PETREL ANTARCTIC BASE RENOVATION, DUNDEE ISLAND, ANTARCTICA

DRAFT COMPREHENSIVE ENVIRONMENTAL EVALUATION (CEE)

Ministry of Foreign Affairs, International Trade and Worship

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EXECUTIVE SUMMARY

Introduction

This draft Comprehensive Environmental Evaluation (CEE) has been prepared by the Environmental Management and Tourism Programme of the Argentine National Antarctic Directorate to assess the potential environmental impacts associated with the proposed renovation of the Petrel Base on Dundee Island in Antarctica. These actions are necessary because the state of the current facilities of the Petrel Base presents risks to both the environment and its personnel, and the maintenance or repair of these facilities would be insufficient to achieve adequate environmental performance.

In 1976 the Petrel base became a temporary summer base, after a fire destroyed its main accommodation building. From that moment on, the activity at this base, which functioned as both an air and naval station, was significantly reduced, limited to periodic maintenance for short periods of time in the southern summer. Its air activities were transferred to the Marambio base, which has constituted the hub for the Argentine Antarctic Programme air activities from 1976 to the present.

In recent years, the increase in scientific activity of the Argentine Antarctic Programme, added to changes in climatic conditions and the new means incorporated into the activity, has made us rethink the way we carry out our science and the consequent logistical support required. Therefore, the development of the Petrel base also highlights the inconveniences that arise in the access, operation and maintenance of the Marambio base in order to support the activity of the Argentine Antarctic Programme.

This draft GEA has been prepared following the requirements of Article 3, Annex I to the Protocol on Environmental Protection to the Antarctic Treaty and the Revised Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1 [2016]) and the applicable laws of Argentina.

Activities to be carried out

The scope of this draft Comprehensive Environmental Evaluation (CEE) includes all activities in the Antarctic Treaty Area associated with the renovation of the Petrel Base. These include the following project components:

- Renovation and use of Base facilities
- Construction and use of a new runway
- Construction of the photovoltaic power plant
- Improvement and use of water supply lagoons

The proposal for remodelling the Petrel Base includes all activities related to the design, construction and use of the new base, also including the dismantling of existing buildings, civil and foundation works, fitting-out works, logistics and transportation, and installation and commissioning of the new base.

New runway construction activities refer to the construction and use of runways and associated ground facilities, temporary on-site facilities during the construction phase, the installation and use of machinery, and runway maintenance and dismantling.

The activities related to the construction and use of a photovoltaic power plant refer to that of an array of solar panels and include design options for the solar park, the construction and installation of solar panels in the solar park, civil and foundation works, construction and logistics, and the installation and commissioning of the new photovoltaic power plant.

Finally, the activities described in this GEA refer to the design and establishment of lagoons to supply water to the Petrel Base, and include design options, construction, civil works, and logistics for water supply to the Base.

The temporary scope for the Petrel Base renovation begins in the summer of 2023/24, with Phase II for Fitting-Out and Services lasting until the end of summer 2028/29 according to the following general schedule:

Preparation phase: Studies

The objective of this phase is to plan the development of the base, solving implementation problems, establishing the different phases, material requirements and execution times. Although decisions will be made throughout the base modernisation process, it is during this phase that the most crucial decisions will be made, relating to the design parameters to be implemented and the capabilities to be developed to meet the needs of the Argentine Antarctic Programme.

Phase I Petrel, permanent base[1]

The objective of this phase will be to change the situation of the Petrel Base before the Antarctic Treaty community, from a temporary base to a permanent base, assigning a team for overwintering. In conjunction with a summer work team, this team should start the renovation activities at the base. The objective of this phase responds to the need to maintain the base operational throughout the year in order to carry out maintenance and improvement activities.

Phase II Fitting-out and services

The objective of this phase is to increase staff accommodation capacity, while ensuring enough space for storing the materials and machinery necessary for development of the base. This will achieved by starting the construction of a new accommodation building, commissioning the base hangar, using the old buildings, removing any unused structures or those currently without a purpose, and the environmental correction of the base through the collection, classification, storage and withdrawal of the historical remains of the base.

Phase III Provision of own services

The objective of this phase is to launch the use of the base as a scientific centre and to use the base as a passenger and cargo transfer terminal for the Argentine Antarctic Programme.

Phase IV Provision of services to third parties

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1 As part of this preparatory phase, an Initial Environmental Assessment (IEA) was made, available at IEA - Repair and Maintenance Works at Petrel Base, Dundee Island. 2021-2022 Summer and Winter Antarctic Campaign.

The objective of this phase is to enable use of the base as a transfer terminal for passengers and cargo to other Antarctic programmes with the surplus capacities of the base.

Phase V Consolidation

This phase will consist of the optimisation of the systems and services provided by the base, focused on achieving the greatest efficiency in its operation. During this phase, evaluation of the achievements and the possibilities will become more important for improving the base in light of the services provided to the Argentine Antarctic Programme and eventually to other programmes. Any processes designed to duplicate the means required to achieve greater flexibility in the services provided will begin during this phase.

Alternatives

When analysing alternatives, the option of not renovating the Petrel Base was considered at the beginning of the project, and the alternative of improving the current buildings was also considered many times. These alternatives were discarded because in the short term they would imply the closure of the Petrel Base, since the services, systems and facilities have no longer completed their life cycle. In fact, the alternative of using it as a temporary base was not efficient. Different design alternatives were therefore considered for the Base, the type of buildings, the type of civil and mechanical engineering solutions for building and operating the station and the proposed runways, the different orientations and length of the runway, the options for photovoltaic power plants, as well as the logistics for the project and the dismantling of the existing station.

Environmental conditions

The Petrel Base is located at the northern end of the Antarctic Peninsula, the region with the highest activity on the entire continent. Specifically, the Base is located on Dundee Island, and within the only ice-free area on the island: Cape Welchness. This sector consists of a triangular area covering approximately 2.5 km^2. Most of this area has a very flat surface, with a drop of only a few metres, especially on its outer edges, which border the sea and are eroded by small streams, with the other margins marking the crest of the lateral moraine of the Rosamaría glacier. The maximum extent of this flat sector is 1950 m north-east to south-west and 1400 m north-west to south-east. The environmental conditions of Cape Welchness, its geographic location, the local characteristics of the terrain and the meteorology make it suitable for the construction of a runway for various types of aircraft.

Environmental Impact Assessment

This draft EIA presents a full Environmental Impact Assessment for the proposed activities. The methodology for the impact assessment is based on the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1 [2016]) and follows a four-step analysis that includes:

1. Identifying the activities and actions involved;
2. Identifying environmental components that are exposed or at risk;
3. Identifying the effects of the proposed activities;
4. Identifying the impacts;
5. Assessing the significance of the impacts identified; and

6. Establishing the necessary mitigation measures.

The assessment identifies a variety of direct, indirect, and cumulative impacts on exposed environmental components. The most significant environmental impacts expected from the proposed activities are:

- The release of greenhouse gases that contribute to global climate change due to the use of vehicles and machinery;
- Alteration in the physical landscape, in watercourses and meltwater pathways and alteration of permafrost due to the introduction of anthropic elements;
- Modification of soil quality due to the release of chemical substances during construction or when there are spillages or leaks;
- Modification of the network of surface watercourses due to the construction of buildings and the runway; and
- Degradation of the marine coast due to the use of vessels and the release of effluents.

In general, the proposed activities are expected to generate a number of environmental benefits, including:

Reduced contribution to global climate change through increased renewable energy generation and increased efficiency of the proposed station buildings and systems;

Reduced pollution of the local marine environment through best practices in wastewater treatment;

Reduction of the risk of introduction of non-native species by the application of procedures and guidelines;

Better support for science through better laboratory spaces and better facilities.

Mitigation measures

A total of approximately 30 mitigation measures were established, the most significant being:

- applying the measures established in the Non-Native Species Manual;
- complying with the provisions of the Waste Management Plan and in the Instructions for preparing base waste;
- evaluating the site in accordance with the CEP's Clean-Up Manual and (b) complying with the provisions of the Waste Management Plan and in the Instructions for preparing base waste;
- avoiding the formation of snow tails and ice foots, (b) affecting the minimum possible surface, (c) not incorporating anthropic elements on surface watercourses and (d) controlling that there is no accumulation of water; and
- respecting the provisions of Resolution 2 (2004) - Guidelines for the operation of aircraft near concentrations of birds in Antarctica and (b) establishing flight routes that avoid overflying concentrations of birds.

Monitoring programmes

A monitoring programme has been established that aims to obtain regular and verifiable information on the impact of the Petrel Base renovation activities by establishing environmental condition and performance indicators to monitor the project's effects on the environment and assess the need to suspend, cancel or modify the activities. It has three components:

- Environmental Condition Monitoring Programme;
- Environmental Performance Monitoring Programme, and
- Climate Change Monitoring Programme.

Conclusions

After a comprehensive evaluation of the proposed activities and their related mitigation measures, it has been concluded that the proposed activities are likely to have a greater than minimal or transitory impact on the Antarctic environment. We thus conclude through this draft GEA that the proposed activities should proceed on the basis that the positive impacts in terms of improvements to safety, environmental protection, and ability to support science are generally greater than the negative impacts associated with the proposed activities.

1 INTRODUCTION

Since 2002, the Argentine Republic has been considering the need to achieve greater efficiency in the activities it carries out in the Antarctic continent, concentrating it on supporting national scientific and technological activity and on the ability to provide to other countries any services and knowledge necessary to facilitate their Antarctic tasks, when so requested.

For this reason, the Environmental Management and Tourism Programme of the National Antarctic Directorate has prepared this draft Comprehensive Environmental Evaluation (CEE) to assess the potential environmental impacts associated with the modernisation of the Petrel Base. The project consists of the following elements: renovation of the current base buildings, construction of new buildings, construction of an airport area with two runways, construction of a photovoltaic power plant and the expansion and use of two lagoons for water supply. The proposed activities are necessary because the current buildings, facilities, and associated infrastructure at Petrel Base pose numerous environmental risks and their repair is not efficient.

1.1 Petrel Base

1.1.1 Petrel Base Location

Petrel Base is located on Cape Welchness, Dundee Island, situated east of the north-eastern tip of the Antarctic Peninsula and south of Joinville Island, in the Joinville Archipelago. Dundee Island has a circular shape with a maximum extension of 27 km in an E-W direction. Its 450 km^2 are currently almost totally covered by glaciers that form ice gullies that fall sharply into the sea (Figure 1).

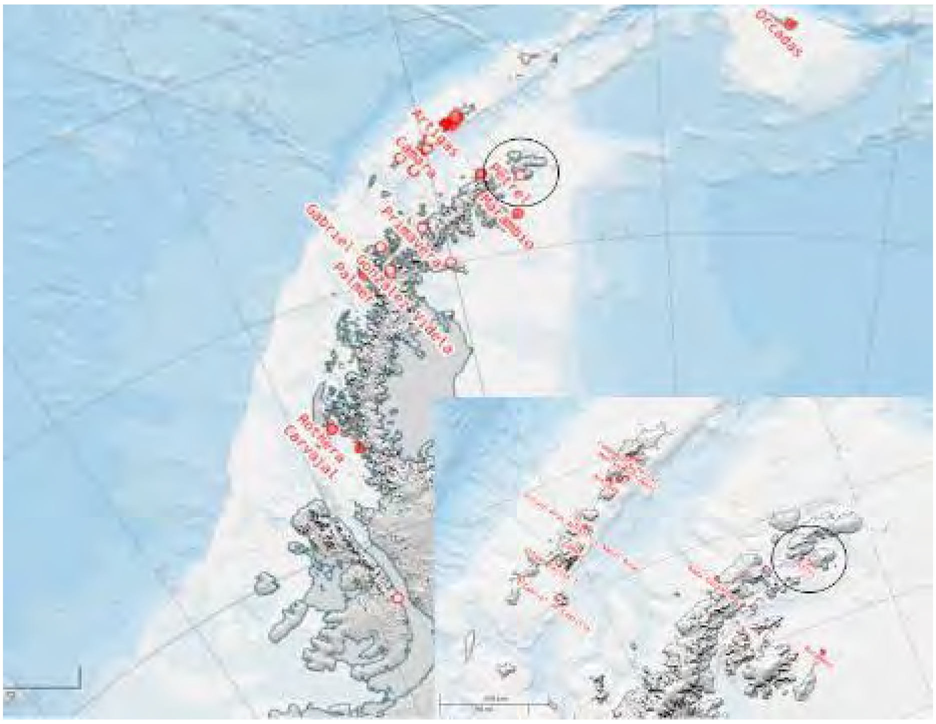

Figure 1: General location of the Petrel Base on Dundee Island, in the north of the Antarctic Peninsula.

On the island, one of the few ice-free areas is Cape Welchness, located on the western part of the island. This cape consists of a triangular area covering about 2.5

km^2. On the east it borders the extensive ice cover of the island, from which it is separated by the crest of the lateral moraine of the glacier called "Rosamaría" (Figure 2).

Figure 2: Location of Petrel Base on Dundee Island and specifically on Cape Welchness.

Most of Cape Welchness presents a flat surface with a drop of only a few metres, especially on its two outer edges that border the sea and are eroded by small rivulets. The extent of the ice-free flat sector is about 1500 m in a NE-SW direction, and 1400 m in a NW-SE direction. The environmental conditions, geographical location, local characteristics of the relief and meteorology indicate that Cape Welchness was an appropriate place for the construction of areas to be used by aircraft of different sizes.

The base facilities were located on rocks 18 metres above sea level, at the foot of the Rosamaría glacier in Petrel Cove (the only and relatively small ice-free area on the island, with access by sea and by air via air-planes with skis), on Punta bajos in Cape Welchness on Dundee Island in the Joinville archipelago (Figure 3). Its geographic coordinates are 63°28’S 56°17’W.

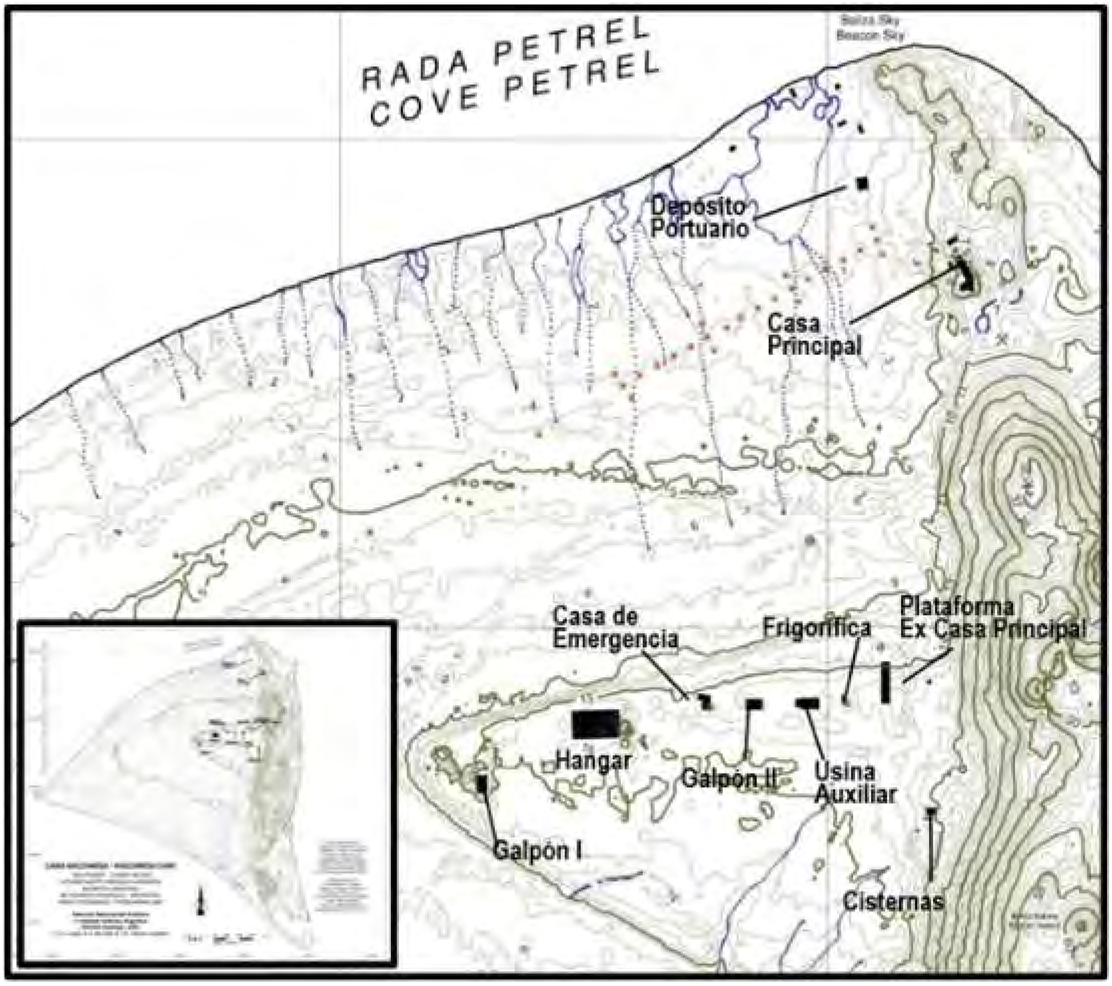

Figure 3: Location of the Petrel Base facilities at Cape Welchness.

Cape Welchness consists of a relatively flat, triangular area covering about 2.5 km^2. This triangular-shaped plain borders on one side with a high ridge of glacial sediments ("moraine") that runs roughly N-S, parallel to the local edge of the Dundee Island ice field (Rosamaría Glacier), and with the sea, with Petrel Cove to the north and the Antarctic Strait to the south. In its central part, and bordering the moraine of the Rosamaría glacier, there is a zone of homogeneous height that is 5 to 7 metres higher than the lower zone, constituting the so-called upper platform.

The lower platform is a flat surface with irregularities of a few metres in height, especially on its outer edges that border the sea and are eroded by temporary streams. It has an average elevation of 4 metres above sea level, is gently undulating and has an area of approximately 1 500 000 m², with a maximum length of 1 900 m in the NE-SW direction (in the direction of the observer's line of sight) and 1 400 m in a NW-SE direction. In the SE sector there are active temporary streams that have eroded channels that are more than 2 m deep.

1.1.2 History of the Petrel Base

The British sailor James Clark Ross had seen it on his Antarctic expedition (1839–1843), but did not recognise that it was an island. On 8 January 1893 it was recognised as an island by Captain Thomas Robertson, during a whaling expedition from Dundee (Scotland), from where his ship set sail along with three other ships.

At the end of the 1940s, the Cape Welchness area of Dundee Island had been selected as a preferred point to install aeronautical infrastructure there given the physical and meteorological conditions of the location. The Petrel Naval Refuge was built there during the 1950/51 Antarctic Naval Campaign. From that year onwards, a permanent crew was maintained at the base. Used by the Naval Aviation between 1951 and 1966, all the reports collected for nearly 15 years endorsed the permanent installation in Dundee of a Naval Air Station. The base facilities were located on rocks 18 metres above sea level, in Cape Welchness, Punta Bajos at 63º 28’ S and 56º 17’ W, the only and relatively small ice-free surface on the island, with access by sea and by air via planes with skis.

On the north side of Cape Welchness is the best anchorage in the area, Petrel Cove, which is well sheltered from the frequent and violent westerly winds. The only drawback of the cove is the persistence of ice that closes it off for much of the year. Between the cape and the interior glacier of the island there is a high moraine with stony materials and some fossils carried by the ice, presumably from somewhere very far off.

The month of January is usually the most appropriate to operate with ships, aided by three beacons: Balbino, Sky (the only one still at the base) and one that indicates Punta Bajos, a dangerous sector to navigate due to its shoals and rocks just below the surface of the water. During the 1966/67 Antarctic Naval Campaign, the Naval Construction Battalion carried out works that resulted in a firm ground runway (gravel-soil), thus improving the existing one and making it 850 m long and 40 m wide. Beacons, a metal hangar, an accommodation building, communication equipment, antennas, a workshop and other means were also added.

In December 1966 it was named the "Petrel Naval Detachment"; The new construction was inaugurated on 22 February 1967. The base was equipped with different types of aircraft (''Beaver'', "Twin Otter”, "Hiller Porter") and carried out tasks of air-naval and naval traffic control in the area, carrying out important survey and salvage tasks.

In August 1971 the base was the starting point for the air rescue of a wounded and a sick person from British base Fossil Bluff, located at 71º South latitude, on the east coast of Alejandro Island
I. A Fairchild Pilatus PC-68 aircraft, registration 4-G-1, was deployed for this task. The itinerary followed was from Petrel base, passing through Matienzo base, Palmer base, Adelaida base, Fossil Bluff base. And from there to the Palmer base - Marambio base, the city of Río Gallegos, the city of Buenos Aires, where they were taken to the British Hospital.

The British government thanked our country for this rescue, which is a little-known fact, but it was one more milestone in the history of the rescues carried out by our country on the white continent. During the winter of 1974, a fire in the main house forced the evacuation of all the staff and the temporary readaptation of a workshop as a home. In February 1978 it became a temporary summer base. The studies aimed at reactivation of the base were resumed at the beginning of this century, and the decision to advance these studies was made during the year 2020.

Since 2002, the Argentine Republic has been considering the need to achieve greater efficiency in the activities it carries out in the Antarctic continent, concentrating it on supporting national scientific and technological activity and strengthening its ability to provide to other countries any services and knowledge necessary to facilitate their Antarctic tasks, when so requested.

The studies required that the efficiency sought did not demand a greater number of ships, aircraft and vehicles than those used up to that moment in the scientific, technical and logistic activities of the Argentine Antarctic programme. Similarly, they should not involve a greater use of ships and aircraft, that is, they should maintain the same number of days of use of the ships and flight hours of the aircraft.

After various analyses, surveys were carried out to determine the aptitude, feasibility and acceptability of the reconditioning of Petrel Base as a multimodal cargo and passenger exchange centre. Achieving this would require the development of a deep-water port and an aerodrome suitable for year-round operation of medium and small aircraft, together with the services associated with these two modes of transport.

Thus, it was determined that the development of the Petrel Base “would allow the expansion of the possibilities of the city of Ushuaia and create an air bridge between this city and Petrel”. The actions to reactivate the Petrel Antarctic Base as a temporary base began on this date. The first overwintering was planned for the 2015/2016 campaign, but this could not be materialised due to several drawbacks and the base only continued to operate on a temporary basis. As of the 2017/2018 campaign, budget adjustments prevented it from opening as a temporary base, and it remained closed until it reopened permanently during the Antarctic summer campaign of 2022.

1.1.3 Petrel Base Description

The Base's facilities are located in two well-differentiated sectors. The first sector, the Accommodation Building, is located in the northern sector of Cape Welchness, on the downward slope of the frontal moraine that marks the limit with the glacier (Figure 4). The Port Depot is on the coast. The rest of the facilities are located on the upper platform of the area, constituting a series of buildings arranged in a linear fashion (E-W).

Figure 4: View of Petrel Base.

The current buildings at the base are (Figure 5):

- Accommodation Building.
- Main Power Plant.
- Hangar.
- Facilities Depot (tools and hardware spare parts).
- Cold Room.

- Cisterns.
- Auxiliary Power Plant.
- Emergency House.
- Vehicle Shed.
- Runway

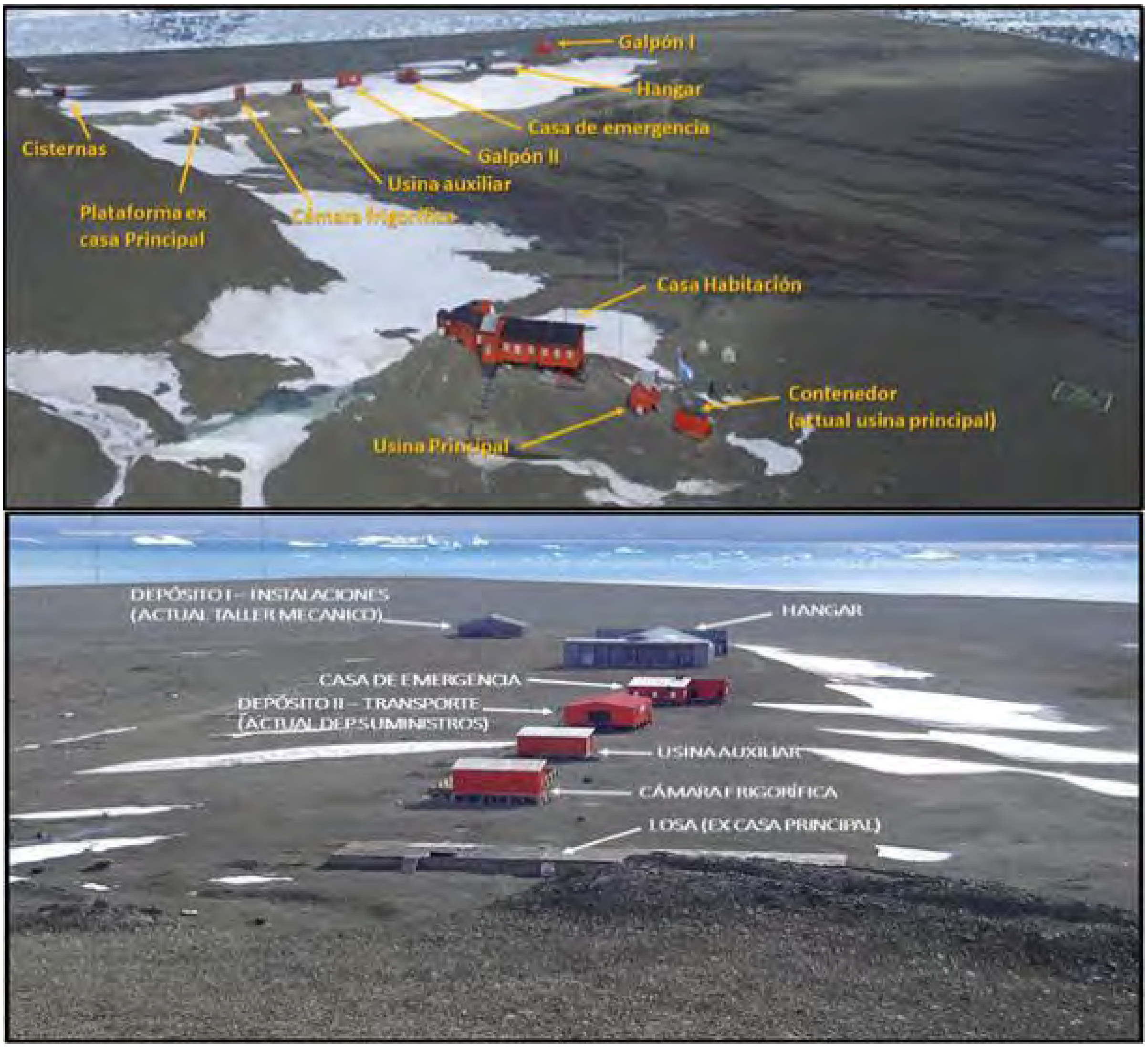

Figure 5: View of the buildings currently making up Petrel Base: Accommodation Building, Main Power Plant, Hangar, Facilities Depot (tools and hardware spare parts), Cold Room, Cisterns, Auxiliary Power Plant, Emergency House and Vehicle Shed.

1.1.4 General Description of the Facilities

The buildings date from the origins of the base and have not been maintained in recent decades, therefore many are in poor condition. Some are minimally inhabitable. In this context, there are two series of buildings located in the base area. One series consists of the hangar, the former power plant, the emergency housing, the vehicle shed and the cold room (Figure 5). These are aligned perpendicularly to the Punta Bajos headland. The other series is made up of the main house (accommodation), the power plant and a materials enclosure, arranged in columns in reference to the moraine deposit produced by past activity of the Rosamaría glacier. All these buildings suffer from the wear caused by the passing of the years, the climate and the lack of regular maintenance during the time the base has not been in use. This is to highlight that the two groups of buildings are at least 500 m apart. The facilities that currently make up the Petrel Base are as follows.

Figure 6: General view of the Main House.

1.1.4.1 Main House

It is located in the northern sector, on the lower platform close to the moraine of the glacier. It is located 450 m from the group of service facilities. The house is made of wood panels with a corrugated sheet metal roof (Figure 6). It is made up of five modules that indicate its construction in stages. It has a total area of 275.34 m². It was fitted out in the years in which the base was operated as a temporary base. It is a construction consisting of five parts, which are:

- Accommodation (eight Bedrooms).
- Bedroom, Living Room, Games Room, Infirmary and Radio Station.
- Bathroom, Mezzanine and Entrance Hall.
- Dining Room.
- Kitchen and two Depots.

It was fitted out in the years in which the base was operated as a temporary base. The last year of operation, new wiring was placed and stoves were installed so the Petrel Base could operate throughout the year. At present, works continue to be carried out in the electrical, gas, water, sewage and insulation systems for optimal functioning of the house. Except for the aforementioned works, no large infrastructure works were carried out on the house since it has been planned for removal. The house will remain in use until it is replaced by the new main house of the base. Once the replacement is in use, it will be disassembled.

1.1.4.2 Hangar

A metallic construction covered with corrugated sheet of about 1150 m^2 (25.3 m wide by 45.5 m long). It has a concrete floor and two access gates. Its structure is in a good state; although some corrugated sheets need to be replaced and the gates need to be entirely repaired or replaced, since their bearings and guides are in an advanced state of corrosion. Each gate has eight leaves and each leaf is 3 m wide and 6 m high. In recent years, it housed a large amount of waste (which has been removed) (Figure 7).

Figure 7: General view of the hangar in 2005.

1.1.4.3 Emergency House

The building is in very good condition. The electrical, water and gas installations must be completed. It has limitations in terms of the sewage system because it is located about 500 m from the coast. Capacity for 12 people. It consists of a 6.45 x 9.04 m bedroom, a kitchen and a bathroom. Part of the kitchen needs to be finished, as well as part of the bathrooms.

1.1.4.4 Warehouse I - Facilities Warehouse

A shed of 27 x 10 m with a ceiling height of 7 m. It is used to store hardware materials and tools (Figure 8).

Figure 8: General view of Warehouse I

1.1.4.5 Warehouse II

A wooden building of 16 x 10 x 4.3 m (maximum height). It is in good condition. The Base's MB Unimog vehicle was kept here. It is the ideal place for installing the incinerator and compactor. This building is expected to be maintained throughout the development of the Petrel Base renovation project (Figure 9).


Figure 8: General view of Warehouse II

1.1.4.6 Former Power Plant (current secondary power plant)

It consists of a container that is next to the Main House. Inside is a 2-cylinder 31KVA DEUTZ TYPE A2L power generator (UP TO 45 A) – three-phase – 380 Volts/50 Hertz with neutral. This generator feeds only the sector with the house. It is in perfect condition and the generator works perfectly. Next to this container another shed was made to place another generator set (Figure 10).

Figure 9: General view of the former power plant (emergency power plant).

1.1.4.7 Cold Room

The cold room building has a size of 3.9 x 8.60 x 4.16 m at its highest point and 3.44 m at the lowest. Inside it has a cold room in perfect condition, although without a motor (Figure 11).

Figure 10: General view of the Cold Room.

1.1.4.8 Power Plant (current facilities workshop)

Building whose interior consists of two premises. One for installation of a generator and another a bedroom for the plant personnel on guard. Inside it is installed a DEUTZ BF 6L913 generator engine. The auxiliary power plant used to provide electricity to the building group located on the upper platform of the sector (all facilities except the Main House) (Figure 12).

Figure 11: General view of the Power Plant (in disuse)

1.1.4.9 Port Depot

Depot located near the coast and which has been used to store boats and other materials associated with activities carried out in the marine area (Figure 13).

Figure 12: general view of the Port Depot.

1.1.4.10 Cisterns (unused)

The base has only 2 cisterns, of 30 000 litres each. They are out of service and must be removed. For this reason, during these last Antarctic campaigns, all the fuel used for electricity generation was transported in 200-litre drums (Figure 14).

Figure 13: General view of the Fuel Cisterns, currently not in use.

1.1.4.11 Runway

Three aircraft runways were built, designed and built in the mid-1960s at Petrel Base. It was precisely in the month and year that the base opened that one of the runways was used by a Beaver brand aircraft (4-G-1). For decades, and to this day, none of the runways is in use. Therefore, due to the action of natural agents (meteorological, edaphic and glaciological), it can no longer be said that they continue to operate as such. One of the main agents that have caused this effect are the various rivulets that cross them, and today they could not even be used as emergency runways. Alternatively, small planes such as Twin Otters can land on the Rosamaría glacier, although some summers the glacier may not be operational due to glaciological/climatic reasons, as happened this summer. Finally, the station has a heliport near the current main house that is in good condition (Figure 15).

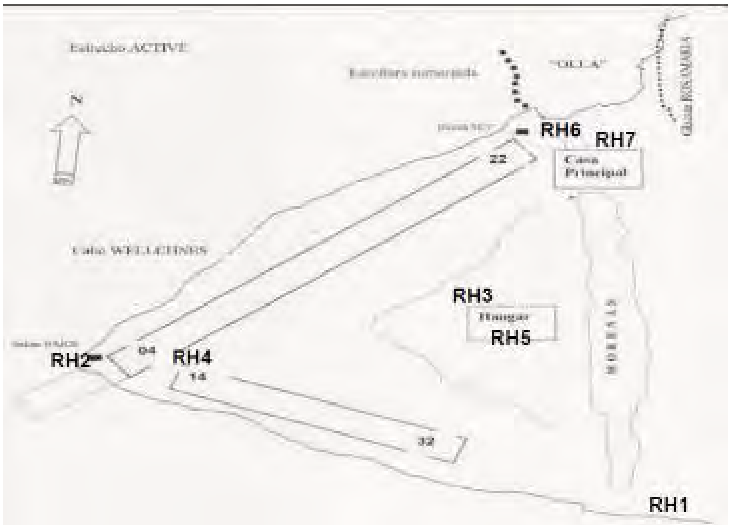

Figure 14: Location of the runways the Base used to have.

1.2 Need for remodelling the Petrel Base

The Argentine Antarctic Programme has maintained an uninterrupted presence in Antarctica for 118 years, focusing on scientific activity and, since 1959, supporting and strengthening the Antarctic Treaty as an original signatory country. This presence was accompanied over the years by a logistical development adapted to the objectives and needs of each moment. Thus, a network of permanent scientific stations, summer stations and refuges was configured which, with the logistical support of various means of transport, allowed carrying out our country's activities in Antarctica.

Over the course of the decades, some of the bases and shelters changed their configurations. Some of the permanent bases changed to summer bases and vice versa, while others were permanently or temporarily deactivated. To date, Argentina has 6 permanent stations and 7 summer season stations in Antarctica. In this context, the challenges of the 21st century have driven new revisions both within the national programmes and in the debates held in the different forums of the Antarctic Treaty.

Thus, the process carried out in 2014 by SCAR, *Horizon Scan*, allowed Antarctic researchers of different nationalities to explore what the critical research questions for the next decade and beyond would be, in recognition of the growing importance of Antarctic science and research in global debates. For its part, in 2015, the project *ANTARCTIC ROADMAP CHALLENGES (ARC)*, led by the Council of Managers of National Antarctic Programs (COMNAP), was the next step. Recognising that Antarctic logistics requirements are complex and challenging, the ARC project allowed the science support community to discuss all critical questions identified by *Horizon Scan* and think about the many aspects of logistics support, including infrastructure, technology and energy requirements.

These works, in which our researchers and logisticians actively participated, contributed to the internal debates of the Argentine Antarctic Programme, which had already entered the 21st century with a broad logistical deployment, but one which had to be rethought in light of the new challenges and in search of greater efficiency. The current need for logistical support of Argentine scientific activity and the growing international cooperation, encouraged by the good ties between the national programmes and the incorporation of new members of the Antarctic Treaty, were determining factors when evaluating whether the logistical capacities of the existing infrastructure required adaptation. Today, the provision of logistics capacities for essential and extraordinary services and the availability of supporting infrastructure are required to provide access to the region.

This framework included debates that had begun at least 15 years ago, in relation to the situation of Petrel Base, located on Dundee Island and which suffered a major fire in the 1970s, which is why it ceased to function permanently, operating since then only as a summer base, but without activities other than a minimal maintenance of the remaining infrastructure. In a joint interministerial effort, there was an assessment regarding reconditioning of the Petrel station to provide it with capacities that give it a role as a logistics centre that can be used throughout the year to support the scientific activities of our National Antarctic Programme.

The potential to once again harbour an operational airstrip that allows the direct combination of air and sea transport in a coastal area was evaluated, resulting in great interest to improve the logistics capabilities and provide more and better logistics support to science within the framework of the challenges of the 21st century.

Considering that there are vast regions of Antarctica that remain virtually unexplored, a more effective use of existing facilities, rather than the expansion of infrastructure at other sites, was evaluated as a way to increase scientific performance. The ability for rapid deployment of teams of scientists to rapidly changing regions to collect baseline observations was also considered a priority.

For its part, the recovery of the icebreaker ARA Almirante Irizar (RHAI) and the acquisition of new ships (small despatch vessels) in 2015 were also determining factors in the decision. Having recovered these capabilities, the modernisation of Petrel Base will create a synergy that will enhance logistical support for science in a scheme that results in positive savings. A facility of these characteristics will serve as a point of support not only for the development of Argentine Antarctic activity, including the exercise of the SAR (search and rescue) responsibilities of our country, but also to support the activities of other national programmes.

Likewise, the remodelled Petrel Station will facilitate the connection between the Antarctic continent and South America, especially with the city of Ushuaia in Tierra del Fuego, one of the “gateways" to Antarctica. This Argentine city that offers logistic, scientific, academic and tourist services can now be combined with a centre located in Antarctica with joint port and airport operational capacities, which will expand the possibilities for the development of science on the white continent, an essential objective of the Argentine Antarctic Programme.

The evaluation of the base modernisation not only considered the possibility of expanding and providing flexibility in the transfer capacity of scientific groups, but also considered that it was essential to provide the same base with new scientific infrastructure capacities, thus planning the construction of a 462 m2 laboratory with capacity to house 8 (eight) laboratories. Both this laboratory and the expanded logistical capabilities to reach new places on the Antarctic continent will broaden the horizon of multidisciplinary research and international cooperation that our country can sustain.

Fully in line with the discussions in the Antarctic Treaty forums, continued and enhanced cooperation remains a high priority for our country, recognising that no country has the means to simultaneously pursue all aspects of top-priority Antarctic science. Parties are required to work together to achieve Antarctic scientific goals and priorities.

In conclusion, this project expects to achieve the provision of greater access throughout the region and throughout the year and the availability of logistics and infrastructure that enables researchers to do their best work where it is needed. In this way, we expect to contribute to increase the chances of success and meet the scientific priorities of our country and the Antarctic community, in an efficient and cost-efficient manner. Finally, all these new logistical capacities may be made available to other National Antarctic Programmes in order to strengthen international scientific cooperation, one of the essential pillars of the Antarctic Treaty System.

Also, the northern part of the Antarctic Peninsula (AP) is one of the places most affected by climate change in the world (Chown et al, 2022; Turner et al. 2009). This area, which is undergoing processes of great change, is the area where the Argentine Antarctic Programme has its largest concentration of scientific stations and, therefore, where it has the largest deployment of scientists and projects throughout the year, especially in summer.

Renovation of the Petrel Base is also necessary for two other reasons, in addition to those previously stated in relation to the Argentine Antarctic Programme. On the one hand, the current situation of the Petrel Base – due to its non-regular use – raises, on the one hand, the need to attend to the emergencies that arise from the environmental aspects and impacts associated with this condition. The state of the facilities exposes the natural values of the island to risks associated with the waste and fuel management, among others. These conditions initially raised the need for its general repair and the general removal of historical residues stored therein. At a later stage, there was an evaluation of the convenience of taking this opportunity to redesign the Antarctic logistics system of our country, with the aim of centralising operations of this nature and the support for science and solving some inconveniences that have been occurring in recent years.

The other condition underlying the need to renovate Petrel Base is that since the runway was created on Marambio Island in 1969, the airborne entry point for the Argentine Antarctic Programme has been Marambio Base. But in recent decades, especially in recent years, the impacts of climate change observed in the permafrost of Marambio Island have made the Marambio runway difficult or impossible to operate on a large number of days, especially in the summer months, which is when the most air activity takes place. This trend has been observed with increasing frequency and has led to the need to reinstate the runway at Petrel Base in order to avoid losing that much-needed logistical capacity for Argentina to carry out its research projects and programs in the region (see alternatives section).

