India once formed a contiguous landmass. Geologically, the area offers possibilities of detailed correlation between the rocks exposed all along the eastern coast of India (high grade granulite, charnockites, khondalites) with rocks of Prydz Bay area (Kanao et al., 1994, Rao et al. 1995, Yoshida et al., 1999, Brauo and Kriegsman, 2003, Ghosh et al 2004, Mishra et al 2006). Apart from this:

- Integrated geophysical–geological studies will help understanding India-East Antarctic rifted margins and its role in the crustal evolution during Grenvillian and Pan African events

- The study of Lambert Glacier, the fastest moving glacier in Antarctica, opens an exciting new vista in glaciological studies.
- The movement of the continental ice margins along the Ingrid Christensen coast as also the accumulation and ablation pattern of the snow on the coast will be monitored.
- Late Quaternary glaciations in the Vestfold and Larsemann Hills areas remain a topic of intense academic interest.
- The studies on the sediment records available in the lakes of the area will supplement the research pertaining to palaeoclimate by earlier workers (Gillieson et al., 1990; Hodgson 2001, 2005, 2006) beyond Holocene.
- The new research base offers an ideal location for yet another geomagnetic observatory in Antarctica, linking it with the Maitri research station as well as India. GPS will be operated for studies of crustal deformation and atmospheric sciences such as TEC, Scintillation and water Vapor content. Studies on the measurement of current drift of the Indian sub continent with respect to this region of Antarctica will complement similar studies being undertaken by the Indian scientists at Maitri. The GPS station operational at Maitri, which contributes to the International Earth Rotation Services (IERS) for the realization of ITRF 2000, will be linked to this GPS station as well as with the one existing at Davis, under the SCAR-GPS campaign.

1.2.3 Oceanographic studies

Physical chemical and biological oceanographic studies in the Indian Ocean sector of Southern Ocean will receive impetus. A long term and systematic approach regarding the time series observations of hydrographic parameters at different locations in the Prydz Bay area will be carried out to understand the quantity, causes and year to year variability of freshwater input in the Prydz Bay area.

1.2.4 Environmental studies

Supplementing the ongoing studies at the Maitri station to understand the impact of anthropogenic activities on the pristine Antarctic environment, similar studies would be initiated at the new site. Impact not only due to local activity but also due to land-based anthropogenic impact shall be studied, as Antarctic coast is becoming a sink for the aerosol deposition. Aerosol spectrometer, Aethalometer and Multistage Impactor shall be operated around the new site to collect long-term data. Study of particulate matter in water and sediment will provide useful tool to assess the environment.

Determination of other environmental indicators i.e. studies of fauna, their population trends and anthropogenic impacts on other biotic and abiotic factors on the coastal Antarctic ecosystem shall be carried out. These studies will thus generate a spatial spread of data in two widely separated coastal oasis of Antarctica.

1.2.5 Biological studies

Biological studies at the new site have potential to explore new vista in:

- Biodiversity study of sea-ice microbial community
- Conservation of terrestrial & aquatic biota (fungi, lichens, bryophytes, micro fauna like protozoans, nematodes, tardigrades), aerobic bacteria
- Monitoring of wild life population and behavioural studies

Even while using Antarctica as a platform for conducting scientific research, India has always recognized the importance of preserving the pristine nature of the continent, which modulates the intricate global climate processes. To uphold these commitments, India ratified the Protocol on Environmental Protection to the Antarctic Treaty in April 1998.

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2. DESCRIPTION AND NEED OF THE PROPOSED ACTIVITY

2.1 Need for the station

India through its sustained presence in Antarctica since 1981 has conducted scientific experiments, both at Dakshin Gangotri and Maitri in various disciplines. In view of the emerging trends in Antarctic research, India now intends to broaden the scope of its scientific research in Antarctica by complementing the existing studies from an additional location, so that the studies are regional and comprehensive rather than being site-specific.

Antarctica plays a significant role in global science by providing a platform for observing and measuring several natural parameters like global warming, nature of upper boundary layer, fluctuation in total magnetic field of earth, geological evolution of the crust and movement of crustal plates, fluctuation of continental ice margin etc. Understanding the monsoons and the effect of polar climatic regime in its generation, has been one of the most sought after objectives of climatic and meteorological research being undertaken in Antarctica by India, as it has direct implications on the predominantly agricultural based societal needs.

India has launched several programmes on microbiological diversity, physical oceanography and atmospheric research in the Indian Ocean sector, through regular cruises of its oceanographic research vessels (Vyas et al., 2003, 2004, Anil Kumar et al., 2005; Bhandari et al., 2005; D Souza et al, 2006; Luis et al., 2006; Mathur et al., 2006; Singh et al., 2006, etc.). Similar research in the Antarctic- Southern Ocean sectors of the Indian Ocean would be of interest to supplement and enrich the database.

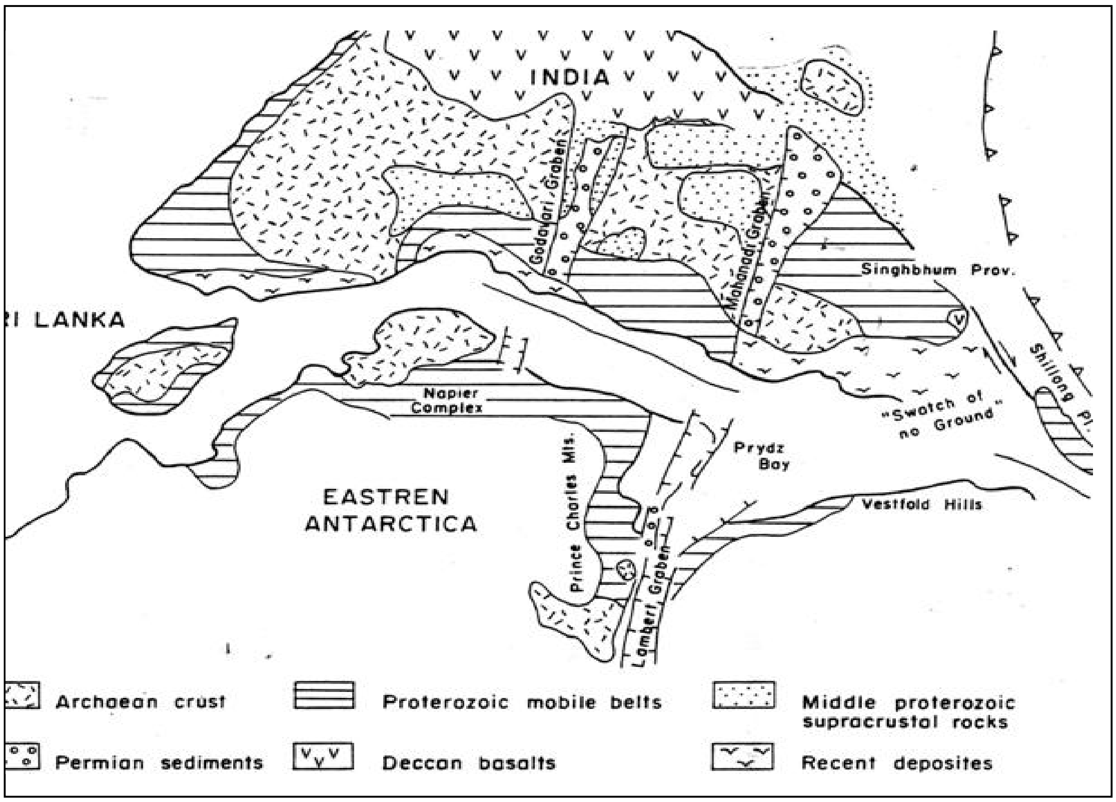
The need to have a location at the proposed site in Larsemann Hills is justified in view of the following scientific and logistic factors:

- The present Indian Antarctic station Maitri, is located in a sub auroral zone, while the proposed site at Larsemann Hills is located in auroral zone. The data set obtained from the two stations would be complementary to each other and would help in understanding the development and movement of longitudinal propagation of localized auroral current systems in a unique way.
- The magnetic field lines originating from Maitri pass over oceans and end up near Greenland in the ocean. There is no magnetic station under the footprint of this field line for conjugate area studies. On the other hand, the field lines originating from Larsemann Hills pass over Middle East and Europe (close to Hungary and Denmark). Both the countries have operational magnetic observatories and the combined data can be used for conjugate area studies.
- India is planning to launch its own polar synchronous satellite - OCEANSAT-2 with a payload of Ocean Color Monitor and Scatterometer followed by RISAT-1 in 2008 for monitoring global chlorophyll, winds and sea ice characteristics respectively. Earth station at Larsemann Hills (76^{o} E) will be extremely useful for having an extended coverage over the Indian Ocean sector of the Southern Oceans, as also the online transmission of data to archival centres in the mainland. The in-situ data collected over the oceans near Larsemann Hills will help in validating ocean circulation models being developed for Southern Ocean.

- The Mahanadi Graben located on the Eastern Ghat Mobile Belt of India exposes an entire sequence of rock types ranging in age from middle/late Proterozoic to Permian. A similar sequence is found to be present along the Lambert Graben. The correlation between the two distant locations with respect to lithology, structure, tectonics, P.T.t., and other geological constraints would help in fine-tuning the Gondwana fit (Figure 4). The significance of this region is best explained by Reading (2006) in the following lines;

"Although there is reasonable outcrop exposure around the Antarctic coastline, the mountain ranges surrounding the Lambert glacier are the only outcrop in the interior of East Antarctica and thus provide a window into understanding the assembly of Gondwana and earlier super continent".

Figure 4 : India-Gondwana Fit

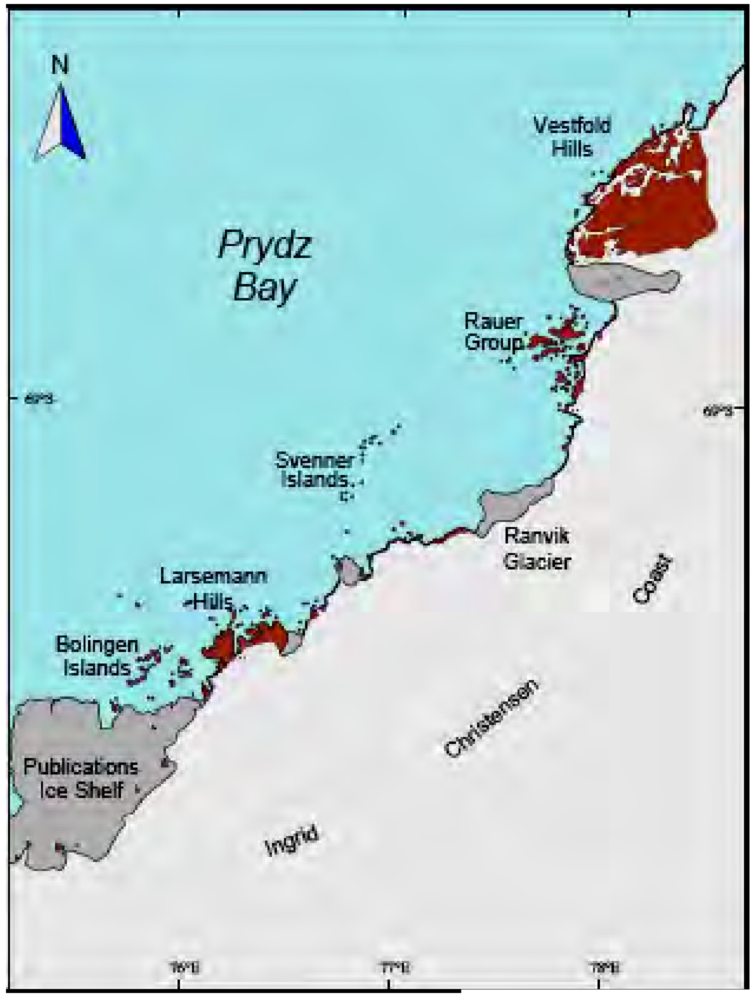


- There are very few locations available along the east Antarctic margin like Larsemann Hills that are free of ice shelf and easily accessible.

2.2 Location of site

The proposed location for new research base is at Larsemann Hills of Prydz Bay area. The Prydz Bay represents an embayment along the Eastern Antarctic margin, lying between the East Longitudes 66^0 and $79^{0.}$ The Amery Ice Shelf on the southwestern side and Ingrid Christensen Coast on the southeastern end define its limits. Isolated islands, promontories, peninsulas and nunataks occurring along the continental ice, describe the rocky terrain exposed in the area, which, from North-East to South-West, fall under Vestfold Hills, Rauer Group, Svenner Island, Larsemann Hills and Bolingen Islands respectively (Figure 5).

Figure 5 : Prydz Bay Area



Source AAD

The Larsemann Hills (69°20’S to 69°30’S Lat : 75°55’E to76°30’E Long), named after Mr. Larsemann Christensen, is an ice-free coastal oasis fringing the Prydz Bay and is located approximately midway between the eastern extremity of the Amery Ice Shelf and the southern boundary of the Vestfold Hills .

There are two main peninsulas on the two extremities of the Larsemann Hills, namely the Broknes and the Stornes Peninsulas (Figure 18). In between these two, there are number of islands of varying dimensions and some unnamed promontories. Westwards, the Clemence Fjord separates Broknes Peninsula from Stinear Peninsula and Fisher Island. The area north and westwards is marked by a number of islands, namely Harley, Easther, Breadloaf, Butler, Betts, McLeod, Jeason, Solomon and Sandercock Island. Geomorphology of the area has been described in detail by Gillieson et al.,(1990), Burges et al., (1994), Hodgeson et al., (2001, 06), Ravindra et al., (2004) and several others.

The area exposes Late Proterozoic rocks comprising gneisses with intrusive granite bodies (Stuwe et al, 1989; Beg, 2005). The physiographic disposition of rocks exhibits low rising strike ridges, lying between the heights of 65 m to 85 m above msl in general. However, the hills close to the continental ice rise to more than 105m. The highest elevation in Larsemann Hills is observed to be 153 m above msl in the Broknes peninsula. The hills are dissected by steep valleys. One such feature represented by the western margin of Thala Fjord, is a N-S running lineament (fault) that runs for a distance of about 5 km. The landscape is controlled by the lithology and geological structures, particularly joints and lineaments. Wind, snow/ice and chemical processes have been the main agencies responsible for the weathering and erosion.

The selected site (69°24’28.8”S: 76°11’14.7”E) is an unnamed pear shaped promontory, trending NE-SW that has its broader end towards sea (Figure 6). The northern and western slopes have a high gradient with the edge being exposed in the form of a steep cliff. The southern margin merges with Polar ice. The western part has ice upto 50 m thick at places and hence hills are inaccessible from this end. The area is fairly undulated, and encased by Thala fjord and Quilty bay, and remains ice-free during most of the months in year. Water is available in a big lake and five small lakes. The big lake (numbered as 37 by Gillieson et.al, 1990) holds water that is saline in characteristics. Smaller lakes, however, have been found suitable for drinking purpose. The site is accessible from open sea through a passage between McLeod and Sandercock Island. A suitable landing site at the northeastern corner of the promontory is an area of low gradient, where landing can be made by barges. With some effort, a flat surface can be carved out of the sloping rocky ground for off -loading cargo on to the land. The area being rocky, an approach road will be made from the landing site up to the proposed site of the station. The flat ground available at location is suitable for the construction of the base.

2.3 Scope of CEE

All the principal activities pertaining to the proposed base inclusive of design, transportation of men, material and machine during construction and operation have been considered in development of this report. The proposed scientific studies have also been taken into consideration, while formulating the CEE.

The CEE has been prepared in accordance with Annex I of the Protocol on Environmental Protection to the Antarctic Treaty (The Madrid Protocol 1991) and the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 4, XXVIII ATCM, 2005). Environmental monitoring during construction and operational phases will adhere to the Practical Guidelines for Developing and Designing Environmental Monitoring programmes in Antarctica (COMNAP, 2005), with regard to various aspects of pollution indicators.

2.4 Proposed facilities at the Station

The Station is being designed as an ergonomic entity in harmony with the local environment. It is proposed to build a self-contained thermally insulated double-storey structure on stilts. While the ground floor will house the general facilities like, storage, laboratories, general facilities etc., upper floor will be used for living accommodation, kitchen, lounge, offices, recreation facilities, medical room, etc. State-of-the-art communication facilities as well as laboratories will be established at the station. As the building is proposed to be constructed at around 50 m above msl, the structure will be visible while approaching the area from north. The designed life span of the station has been envisaged as 25 years. Footprints and different views of site location are shown in Figure 6 a to 6 e.

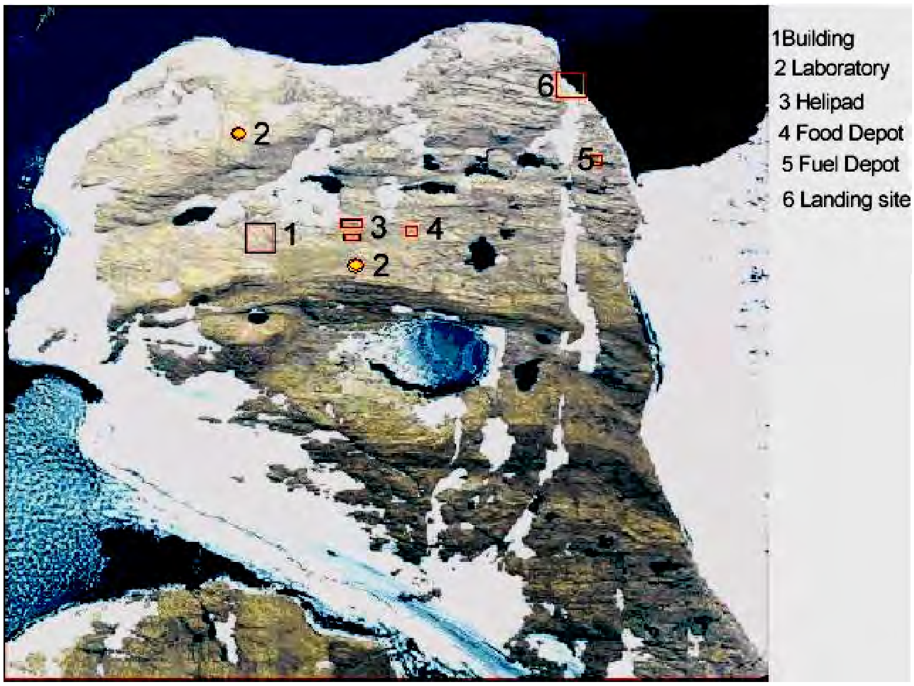
2.4.1 Living accommodation

The Station is being designed to accommodate 25 people during summer and 15 people during winter period *(Appendix 1)* with all the facilities to carry out routine as well as scientific work.