1.2.1.1 Buildings

1.2.1.1.1 Main House

Most sectors of this building have their original bases made up of individual foundation footings, columns and beam underpinning, on which rests a wooden structure with wood siding on the outside and hardboard inside the house. The insulating material used can be seen to be styrofoam (due to hardboard deterioration). The floor of the accommodation is made of wood and the outside roof is made of sheet metal and the ceilings inside of hardboard.

Due to the fact that the construction foundation was laid on active permafrost (soil not suitable for the foundation of structures), some footings have suffered differential settlement. Cracks caused by this cause can be observed. As a solution to these settlements, gabions have been used to reduce the lateral movement of the soil, and in the places where the footing separated from the ground, erroneous solutions were chosen of building footings and pupils between supports, thereby causing a change of moments in the beam leading to cracking (flexural failure in its fractionated portion).

Currently, concrete exposed to the elements shows the destruction of the outer layers caused by freezing, leaving the reinforcement steel exposed with its resulting corrosion. Although efflorescences have not been detected, it is possible that these detachments are aggravated by the use of poorly washed aggregates from the area in the preparation of the concrete. The presence of rust stains on columns and beams indicate that the reinforcement coatings were not made as required.

The sanitary installation is precarious, and its distribution can be appreciated in the Sanitary and Gas Installation Plan in the Main House. It is important to note that there are significant limitations in the supply of drinking water, since the area does not have a water supply (reservoir, lagoon, etc.), nor reverse osmosis desalinators that allow water to be supplied from the sea.

The house does not have central heating. The dining room has a wood-burning stove. The rest of the heating is achieved with electric oil radiators and portable kerosene stoves (these elements increase the probability of fires and the accumulation of toxic gases). The base was partially conditioned in the years in which it was operated as a temporary base. At present, tasks continue to be carried out in the electrical, gas, water, sewage and insulation systems for optimal functioning of the house.

Except for the aforementioned tasks, no large infrastructure works were carried out on it. Since it is expected to be removed and it is located in the place that will be the head of the runway that is planned to be built. For this reason, the current house should only be maintained until the new house is built, without carrying out large infrastructure works on it.

1.2.1.1.2 Hangar

Structure built on hard stratified sedimentary rocks. It is estimated, from what can be seen, that it is founded on a 0.5 m thick continuous footing, on which rests a very robust structure of steel profiles and galvanised sheet metal enclosure. The structure can be seen in the Hangar Structure Plan. It is made up of a ridgebeam, fixed-end frames with increased cross sections to reduce buckling due to dents with their respective stiffeners, purlins and bracing.

The floor is made up of concrete slabs, the covered area is 1150 m^2 (25.3 m wide by 45.5 m long). It has two access gates with the same characteristics, 18.03 m wide by 6.6 m high, each made up of eight leaves that slide on steel rails. An access door made of smooth steel plate is located on one of said leaves of each gate. Inside there are two masonry premises made of unplastered cement blocks that serve as offices and depots. Due to the stored rubbish, it has not been possible to take the exact dimensions of these, but they seem to cover a surface of approximately 30 m^2.

The sheets and the structure were joined using J clamps, of different metallic material, without the corresponding insulation. This has caused the effect of a galvanic cell between the galvanised sheet and the aforementioned clamps, due to the different electronegativity of the metals used, with the consequent corrosion of said sheets in the joint areas, some these even showing cuts along the joint line.

Although no type of maintenance has been carried out for a long time, the structure is in an acceptable state of conservation, with some minor repairs due. Due to the lack of maintenance on the gates, the accumulation of rust on the rails and bearings makes it difficult for them to slide normally. On the other hand, the sheets show structural deterioration. Currently, this construction has neither electrical, gas, nor sanitary installations.

There was waste inside that has been gradually removed. It had sectors inside with a foot of ice as a result of leaks in the ceiling. In 2015, work began to remove the waste stored inside the hangar. Finally, during the 2022/2023 campaign, the following actions were carried out (Figure 16):

- Total removal of the waste.
- Complete repair of each of the 8 leaves of the East and West gates of the Hangar.
- Replacement of metal sheets and sealing of leaks.
- Partial repair of exterior masonry.
- Installation of electrical network.
- Painting of exterior.

Figure 15: Current state of the Hangar after the maintenance and conditioning tasks carried out in the 2022 campaign.

1.2.1.1.3 Emergency House

Structure built on hard stratified sedimentary rocks. The construction consists of two well-differentiated buildings (see Emergency House Plan), with their respective structures linked by a beam underpinning (see Emergency House Structure Plan). One of the buildings makes up the accommodation and the other the kitchen and bathroom. Both constructions are built upon individual foundation footings, columns and beam underpinnings (see Emergency House Structure Plan), on which rests a wooden structure with wood siding on the outside and hardboard on the inside of the building, insulated with styrofoam.

The building is in a good state of conservation, although the concrete of the structure is cracked and chipped like the rest of the constructions on the base that have concrete exposed to the elements. During the summer of 2021/2022 the following maintenance tasks were carried out:

- Roof repair and sealing of leaks.
- New electrical installation.
- Installation of heating system
- Adaptation as an emergency house.

This building will be maintained until the new main house of the base is built.

1.2.1.1.4 Warehouse I - Facilities Warehouse

Structure built on hard stratified sedimentary rocks. This construction has similar characteristics to the Hangar. Founded on a 0.5 m thick continuous footing supporting a very robust structure of steel profiles and galvanised sheet metal. As can be seen in the Structure Plan of Warehouse I, it is built with embedded frames with increased cross sections to reduce buckling due to dents with respective stiffeners, purlins, and bracing. The floor consists of concrete slabs. The covered area is 191.36 m^2 (18.4 m wide by 10.4 m long). It has an access gate 2.8 m wide by 2.8 m high, made up of two leaves. It also has a smooth steel plate access door.

Like the Hangar, the sheets and the structure were joined using J-type clamps of different metallic material, without the corresponding insulation, causing corrosion of the sheets at the joints. The structure is in an acceptable state of conservation, requiring some minor repairs, such as changing metal sheets, repairing the gate, etc. This construction does not have any type of facilities (electric, gas or sanitary).

It is currently used as a mechanical workshop. During the 2021 campaign, the following tasks were carried out:

- Replacement of exterior sheets and sealing of leaks.
- Installation of electrical network.
- Construction of an access gate for vehicles.
- Placement of shelves for the storage of tools and spare parts. It is expected to

be removed once the new base workshops are built.

1.2.1.1.5 Warehouse II

Structure built on hard stratified sedimentary rocks. Founded on individual footings that support bolted steel plates. Upon these are placed double T steel profiles, which together with beams of the same material and type, but of different dimensions, support the slabs and the rest of the structure of the shed. The slabs that make up the floor of Warehouse 11 cover an area of 122.72 m^2, and the remaining 40.91 m^2 of the floor are made of wood. The floor of the shed is raised 1.3 m from the ground. The entry has a metal ramp with a slope of 33%, that is, it forms an approximate angle of 20°. Access to this construction is through a 3.3 m wide by 2.6 m high smooth sheet metal gate. This has a pedestrian door for access. The structure can be seen in the Plan of Structure of Warehouse II. It consists of girder trusses, purlins and bracing.

As of 2015, it was used as a vehicle garage where a Unimog 416 vehicle was stored. During the summer of 2021/2022, the following maintenance tasks were carried out (Figure 17):

- Replacement of most of the exterior sheets and sealing of leaks.
- Comprehensive gate repair.
- Ramp removal.
- Electrical installation.

- Placement of shelves.

Figure 16: Maintenance tasks carried out in the 2022 Campaign in Warehouse II.

It currently works as a supply depot. This building is expected to be maintained throughout the development of the Petrel base renovation project.

1.2.1.1.6 Former Power Plant (current secondary power plant)

Structure built on hard stratified sedimentary rocks. The covered area of this building is 40.4 m^2 (4.8 m of façade and 8.5 m long). Building founded on individual foundation footings, columns and beam underpinnings, on which rests a wooden structure with wooden cladding on the outside, without lining on the inside or insulation. Uncoated slabs are supported on the beam underpinnings, which constitute the floor of the construction. The roof is made of sheet metal and wood. It consists of two rooms. One is the old engine room, in which there are two foundations of old generator set engines, and the other would be joined as an office and bedroom.

During the summer of 2019/2020, a DEUTZ BF 6L913 engine generator was installed to provide electricity to the Hangar. The electrical network has been changed and the corresponding engine generator control panels have been installed. Currently, it provides electricity to the building group that is located on the upper platform, except for the cold room.

1.2.1.1.7 Cold Room

Structure built on hard stratified sedimentary rocks. The covered area of this construction is 39.2 m^2 (4 m high, 4 m wide and 9.8 m long). Building founded on individual foundation footings, columns and beam underpinnings, on which rests a wooden structure with a galvanised sheet lining, without interior lining or insulation. Uncoated slabs are supported on the beam underpinnings, which constitute the floor of the construction. The roof is made of sheet metal and a wooden structure. Inside it has a cold room without a motor, but in excellent condition. The concrete exposed to the elements is in the same condition as in the rest of the buildings. It does not currently have any type of facilities and remains unused. It is to be removed and installed in the proposed new Main House.

1.2.1.1.8 Power Plant (current facilities workshop)

Structure built on transported moraine material, near the Main House. The covered area of this building is 44.39 m^2. It consists of three premises (see Power Plant Plan): Power plant, workshop and an unheated entrance hall. The plant is founded on a stand, on top of which rests a wooden structure with wood cladding and an interior hardboard lining with styrofoam insulation. The unheated entrance hall is founded on individual footings that support a precarious wooden propping, upon which rests a wooden structure with wood cladding on the outside and hardboard lining on the inside, with styrofoam insulation.

The workshop is a wooden structure with wood cladding on the outside and hardboard lining on the inside with a styrofoam insulation, whose foundation is entirely propped up. The floor in these premises is made of wood. The roof of the entire building is made of sheet metal and a wooden structure. The concrete exposed to the elements is in the same condition as in the rest of the buildings. Like the Main House, because it was founded on soil that is unsuitable for this purpose, the entire structure of footings, columns and beam underpinnings has had to be propped up.

The building is not currently functioning as a power plant. It is used as a facilities workshop. The electrical system has been renewed, the roof repaired and the leaks sealed to facilitate its use. It is expected to be removed once the new base workshops are built.

1.2.1.1.9 Port Depot

It has been in the same condition for many years. Structure built on transported moraine material. The covered area of this construction is 13.44 m^2 (4.2 m of façade and 3.2 m deep). It is founded on a stand, on which rests a wooden structure with wooden lining outside and inside with no insulation. The roof of the building is made of smooth sheet metal and a wooden structure. It lacks any kind of facility. It is in good condition.

It is proposed to be recycled and used until it must be demolished, since it is located in the area at the head of the main runway.

1.2.1.1.10 Cisterns

At the base, fuels are only stored in 200-litre metal drums. Fuel management was the responsibility a petty officer, the Base Manager and Chief. There are two cisterns close to the antenna field, with a capacity to store 20,000 litres each, but they are out of service. There are obvious signs of high corrosion and their visible disconnection with any building confirm their disuse. Likewise, it is worth noting that they are empty and in their vicinity there were no spills nor odours implying the presence of fuel (Figure 18).

Figure 17: Current status of the tanks at Petrel Base.

1.2.1.1.11 Conclusions on the general condition of the buildings[2]

The general condition of the buildings can be summarised in the following table 1:

Table 1: General condition of the buildings currently located at Petrel Base.

<table>
<tr><th>Buildings</th><th>Structure</th><th>Electrical installation</th><th>Sanitary installation</th><th>Gas installation</th><th>Condition of heating system</th></tr>
<tr><td rowspan="2">Main House</td><td>Bad</td><td>Fair</td><td>Bad</td><td>Good</td><td>Insufficient and dangerous</td></tr>
<tr><td colspan="5">Demolish and build in the airport facilities sector. It will have to be used as the workshop residence during construction of the new Main House.</td></tr>
<tr><td rowspan="2">Hangar</td><td>Good</td><td>Nonexistent</td><td>Nonexistent</td><td>Nonexistent</td><td>Nonexistent</td></tr>
<tr><td colspan="5">Recycle and rehabilitate for use</td></tr>
<tr><td rowspan="2">Emergency House</td><td>Bad</td><td>Not connected</td><td>Nonexistent</td><td>Nonexistent</td><td>Nonexistent</td></tr>
<tr><td colspan="5">Demolish and rebuild a new one with sufficient capacity for the entire base crew. The current capacity is insufficient.</td></tr>
<tr><td rowspan="2">Warehouse 1</td><td>Good</td><td>Nonexistent</td><td>Nonexistent</td><td>Nonexistent</td><td>Nonexistent</td></tr>
<tr><td colspan="5">Recycle and use</td></tr>
<tr><td>Warehouse 2</td><td>Good</td><td>Nonexistent</td><td>Nonexistent</td><td>Nonexistent</td><td>Nonexistent</td></tr>
</table>

[2] Based on the 2006 Petrel Base Technical Report – Evaluation of the feasibility of expanding and modernising the PETREL Antarctic base, commissioned by the National Antarctic Directorate.

	Recycle and use				
Main Power Plant	Bad	Nonexistent	Nonexistent	Nonexistent	Nonexistent
	Demolish and build a new power plant, since the original foundation is deteriorated and unsuitable for the installation of engines.				
Cold Room	Bad	Nonexistent	Nonexistent	Nonexistent	Nonexistent
	Partial proposal: Demolish and install in the main house, proposal for building taking into account that the cold room itself can be recovered simply by installing a compressor motor.				
Auxiliary power plant	Bad	Nonexistent	Nonexistent	Nonexistent	Nonexistent
	Demolish and build in the airport facilities sector. Must be demolished after construction of the new House				
Port Depot	Good	Nonexistent	Nonexistent	Nonexistent	Nonexistent
	Recycle and use				

The technical inspection carried out at that time proposed the following tasks:

- Recover the buildings with metal structures (Hangar, Warehouse I and Warehouse II) and the Port Depot.
- These structures must be subjected to a periodic maintenance plan that allows preserving and extending their useful life. Work must also be carried out to allow each of these to be recovered to optimal conditions.
- Building a new Main House, Emergency House and Power Plant in the area of the airport facilities, as this is the sector of land that is suitable for building. The current Main House must be used as a workshop house during the construction works. For the new construction project, it would be convenient to try to make all concrete structures remain in closed areas and not outdoors.
- Demolish the following buildings: Main House, Power Plant, Former Power Plant, Emergency House and Cold Room (considering that the cold room itself can be recovered).
- Install a sewage treatment plant and a reverse osmosis desalination plant.
- Build new fuel tanks (cisterns). The current ones are not in usable condition.
- Remove all the concrete structures of old buildings to expand the area suitable for construction.

The condition of the buildings and the environment at Petrel base is deficient (caused by ground movements – due to its location on a moraine – and has a large accumulation of historical residues) and requires extensive conditioning and modernisation tasks to allow use throughout the year. The condition of the buildings and the environment at Petrel base is deficient (caused by ground movements – due to its location on a moraine – and has a large accumulation of historical residues) and requires extensive conditioning and modernisation tasks to allow use throughout the year. The most important conclusion regarding the buildings is that their bad condition does not allow the intensive development of scientific activity projects at the Base.

1.2.1.2 Energy generation

The base currently has 150 KVA generators, equivalent to the generation of 120 KVA equivalent to 96 KW hours. These are planned to be replaced in the future with two 350 KVA generators equivalent to 280 KW. It is also important to note that the base facilities, being old and deteriorated, present significant energy losses, with limited conservation of any heat energy generated. Although this energy is mostly electric, a more modern heating system for the facilities must be foreseen in the future, as well as improvements in the electrical installations.

The two operating generators were installed during the 2021/2022 Antarctic Campaign. One of them was located in the current Main Power Plant and the other in the Auxiliary Power Plant. The distance between the main house and the rest of the buildings on the base meant that there are currently two independent electrical circuits.

The first consists of the main house, which receives the electricity generated by the motor generator of the Auxiliary Power Plant, and the second, made up of all the rest of the buildings and fed by the motor generator of the Main Power Plant. During the 2021/2022 Campaign, the following tasks were carried out:

- Transport and installation of 2 generators in the Main Plant.
- Assembly of board per Generator.
- Assembly and placement of the general board with commuting switches at the Main Power Plant.
- Laying of cables between the Secondary Power Plant and the Main Power Plant.
- Assembly and placement of distribution boards in phases (Main House and Emergency House).
- Laying of wiring between distribution board and facilities.

1.2.1.3 Fuel Management

The base has 2 cisterns of 30 000 litres each, which are out of service and must be removed. They are empty and in their vicinity there are no hydrocarbon spills, nor odours that imply the presence of fuel.

The station does not have automated surveillance methods in the event of spills, and the fuel transfer systems use manual pumps. It is also pertinent to clarify that the sectors where fuels are stored are far from places of concentration of flora and fauna, or close to natural environmental values, such as natural bodies of water.

For this reason, all fossil fuels are stored in 200-litre metal drums. Most of the fuel at the base is stored indoors, inside the hangar. In the hangar there are fuel drums from past summers.

Among the fuels, the presence of Kerosene, Premium Gasoline, JET JP-1, bottled natural gas and SAB diesel can be highlighted. Oils and lubricants are also stored there.

Some of the drums are stowed semi-elevated (inside the hangar) in order to avoid "ice feet" developing at their bearing points. Fuels, oils and lubricants for daily use are stored in the open air on a concrete stall located close to the power plant. In it, SAB diesel drums and oils are kept in stock that are used to replace the fuel consumed by the daily use of the base generator. To date the base does not have bulk fuel storage tanks.

It is planned to acquire cisterns to progressively replace the use of fuel drums. The installation of these is expected to start this year. Subsequently, larger capacity vertical fuel tanks will be available. Since last year, the base has vehicles for fuel storage and the transfer of drums. The drums in poor condition have been replaced and prepared for withdrawal to the American continent.

1.2.1.4 Waste Management

One of the critical aspects generated at Petrel Base – due to its irregular use – is related to the storage, processing and transport of waste. The situation of waste at the base was one of the most sensitive points, since an accumulation of waste, drums, crates and old construction materials had occurred in different sectors of the base[3].

One of the sectors that required the most attention was the Hangar, where there was a lack of labelling and sectorisation of the waste that has remained as remnants in the premises from past campaigns in the Hangar. This situation was worked on and solved in the most recent summer campaigns, where all the waste present at the Base was processed and conditioned and has been evacuated, with its total removal expected to be achieved in the 2022/2023 summer campaign.

All waste management at the Base was carried out following the Argentine classification based on the biodegradation capacity of the waste, the dangerousness and the possible final disposal methods to be used. This classification establishes six groups, respecting, in general terms, what is established in the Protocol:

- ***Group I***: Biodegradable (solid) waste. This group includes biodegradable waste, such as food remains, paper, wood and clean rags.
- ***Group II***: Non-biodegradable (solid) waste. Consisting of elements with very slow or no natural degradation – non-biodegradable waste – such as plastics, (including PVC, polystyrene, polyurethane, and rubber), polyethylene, rubber, metal cables, synthetic fibres, ashes from Group I waste incineration, expired food, metal containers, residues from the treatment of Group V items.
- ***Group III***: Hazardous waste (solid and liquid). Includes hazardous waste (liquid, solid and gaseous) arranged in the 46 “Y” categories of Annex I of Law
  24,051 on Hazardous Waste. Apart from the solid hazardous waste of this group, it also contains any elements impregnated with hazardous liquid waste

[3] Situation that was pointed out by the last inspection carried out in 2015 by the United Kingdom.

(rags, burlap, paper, cans, brushes, treated wood, oil filters)

- ***Group IV:*** Inert waste (solid). This category includes solid waste, generally considered as “inert”, in the sense that its degradation does not contribute harmful elements to the environment, although its dispersion degrades its aesthetic value and can cause accidents to personnel. This group contains glass, cans, sheets of metal, remains of metal structures, drums (clean), wires, remains of concrete or concrete, bricks, packing straps, etc.

- ***Group V***: Liquid biodegradable waste. (Wastewater and domestic liquid waste). Here we consider wastewater and domestic liquid waste from kitchens, bathrooms, sinks, etc. It does not include liquid waste that may be mixed with hazardous liquid waste, for example, water mixed with oil remains, coming from workshops.

As mentioned, the management of hazardous waste is especially regulated by National Law 24,051 (promulgated in January 1992) and by its Regulatory Decree No. 831/93. On the other hand, in 2002 Law 25,612 was enacted, on "Integral Management of Industrial Waste and Service Activities", but the risk levels (mentioned in Article 7 of the regulation) necessary for its implementation have not been established, for which reason said standard is not regulated.

An analysis of the Hazardous Waste generated within the Petrel Base was carried out and it was established that it is produced from the following activities[4]:

Use, Maintenance and Construction of Buildings

- Maintenance work with paints and adhesives. Waste: Y12 (Paint remains) /Y48Y12 (Rags and brushes with paints) /Y48Y13 (Rags and brushes with adhesives and lacquers)
- Changes of lights. Waste: Y29 (Fluorescent tubes).
- Sealing work with bituminous membranes. Waste: Y48Y11 (Membrane remains).
- Maintenance and repair of machines and equipment: Y48Y8 (Filters and rags with oil) /Y9 (Fuel with water) /Y48Y9 (Rags contaminated with fuel).
- Preparation of Drums as Containers. Waste: Y9/Y48Y9 (Rags and diatom impregnated in fuels).
- Disposal of batteries from electronic equipment. Waste:

Y26/Y29. Staff medical and dental care.

- Patient medical care. Waste: Y1 (Gauze, syringes, etc.).
- Expired pharmaceuticals. Waste: Y2.

[4] This classification uses the "Y" letter categories subject to control by the National Law of Hazardous Waste of Argentina (Law No. 24051).

- Communications and Computer Maintenance.
- Equipment battery replacement. Waste: Y26/Y29.

Power Generation by the Plant

- Maintenance and Control of Generators. Waste: Y48Y8 (Filters and rags with oil) /Y9 (Fuel with water) / Y48Y9 (Fuel contaminated rags).
- Losses or spills of Fuel. Waste: Y48Y9 (Rags and diatom impregnated in fuels).
- Replacement of Coolant Liquids. Contaminated packaging. Waste: Y48Y42
- Replacement of Generator Batteries: Waste: Y31Y34

Power Generation for Heating

- Maintenance and Control of Heating Equipment. Waste: Y8 (Used oil) / Y48Y8 (Filters and rags with oil) / Y48Y9 (Rags and diatom impregnated with fuel).
- Losses or spills of Fuel. Waste: Y48Y9
- Handling of Fuels and Lubricants
- Maintenance of the SAB diesel/JP1 Cisterns. Waste: Y48Y9Y12/Y48Y12.
- Losses or spills in Supply of SAB diesel/JP1. Waste: Y48Y9 (Contaminated rags, earth and diatoms).
- Losses or spills of SAB diesel in Cisterns or Drums. Waste: Y48Y9 (Contaminated rags, earth and diatoms).
- Losses or spills of JP1 when supplying Aircraft. Waste: Y48Y9 (Contaminated rags, earth and diatoms).
- Fuel contaminated with water. Waste: Y9.

1.2.1.5 Obtaining Water

The current capture method is quite precarious, consisting of the use of pumps and portable hoses with which the tanks on the base are filled. Water collection is not an easy task, even less so in times of low temperatures, since, depending on water availability in the lagoons, intake sources vary over the months. During the summer the water is obtained from a natural lagoon near the accommodation building. During the 2021/2022 Campaign, a melting system was installed that works using the hot gases from the Power Plant generator next to the house. It is used during the winter to melt freshwater ice collected from the sea. The system has the capacity to produce the water necessary for a crew of 25 people.

1.2.2 General environmental situation of the Base

1.2.2.1 Environmental impacts present

The current situation of the Petrel Base generates numerous aspects and environmental impacts that expose the natural values of the area to risks of contamination and environmental damage. To minimise this situation and prevent it from worsening, in the last year the habitability of the base was improved, through the integral maintenance of the Accommodation Building, the conditioning of the Emergency House and the integration of the electrical system. In addition, work is underway to put the refrigeration chamber, the effluent treatment plant, the melter and the incinerator into operation.

On the other hand, disused fuel tanks were removed and new ones were brought in to be installed and avoid the use of fuel drums. In addition, the Hangar gate and its roof are being repaired for the storage of road machinery. The polluting sources of the base are reduced to fuel spills. It should be noted that they are stored inside the hangar that has a concrete floor. To a lesser extent, there is also fuel stored in the vicinity of the plants.

The main sources of environmental risk identified due to the current state of the base are:

- Deficiencies in fuel management that generate different spill scenarios that expose natural values to possible contamination events.
- The lack of renewable energy sources means that the current base only uses an energy matrix based on fossil fuels.
- The continued presence of historical residues that must be eliminated because they contaminate the area of influence.
- Deficiency in effluent treatment systems and systems for obtaining drinking water.
- Deficiency in energy management due to the poor condition of the electrical system, which is inefficient in its use of fuel to generate energy.
- Flaws in the efficiency of heating systems that generate excessive fuel consumption.

1.2.2.2 Historical Residues[5]

The station has a large remnant of historical residues (see sketch), this being one of the main features and challenges of the base. It is not possible at this time to specify precise quantities or volumes, but it can be anticipated that the quantities are significant. Although the base chief will detail the amounts in his final campaign report, it is understood that the largest proportion comes from the remains of the house that burned down in the mid-1970s. These were inside the hangar, and to a lesser extent, the station has some very clear accumulations outdoors that would have to be eradicated and which are detailed below:

SE coastal sector of the base: Here is one of the accumulations of historical waste. In it, you can see two mechanical motors, an electric motor, a winch, pieces of iron, steel cables and other structures from past activities (RH1). On the other hand, at the foot of the beacon located in Punta Bajos, there is a significant amount of materials such as pipes, remains of drums, steel slings, remains of wood, wires and other structures (RH2). Also between the hangar and the food storage there is another remnant of inert waste, consisting

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[5] The evaluation of sites with historical residues and the subsequent clean-up procedures follow the provisions of the Manual on Antarctic Clean-up (Resolution 1 [2019]).

of iron pipes, concrete pipes, caterpillar tracks and other artefacts. Reality indicates that many of these, having been out in the open for a long time, are contaminating the soil as a result of their high levels of corrosion (Table 2, Figures 19 and 20).

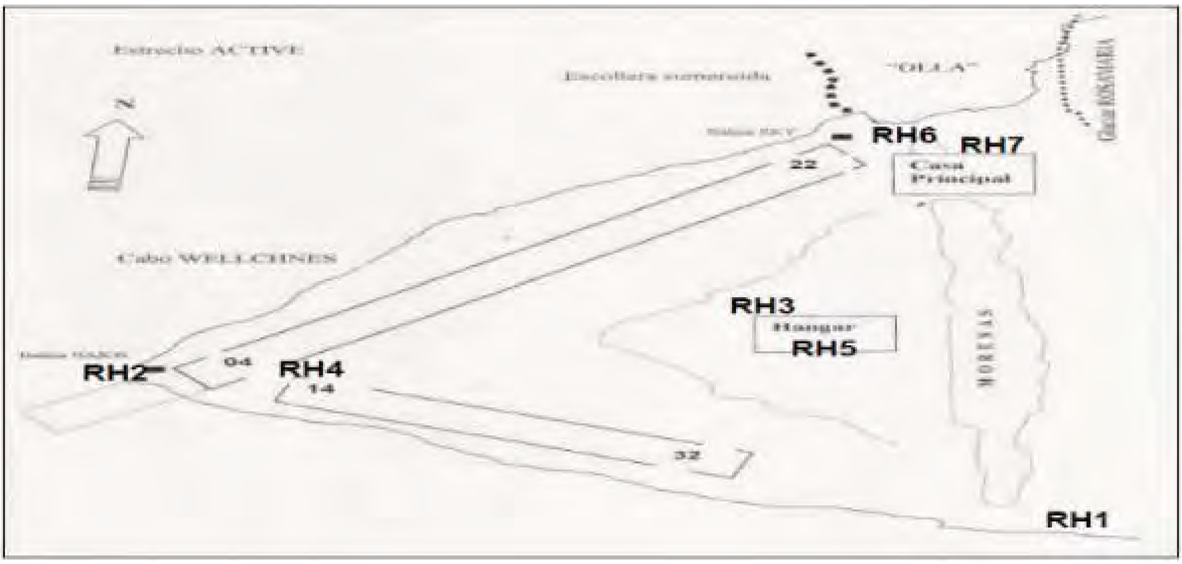
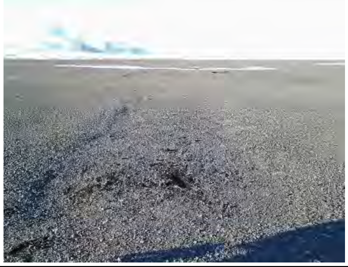


Figure 18: Sketch with the location of the sites with historical residues in the Base area.

Table 2: Sites with historical residues present in the Base area.

Historical waste deposit RH1	SE coastal sector of the base: Here is one of the accumulations of historical waste. In it, you can see two mechanical motors, an electric motor, a winch, pieces of iron, steel cables and other structures from past activities (RH1). ***State of 21-22 Antarctic Summer Campaign*** **This sector has less amount of waste, at least in sight. There are several half-buried items on the coast. During our stay, we moved some of these away from the shoreline since fauna uses this space, and animals were frequently observed lying on the waste.**	
Historical waste deposit RH2	At the foot of the beacon located in Punta Bajos there is a significant amount of materials such as pipes, remains of drums, steel slings, remains of wood, wires and other structures (RH2). ***State of 21-22 Antarctic Summer Campaign*** **Currently the Punta Bajos beacon is fallen. In itself, the sector has less waste than detailed in the previous report, with remains of the beacon, cables, wires and steel slings being observed.**	
Historical waste deposit RH3	Between the hangar and the food storage there are more remains of inert waste, represented by iron pipes, concrete pipes, caterpillars and other artefacts. There is also a group of remains of concrete sewer pipes stored in wooden boxes, which can be reused in a concrete stall without having to be taken away (RH3). ***State of 21-22 Antarctic Summer Campaign*** **Same conditions as those detailed in the report of the 14-15 Antarctic Summer Campaign.**	

Historical waste deposit RH4	Scouring the terrain, we detected what was apparently the head of an alternative runway, around 30 m^2 of soil contaminated with hydrocarbons (pitch). Its origin, according to our analysis, could be a residual product after having burned it in the open years ago, to mark the direction of the secondary runway (RH4). ***State of 21-22 Antarctic Summer Campaign*** **The contamination marks have not been found.**	
Historical waste deposit RH5	According to what has already been described in the waste section, inside the hangar there are large amounts of historical waste already stowed to be taken away (RH5). ***State of 21-22 Antarctic Summer Campaign*** **Same conditions as those detailed in the report of the 14-15 Antarctic Summer Campaign.**	
Historic waste deposit RH6	In the vicinity of the Ski Beacon, towards the NNE sector of the main house: a historical residual deposit has been detected on the moraine located in this sector. Here there are visible remains of wood, plastic, rubber, glass, metal, ceramic, etc. (RH6) ***State of 21-22 Antarctic Summer Campaign*** **Same conditions as those detailed in the report of the 14-15 Antarctic Summer Campaign.**	
Historic waste deposit RH7	Passing the moraine, in a straight line to the main house, another centre has been detected with buried and semi-buried historical residues (RH7). ***State of 21-22 Antarctic Summer Campaign*** **Same conditions as those detailed in the report of the 14-15 Antarctic Summer Campaign.**	

Also noteworthy as a negative environmental aspect, in general, is the presence of small residues from past activities in the surroundings of all the base facilities, as well as along the entire coastal sector of the entire point (between 4 and 5 km), as well as in different parts of the base.

In the vicinity of the Ski Beacon (RH6) , towards the NNE sector of the main house: a historical residual deposit has been detected on the moraine located in this sector. Here there are visible remains of wood, plastic, rubber, glass, metal, ceramic, etc. Likewise, on the other side of the moraine, in a straight line to the main house, another centre has been detected with buried and semi-buried historical residues (RH7). The amounts in both these cases cannot be specified, but due to the type of waste displayed and the state in which they are found, it is presumed that they have been in place for many years. Also, they would not be the only ones, since there are places in the vicinity of the moraines that were not covered in detail, although when walking you can see these, in some cases, on the surface because they were buried in the substrate (Table 2, Figures 19 and 20).

Figure 19: View of some sites with historical residues in the Base area.

1.2.2.3 Actions to mitigate the present environmental impacts

The presence of the aforementioned impacts due to the deterioration of the base facilities (especially fuel handling and waste management) made it necessary to start maintenance tasks and the replacement of many of the facilities in order to comply with the environmental requirements in the Antarctic Treaty Area, while the new project for Petrel was being developed. Petrel Base operated as a permanent station for the first time so that the personnel could carry out the necessary tasks. The following actions, among others, were carried out:

Tasks for improving the habitability of the current main house.

- Wire replacement.
- Replacement of plastic pipes.
- Placement of plaster board.
- Placement of structural steel.
- Replacement of corrugated roof sheets.
- Replacement of wood (phenolic plywood and tongue and groove).

Partial repair of the Hangar (gates, interior premises).

- Integral repair of the access gates (at least the main one).
- Replacement of deteriorated metal sheets.
- Exterior painting.
- Minor repairs on concrete slabs (internal hangar floor).
- Glass replacement in side windows.

Integral reconditioning of the building destined to constitute the emergency house.

- Connection with power grid.

- Replacement of wiring and electrical appliances. - Replacement of corrugated sheets of the roof.
- Repair and painting of interior walls (Change of phenolic and tongue-and-groove plywood plates).

Electrical system (installation of a new generator – Unification of the electrical network of the base – tour and repair of power lines and their boards).

- Transport and Installation of 2 generators in the Main Power Plant
- Assembly of board per Generator
- Assembly and placement of the general board with commuting switches at the Main Power Plant.
- Laying of cables between the Accommodation Building Power Plant and the Main Power Plant
- Assembly and placement of distribution boards in phases (Main House and Emergency House).
- Laying of wiring between distribution board and facilities.

Water system (commissioning of the melter – temporary installation of a water purification plant – water storage system).

- Commissioning of the water melter located next to the Main Generator near the Main House
- Placement of 2 electrical resistances of 1500 W each
- Installation of a 3 hp three-phase centrifugal pump.
- Replacement of water pipes from the melter to the water tank in the Main House.
- Installation of a Water Desalinator/Purifier in a location to be designated, close to the Main House and under cover to maintain the operating temperature.
- Cleaning of the water tank of the Main house.

Sewage treatment system (Installation of a sewage liquid treatment plant – sewer circuits).

- General tour of the sewage system from toilets to the main tank of the sewage system.
- Connection of the sewage system to the main tank.
- Installation of a new discharge pipe for treated sewage liquids down to Petrel Cove
- Installation of maceration and settling tanks
- Removal of the old sewage discharge pipe.
- Emptying of the old discharge lagoon.
- Removal and storage of contaminated sediments for their subsequent withdrawal to the mainland.

Comprehensive repair of the cold room.

- Power line to the cold room building ▪ Replacement of the electrical system.
- Manufacture and installation of control panels.
- Placement of refrigeration equipment.
- Control of cold losses and sealing.
- Installation of lighting.

Building heating systems (installation of heaters and comprehensive revision of existing heaters).

- Review of the internal electrical network of the main and emergency houses, and electrical wiring for heating.
- Installation of new stoves.
- Removal and redistribution of old heaters.

Preparation and evacuation of historical waste.

- Removal of disused concrete structures (dead).
- Mechanical demolition of the foundations of the original main house of the base, currently destroyed.
- Processing of disused iron structures and metal pipes and their preparation for evacuation (cutting down to reduce their sizes and packaging)
- Packaging and removal of historical waste.
- Removal of classified historical waste from the hangar.
- Cutting and removal of disused cisterns.
- With respect to concrete structures, the following procedure will be followed: a) Antenna dead bodies. These will be removed and the antenna towers will be dismantled. Any towers that are in conditions for reuse will be stored and those that are deteriorated and stored will be cut and prepared for their withdrawal to the mainland.
- Platform of the old main house. It will be demolished mechanically. The material will be removed and stored for its withdrawal to the mainland. Part of the material may be reused for foundations or other uses considering its "inert" condition.
- Other concrete constructions. They will be demolished and stored for removal to the mainland.

Fuel supply system.

- Removal of the two existing cisterns, which will also be cut for their subsequent withdrawal to the mainland.
- Installation of 2 cisterns in the vicinity of the current house and another three in the sector where the disused cisterns are located, which will be cut up and taken away.

- Construction of the supports once the location where the cistern park will be established has been defined.
- A tanker lorry will be used to load and unload the cisterns. This vehicle will be stored inside the base Hangar and will only be used for fuel transfer.
- Use of a pump for fuel handling.

1.2.2.4 Conclusions

The Petrel Base has suffered significant deterioration due to irregular use over the years and the effects of extreme weather conditions. The conditions it presented two serious drawbacks. On the one hand, the impossibility of carrying out significant research programs, since the building conditions did not allow for the necessary logistics. On the other hand, the precarious condition of the buildings generated numerous negative environmental impacts that affected the natural values of the area. Although Argentina began important maintenance actions to improve the conditions and eliminate significant environmental aspects (presence of waste, fuel management, etc.), the evaluation carried out has established that the most appropriate solution is the comprehensive renovation of the base, given that there are structural flaws in the facilities that are difficult to solve. Although renovation of the base will cause an impact that is greater than minimal or transitory, once built it will be possible to minimise or eliminate the environmental impacts that are present today. For Argentina, it is an opportunity to renew one of its bases for the first time, using sustainable technologies and techniques that will allow a significant change in the features the base can provide to the Argentine Antarctic programme.

1.2.3 Objective of the proposed activity

Based on what was stated in the review of the current situation at Petrel Base, the following objectives are proposed

- To reconvert the Petrel Antarctic Base (BAP) into the central node of the Argentine Antarctic Programme (PAA) to support Argentine science and logistics activities through the development of scientific infrastructure (laboratories) and logistics (airfield, warehouses, etc.), which allow permanent operation of the base, ensuring the development and support of science and a logistical link between Antarctic Bases (permanent and temporary) with the ports and airports located on the Argentine Continental Territory in order to achieve:
    - The development of a scientific node integrated with multidisciplinary laboratories for research, science and technology, which allows scientists to stay and transit, together with the reception, storage, analysis and dispatch of samples.
    - A logistics node that allows for a close link between air and sea logistics, in order to optimize support for scientific research in the Argentine Antarctic Territory through an efficient Argentine Antarctic Logistics Activity (ALAA), the Search and Rescue System (SAR), and
    - Redirecting the use of the resources applied by our country to support the scientific activity of the Argentine Antarctic Programme, without the need to

increase them, providing greater flexibility in the logistical support provided and a better link between our country and Antarctica.

- Support international cooperation activities with other Antarctic programmes with the remaining scientific and logistical capacity.
- Take advantage of the access facilities of Petrel base for air and naval vessels to centralise search, rescue and medical evacuation activities towards the American continent.

2 PETREL BASE PROJECT

In 1976 Petrel Base became a temporary summer base, after a fire destroyed its main accommodation building. From that moment on, this base, which functioned as an aero-naval station, significantly reduced its activity, which was limited to periodic maintenance for short periods of time in the southern summer. Its air activities were transferred to Marambio base, which from 1976 to the present became the centre of air activities of the Argentine Antarctic Programme.

In recent years, the increase in scientific activity of the Argentine Antarctic Programme, added to changes in climatic conditions and the new means incorporated into the activity, has made us rethink the way we carry out our science and the consequent logistical support required. The development of Petrel base, therefore refers us to the drawbacks that arise in the access, operation and maintenance of Marambio Base to support the activity of the Argentine Antarctic Programme (PAA). These drawbacks can be summarised in the following points:

- Only one of the four ships used by the PAA can access Marambio base by sea, which is the “Almirante Irízar” icebreaker, therefore limiting the possibilities of deploying scientists from Marambio base to other bases by sea.
- The increasingly frequent above-zero temperatures affect the conditions of the active layer of permafrost on the runway, leaving it unusable for an increasing number of days year after year during the summer season, when the most flights are made to the island.
- This base is supplied mainly by sea, with the use of naval helicopters, with a large consumption of flight hours that could be applied to scientific activities in other areas.