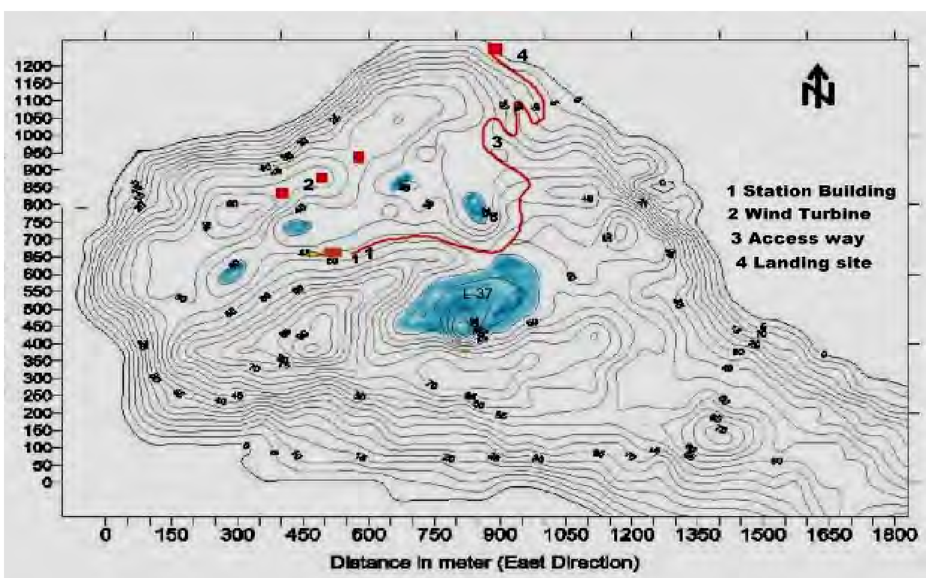
2.4.2 Laboratories

The base will have well-equipped laboratories on the ground floor which would cater to earth and biological sciences as well as environmental studies. Some laboratories such as meteorology, astronomy, geomagnetism and seismology would be located outside of the main station to avoid radio interference, manmade noise and other disturbances (Figure 6). An environmental monitoring laboratory would be among the first facilities to be established to monitor the environmental parameters.

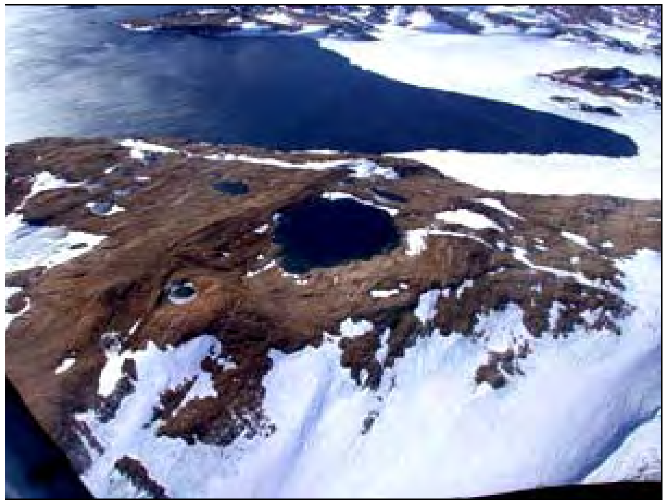
Figure 6: Layout plan of the station building and other infrastructure



(a)



(b)



(c)

(d)

(e)

2.4.3 The Medical facilities

The sick bay and medical room will be housed on the first floor and will have all the modern facilities including an Operation room. The facility will be designed as per the best practice guidelines for sterility and efficiency. Proper health care and safety measures will be enforced to minimize any risk.

2.4.4 The Kitchen and dining

The kitchen and the dining, both adjacent to each other and on the first floor, will be designed to foster the concept of group living in the harsh conditions of Antarctica. The lounge and auditorium will be multifunctional in scope providing facilities for group meetings, discussions and indoor recreation.

2.4.5 The Garage, workshop and Stores

It is proposed to provide these facilities on the ground floor, which would be easily accessible. This structure will comprise pre-fabricated modules with a stress on keeping the noise levels to the minimum.

2.4.6 Waste Management

A well designed wastewater treatment system and a comprehensive solid and liquid waste management system would be implemented with minimum waste generation at source. There will be an overall attempt to keep the environmental impact due to waste generation at minimum.

2.4.7 Water Management

Drinking water demands shall be fulfilled mainly by the small fresh water lakes, which get their recharge through snow accumulation. Recycled grey water will be used for supplementing the water requirements in toilets etc.

2.4.8 Energy Management

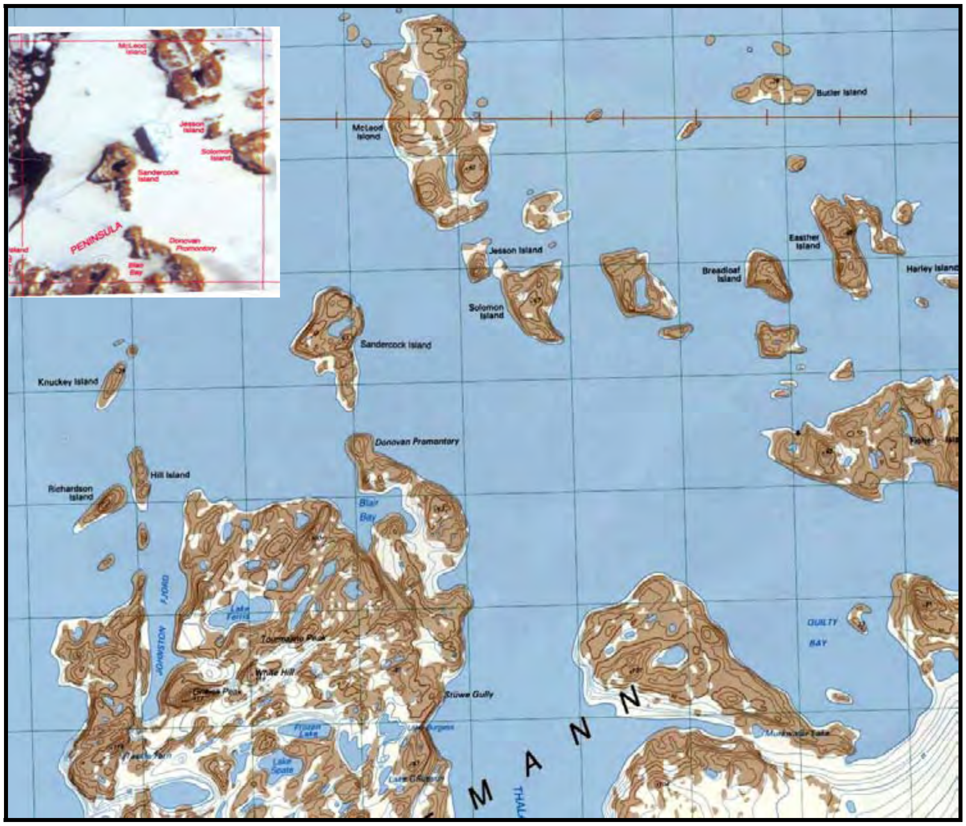
While the fuel based power generation system will remain the main source of energy the attempts will be made to supplement the power demand with alternate source like wind and solar energy. The heat generated from the generators will be utilized in heating the station using Combined Heat and Power concept. These provisions will reduce the environmental impact of the fossil fuel.

2.5 Shipping and logistics

2.5.1 Accessibility from the open ocean

The promontory is accessed through the gap between the McLeod and Sandercock Islands Figure 7). This area of the sea has been found to be open during early February 2004, 05 and 06 with presence of some isolated icebergs on the outer periphery. An isolated iceberg was found berthed between the McLeod and the Sandercock islands but comparison of imageries of past few years have shown that the said iceberg is firmly grounded and is getting destroyed (Inset Figure 7).

Figure 7 : Larsemann Hills and Surroundings



(Source AAD)

In Prydz Bay area, bathymetry data was available only upto McLeod Island in navigational charts. During late February 2006, preliminary multibeam swath bathymetric surveys *(Appendix 2 and 3*) were undertaken along a corridor from the grounded iceberg to the western face of the Larsemann promontory to define an approach channel for the ship. The NW-SE trending corridor from the grounded iceberg to the promontory measured about 6 km and had a width of about 2.5 km. Bathymetric data totaling 122 line km was collected along 22 survey lines within the corridor. The minimum depth recorded in the channel was 10 m and the maximum, 460 m.

2.5.2 Transportation and Movement

The men and material would be transported through an ice class ship. Two heavy–lift helicopters will also be used. The weight of the various components of the station will be modulated to conform with the lifting capacity so that transportation of container/modules will be possible by helicopter from ship to site. In addition, barge may also be used for movement of odd-size and heavy equipment/machinery. A Russian airstrip exists about 6 km away from the proposed site and this may also be used as an option to send men and material. The fuel will be transported using flexible pipes by pumping directly from the ship to the shore.

2.6 Construction of Station

The construction is proposed to be initiated in the austral summer of 2008 after getting the necessary approval of the CEP. It is planned to complete the construction activity during two austral summers, by using pre-fabricated structures/modules. A dedicated work force of 25-30 will operate from the ship. One Igloo hut, already placed at the site during 2004-05 will be supplemented by another hut this summer to act as emergency shelters.

Different stages of design development are scheduled as follows:

Basic requirement framework	*April-June 2006*
Expression of Interest	*August-September-2006*
Concept Proposal	*November 2006*
Selection of Architect	*Early December 2006*
Design Development	*May- 2007*
Construction	*Austral Summers of 2008 and 2009*

2.7 Installation of Wind Turbines and Solar Panels

It is proposed to supplement the energy demands through wind and solar energy. The wind turbines shall be installed near the station on the hills, while the solar panels will be placed over the walls and the roofs of the station.

2.8 Decommissioning of Station

The station is designed for total life span of 25 years. Every five years, strength of the station shall be assessed through inspection and material testing. Any strengthening or replacement of a particular block or a portion would be carried out without disturbing adjacent structure. The decommissioning of the station will depend upon the health of the structure and/or the completion of the objectives of the planned scientific activities after its envisaged life.

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3. STATION DESIGN

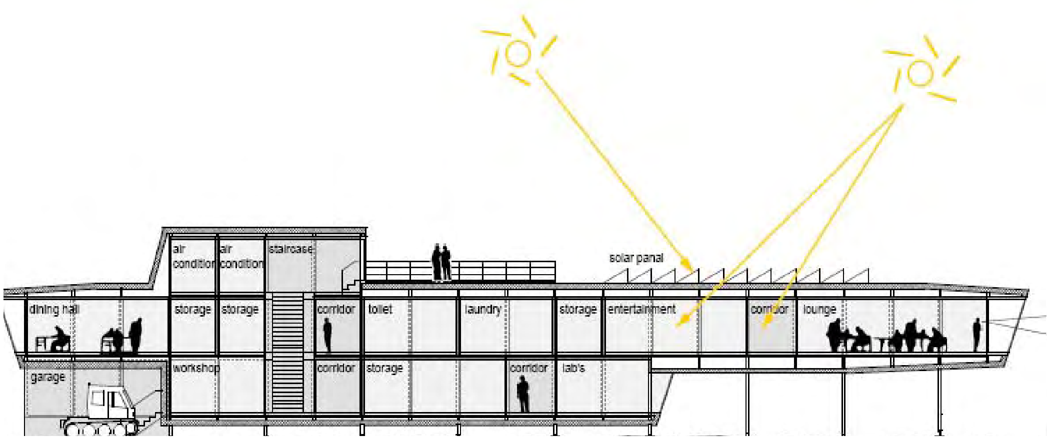
3.1 Station Description

The Station design has been drawn based upon logistic needs, operational demands, trouble free supply and maintenance of life supporting systems. Design and placement of the module is conceptualized to keep minimum movement of men and material in and around station, to reduce the footprint on the area.

An expert committee comprising specialists from School of Planning and Architecture, New Delhi, Central Building Research Institute, Roorkee, Structural Engineering Research Centre, Chennai, Mormugao Port Trust, Goa and a Civil Engineer with experience of building construction in Antarctica, selected the design offered by M/s IMS Ingenieurgesellschhaft mbH. This German company, selected out of the four short listed firm, was involved in general planning for the new German Antarctic research station Newmayer III at Ekstron iceshelf, west of Atka Bay. The recommended conceptual design (Figure 8) is environmental friendly and commensurate with the environmental Protocol vis a vis objectives and requirements of the base.

Figure 8 : Artist's Impression of Building

Perspective View



Sectional Elevation

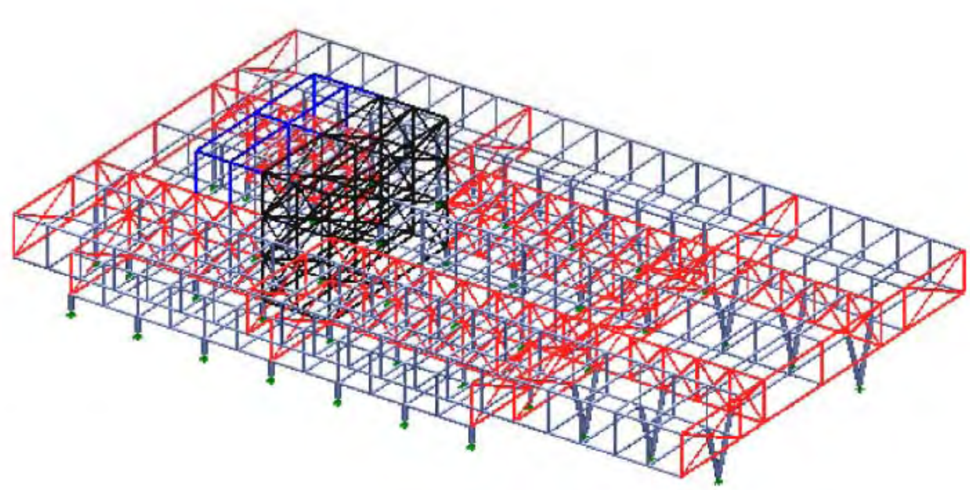
3.2 Structural Design

3.2.1 Base Foundation and Stability

The structure conceptualizes placing containers on a platform and uses their load carrying capacity and stability for load transfer. The containers will be fitted by standard fixing elements (stacking cones and bridge fittings), friction-locked together and will build a 3D-sheet type bearing system. The foundation platform shall be designed as an elevated girder grid construction which will be supported on columns (Figure 9).

The columns will be designed as vertical adjustable spindles. For the absorption of vibrations and the compensation of deformations it is envisaged to place the columns on elastomere bearings. The foundation of the building is designed to suit firm rock base. Considering the high wind loads on the building and the low dead weight of the structure, additional anchors will be arranged under the footings to avoid lifting off, of the columns from the ground.

Figure 9: Base, and Structure of the Building



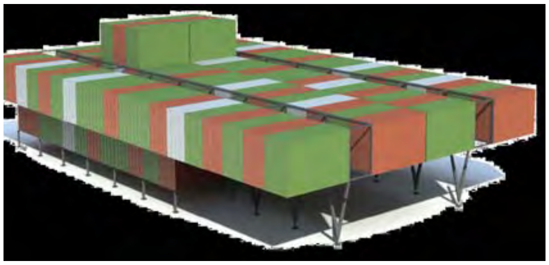
All steel members will be protected against corrosion by robust galvanizing. Since the columns will be exposed to snowdrift and thus to stronger abrasion, an additional coating will be applied on these higher strained members.

The structural elements of the platform will be prefabricated and assembled on site by friction grip screws. Welding on site is not planned. The elements of the platform structure will be fabricated from rolled steel sections of ordinary structural steel. Only for the elements exposed to higher loads and extreme weather conditions like the columns, steel with high viscosity at low temperature (ML- or NL-type) will be used.

3.2.2 Outer Shell

An additional exterior jacket (outer hull) will be erected around the containers. It will protect the internal space from wind, precipitation and irradiation. This exterior jacket forms the visible corpus of the station. The facade system is constructed of sandwich elements comprising a PUR-core between steel sheet covers. The panels will be of a special construction that combines the standards for cold stores and for façade systems (Figure 10). From the cold stores a special locking system for the splices will be used, so that they cannot loosen because of wind-inducted vibrations.

Figure 10 : Inner Base of Container and Outer Shell



Inner Base of Containers

Outer Shell

By providing a PUR-core, the elements will have a high shear resistance to withstand the wind forces, good temperature performance to withstand lower temperature upto -45^{0}C and to eliminate vibrations, which are higher than that of elements with a mineral-wool core. Due to corrosion protection provided by Al-Zn, the covering steel sheets will give a longer lifetime and a higher irradiation resistance than other materials, e. g. plastics and coatings. All the joints will be sealed against wind and snow by special gaskets and lockings.

3.2.3 Aerodynamic Stability

Since the site of the station represents a region of katabatic winds, following design criteria have been given due consideration:

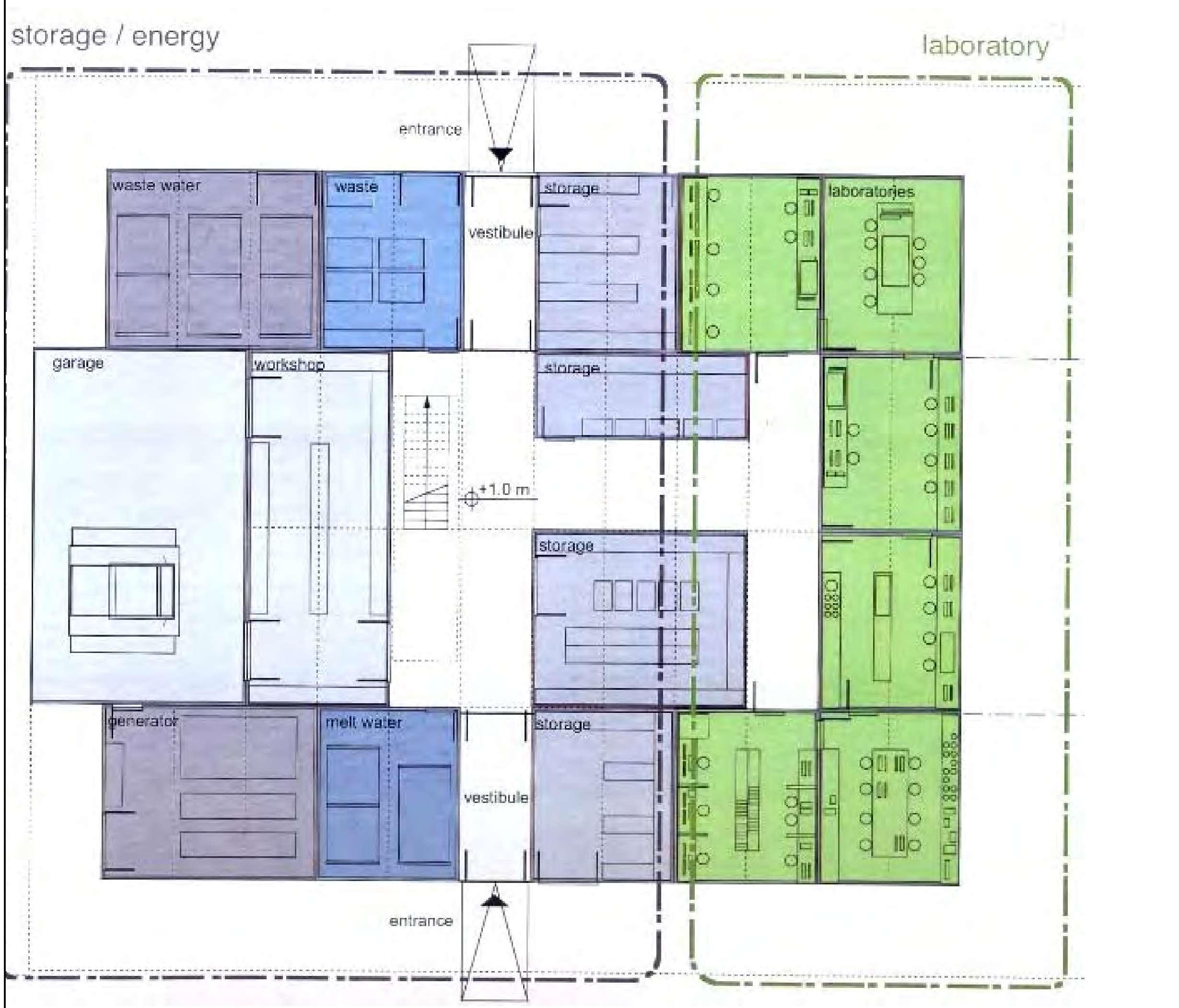
- Providing free passage for wind to pass above and under the structure
- Positioning the station in such a way so that winds pass the structure perpendicularly

The wind tunnel tests would be performed on the model of the station at Structural Engineering Research Centre (SERC), a reputed national laboratory under the Council and Scientific and Industrial Research (CSIR), by providing vital statistics on wind flow and wind pressure measurements.