Use of the Petrel base would avoid the points indicated above, thus achieving a better distribution of the resources and transport facilities applied in support of the PAA, which are the same in a greater number of scientific activities with the same resources.

For all the above reasons, since 2002 the Argentine Republic has considered the need to achieve greater efficiency in the activities carried out on the Antarctic continent, concentrating on supporting national scientific and technological activities. The studies required that the efficiency sought not demand a greater number of ships, aircraft and vehicles than those used up to that moment in the scientific, technical and logistical activities of the Argentine Antarctic Programme. Similarly, they should not imply a greater use of ships and aircraft, that is, they should maintain the number of days of employment of ships and flight hours of aircraft.

After various analyses, surveys were carried out to determine the aptitude, feasibility and acceptability of the reconditioning of Petrel Base as a multimodal cargo and passenger exchange centre. It was considered that this could be achieved by the development of a port and an aerodrome suitable for year-round operation of medium and small aircraft, together with the services associated with these two modes of transport.

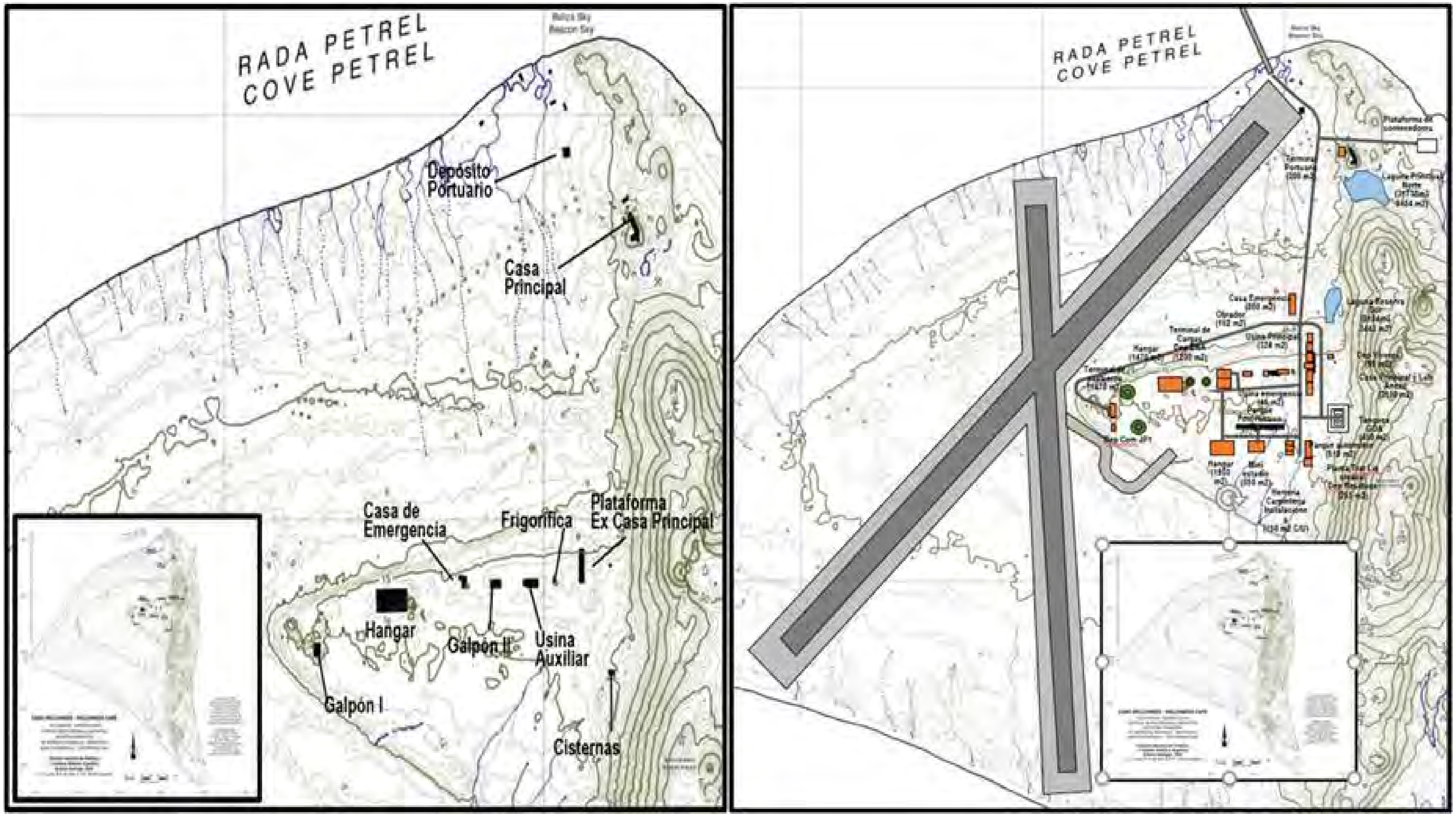


Figure 20: Comparative general diagram of the Petrel Base renovation project. On the left the arrangement

From this date onwards, actions were initiated to reactivate the base in a temporary function. The first overwintering was planned for the 2015/2016 campaign, but this could not be materialised due to several drawbacks and the base only continued to operate on a temporary basis. Since the 2017/2018 campaign, budget adjustments prevented it from opening as a temporary base, and it has remained closed to this day.

The reconversion of the Petrel Joint Antarctic Base into a logistics and scientific node implies initially having the necessary facilities for storing construction material, road equipment, their spare parts and specific tools. Regardless of the areas defined by operational responsibilities, in the design stage all the buildings, facilities and basic services will be considered as a whole, avoiding the need for later constructions that would create inconveniences to the normal operation of the services and networks of the new base.

When designing the base we have considered the existing constructions in the conditions detailed above and the constructions that need to be built. Figures 22 and 24 illustrate the general perspective of the original project[6].

Figure 21: Original general design of the new Petrel Base.

2.1 General Description of Proposed Activities

The general actions to be carried out at Petrel Base for its renovation are described below, including actions for dismantling the old facilities and removal of the historical residues that exist therein, as well as the design, construction and total operation of the proposed base, which includes the logistics and transportation of materials and equipment, the civil works to be carried out, the installation of the systems to be operated, and the commissioning of the new one. The project guidelines are based on the readjustment of the existing installation and its adaptation to the future operational functions of the base, determining the required infrastructure

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6 See the section on the analysis of alternatives to see the final version after determining the non-feasibility of building the quay.

to provide support for the two landing strips and a quay with capacity for loading and unloading polar ships.

2.1.1 Construction of new facilities

On the glacier-free surface of 1.8 km, and with the purpose of ordering the project and the necessary facilities, zones were divided according to the operational and functional competences of the base. The facilities and activities were grouped into the following areas (Figure 23):

- Facilities Area
- Science Area
- Photovoltaic Field Area
- Airport Area
- Port Area[7]
- Base Services

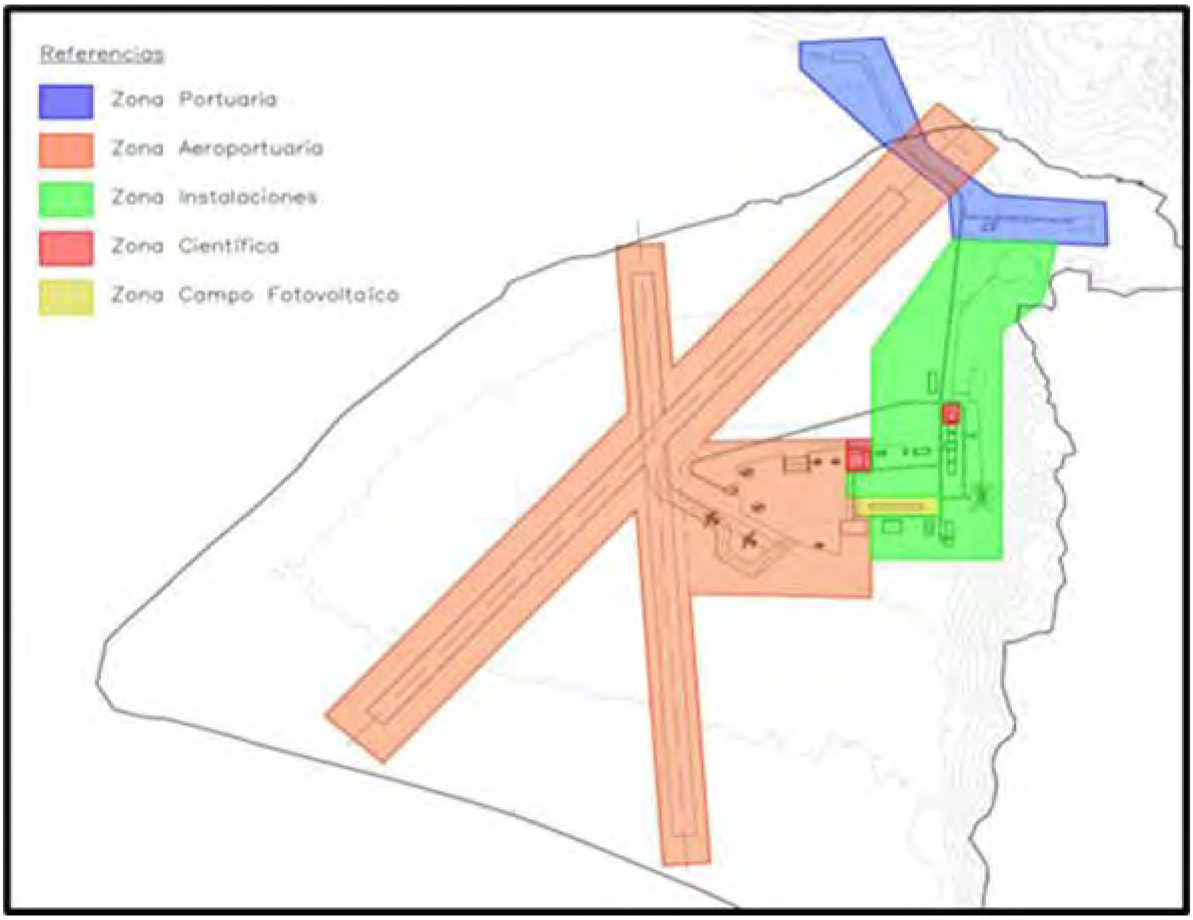


Figure 22: Original zoning of the Petrel Base project.

[7] The original project included a port area, see the analysis of alternatives where this idea was discarded.

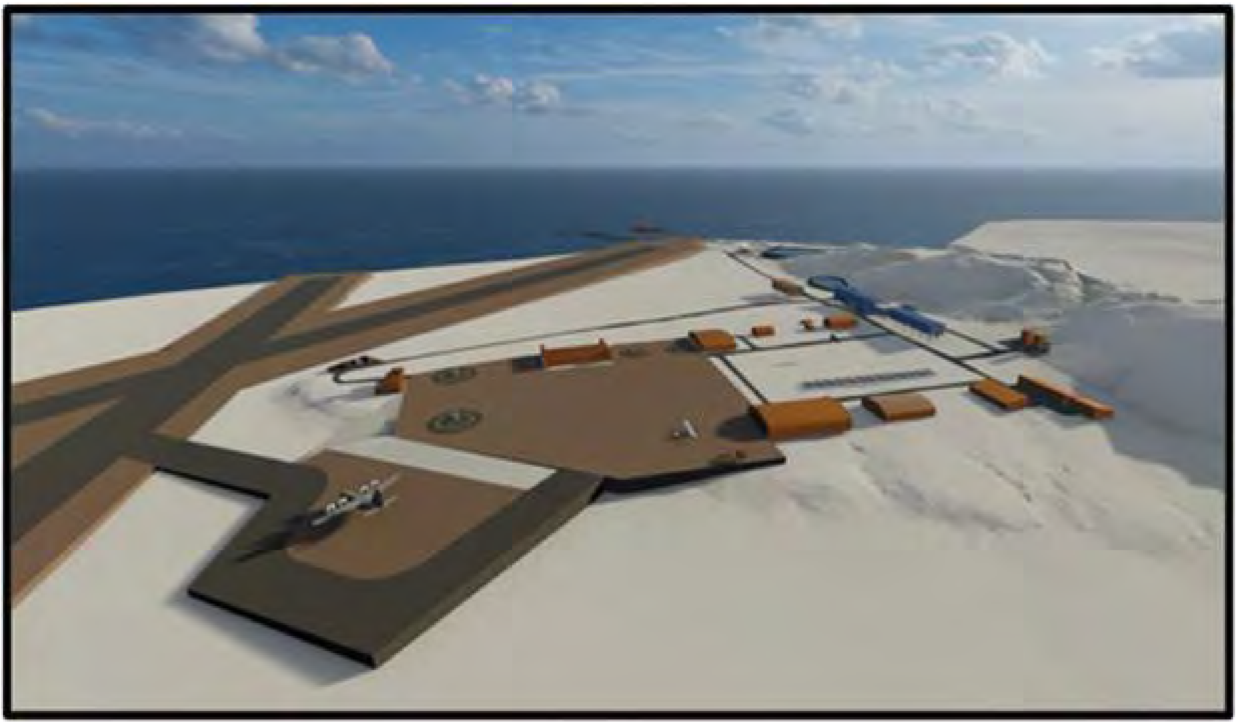


Figure 23: General view of the Petrel Base after its reconversion.

2.1.1.1 Facilities Area

This point covers all the buildings and their basic services that enable operation of the base as such and that will be built for its comprehensive renovation. Below is a brief description of each building listed in the computer image illustrated in Figure 25:

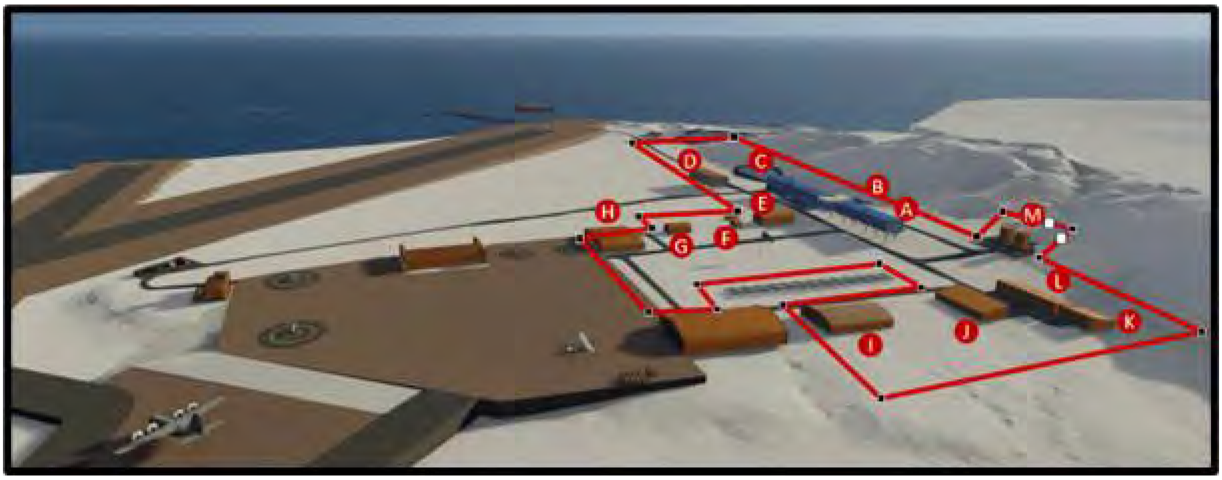


Figure 24: Base Area component.

The Base Area involves the construction of the following components (Figure 25):

A – Main House

B – Food depot

C – North Reserve Lagoon and South Main Lagoon

D – Emergency House

E – Main Power Plant

F – Emergency Power Plant

G – Supply Depot

H – Cargo Terminal

I – Mini stadium/Sports Centre

J – Workshops

K – Treatment Plant

L – Vehicle Garage

M – Vertical Tanks

2.1.2 Scientific Area

The Petrel base originally had a main house that was destroyed by a fire in 1974. As of that date, the old workshop began to be occupied as an accommodation building, and was modified for that purpose. From 1976 to 2021, the base was operated irregularly during the Antarctic summer months. The limitations in fuel storage for power generation, the deficient state of its electrical system, the difficulty in obtaining water and the absence of a sewage treatment plant decisively limited the number of personnel that operated the base.

Scientific studies carried out in the area were limited by the lack of facilities dedicated exclusively to science. This situation was tolerated as the base operated as a transient station for a short time during the southern summers. The reactivation of the base as a permanent base imposed the need to have adequate facilities for scientific endeavours.

The decision to remodel Petrel base as a central point for the distribution and support of the Argentine Antarctic Programme activities will provide the necessary foundation for the installation of a multidisciplinary laboratory that meets the needs of science at the base, recovering in this way its scientific capabilities. As a starting point, a space for science was planned in the accommodation building to be built, with the space dedicated to science to be expanded later on with a building entirely dedicated to research.

Considering that the general objective of the remodelling of Petrel base is to contribute to the fulfilment of the scientific, technical and logistical tasks of the Argentine Antarctic Programme, complying with the regulations of the Antarctic Treaty and current protocols, within this framework, the need arises to have facilities dedicated to science that cover the following needs:

- Accommodation for scientific personnel, considering the Petrel base as a point for centralising samples taken in other areas and analyse them in situ, with dry, wet and dirty laboratories and a storage area for their dispatch.
- Accommodation and research capacity for scientific personnel in transit, satisfying the requirements for analysis or storage of samples that arise from the operating times of aircraft and ships.

The laboratory has been projected as an annex to the main house. For this reason, this building continues the line of the Accommodation Building, extending it to the north, on the edge of the upper platform of Cape Welchness. The building will apply the same construction techniques used in the Accommodation Building. The structure will be assembled independently, with a foundation of piles and alumna maintaining the levels of the Accommodation Building. Given the difference in height from the ground, one more floor will be added below the level of the Accommodation Building (Figure 26).

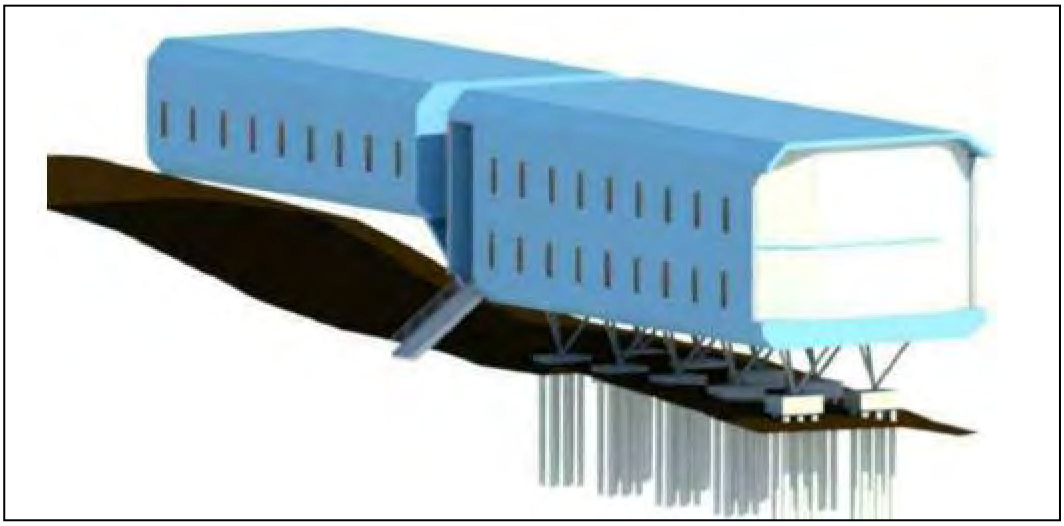


Figure 25: General view of the Laboratory.

The laboratory is projected to have two floors. The upper floor, at the level of the floor of the Accommodation Building, to house EIGHT (8) laboratories, and a lower floor for accommodation with TWELVE (12) rooms with capacity for TWENTY-FOUR (24) people in total and TWO (2) rooms of 36 m^2 each. The building will occupy a minimum area of 462 m^2, which makes a total usable area of 924 m^2 (Figure 27).

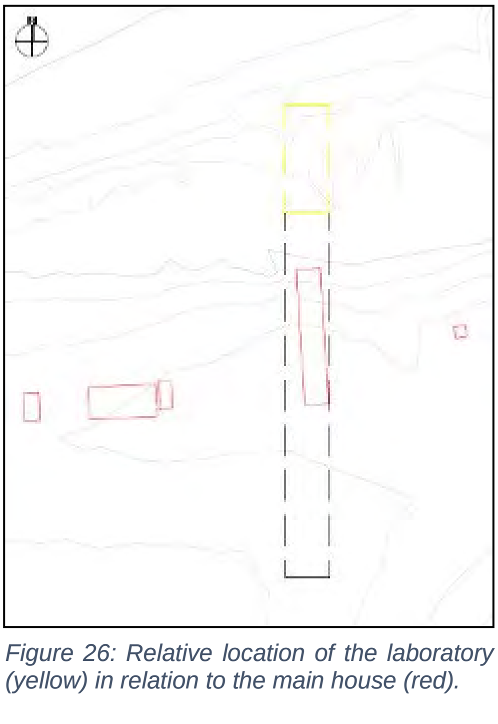


Figure 26: Relative location of the laboratory (yellow) in relation to the main house (red).

2.1.3 Photovoltaic Field Area

Power is essential to enable Base activities such as running motors, heaters and other equipment including station and field electric generators, heaters, water and waste systems. Argentina has used hydrocarbon-based fossil fuels as the main means of supplying energy in Antarctica. Fuel is normally purchased commercially and is subject to fluctuating world market prices. It is transported to Antarctica by ship and the burning of fuel is necessary to propel the ship. Therefore, reducing fuel use saves operating costs, reduces the potential impact of a fuel spill, and reduces the pollutants emitted throughout its life cycle. The integration of renewable energies in Base power plants is becoming the alternative adopted to reduce environmental impacts, extend autonomy and minimise energy costs.

In the environmental review of the activities at Base Petrel by the Environmental Management and Tourism Programme, the exposure of the island's drainage network due to the accumulation of fuels was identified and valued. The fundamental problem mentioned in said report is the “great spatial scattering of storage and transfer sites”. Although management problems have been minimised since reactivation of the Base, fuel management presents a long list of negative environmental aspects and impacts that affect the environmental conditions of the area impacted by the Base.

The management of fuels (SAB diesel, JP-1, gasoline), gas, oils, lubricants and antifreeze, involves the movement and storage of large volumes annually, therefore, any decrease in this amount represents a minimisation of risks and associated environmental impacts. We would like to recall that among the environmental principles set forth in Article 3 of the Protocol to the Antarctic Treaty, it is established that "activities in the Antarctic Treaty area shall be planned and conducted so as to limit adverse impacts on the Antarctic environment and dependent and associated ecosystems”. So too, the *Council of Managers of National Antarctic Programs* (COMNAP, 2005) has established recommendations for fuel supply procedures, as well as for contingency plans for oil spills and for the prevention of spills and fuel storage at Antarctic Stations and Bases.

Trying to solve these problems, several countries have intensified their actions related to the use of eco-technologies and renewable energies (Boccaletti & Di Felice, 2010; de Christo *et al*, 2016; Olivier, Harms & Esterhuyse, 2008). For this reason, the purpose of the proposed activity is to reduce the consumption of fossil fuels by using renewable sources in the generation of base energy and in this way also reduce the emissions produced by the combustion of Antarctic diesel. Argentina has already begun using renewable energy, especially solar panels, with a first experience at Marambio Base. This project at Base Petrel is the continuation of that line of work.

After the analyses carried out by specialists in the field in a pilot study including more than three years of measurements at Marambio Base, it can be deduced that the incorporation of electric power generation systems using solar panels, with their corresponding alternating current inverters at Petrel Base, is an extremely viable and timely option.

The solar panels are the REC245PE model by REC PICK ENERGY. The factory guarantees a useful life for the panel of 10 years and a stable nominal power for up to 25 years. A total of 576 panels will be used. The construction of the photovoltaic field will be carried out in two stages.

- Stage I: Will consist of the installation of a first group of TWO HUNDRED (200) panels. It will be built during the first year of the project. This construction will make it possible to evaluate in situ the power delivered to the electrical grid and the changes and/or modifications to be made in the execution of Stage II of this project.
- Stage II: Will consist of the installation of a second group of THREE HUNDRED AND SEVENTY-SIX (376) solar panels, thus completing the projected solar field. This stage will be built during the second year of the project.

The solar panels will be installed on fixed metal structures. Each structure will contain TWELVE (12) panels constituting a solar row or table. Each of them will be oriented to the north, keeping the panels at an inclination of 63º. SIXTEEN (16) tables will be built in stage I and THIRTY-TWO (32) tables in stage II. Each solar table will be separated from the one in front by a distance of 8 metres to facilitate exposure to the sun and avoid shadows. Laterally, the distance between tables will be 5 m, which will facilitate the circulation of vehicles and the formation of snow queues.

Since the generators at the base will be working permanently, the photovoltaic field will be connected to the electrical system via inverters. For this reason, the use of a battery bank is not foreseen. 3 inverters will be used, each one serving a third of the solar panels, although in the first stage a single inverter will be used for the 200 panels. The inverter will be connected to the general board of the Power Plant. The inverters will be placed at the back of the field of solar panels in a box, whose size will not exceed 2 m^3 (2 m wide, 1 deep and 1 m high).

It is expected that 200 panels will generate 24% of the total energy generated using the 120 KVA generators that the base has. This includes the 200 panels to be installed during stage I of the project. In stage II, adding 356 solar panels and keeping the same generators, it is estimated that 68% of the energy generated will be reached. In stage II it is estimated that, if the 120 KVA generators are maintained, the 576 panels, during the sunny days in the months of November, December, January and February, would be enough to supply energy to the entire base (Figure 28).

Once the 350 KVA generators to be installed during the following stages of the Petrel base development project are installed, the annual percentages will become 8 and 23% respectively. During the summer months, the 576 panels will only cover 40% of the total energy.

Each structure will contain 12 panels constituting a solar row or table. Each solar table will be separated from the one in front by a distance of 8 metres to facilitate exposure to the sun and avoid shadows. Laterally, the distance between tables will be 5 metres, which will facilitate the circulation of vehicles and the formation of snow queues. Eventually it could be possible to make a deeper arrangement maintaining the distances between the solar tables (Figure 29).

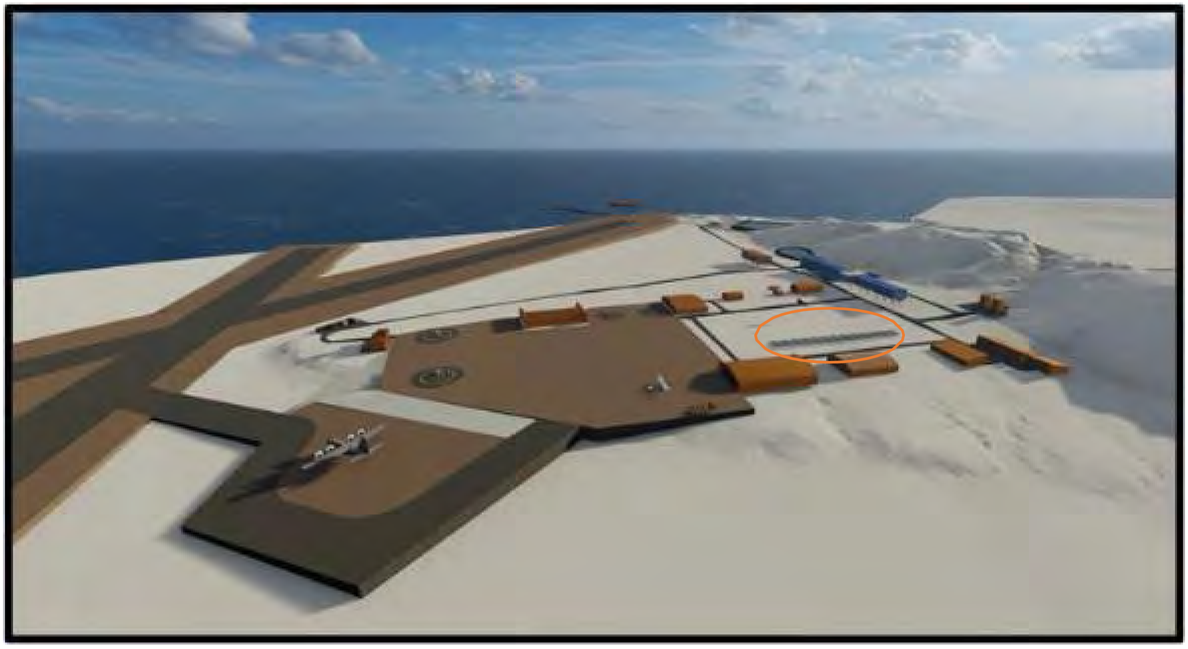


Figure 27: General location of the solar panels.

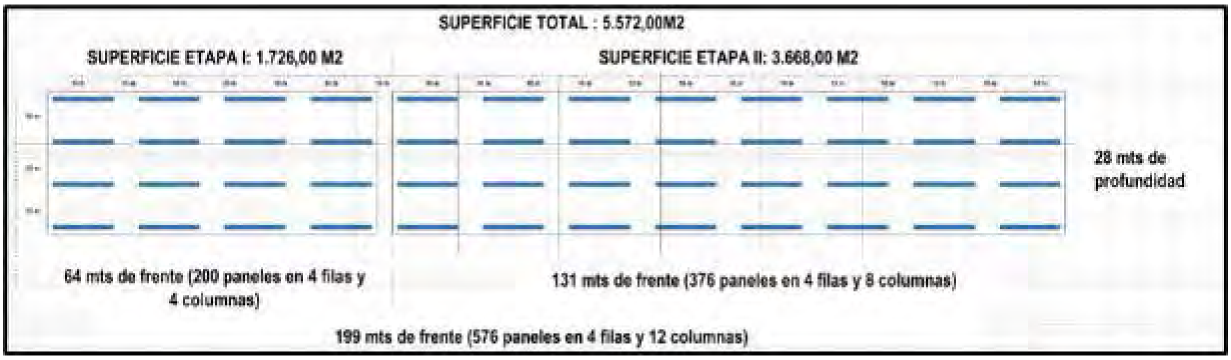


Figure 28: Specific arrangement of the tables with the solar panels.

If we take the maximum electrical generation capacity of the generators and the electrical generation capacity of the solar panels during each month of the year on Petrel Base, we can infer the energy contribution and the fuel savings of the generators due to their working less. In this regard, the estimated fuel savings due to the use of solar panels during stages I and II and with different generator powers (at a similar power percentage due to the growth of the Base) is as follows (Table 3):

Table 3: Calculation of fuel savings.

Generator	Line	200 panels	576 panels
120 KVA	Savings (L):	26 010.12	74 909.16
	% of the total	24%	68%
	Equivalent to:	100 drums	262 drums
350 KVA	Savings (L):	26 537.29	76 427.40
	% of the total	8%	23%
	Equivalent to:	92 drums	267 drums

It can be seen that the savings in litres is similar in both types of generators, varying only in the percentage of total fuel consumed.

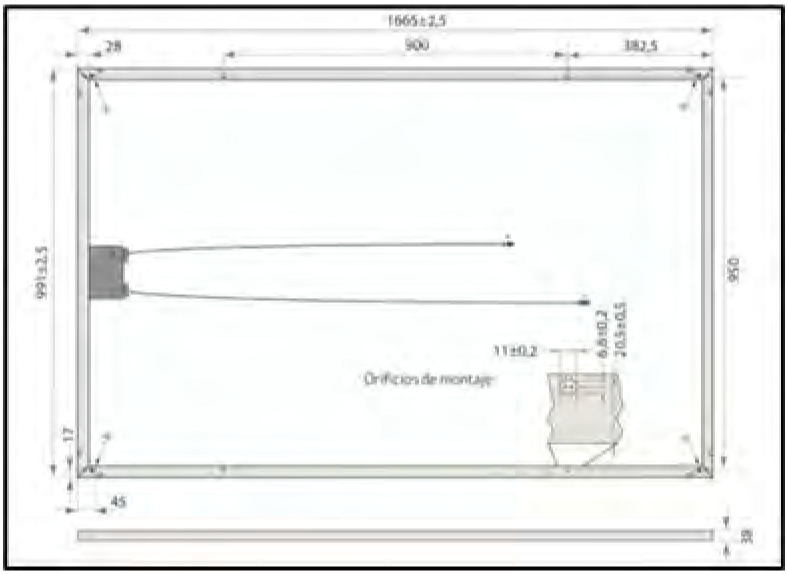


Figure 29: Diagram of the solar panel model to be used.

Each solar panel has a size of 166 x 950 x 38 mm with a total area of 1.65 m^2. Likewise, on the side with the solar cells it has a 2.8 cm wide frame edge. Considering these measurements, the panel has a usable area of 1.50 m^2 (Figure 30).

2.1.4 Airport Area

2.1.4.1 Runways

There were three aircraft landing strips at Petrel Base, designed and built in the mid-1960s. It was precisely in the month and year of the inauguration of the base, that one of the runways was used by a Beaver aircraft (4-G-1). To date, none of the runways has been used for decades.

The topographic characteristics of Cape Welchness are appropriate for building up to two runways, with favourable weather and altimetric conditions for a Hercules C-130 type fixed-wing aircraft to operate with its better performance and in safe conditions. The C-130 aircraft will be the critical aircraft for this aerodrome and therefore the basis for its study and development.

The direction of both runways, the taxiway and operating platforms for the different types of aircraft that will operate in the area were adjusted to the design parameters of the International Civil Aviation Organisation (ICAO) and other current regulations for runways located in the Antarctic Continent, thus allowing other countries to operate and use derivative services such as SAR, cargo and logistics, among others.

The Main Runway with a projected orientation of 03/21, will reach an approximate operational length of 1500 metres, the Auxiliary Runway will have a length of 1200 metres, and a direction of 17/35 (Figure 30). Both runways will comply with the international regulatory requirements regarding safety spaces at the ends and sides of each runway. They will also be built in compliance with the requirements established in the Antarctic Treaty System, related to the care and preservation of the environment.

The soil of the place is made up, as stated in the "Geocriological-Geotechnical Study for the design of airstrips in Cape Welchness" (Developed by the Argentine Antarctic Institute in November 2006), of medium and fine gravel, sand, little to no existence of clays and in turn, there is presence of dry permafrost at an average depth of 1.40 metres. Likewise, the runway layout presents differences in levels of up to 5 metres, therefore requiring levelling prior to the layout of the runways (Figure 31).

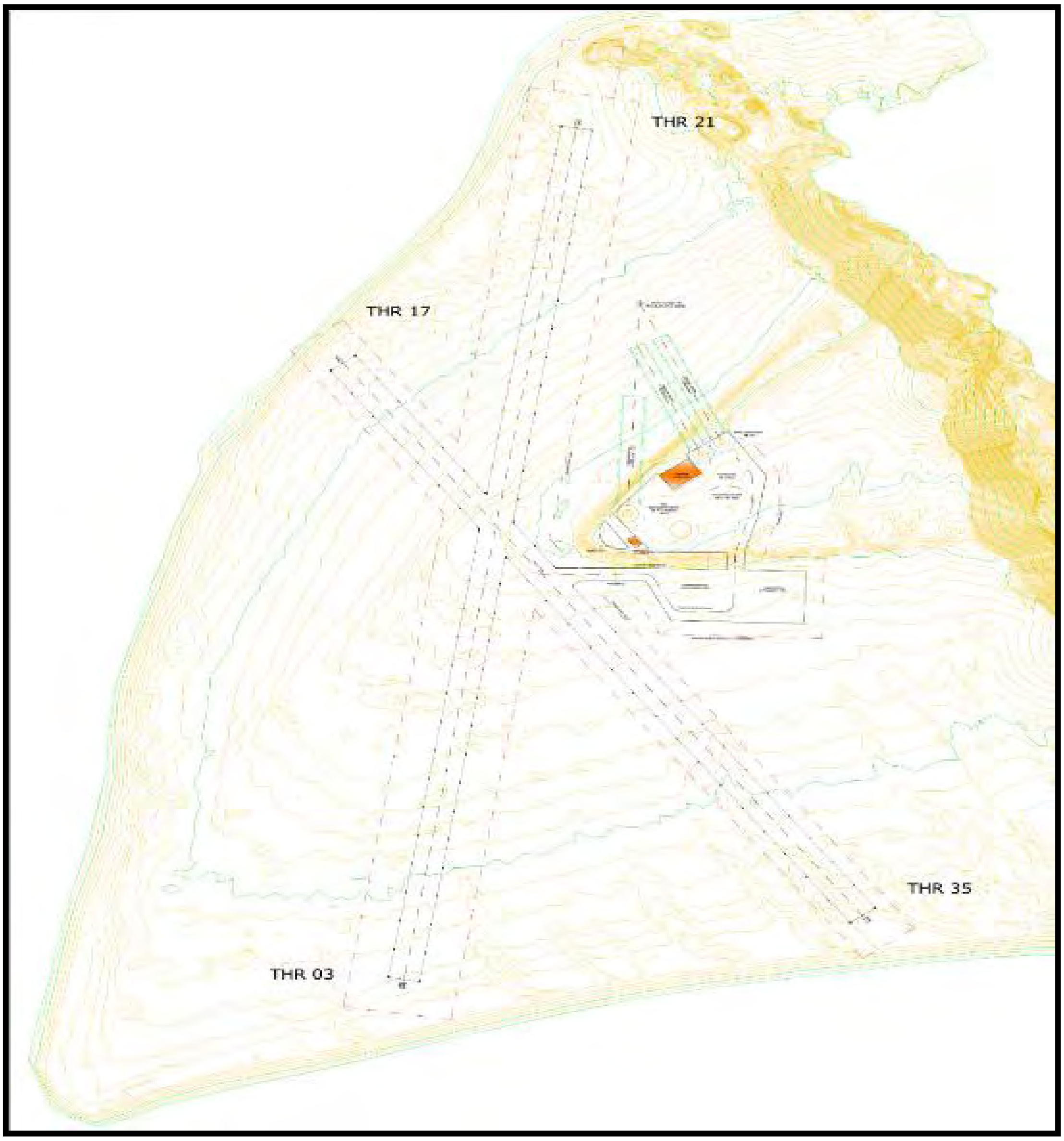


Figure 30: Location of the runways to be built and the airport area.

The taxiway and the platform for aircraft operation were sized in front of the hangar adopting a Twin Otter aircraft as a reference aircraft, which, although not currently operating in the Argentine Antarctic Programme, is expected to resume its operation in the medium term. On the other hand, this type of aircraft is widely used by other Antarctic programmes, which is why it is not ruled out that they could operate at Petrel Base for various reasons (SAR, mechanical assistance, fuel supply, air evacuations, etc.). The capacity of this area for the operation of medium-sized helicopters such as the MI-171 was also verified.

The location of two platforms was considered to operate with helicopters, medium-sized aircraft and two C-130 aircraft simultaneously with a considered margin between aircraft/objects of 7.5 metres. Areas will be provided for service streets, a manoeuvring area and ground equipment storage. There will be a designated isolated parking stand 100 metres from the facility or from other parked aircraft (Figure 31).

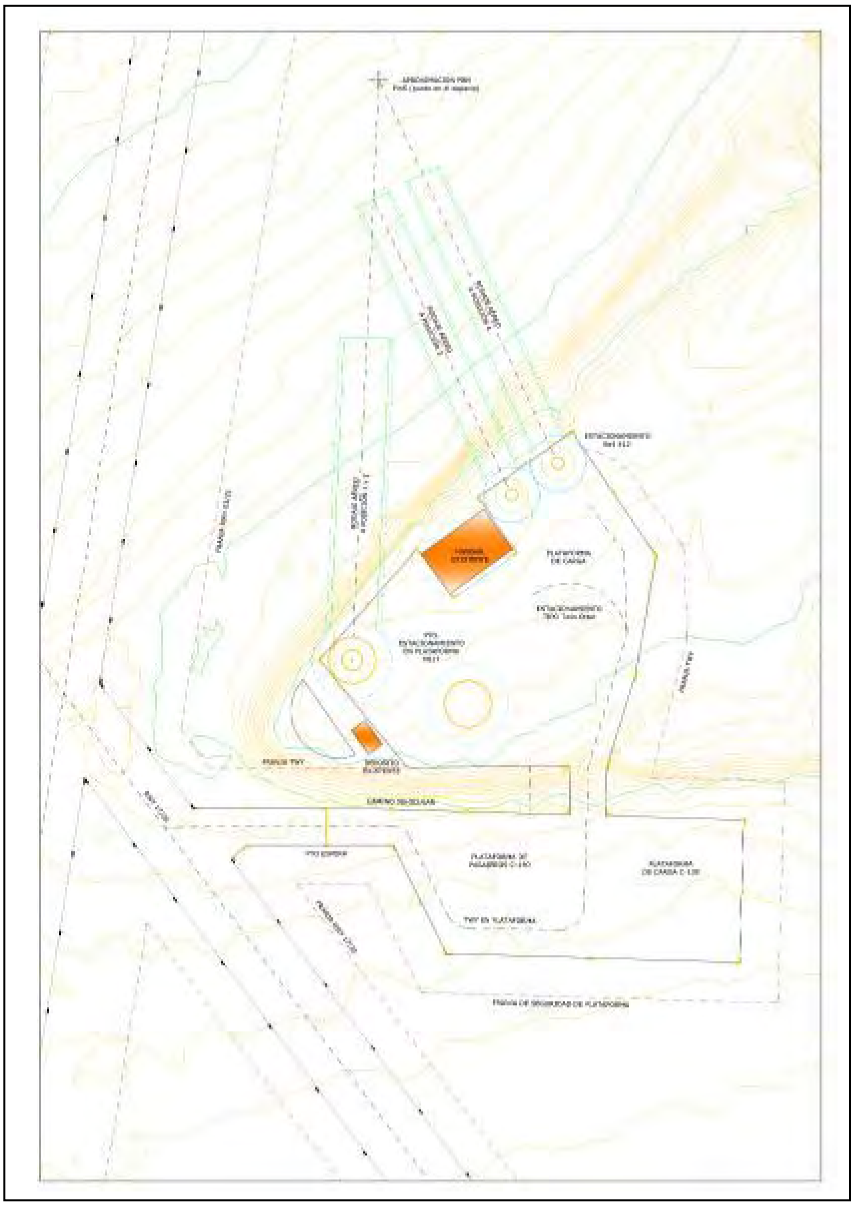


Figure 31: General layout of the airport area.

The following stages have been established for construction of the airport area:

- Stage 1 of the project would include the construction of the main runway 03/21 for precision operations, 2 heliports (for B-412 and Mi-17), with a taxiway, aircraft and cargo apron on the lower peninsular site. Procedure diagrams. Vehicle streets, aerodrome lights. Infrastructure of the passenger terminal, operational offices, control tower and concurrent services. VOR/DME radio. Communications.

- Stage 2 of the project incorporates construction of the secondary runway 17/35 for non-precision operations, 2 heliports (for B-412 and Mi-17), a taxiway and an aircraft and cargo apron on the upper peninsular site. Incorporation of the GBAS landing system, and in order to increase operational safety, the installation of an RSMS Radar and Meteorological Radar at the Marambio aerodrome (TMA MBI), as this radar site has greater coverage since it is on a plateau.

2.1.4.2 Airport Facilities

The Flight Tower and Passenger Terminal will be located at the current position of Warehouse I, at the western end of the upper platform of Cape Welchness. It will constitute a single three-story building, which will contain all the services of the passenger Terminal itself (with its corresponding bathrooms), fire service (offices and parking for the fire engine), communications, meteorology, aerodrome headquarters and control tower. It will occupy a floor area of 341 m^2 and will have a total of 646 m^2 useable surface for services (Figure 32).

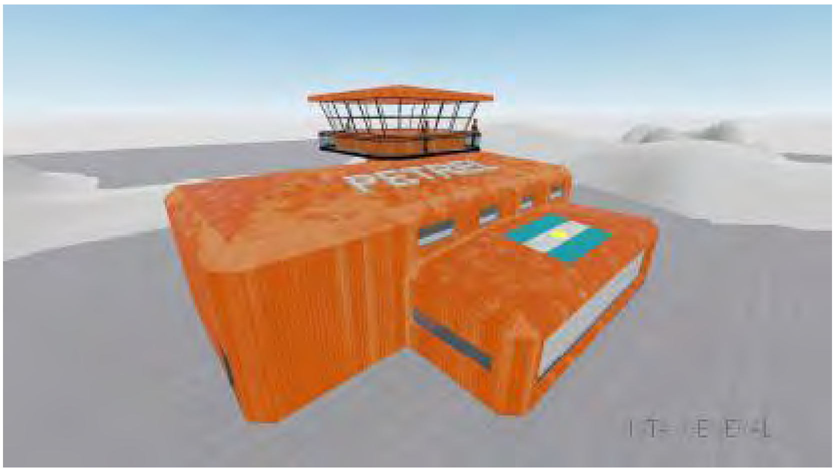


Figure 32: General view of the flight tower and passenger terminal.

They will provide the following services:

- Communications and Air Navigation: The communications equipment will be in accordance with ICAO international standards and will be installed in the Flight Tower.
- Aircraft Rescue and Fire Fighting Service (ARFF): There will be a 4x4 self-propelled fire engine, of the OSHKOSCH or ROSEMBAUER type, in compliance with current regulations.
- Passenger terminal: The terminal must have sufficient physical space to house up to 80 people in transit, with adequate heating and toilets. Aspects that will allow passengers to remain concentrated after having checked in.
- Beaconing and runway indication: Initially, a mobile beaconing system of the NAVITRONIK type or similar will be used, with battery and remote control by radio frequency until the most suitable fixed system, resistant to inclement weather, is defined.

- Weather Station: To be located in the Passenger Terminal and Control Tower building. In addition, 1/2 weather stations will be installed as an aid to air navigation. It will provide a forecast service with support from the Marambio Base Meteorological Station.
- Control Tower: To be located in the same building as the Passenger Terminal. It will coordinate the aircraft arriving and departing from the BACP. This location and height allows direct visual control over both runways, the aircraft operating platform, the taxiway and the helicopter operating platform.
- Air Communications: Communications related to the National Meteorological Service and to aircraft in flight or about to land or take off will be carried out and coordinated. It will provide the Aeronautical Information Service (ARO-AIS) and Communications.

2.1.4.3 Hangars

Regarding the Hangars (Figure 33), the Hangar for aircraft that already exists at the base will be used, which has a covered area of 1150 m^2 on which recovery works have already begun, consisting of repairing the roof, gates and subfloor. It will be used mainly for the storage and maintenance of aircraft. It will be completely reconditioned and put into value. In the same way, the deposits that are inside will be repaired (Figure 33).

This hangar will be used for the storage of helicopters and as a workshop for tools and flight support equipment. On the west access of the hangar, the necessary works will be carried out to consolidate the land and form the operation platform for helicopters, with 10 000 m^2 for the safekeeping and operation of aircraft.

In addition, a new helicopter hangar will be built in order to complement the already existing hangar at Petrel Base. The construction of a new Hangar was projected in the south west sector of the upper platform of Cape Welchness. This hangar will be located to the west of the mini-stadium/Sports Centre of the base. Its intended use will be to shelter a MI 171E supply helicopter in Argentina.

This project to locate new premises inside the existing Hangar at Petrel Antarctic Base, which is expected to house the MI-171e and Bell 412 weapons systems. The provision of these premises was organised in two facing modules, which are designed to be located on the rear sides of the Hangar, and whose dimensions result in a 3.40 m front for each module, 12.40 m deep, and a maximum height of 2.40 m; in compliance with the operational requirement of having a covered area of 84 m^2 on the ground floor.

Figure 33: General view with the location of both hangars.

2.1.4.4 JP1 fuel tank and pump

A JP1 fuel for aircraft storage area will be installed. This platform will be located to the south of the Passenger Terminal and relatively close to the taxiway, but maintaining a safe distance. It will also be in an area close to two heliports. Cisterns with a storage capacity of 35 000 litres will be installed there. All will be connected to one another, with a corresponding supply system for the aircraft. This platform will have its spill containment tray.

The JET-A1 Cistern Park is located within the Petrel Joint Antarctic Base, about 40 m SW of the MI Hangar; 170 m south of the cargo terminal and DNA Deposit; 160 m south of the Hangar; 190 m southeast of the Passenger Terminal and 120 m southwest of the sports centre. The location responds mainly to safety in the facilities and the possibility of containment in the event of a spill.

The JP1 fuel will be used mainly for the operation of helicopters and small aircraft (Twin Otter type). The refuelling of large aircraft (C-130 Hercules) is not anticipated. However, the storage capacity of 35 000 litres is equivalent to a C-130 aircraft fuel tank. This capacity has been calculated as the maximum necessary for a critical situation.

2.1.5 Port Area[8]

The construction of a quay with the capacity to moor ships of up to 120 metres in length has been analysed, with a basin of calm waters and protected from ice debris for vessels such as rubber boats or barges. The place designated for installation of the quay is the sector located to the north of Cape Welchness, on Petrel Cove. That area is where ships normally operate.

The area presents favourable bathymetric characteristics 250 metres from the coastline, with a depth of 10 metres at the foot of the quay, allowing the mooring and operation of

[8] This development was included in the original project but later discarded in the analysis of alternatives.

ships. From the studies carried out on other docks and existing coastal works in Antarctica, in which the most appropriate construction methods and materials were analysed, it was concluded that it was necessary to use metal sheet piling to meet the demands of the thrust and impacts of the ice.

This material, which is found in the most important docks in Antarctica, will only be placed on the operational perimeter of the dock that is most exposed to ice, providing a metal support structure inside, and filled with compacted soil from Dundee Island. This work is still under study, since the studies corresponding to the seabed in the northeast area of Cape Welchness have not been completed.

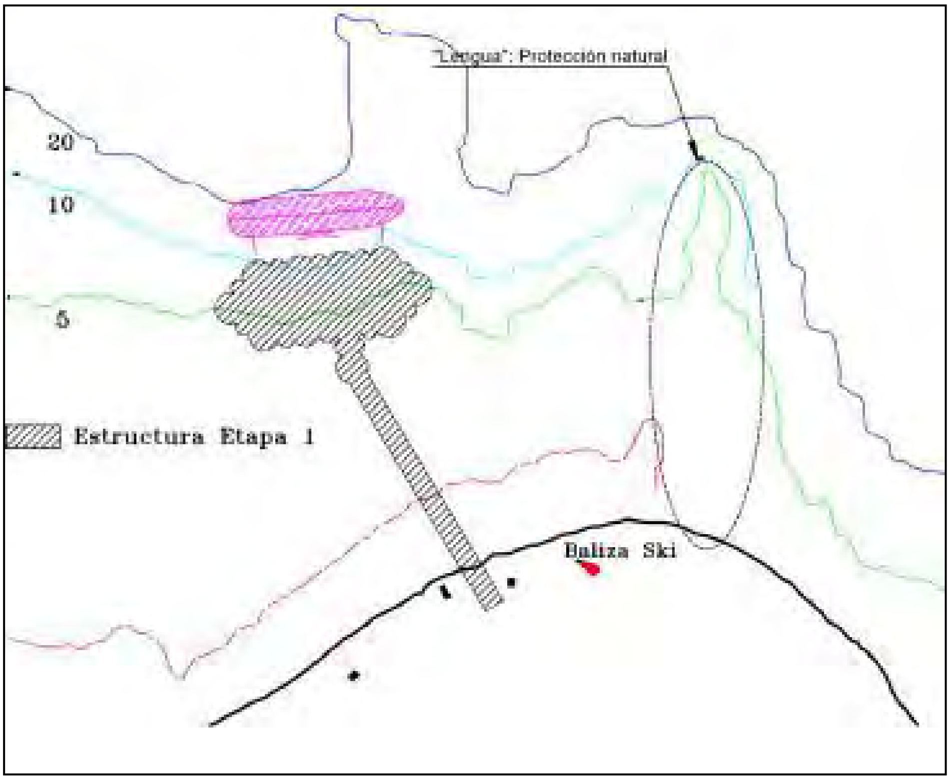


Figure 34: Diagram showing the potential location of the quay at the Petrel Base.

The optimal location for the quay to be built is to the west of the naturally shallow “shoal” that acts as a defence against icebergs that may affect the structure of the quay. It should also be to the west of La Botera, a sector where ice blocks are smaller, and there could therefore be safe navigation (Figure 34).

From the study of the existing bathymetry of the area, it is established that on the shore there is a sector of the coast that enters the sea in the shape of a “shoal”, an approximate distance of 200 linear metres with very little depth, down to approximately 3.00 m, leaving both banks sectors with an approximate depth of 7.00 m. The northwest sector has small isolated blocks of ice. The number of ice blocks is observed to decrease towards the west, becoming more separated from each other in that direction.

The considered coastal infrastructure will have:

- A separate installation for the designated port authority, allowing compliance with the administration, regulation, control and operation of the port system.

- An autonomous system for the transfer of Antarctic Diesel fuel from ship to land, with a bank of pumps, a reduced battery of tankers on the coastline and flexible hoses.
- A containerised or palletised cargo reception service, with capacity for transfer, collection, custody and transshipment.
- Freshwater supply service to ships.
- Reception and dispatch of passengers in transit.
- Launch or removal of small vessels by ramp.

2.1.5.1 Port Unit

To be located near the current house. This house must be structurally evaluated and eventually conditioned for installation of the port authority with the different offices for the administration and coordination of operations and manoeuvrers on the quay, unloading, stockpiling and loading of goods.

2.1.6 Dismantling and Recovery of existing facilities

Argentina has been carrying out inspections at Petrel Base in order to establish the state of the buildings and determine the possibility of maintaining or replacing them. In 2006, a technical review of the facilities was carried out and the following tasks were proposed:

- Recover the buildings with metallic structures (Hangar, Warehouse I and Warehouse II) and the Port Depot until they must be removed according to the schedule of activities for the renewal of Petrel Base.
- These structures must be subjected to a periodic maintenance plan that allows preserving and extending their useful life. Work must also be carried out to allow each of these to be recovered to optimal conditions.
- Building a new Main House, Emergency House and Power Plant in the area of the airport facilities, as this is the sector of land that is suitable for building. The current Main House must be used as a workshop house during the construction works. For the new construction project, it would be convenient to try to make all concrete structures remain in closed areas and not outdoors.
- Demolish the following buildings: Main House, Power Plant, Former Power Plant, Emergency House and Cold Room (considering that the cold room itself can be recovered).
- Install a sewage treatment plant and a reverse osmosis desalination plant
- Build new fuel tanks (cisterns). The current ones are not in a condition to be used
- Remove all concrete structures from old buildings to expand the area suitable for construction

- Another no less important issue to take into account is the withdrawal of currently accumulated garbage. An approximate volume of 5000 m of garbage to be removed is estimated, including demolitions.

Based on this diagnosis and depending on the time elapsed, we can establish which buildings will be removed and which will be recovered (Figure 35):

- Accommodation Building: It was fitted out in the years in which the base was operated as a temporary base. In its last year of operation, all the new wiring was laid and stoves were installed with a view to the Petrel Base operating year-round. At present, tasks continue to be carried out in the electrical, gas, water, sewage and insulation systems for optimal functioning of the house. Except for the aforementioned tasks, no large infrastructure works will be carried out on it, since it is planned for removal. The house will remain in use until the new main house on the base is replaced. Once replaced, it will be disassembled.
- Main Power Plant: Due to the current state of the Power Plant (currently the facilities workshop), a container with a 150 KVA generator was installed on a concrete stall near the Main House. This container provides energy to the main house and the current facilities workshop. During the summer of 2021/2022, a temporary metal shed was installed next to the container, on the same concrete platform, which will serve provisionally to install the generators that will be taken there during the 2022/2023 campaign. Said place will function as the provisional Main Power Plant until the Main Power Plant planned in the Petrel Base renovation project is built.
- Hangar: In 2015, work began to remove the waste stored inside the hangar. Finally, during the 2021 campaign, all the waste was removed and prepared for its withdrawal during the summer of 2022/2023. During the coming summer it is planned to continue the maintenance works by installing a heating system, new lights and repairing the floor. This building will remain in the new Base.
- Warehouse I: Currently used as a mechanical workshop. During the 2021 campaign, the following tasks were carried out: replacement of exterior metal sheets and sealing of leaks, installation of the electrical network, construction of an access gate for vehicles, placement of shelves for the storage of tools and spare parts and its removal is planned once the new workshops on the base are built.
- Warehouse II: Maintenance tasks were carried out during the summer of 2021/2022. It currently works as a supply depot. This building is expected to be maintained throughout the development of the Petrel base renovation project.
- Cold Room: Unused buildings. Their removal is anticipated.
- Cisterns: The base has only 2 cisterns of 30 000 litres each. They are out of service and must be removed. Their removal is anticipated during the summer of 2022/2023.
- Auxiliary Power Plant: During the summer of 2019/2020 a generator motor was installed to provide electricity to the Hangar. The electrical network has been changed and the corresponding engine generator control panels have been installed. It currently provides electricity to the group of buildings located on the upper platform, except for the cold room.

- ➢ Emergency House: The building is in good condition. This building will be maintained until the new main house of the base is built.
- ➢ Port Depot: We propose its recycling and use until its demolition, which is planned because it is located in the area at the head of the main runway that will be built.

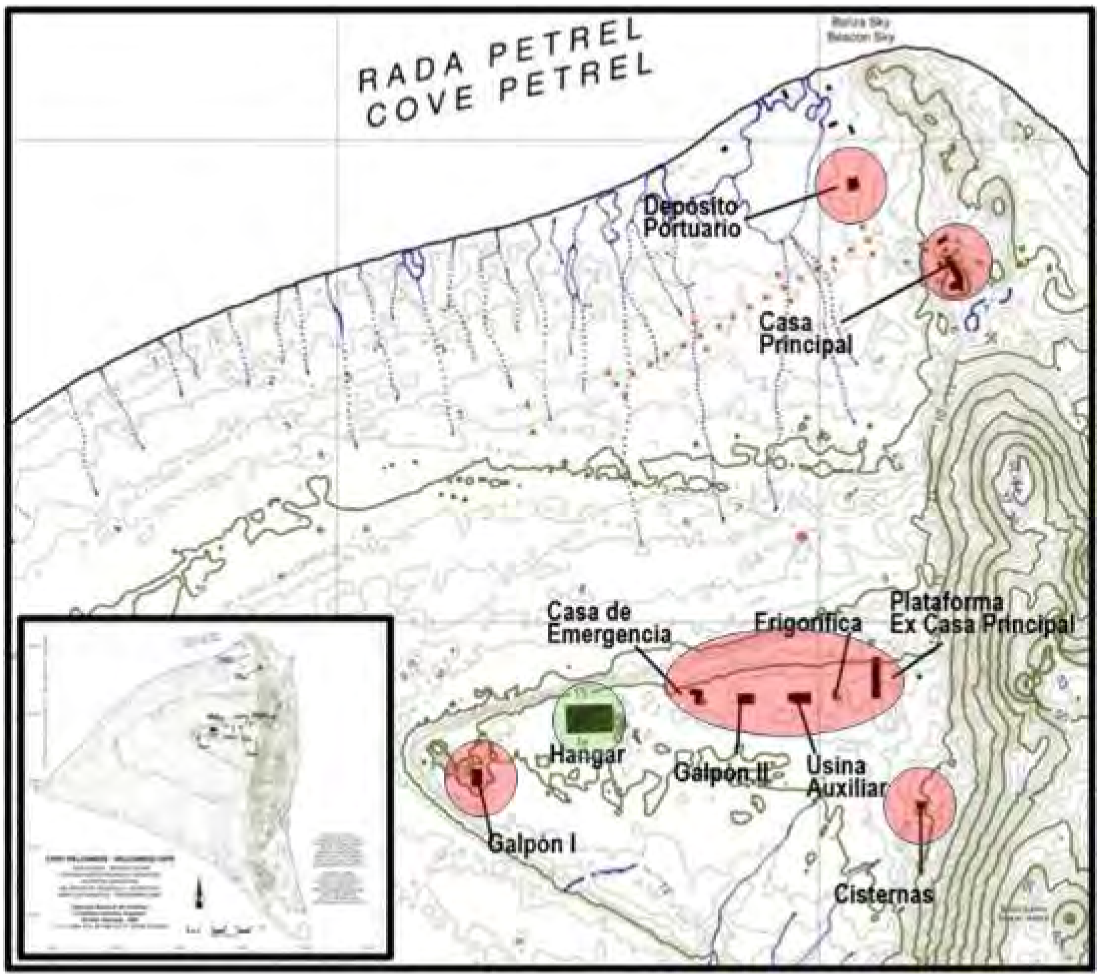


Figure 35: Sketch of the Base indicating which facilities will be removed (red) and which will be maintained (green).

2.2 Scope of the Project

The scope of this draft Comprehensive Environmental Evaluation (CEE) includes all activities in the Antarctic Treaty Area associated with the renovation of the Petrel Base. These include the following project elements:

2.2.1 Remodelling of the Base Facilities

The proposal for remodelling the Petrel Base includes all activities related to the design, construction, and use of the new base, also including the dismantling of existing buildings, civil and foundation works, fitting-out works, logistics and transportation, and installation and commissioning of the new base.

2.2.2 Construction and Use of the New Runway

The activities described in this CEE relate to the construction and use of the proposed runways and associated ground facilities, temporary on-site facilities during the construction phase, the installation and use of machinery, maintenance and decommissioning of the runway.

2.2.3 Construction and use of the Port Area[9]

The activities described in this CEE relate to the construction and use of a port area and associated land facilities, temporary on-site facilities during the construction phase, the installation and use of machinery, maintenance and decommissioning of the port.

2.2.4 Construction of the Photovoltaic Power Plant

The activities described in this CEE relate to the construction of the photovoltaic power plant and include design options for the solar field, the construction and installation of solar panels in the solar field, civil and foundation works, construction and logistics, and the installation and commissioning of the new photovoltaic power plant.

2.2.5 Water Supply Lagoons

The activities described in this CEE relate to the design and establishment of the lagoons to supply water to Petrel Base, and include design options, construction, civil works, and logistics for water supply to the Base.

2.2.6 Area of the Activities

The area affected by the proposed activities (renovation of facilities, construction of a port area, installation of a photovoltaic power plant and establishment of water supply lagoons) is Cape Welchness on Dundee Island in Antarctica. The activity will be carried out within the current radius of occupation and development of the scientific and logistical activities of Petrel Base (Figure 36).

Dundee Island is located in the northeastern sector of the Antarctic Peninsula, it is part of the Tierra San Martín (Graham Land) group of islands and is presented by the D'Urvill, Joinville, Bransfield islands and several smaller islets. It has a maximum extension of 27 km in the west-east direction. Currently, its 450 km^2 are covered with glaciers that fall precipitously into the sea. The activities described in this CEE will be carried out on the only ice-free area of the island that is located in the western part of the island, with the following geographical coordinates: 63° 28’ 0" south latitude and 56° 17’ 0" west longitude (Figure 36). This sector, called Cape Welchness, consists of a triangular area covering approximately 2.5 km^2. Most of it has a very flat surface with a drop of a few metres, especially on its outer edges that border the sea and are eroded by small streams, with the other margins marking the crest of the lateral moraine of the Rosamaría glacier. The maximum extent of this flat sector is of 1950 m in the northeast to southwest direction and 1400 m in the northwest to southeast direction.

Geologically, this sector of Dundee Island consists of two units of sedimentary Cretaceous and Triassic rocks. A Cretaceous sedimentary package of consolidated shale and mudstone is located in the east-southeast part of the Petrel plain and crops out at the eastern limit

[9] This development was included in the original project but later discarded in the analysis of alternatives.

of the lateral moraine. Along the coastal area, outcrops of marine shale and mudstone of the Trinity Group were found during periods of low tide. Complex glacial and fluvioglacial deposits, deposited from the Late Pleistocene to the present, complete the stratigraphic succession (Figure 37).

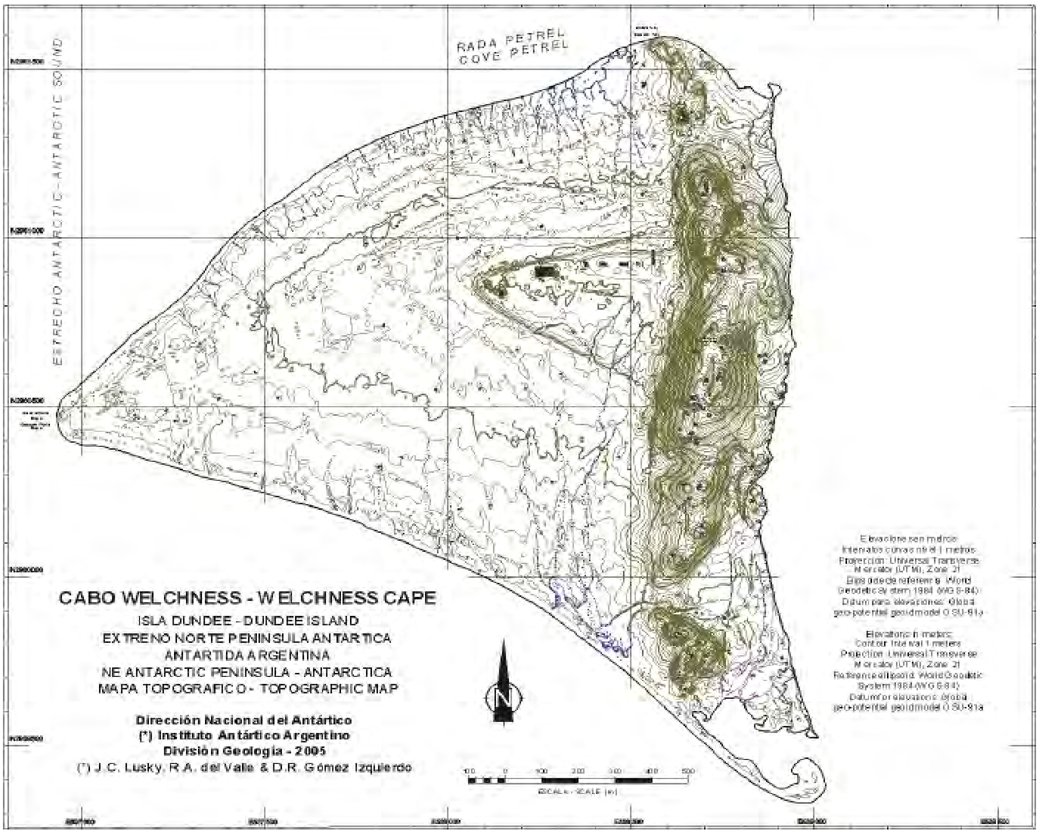


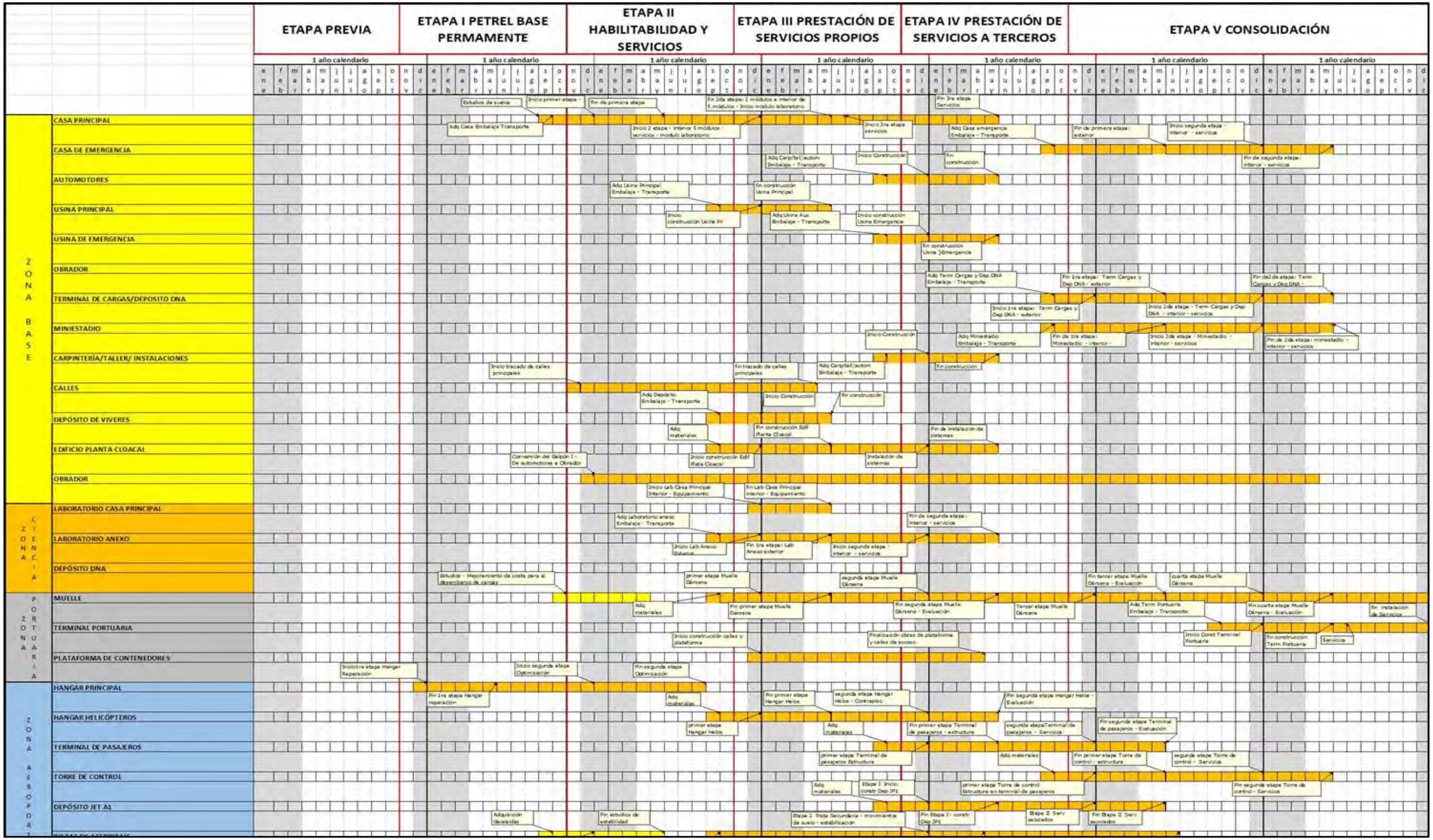
Figure 36: Cape Welchness, area affected by the Petrel Base renovation activities.

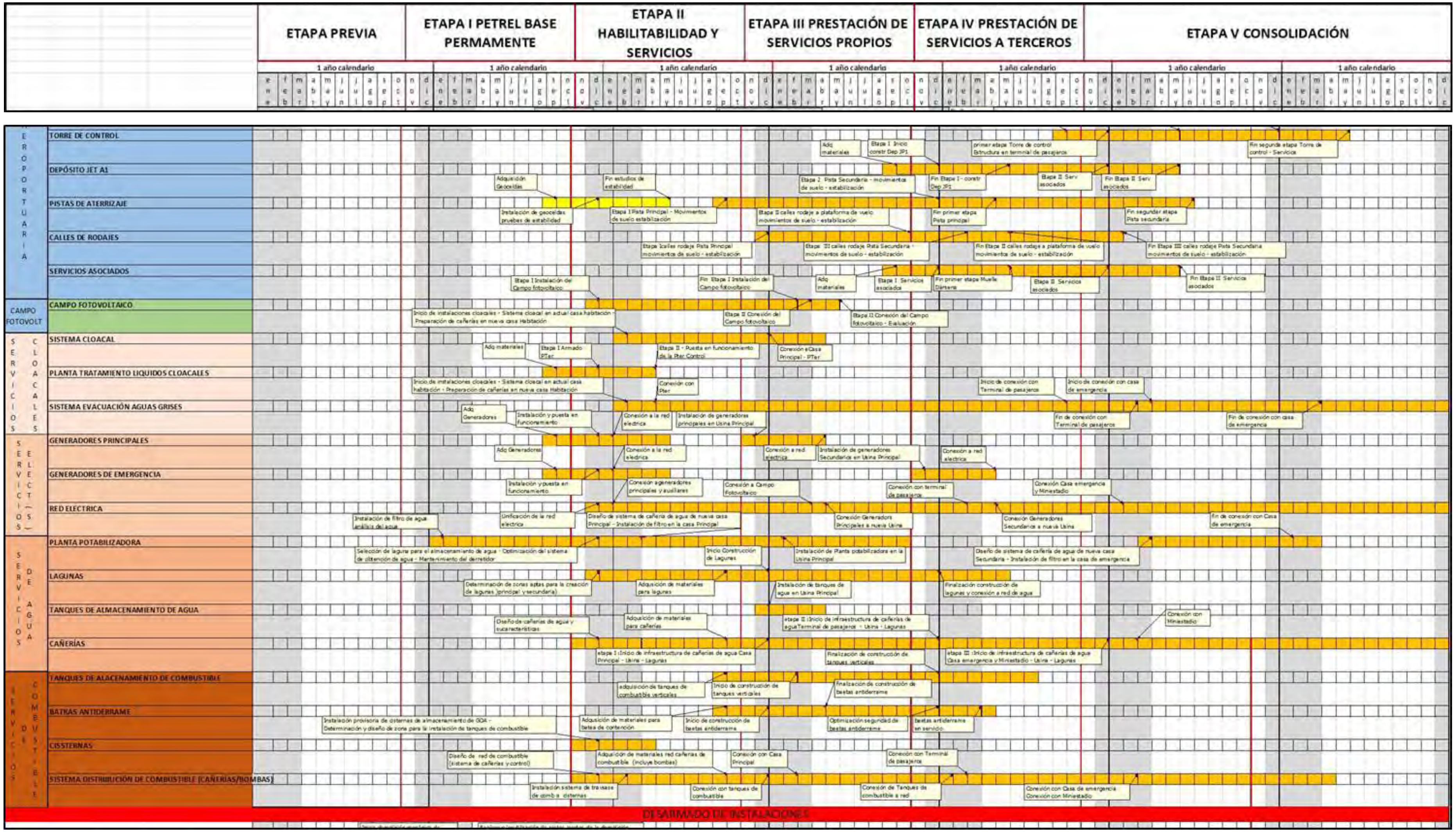
The environmental conditions, geographical location, local characteristics of the relief, and meteorology of Cape Welchness make it a prosperous location for the renovation of the Base, the construction of a runway for aircraft of various types and for all other planned activities. In addition, the criteria that guided the choice of carrying out these activities were:

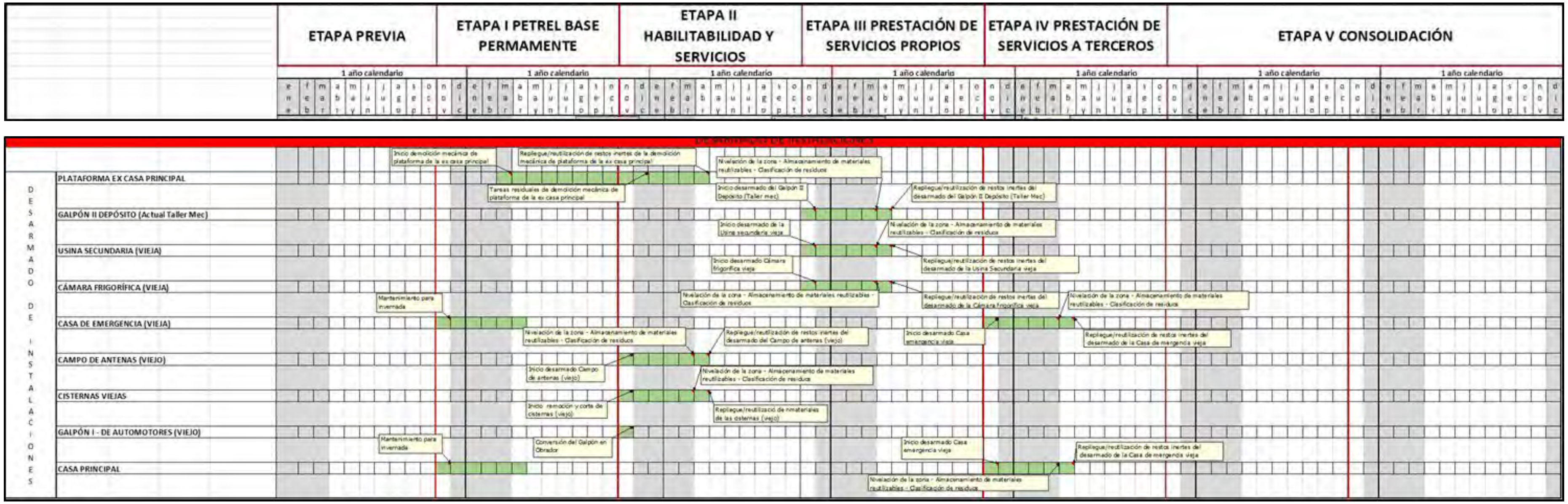
- The area for the facilities is already impacted by existing buildings;
- Minimum surface impacted and limited to Cape Welchness;
- Minimum movement of materials for construction of the runway;
- Minimum movements for land levelling;
- The type of soil;
- The orientation of the runway towards the strongest winds;
- The vulnerability of the area to the impacts of climate change;
- The absence of obstacles on the line of approach for flights;
- The cumulative environmental impacts are minimal;

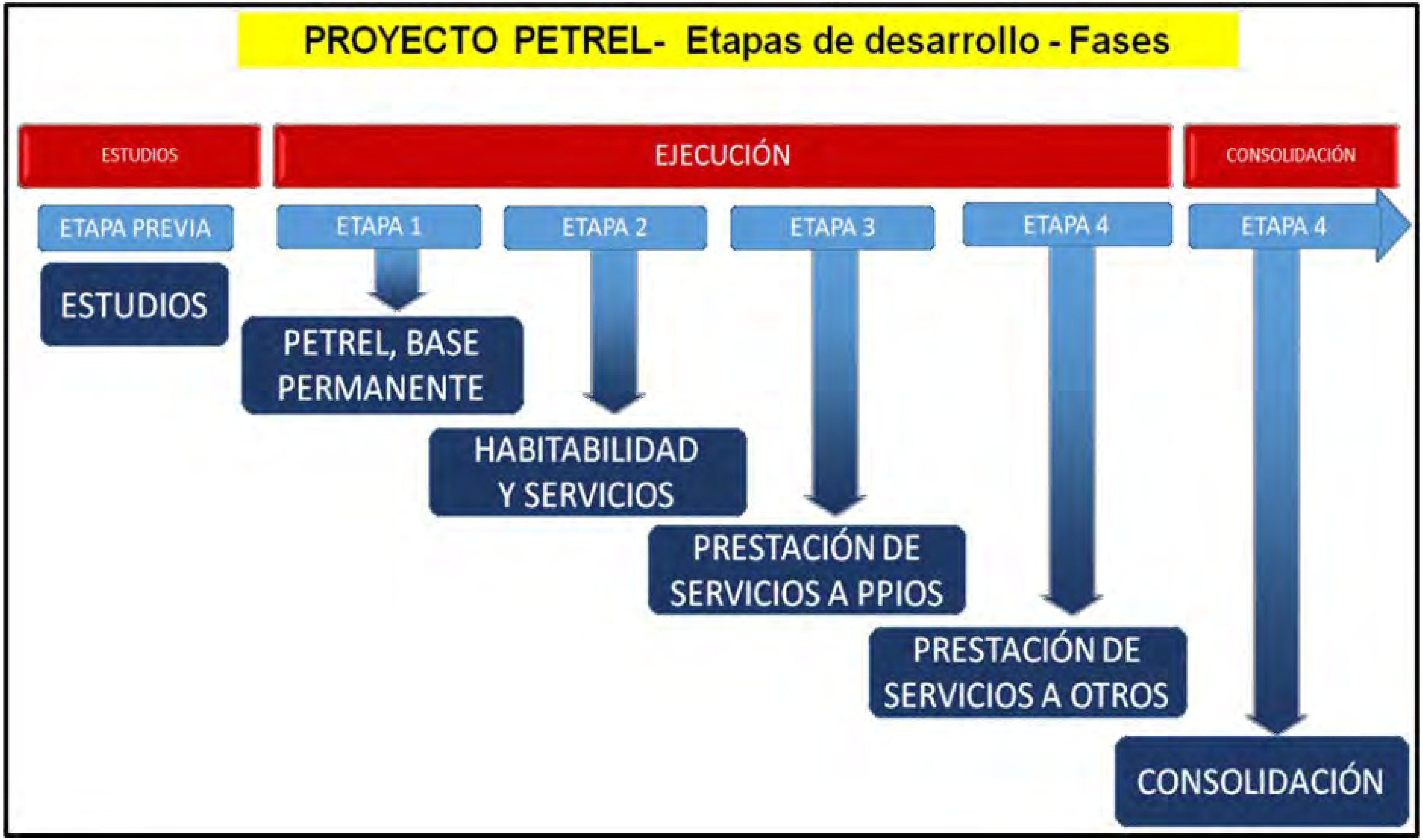
2.2.7 Project Schedule and Stages

2.2.7.1 Project Schedule (attached as Annex I)




ETAPA PREVIA
ETAPA I PETREL BASE PERMAMENTE
ETAPA II HABILITABILIDAD Y SERVICIOS
ETAPA III PRESTACIÓN DE SERVICIOS PROPIOS
ETAPA IV PRESTACIÓN DE SERVICIOS A TERCEROS
ETAPA V CONSOLIDACIÓN
1 año calendario
AEROPORTUARIA
TORRE DE CONTROL
DEPÓSITO JET A1
PISTAS DE ATERRIZAJE
CALLES DE RODAJES
SERVICIOS ASOCIADOS
CAMPO FOTOVOLT
CAMPO FOTOVOLTAICO
SERVICIOS CLOACALES
SISTEMA CLOACAL
PLANTA TRATAMIENTO LIQUIDOS CLOACALES
SISTEMA EVACUACIÓN AGUAS GRISES
SERVICIOS ELECTRICOS
GENERADORES PRINCIPALES
GENERADORES DE EMERGENCIA
RED ELECTRICA
SERVICIOS DE AGUA
PLANTA POTABILIZADORA
LAGUNAS
TANQUES DE ALMACENAMIENTO DE AGUA
CAÑERÍAS
SERVICIOS DE COMBUSTIBLE
TANQUES DE ALMACENAMIENTO DE COMBUSTIBLE
BATEAS ANTIDERRAME
CISSTERNAS
SISTEMA DISTRIBUCIÓN DE COMBUSTIBLE (CAÑERÍAS/BOMBAS)
DESARMADO DE INSTALACIONES