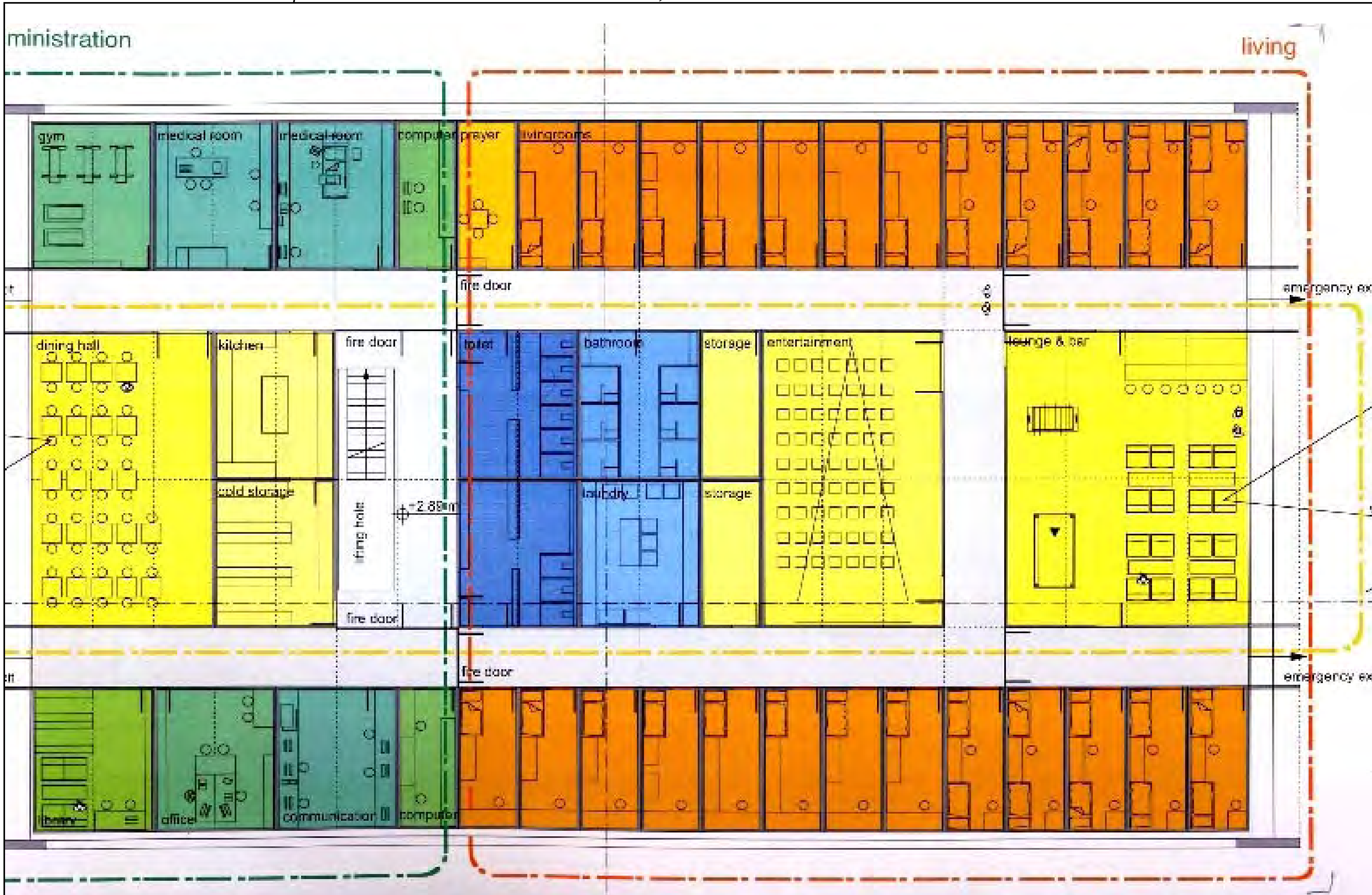
3.3 Room System

The rooms of the research station are designed to be built up in modular construction using standard containers (20’ long, 8’ wide and 9.5’ high). The advantage of this system is the ease of transport by truck or ship in India as also in Antarctica. The inner walls of the rooms shall be lined with plasterboards and will create a comfortable indoor environment. The inner layer would consist of mineral-wool for fire protection, thermal insulation and sound absorption The floors of the rooms will be built up with a mineral-wool filling and floor panels. Between the outer shell and the walls of the containers, a cavity will be arranged to prevent condensation effects. The windows in the outer shell are also included in the inner walls and will have provision for inner darkening by using roller shutter. For safety of the inmates, the outer windows will be fitted in locked version (Figure 11).

Figure 11 : Facility Distribution in Ground and Upper Floor



Plan of Ground Floor



Plan of Upper Floor

3.3.1 Fire Protection

Besides the technical fire protection like smoke detectors and alarm systems, the building design also considers the protection against fire. Each room will be a solitary fire compartment and rated at F30 (Fire resistance for 30 minutes). Rooms with higher fire loads or fire danger are rated F90. For the fire protection, groups of rooms will be separated by fire walls into fire areas. Emergency stairs shall be provided into safe areas for emergency evacuation and the escape routes will be marked. Safety lights and a smoke removal system will be provided. All materials of the stations will be fire proof or at least flame resistant.

3.3.2 Energy supply

The station shall be supplied with power (electrical energy) and heat (thermal energy) by CHP units (combined heat and power) only. CHP units will be designed to perform for the complete range from minimum to maximum energy demand. Low noise diesel engines, low voltage switch gear, heat distribution panel, hot water generation, one day diese
automatic fire extinguishing system will be installed in one plant room. Contact
established with national and international players for supplementing the energy requirements by alternate sources like wind and solar energy.

3.3.3 Heat Ventilation and Air Conditioning

Heating of the station shall be provided by thermal radiators (the utilization of waste heat allows to reduce the number of CHP units to two). In comparison with oil based radiator, this will help saving of diesel fuel and therefore the emissions to air. This will also reduce the impact on environment. In order to minimize heat loss, the heat piping will be installed inside the container casing.

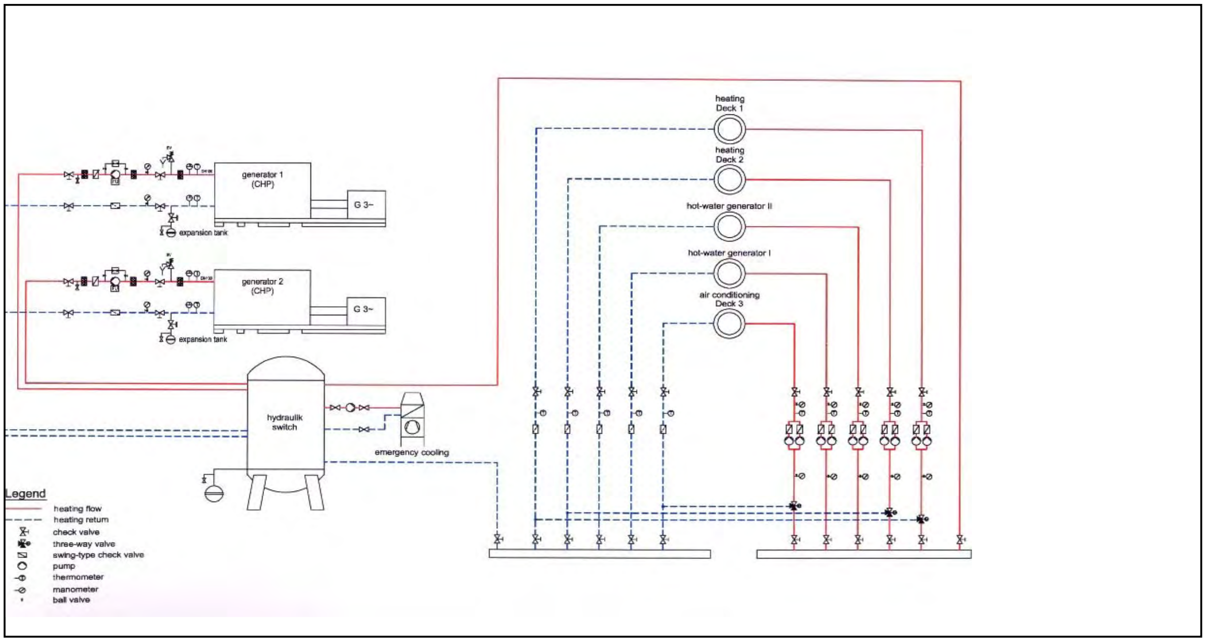
Conditioned air to the station will be supplied according to minimum rate of fresh air supply and heating of the station will be with thermal radiators. The operational expenses will be therefore minimized. Airflow regulators will allow optimum adaptation of air flow to the areas of demand. The two-stage heat recovery system will enable at stage two, the reutilization of humidity from the discharged air; hence operational expenses of the air conditioning system are very efficiently minimized. The “intelligent” integration of heat recovery system will allow reutilizing the heat of the discharged air optimally (Figure 12). Assembly of the ventilation & air conditioning plant room shall be on top of station (Deck 3). Sound attenuation will be applied not to produce noise to disturb the occupants and surroundings. Provision will be made to control ventilation from room and zones whenever required.

3.3.4 Water Supply and Wastewater Management

Water quality shall be improved by two stage filtration when it shall be sourced from lake. Fresh water demand will be reduced by reutilization of treated shower effluent. Corrosion proof material shall be used for complete water supply system.

Treatment of the shower effluent in the specific reactor will be used as water for toilets subsequently; hence water demand will be minimized by reutilization. Potable water demand will be supplemented by treated seawater. The design of the waste water system with biological clarification plant will be selected to maintain the desired effluent standards. Sanitary installations will be selected according to demand and use. Installation of wastewater piping inside the thermal insulation casing will be frost proof.

Figure 12 : Proposed HVAC System

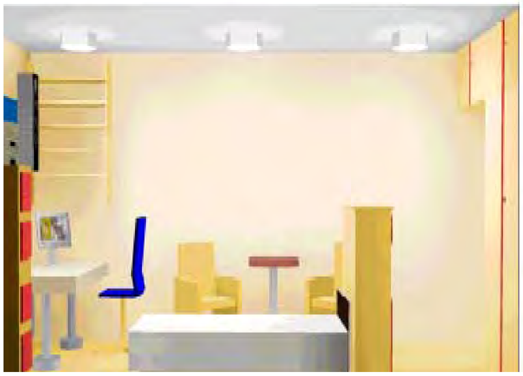


3.3.5 Lighting

Lighting fixtures will be equipped with energy saving technology. Incandescent lamps with "warm" light temperature will be installed in comfort zones. At other places compact fluorescent light or fluorescent light with electronic ballast shall be fixed (Figure 13). All lamps shall be installed as per requirement of light and temperature in the rooms. Living and common rooms will be fitted with "warm white" light (3,000 K); offices, laboratories and technical rooms with "neutral white" light (4,000 K). Areas with a brightness of 2,000 Lx or more can be equipped with "bio lamps" (6,500 K); these provide light which is largely same as natural sunlight. A light calculation will be executed for each area in order to provide optimum adequacy in illumination. For the selection of lighting fixtures, glareless and easy handling lamps will be considered. The lighting installation will provide possibility to adapt the illumination depending upon seasons.

Figure 13 : Artist's Impression of Lighting Arrangement in Rooms

Laboratory

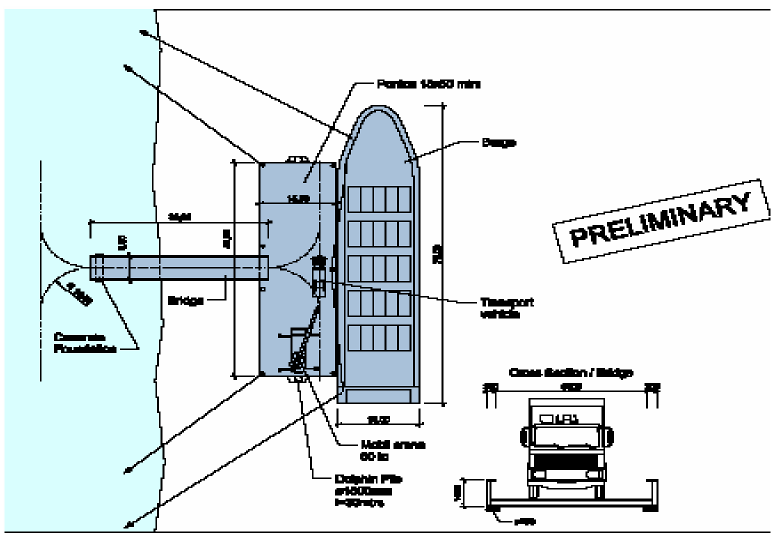


Living Room

3.4 Shipping and Transportation

The MI-8 helicopters or better alternatives that have carrying capacity of 4000 kg or more will be used to shift the containers from ship to the site. The container modules may or may not be fully equipped, depending upon the load carrying capacity of the helicopter. Equipping of modules will be effected in India, so that required changes if any can be made before loading these on the ship. Supply of material to station from a boat landing may also be considered. A vehicle access road shall be constructed from landing site to station. The pontoon of the boat landing shall be fixed at two dolphin–piles (Figure 14). The access between land and pontoon will be made by a movable bridge to compensate the tidal range. For unloading from the barges, mobile cranes may be used.

Figure 14 : Artist's Impression of Landing Site



3.5 Emission abatement in Station Design

Station design is prepared meeting the provisions of Environmental Protocol. Prefabrication of the material will reduce the activity during transportation and at the construction site and ultimately the noise and air emissions shall be reduced. Optimization of the cable and piping length will reduce raw material utilization, maintenance requirement and more manpower. Use of eco-friendly material with high insulation will have control over heat loss from the building so it will save extra energy requirement. Introduction of CHP will help to reduce the fossil fuel requirement for station heating.

Water conservation in terms of optimization and reutilization will reduce the water requirement and thus energy demand required to collect, transport and treat the water and wastewater. This shall be achieved by using optimized spray shower, waterless urinals and recycling of gray water after treatment for flushing into toilet

Energy system is designed to implement electrical energy produced from solar and wind power thus having less dependency upon fossil fuel based generators. At all the places according to light calculation, CFL will replace incandescent lamps thus minimizing electrical requirement and giving better illumination.

3.6 Decommissioning

The decommissioning of the building can be executed similar to the erection by unlocking the fixing elements and lifting off the containers. For the decommissioning and removal of the boat landing only the dolphin piles shall be needed to be removed. Provisions are made in design not to produce waste material at site. All the building modules can completely be removed and transported back to India after decommissioning.

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4. ALTERNATIVES TO PROPOSED ACTIVITY

A review of the Indian Antarctic Programme was undertaken by an Expert Committee (Rao, 1996), which recommended broadening of India's scientific data base in Antarctica for having a regional spread of the data rather than a localized one. A Task Force was, therefore, constituted to go into the details and recommend a suitable site after considering all the pros and cons. This Task Force undertook reconnaissance traverses all along the eastern coast of Antarctica from India Bay at 11° E. longitude to 78°E longitude in Prydz Bay, to examine all possible alternatives suiting the scientific and logistic requirements set for the future station.

4.1 Alternative Locations at Regional Level

Three alternatives were suggested in the Review Report, mentioned above, based on the scrutiny of published literature and feedback from different Indian and international expeditions to Antarctica. These were:

a) Antarctic Peninsula,

b) Filchner Ice shelf

c) Amery Ice shelf – Prydz Bay area

4.1.1 Antarctic Peninsula

Antarctic Peninsula is the most crowded place in Antarctica, so far as the stations of different nations and the visits of the tourists to the icy continent are concerned. The area is also very sensitive to the global warming as has been demonstrated by the international studies, which have shown that the Peninsula has warmed by 2° C since 1950 (Cook et al., 2005).

4.1.2 Filchner Ice Shelf

The Filchner Ice Shelf poses serious logistic constraints in maintaining a research station as the sea ice condition in this area are very tough. The Weddell Sea expedition by India in 1989-90 had brought to light the unpredictable ice conditions in this area.

4.1.3 Amery Ice shelf – Prydz Bay area

Against the above backdrop, the Task Force comprising experts in domains of science and logistics explored the Amery Ice shelf -Prydz Bay region of East Antarctica during February 2004 and examined the area between 66^0 E and 78^0 E Longitude in detail. After extensive traverses in the Vestfold Hills, Rauer Group of islands, Larsemann Hills and Bolingen islands, apart from the area along the Mawson Coast, the Task Force recommended a rocky promontory between Quilty Bay and Thala Fjord in the central part of the Larsemann Hills, bound by latitudes $69^0 24'$S and $69^0 25'$ S and longitudes $76^0 10'$E and $76^0$14'E, as the most suitable site for the new Indian base.

4.2 Alternate Sites examined within Prydz Bay

4.2.1 Vestfold Hills

Task Force took extensive traverses in Vestfold Hills, Rauer Group of islands, Larsemann Hills and Bolingen islands. While the Vestfold Hills, supporting the Australian Station Davis, was found to be an ideal location, it was observed that the approach to this low lying rocky terrain supported a number of rookeries and colonies of giant Antarctic and snow petrels, molting sites of seals etc. The depth to the bedrock in the open waters was generally shallow, as indicated by the grounded icebergs, north of the Long Peninsula. The area of ASPA 143 on the Marine Plains and ASPA 167 on Hawker Island on one side and the existing station Davis in the central parts does not leave much choice for any additional infrastructure.