ETAPA PREVIA
ETAPA I PETREL BASE PERMAMENTE
ETAPA II HABILITABILIDAD Y SERVICIOS
ETAPA III PRESTACIÓN DE SERVICIOS PROPIOS
ETAPA IV PRESTACIÓN DE SERVICIOS A TERCEROS
ETAPA V CONSOLIDACIÓN
1 año calendario
DESARMADO DE INSTALACIONES
PLATAFORMA EX CASA PRINCIPAL
GALPÓN II DEPÓSITO (Actual Taller Mec)
USINA SECUNDARIA (VIEJA)
CÁMARA FRIGORÍFICA (VIEJA)
CASA DE EMERGENCIA (VIEJA)
CAMPO DE ANTENAS (VIEJO)
CISTERNAS VIEJAS
GALPÓN I - DE AUTOMOTORES (VIEJO)
CASA PRINCIPAL
Inicio demolición mecánica de plataforma de la ex casa principal
Repliegue/reutilización de restos inertes de la demolición mecánica de plataforma de la ex casa principal
Tareas residuales de demolición mecánica de plataforma de la ex casa principal
Nivelación de la zona - Almacenamiento de materiales reutilizables - Clasificación de residuos
Inicio desarmado del Galpón II Depósito (Taller mec)
Repliegue/reutilización de restos inertes del desarmado del Galpón II Depósito (Taller Mec)
Inicio desarmado de la Usina secundaria vieja
Nivelación de la zona - Almacenamiento de materiales reutilizables - Clasificación de residuos
Inicio desarmado Cámara frigorífica vieja
Repliegue/reutilización de restos inertes del desarmado de la Usina Secundaria vieja
Nivelación de la zona - Almacenamiento de materiales reutilizables - Clasificación de residuos
Repliegue/reutilización de restos inertes del desarmado de la Cámara frigorífica vieja
Mantenimiento para invernada
Nivelación de la zona - Almacenamiento de materiales reutilizables - Clasificación de residuos
Inicio desarmado Casa emergencia vieja
Repliegue/reutilización de restos inertes del desarmado de la Casa de mergencia vieja
Nivelación de la zona - Almacenamiento de materiales reutilizables - Clasificación de residuos
Repliegue/reutilización de restos inertes del desarmado del Campo de antenas (viejo)
Inicio desarmado Campo de antenas (viejo)
Nivelación de la zona - Almacenamiento de materiales reutilizables - Clasificación de residuos
Inicio remoción y corte de cisternas (viejo)
Repliegue/reutilizació de nmateriales de las cisternas (viejo)
Mantenimiento para invernada
Conversión del Galpón en Obrador
Inicio desarmado Casa emergencia vieja
Repliegue/reutilización de restos inertes del desarmado de la Casa de mergencia vieja
Nivelación de la zona - Almacenamiento de materiales reutilizables - Clasificación de residuos


PROYECTO PETREL- Etapas de desarrollo - Fases
ESTUDIOS
EJECUCIÓN
CONSOLIDACIÓN
ETAPA PREVIA
ETAPA 1
ETAPA 2
ETAPA 3
ETAPA 4
ETAPA 4
ESTUDIOS
PETREL, BASE PERMANENTE
HABITABILIDAD Y SERVICIOS
PRESTACIÓN DE SERVICIOS A PPIOS
PRESTACIÓN DE SERVICIOS A OTROS
CONSOLIDACIÓN

BASE PETREL
Distribución actual de instalaciones

BASE PETREL
Distribución futura
de instalaciones
RADA PETREL
COVE PETREL
ESTRECHO ANTARTICO
CABO WELCHNESS - WELCHNESS CAPE
ISLA DUNDEE - DUNDEE ISLAND
EXTRENO NORTE PENINSULA ANTARTICA
ANTARTIDA ARGENTINA
NE ANTARCTIC PENINSULA - ANTARCTICA
MAPA TOPOGRAFICO - TOPOGRAPHIC MAP
Dirección Nacional del Antártico
(*) Instituto Antártico Argentino
División Geología - 2005
(*) J.C. Lusky, R.A. del Valle & D.R. Gómez Izquierdo
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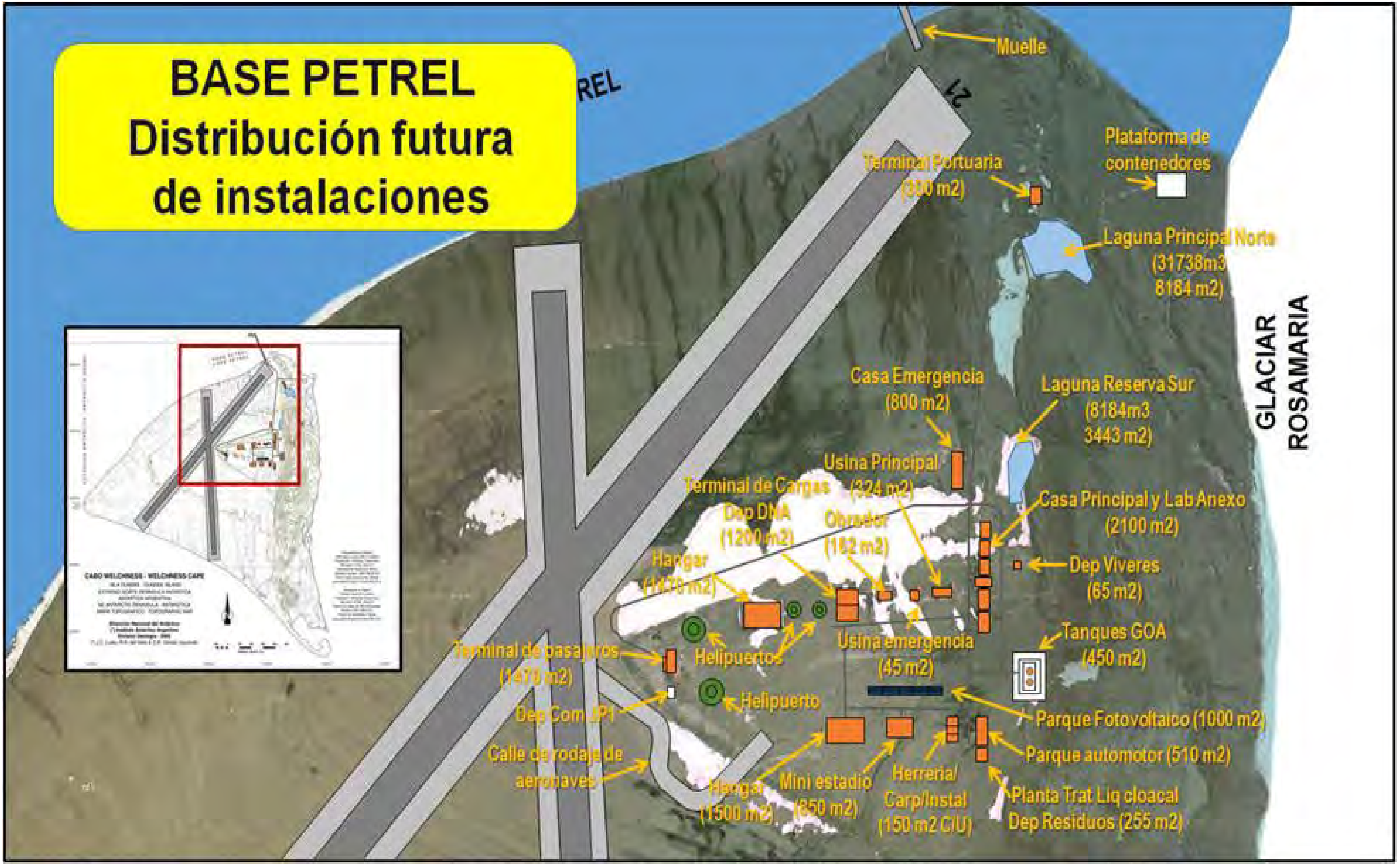
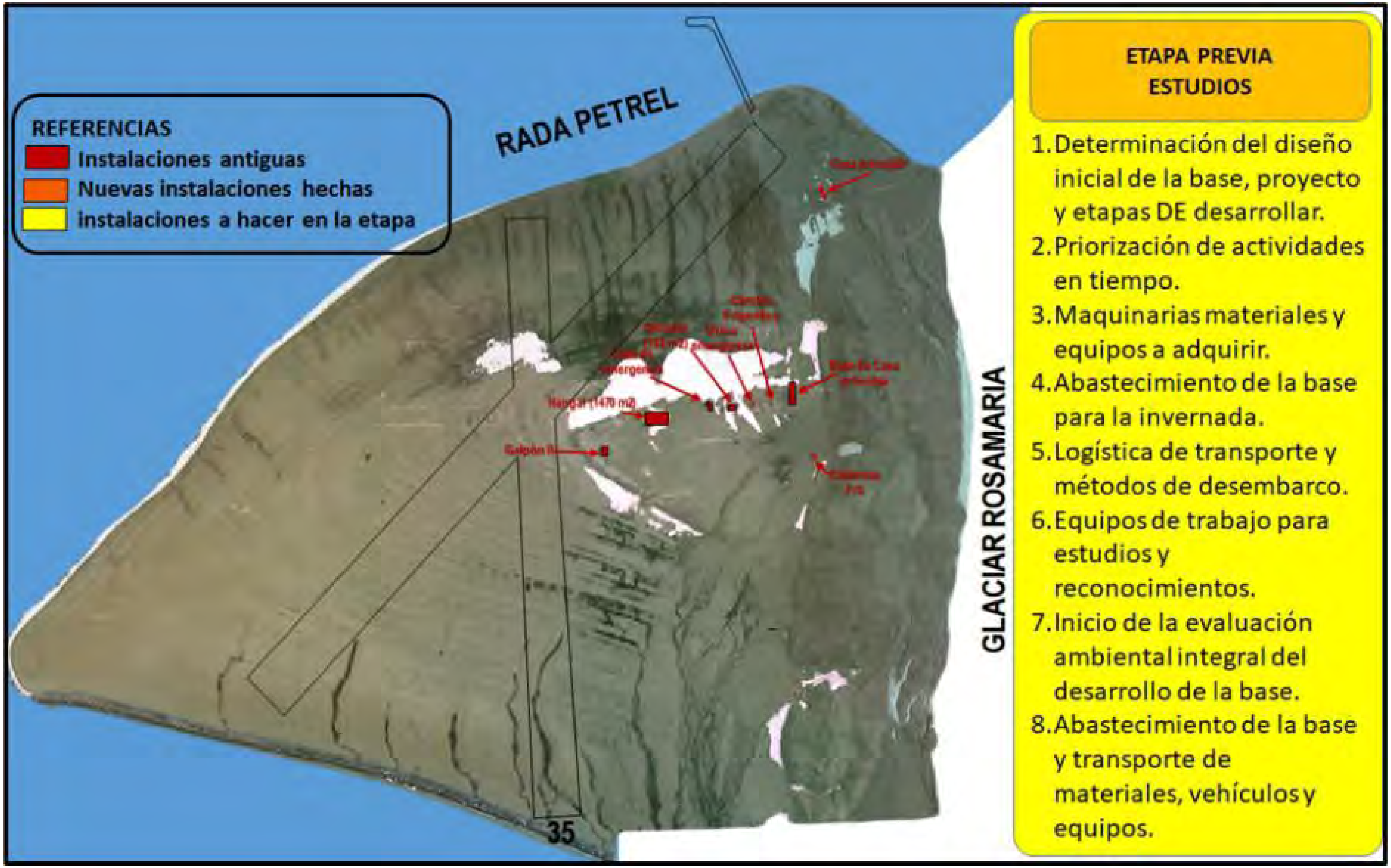
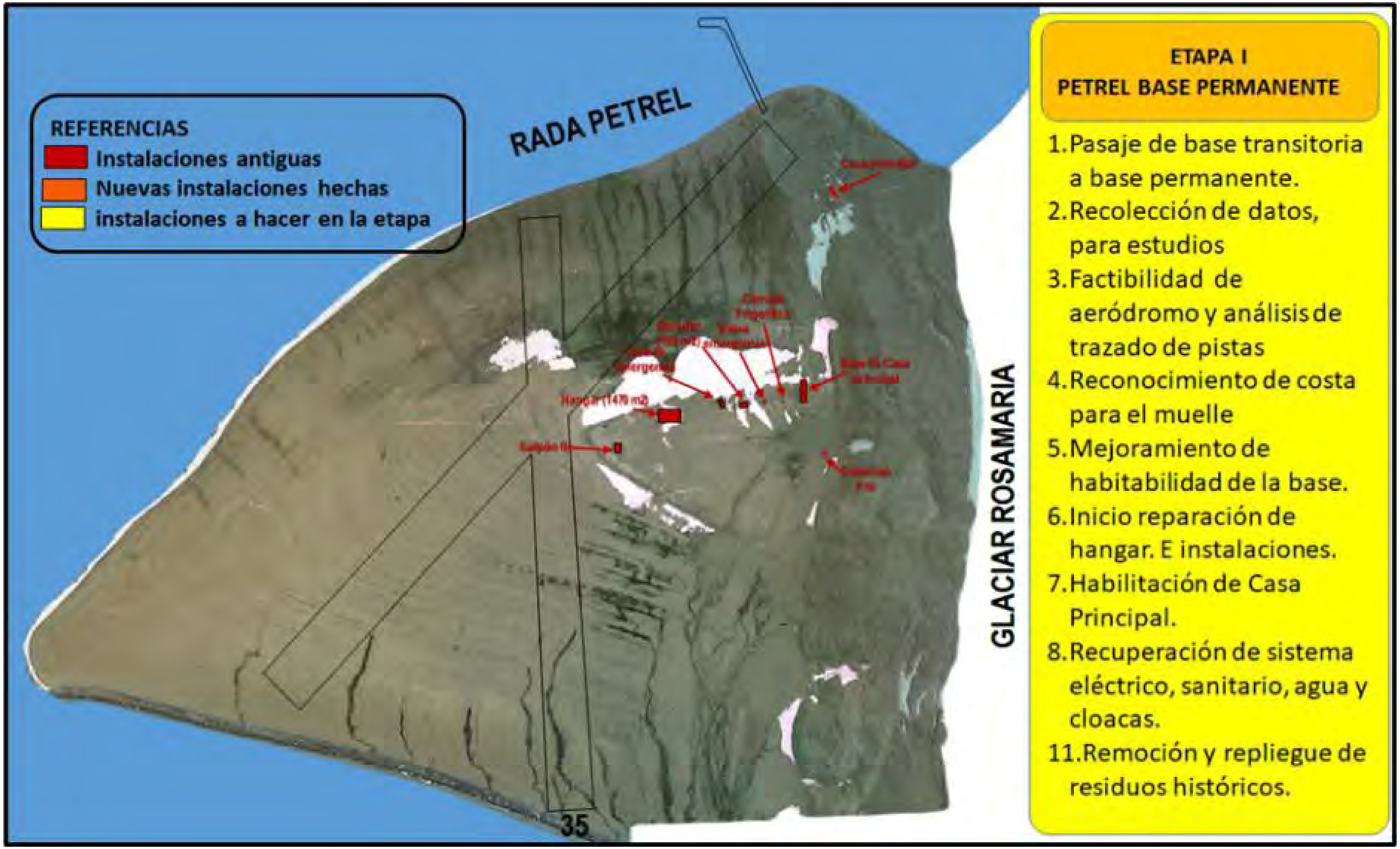

BASE PETREL
Distribución futura
de instalaciones
REL
21
Muelle
Terminal Portuaria
(300 m2)
Plataforma de
contenedores
Laguna Principal Norte
(31738m3
8184 m2)
GLACIAR
ROSAMARIA
Casa Emergencia
(800 m2)
Laguna Reserva Sur
(8184m3
3443 m2)
Usina Principal
(324 m2)
Terminal de Cargas
Dep DNA
(1200 m2)
Obrador
(182 m2)
Casa Principal y Lab Anexo
(2100 m2)
Dep Viveres
(65 m2)
Hangar
(1470 m2)
Tanques GOA
(450 m2)
Usina emergencia
(45 m2)
Terminal de pasajeros
(1470 m2)
Helipuertos
Helipuerto
Dep Com JP1
Parque Fotovoltaico (1000 m2)
Parque automotor (510 m2)
Calle de rodaje de
aeronaves
Hangar
(1500 m2)
Mini estadio
(850 m2)
Herreria/
Carp/Instal
(150 m2 C/U)
Planta Trat Liq cloacal
Dep Residuos (255 m2)
CABO WELCHNESS - WELCHNESS CAPE


REFERENCIAS
Instalaciones antiguas
Nuevas instalaciones hechas
instalaciones a hacer en la etapa
RADA PETREL
GLACIAR ROSAMARIA
35
ETAPA PREVIA
ESTUDIOS
1. Determinación del diseño inicial de la base, proyecto y etapas DE desarrollar.
2. Priorización de actividades en tiempo.
3. Maquinarias materiales y equipos a adquirir.
4. Abastecimiento de la base para la invernada.
5. Logística de transporte y métodos de desembarco.
6. Equipos de trabajo para estudios y reconocimientos.
7. Inicio de la evaluación ambiental integral del desarrollo de la base.
8. Abastecimiento de la base y transporte de materiales, vehículos y equipos.


REFERENCIAS
Instalaciones antiguas
Nuevas instalaciones hechas
instalaciones a hacer en la etapa
RADA PETREL
GLACIAR ROSAMARIA
Hangar (1470 m2)
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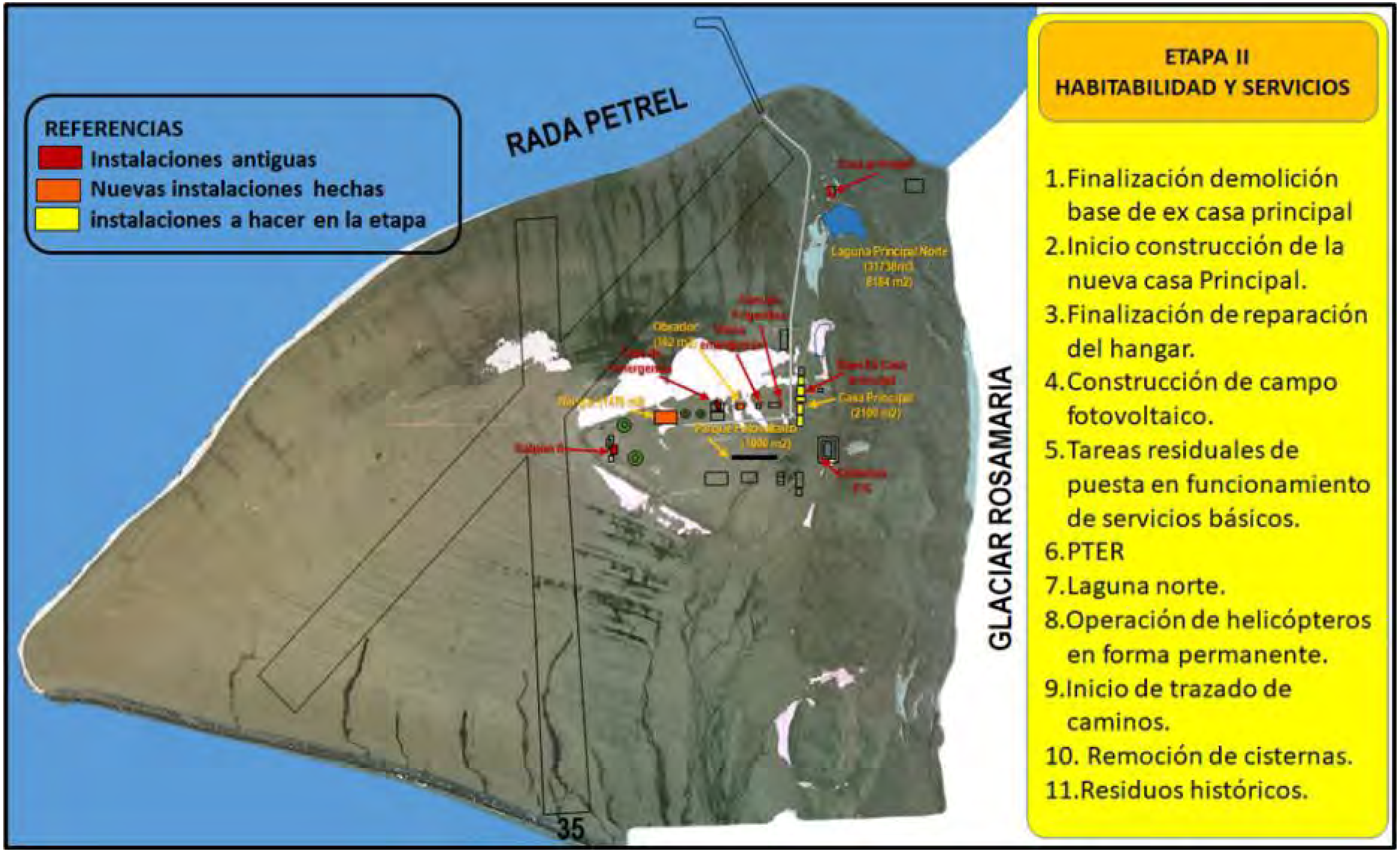
ETAPA I
PETREL BASE PERMANENTE
1. Pasaje de base transitoria a base permanente.
2. Recolección de datos, para estudios
3. Factibilidad de aeródromo y análisis de trazado de pistas
4. Reconocimiento de costa para el muelle
5. Mejoramiento de habitabilidad de la base.
6. Inicio reparación de hangar. E instalaciones.
7. Habilitación de Casa Principal.
8. Recuperación de sistema eléctrico, sanitario, agua y cloacas.
11. Remoción y repliegue de residuos históricos.


REFERENCIAS
Instalaciones antiguas
Nuevas instalaciones hechas
instalaciones a hacer en la etapa
RADA PETREL
GLACIAR ROSAMARIA
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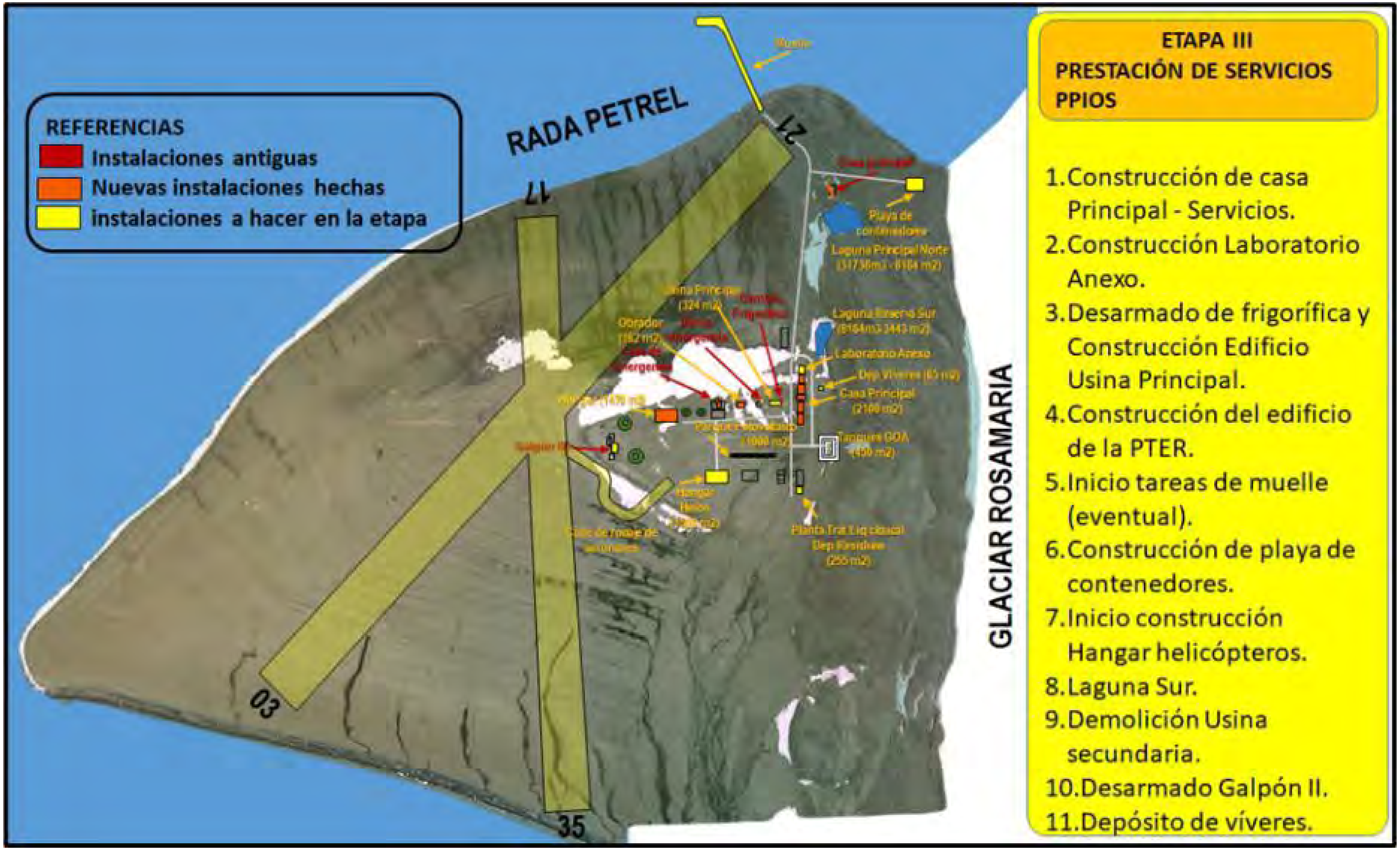
ETAPA II
HABITABILIDAD Y SERVICIOS
1. Finalización demolición base de ex casa principal
2. Inicio construcción de la nueva casa Principal.
3. Finalización de reparación del hangar.
4. Construcción de campo fotovoltaico.
5. Tareas residuales de puesta en funcionamiento de servicios básicos.
6. PTER
7. Laguna norte.
8. Operación de helicópteros en forma permanente.
9. Inicio de trazado de caminos.
10. Remoción de cisternas.
11. Residuos históricos.


REFERENCIAS
Instalaciones antiguas
Nuevas instalaciones hechas
instalaciones a hacer en la etapa
RADA PETREL
17
21
03
35
GLACIAR ROSAMARIA
ETAPA III
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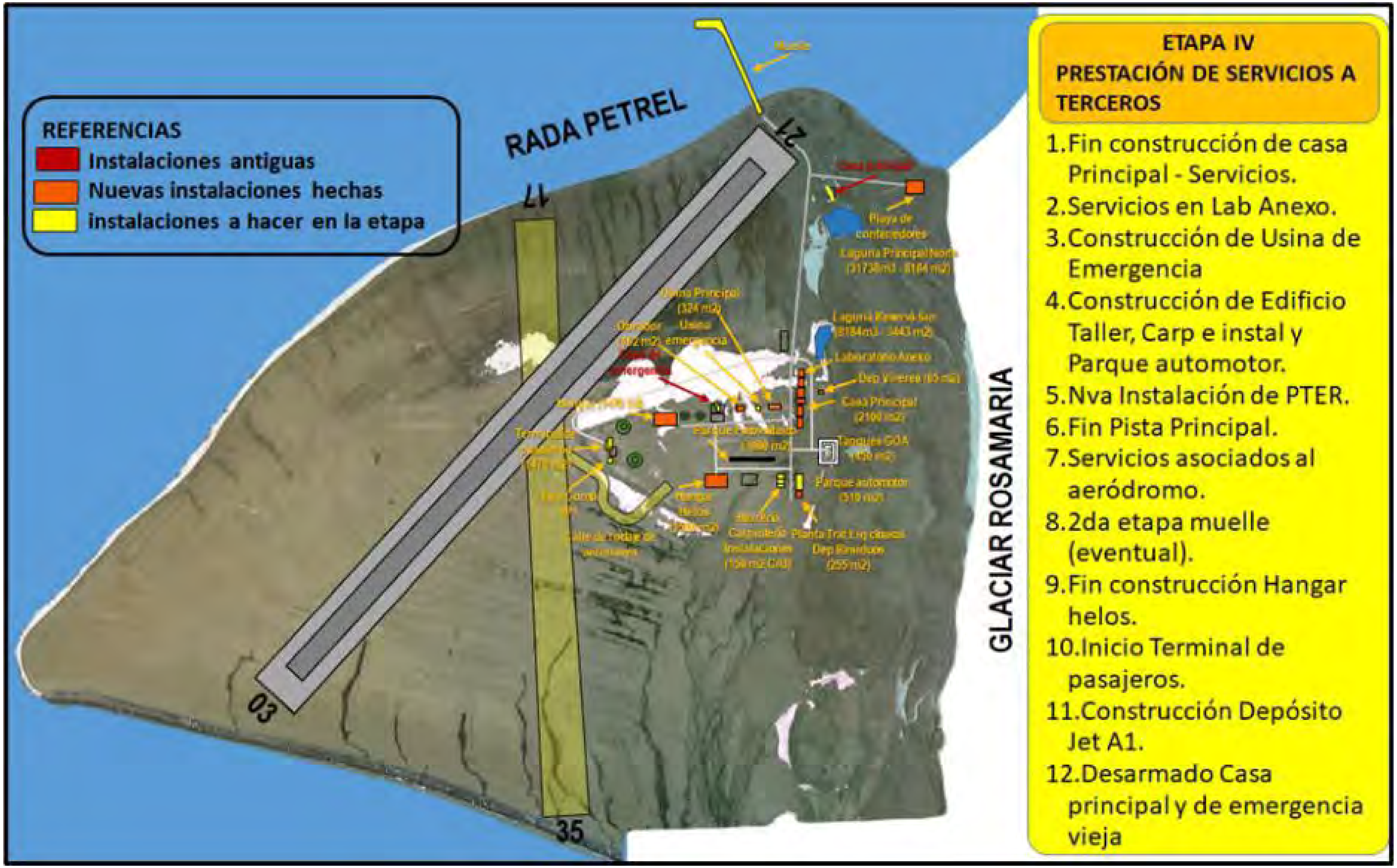
1.Construcción de casa Principal - Servicios.
2.Construcción Laboratorio Anexo.
3.Desarmado de frigorífica y Construcción Edificio Usina Principal.
4.Construcción del edificio de la PTER.
5.Inicio tareas de muelle (eventual).
6.Construcción de playa de contenedores.
7.Inicio construcción Hangar helicópteros.
8.Laguna Sur.
9.Demolición Usina secundaria.
10.Desarmado Galpón II.
11.Depósito de víveres.



REFERENCIAS
Instalaciones antiguas
Nuevas instalaciones hechas
instalaciones a hacer en la etapa
RADA PETREL
GLACIAR ROSAMARIA
21
17
03
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ETAPA IV
PRESTACIÓN DE SERVICIOS A TERCEROS
1.Fin construcción de casa Principal - Servicios.
2.Servicios en Lab Anexo.
3.Construcción de Usina de Emergencia
4.Construcción de Edificio Taller, Carp e instal y Parque automotor.
5.Nva Instalación de PTER.
6.Fin Pista Principal.
7.Servicios asociados al aeródromo.
8.2da etapa muelle (eventual).
9.Fin construcción Hangar helos.
10.Inicio Terminal de pasajeros.
11.Construcción Depósito Jet A1.
12.Desarmado Casa principal y de emergencia vieja


REFERENCIAS
Instalaciones antiguas
Nuevas instalaciones hechas
instalaciones a hacer en la etapa
RADA PETREL
17
21
03
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GLACIAR ROSAMARIA
ETAPA V
CONSOLIDACIÓN
1. Construcción Casa de emergencia (fin 2025).
2. Construcción de Mini estadio (fin 2025).
3. Construcción de Terminal Portuaria (fin 2025).
4. Fin Pista Secundaria.
5. 3ra etapa muelle (fin sujeto a estudios).
6. 2da etapa Terminal de pasajeros (Fin 2025).
7. Construcción torre de control (fin 2025).

Figure 37: General outline of the initial proposal for the new Petrel Base (the quay was excluded in the analysis of alternatives).

2.2.7.2 Project Stages

The initial development of Petrel Antarctic Base (BAP) (Figure 38) has been thought of as a process consisting of a preliminary stage and four well-defined stages. Each stage may or may not span a calendar year. The duration of each stage will be subject to achievement of its objectives. The sequence of the stages responds to the logic for development of the base. However, it is possible that activities from different stages can be developed simultaneously. This possibility is foreseen based on construction times, the possibilities for transportation of supplies and the particular characteristics of the geographical environment (geography, weather conditions and periods of access to the area).

Regarding the duration over time of each stage of development, it has been foreseen that each one of them will have a duration of no less than one calendar year. The beginning of each stage (its execution) is considered from the beginning of the Antarctic summer (first days of December). Given the complexity and diversity of the activities to be carried out, it is probable that the execution of each stage will extend in time beyond the year anticipated. This expectation leads to the clarification that the execution of a stage of development does not exclude the possibility of its execution simultaneously with other activities planned in a later stage.

In short, the established stages respond to a logical planning methodology, which cannot be rigid and is therefore subject to adjustments and adaptations. The planned stages are the following:

- Preliminary Stage: Studies
- Stage 1 Petrel, permanent base
- Stage 2 Habitability and services
- Stage 3 Provision of own services
- Stage 4 Provision of services to third parties

Preliminary phase: Studies

The objective of this stage is to plan the development of the base, solving implementation problems, establishing stages, material requirements, execution times. Although decisions will be made throughout the base modernisation process, it is during this phase that the most crucial decisions will be made, relating to the design parameters to be implemented and the capabilities to be developed to meet the needs of the Argentine Antarctic Programme.

Stage 1 Petrel, permanent base[10]

The objective of this stage is to change the situation of the BAP before the Antarctic Treaty community, from a temporary base to a permanent base, assigning a team for overwintering. This team, together with a summer work team, should start the renovation activities at the base. The objective of this phase responds to the need to maintain the base operational throughout the year in order to carry out maintenance and

10 To carry out this stage, an Initial Environmental Evaluation (IEE) was prepared, which was presented by Argentina and is available: IEE - Repair and Maintenance Works at Petrel Base, Dundee Island. 2021-2022 Summer and Winter Antarctic Campaign.

improvement activities. Its permanent operation will also facilitate sending the different groups organised to carry out the environmental and design work of the base.

It is during this stage that the different design alternatives will be evaluated based on the environmental standards set by the Antarctic Treaty System. Upon completion of this stage, the general design of the base must be complete. The stage will end with the presentation of the Comprehensive Environmental Evaluation of the base at the Antarctic Treaty Consultative Meeting.

Stage 2 Habitability and Services

The objective of this phase is to increase staff accommodation capacity, while ensuring enough space for storing the materials and machinery necessary for development of the base. To do this, the construction of a new accommodation building will begin, as well as the commissioning of the base hangar, the use of the old buildings, the removal of structures in disuse or without a current purpose and the environmental remediation of the base through the collection, classification, storage and removal of historical waste from the base. It is during this stage that new constructions will begin based on the decisions already made.

Stage 3 Provision of Own Services

The objective of this stage is to begin the use of the base as a scientific centre and to use the base as a passenger and cargo transfer terminal for the Argentine Antarctic Programme.

Stage 4 Provision of Services to Third Parties

The objective of this stage is to enable use of the base as a transfer terminal for passengers and cargo to other Antarctic programmes with the surplus capacities of the base.

2.2.7.4 Facilities to be built

	PRELIMINARY STAGE	STAGE I PETREL, PERMANENT BASE	STAGE II HABITABILITY AND SERVICES	STAGE III PROVISION OF OWN SERVICES	STAGE IV PROVISION OF THIRD PARTY SERVICES	STAGE V CONSOLIDATION
MAIN HOUSE						
EMERGENCY HOUSE						
VEHICLES						
MAIN POWER PLANT						
EMERGENCY POWER PLANT						
WORKSHOP						
LOADING TERMINAL/DNA DEPOT						
MINI STADIUM						
CARPENTRY/WORKSHOP/FACILITIES						
STREETS						
FOOD DEPOT						
SEWAGE PLANT BUILDING						
WORKSHOP						
MAIN HOUSE LABORATORY						
ANNEX LABORATORY						
DNA DEPOT						
QUAY						
PORT TERMINAL						
CONTAINER PLATFORM						
MAIN HANGAR						
HELICOPTER HANGAR						
PASSENGER TERMINAL						
CONTROL TOWER						
JET A1 DEPOT						
RUNWAYS						
TAXIWAYS						
ASSOCIATED SERVICES						
PHOTOVOLTAIC FIELD						
SEWAGE SYSTEM						
LIQUID TREATMENT PLANT SEWERS						
GRAY WATER EVACUATION SYSTEM						
MAIN GENERATORS						
EMERGENCY GENERATORS						
ELECTRICAL NETWORK						
WATER TREATMENT PLANT						
LAGOONS						

WATER STORAGE TANKS						
PLUMBING						
FUEL STORAGE TANKS						
NON-SPILL PANS						
CISTERNS						
FUEL DISTRIBUTION SYSTEM						

2.2.7.5 Installations to be removed

	PRELI MINAR Y STAGE	STAGE I PETREL, PERMANENT BASE	STAGE II HABITABILITY AND SERVICES	STAGE III PROVISION OF OWN SERVICES	STAGE IV PROVISION OF THIRD PARTY SERVICES	STAGE V CONSOLIDATION	
FORMER MAIN HOUSE PLATFORM							
WAREHOUSE II DEPOT (Current Mech Workshop)							
SECONDARY POWER PLANT (OLD)							
COLD ROOM (OLD)							
EMERGENCY HOUSE (OLD)							
ANTENNA FIELD (OLD)							
OLD TANKS							
WAREHOUSE I - VEHICLES (OLD)							
MAIN HOUSE							

References

- Construction
- Recovery of installation
- Removal
- Planning

2.2.7.6 Sequence of the deconstruction of buildings and structures to be removed:

No.	Building	Opportunity	Observations
1.	Platform of the former house Main (burnt down)	Stage I	As part of the removal of old structures without current use
2.	Cisterns	Stages I and II	
3.	Antenna field	Stages I and II	
4.	Cold room	Stages II and III	After installation of the refrigerators
5.	Auxiliary power plant	Stages II and III	After construction of the new Main Power Plant

6.	Emergency house	Stages III and IV	Once construction of the Main House has been completed
7.	Warehouse II – Depot	Stages II and III	Before starting with the passenger terminal
8.	Current Main House	Stages III and IV	When starting construction of the Emergency house

2.2.7.7 Sorting, packing, stockpiling for withdrawal from the Antarctic continent

The elements that make up the structure of each building will be classified as the removal of each one progresses. The sequence to be carried out will be the following:

- Evaluation of the construction method stage.
- Determination of the groups of waste that will be produced
- Evaluation of possibilities of reusing the materials.
- Provision of packaging for the waste storage.
- Anticipation of conditions for carrying out the task (See 4.6.1 Deconstruction method)
- Execution of the tasks.
- Waste packaging.
- Transport and stowage in assigned sectors
- Shipment of waste on ships used by the Argentine Antarctic Programme. The entire process will be supervised and certified by the Base's environmental manager.