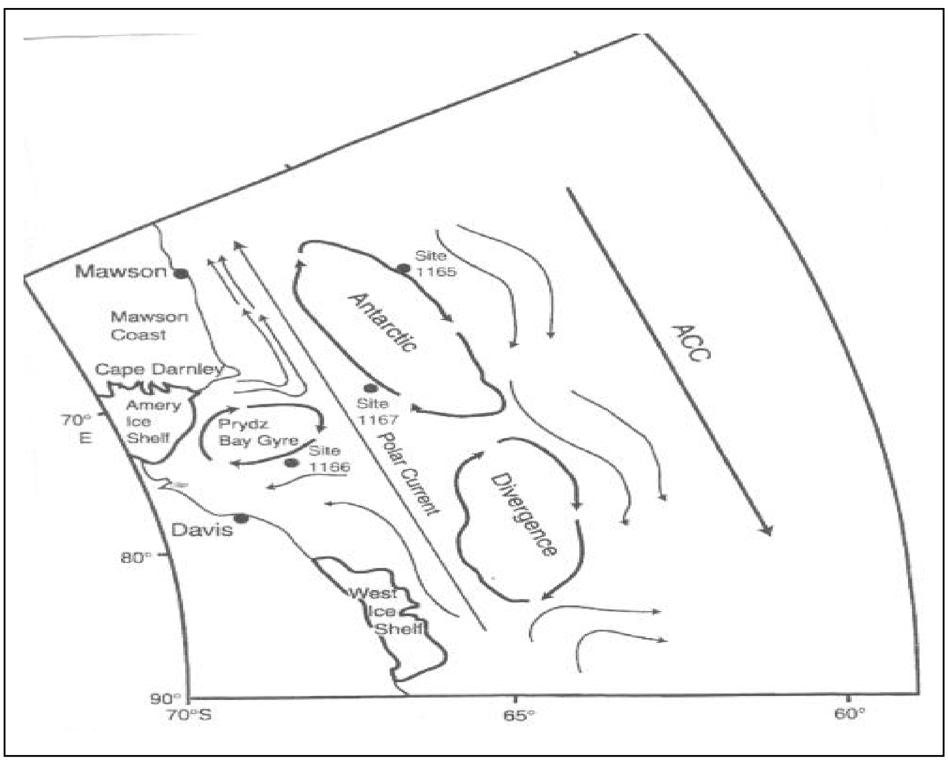
4.2.2 Rauer Group of islands

The Rauer Group of islands was found to comprise a number of closely spaced islands of limited aerial extent. The number of fresh water lakes as the source of potable water and flat land essential for construction purposes, was limited. The Task Force landed on five sites in the Rauer Group and measured depth, temperature and conductivity of lake water at two sites. The sites visited include:

- Filla Island (68048’20” S Lat & 77049’15” E Long)
- Hop Island (68049’20” S Lat & 77041’30” E Long)
- Varyag Island (68051’00” S Lat & 77047’30” E Long)
- Torckler Island (68053’30”S Lat & 770 50’ 00 E Long) and
- Macey Peninsula (68055’12”S Lat & 77055’ 30” E long)

The CTD measurements in one of the pro-glacial lake in Macey Peninsula indicated depth of the melt water lake to be 12 m. The water being fed by a glacier was of good potable quality. The two other lakes examined in the Filla Island were of shallow depth and contained brackish water. The Varyag, Hyslop, Lokot and Torckler Islands, located in the central and southern parts, have a difficult approach from the sea due to presence of a number of isolated islands blocking the passage as well as the cluster of icebergs brought together by westerly currents (Figure 15).

Figure 15 : Ocean currents in the Prydz Bay Area



Rauer Group is a rare area of wild life concentration. The islands support breeding grounds for Snow, Cape, Antarctic and Southern Giant petrels as well as Southern Fulmar. There are several rookeries of Adelie penguins and haul-out area of Weddell Seals spread over in the area. The northern islands (Lookout, Slon and Filla Islands) are known for the concentration of Weddell Seals. The central parts of Filla island shelter snow petrels. The western ends of this island, as also the Buchan Island north of it, are the sites of Adelie penguins' rookeries. The Hop Island, in the western end, is another area of concentration of wildlife. One of the biggest penguin rookeries of this region is located here (Figure 16). Restrictions on flying operations are in vogue in most of the area in Rauer Group of islands.

Figure 16 : Penguin Rookery at Rauer Group Island

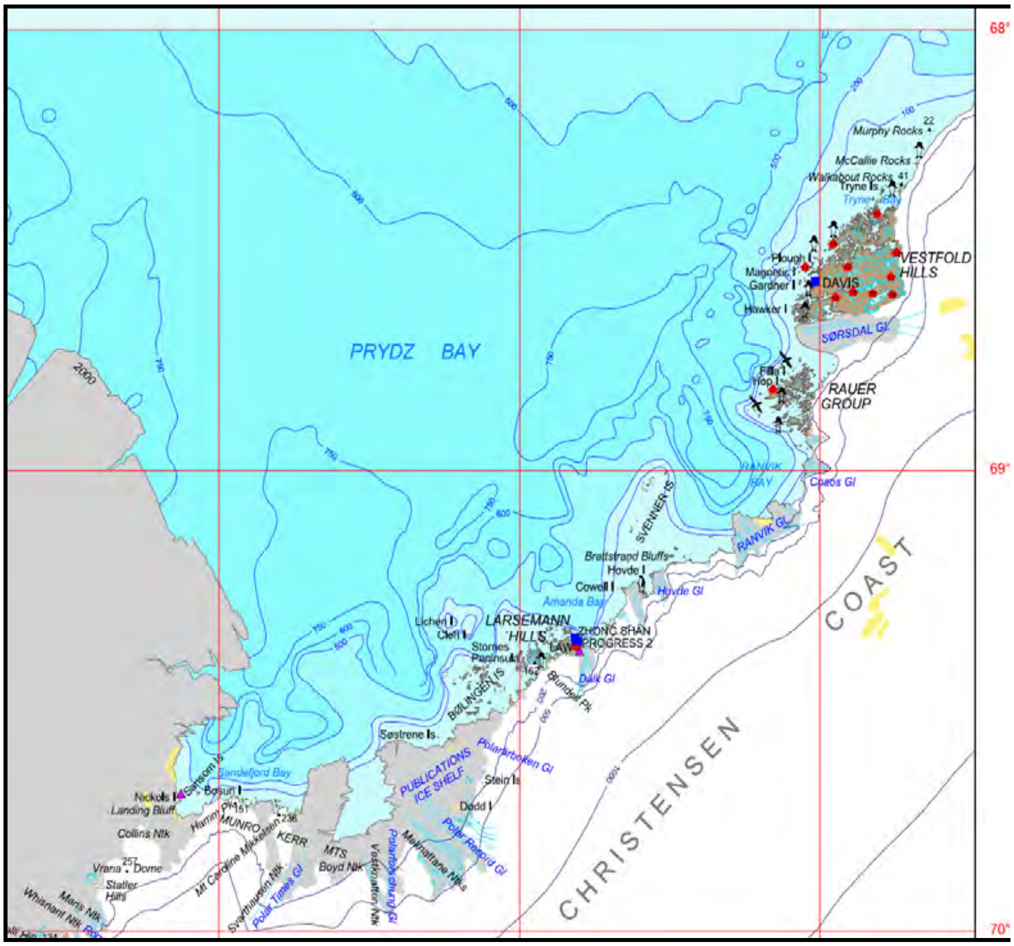
There are no Antarctic stations located in this area. However, Australian Antarctic Division is managing two "Refuge Huts", (an Igloo and a Googol) at Hop Island for monitoring the breeding and behavioral pattern of penguins. The Task Force did not recommend this site so as not to disturb the intrinsic wild life values of the area (Ravindra et al., 2004).

4.2.3 Area between the Bolingen and Svenner Islands (Larsemann Hills):

The area between Bolingen and the Svenner islands (Figure 17) bounded by the Polar Record Glacier, off the Publication Ice shelf on one side and the Brattstrand Bluffs on the other side, was found to encompass many ice free peninsulas and Islands. Within the limits of this region, the Task Force focused its attention on Larsemann Hills.

The Larsemann Hills (69^{o}20'S to 69^{o}30'S Lat ; 75^{o}55'E to76^{o}30'E Long) at Prydz Bay is an ice-free oasis on the Ingrid Christensen Coast, Princess Elizabeth Land, located approximately midway between the eastern extremity of the Amery Ice Shelf and the southern boundary of the Vestfold Hills. At 50km^2, it is the second largest of four major ice-free oases found along East Antarctica's 5000 km coastline (Hodgson, et al. 2006). The region includes two main peninsulas, the western, named Stornes and the eastern named Broknes. In between these two peninsulas, there are number of islands of varying dimensions. Four Antarctic stations viz. the Progress I & Progress II (Russia), Law- Racovita (Romania) and Zhongshan (China) are located along the edge of the Broknes peninsula. A cluster of icebergs and some islands such as Striped, Lovering and Manning Islands mark the northern boundary of the Broknes Peninsula. The westerly currents break the fast ice during early summer facilitating the entry of the vessels quite close to the stations. Westwards, the Clemence Fjord separates Broknes Peninsula from Stinear Peninsula and Fisher Island. The area north and westwards is marked by a number of islands, namely Harley, Easther, Breadloaf, Butler, Betts, McLeod, Jeason, Solomon and Sandercock Island.

Figure 17 : Location of Bolingen and Svenner Islands, Rauer Group and Vestfold Hills



Source: AAD

In the Larsemann Hills, a promontory located between Quilty Bay and Thala Fjord, was found to be the most suitable site for the Indian base. The promontory has a number of fresh water lakes with sufficient depth that can serve as the source for drinking water. The approach from the sea in February opens and ships could come quite close to the landing site, where after the barges could be put into operation. The area is located in the central part of Larsemann Hills and is about 10-km crow fly distance from existing Antarctic stations of Australia-Romania, China and Russia.

The pear shaped promontory where the station is to be built has its broader end towards sea, trending NE-SW. The northern and western slopes have a high gradient with the edge being exposed in the form of a steep cliff. The southern margin separates Polar ice margin and the hills thereupon by a narrow bay. This part has ice up to 50 m thick at places and hence not suitable for approaching the hills. This area is fairly undulated and encased within Thala Fjord and Quilty bay which remains ice-free in most of the months in a year. Water is available in form of a big lake and five small lakes. The big lake holds water with saline characteristics, however small lakes were found suitable for drinking purpose. It is found possible to access this place through sea from NNE part of the Promontory. The advantages of the site have been mentioned in Chapter 2.

4.3 Alternative Locations in Larsemann Hills

- The alternates sites examined in the Larsemann Hills include:
- Tonagh Promontory at the western edge of Larsemann Hills
- Area adjoining Lake Ferris and northern margins of Stornes Peninsula
- Area west of Johnston Fjord
- Donovan Promontory
- Fisher Island
- Area north of Murkwater Lake, on the Promontory between Quilty Bay and Thala Fjord

Tonagh Promontory: A promontory located on the western edge of Larsemann Hill exposes a flat terrain rising approximately 40m above sea level. A landing was made at $69^0$26’00.6” S. Latitude and $75^0$59’37.8” E. Longitude. A chain of small islands northwards was found to block the entry to this promontory. A number of grounded icebergs were found within the fast ice, west of the hills, indicating shallow depth to bedrock. The area is devoid of a source of fresh water and hence was not considered suitable for habitation.

Lake Ferris and northern margin of Stornes Peninsula: Lake Ferris and the area adjoining to it is located at the northern most margin of Stornes Peninsula ($69^0$24’S Latitude and $76^0$08.5’E Longitude) and can be approached from the sea. Low lying, beach landing is available. There are two interconnected lakes fed by snowmelt but no permanent source of recharge like a feeder channel from a glacier. Most of the lakes are of shallow depths and were found in the frozen condition. The area is extremely undulating.

Profuse growth of algae and moss was observed on the exposed rock surface. Fast ice could still be seen in the adjoining area in sea at the time of visit i.e. middle of February. Lots of seals were found molting on this ice. The occurrence of fossiliferous marine Pliocene sediments about 4 Ma old in this peninsula, makes this area of geological significance that requires preservation (Quilty et al., 1990a,b, 1993). Rare aluminum borosilicate- boralsilite described in 1998 from this area is known from only one other locality world wide (WP8, 2006). It was thought best to leave the area undisturbed for the reasons mentioned above.

Johnston Fjord: The location at $69^0$24’47.1” S. Latitude & $76^0$03’48.4” E Longitude at the hills east of Johnston Fjord is marked by the presence of a very prominent lineament running N-S. The lineament can be traced from west of Malachite Lake to west of Tumbledown Hill and further in the northerly direction up to Hill Island. There are two lakes in the immediate vicinity of the site but both are shallow with moderate to high salinity. The approach from the north and east is blocked by a number of islands. This area was not found suitable for the purpose of supporting a station.

Donovan Promontory: This promontory at the eastern extremity of Stornes Peninsula also exhibits a prominent N-S trending lineament, parallel to the one described above (Johnston Fjord). The area exposes number of glacial lakes, viz. Lake Gillieson, Lake Burgess and channels like Stuwe Gully etc. A landing was made at $69^0$24.7’ S. Latitude & $76^0$08.5’E

Longitude. The area was found to be rugged and lacking suitable topographic flat for construction activity. Though there are a number of lakes in the area, they are very small and shallow in depth. The sheltered Bay (Blair) is too narrow with steep cliffs on the hill side. The topography and general lay out of the area do not justify locating a station on this site.

Fisher Island: Separated from the Broknes and Stornes Peninsulas by Clemence and Thala Fjords respectively, the Fisher Island is a bow shaped island situated very close to the continental ice. It is one of the biggest islands in terms of geographical area. It's approach from the north is blocked by a group of small islands but the western margin can be approached from McLeod Island. Physiographically, the western part has high relief with highest peak at 117m. In comparison, the eastern part exhibits moderate relief and open stretches. The location at $69^0$23'32"S Latitude & $76^0$13'23.4" E Longitude offers a near flat ground very close to fast ice for landing purposes. Australia maintains an astronomical station at this site. There are six lakes in the eastern parts but none has substantial depth or area. Fresh water bodies of limited depth and extent are present.

The Island is not connected to the continental ice of the Antarctica as a narrow stretch of open sea separates it from Stinear Peninsula.

4.3.1 Broknes Peninsula

This area is ice free and undulatory in general, except the north eastern part where three stations are already existing namely Law- Racovita, Progress II and Zhongshan. Few lakes are available to cater to the routine water demands of the existing stations. There is a general scarcity of the potable water. Water in most of the lakes has high salinity. Ships providing supply to stations are usually anchored 5 nm. away, from the coast because access to the eastern shore of Broknes by small boat or barge is difficult (and sometimes impossible) due to ice debris that cover hundreds of metres off shore, blown by the prevailing north-easterly winds. Sea ice conditions are highly variable. Helicopters are therefore the only reliable means by which persons and supplies can be transported ashore quickly.

The positioning of the new Indian station in this area was not found sustainable on following grounds:

1. There are already three stations existing within close distance to one another,

2. Resources in respect of drinking water are scarce,

3. Regular scientific observations on meteorology, magnetism, atmospheric conditions are being carried out by the three stations. Setting up any additional Observatory in the area will result in interference of the output.

4. The area south of Seal Cove in the Broknes Peninsula is rugged and does not provide an easy access to the ship for off loading the cargo.

4.4 Alternative transport to the Station

The essential men and materials, as far as possible shall be transferred through helicopters from the ship. This may produce some noise pollution due to frequent flying of helicopters to the site but as there are no penguin rockeries or Antarctic bird colonies along the proposed corridor of flight operation, the impact on the wild life is expected to be negligible. The barges may be put in operation once a facility to offload the cargo on to a platform near the landing site is finalized.

A few other alternatives to access the station site were also assessed. These are:

- Transporting of all the men and material from Hobart/ Cape Town to the air strip located near the site by using air operators network of either Australian or DROMLAN. From here the material may be towed by Piston

Bully over the ice and then by ATV/Dozer to the site. Difficulty in this option will arise due to the undulated nature of terrain and the movement of the material over it. Other disadvantages of this option are that all the heavy materials will have to be airlifted and the uncertainity about the flight schedules due to weather uncertainties would continue to haunt. High cost of operation is also one of the negative points in this option.

- Sharing the ship with other stations located in this region for logistic purposes, to encourage minimum environmental impact. This option will be explored once the major shipment of construction material is over.

4.5 Alternative of not proceeding with the activity

The alternative of not proceeding with the activity has been given due thought during the planning phase. It was considered whether the proposed research could be carried out from existing stations in the Larsemann Hills or any other station in the region. However, the option did not find favor because of not meeting the national aspirations of having a station located favorably to supplement the data collection in entire Indian Ocean sector between India and Antarctica. While the area between the equatorial waters of the Indian Ocean is adequately covered by data buoys and satellites, the new site would cover the area of southern Indian Ocean and the gap area located in the Southern Ocean and Antarctic sector of the Indian Ocean by having an earth Station in line with the OCEANSAT II satellite of India for efficient data transfer.

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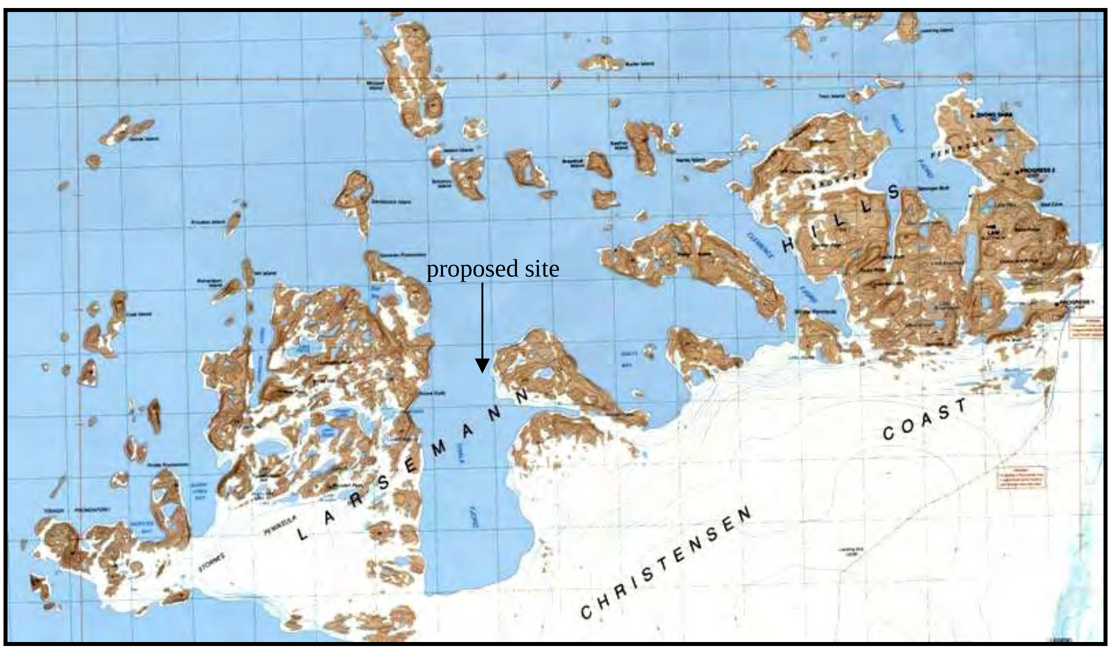
5. INITIAL ENVIRONMENTAL REFERENCE

5.1 Location

The Larsemann Hills (69°20'S to 69°30'S Lat: 75°55'E to76°30'E Long), an ice-free area of approximately 50 km^2, is located on the Ingrid Christensen Coast of Princess Elizabeth Land in East Antarctica   To the northeast of the hills are the Rauer Islands and the Vestfold Hills and to the west-southwest are the Bolingen Islands and the Amery ice shelf. The area was not discovered until 1935 when Captain Klarius Mikkelsen, led an expedition for the Norwegian whaling magnate, Lars Christensen. Subsequently Australian National Antarctic Research Expedition (ANARE) led by Dr. Phillip G. Law landed in the area in March 1954 (Burgess et al., 1994).

Four research stations namely the Progress I & Progress II (Russia), Law- Racovita (Australia-Romania) and Zhongshan (China) are located on the Larsemann Hills. The westerly oceanic currents break the fast ice during early summer facilitating the entry of the vessels quite close to these stations. The Indian Antarctic base is proposed to be located on an ice-free rocky area, situated between Quilty Bay on the east and Thala Fjord on the west (Figure 18).

Figure 18 : Larsemann Hills



(Source: AAD)

5.2 Geology

5.2.1 Geology of the Larsemann Hills

The local coastline has many indentations with fjords forming deep inlets. The highest point in the promontory where the station is being proposed is around 105 metres above msl. Geology of the area has been established by the detailed work of Sheraton and Collerson

(1983); Stuwe et al.(1989); Carson et. al. (1995); Zhao et al. (1995); Wang and Zhao (1997); Reading (2006) etc. The area is dominated by paragneisses which are more aluminous than similar rocks of the Rauer Group. Magnetotelluric deep sounding study in the region of Zhongshan station has established that the lithospheric thickness of Larsemann Hills is 140 km, and that the crustal high conductivity layer is situated at 22 km (Kong et al., 1994). The detailed bibliography concerning Larsemann Hills is available in the Working Paper No 8 submitted at XXIX ATCM, Edinburgh.

5.2.2 Geology at the Proposed Station Site

The proposed station site predominately exposes gneisses trending NE-SW and at low angles ranging 30^o to 45^o towards SE in the northern and northwestern part and near vertical in the southern and southeastern parts. On the basis of mineralogical assemblages and mode of occurrence of garnets, three distinct gneissic litho-units and a granitic body are identified (Beg, 2005).

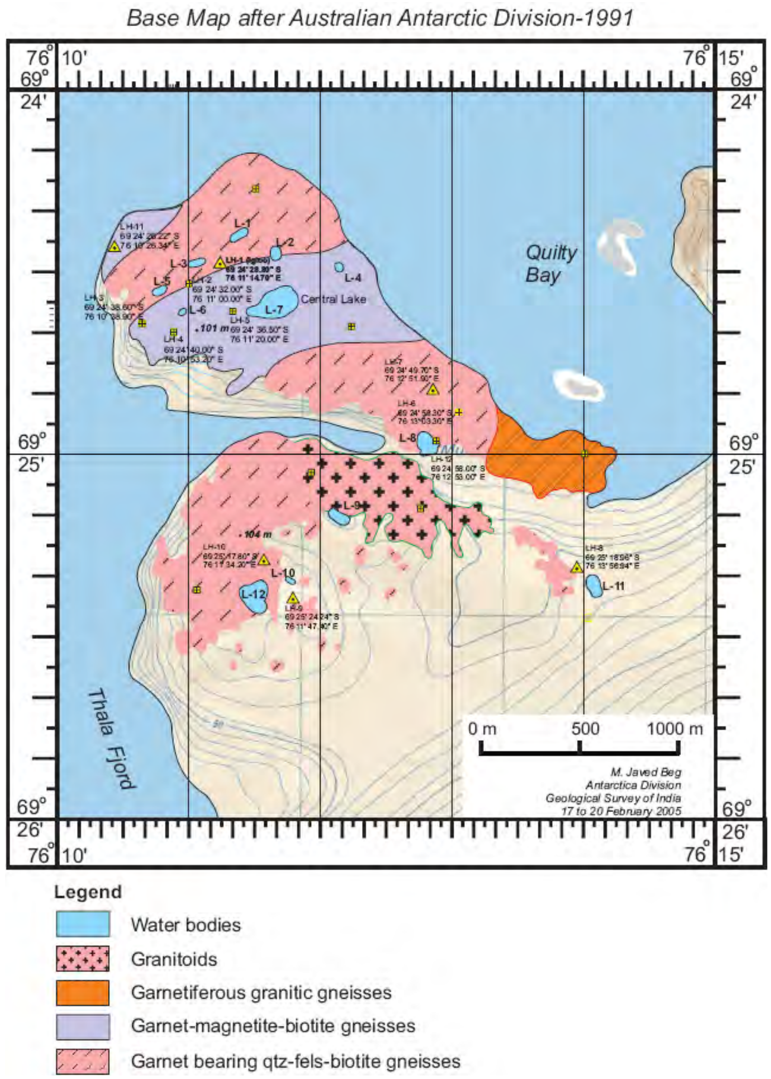
Granitoids: Exposed south-east of the intersection of 69^o 25’ S & 76^o 12’ E and north-east of Lake L-9 (Figure 19), the granitoids are medium to coarse grained with alkali feldspar as porphyroclasts. These granitoids are traversed by thin aplitic veins.

Garnetiferous granitic gneisses: Exposed in the eastern part of the area, the gneisses are composed of quartz, pink-feldspars and very fine crystals of garnet, with biotites defining the foliation planes sympathetic to the general trend of NE-SW. The primary foliations are masked by horizontal to sub-horizontal tensional fractures almost confirming to the topography. Sheeting effects are commonly seen in granites due to the release of superincumbent load. In the extreme east of the exposure, close to polar ice cap, a few enclaves of pink granites are also seen.

Garnet-magnetite-biotite gneisses: Trending NE-SW, 30 to 45 degrees due SE, this unit is exposed around the central lake (L-7), and extends up to lake L2 in the northwest and up to about 250 m southeast from the edge of the Lake L-7 (Figure 19). A small patch of the same unit is exposed at the northwestern extremity of the peninsula. The quartz-magnetite-biotite gneiss occupying the higher grounds is marked by the presence of small magnetite crystals evenly distributed throughout. At places small sized garnets are found in pockets. These gneisses are traversed by pegmatite, and aplitic veins have partly digested enclaves of older gneisses.

Garnet bearing quartz-feldspar-biotite gneisses: Most predominant litho-unit of the area, this unit is exposed in the northwestern part of the peninsula and north of lakes L-8 & L-12 (Figure 19). These gneisses consist of quartz and feldspar with biotite defining the foliation planes. Garnets occur as porphyroblasts within the gneisses. The size of the garnets varies from about 2 mm in the north-western side to less than 1 mm in the south eastern parts and is evenly distributed throughout. These are traversed by thin pegmatite and aplitic veins and have a few partially digested enclaves of older gneisses rich in melanocratic minerals.

Figure 19 : Geological Map of Grovnes Peninsula



5.3 Glaciology

The glaciological history of the Larsemann Hills is conspicuously different from most of the known ice-free areas of Antarctica in the sense that parts of the Larsemann Hills have been shown to be ice-free during the Wisconsin times. The dating of the moss deposits at 24,950 years BP (Burgess et al., 1994) has necessitated a reconsideration of the Pleistocene history of the region as the earlier workers (Gillieson et al., 1990) had postulated that the Larsemann Hills became ice-free by 10,000-20,000 years BP. More recently, the late Quaternary climate history of the region has been reconstructed by Verleyen et al. (2004).

5.3.1 Geomorphology

The area has a low, gentle and rolling topography merging with the polar ice cap in the south-southeast and surrounded by sea in other three directions. It is punctuated with small islands to the north & northeast. Starting from the mean sea level, it rises up to an elevation 150 m near the polar ice cap with the highest rocky outcrop exposed at 104 m above mean sea level.

The area is generally devoid of glacial morains but at a few places glacial striations are noticed. The area is dotted with small, perennial lakes.

5.4 Soil

The remarkable characteristic of the Larsemann Hills is the absence of moraine deposits as in most coastal areas of east Antarctica (Gasparon et al., 2004). Due to low temperatures, weak chemical weathering processes take place, resulting in the enrichment and migration of chemical elements. The highest migration is noted in Ca, followed by Mg, Sr, Zn, K and Na. The average ratio of SiO_2/Al_2O_3 is 5.79, which shows a weak chemical weathering property of the soil. Compared with the parent rock, SiO_2 and Al_2O_3 have been eluviated. There is a trend of increasingly strong weathering from south to north (Wang, et al. 1997).

5.5 Lake Water Characteristics

There are over 150 freshwater lakes in the Larsemann Hills, ranging from small ponds less than 1 m deep to glacial lakes up to 10 ha and 38 m deep. Some of these water bodies are ice free for brief periods or partially ice free in the summer months when their water temperatures increase rapidly, reaching $+8^0$C in some of the shallower ones. For the remainder of the year (8–10 months) they are covered with ca 2m of ice (Hodgson et al., 2006). The lakes around the proposed site are in general young excepting the major lake (L-37, Gillieson et al., 1990). The waters have low conductivity and exceptionally low turbidity.

Data on hydrochemical properties of 13 lakes in the proposed site indicates that Na^+ and Cl^- are predominant ions in the water, but no CO_3^{--} is present. Hence, all lakes belong to Na^+ group. The concentrations of nutrient substances (N, P, SiO_2) are rather low; inorganic nitrogen exists mainly in the form of NH_4^+-N, both in water and in the snow. The relatively high concentrations of Na^+, Cl^- and SO_4^{--} suggest that the precipitation in the Larsemann Hills is dominated by marine conditions.

5.6 Climate

5.6.1 Overview

The area is marked by persistent strong katabatic winds that blow from the north-east on most summer days. Daytime air temperatures from December to February frequently exceed 4˚C, with the mean monthly temperature a little above 0˚C. Pack ice is extensive inshore throughout summer, and the fjords and embayment are rarely ice-free. Snow cover is generally thicker and more persistent on Stornes Peninsula than Broknes Peninsula. Severe weather is experienced in the region with the occurrence of storms and the intensity of some lows exceeds that of a tropical cyclone/hurricane with central pressures as low as 930 hPa and maximum winds of 50 meter/second (~100 kt). Extreme minimum temperature recorded so for is -40^0 C (Turner and Pendlebury, 2004).

5.6.2 Snowfall

Frequency of snowfall days is higher in winter than in summer; the percentage of sunshine days is 50% in summer while overcast and cloudy days are dominant in winter. Precipitation occurs as snow and is unlikely to exceed 250 mm water equivalent annually (Hogdson et al., 2001).

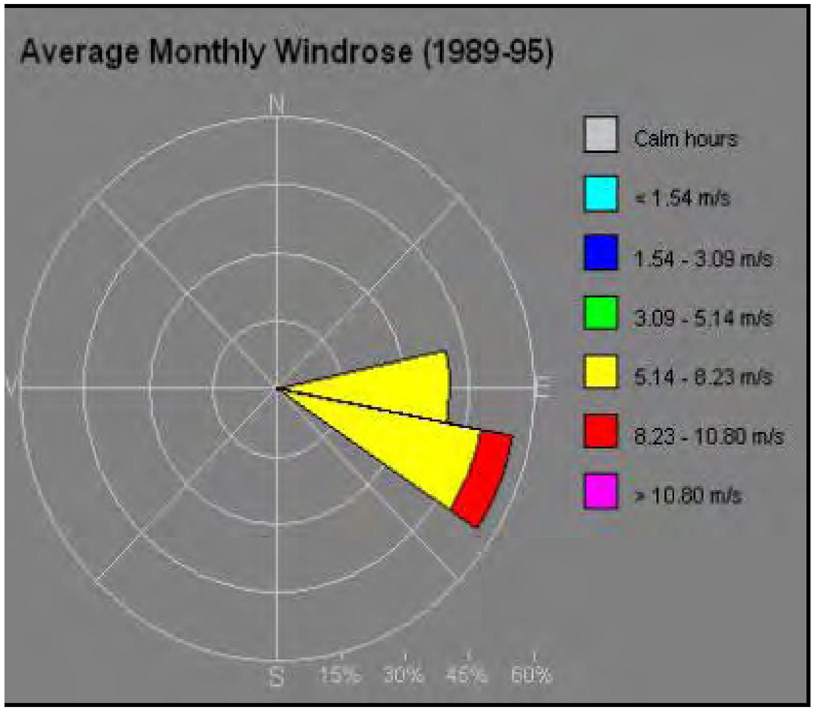
5.6.3 Katabatic Wind

Data indicates that calm conditions often occur between 1800 to 2400 hrs (local time) and gales between 0700 and 1200 hrs in summer and autumn. Observations made at Zhonshang station situated close to the proposed site, depicts that katabatic winds are dominant in January and October (Turner and Pendlebury, 2004)**.**

Gale frequency is considerably higher in winter than in other seasons with no diurnal variation. Annual mean wind speed 7 m/s second is recorded at Zhongshan station. Maximum wind speed is recorded 50 m/s. Number of gale days prevail 47% (171 days) on an annual mean basis

At Zhongshan Station, easterly winds prevail all the year round (Figure 20). As seen from the monthly average wind direction record on an annual basis, east-northeast to east-southeast wind directions (67.5 – 112.5) have a frequency of 72%, of which 31% is due to the east wind and 27% for east-southeast winds (Appendix 4).

Figure 20 : Windrose at Larsemann Hills



5.6.4 Humidity

The relative humidity is 57% on a yearly basis. It is higher in the Larsemann Hills only when the temperature is above 0^oC, leading to a higher content of water in air in mid-summer. Additionally, during a snowstorm or blowing snow episode, the relative humidity is higher too, sometimes in excess of 90% but absolute humidity remains low (Turner and Pendlebury, 2004).

5.6.5 Sea Ice

The sea ice conditions in the Prydz Bay are controlled by the presence of Dalk Glacier. This glacier produces large icebergs. The sea ice situation is improved with westerly winds, but the frequency of westerly wind events is very insignificant in this area. During the summer period, the Bay is clear of ice except in the fjords where ice breakout does not occur in some seasons.

The sea ice grows steadily during March – September, with maximum growth in April – June; it experiences steady melting in November – December, and a minimum in extent in February. Based on 1973-92 observations, the ice extends as far north as 57^oS as its northernmost limit(Turner and Pendelbury,2004).

It has been observed that ice-free sectors often emerge on the west side of the Prydz Bay and an ice dam occurs on the east side in December – January, and the ice is nearly disintegrated in February. In contrast, ice along the Larsemann Hills shore is always present in some of the years and moves away only when westerly winds are persistent. However, the westerlies have low frequency of occurrence, which is indicative that the ice distribution bears a close relation to wind direction and orography on a local basis.

5.7 Anthropogenic Impact - Background Information

Human occupation commenced in this area in 1986, with the establishment of four scientific bases by Australia (Law Base), Russia (Progress I and II) and China (Zhongshan) situated around 10 km away in NE direction from the proposed site. All these stations are situated within a radius of 2 km from each other. Ninety-three organic compounds including n-alkanes, lipidal isopentadienes, aromatic hydrocarbons, polycyclic aromatics, alcohols, aldehydes, ketones, esters, monocarboxylic acids and phthalic esters in the range of 0.027-4.79 mg/L have been identified in the Mochou and Heart lakes of the of Broknes area. Organic compounds like BHC, DDT and PCBs have also been detected in the water at concentrations of 0.012-0.356 mg/L (Li et al., 1997). Occasional ship-based tourist visits have also been made to the area since 1992.

5.7.1 Baseline Monitoring Information

5.7.1.1 Water Quality

Water samples collected from various lakes in the vicinity of the proposed site during the summer 2004 were analyzed for dissolved salts. Excepting the L-7 (Figure 19) which was saline in nature, the water quality from other lake was in general potable. Some of the important physico-chemical parameters of water of these lakes are provided in Table 1. The water bodies, L1, L2, L3, & L5 (Figure 19) besides being shallow reveal low hydraulic detention period/ high flushing rate.

Table 1 : Physico chemical Properties of Water Bodies at Larsemann Hills

Parameters	**Lake-L1**	**Lake-L3**	**Lake-L7**	**Lake-L8**	**Lake-L9**
Temperature (^oC)	-0.1	-0.1	-0.1	0.1	0.1
pH	6.1	6.1	6.1	6.4	6.0
Conductivity (ms/cm)	80	80	930	120	20
PO_4 (mg/l)	0.73	0.71	0.72	0.72	-
NO_3 (mg/l)	0.3	0.4	0.2	0.2	0.2
Fe (mg/l)	0.12	0.03	0.08	0.15	0.13
Alkalinity (mg/l)	4.0	4.0	16	6.0	4
Chloride (mg/l)	5.95	5.26	70.73	8.0	2.04

The lake water samples were collected from two lakes in the McLeod Island located close to the proposed site for multi-parameter probe analysis.

The results of the physico-chemical analysis of same lakes numbered as 33 and 34 by Gillieson et al., 1990 are shown below in Table 2.

Table 2 : Physico chemical analysis of Lakes of McLeod Island

Parameters	Lake-33	Lake-34
Water temperature (0C)	3.7	2.6
pH	6.57	6.74
Conductivity (μS/cm)	197	261
Chloride (mg/l)	59.3	75.7
Sodium (mg/l)	14.7	13.1
Potassium (mg/l)	0.5	0.5
Calcium (mg/l)	0.5	0.5
Magnesium (mg/l)	3.0	3.0

ND – Not Detected

5.8 Flora and Fauna

Extensive surveys have been carried out in this area. Seventeen species of rotifers (11 Monogononta and six Bdelloidea), three tardigrades, two arthropods, as well as protozoans, a platyhelminth and nematodes have been reported from 13 freshwater lakes (Dartnall, 1995). The benthic communities of the deepwater lakes are dominated by thick cyanobacterial mats (Ellis et al., 1998).

5.8.1 Flora

Sampling of the coastal areas from the Vestfold Hills to the Larsemann Hills indicates that the flora of the Ingrid Christensen Coast is relatively uniform, and restricted to bryophytes, lichens and terrestrial algae. Although few collections have been undertaken, it is believed that the nature of the basement rock, the relatively recent exposure from the ice cap and the prevailing wind direction in the greater Prydz Bay area contribute to the fact that less than 1% of the Larsemann Hills has vegetative cover. Five introduced vascular species have been observed in the vicinity of the existing station buildings of Brokens peninsula.

Most terrestrial life, including mosses, lichens and accompanying invertebrates are found inland from the coast. Nevertheless, large moss beds are known to occur in sheltered sites on the larger islands (particularly Kolløy and Sigdøy), associated with Adelie penguin moulting sites, and nunataks in the southwest. There are seven positively identified moss species in the region: *Bryum pseudotriquetum* which is most abundant, *Grimmia antarctici*, *Grimmia lawiana*, *Ceratodon pupureus*, *Sarconeurum glaciale*, *Bryum algens* and *Bryum argentum*.

The bryophyte flora also comprises one species of liverwort *Cephaloziella exiliflora*, which is found on an unnamed outcrop south of Stornes and known from only four other Antarctic localities. Lichen coverage is considerable on north-eastern Stornes and Law Ridge on Broknes and the lichen flora of the region comprises at least 25 positively identified species. Although no systematic studies have been undertaken in the area, similar work conducted in nearby locations on the Ingrid Christensen Coast suggests that it would not be unreasonable to expect the Larsemann Hills to exhibit close to 200 non-marine algal taxa, and 100–120 fungal taxa (WP8, 2006).