2.2.7.8 Construction of new facilities

The new facilities at Petrel Base will be built sequentially once the Comprehensive Environmental Evaluation project is approved as regulated in the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1 [2016]). The approval of the Comprehensive Environmental Evaluation will allow the project to advance beyond Stage II. (It must be taken into account that the project for remodelling Petrel Base, anticipates, up to stage I, the improvement of the facilities and their environmental clean-up).

The construction of the new facilities begins in Stage II of the project. When an old construction is replaced by a new one, the old one must be dismantled. The logic followed for the development of the new base facilities is as follows:

- Recovering the base so that it can function throughout the year (permanent base).
- Increasing accommodation capacity (construction of the new house) and increasing the capacity of associated services (energy, water, sewage, fuel).
- Developing the scientific capacity of the base (construction and operation of laboratories).
- Completing the capacity of services at the base for their operation and development of reserve capacities (emergency house, lagoons, auxiliary power plant).

- Development of airport capacities.

Likewise, it should be considered that each of the project development stages (Stages II to IV) has a minimum execution time of one year, a time that may be extended if it runs into difficulties (weather, logistics or construction difficulties) that may arise during the planned works. According to the planned schedule, the new facilities (and services) will be developed in the following stages:

2.2.7.9 Stage II – Habitability and services

	PRELI MINAR Y	STAGE I PETREL, PERMANENT BASE	STAGE II HABITABILITY AND SERVICES	STAGE III PROVISION OF OWN SERVICES	STAGE IV PROVISION OF SERVICES TO THIRD PARTIES	STAGE V CONSOLIDATION
MAIN HOUSE						
MAIN POWER PLANT						
STREETS						
FOOD DEPOT						
SEWAGE PLANT BUILDING						
WORKSHOP						
MAIN HOUSE LABORATORY						
ANNEX LABORATORY						
QUAY						
MAIN HANGAR						
HELICOPTER HANGAR						
RUNWAYS						
PHOTOVOLTAIC FIELD						
SEWAGE SYSTEM						
SEWAGE LIQUID TREATMENT PLANT						
GRAY WATER EVACUATION SYSTEM						
MAIN GENERATORS						
EMERGENCY GENERATORS						
ELECTRICAL NETWORK						
WATER TREATMENT PLANT						
LAGOONS						
PLUMBING						
FUEL STORAGE TANKS						
NON-SPILL PANS						
CISTERNS						
FUEL DISTRIBUTION SYSTEM						

2.2.7.10 Stage III Provision of own services

	PRELIMINARY STAGE	STAGE I PETREL, PERMANENT BASE	STAGE II HABITABILITY AND SERVICES	STAGE III PROVISION OF OWN SERVICES	STAGE IV PROVISION OF THIRD PARTY SERVICES	STAGE V CONSOLIDATION
MAIN HOUSE						
VEHICLES						
MAIN POWER PLANT						
EMERGENCY POWER PLANT						
CARPENTRY/WORKSHOP/FACILITIES						
STREETS						
FOOD DEPOT						
SEWAGE PLANT BUILDING						
WORKSHOP						
MAIN HOUSE LABORATORY						
ANNEX LABORATORY						
QUAY						
CONTAINER PLATFORM						
HELICOPTER HANGAR						
PASSENGER TERMINAL						
JET A1 DEPOT						
RUNWAYS						
TAXIWAYS						
ASSOCIATED SERVICES						
PHOTOVOLTAIC FIELD						
SEWAGE SYSTEM						
GRAY WATER EVACUATION SYSTEM						
MAIN GENERATORS						
EMERGENCY GENERATORS						
ELECTRICAL NETWORK						
WATER TREATMENT PLANT						
LAGOONS						
WATER STORAGE TANKS						
PLUMBING						
FUEL STORAGE TANKS						
NON-SPILL PANS						
FUEL DISTRIBUTION SYSTEM						

2.2.7.11 Stage IV – Provision of services to third parties

	PRELIMINARY STAGE	STAGE I PETREL, PERMANENT BASE	STAGE II HABITABILITY AND SERVICES	STAGE III PROVISION OF OWN SERVICES	STAGE IV PROVISION OF THIRD PARTY SERVICES	STAGE V CONSOLIDATION
MAIN HOUSE						
EMERGENCY HOUSE						
VEHICLES						
EMERGENCY POWER PLANT						
LOADING TERMINAL/DNA DEPOT						
MINI STADIUM						
CARPENTRY/WORKSHOP/FACILITIES						
SEWAGE PLANT BUILDING						
WORKSHOP						
ANNEX LABORATORY						
QUAY						
CONTAINER PLATFORM						
HELICOPTER HANGAR						
PASSENGER TERMINAL						
CONTROL TOWER						
JET A1 DEPOT						
RUNWAYS						
TAXIWAYS						
ASSOCIATED SERVICES						
GRAY WATER EVACUATION SYSTEM						
EMERGENCY GENERATORS						
ELECTRICAL NETWORK						
LAGOONS						
PLUMBING						
FUEL STORAGE TANKS						
NON-SPILL PANS						
FUEL DISTRIBUTION SYSTEM						

2.2.7.12 Stage V – Consolidation

	PRELI MINAR	STAGE I PETREL, PERMANENT	STAGE II HABITABILITY AND SERVICES	STAGE III PROVISION OF OWN SERVICES	STAGE IV PROVISION OF SERVICES TO THIRD PARTIES	STAGE V CONSOLIDATION
EMERGENCY HOUSE						
LOADING TERMINAL/DNA DEPOT						
MINI STADIUM						
WORKSHOP						
QUAY						
PORT TERMINAL						
PASSENGER TERMINAL						
CONTROL TOWER						
JET A1 DEPOT						
RUNWAYS						
ASSOCIATED SERVICES						
GRAY WATER EVACUATION SYSTEM						
ELECTRICAL NETWORK						
WATER TREATMENT PLANT						
PLUMBING						
FUEL DISTRIBUTION SYSTEM						

2.2.8 Logistics necessary for the project

The development of Petrel Base constitutes the greatest challenge in the last 50 years for the Argentine Antarctic Programme, since the last base built by our country dates back to 1969. In this case, we are addressing the need to dismantle almost all the facilities of the Petrel Antarctic Base and replace them with others that provide the same functions and also new capabilities.

In this sense, the following general activities should be planned and carried out at Petrel Base:

a) Operation of the Petrel Antarctic Base on a permanent basis, which will facilitate execution of the tasks of dismantling and reassembling the facilities.

b) Preparation, transportation and landing of cargo at Petrel Base, which will serve for the construction of the new facilities and the operation of the base.

c) Progressive dismantling of the installations to be removed, which also implies the preparation and storage of the materials to be evacuated.

d) Progressive assembly of the new facilities, which implies earthworks and the generation of waste to be prepared and stowed for its withdrawal.

e) Collection of historical waste and waste generated at the base due to its operation and the construction and dismantling of facilities.

These general tasks, which are reflected in the development stages and schedule, should be framed within the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1 [2016]). All activities were evaluated from the points of view of the environment, risk (occurrence and evacuation times) and the possibilities of completing the tasks on time and opportunity, resulting in the following matrix (Table 4):

Table 4: Evaluation criteria for facilities.

No.	Concepts					Assigned value
	Environment	Development of logistics activity(ies)	Risk	Development of science activity(ies)	Number of Staff	
1	Minimum	ideal	Minimal risk	ideal	Enough	4
2	Expected contingencies	Enough	Low risk	Enough	Exact	3
3	Contingency plan	Fair	Medium risk	Fair	Limited	2
4	Enlistment of contingency measures	Limited	High risk	Limited	Indispensable	1
5	Without interference	Without interference	Without interference	Without interference	Without interference	0
6	Likely (-50% occurrence)	Insufficient	Probable and rare T(-50% occurrence)	Insufficient	Less than necessary	-1
7	Possible (+50% occurrence)	Risky	Possible and very rare T (+50% occurrence)	Null	Null	-2

2.2.8.1 Permanent operation of the Petrel Antarctic base

As previously indicated, and as notified to the Council of Managers of National Antarctic Programs (COMNAP), Petrel currently functions as a permanent base for the Argentine Antarctic Programme. Its permanent operation implied the evaluation of the following topics in view of the future development of the base:

Advisability for the base to be operated year-round or only during the summer in light of the reconversion tasks (Table 5):

Table 5: Analysis of the advisability of changing the use of the Base.

No.	Activity	Permanent Operation (winter)	Operation in Summer only
1	Environmental forecasts	3	3
2	Logistical tasks to be carried out (Maintenance, removal of facilities, historical waste)	4	1
3	Risk of accidents / air evacuations	1	2
4	Development of scientific activities	3	2
5	Number of staff needed	3	3
	TOTAL	14	11

The variables in Table 5 were analysed in light of the tasks aimed at recovering the base in the shortest possible time and it was verified that it was convenient to activate it permanently. The environmental conditions, mitigation measures and contingency plans may be carried out adequately in both cases. These measures and forecasts can only be affected by the number of personnel to be posted at the base.

With respect to logistical tasks, although they require a greater deployment of logistical effort in winter than during the summer, the winter is considered more appropriate due to the amount of time that will be available at the base. Regarding the level of risk during the winter, a factor that has been considered and does not appear in the table is the possibility of medical evacuation from the base. The proximity to the Marambio base ensures timely air evacuation

Scientific activities may be greater during the winter, as there are more possibilities of carrying out studies during the Antarctic winter, by sending scientific personnel during that period. The proximity to the Marambio base facilitates the transfer of personnel. Likewise, considering the studies required for development of the base, the possibility of carrying them out during the winter and obtaining data during this period will be useful. Finally, the necessary personnel will always be the exact personnel required for the tasks to be carried out, since the habitability of the base is limited, both in summer and in winter.

Preparation, transport and landing of cargo at Petrel Base

The remodelling of the Petrel Antarctic Base involves a large amount of cargo to be transported to Antarctica. These will be staggered in time, according to the development stages of the base.

Preparation of the loads will require a detailed study including the following factors:

- Development stage and schedule. The tasks to be developed each year will be determined according to the progress of the development project.
- Facilities to be built or under construction. The works to be started or continued will be evaluated according to the volumes to be transported.
- Complementary loads for development of the base. Any necessary detail materials will be determined for completion of the works in stages. It is expected that there will be goods (minor equipment and materials to complete works already completed or in progress.
- General loads for operation of the base. These will be the loads (fuel, refrigerated loads and others) necessary for the annual operation of the Base.
- Opportunity to load and unload loads. It is worth highlighting that the transport of cargo to Petrel Base will be carried out during the development of the regular activities carried out by the Argentine Antarctic Programme during the Antarctic summer (changing of crews, transfer of scientists and supplying of Argentine bases). It will involve the coordination of activities and an adequate synchronisation of materials.

Means used: In general, the loads will be transported by sea. For this, up to 4 ships will be used to support the transport of cargo. However, the loads must be prepared for:

- Being able to be handled in the holds of the ships (capacity and characteristics of the holds and cranes)
- Transfer of cargo between different vessels. According to the places and methods used to this effect (in port, sponsored ships, etc.)
- Transfer and transport of cargo in smaller vessels (pontoons, boats, landing craft)
- Minor vessels used. The programming of the activities must take into account the smaller vessels that will be used to unload the different packages and the opportunities in which this will be done. The type of small craft that each vessel will have will be taken into account.
- Cargo landing areas. The base has two areas defined for disembarking cargo, which are a sector on the north coast, in Petrel Cove in an area close to the moraine of the Rosamaría Glacier, and in the central sector of the south coast in the Antarctic Strait. Eventually, a provisional dock that can be dismantled will be prepared in order to unload materials with the pontoon.
- Land means used for unloading on the landing beaches. In general, handlers will be used. The capacity of the handlers' arm and the position it adopts on the coast for unloading will be taken into account.
- Stowage and storage areas. Depending on the characteristics of the loads, they may be stored in outdoor areas designated for this purpose. Others can be stowed inside the main hangar of the base. In the latter case, the volume and weight of the packages will be considered in reference to the spaces available within the hangar and the machinery for their handling.

- Transportation by air. They will be used for smaller and lighter loads. They may also be used for unloading from the icebreaker ship to Petrel Base.

2.2.8.2 Transport and unloading system

It will consist of the following elements (Table 6):

Table 6: Logistical elements for the renovation of Petrel Base.

MEDIA	ELEMENTS	USED FOR:
Vessels	Icebreaker	Cargo transportation from the city of Buenos Aires to the vicinity of Petrel Base. The transport of cargo and waste from Petrel Base to the city of Buenos Aires.
	Transport	
	2 Polar despatch vessels	
Small boats	2 landing craft	Transportation of cargo in the vicinity of the Petrel Base to the coast of the base Transportation of cargo and waste from the shore of the base to the ship
	6 inflatable boats	
	1 Pontoon	
Terrestrial means	Handler	The transfer of loads and waste from the coast to their place of stowage and storage and vice versa
	2 Lorries	
Aircraft	C-130	Transportation of small volume cargo from the American continent to the Marambio base
	Helicopter	Cargo transfer from Marambio base to other ships. Unloading in the vicinity of Petrel Base, from the Icebreaker to the Base

Ships, aircraft and smaller vessels are those regularly used by the Argentine Antarctic Programme to carry out its tasks of deploying scientists, crew relief and base replenishment.

Landing and loading areas

Considering that Cape Welchness consists of a triangular area covering about 2.5 km2. The eastern face of this triangle borders the crest of the lateral moraine of the glacier called "Rosamaría". The other two sides of this triangular area are bordered by mirrors of water. The north side or north coast limits with the Petrel Cove and the south side or south coast with the Antarctic Strait.

Most of Cape Welchness has a flat surface with a drop of a few metres, especially on its two outer edges that border the sea and are eroded by small rills. Both coasts, about 1500 metres long each, have the same characteristics. Both coasts, like the entire area of the lower shelf of Cape Welchness, are composed of fluvio-glacial sediments made up of fine-grained gravels, with mostly angular clasts. The rest of the gravel is made up of mud and sand. The seabed adjacent to the coasts has the same composition, together with compact and erosion-prone sedimentary rocks, which are well stratified in thin banks (0.2-0.8 m) presenting a gentle slope as we move further away from the coast.

2.2.8.3 Selection of landing and boarding areas

The characteristics of the coasts indicated above indicate that both, along their entire length, are favourable to access by small boats. For this reason, the cargo landing areas were selected taking into account the following factors:

- Proximity to stowage areas, which reduces land transport times from the coast to the stowage place.
- Ease of access to the coast, due to the fact that the lower platform of Cape Welchness has areas where the rills produce flood-prone areas.
- Areas already impacted by vehicle traffic in previous years, due to the operation of the base since 1951.
- Accumulation of sea ice on the coasts, due to the normal circulation of debris and ice ribbons in the Antarctic Strait and Petrel Cove.

No.	Concepts				
	Proximity to stowage areas	Ease of access to the coast	Areas already impacted	Ice buildup	Assigned value
1	Fence	Good	With impact	Never	2
2	Close	Fair	Little impact	By periods	1
3	Far	Bad	No impact	Always	0

In the evaluation, 2 sectors were selected on each of the coasts.

No.	Activity	N1	N2	S1	S2
1	Proximity to stowage areas	3	1	2	1
2	Ease of access to the coast	3	1	0	2
3	Areas already impacted	3	1	1	1
4	Ice buildup	2	2	2	2
	TOTAL	11	5	5	6

During the evaluation, area N1 was chosen as a priority unloading area for sea transport and area S2 as an alternative area for when N1 is covered in ice. Likewise, in these two areas, a cargo landing place was established, another for the temporary installation of a removable ad hoc dock and a place for stowing historical waste ready for its removal (Figure 39).

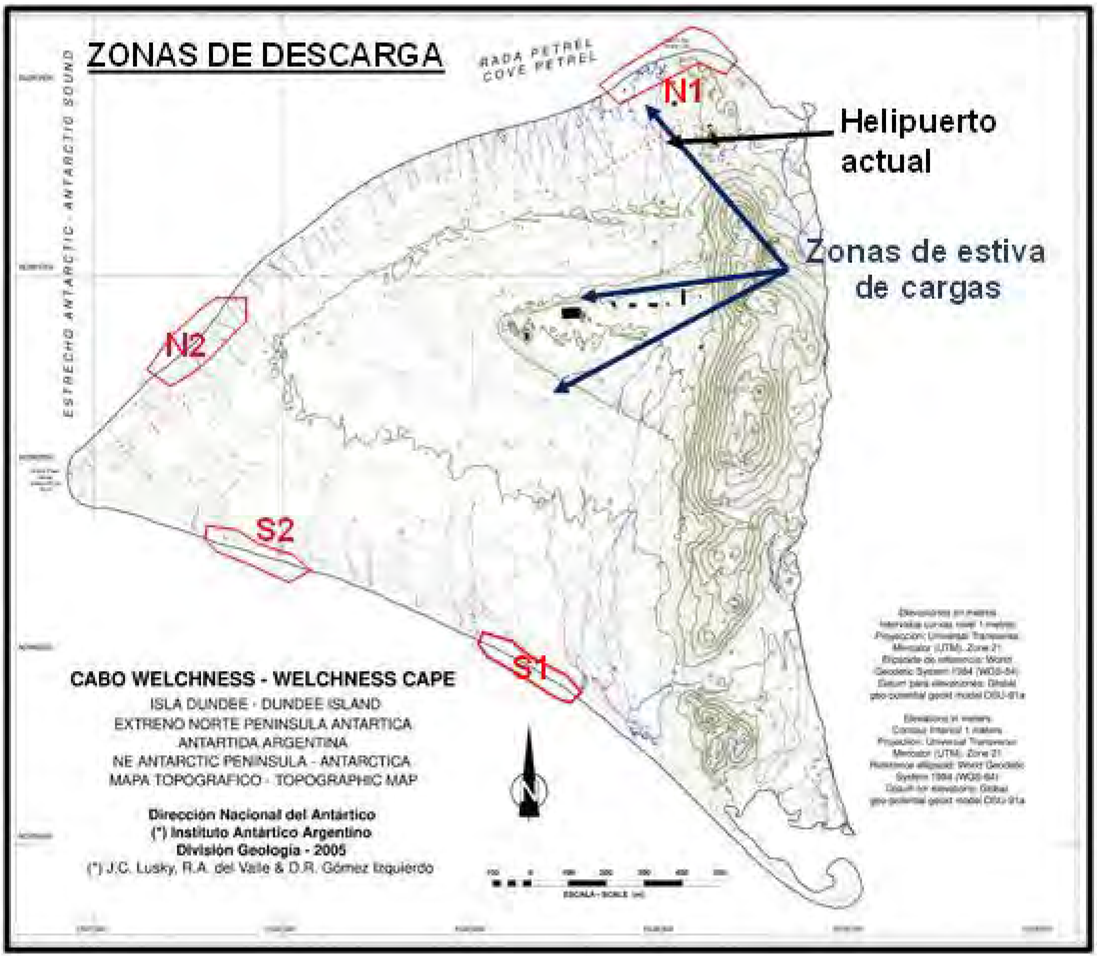


Figure 38: Likewise, in these two areas, a cargo landing place was established, another for the temporary installation of a removable ad hoc dock and a place for stowing historical waste ready for its removal.

2.3 Scientific research in the new Base

The renovation of Petrel Base has as its fundamental objective to promote the Argentine Antarctic Programme for the development of scientific tasks in the Antarctic Continent. Argentina has a long scientific tradition in Antarctica since the Argentine Antarctic Institute is the first Scientific Institute in the world created exclusively to develop scientific and technological research in Antarctica.

The IAA has its own endowment of more than 100 researchers, technicians and administrators, who develop their tasks in the areas of Life Sciences, Earth Sciences, Social Sciences, Physicochemical Sciences and Environmental Studies and Scientific Coordination. 60% are researchers graduated in various disciplines. 70% of the activities are carried out in cooperation with researchers from universities and national science and technology organisations, and 60% incorporate some component of international scientific cooperation, in association with national Antarctic Programmes of other Parties to the Antarctic Treaty, as well as universities and research centres from more than 20 countries.

Science is the most important human activity in Antarctica, given that it is what allows us to meet the objectives of the Antarctic Treaty and especially the conservation objectives set out in the Madrid Protocol. Argentina has set itself the objective of strengthening its scientific programme in Antarctica as the main line of its Antarctic policy, whose principles are to strengthen the Antarctic Treaty System.

The lines of work considered to achieve improvements in the Antarctic scientific program by Argentina were, on the one hand, ensuring that all Argentine bases have laboratories and quality equipment to carry out science and improving those that already exist. On the other hand, achieving the development of research programs in its 13 bases will allow Argentina a geographical scope to develop scientific projects that can investigate the main problems that the continent presents today.

Another of the lines of work is the reconditioning of Petrel Base, which will enable taking advantage of its privileged geographical location to achieve a significant improvement in Antarctic logistics in terms of costs and efficiency. In this way, achieving the renewal of Petrel Base is a significant aspect for Argentina to be able to improve its scientific activity on the Continent and to collaborate with the fulfilment and objectives of the Antarctic Treaty System, given that better laboratories and logistics resources are essential to achieve better science.

2.3.1 Contribution to the objectives of the Antarctic Treaty and the Protocol

The scientific and technological activities carried out by the IAA cover a wide spectrum of scientific disciplines, many of them considered priorities. Of these we can highlight the research programmes studying the connections between Antarctica and Argentine South American territory in order to reveal the intimate biogeographical relationships between both regions, both current and those of the geological past.

The study of the effects of climate change is also of very high priority, as its study makes it possible to estimate changes in different physical and chemical parameters, their impact on marine and terrestrial biota, and the response of Antarctic species to these changes. Monitoring the evolution of glacier retreat in the context of climate change is also one of the lines of current research.

Likewise, and given the crucial role of the conservation of living resources in the southern seas, we prioritise the permanent monitoring of key species to identify and mitigate human-induced impact on them, mainly associated with fisheries, and distinguish it from the impact from natural sources, which knowledge is essential in the design and promotion of conservation measures within the scope of the Antarctic Treaty.

On the other hand, research in the upper atmosphere, especially that linked to the study of the thinning of the ozone layer, which can generate adverse effects both on terrestrial and marine biodiversity and on human health, not only in Antarctica, but also Also in Patagonian regions, has been carried out for decades by our country and in cooperation with other national programmes, having contributed greatly to the knowledge and monitoring of trends in this regard. Other upper atmosphere research is related to the study of space weather, which currently make it possible to detect disturbances and predict solar phenomena, which can cause problems in terrestrial communication systems and global positioning systems (GPS).

For its part, the seismological network based in the multidisciplinary laboratories installed in Argentine Antarctic Bases contributes to international networks for the detection and monitoring of seismic events. With extensive development and excellent results, the Argentine Antarctic Institute carries out lines of microbiological research aimed at identifying possible biotechnological applications derived from the study of Antarctic organisms, such as the bioremediation of soils contaminated by hydrocarbons from native microorganisms.

Contamination by plastics and microplastics is one of the latest additions to the primary lines of research. This aims to respond to a problem that today is of national and international concern and that has been duly incorporated into research needs in different forums of the Antarctic Treaty, such as the CEP and SCAR. The lines of study in Social Sciences have a very interesting potential for a country with a history spanning more than a century of activities in the Antarctic continent. These studies are a key tool for looking ahead and planning for the future.

From what has been expressed so far arises the deep relationship between the lines of research promoted by the Argentine Antarctic Programme and those that arise from the Scientific Committee on Antarctic Research (SCAR), as well as issues on which the Council of Managers of National Antarctic Programs (COMNAP) advises, such as renewable energy. Likewise, it is important to highlight the promotion work carried out by the Argentine Antarctic Programme to promote, finance and execute lines of research that make it possible to respond to the research needs identified by the Committee for Environmental Protection of the Antarctic Treaty in its five-year work plan and in the Climate Change Response Work Programme. Contributing to decision-making and the development of management tools for the conservation of the Antarctic continent is central and part of a long-term policy of our country in Antarctica.

The contribution of scientific information to the Scientific Committee of the Convention for the Conservation of Antarctic Marine Living Resources also deserves special mention, as our country has been a member of the network of CEMP sites for decades, providing highly-needed and quality scientific information for decision-making.

2.3.2 Contribution to the science of the Argentine Antarctic Programme

The new Multidisciplinary Antarctic Laboratory that is planned to be built at Petrel Base will make it possible to expand the infrastructure capacities of the network of laboratories that the Argentine Antarctic Programme, through the governing body for scientific activity in our country, the Argentine Antarctic Institute, has in the different Antarctic bases.

As indicated in section 1.2 (need and justification for remodelling), both this laboratory and the expanded logistical capacities to reach new places on the Antarctic continent will broaden the horizon of multidisciplinary research and international cooperation that our country can sustain.

The scientific work to be carried out in these laboratories will have an interdisciplinary and inter-institutional approach, with working groups made up of researchers in natural and social sciences from the Argentine Antarctic Institute and member institutions of the Inter-Institutional Council of Science and Technology (CICyT), as well as with international scientific organisations, under the coordination of the National Directorate of the Antarctic and the Argentine Antarctic Institute.

The research activities that are carried out in the new laboratories or that can be carried out in other Antarctic locations thanks to the expanded logistical support capabilities of Petrel Base, will contribute to the development of the priority lines of research mentioned above carried out under the direction of and coordination of the Argentine Antarctic Institute

The general scope of the Multidisciplinary Antarctic Laboratories (LAM) will be to contribute to the training of human resources, the generation of basic and applied knowledge and knowledge required to provide scientific information for decision-making on policies.

Having a new LAM with similar characteristics to the one existing at Carlini Base, on the other side of the Antarctic Peninsula, will allow us to compare the behaviour of marine and terrestrial ecosystems in both areas and broaden our knowledge of their response to climate change. Among the scientific activities that can be carried out in the surroundings of the Base as well as on nearby islands, we can mention:

- Bioremediation studies of soils contaminated with diesel
- Monitoring and databases of the hydrographic characteristics and phytoplankton dynamics in areas close to the Base.
- Research on Notothenioidei fishes.
- Deep distribution of Antarctic macroalgae in a global change scenario.
- Glacier dynamics and mass balance;
- Breeding, ecological feeding and winter dispersal of Pygoscelid penguins.
- Population dynamics of marine mammals on land.
- Biodiversity and ecology of planktonic components in lakes and terrestrial and freshwater algae.
- Persistent organic pollutants.
- Microbial ecology and ecophysiology and ecotoxicology of Antarctic organisms.

- Effects of global warming on birds and other species in the Antarctic food chain.
- Monitoring of contamination by micropastics in fauna, soil, water and air.
- Studies on the geology and palaeontology of the sector, as well as having a new station for geodetic, geophysical, and seismological studies.

Today Antarctica is considered one of the most relevant natural laboratories in the world, and together with the Southern Oceans it plays a fundamental role in regulating processes such as the climate and carbon dioxide absorption. Research in these regions is crucial to understanding phenomena of national, continental and global importance. In addition, rapid changes are occurring in vast areas, which will require the capabilities to reach a new level of activities in the coming decades.

3 APPROACH OF THE ENVIRONMENTAL IMPACT ASSESSMENT

Given that the activities planned in this proposal are to be carried out in the Antarctic Treaty Area, the Protocol on Environmental Protection to the Antarctic Treaty (the Protocol) establishes in its Article 3 a series of environmental principles that can be considered as a guide for achieve the protection of Antarctica and its dependent and associated ecosystems. Said article establishes that “the protection of the Antarctic environment and dependent and associated ecosystems and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area”.

To give effect to the aforementioned general principle, Article 3.2(c) demands that "activities in the Antarctic Treaty area shall be planned and conducted on the basis of information sufficient to allow prior assessments of, and informed judgments about, their possible impacts on the Antarctic environment and dependent and associated ecosystems and on the value of Antarctica for the conduct of scientific research".

On the other hand, Article 8 of the Protocol introduces the term ***Environmental Impact Assessment (EIA)***, and establishes three categories of impacts on the environment: ***less than a minor or transitory impact, a minor or transitory impact and more than a minor or transitory impact, according to their relevance***. The same article mentions that “***Each Party shall ensure that the assessment procedures set out in Annex I are applied in the planning processes leading to decisions about any activities undertaken in the Antarctic Treaty area***”. For this reason, in Annex I of the Protocol, Article 1.1 establishes that “***The environmental impacts of proposed activities referred to in Article 8 of the Protocol shall, before their commencement, be considered in accordance with appropriate national procedures***” and also in its Article 1.2 it establishes that only “if an activity is determined as having less than a minor or transitory impact, the activity may proceed forthwith.”

The Petrel Base Renovation Project has been analysed and determined as an activity that will have “***greater than minimal or transitory impact.***” This conclusion can be obtained preliminarily given the impacts and scope of the actions to be carried out and as such it is appropriate that they be preceded by a ***Comprehensive Environmental Evaluation (CEE)***. In the following sections we will develop the necessary procedure as established in the regulations of the Antarctic Treaty for these cases.

3.1 Environmental Assessment Procedure for the Petrel Base project

In accordance with the provisions of Article 8 of the Madrid Protocol and Article 3 of Annex I to the aforementioned Protocol, the proposed activity will have a more than minimal or transitory impact, which is why it is subject to a technical-administrative Comprehensive Environmental Evaluation (CEE) procedure. In this sense, it is noted that in order to carry out said evaluation it is necessary to comply with all the environmental requirements established in "Resolution 1 (2016) - Guidelines for Environmental Impact Assessment in Antarctica", approved by the Antarctic Treaty Consultative Meeting (ATCM).

An important aspect to take into account is that the activities that make up the project cannot be divided for analysis, but must be planned and evaluated in a joint and comprehensive manner, as established by ATCM Resolution 1 (2016) in 3.1.1: "Defining the Activity": "…taking a holistic approach to defining the scope of the activity. Careful consideration is required to determine the full scope of the activity so that the impacts can be properly assessed. This is necessary to avoid preparing a number of separate EIAs on actions which indicate an apparent low impact, when in fact, taken in its entirety, the activity actually has potential for impacts of much greater significance. For example, a proposal to construct a new station should also discuss in detail the associated logistics, major scientific infrastructure, and ancillary facilities beyond the main station building (e.g. roads, helipads / airstrips, communication facilities etc.). This is particularly common where a number of activities take place at the same site either spatially and/or temporally. Where activities are to be undertaken at sites which are visited repeatedly by one or more operators the cumulative effects of past, current, and reasonably foreseeable activities should be taken into consideration...".

Finally, it is necessary to clarify with regard to the Global Environmental Assessment, Article 3.5 of Annex I of the Protocol establishes that no final decision shall be taken to proceed with the proposed activity in the Antarctic Treaty area unless there has been an opportunity for consideration of the draft Comprehensive Environmental Evaluation by the Antarctic Treaty Consultative Meeting on the advice of the Committee for Environmental Protection (CEP) (according to subsections d) and e) of Article 12 of the Protocol), provided that no decision to proceed with a proposed activity shall be delayed through the operation of this paragraph for longer than 15 months from the date of circulation of the draft Comprehensive Environmental Evaluation. Therefore, the competent authority to decide in the CEE procedure is the Antarctic Treaty Consultative Meeting with the advice of the Committee for Environmental Protection (CEP).

3.1.1 Determination of the Environmental Impact Category

In accordance with Annex I, a draft CEE must be prepared if the Party proposing an activity has determined that the activity is likely to have more than a minor or transitory impact. This determination will be made in accordance with the corresponding national procedures, and in reference to the provisions and objectives established in the Protocol. In this case, the PGAyT determined that the submitted Project has a more than minor or transitory impact, even without jointly evaluating the other elements that would make up the entire project (construction of the runway, new buildings, etc.).

In this case, some of the impacts generated by the proposed general activity (Petrel Antarctic Base Comprehensive Renovation Project) can be established:

- Modification of, or risk to, the intrinsic value of Antarctica, including its aesthetic and wildlife values and its value as an area for conducting scientific activity due to the introduction of anthropic elements;
- Substrate and landscape modification by removal and installation of buildings;
- Pollution of the marine environment and of the terrestrial, freshwater, and atmospheric environments due to emissions into the atmosphere from the use of energy generators and other anthropic activities;

- Pollution of the air environment by introducing primary and secondary pollutants into the atmosphere (NOx, COx, SOx, and particulate matter);
- Disturbance to wildlife due to noise generation from human activities for the installation of new facilities;
- Pollution of the marine environment and of terrestrial and freshwater environments;
- Introduction of pathogens;
- Toxicity and other chronic impacts at the species, habitat and ecosystem levels;
- Physical changes to the landscape (eg, erosion, trails);
- Physical changes in the surface drainage network;
- Physical and chemical changes in the permafrost roof and on moraine ice cores;
- Modification of glacial landforms (removal of the northern end of the moraine);
- Introduction of non-native species;
- Modification of the distribution, abundance or biodiversity of species or populations of species of fauna and flora;
- Changes in the behaviour, physiology and reproductive success of wildlife;
- Physical damage to flora and
- Modification of the distribution, abundance or productivity of species or populations of flora species, among other impacts.

When these impacts are analysed based on the extension, duration, intensity, probability and legal aspects of the actions that generate them, it is observed that due to their quantification, many have a high risk, especially due to their duration (impact for more than ten years), intensity (irreversible changes) and probability (unavoidable occurrence). Another important aspect is that in a project of this magnitude, the "cumulative impacts", that is, the combined impacts of the activities, become significant and can occur over time and/or in space, and can be additive, interactive or synergistic.

The preliminary analysis (culminating in the comprehensive impact evaluation through the final impact matrix) of the activity allows us to assert that this project must be preceded by a draft ***Comprehensive Environmental Evaluation (CEE)***, as required by the Protocol, its Annex I and ATCM Resolution 1 (2016), given that the expected impacts are to be ***"more than minor or transitory"*** and therefore its approval must comply with the procedures established in Annex I to the Protocol and Resolution 1 (2016) for a CEE.

3.1.2 Procedure for a Comprehensive Environmental Evaluation

The EIA is a process having the ultimate objective of providing decision makers with an indication of the environmental consequences of the proposed activity (Figure 1 of Resolution 1 [2016]). The process of predicting the environmental impacts of an activity and assessing their significance is the same regardless of the apparent magnitude of the activity. Some activities require no more than a cursory examination to determine impacts, although it must be remembered that the level of assessment is relative to the significance of the environmental impacts, not to the scale or complexity of the activity. The process of preparing the EIA will result in an improved understanding of the likely environmental impacts. Thus, the picture that emerges in relation to the impacts of the activity will determine how much further the EIA process needs to be taken, and how complex it should be.

In accordance with Annex I to the Protocol, a draft CEE should be prepared if the Party proposing an activity, or a Party to which an activity proposal has been submitted, has determined that an activity is likely to have more than a minor or transitory impact. The draft CEE should then be distributed to all consultative and non-consultative Parties as well as the advisory bodies to the Antarctic Treaty System, which, in turn, will make it publicly available for comment. The Parties shall be allowed a period of ninety days to make comments. As well as being circulated to the Parties, the CEE project must be forwarded to the Committee for Environmental Protection (CEP) and at least 120 days before the next ATCM so that it can be properly analysed.

Once this has occurred, the CEP Chair will establish an open-ended intersessional contact group (ICG) to consider the draft CEE, and will consult with CEP Members to identify a suitable consult with CEP Members to identify a suitable convener and to agree the terms of reference. The ICG will report to the next CEP meeting, which will discuss the draft CEE and provide advice to the ATCM. Article 3.5 of Annex I states that no final decision shall be taken to proceed with the proposed activity in the Antarctic Treaty area unless there has been an opportunity for consideration of the draft CEE by the ATCM on the advice of the CEP, provided that no decision to proceed with a proposed activity shall be delayed for longer than fifteen months from the day of circulation of the draft CEE.

Once the comments have been received, the Party that has submitted the CEE must review and include such comments in its original project in order to submit a final CEE to the CEP. This is established in Article 3.5 of Annex I when it mentions that “A final CEE shall address and shall include or summarise comments received on the draft CEE. The final CEE, notice of any decision relating thereto, and any evaluation of the significance of the predicted impacts in relation to the advantages of the proposed activity, shall be circulated to all Parties, which shall also make them publicly available, at least 60 days before the commencement of the proposed activity in the Antarctic Treaty area.”

3.2 ATCM Measures Applicable to Proposed Activities

A preliminary evaluation of the set of requirements to be taken into account for the design, construction and operation of the renovation of the base, airport area, port area and photovoltaic plant was carried out for the activities proposed in this CEE, in order to ensure compliance with the requirements established in the current environmental protection regulations that apply to Antarctic Bases in relation to the protection of the Antarctic environment.

A list of regulations and specific requirements was built, starting in the first instance from the specific regulations of the Antarctic Treaty System that have enforceable obligations at this stage of the project:

- Antarctic Treaty

- Protocol to the Antarctic Treaty – Annex I (Environmental Impact Assessment)
- Protocol to the Antarctic Treaty – Annex II (Conservation of Antarctic Fauna and Flora)
- Protocol to the Antarctic Treaty – Annex III (Waste Disposal and Waste Management)
- Protocol to the Antarctic Treaty – Annex IV (Prevention of Marine Pollution)
- Non-Native Species Manual – ATCM – Argentine Antarctic Programme
- Resolution 5 (2019) Reducing Plastic Pollution in Antarctica and the Southern Ocean.
- Resolution 2 (2004) Guidelines for the operation of aircraft near concentrations of birds in Antarctica.
- COMNAP Fuel Manual (Version 1.0 01 April 2008)
- COMNAP's Framework and Guidelines for Emergency Response Action and Contingency Planning in Antarctica
- COMNAP - Advancing Antarctic Station Waste Water Management

3.3 Antarctic Treaty System. General Rules

- Law 15 802. Ratifies the Antarctic Treaty.
- Law 24 216. Approves the Protocol on Environmental Protection to the Antarctic Treaty.
- Law 25 260. Approves Annex V to the Protocol on Environmental Protection to the Antarctic Treaty: Area Protection and Management.
- Law No. 18 513. Establishes the legal, organic and functional bases for the planning, programming, direction, execution, coordination and control of Argentine Antarctic activity.
- Decrees No. 2316/1990 and 207/2003
- Administrative Decisions of the Chief of the Cabinet of Ministers 509/2004 and 70/2020
- Decree 368/2018. Creation of the Joint Antarctic Command.
- Provision 87/2000. National Directorate of the Antarctic. Approves measures for compliance with the Protocol on Environmental Protection to the Antarctic Treaty

3.4 Rules referring to the environmental impact assessment process

- Annex I to the Protocol on Environmental Protection to the Antarctic Treaty
- ATCM Resolution 1 (2016). Guidelines for Environmental Impact Assessment in Antarctica.
- Resolution 2 (2005) of the ATCM. Practical Guidelines for Developing and Designing Environmental Monitoring Programmes in Antarctica

3.5 Regulations referring to the conservation of Antarctic Fauna and Flora

- Annex II to the Protocol on Environmental Protection to the Antarctic Treaty
- Resolution 4 (2016), of the ATCM. Non-Native Species Manual.

3.6 Regulations referring to waste management and effluent management.

- Annex III to the Protocol on Environmental Protection to the Antarctic Treaty.
- Res. 1 (2019) of the ATCM. Antarctic Clean-up Manual.
- Res. 5 (2019) of the ATCM. Reducing Plastic Pollution in Antarctica and the Southern Ocean.
- Law 24 051. National Law on Hazardous Waste. Regulatory Decree 831/1993
- Law 25 612 on minimum budgets for environmental protection on the comprehensive management of waste of industrial origin and service activities.
- Law 25 916 of minimum budgets for the comprehensive management of household waste.
- Resolution 97 (2001). Regulation for the Sustainable Management of Sludge Generated in Liquid Effluent Treatment Plants.
- Res. 1 (2014) of the ATCM. COMNAP Fuel Manual guidelines
- Legislation of the province of Tierra del Fuego
- Provincial Law 105 (modified by Law 1 119): regulates the generation, handling, transportation, treatment, and final disposal of hazardous waste. Provincial Registry of Generators and Operators of Hazardous Waste. Annual Affidavit. Categories subject to control. Accreditations for Carriers.
- Dec. 559/93: partially regulates Law 105 on Hazardous Waste. Obligations (proper separation and delivery of untreated hazardous waste to authorised carriers).
- Ley 55/92, Title III Chapter I. Decree 1333/93, Annex II. Water contamination. Generation and control of liquid effluents. Quality Guide Levels, allowable discharge parameters.
- Decree 1056/85. Residual effluents. Prohibition of discharge without prior purification or neutralisation treatment. Regulation of Law 237.
- Resolution (DPO and SS) 341/01 (12/6/2001) - Provincial Directorate of Sanitary Works and Services

3.7 Regulations related to water management

3.7.1 National Legislation

- Law 25 688. Environmental Water Management Regime
- Legislation of the province of Tierra del Fuego
- Law 1126/16. Framework law for the comprehensive management of water resources.
- Regulations referring to the prevention of marine pollution
- National Legislation
- Annex IV to the Protocol on Environmental Protection to the Antarctic Treaty.
- ATCM Resolution 3 (2006) approves the Practical Guidelines for Ballast Water Exchange in the Antarctic Treaty Area.