5.8.1.1 Lake and stream biota

Most of the phytoplankton comprises autotrophic nanoflagellates, though dinoflagellates occur in many lakes, and a desmid belonging to the genus *Cosmarium* is a major component of at least one lake. Heterotrophic nanoflagellates are more common than autotrophic nanoflagellates, though exhibiting low species diversity (only three or four species in most lakes), and particularly abundant in shallow lakes (*Parphysomonas* is very common). Ciliates are found in low numbers with *Strombidium* the most common species, and a species of *Holyophyra* also found in most lakes. Rotifers occur sporadically in a number of lakes and the cladoceran *Daphniopsis studeri* is widespread, but found in low numbers.

The most obvious biotic feature observed in almost all the lakes is an extensive blue-green cyanobacterial felt, which has accumulated since ice retreat and is consequently thickest on the islands and thinnest in young lakes adjacent to the polar plateau. These cyanobacterial mats are found to be of exceptional thickness of up to 1 m, not normally observed in other Antarctic freshwater systems, and are also widely distributed in streams and wet seepage areas (WP 8).

5.8.2 Vertebrate Fauna

Near the new station location, no known breeding sites for any vertebrates exist. At Broknes, ecological and biological studies on the south polar skua *Catharacta maccormicki* have been carried out during January 1989-February 1990 by Wang indicate that the Larsemann Hills also provide breeding sites for other seabirds, such as the snow petrel *Pagodroma nivea* and Wilson's storm petrel *Oceanies oceanicus*, which nest mainly in the eastern part of the Hills (Wang, 1991).

Three species of seabird, South polar skuas, Snow petrels and Wilson’s storm petrels, breed within the Larsemann Hills . Approximate numbers and locations of breeding pairs are documented for Broknes, and particularly eastern Broknes, but their distribution throughout the remainder of the area is uncertain.

South polar skuas (*Catharacta maccormicki*) are present between mid-late October and early April, with approximately 17 breeding pairs nesting on Broknes and similar numbers of non-breeding birds.

Snow petrel (*Pagodroma nivea*) and Wilson’s storm petrel (*Oceanites oceanicus*) nests are found in sheltered bedrock fragments, crevices, boulder slopes and rock falls, and are generally occupied from October until February. Approximately 850–900 pairs of Snow petrel and 40–50 pairs of Wilson’s storm petrel are found on Broknes, with concentrations of Snow Petrels at Base Ridge and on rocky outcrops adjacent to the Dålk Glacier in the east and the plateau in the south.

Despite the suitable exposed nesting habitat, no Adelie penguin (*Pygoscelis adeliae)* breeding colonies are found at the Larsemann Hills. However birds visit from colonies on nearby islands during summer to moult. Emperor penguins (*Aptenodytes forsteri*) also occasionally visit from the Amanda Bay rookery.

5.8.2.1 Seals

Weddell seals (*Leptonychotes weddelli*) are numerous on the Larsemann Hills coast. Aerial surveys during the moulting period have observed greater than 1000 seals, with multiple large groups (50–100 seals) hauled out in Thala Fjord and on rafted ice immediately to the west of Stornes, and numerous smaller groups amongst offshore islands and ice to the north-east of Broknes. Crabeater seals (*Lobodon carcinophagus*) and Leopard seals (*Hydrurga leptonyx*) are also occasional visitors (WP8, 2006).

5.8.3 Invertebrate Fauna

Little research has been conducted with regard to terrestrial invertebrates in the Larsemann Hills. Five genera of terrestrial tardigrade (*Hypsibius*, *Minibiotus*, *Diphascon*, *Milnesium* and *Pseudechiniscus*), which include six species, are known to be present in localities associated with vegetation. The lakes and streams provide a series of habitats that contain a rich and varied fauna very typical of the Antarctic region. Seventeen species of rotifer, three tardigrades, two arthropods, protozoans, a platyhelminth and nematodes have been reported. The cladoceran *Daphniopsis studeri*, one of few species of freshwater crustacea known to occur in the lakes of continental Antarctica, has been identified in most Larsemann Hills lakes and represents the largest animal in these systems (WP8, 2006).

5.9 Protected Areas and Historic Sites and Monuments

The Larsemann Hills area is proposed to be designated as Antarctica Specially Managed Area (ASMA) with the joint efforts of Australia, China, Russia, Romania and India. Other than proposed ASMA no other ASPA or HSM exist in the area. Two protected areas in the Prydz Bay region are ASPA 143: Marine Plain (68°3'36"S 78°6'57"E), located on Mule Peninsula and ASPA 167: on Hawker Island (68°35' S 77°50'E). Historic Site and Monument (HSM) 6: Walkabout Rocks (68°21'57"S 78°31'58"E) and HSM 72: Cairn on Tryne Islands (68°21'57"S 78°24'E) are also located within the Vestfold Hills.

5.10 Prediction of Future Environmental Reference in the absence of Proposed Activity

In the Larsemann Hills, human presence has continued since 1986. Sporadic tourist activity has also been reported. In the absence of the proposed activity, the aesthetic and natural values of the area adjacent to the proposed base are likely to remain unchanged. However with existing operation in Larsemann hill some impact will occur over this area also.

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6. IDENTIFICATION AND PREDICTION OF IMPACTS

6.1 Methods and Data used for Prediction of Impacts

For the prediction of likely impact and assessment, various environmental indicators have been selected subject to the value judgment, relevance to the area and project activity. The baseline information has been collected from primary and secondary data available from scientific publications. Relevant site-specific baseline information for environmental monitoring has also been collected to establish the environmental condition prior to commencement of the project activity. Specific project activities including energy, water supply, waste management, scientific activities and associates logistics etc. have been clearly defined to demarcate station footprints.

Necessary references were adopted from USEPA, the Greenhouse Gas Inventory and the Emission Source Classification, Central Pollution Control Board, New Delhi, National Atmospheric Emission Inventory etc. U.K. EIA guidelines are considered while identification and prediction, and mitigation measures were defined by putting the benchmark of Madrid Environmental Protocol. From construction to decommissioning, strict environmental conservation measures will be implemented under the supervision of NCAOR.

Further, direct, indirect, cumulative and unavoidable impacts were examined and matrix has been drawn to assess the predictive impact. Following area have been identified for studying the possible impacts :

- Physical disturbance
- Air
- Water
- Noise
- Oil spill and other waste
- Flora and Fauna

6.2 Impact due to Construction Activities

6.2.1 Physical Disturbance

The project activity will take place in form of construction of the building for living and laboratory complexes, utility services, fuel storage, associated pipelines, helipad and landing point. Wind turbine is proposed to be installed in order to supplement the energy demand. This turbine will occupy some area for erection of the tower in the vicinity of the station. From the platform of landing site to the station, access pathway will be developed which will be around three meters wide and about 800 meters long. Two helipads covering an area of 60 sq. m in front of the main building will also contribute to the physical disturbance to the area. Equipment needed to construct the building, laying pipe and cables placed at the site will occupy about 150 sq. m. There will be some disturbance to the rocks that will be used as foundation for the stilts to be anchored to these rocks.

6.2.2 Impact on Air Quality

There will be some transient effect on the air quality because of the ship and air operations, use of generators as also due to the construction activities. Fossil fuel consumption will result in emissions of SO_2, NOx, CO, CO_2 and suspended particulate matter to the atmosphere.

6.2.2.1 Impact due to supply ship

It is estimated that two austral summers will be required to build the station.. The ship will be anchored near the site for a minimum period of 50 days to facilitate the construction activity. Supply ship will use Intermediate Fuel Oil (IFO) and Marine Diesel Oil (MDO). For the calculation of fuel consumption and emission, the data of Ice class ship Emerald Sea has been used. However, cumulative and daily fuel consumption may change depending upon the weather, sea ice condition and speed of the ship during operation. Fuel consumption during drifting in the ice may vary from 35 MT/day to 42 MT/day of IFO and 3.5 MT/day of MDO. However at idling stage, this consumption may drop to 4 to 4.5 MT/day of IFO and 3.5 MT/day of MDO. In open sea area, fuel consumption pattern appears to be 26.5 to 45 MT/day IFO and 3.5 MT/day of MDO considering ship's run on single or twin engines.

The details of the emission during the voyage in open sea, ice navigation and idling period are given in Table 3.

Table 3 : Predicted Air emission from Ship during Ice Navigation

Emission Factor

Emission Factor Kg/m^3 of fuel Burn*	PM	SO_2	NOx	CO	TOC	Methane	NMTOC
IFO	0.84	27	5.64	0.6	0.1248	0.0336	0.0912
MDO	0.24	28.26	2.88	0.6	-	-	-

**Emission factor calculation is referred from USEPA air chief, AP-42 Ver 8.0. IFO is considered as No 4 fuel oil and MDO is considered as No 2 fuel oil with uncontrolled burning. Sulfur content in the fuel oil is considered as 15000 ppm*

Total Emissions

Type of Fuel	Fuel Consumption in 50 Days (m^3)		Total Emission of Pollutant considering 50 days alongside (kg)-35 days idling 15 days ice navigation						
	Ice Navigation	Idling Condition	PM	SO_2	NOx	CO	TOC	Methane	NMTOC
IFO	555.5	148	591	19000	3969	422	88	24	64
MDO	62	145	50	5846	596	124	-	-	-
Total	617.5	293	641	24846	4565	546	88	24	64

6.2.2.2 Impact due to air operations

The major shifting of men and material during construction phase will be by two helicopters each capable of carrying at least 4-5 ton under slung. Approximate 2040 kg per day of the ATF (Jet A-1), will be required to operate both the helicopters (All calculations are based on fuel consumption of MI8 helicopter). This consumption will emit pollutant as line source as shown in Table 4:

Table 4 : Predicted emission from helicopters

Parameters	Pollutant (kg) for 200 hours of helicopter operation (2 helicopters)						
	PM*	**SO_x**	**NOx**	**CO**	**CO_2**	**Methane**	**NMVOC**
Emission Factor (kg/t) of fuel consumption	0.2	0.72	0.19	12	859	1.43	2.84
Emission Load (kg)	16	59	15.5	979	70094	117	232

Source: Emission factors are considered from UK National Atmospheric Emission Inventory (2002)

** Particulate Matter refers to particle produced by fuel consumption with a diameter less than or equal to 10 µm*

6.2.2.3 Impact due to generators

Generators of 35 kW shall be in use during the construction activity to provide electricity to the equipments needed for building erection, carpentry and for electric radiator in shelter hut. These generators will run on lead-free gasoline. Considering gasoline consumption as 315 g (382 cc) per kw-hr, it is estimated that around 13.5 litre per hour will be consumed by generators. The generators may be run for around 10 hours a day. Considering 40 days operation, the emissions from the generators are provided in Table-5 .

Table 5 : Emission from the Generators

Parameters	Pollutants (kg)				
	PM-10#	**NOx**	**SOx**	**CO**	**CO_2****
*Emission factor (kg/kW-hr) of energy generated	4.38E-04	6.69 E-03	3.59 E-04	2.67 E-01	6.56 E-01
Pollution Load (kg) In span of 40 days run Daily 10 hours	6	94	5	3738	9193

**Emission factors are calculated referring AP-42 of USEPA, 2000 of uncontrolled gasoline fuel burning in industrial engine.*

#PM-10= particulate matter assumed to be less than or equal to 10 µm aerodynamic diameter and greater than and equal to 1 µm diameter

***Assumes 99% conversion of carbon in fuel to CO2 with 86% weight % carbon in gasoline*

6.2.2.4 Impact due to ATVs

Terrain at the site is undulated which needs suitable All-Terrain Vehicles (ATVs) to drive on this surface. Two ATVs which will run on gasoline will be in operation during construction activity to facilitate transportation in limited area. The expected emissions from the ATVs are provided in Table 6.

Table 6 : ATV Emission Rate (FAQ ATV Riders, 2000)

Emission rate

Category	ATV emission rates (gram per mile)			
	PM	NOx	CO	HC
Baseline four stroke	0.1	0.4	48.5	2.4
ATV meeting EPA standards	0.1	0.3	42.9	1.6

Pollution Load

Category	Total ATV emission (kg) in 15 miles run by 2 vehicles			
	PM	NOx	CO	HC
Business as usual scenario	0.12	0.5	58	3
ATV meeting EPA standards	0.12	0.4	51	2

6.2.2.5 Impact due to use of forklift

Forklift will be unavoidable during the construction phase. However, the operation shall be limited to move material from the landing to the construction site. This machine will operate on gasoline and will be operated for 6-8 hours in a day with the 2 t capacity. Air emission from the forklift is estimated to be very insignificant (Table 7).

Table 7 : Emission Standards for fork lifter (Emission Standards for New Nonroad Vehicles, 2002-USEPA)

Year to be implemented	NO_X+HC	CO
2007	2.7 g/kW-hr	4.4 g/ kW-hr

6.2.2.6 Impact due to Crane

Two cranes of 5 tons capacity each, one near the landing site and other at the construction site, will be operated. In the operational phase, cranes will have limited use for maintenance purpose only. The air emission from these cranes will be very insignificant.

6.2.3 Impact on Water Quality

6.2.3.1 Waste from Ship

All the workers engaged in construction work would be staying on board the ship. Including the crew members, around 95 people will be on board, which will produce approximately 10 m^3 of waste per day.

6.2.4 Oil Spill and other waste

Fuel is required at the construction site for ship, barge, helicopter, generator and other vehicles. Mainly IFO/MDO, ATF, gasoline and lubricants shall be in use for various operations. For helicopter operations, refueling will be done on the ship and ATF will be stored in 10 kl double-skin tanks or drums. At the site, the fuel will be stored in 5 kl tanks and 20 barrels containing ATF for emergency purposes. Fuel spill may occur during filling the tanks from the barge, leakage from the vehicle engines and from the barrels filled with ATF and lubricants. Fuel spill may also take place while refueling. This fuel after spilling may contaminate the top soil and may be toxic in nature.

Construction activity will generate non-hazardous waste comprising mainly packing material, plastics, wood, small tin etc. and hazardous waste comprising batteries, waste fuel, lubricants, paints sealant etc.

6.2.5 Impact on Flora and Fauna

Even though there are no rookeries at the site, stray penguin visits have been noticed occasionally. Seals have also been observed near the site. The noise produced during construction activity may result in some disturbance to these animals. There is also a threat of introduction of alien species to the environment.

6.2.6 Impact on aesthetic and wilderness values

Machineries associated with construction activity will have minor visual impact and loss of the wilderness value.

6.2.7 Impact of Noise

Noise pollution is recognized as emerging threat in Antarctica. Anthropogenic noise impact may have detrimental impact on human being as well as marine life. Helicopter is one of the sources of noise pollution which generates more than 140 dBA noise. Other vehicles and generators which will remain in operation at the site for longer duration will have adverse impact on the workers.

6.3 Impact due to Operation Activity of the Station

6.3.1 Physical Disturbance

Equipment installation for scientific experiment may be for long term or short term, which will contribute to physical disturbance. Electrical cables will be required to transmit the electricity from the generator room to the building, laboratory and other modules. This encased cabling will result in physical disturbance. Piping for wastewater discharge from the treatment plant to the discharge site at sea will occupy some area. It is estimated that approximately 1650 square meters of land area will be required to build the structure inclusive of the main building, fuel and food depot, platform at landing site etc. Around 200 metres piping is required for water intake from lake, 400 metres for intake from sea and around 500 metres piping is to be laid for wastewater discharge to sea. In addition, a 700 metres long fuel distribution line is proposed from the fuel depot to the station building. All these structures and piping will cause physical disturbance to the area. The likely footprint of the activity have been shown in the Figure 6 a and 6 b.

6.3.2 Air emission

During the operation of the station, air emission will be produced from supply vessel, generators, incinerators, vehicles etc. Fugitive emissions are also expected from stored fuel tanks. These emissions will comprise, carbon dioxide, carbon monoxide, oxides of sulfur, nitrogen and other gases along with heavy metals if they cross the permissible limits.

6.3.2.1 Supply Ship

Ice-class ship will be used for supply of the material, fuel, bringing back the harmful undisposable waste of the station and transportation of scientists and logistics personnel to the station. The emissions from the ship will be as given in Table 3, depending upon the period of stay of ship at the outer anchorage near the station.

6.3.2.2 Helicopter

When station will be fully in operation, use of higher capacity helicopters will be replaced by smaller varieties such as AS 350, Bell 407 etc., which will be used for traverses to inner mountain ranges. Fuel consumption of this type of machine shall be in order of 170 liter/hr of ATF (Jet-A1). Around 20 sorties are anticipated for transferring to and fro, ship to station and another 25-30 for scientific traverses beyond the limits of the station. It is estimated that total fuel consumption for the operation confined to station site will be in order of 950 kg. The predicted emission from the helicopters is shown in Table 8:

Table 8 : Predicted emission from helicopters around the site

Parameters	Pollutant (kg)						
	PM	SO_x	NOx	CO	CO_2	Methane	NMVOC
Emission Factor (kg/t) of fuel consumption	0.2	0.72	18	12	859	1.43	2.84
Emission Load (kg)	0.2	0.7	0.2	11.5	820	1.5	2.5

6.3.2.3 Generator

It is estimated that the total requirement of power will be about 200 kW during summer and 170 kW during winter. Fuel operated generators will be used as main power source. The heating system inside the station will work on Combined Heat and Power (CHP) mechanism. This will help to reduce power demand by 95 kW during summer and by 65 kW during winter. One 125 kVA generator plus a stand-by would be installed to meet these power requirements. The following emissions are expected to impact the air quality (Table 9):

Table 9 : Emission from diesel generators during station operation in a Year

Generator	Fuel Const. (m^3/year)	Total Emission of Pollutant (kg)				
		PM 10#	SO_2	NOx	CO	TOC
*Emission Factor (kg/m^3) of fuel burn		1.0248	0.744	11.724	0.8064	0.2856
125 kVA Genset (24 hours run for 365 days)	182	187	136	2136	147	52

**USEPA, AP-42 of electric generation from internal combustion engine, uncontrolled operation*

#PM-10= particulate matter assumed to be less than or equal to 10 µm aerodynamic diameter and greater than and equal to 1 µm diameter

6.3.2.4 Vehicles

During operational activities of the station, two ATVs shall ply between station, food depot and laboratories to ferry material and scientific equipments. Considering 15 miles run of two ATVs and maximum number of 100 days of plying in a year, total emission into the air will be of the order of 0.3 kg of particulate matter, 0.9 kg of oxides of nitrogen, 130 kg of carbon monoxide and 2.4 kg of hydrocarbon.

Cranes and forklift will have limited use once the station would be in operation. Crane will be used only for replacement of the panel, vehicle maintenance and transfer of the material from barge to the platform. Forklift will also be used occasionally to place the material. Use of these vehicles is limited to the confined area and for very few hours in a year. Operation of these vehicles will release insignificant pollutant into air. It is estimated that fuel required for the crane is 500 liters of ATF and for forklift it is 200 litres of gasoline every year.

6.3.3 Impact on Water Quality

Total water requirement for the station will be of the order of 2.6 m^3/day based on 100 litre per person per day for 25 persons. Twenty percent of the water requirement of the toilet will be met through recycled water, thereby reducing the water requirement of potable type to 2.3 m^3 per day during summer and 1.5 m^3 during the winter period. The quality of water in the lakes is likely to be affected if the water is overdrawn as the lakes are shallow in depth. The station structure will be located so as to keep the lake eco system free of any effect of the emissions from the generators and the vehicular movement

About 2.3 m^3 of wastewater will be generated per day from the toilet, laundry, and kitchen during summer and 1.3 m^3 per day in winter. The wastewater will be discharged into sea through pipes after treatment. There are chances of leakage through the pipes. Wastewater discharge into the sea may temporarily affect the quality of water.

6.3.4 Waste (Solid and semi solid)

Approximately fifteen kg of solid waste is expected to be generated per day in the form of organic waste from the kitchen during winter and about 20 kg during summer. Other solid waste will include packing material, unserviceable items such as steel, tin, wood, glass, etc., sludge generated from wastewater treatment system and dewatering unit and ash from the incinerator unit. Some waste will also be generated from the vehicle workshop. Organic waste will be incinerated at the site which will emit particulate matter, carbon soot, CO, oxides of nitrogen and sulfur.

Waste generated inside the station will be of different categories. If left unattended, it may be hazardous to the environment and have both short and long term effects. Waste will also be generated from launching of the meteorological balloons and other laboratories.

6.3.5 Noise Quality

During the operation of the station, noise will be generated from the helicopter operation, generator operation and vehicular movement. Helicopter will produce around 125 dBA at 10 meter distance. Keeping engine on for longer duration may cause temporary hearing impairment if persons remain present near the helicopter.

Although the generators will be fitted with acoustic enclosures for noise barrier and will maintain the USEPA and CPCB standards for the noise emission, some noise would be generated.

6.3.6 Fuel Spill

Fuel will be needed for various operations at the stations. Oil spill may occur from leakage from engine, overflow from the tanks, accidents and during the process of decanting.

6.3.7 Aesthetic and Wilderness Value

Station is designed to be a two-storey building which will cover around 1650 sq. m area including the laboratories, food and storage facilities. Operation of the station and movement of the rotor of the wind turbine at the site will have some impact on the visitors. The Station would be visible from the sea only if the line of the sight is clear.

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7. MITIGATION MEASURES

Mitigation measures during construction and operational activities

7.1 Physical Disturbance

Physical disturbance would be controlled by restricting most of the activities in a limited area. Human impact will be confined to predefined areas whereas access will be leveled without causing much disturbance. Any structure will be placed in such a way that for maintenance or for replacement after expiry of its life it can be completely removed from the place to make the impact reversible. The equipment used during the construction phase would be removed from the site after completion of the building. The discharge pipelines will be laid avoiding the catchment area of the lakes.

7.2 Impact on Air Quality

Emission generated from the machinery and equipment predicted to have a cumulative impact on the environment will be controlled through optimization of the same. All the vehicles used for construction and operational purposes will be maintained efficiently to ensure low air emission.

7.2.1 Supply Ship

Since the supply ship will be berthed far from the site, the emissions from the ship at the idling stage are likely to be minimum producing insignificant impact on the station site. The expedition ship will be complying with the provisions of MARPOL Annex VI on air emissions. The possibilities of sharing the ship logistics after the construction stage will be preferred.

7.2.2 Helicopter

Helicopter will remain in the air only for 10 to 15 minutes for each sortie and will fly at 600 to 1000 feet above the msl so all the emissions will have very high probability of dilution and dispersion due to higher ventilation coefficient. It will be a line source emission not point source so it will have larger dispersal area and it is not going to affect directly or indirectly the flora or fauna or lake system of the area. The landing site shall be far away from the lakes.

Flying of the helicopters during the operational stage to the interior mountains will not have any direct impact on the site because of the distances involved.

7.2.3 ATV

Vehicles meeting the USEPA-2006 standards will be used to ply at the site which will help to reduce the emission in air. Emissions will be restricted to the order of 1.6 grams of hydrocarbon, 42.9 grams of carbon monoxide, 0.3 grams of nitrogen oxides and 0.1 gram of particulate matter per mile of run.

7.2.4 Generators

Fossil fuel generators mainly based on gasoline will be used to facilitate the construction work. Emissions from the generators are not very significant as the ventilation coefficient is very high. Gasoline of low sulfur and lead free type meeting the environmental norms of USEPA and CPCB will be used. The generators will be placed suitably taking into consideration the prevailing wind direction to avoid any contamination to the lakes. The upkeep and maintenance of the generators will be given high priority to keep the emissions at minimum.

Further to reduce emission, these generators will be operated on ATF rather than on diesel (Table 10). Generator will also be fitted with particulate arrester and stack height will be sufficiently high for proper dispersion of pollutants.

Table 10 : Emission from generators during station operation

Generator	Fuel Consumption (m3/year)	Total Emission of Pollutant (kg)				
		PM 10#	SO2	NOx	CO	TOC
*Emission Factor (kg/m3) of fuel burn		1.0248	0.744	11.724	0.8064	0.2856
75 kVA Genset (8 hours run For 365 days)	41	42	30	476	33	12
62.5 kVA (24 hours run for 365 days)	105	108	78	1232	85	30
Total	146	150	108	1708	108	42

Building will be designed as energy efficient and interiors of the building will be decorated to make best possible use of day light and avoid heat loss. Occupant shall be given proper training to use energy efficiently. The intake and discharge pipes will be heated only during the operations to save the energy. Wherever possible all the flow of recycled water, fuel and collection of the gray and black water will be gravity based.

7.2.5 Cranes and Forklift

Only one forklift will be operated which will run on gasoline. Impact on the air quality from the forklift use is not considered to be significant.

7.3 Impact on Water Quality

7.3.1 Waste from ship

The expedition ship will abide by MARPOL and Antarctic shipping guidelines thereby taking due care about the provisions of the environmental protocol. No waste produced in the ship will be discharged in the Treaty area. Treated wastewater will be discharged as per the prevailing provisions.

During the operation, stress will be on summer scientific activities around three months at the Larsemann hills site, but the ship will move away from the area as soon as material transfer is over. It will come again to collect the waste material from the site at the end of summer. So in all the ship will remain at the site for only 10-15 days.

7.3.2 Water quality at site

During the construction phase, water will not be drawn from the lakes, except for minor concreting. The ship will be used as a platform for most of the activities thereby reducing the water requirement for human consumption.

Potable water requirement from the lakes shall be supplemented by withdrawing and treating seawater with ultra filtration system. Seawater will be pumped from sea to the station building where it will be made available for further use after desalination. Snow traps will be laid at appropriate locations to increase the melt water content of the lakes.

Method of wastewater treatment and disposal will be in compliance with the basic requirements of the Protocol on Environmental Protection to the Antarctic Treaty. Rotating biological contactors or submerged aerated media processes will be installed to achieve an effluent quality of <20mg/L BOD_5 and SS and <200cfu/100ml faecal coliforms. The system will be able to disinfect the pathogenic bacteria before final discharge into sea. Basic specified criteria includes high effluent quality, compactness, low power use, low sludge generation, reliability, simplicity of operation and the ability to treat variable wastewater loads. Extra care would be taken to check and eliminate the leakages.

7.4 Noise Environment

The ship will be berthed away from the peninsula to minimize the disturbance due to the noise. The helicopters will shut off their engines at the site to minimize noise disturbance. The silent generators adhering to the USEPA and CPCB standards will be used to keep the noise levels at minimum.

7.5 Impact of Oil Spill

During the construction phase, few barrels of Jet A-1 will be stored at the site over a platform to avoid any direct touch with ground and facilitate recovery of oil leakage if any. Care will be taken to avoid any oil spill during refueling or decanting from the barrels which will be checked frequently for any leakage. Sorbent material will be kept at fuel-handling sites. An oil spill contingency plan will be in force at the station to take care of any unforeseen eventuality.

According to the requirement during operation stage, around 200 kl of ATF will be stored in 10 numbers of 20 kl double skinned tanks. Gasoline will be stored in 10 numbers of 205 liters drums and other lubricants will also be stored in the drums. Part of the fuel will be stored at an alternate fuel depot at a safe distance form the previous one as a safety measure. Due care will be taken to ensure that these depots do not fall on the catchment area of the lake system

7.6 Impact of other waste

Since prefabricated material will be used for the erection of the building, the generation of the solid waste is expected to be at minimum. All the packing material will be stored in boxes and backloaded to ship. Maintenance-free battery will be used to minimize chances of any acid leak.

A comprehensive waste management plan will be enforced wherein collection, segregation and disposal techniques will be taken care of. Waste will be removed from the Treaty area and will be brought back to India for disposal. A compactor for reducing the volume of the solid non-combustible waste and plasma pyrolysis system for organic waste will be used. The ash will be collected and sealed in drums for disposal. Medical waste will be disposed as per the USEPA/CPCB Guidelines. Sludge obtained from the Rotating Biological Contactor and other allied units will be dewatered through centrifuge. Solid sludge will be collected in drums, sealed and removed from the Treaty area subsequently.

7.7 Impact on Flora and Fauna

Utmost care will be taken to avoid any interference with the local wildlife. Precautions will also be taken to avoid introduction of any alien species of microorganisms to the environment. Care shall be taken to irradiate the food material and other packing material with UV light to kill microorganism present if any, before taking to site.

7.8 Impact on Scientific activities

All the experiments related to astronomy, geomagnetism and atmospheric sciences will be conducted in separate laboratories, away from the station. All the electrical equipment installed at the station will meet the Electromagnetic Compatibility standards.

7.9 Aesthetic and Wilderness Value

The station design and the location will have minimum impact on the aesthetic value as the compact structure in a low-lying area will not have a strong visual impact. Wind turbine of smaller capacity will be preferred to reduce the impact value of the larger capacity turbine.

Impact Matrix

Impacts associated with station's operation and construction activities are identified and defined in matrices (Table 11). Impacts, mitigation measures related to the impact and ranking of the activities are defined below, according to its extent, duration, intensity and significance:

Extent	*Site Specific*	*Area adjoining to operational or construction site*
	local	*Within Larsemann Hills, approach way from ship to site and other modules*
	regional	*Prydz Bay Area*
	continental	*Antarctica and southern ocean*
	global	*All continent and sea*
Probability	*unlikely*	*Should not occur under normal operation and condition*
	Low	*Possible but unlikely*
	Medium	*Sometimes may occur*
	High	*Likely to occur during span of project*
	Certain	*Certain to occur*
Duration	*very short*	*Few minutes to hours*
	short	*Few hours to Few weeks*
	medium	*Few weeks to Few months*
	long	*Few months to Few years*
	very Long	*Decade to Century*
Significance	*A*	*Insignificant low impact not injurious to land and environment*
	B	*Measurable impact, but with proper planning is not injurious to land*
	C	*High Impact on environment, but can be curbed by taking proper precautionary measures*
	D	*Impact on environment but considered good*
	E	*Impact that will be detrimental to environment*

Table 11 : Impact Matrix and Mitigation Measures during Construction and Operation

Environmental Parameters / Indicator	**Potential Impact from activities**	**Extent**	**Duration**	**Probability**	**Significance**	**Mitigation Measures**
Physical Disturbance *Construction*	Erection of the structure, pipe laying, access pathway, wind turbine	Local	Long	Certain	B	Physical disturbance would be controlled by restricting most of the activities in limited area.
Operation	Occupied area of building, fuel and food depots, piping and off-loading platform, cable laying, laboratories etc.	Local	Long	Certain	B	• All activities will be carried out in defined area. • Laying of pipes will avoid use of frequent transportation for fuel and related activities. • Structure shall be removed after useful life is over.
Air Quality *Construction*	Supply Ship, Helicopter, Generator and Vehicles, Use of fossil fuel	Local to global	Medium	Certain	C	Abiding by MARPOL 73/78. Annex IV will ensure use of quality fuel and thereby controlled emissions.
Operation	Generator, incinerators for organic waste burning, supply ship, helicopter	Local to global	Medium	Certain	B	• Abiding by MARPOL 73/78. Annex IV will ensure use of quality fuel and thereby controlled emissions. • Ship and helicopter will be operated for very short duration. • Plasma-pyrolysis will be used for organic waste burning.

Environmental Parameters / Indicator	**Potential Impact from activities**	**Extent**	**Duration**	**Probability**	**Significance**	**Mitigation Measures**
						• Alternate energy source will reduce the fossil fuel consumption
Water Quality *Construction*	Solid-waste and wastewater release from the ship, which will introduce nutrients, heavy metals, faecal coliforms to the marine ecosystem	Regional	Short	Low	B	• Organic waste, except plastic will be burnt in incinerator, rest of the solid waste will be stored for proper disposal out of Treaty area • Treated and disinfected sewage will be stored in the tanks for disposal.
	Lakes at the site may be affected due to dispersal of solid waste and mixing of the carbon soot from the emission of vehicles, generator	Local	Medium	Medium	B	Keeping generator away from lake in downwind direction
Operation	Consumption of drinking water from the lake will reduce water level in the lake, wastewater pipe may leak from discharge pipe and mix with lake and contaminate water	Local	Long	Low	C	Potable water requirements will be supplemented by desalinated water from sea. Generator operation and solid waste burning will be carried out in the downwind direction from lake of prevailing wind.
	Solid-waste and wastewater release from the ship, which will introduce nutrients, heavy metals, faecal coliforms to the marine ecosystems	Local	Short	Low	A	Organic waste, except plastic will be burnt in incinerator, rest of the solid waste will be stored for proper disposal out of Treaty area

Environmental Parameters / Indicator	Potential Impact from activities	Extent	Duration	Probability	Significance	Mitigation Measures
	Wastewater discharge into sea will introduce heavy metal, bacteria, nutrient and deplete dissolved oxygen which may be detrimental to phyto and zoo plankton of marine ecosystem	Local	Medium	Medium	C	Treated and disinfected sewage will be stored in the tanks for disposal.
Noise Quality *Construction*	Noise will be produced during helicopter flying, generators and vehicle movement. High noise will disturb the fauna of the area like breeding activity, migration and other biological activity	Local	Very short	Certain	A	During construction phase noise intensity will be of short duration. However limited flying hours, silent generators and adequate construction method will mitigate noise levels and its duration
Operation	Noise will be produced during ice breaking, helicopter flying, generators and vehicles. High noise will disturb the fauna of the area like breeding activity, migration and other biological activity	Local	Longrt	Certain	B	The ship will be berthed away from the peninsula to minimize the disturbance due to the noise. The helicopters will shut off their engines at the site to minimize noise disturbance. The silent generators adhering to the USEPA and CPCB standards will be used to keep the noise levels at minimum.
Oil Spill *Construction*	Decanting of fuel and refueling.	Local	Long	Low	B	• Sorbent material will be available at site. Proper attention and high

Environmental Parameters / Indicator	**Potential Impact from activities**	**Extent**	**Duration**	**Probability**	**Significance**	**Mitigation Measures**
						standards of valves, tanks and drums shall be used for storage of the fuel. • Suitable platform to put drums will be made with due care to follow drainage towards sea rather than lakes. • Oil spill contingency plan will help to combat any accidental spills.
Operation	Decanting of fuel and refueling.	Local	Long	Low	C	• Sorbent material will be available at site. • Proper attention and high standards of valves, tanks and drums shall be used for storage of the fuel. • Suitable platform to put drums will be made with due care to follow drainage towards sea rather than lakes. • Oil spill contingency plan will help to combat any accidental spills.
Solid-waste *Construction*	Waste generated will be of different categories. If left unattended, it may be hazardous to the environment and have both short and long term effects.	Local	Medium	Low	B	• All the packing material will be stored in boxes and back loaded to ship. • Maintenance free batteries will be used • Comprehensive waste management plan will be enforced. Waste will be removed from the Treaty area.

Environmental Parameters / Indicator	**Potential Impact from activities**	**Extent**	**Duration**	**Probability**	**Significance**	**Mitigation Measures**
Operation	Waste generated inside the station will be of different categories. If left unattended, it may be hazardous to the environment and have both short and long term effects.	Local	Medium	Low	C	• All the packing material will be stored in boxes and back loaded to ship. • Maintenance free batteries will be used • Comprehensive waste management plan will be enforced. • A compactor for reducing the volume of the solid non-combustible waste and plasma pyrolysis system for organic waste will be used. • Medical waste will be disposed as per the USEPA/CPCB Guidelines. • Sludge obtained from the Rotating Biological Contactor and other allied units will be dewatered through centrifuge. • Solid sludge will be collected in drums, sealed and removed from the Treaty area.
Aesthetic and wilderness values *Construction*	Vehicle movement, and other construction activities will lead to loss of wilderness and aesthetic value	Local	Long	Certain	A	• All the activities will be confined to defined areas. • Removing the equipment and machinery after use will reduce the impact on wilderness value

Environmental Parameters / Indicator	**Potential Impact from activities**	**Extent**	**Duration**	**Probability**	**Significance**	**Mitigation Measures**
Operation	Emerged building, modules, platform, windmill etc. will lead to loss of wilderness and aesthetic value	Local	Long	Certain	B	• All the activities will be restricted to designated areas • Removing the equipment and machinery after use will reduce the impact on wilderness value • Building and modules will be removed when the useful life span is over • Wind turbine of smaller capacity will be preferred to reduce the impact value of the larger capacity turbine

8. ENVIRONMENTAL MONITORING

Published baseline data on Larsemann Hills as well as that generated in the course of the work at the site during the summer seasons of 2003-04, 2004-05 and 2005-06 have been used to establish the "footprint" of the station. A regular systematic monitoring program will be developed to integrate the work undertaken by other national agencies operating in the area. An environmental monitoring laboratory will be equipped with instruments like aethalometer, aerosol spectrometer, multistage impactor etc. for long term monitoring including physico chemical parameter of lake, marine and air environment. The environmental monitoring programme will establish close linkage between predicted and actual values during construction and operation of the station and facilitate devising mitigation measures that are needed to reduce the adverse impacts. All the workers and the occupants of the station will be given environmental training on the established guidelines. Following parameters are needed to be monitored with regard to environmental indicators:

Table 12: Environmental Monitoring Parameters

Environmental Indicators	Parameters	Duration
Air	Ambient Air Quality Monitoring for SO_2, NOx, CO, ,PM10, carbon soot	8 hourly, 24 hourly during Summer period (three points)
	Wind velocity, wind direction temperature, snow, humidity, cloud cover, rainfall, solar radiation, wind rose	Hourly average on yearly basis
Radiation	Radon level and Gamma counts in atmosphere, soil and rock	Monthly (4-5 points within 1 km radius)
Noise Quality	Ambient noise levels, day and night noise levels (L10, L50, L90), frequency analysis	During Summer (1 m from machines, 4 points on periphery of station 0.5 km radius)
Water Quality (Sea and Lake)	Physico chemical analysis (conductivity, pH, color, TSS,TDS,TOC,DO,BOD,COD, Total hardness, Calcium, Mg, Cu, Fe, Mn,Nitrate, Phenolics, Hg, Cd, Se, As, Cn, Pb, Zn, , Cr, Anionic Detergents, Polynuclear Aromatic Hydrocarbons, Mineral Oil, Alkalinity, Acidity, Organic Nitrogen, Phosphate, Sulfates, Chlorides, Fluoride, Total coliform, Fecal coli form, phytoplankton and Zooplankton. Sediments (Grain Size,TOC, TIC, Cu, Pb, Zn, Cd, Hg, petroleum hydrocarbons, and PAH (benzo a-pyrine, benzo e-pyrine)	Once in a month (from all the available sources minimum six places) during summer period

Land	Soil analysis (TOC, TIC, Cu, Pb, Zn, Cd, Hg, total petroleum hydrocarbon and PAH), grain size, type, behavioral change, erosion potential pre and post construction, Heavy Metal analysis, permafrost layer depth	Once in a year
Ecology of Marine and Lake system	Population size, breeding success, spatial extent, metals, alien species its distribution	Once in a year

Apart from the above-mentioned monitoring parameters, fuel spill monitoring from the fuel storage tank, supply vessel, and refueling into machinery and vehicle shall be carried out. Strict adherence to environmental protocol will be one of the prime objectives during construction and operation of the station. Any fuel spill substantive in nature will be reported. Routine visual inspection will be carried out as a part of the environmental monitoring.