- Law No. 24 089. Approves the International Convention for the prevention of pollution from ships, 1973, protocols and annexes, and the 1978 protocol on the same.
- International Code for Ships Operating in Polar Waters

3.7.2 Legislation of the Province of Tierra del Fuego

- Resolution 729/17: wastewater with hydrocarbons, bilge or slop oil, residual hydrocarbons and solid waste impregnated with them, generated on ships and received in provincial ports, are included in the control regime of the Law 105.

3.8 Standards related to air quality

- National Legislation
- Law No. 20 284. Plan for the prevention of critical air pollution situations
- Legislation of the province of Tierra del Fuego
- Law 55/92, Chapter III. Regulatory Decree 1333/93, Annex IV. Air quality and polluting emissions into the atmosphere. Air Quality Guide Levels.
- Regulations related to land management
- Legislation of the province of Tierra del Fuego
- Law 55: preservation, conservation, defence and improvement of the environment of the Province of Tierra del Fuego, Antarctica and South Atlantic Islands. Chapter II: Of Soils and their Contamination.
- Decree 1,333/93: regulation of Law 55. Annex III (On Soils and their Contamination): Soil Classification, Soil Quality Guide Levels, Guidelines for Effluent Emission to Soils and Subsoils.

3.9 Regulations referring to the generation and transport of energy.

- National legislation
- Provision 97/2019. Undersecretary of Renewable Energies and Energy Efficiency. Technical requirements of Photovoltaic Solar Technology.
- Resolution 1296/2008. Secretariat of Energy. Processing Plants Storage and Mixing of biofuels
- Fire Management Regulations
- Titles 2.1.3.9.1 "Installations of Fire Safety Systems"; 3.9.9 "Fire safety systems"; 5.1.7 "Conservation of Fire Fighting Facilities", of the "BUILDING CODE" of the City of Buenos Aires.
- Chapter 18 "PROTECTION AGAINST FIRE" of Law 19 587 “ON HYGIENE AND SAFETY AT WORK” and ANNEX VII of Decree 351/79 regulating Law 19 587.
- IRAM standard 3597 "Fire-fighting fixed installations" and all IRAM standards specific to each material used in the facilities.

- NFPA standards 101 “Code of Human Safety” Edition 2006, NFPA 13 “Standard for the Installation of Sprinkler Systems” Edition 2007, NFPA 20 “Standard for the Installation of Stationary Fire Protection Pumps” Edition 2007 and NFPA 2001 “Fire Extinguishing Systems Using Clean Agents ” Edition 2008.
- IRAM Standard 11949 "Fire resistance of construction elements Classification criteria"; IRAM Standard 11950 “Fire resistance of construction elements – Test method

3.10 Rules referring to area management

- Annex V to the Protocol on Environmental Protection to the Antarctic Treaty.
- Res. 2 (2011) of the ATCM. Visit report form

3.11 Rules referring to the management of archaeological and palaeontological heritage

- Law 25 743. Protection of Archaeological and Palaeontological Heritage

3.12 Standards on Thermal, thermal transmittance and execution in general

- National Law No. 19 587/72 "Hygiene and Safety at Work" and Regulatory Decrees No. 351/79 and 911/96.
- National Law No. 54 557/95 “Occupational Risks". Decree 1030/2010
- Provincial Law of Buenos Aires 13 059 "Thermal Conditioning required in the Construction of Buildings for a better quality of life and reduction of Environmental Impact."
- IRAM 1860: “Test method for the properties of thermal transmission in stationary regime, by means of the apparatus for measuring the flow of heat”.
- IRAM 11549: “Thermal Insulation of Buildings. Vocabulary".
- IRAM 11559: “Determination of Thermal Resistance and Related Properties in Steady state. Hot Plate Method with Guard”.
- IRAM 11601: “Thermal Insulation of Buildings. Thermal Properties of Building Materials. Total Thermal Resistance Calculation Method.”
- IRAM 11603: “Thermal Conditioning of Buildings. Thermal insulation of buildings. Bioenvironmental Classification of the Argentine Republic”.
- IRAM 11604: “Energy saving in heating. Volumetric coefficient G of heat losses”.
- IRAM 11605: “Conditions of habitability in houses. Maximum permissible values of Thermal Transmittance K”.
- IRAM 11625: “Verification of the risk of condensation of superficial and interstitial water vapour in central sections”.
- IRAM 11630: "Verification of risk of interstitial and superficial condensation in singular points".

- IRAM 11504-4: “Joinery and light integral facades. Exterior windows. Part 4- Supplementary requirements. Thermal Insulation”.
- IRAM 11507-1: “Joinery. Exterior windows. Basic requirements and classification”.
- IRAM 11507-4: “Joinery. Exterior windows. Supplementary requirements. Thermal insulation”.
- IRAM 11659-1: “Thermal insulation of buildings. Verification of its hygrothermal conditions. Energy saving in refrigeration. Part 1- vocabulary, definitions, tables and data to determine the summer thermal load”.
- IRAM 11659-2: “Thermal conditioning of buildings. Verification of its hygrothermal conditions. Energy saving in refrigeration. Part 2- Residential buildings”.
- IRAM 11900: "Energy Efficiency Label for the Heating of Buildings".
- IRAM 11930: "Sustainable construction. General principles".
- ASTM C177: “Thermal Conductivity Test”.
- **Regulations on telecommunications and information technologies**
- Law 27 078. Communications and information technologies.
- Law 19 768. National Telecommunications Law.

3.13 Regulations on the design and operation of aerodromes.

- RAAC 154 (Appendix 8) and 156 applicable to STOL aerodromes.

4 THE NEW PETREL BASE

4.1 Description of Petrel Base

In this section we will describe in greater detail the aspects related to the facilities that will make up the new Petrel Base. As already mentioned, areas were divided into sectors based on the operational and functional competencies of the base to bring order to the project and the necessary facilities. The facilities and activities were grouped into the following areas (Figures 23, 24, 25, 40, 41 and 42):

- Facilities Area
- Scientific Area
- Airport Area
- Port Area
- Photovoltaic Field Area
- Lagoons Area

All the facilities that will make up the new Petrel Base have been designed in accordance with the following climatic parameters:

- Outside temperature: -35 ºC ± 5 ºC
- Indoor temperature: 21 ºC
- Height above sea level: 10 to 20 m
- Outdoor relative humidity: 95%
- Wind (from):
    - Southwest (Dominant): Absolute Maximum Speed of 80 knots (approx. 149 km/h), Frequency of 1%.
    - South (Prevailing): Speed of 31 knots (approx. 57 km/h), Frequency of 23%.

Notes:

- ✓ The calculation of dynamic and static pressures and the effects of pressure compensation (vacuum effect) are considered, considering the modality of katabatic glacier winds.
- ✓ The coefficient of magnetic conductivity is also considered for construction of the building, due to the occurrence of magnetic storms that supersaturate the air with significant static discharges.
- ✓ The maximum possible gusts are considered, produced by storms, with a maximum range of 162 knots (approx. 300 km/h).

4.2 Layout of the original project of the new Petrel Base

Figure 39: General layout of the initial project of the new Petrel Base.

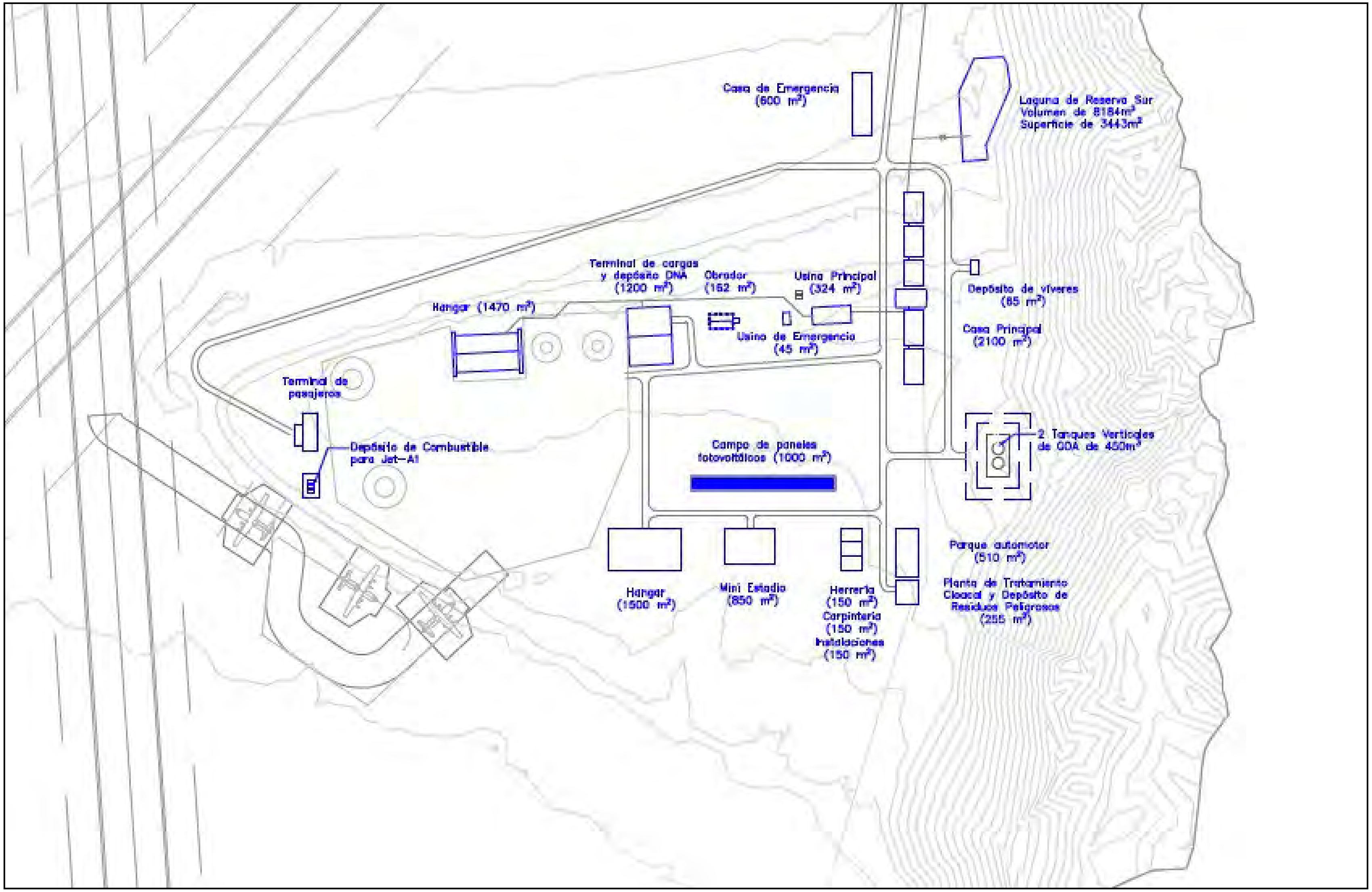


Figure 40: Layout with the arrangement of the facilities in the central base area on the upper terrace.

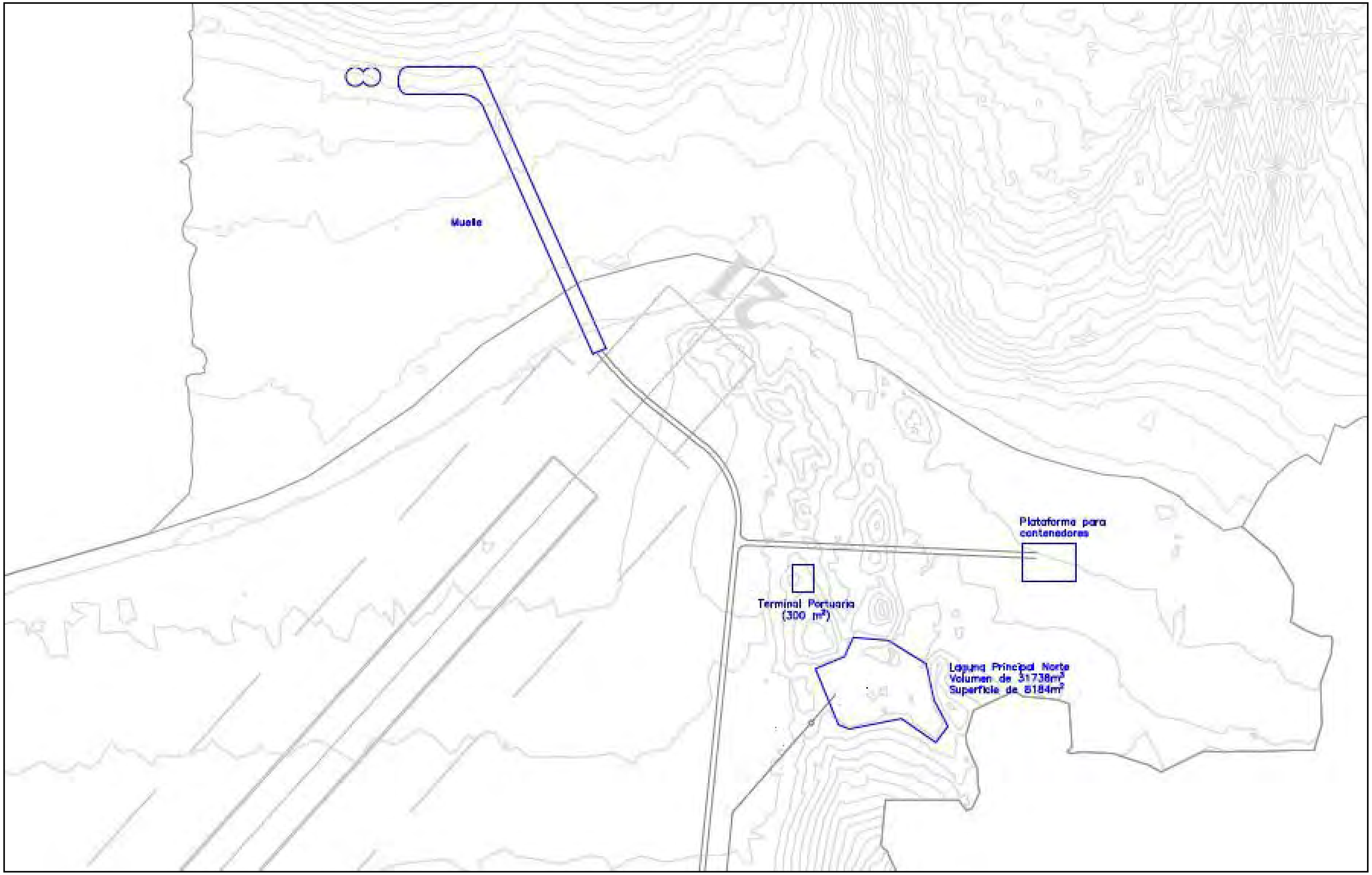


Figure 41: Layout of the facilities in the port area of the new Petrel Base.

4.3 Base Facilities Area

4.3.1 Main House

4.3.1.1 General Description

The new house is projected in close proximity to the location of the old burned-down house, on the raised plain of Cape Welchness. The structure will be assembled independently, founding it by means of piles and alumna until raising it to an average height of 3 metres above the natural terrain. The new infrastructure will be designed for the use of state-of-the-art Antarctic housing accommodation, designed with a self-sustaining concept and technological innovations to allow the use of alternative energies.

It will have an operational capacity of SIXTY (60) permanent staff and EIGHTY (80) who are in transit, reaching a total capacity of ONE HUNDRED AND FORTY (140) people. The proposed building will occupy a minimum area of 1 920 m^2, distributed on two floors. At natural terrain level it will occupy an estimated area of 330 m^2 and on the first floor it will have an area of 1 580 m^2 (Figure 453 and Figure 464)

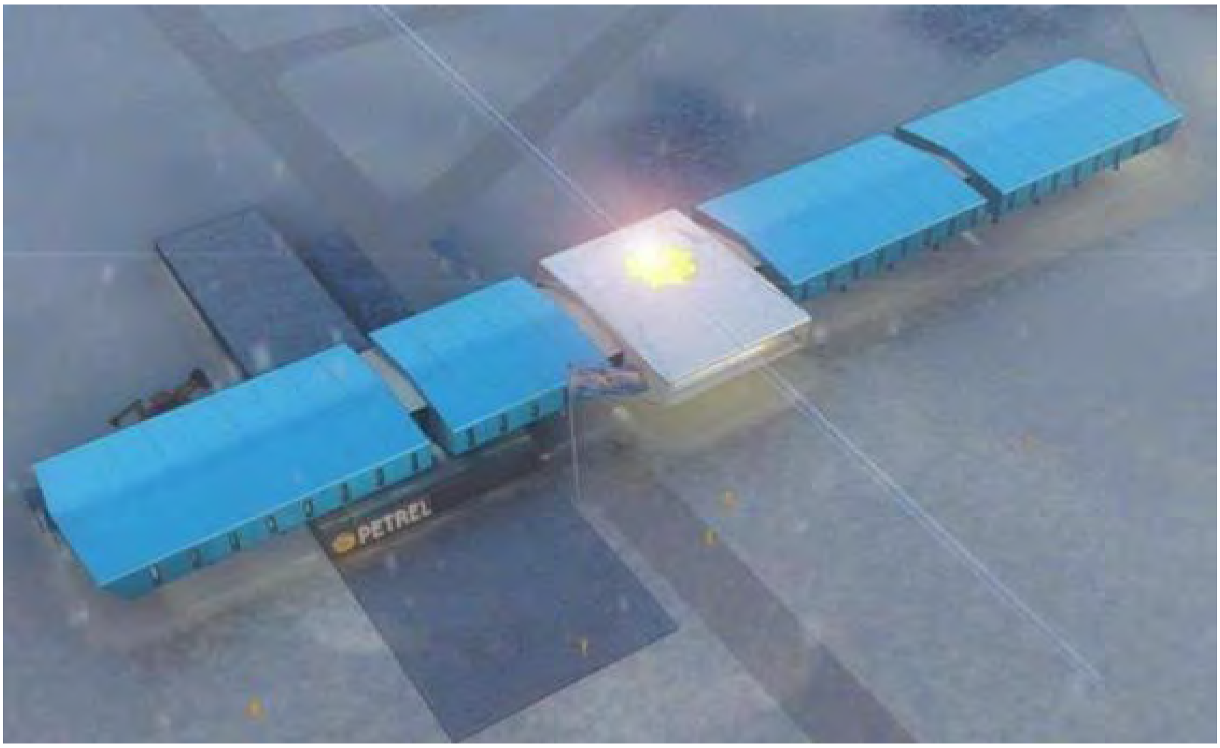


Figure 42: Artist impression of top view of the new main house.

Ground floor:

- Storage area for light vehicles up to 2.5 TON.
- Machine room:
- Water treatment plant sector.
- Independent rooms for the operation of its basic services. (central heating (electric, hot air or water radiators), drinking water tanks, recirculated water system, bathroom sewage tank system, kitchen grease trap system, central fire detection system,

general electricity board, and centrifugal, pressurising, recirculating and sewage pumps).

Figure 43: Artist impression of the side view of the Main House

First floor:

- EIGHT (8) individual rooms with private bathrooms.
- TWENTY SIX (26) rooms for two people with shared bathrooms.
- Infirmary with:
    - Room for patient care.
    - Dental office.
    - X-ray room with leaded walls according to current regulations.
    - Shockroom suitable as an operating theatre (special lighting installations, compressed air system, oxygen and anaesthetic gas installation, as well as electrical and electronic installations, it must have among its equipment a surgical table, a Mayo and croissant table, auxiliary tables, anaesthesia machine, surgical light, electro scalpel, defibrillator, seats, platforms and stairs, among other equipment).
    - Hospitalisation room for four (4) patients with a bathroom.
    - Pharmacy for the storage of traceable and refrigerated medicines.
- Kitchen. (With stainless steel furniture (counters, cupboards, sinks, cabinets, industrial kitchen, convection oven, hood and smoke extractor)).
- Bakery. (with dough roller, kneading machine, four-tray electric pizza oven)
- 2 cold rooms.
- Storage of dry food. (with shelves for goods on two levels)

- A central dining room.
- Office for base chief.
- Office for second base chief.
- Operations office.
- Logistics office.
- Radio station and IT. With HF, VHF, UHF equipment and satellite communications (with three RACKS and workshop sector).
- Meeting room.
- Multipurpose gym for bodybuilding and stationary machines.
- A minimum of FOUR (4) emergency exit doors.
- ONE (1) stretcher lift with a minimum capacity of 1500 kg, which may also be used to transfer internal logistics loads.
- Laundry room (washing machines and dryers).
- General depot.
- TWO (2) common bathrooms.
- ONE (1) scientific laboratory with a capacity for 10 people with an office attached and with three independent modules: dry laboratory, wet laboratory, dirty laboratory.
- Premises for reserve water tanks (minimum capacity 2500 litres).
- Circulations 15% of the total surface.

4.3.1.2 Specific Description

The modular system can be transported by sea using 20-foot containers. The cargo will be protected with packaging and sling-type fasteners suitable for lifting or transporting and pockets on each side to accommodate forklift tines, with standardised dimensions and distance between centres. The packaging dimensions may not exceed the dimensions of a 20-foot (1C) container. The maximum weight will depend on the transport capacity of the ship's cranes (12 000 kg with the crane arm fully deployed; approximate deployment of 16 m, the entire beam).

All the materials to be used must resist extreme temperatures, salt-laden winds due to being close to the sea and be suitable for load handling, unloading and stowage. Each package must be identified and with an attached list of the contents in each one. The packaging will admit disassembly and subsequent reassembly to allow control and verification of the materials to be received.

Supporting structure

Like the foundation system, the supporting structure system and its respective connection with the foundation will be defined in the engineering study of the house, with different proposals for the competent solution of the building having been studied and analysed. In the same way, it must not contaminate the environment and have sufficient structural foundations previously approved by the Project Management.

Once the starting data and hypotheses have been established, simplifications and calculation bases, service period and planning based on the corresponding regulations, the ultimate limit states (due to loss of balance, excessive deformation, transformation of structure into mechanism, breakage of structural elements or joints, instability of structural elements, etc.) and the states of service (in reference to the level of comfort, correct functioning of the building, appearance of the construction, etc.) will be obtained. This process will be based on the analysis of load combinations (permanent, variable and accidental actions) simultaneously and with the use of increase coefficients. Finally, it will be necessary to describe the procedures and/or methods used and checks during the process and once it is finished.

A new load-bearing structure is planned to be built, whose objective will be to support the actions exerted on it and transmit them to the foundations. As a main body there will be a main building whose longitudinal axis will be in the north-south direction, basically consisting of five elevated modules, with a minimum length of 15 m and a maximum length of 30 m depending on the use, divided into a 3 m grid, with a lattice structure system (prefabricated trusses with solid core profiles) in an upper and a lower section arranged in a gabled fashion with mullions, linked by solid core profiles on the external faces.

The structures that support the walls and roofs can be braced by means of cross-beams placed at a certain distance. This lattice system will consist of steel profiles with a galvanised exterior coating, joined at their ends with rigid knots.

The skeleton will be wrapped by the outer walls, which will be fastened by means of stainless steel self-tapping screws to galvanised structural profiles (purlins). It is worth noting the increase in the number of purlins in the multipurpose area due to the increased load during use. The dimensions, distances and characteristics between/of these elements will be indicated accordingly in the project drawings. It is anticipated to use galvanised bent sheet profiles with a thickness of at least 1/8 inches for the skeleton and angle profiles, with tubular and/or round pipes as stiffening elements.

Once the construction materials have been chosen, the basic drawbacks of these elements must be solved:

- Corrosion (paint, etc.).
- Fire protection (fire protection panels, etc.).
- Lateral bending or buckling due to being a slender element subject to the effects of compression loads.
- Maintenance.
- Need for specialised labour for assembly, for example, on welded joints, resulting in the level of rigidity achieved for the assembly.

The project structure is calculated based on the corresponding current regulations, establishing the forces acting on the work, defining structural elements and detailing the required dimensions, heights, lights, layout, among others. The latter is expected to be complemented with the development of one or more calculation models with software adjusted to the real behaviour of the buildings in second order with obtaining the stresses and displacements to check ultimate and serviceability limit states.

The connection system between the foundation and the load-bearing structure itself consists of an inverted tripodal system of cylindrical tubular profiles (supports) of galvanised ASTM A633 Grade E structural steel with an external epoxy and acrylic polyurethane coating in different layers or a sufficient coating to resist the aforementioned effects.

These supports are intended to be able to withstand maximum wind speeds, low temperatures and the effects of possible earthquakes as well as the freezing and thawing cycles of the Antarctic soil.

This triodetic system of directions in multipoints to the structure allows counteracting ground movements. These three supports are joined into a composite profile, a central section formed by the union between two U-shaped cold-rolled open profiles connected to generate a single square closed profile.

Stiffened on the edges of the trunk, there will be plates at 90º, or angle profiles, divided into a triangular shape with its longest side on the base, which will distribute the loads of this central profile towards said surface, which is directly connected to the anchor plate.

The profiles must be joined to the supporting structure by means of bolts and/or welding; This system must be justified detailing characteristics, sizing calculations, as well as the entire foundation system.

Regarding joining methods, for welding without/with filler material, the type of equipment to be used, safety elements and filler material with their respective characteristics must be described, as well as the weld seams; verifying that, in addition to the above, the execution method and related materials are approved by ISO 11611; ISO 9150; ISO 9151; ASME Welding Code; API Welding Code, AWS D1.1 Welding Code, CIRSOC Regulation 301/301-EL, CIRSOC Regulation 304, CIRSOC Regulation 305, etc. for structural welding.

Envelope system

Constructively define the different subsystems of the building envelope system. Each one must be presented, with a description of their behaviour with respect to the forces to which they will be subjected, these being (Figure 45):

- Loads: own weight, wind, earthquakes, snow loads, use loads, among others;
- Action against fire;
- Safety of use;
- Water evacuation;
- Level of impermeability of materials used and behaviour in humid conditions;
- Sound insulation;
- Durability against atmospheric actions and thermal insulation; among others.

The insulating materials to be used in the construction system must ensure as a whole that the enclosures have a thermal transmittance coefficient K less than the maximum admissible coefficient for the comfort level and the winter or summer conditions determined, according to regulations.

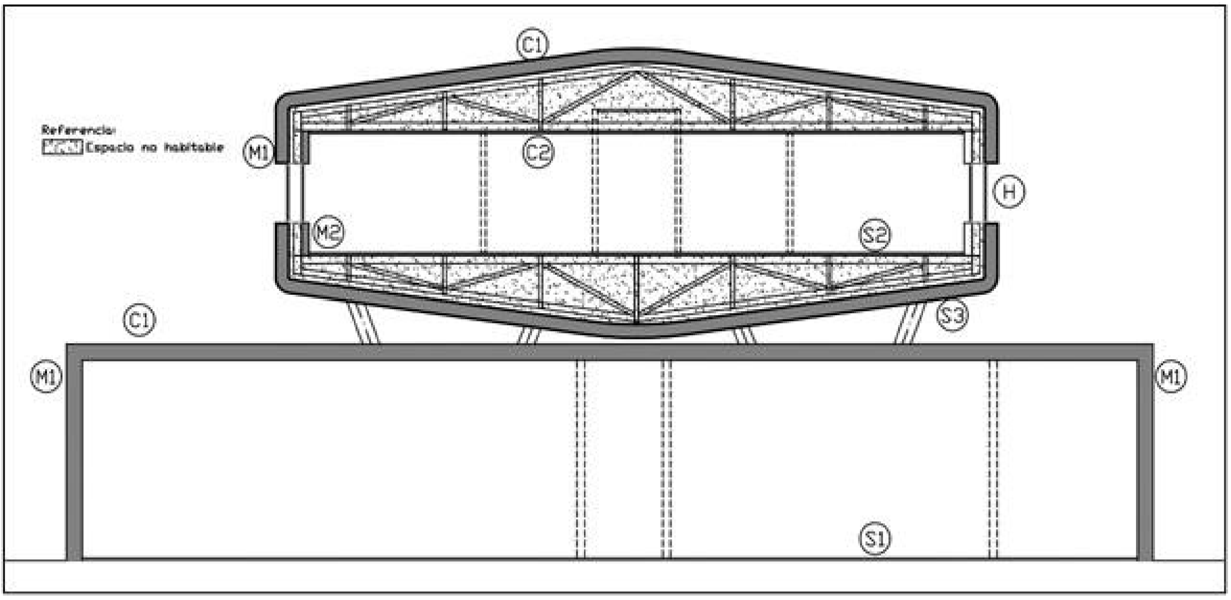


Figure 44: Diagram of the thermal envelope of the building.

The execution of the building should follow the general guidelines that the following construction process describes. The corresponding preliminary tasks must be started to be able to carry out the foundation (Note: the appropriate method is under investigation). Once this is done, as a third step, the tripod profiling system must be executed, the connection between the foundations and the building structure, which will allow the building to be raised by around four metres in order to avoid the accumulation of snow around the bottom of the building.

The structure of the building must continue, which will be composed of a lattice structure system (prefabricated trusses) in the upper and lower sections, linked by pillars on the outer faces. The bracing of the structures can be carried out by means of cross-beams placed at a certain distance.

Once the exterior enclosure is finished, construction must begin inside it under controlled climatic conditions. It is such that the construction of all internal subdivisions with their corresponding facilities and furniture will continue. A list of the elements, tools and machinery to be used during each stage of construction will be required.

The entire building will be made up of six modules, five of these modules are elevated to an elevation of +4.00 m, from ground level, forming a large longitudinal nave and a module at ground level that contains all the technical areas (altitude +-0.00).

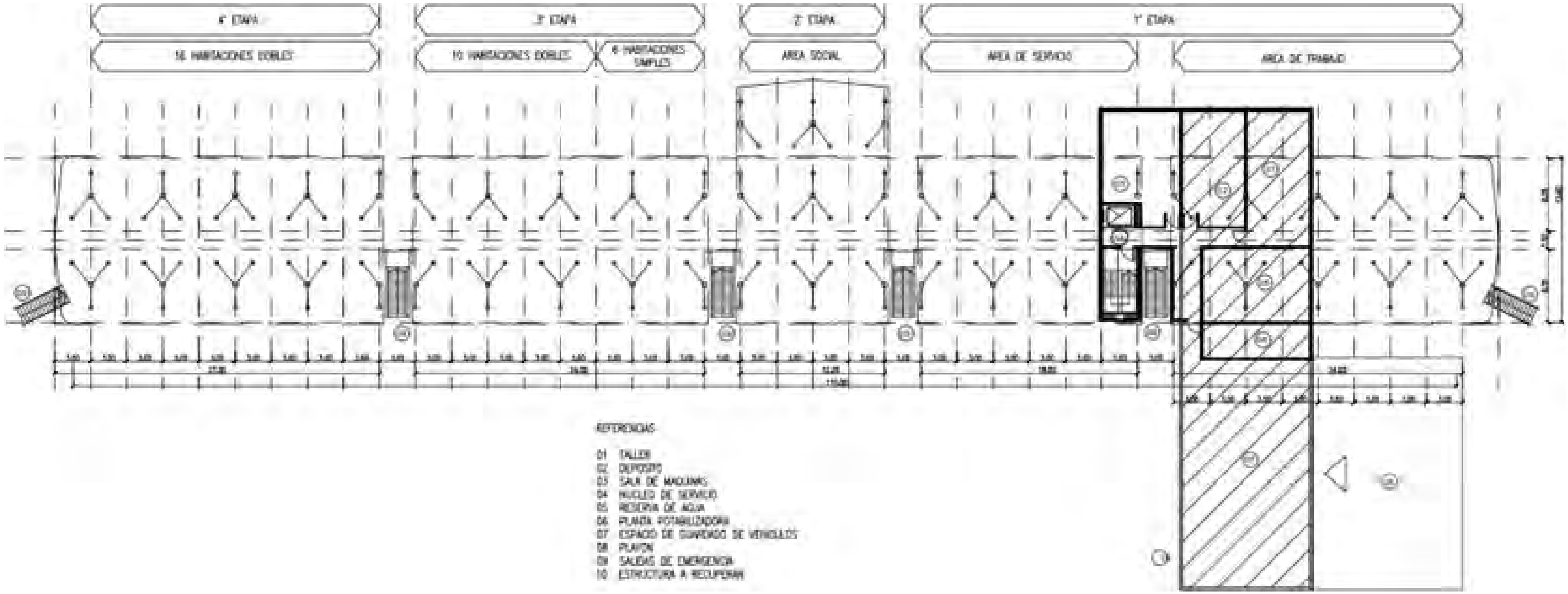


Figure 45: Floor plan of the Ground Floor of the Main House

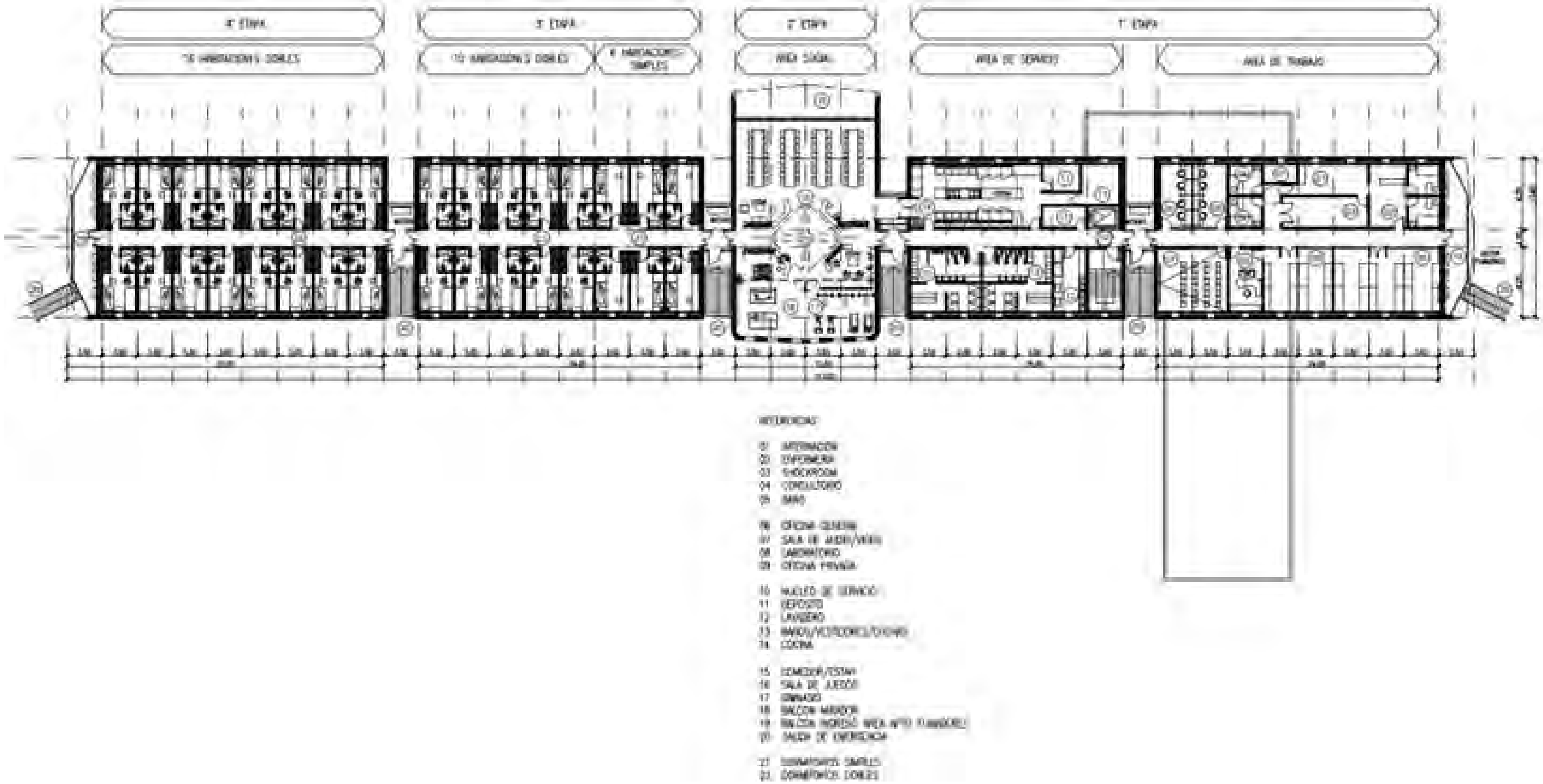


Figure 46: Floor plan of the first floor

4.3.2 Food depot

4.3.2.1 General Description

To provide a place to store any provisions that do not need to be stored in the depots of the Main House, emergency house or other dependencies, a food depot will be installed in the vicinity of the Main House and Emergency House. This building is intended for the storage of food from the entire Petrel Joint Antarctic Base, in order not to saturate the warehouses and kitchen of the Main House.

It will be about 32 m to the east of the Main House and about 110 m to the south of the Emergency House. The building will have a total area of 80 m^2, with walls 0.20 m thick and with dimensions of 8x10 m. Its height will be 4.70 m. It will have two rooms, one for dry food and the other with two reefer-type cold rooms (Figure 47).

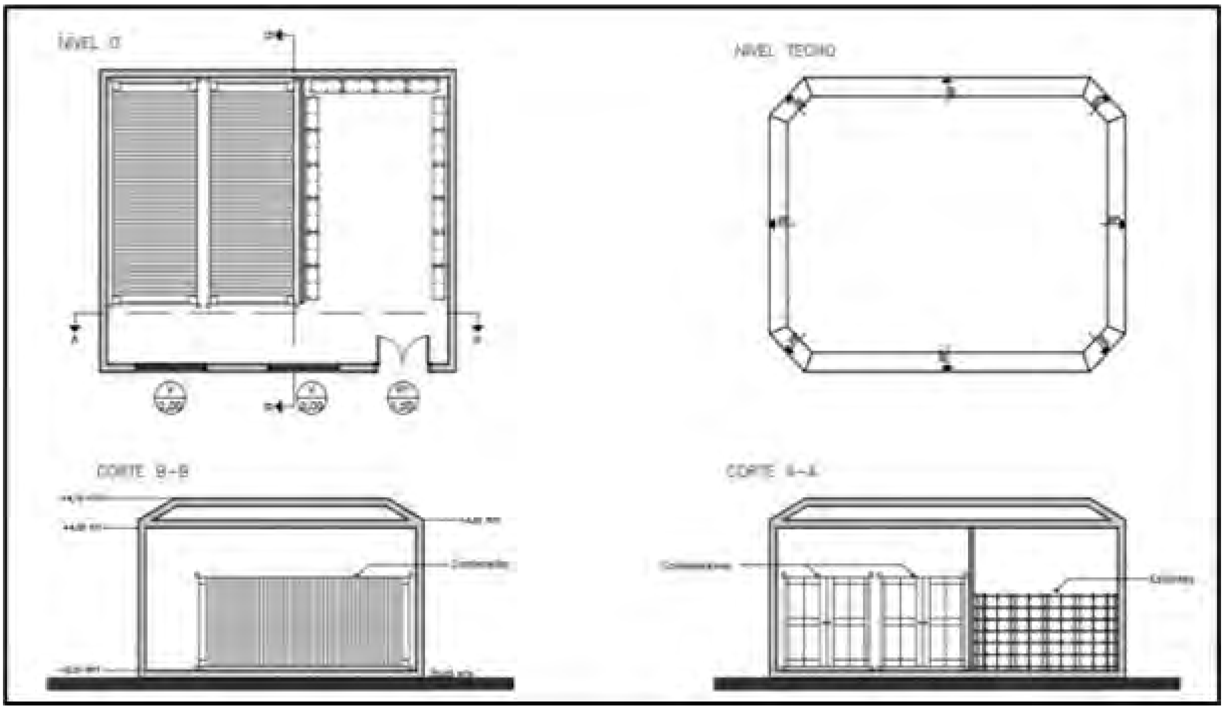


Figure 47: Plans of the food depot.