9. GAPS IN KNOWLEDGE AND UNCERTAINTIES

The following major gaps and uncertainties exist in the assessment of the environmental impacts of the construction and operation of the new Indian base in the Larsemann Hills:

- Uncertainty of sea ice extent during the period January-March.
- The exact berthing spot of the ship close to the landing site is not known.
- The CEE is based on the conceptual design of the station. There may be some modifications based on the site requirements, practical difficulties etc.
- Impact matrix and evaluation have been done according to expert judgment, which are based on the predicted values, and are subject to change depending on the environmental conditions.
- During the long life span of the station, the need-based scientific activities and the energy scenario may change with the developments in the technologies.
- The detailed footprint may vary depending upon the implementation of the final design.
- Detailed topographical survey of the construction site is not yet available.

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10. CONCLUSIONS

The construction and operation of the station at a promontory in the Larsemann Hills will have more than minor and transitory impacts. The major impacts are expected from air emissions and human footprints. With proper mitigation measures like use of CHP concept for heating the station and the renewable energy sources, the impact of fossil fuel on air emissions will be brought to permissible limits.

Establishment of the research base at this site will enhance the scientific efforts and scope for co-operation with neighboring stations.

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ABBREVIATIONS and ACRONYMS

AAD	-	Australian Antarctic Division
AFPOS	-	Asian Forum of Polar Sciences
ALCI	-	Antarctic Logistics Centre International
ASMA	-	Antarctic Specially Managed Area
ASPA	-	Antarctica Specially Protected Area
ATCM	-	Antarctica Treaty Consultative Meeting
ATS	-	Antarctic Treaty System
ATV	-	All Terrain Vehicle
BHC	-	Benzene Hexachloride
CEE	-	Comprehensive Environmental Evaluation
CO	-	Carbon Monoxide
CPCB	–	Central Pollution Control Board
CTD	-	Conductivity, Temperature, Depth
DDT	-	Dichloro-Diphenyl Trichloroethane
DFM	-	Digital Fluxgate Magnetometer
DIM	-	Declination Inclination Magnetometer (DIM)
EIA	-	Environmental Impact Assessment
EMC	-	Electro Magnetic Compatibility
GPS	-	Global Positioning System
GSI	-	Geological Survey of India
HSM	-	Historic Site and Monument
IEE	-	Initial Environmental Evaluation
IFO	-	Intermediate Fuel Oil
ISC	-	International Seismological Centre, U.K.
ITRF	-	International Terrestrial Reference Frame
MARPOL 73/78	-	International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978
MDO	-	Marine Diesel Oil
MEPC	-	Marine Environment Protection Committee
NCAOR	-	National Centre for Antarctic and Ocean Research
NMTOC	-	Non Methane Total Organic Compounds
NMVOC	-	Non methane volatile organic carbon
NOx	-	Nitrogen Oxides

PCB	-	Polychlorinated Biphenyl
PM	-	Particulate Matter
PPM	-	Proton Precession Magnetometer
SO_x	-	Sulfur Oxides
TEC	-	Total Electron Current
TOC	-	Total Organic Compounds
USEPA	-	United States Environmental Protection Agency
USGS	-	U.S. Geological Survey

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Appendix 1

Schedule of Accommodation and Electric Load of Indian New Research Station

Room/Accommodation	No	Approximate Area (m^2)		Approx. Electrical Requirement (KW)	
		Unit (m)	Total	Room Fittings	Oil Based Electric Radiators
Laboratories	6	7x4	168	12	12
Change Room	1	3x2	6	0.1	1
Lounge/Meeting Room	1	12x10	120	0.8	4
Kitchen	1	7x4	28	0.5	0
Dining Hall	1	10x10	100	0.5	4
Service Room	1	3x2	6	0.1	1
MI Room	2	7x4	56	1	2
Rest Rooms (Winter)	15	4x3	180	3	30
Rest Room (Guest/Summer)	10	4x3	120	1.0	10
Gymnasium	1	7x4	28	0.5	2
Entertainment Room	1	10x10	100	0.5	4
Workshop 3 no for electrical, carpentry and mechanical	1	10x6	60	0.5	3
Garage for ATV Dozer, Crane	1	10x6	60	0.5	0
Toilet Room (5 no)	1	10X6	60	0.5	0
Bathroom (4 No)	1	10X3	30	0.6	0
Laundry room including space to hang cloths , dryer and ironing space	1	7x4	28	2	0
Melt water/Boiler Room and RO Plant	1	7x4	28	15..5*	2*
Library	1	7x4	28	0.3	2
Office room	1	7x4	28	0.3	2
Prayer (Meditation) Room	1	4x3	12	0.2	1
Store Room inclusive of cold, warm, General and maintenance room	4	7x4	112	1.0	0
Communication Room	1	7x4	28	1.0	2
Computer Room	1	7x4	28	3.0	2
Generator Room	1	10x4	40	0.3	0

Room/Accommodation	No	Approximate Area (m^2)		Approx. Electrical Requirement (KW)	
		Unit (m)	Total	Room Fittings	Oil Based Electric Radiators
Storage room	1	7x4	28	0.2	0
Wastewater Treatment System Room	1	10x6	60	9.0	4
Incinerator Room	1	4x3	12	10.2*	0
Compactor and Solid Waste collection Room	1	4x3	12	0.2	0
Solar Energy/Wind turbine room	1	7x4	28	0.3	2
Cold storage room	1	7x4	28	2.5	0
Boat/Gemini Room	1	7x4	28	0.2	0
Total Room Area			1650		
Additional 10% for adjustment			165		
Area for corridor and staircase(15-20%) of total area			330		
TOTAL	63		2145	68.3	90
Module Outside of Main Building					
Food Depot (Separate)	2	7x4	28	0.2	0
Fuel Depot (Separate)	2	10x4	80	0.3	0
Laboratories (Separate)	3	7X4	84	6.0	6.0*
Total Including all Above	70		2337	74.8	96

Additional Requirement of Electrical Power

Trace heating element for outfall sewer line of 500 meters	-7 KW*
Trace heating element for water intake pipe line 200 meters	-3 KW*
Trace heating element for sea water intake pipe line 400 meters	-6KW*
Submersible pump for water intake	-2 KW*
Submersible pump for sea water intake	-2KW*
Unaccounted load	-10 KW*
Total	30 KW

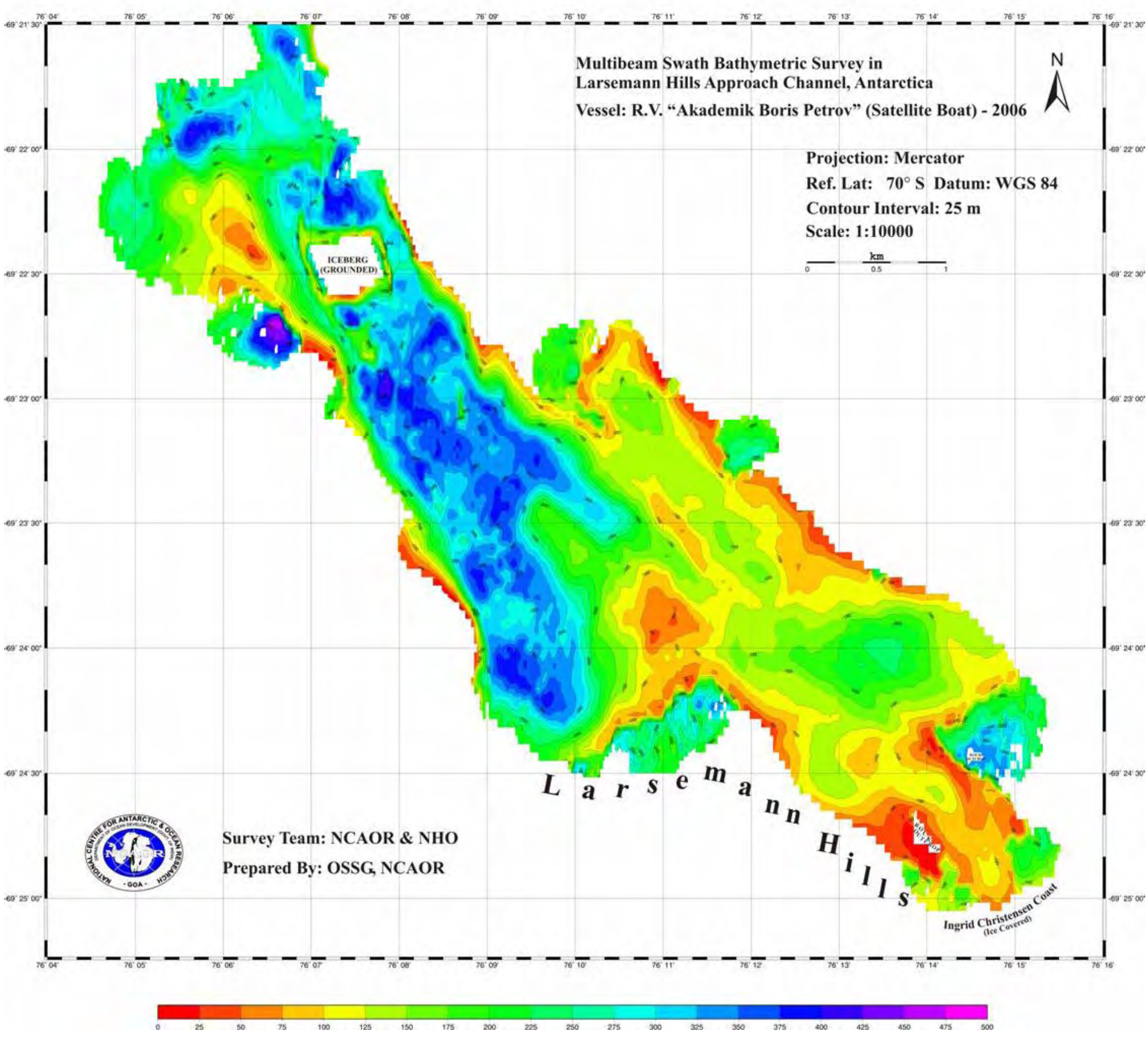
***** *Required only for 6-8 hours in a day*

In winter season power demand will reduce by;

Laboratory – 12 KW
Guest Room - 11 KW
Laboratory (Separate) - 6 KW

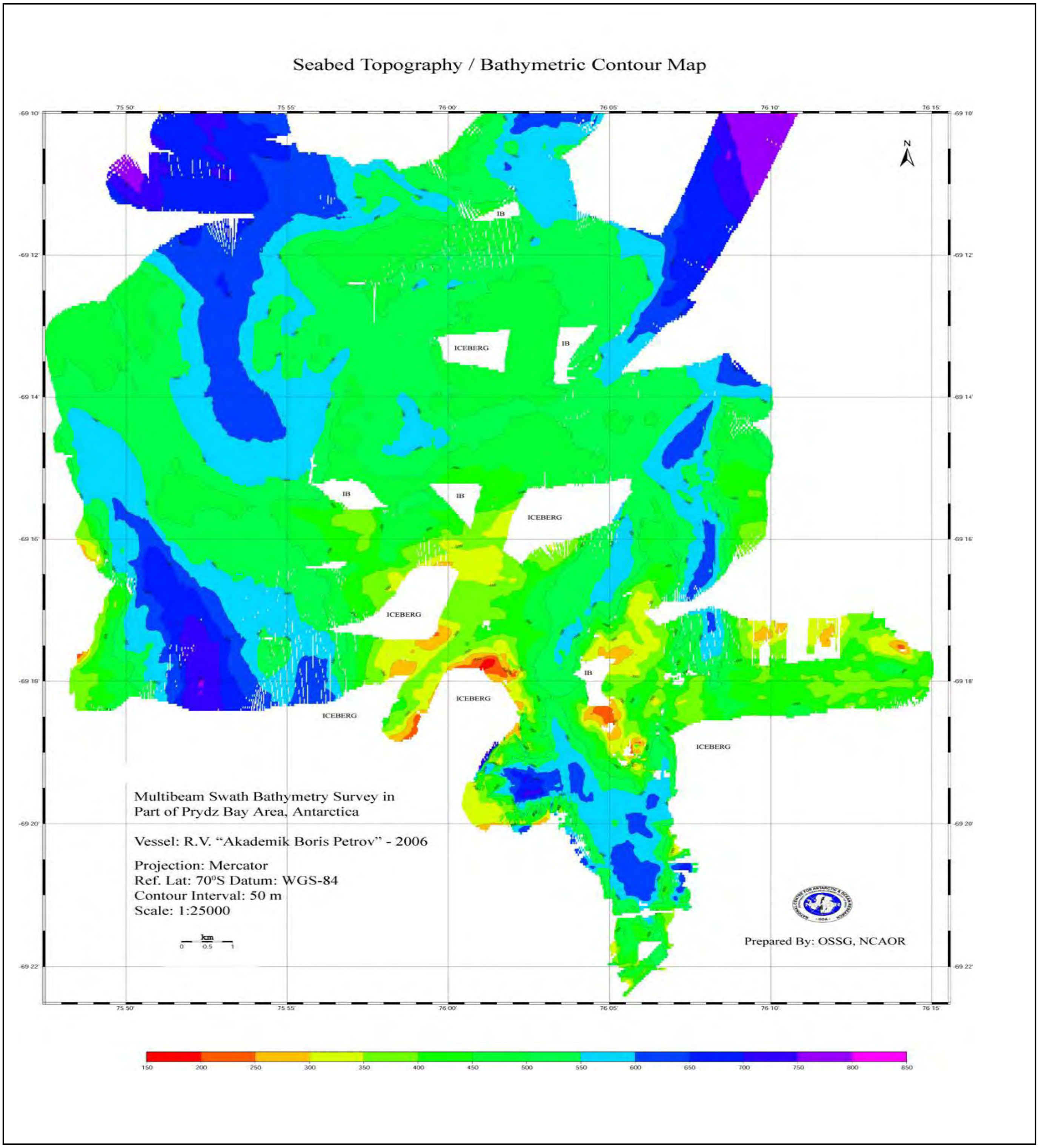
Appendix2

Seabed Topography / Bathymetric Contour Map



Appendix 3

Multibeam Swath Bathymetry in Other part of Prydz Bay

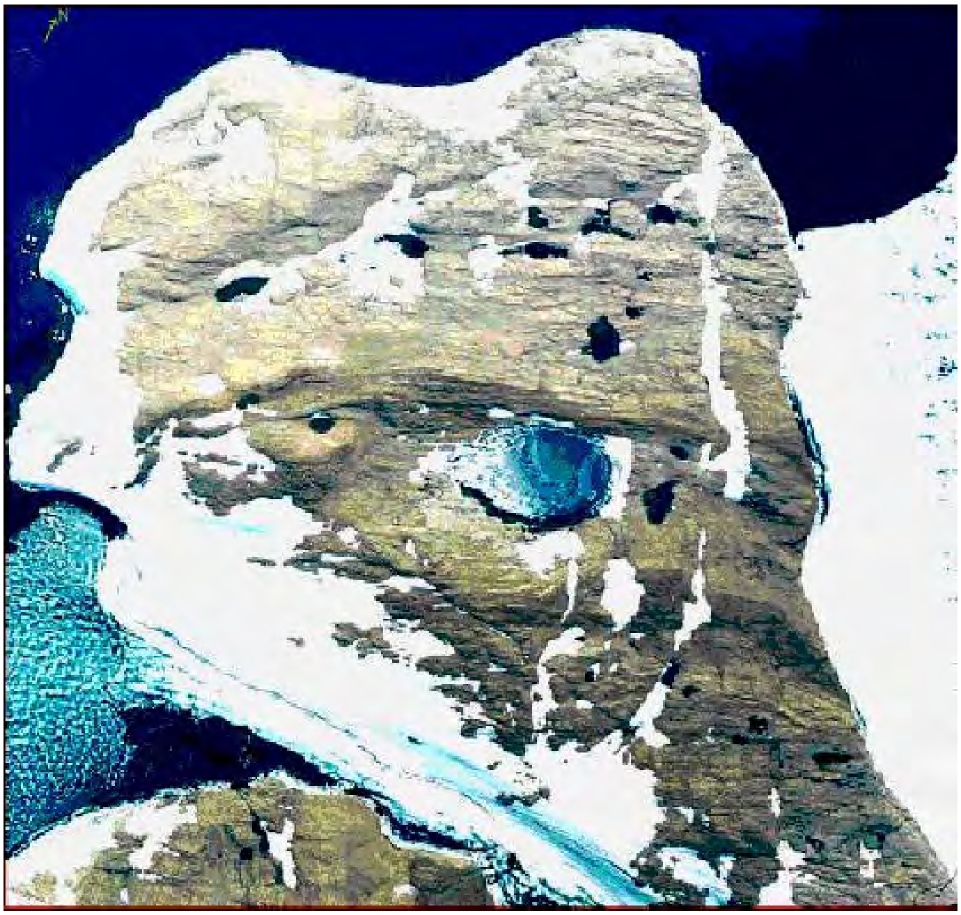


Appendix 4

Annual weather/climate characteristics at Zhongshan (after Turner and Pendlebury, 2004)

Month	Mean daily temperatures (°C)	Highest daily maximum temp. (°C)	Lowest daily minimum temp. (°C)	Mean relative humidity (%)	Mean cloud amount (oktas)	Mean wind direction	Mean wind speed ($m\ s^{-1}$)	Maximum wind gust ($m\ s^{-1}$)	No. of days of gales	Mean MSL pressure (hPa)
Jan	0.4	8.1	-6.8	61	5	E	5.3	33	9	987.9
Feb	-2.7	7.4	-10.6	56	5	E	7.1	33.8	13	985.4
Mar	-8.3	2.3	21.9	56	5.5	E	7.7	44.1	14	985.1
Apr	-12.4	4.8	-29.4	49	4.9	ESE	8	46.2	14	988
May	-16	1.9	-35	57	4.6	ESE	6.9	46	11	987.5
Jun	-14.4	1.2	-36.3	58	4.8	ESE	8	48.1	17	989.9
Jul	-15	2.2	-36.7	56	4.4	E	7.9	47.2	18	987.6
Aug	-15.6	0.9	-39	53	5	ESE	8.4	36.6	18	981.4
Sept	-16.3	0.9	-34.2	52	4.6	ESE	7.8	47.5	15	980
Oct	-11.6	1.7	-28.3	54	4.9	ESE	7.4	48.3	16	981.4
Nov	-5.7	5.1	-19.5	56	5.2	ESE	6.4	35.6	13	985.4
Dec	-0.2	9.6	-11.5	53	4.5	ESE	5.9	38.6	13	985.1
Yearly	-9.8	9.6	-39	55	4.9	ESE	7.2	48.3	171	985.6

Station (69° 22' S, 76° 22' E, 15 m AMSL), Princess Elizabeth Land (1989-95)



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