The execution of the building must follow the guidelines described in the following generic construction process. The corresponding preliminary tasks must be started in order to lay down the foundation. Once finished, the tripod profiling system must be executed, connecting the foundations with the building structure.

The building structure must then be built, which will consist of a lattice system (prefabricated trusses) in the upper section, linked by pillars on the external faces. The bracing of the structures can be carried out by means of cross-beams placed at a certain distance. This structure will be covered with PIR/PUR sandwich panels, creating a wall with excellent insulation and protection from the wind. It must be ensured that each time work is started it continues until its total enclosure (Note: the thickness of the panels is under study). Temporary walls may be used to guarantee the progress of the works with due structural safety based on the meteorological characteristics of Antarctica.

Once the exterior enclosure is finished, construction must begin inside under controlled climatic conditions. The construction of all internal subdivisions will continue, with their corresponding utilities and furniture.

4.3.2.2 Specific Description

Due to the fact that there are certain regulatory gaps in terms of construction in Antarctica, the following values will be adopted as criteria in the sizing and structural checks of future buildings to be built at the PETREL Joint Antarctic Base (Figure 49):

- The building will have a total area of 80 m^2, with walls 0.20 m thick and with dimensions of 8x10 m.
- The Food Depot will have the following itemised premises:
- ONE (1) room of 41 m^2 for Refrigerated and Frozen Groceries with TWO (2) Cold rooms of 10 feet each.
- ONE (1) room of 31 m^2 as a pantry for Dry Food with shelves.

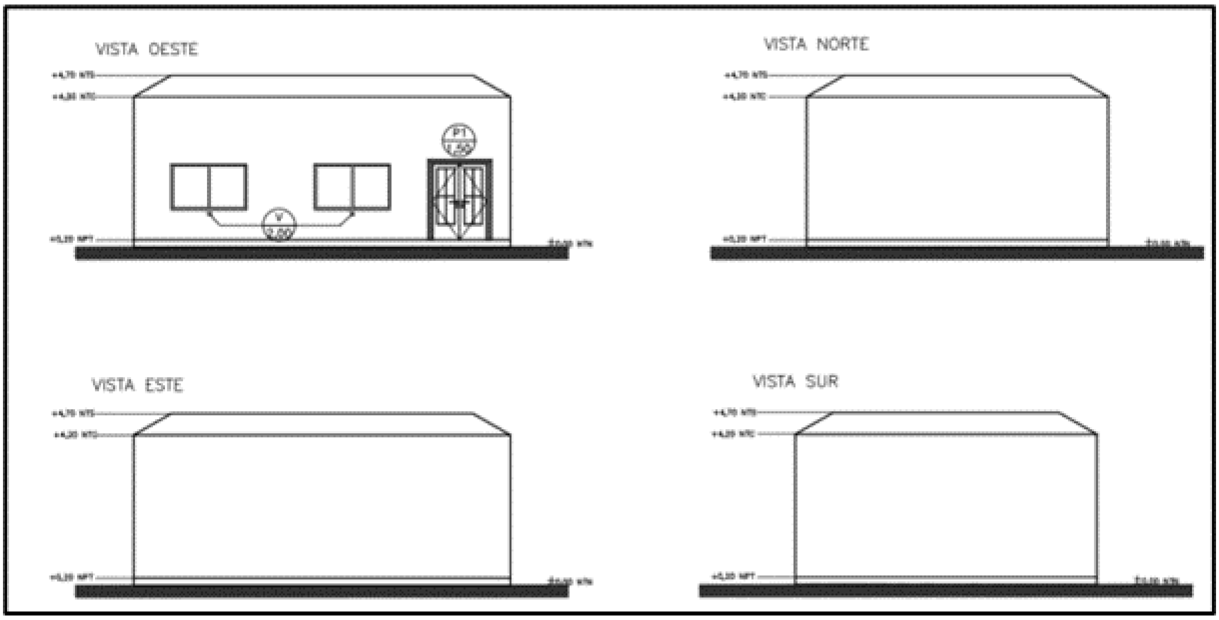


Figure 48: Views of the food store.

4.3.3 Emergency House

4.3.3.1 General Description

The new Emergency House is projected to the north of the Laboratory that is next to the Main House. It will have an N-S orientation. Its structure will be raised on stilts and alumna similar to the buildings mentioned above. It will be raised about 3 m above the natural terrain and will have three floors. The Emergency House will have an area of 695 m^2. Its dimensions will be 36 m long, 19 m wide and 13 m high. It will have a usable area of 1700 m^2 thanks to its three floors.

The building is intended to only be used in an emergency. It will be able to house SIXTY (60) people and let them carry out their daily lives inside. It will have a kitchen and dining space. Leisure spaces such as a living room and library, spaces for medical care and offices, among others. The new infrastructure will be projected for use as a state-of-the-art Antarctic housing accommodation, designed with a self-sustaining concept and technological innovations to allow the use of alternative energies. The lower and upper floors will be oriented to staff accommodation, while the services (dining room, kitchen, offices, etc.) will be located on the central floor (Figure 50).

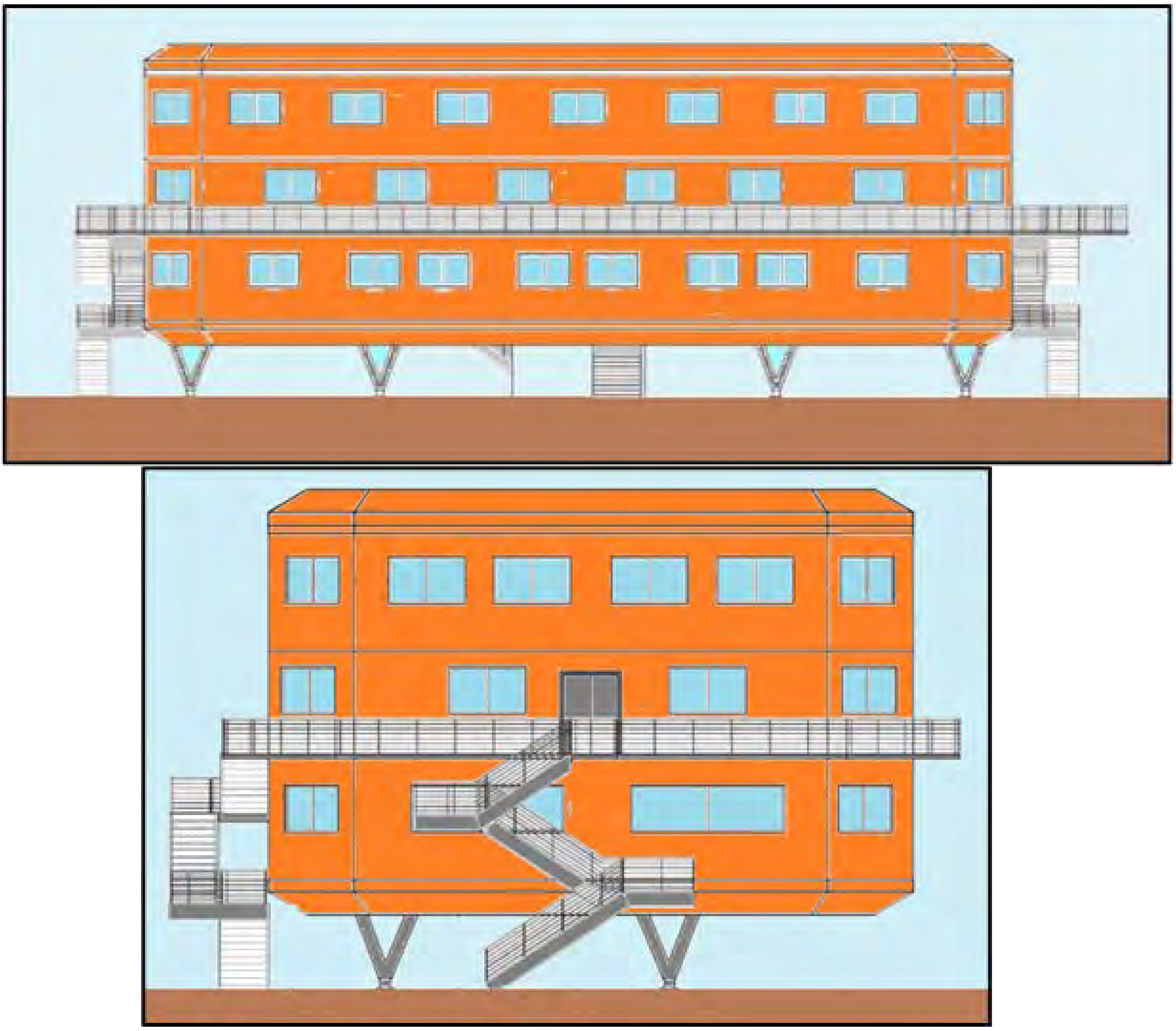


Figure 49: Exterior views of the emergency house.

4.3.3.2 Specific Description

The building will have the following premises (Figure 51):

Ground Floor

- ONE (1) electrical utility room.
- ONE (1) tank and pump room.
- ONE (1) boiler room.

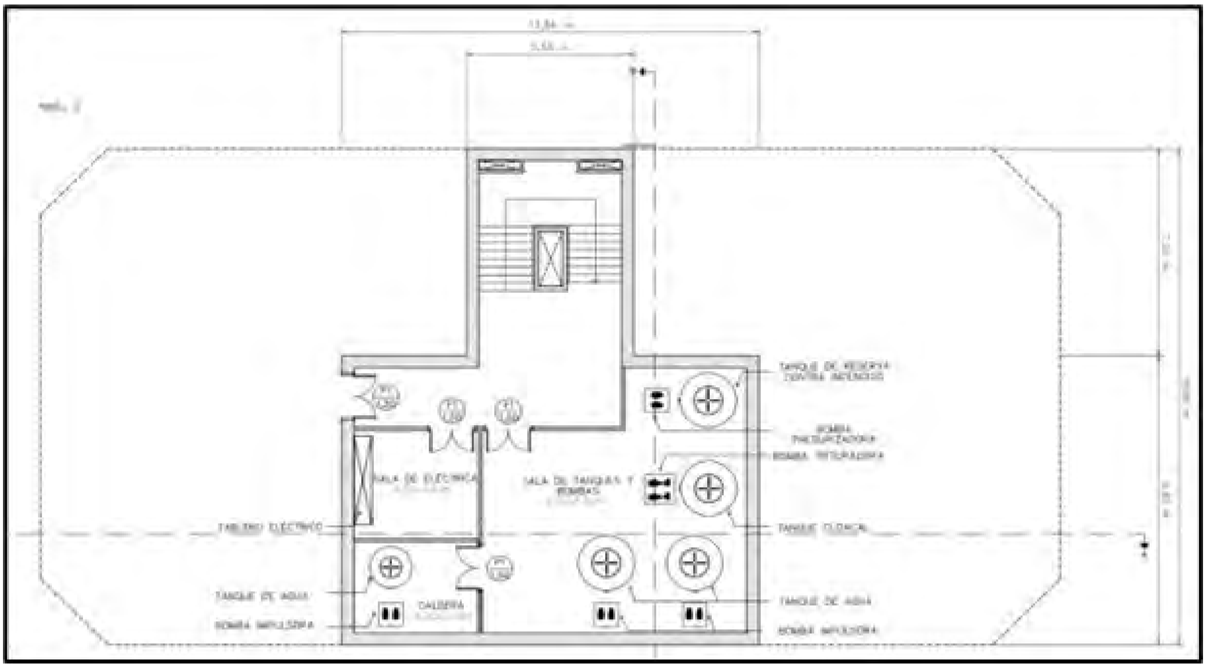


Figure 50: Ground floor plan of emergency house.

Floor 1 (Figure 52)***:***

- EIGHT (8) rooms of 18 m^2 for TWO (2) people.
- EIGHT (8) rooms of 18 m^2 for THREE (3) people.
- A sector for showers and another for sinks and toilets of 24 m^2 each.
- THREE (3) emergency exit doors
- ONE (1) stretcher lift with a minimum capacity of 1500 kg, which may also be used to transfer internal logistics loads.

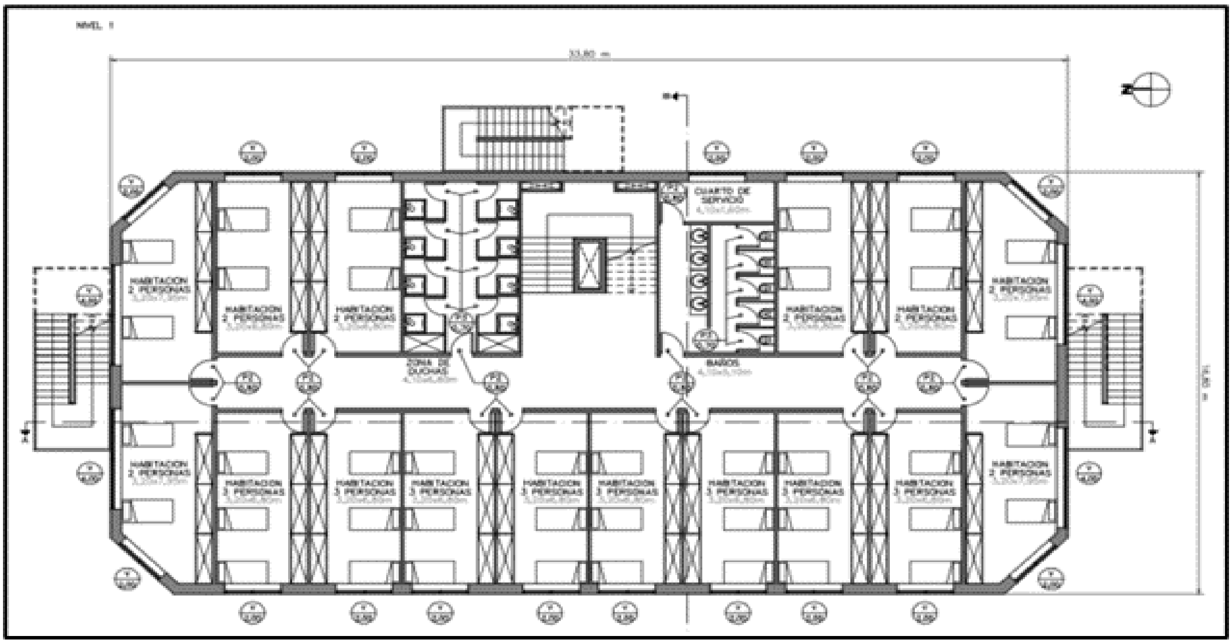


Figure 51: Plan of floor 1 of the emergency house.

Floor 2 (Figure 53)***:***

- Infirmary of 36 m^2
- Office sector of 114 m^2
- THREE (3) emergency exit doors.
- TWO (2) workshops.
- TWO (2) boot rooms.
- ONE (1) meeting room.
- ONE (1) living room.
- ONE (1) library.
- ONE (1) multipurpose room.
- ONE (1) common dining room OF 96 m^2.
- ONE (1) infirmary.
- ONE (1) office.
- ONE (1) hospitalisation room.
- ONE (1) common bathroom (sinks and toilets) of 36 m^2.
- ONE (1) kitchen of 72 m^2.
- ONE (1) stretcher lift with a minimum capacity of 1500 kg, which may also be used to transfer internal logistics loads.

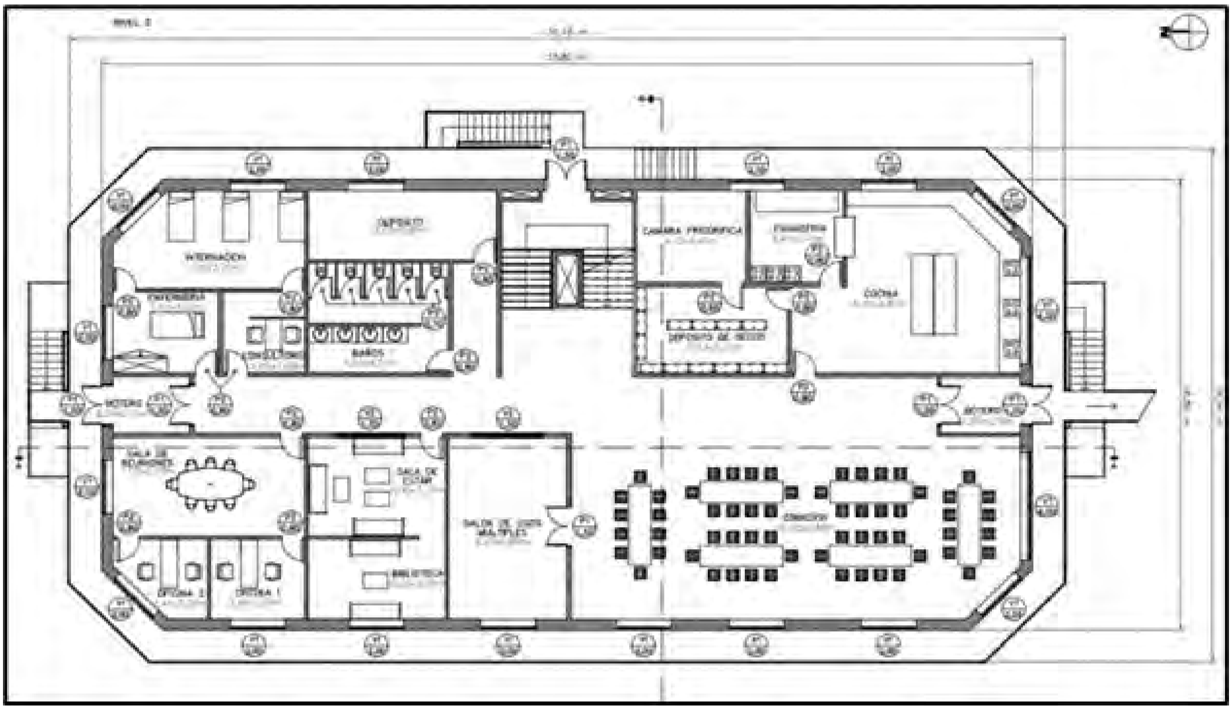


Figure 52: Plan of floor 2 of the Emergency House.

Floor 3 (Figure 54)***:***

- SIX (6) en-suite rooms for ONE (1) person, with integrated bathroom and kitchen.

- THREE (3) en-suite rooms for TWO (2) people, with integrated bathroom and kitchen.
- FOUR (4) apartments for two people, with integrated bathroom and kitchen.
- ONE (1) stretcher lift with a minimum capacity of 1500 kg, which may also be used to transfer internal logistics loads.

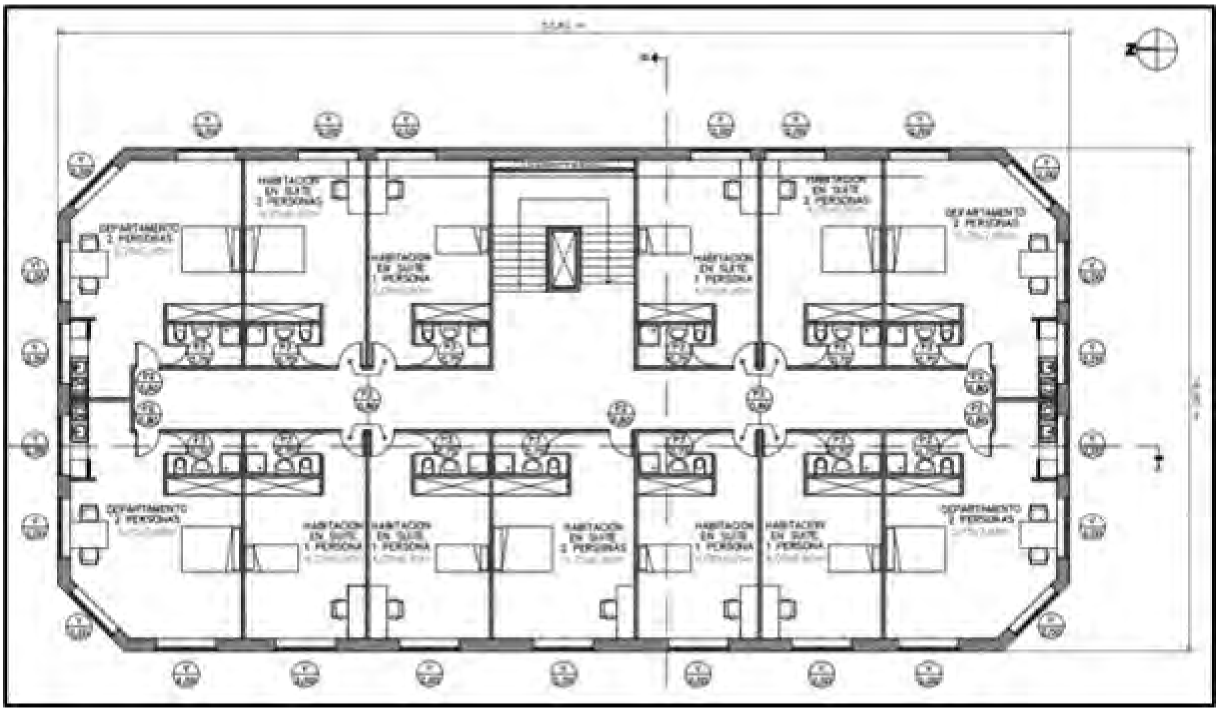


Figure 53: Plan of Floor 3 of the Emergency House.

4.3.4 Main Power Plant

4.3.4.1 General Description

It will be built on the current location occupied by the cold room buildings. Said cold room will be dismantled and taken away to the continent. Its foundations will be removed. The building will maintain the line of the buildings located on the northern edge of the upper platform of Cape Welchness. It will be rectangular with a north-facing roof. It will occupy a total area of 262 m^2 (25.55 m x 10.25 m) and will have a maximum height of 10.25 m (Figure 55).

It will have two floors or levels. The lower floor, where three generators of 250 KVA each will be located. On the side of the building, separated by a fire wall, there will be a plant for melting ice and snow using the heat produced by the electric generators. Three 40 m^3 tanks will be located next to the ice and snow melting plant to store drinking water at above-zero temperatures, also using the heat from the generators. The generator control room will be located on the upper level, together with a small kitchen.

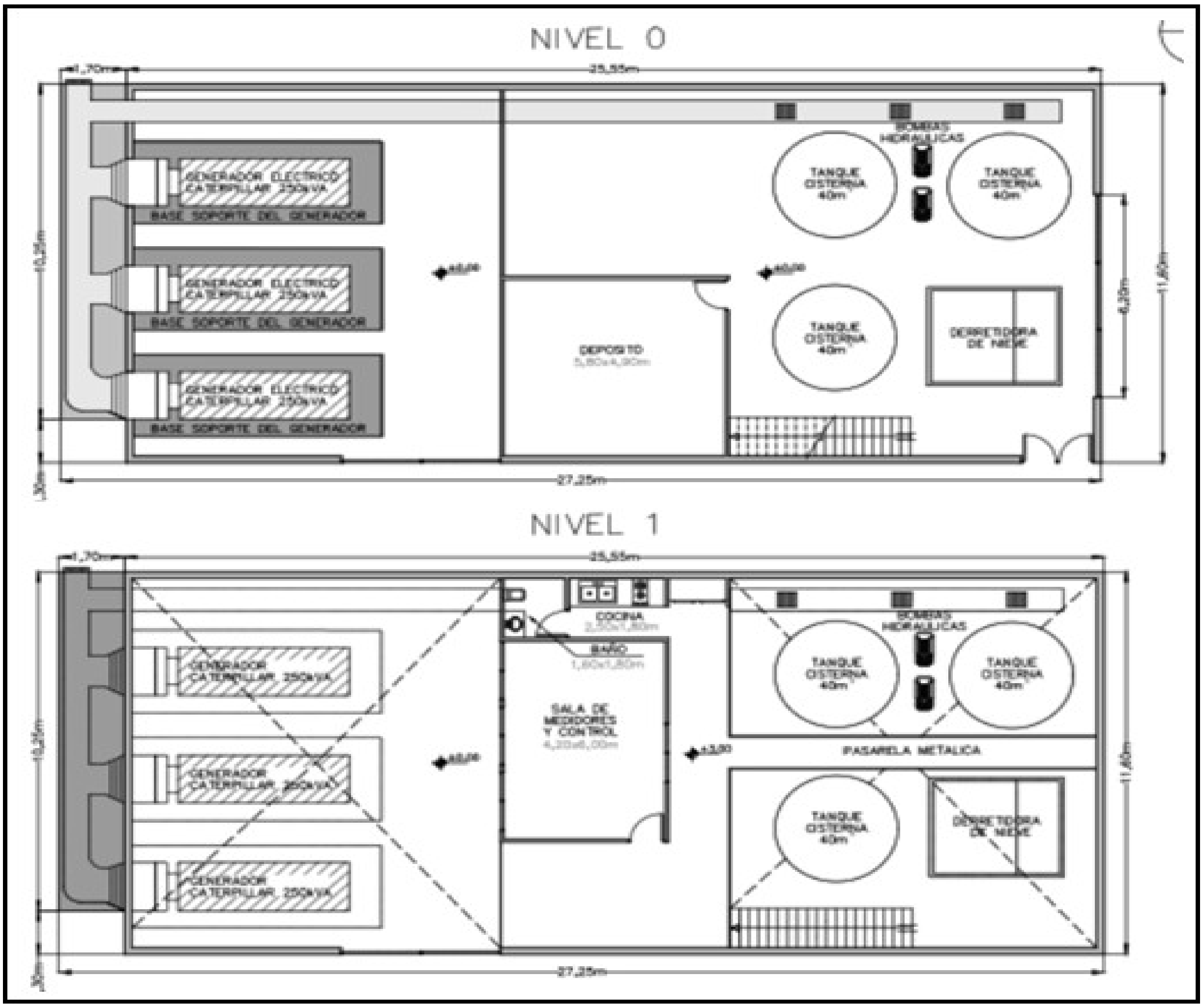


Figure 54: Floor plans of the levels of the Main Power Plant.

4.3.4.2 Specific Description

The building must have the following premises (Figure 56):

Ground floor:

ONE (1) 15.90 m^2 deposit.

ONE (1) 12.65 m^2 tank room to contain TWO (2) water tanks, ONE (1) pressurising pump and ONE (1) grinder pump.

ONE (1) 244.33 m^2 engine room to contain THREE (3) electric generators, FOUR (4) water tanks, TWO (2) hydraulic pumps and ONE (1) snow melter.

First floor:

ONE (1) meter and control room of 25.20 m^2. ONE

(1) kitchen of 4.5 m^2.

ONE (1) bathroom of 2.88 m^2.

Circulations 10% of the total surface.

4.3.5 Emergency Power Plant

4.3.5.1 General Description

The Emergency Power Plant will be located within the Petrel Joint Antarctic Base, in the area where the Emergency Power Plant is currently located, approximately 104 m north of the Photovoltaic Panel Field, 123 m south of the Emergency House, 15 m west of the Main Power Plant and 35 m to the east of the workshop. The building holding the current emergency power plant will be dismantled and removed. It will be a building with similar characteristics to the Main Power Plant, rectangular with a pitched roof, but smaller. It will occupy an area of 42.63 m^2 (8.70 m long x 4.90 m long) and will have a maximum height of 4.92 m (Figure 56).

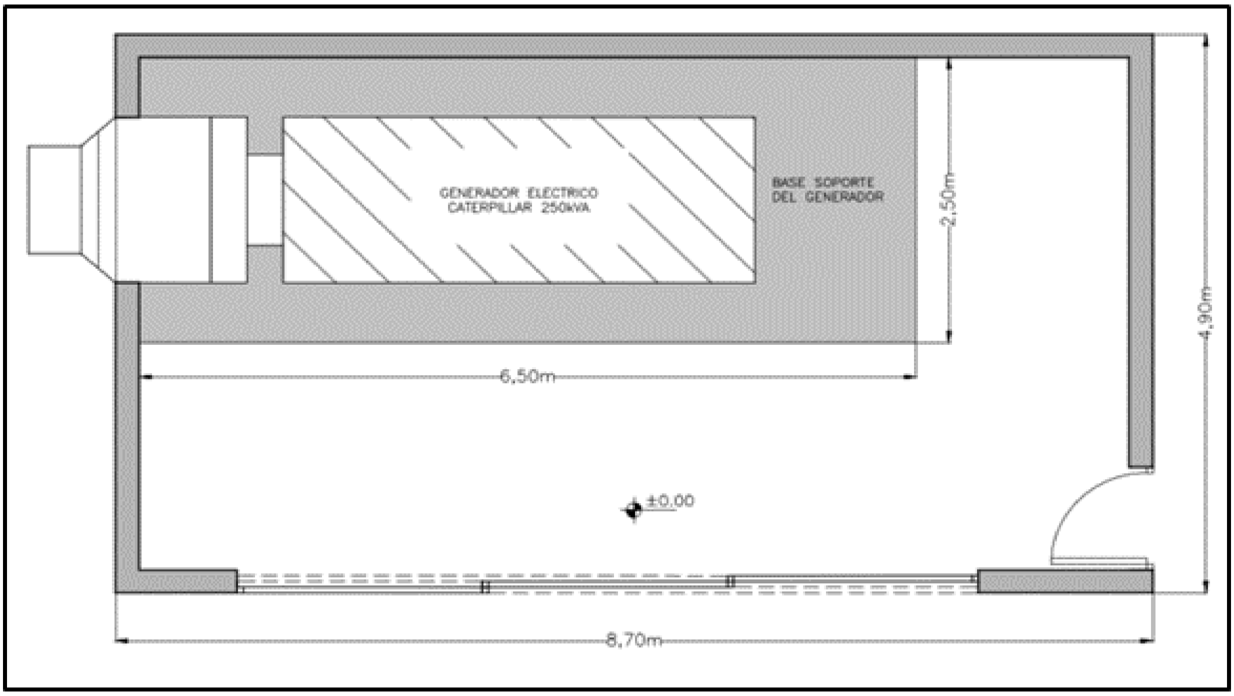


Figure 55: Floor plan of the Emergency Power Plant

4.3.5.2 Specific Description

It will have a single floor. Inside it will house a 250 KVA generator with its control system and boards. The generator will be used exclusively in emergency situations, or for maintenance reasons. The emergency power plant (and its generator) constitutes the base's redundant power generation system (Figure 57).

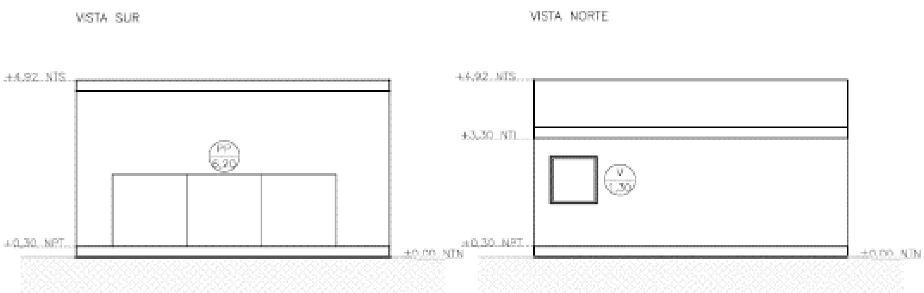


Figure 56: Side view of the Emergency Power Plant.

4.3.6 DNA Depot and Cargo Terminal

4.3.6.1 General Description

A preliminary project was developed to install a building in order to implement a cargo terminal and a warehouse for the National Antarctic Directorate (DNA) at Petrel Antarctic Base. The plant was organised over a total area of 603 m^2, whose dimensions resulted in 30.15 m for the front, 20 m deep, and a maximum height of 10.75 m. The Building is compartmentalised, resulting in a cargo terminal area of 403 m^2, and a depot of 200 m^2 (Figure 58).

The operational requirement for the Cargo Terminal of having a covered area necessary for the stowage of a minimum of 12 pallets of 88" x 108" and 90" height (2.24 x 2.74 x 2.28 m), was met, with the possibility of increasing its stock in height by installing racks, to double its capacity with respect to what is necessary in this first requirement.

In the case of the DNA Warehouse, the location of 10 racks was established for a volume storage capacity of 228 m^3, and access is materialised through a door 1.50 m wide and 2.10 m high. Both buildings have an independent emergency exit in the rear sector of the building.

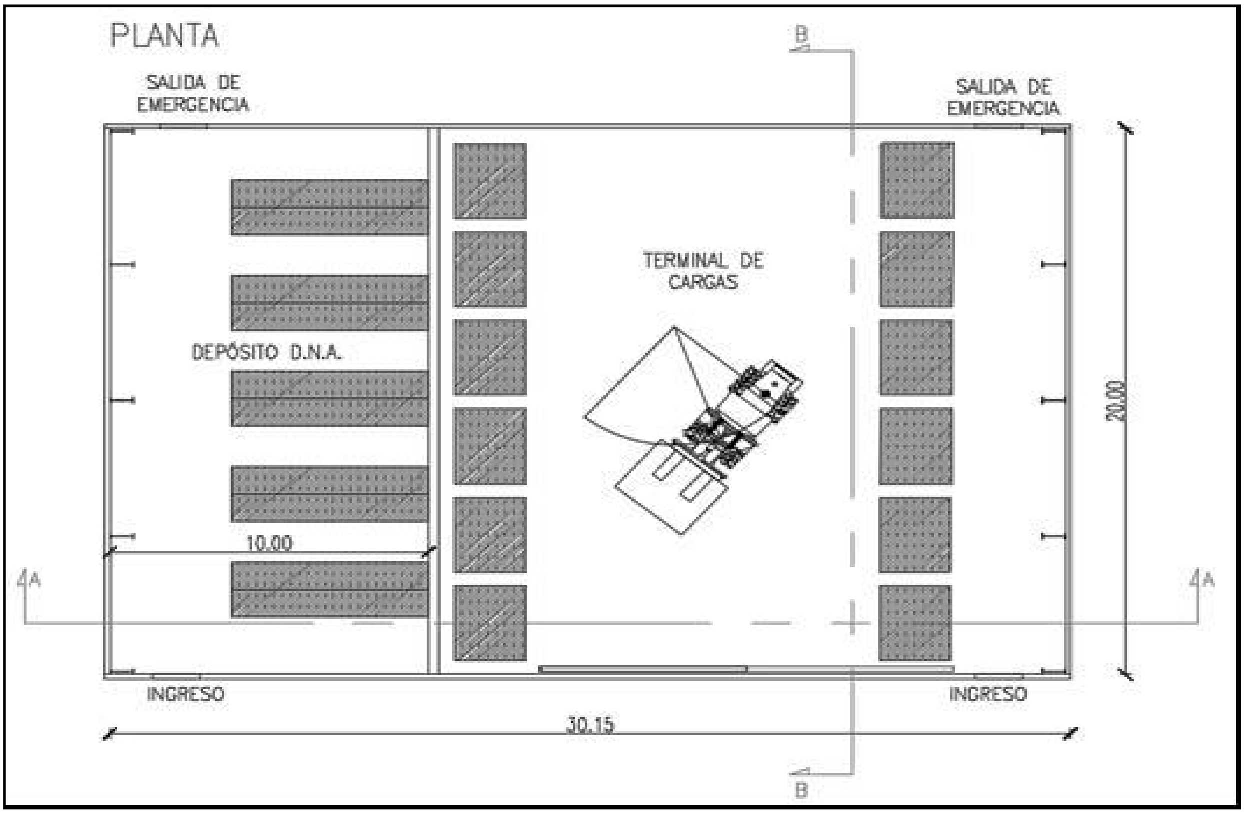


Figure 57: Floor plan of the Depot and Cargo Terminal.

4.3.6.2 Specific Description

The front of the building is oriented to the west. The access gate to the Cargo Terminal is 6.5 m wide and 5 m high. The interior space is designed for the operation of a Terex 760B machine, 7.20 m long and 2.30 m wide, or a brand with similar characteristics, with a claw accessory or front shovel (Figure 59).

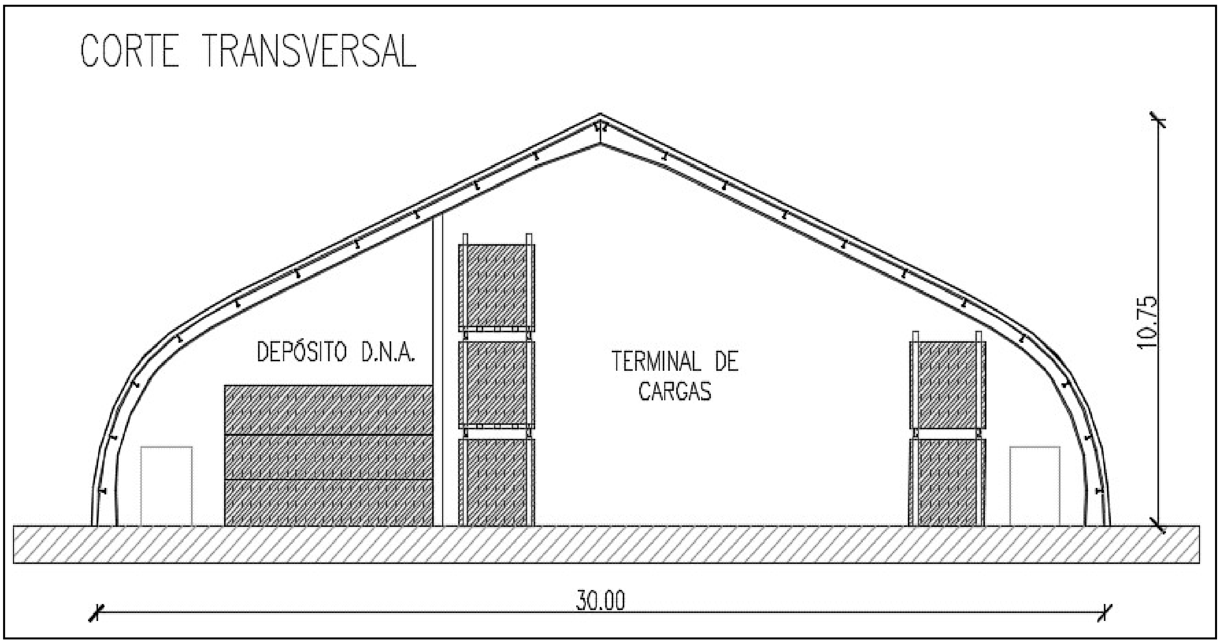


Figure 58: Cross section of the DNA Depot and Cargo Terminal:

The structure was designed in F-36 quality steel, with a full core and with sections of variable heights to optimise its own weight and also save material. 20 cm thick PIR type sandwich panels will be used in the envelope. The floor is raised with a substructure and aluminium plates with thermal insulation. The main characteristics of the profile of this structure, due to the optimised angle of inclination of the roof, is its resistance to the dynamic actions of winds of up to 300 km/h, also giving it good performance in preventing snow accumulation. As an additional constructive advantage providing versatility, the building area may be enlarged if necessary in its longitudinal direction, since by having a structural typology of parallel frames it is possible to dismantle the envelope of the rear sector, place new frames, and finally complete with the required coating surface.

4.3.7 Sports Centre

4.3.7.1 General Description

The sports centre is located within the Petrel Joint Antarctic Base, about 120 m south of the DNA Depot and Cargo Terminal; 50 m west of the MI Hangar; 25 m south of the Photovoltaic Panels Field. It will be 47.00 m long, 34.00 m wide and 9.00 m high. The roof is gabled, with the highest height at 9.90 m and the lowest at 5.40 m. The building may only be used for sports and social uses. It will have several sports facilities, among others a court and a machine room, which will allow the performance of a wide variety of sports and exercises. It will also have separate changing rooms and bathrooms for each gender and a sauna. The building has a sector with stands to seat 128 people (Figure 60).

The construction will have shelves and organisation equipment for the warehouses. EIGHT
(8) treadmills, TWO (2) sets of weights, from 2 to 20 kg, SIX (6) incline bench presses, with their respective weight support and bar, SIX (6) weights kits from 5 to 20 kg, SIX (6) stationary bikes. Sanitary equipment for both bathrooms as detailed above. SIX (6) soap dishes, FIVE (5) toilet paper holders. Sauna equipment to be defined. TWO (2) goals, THREE
(3) sports ball kits (football, basketball, volleyball, handball).

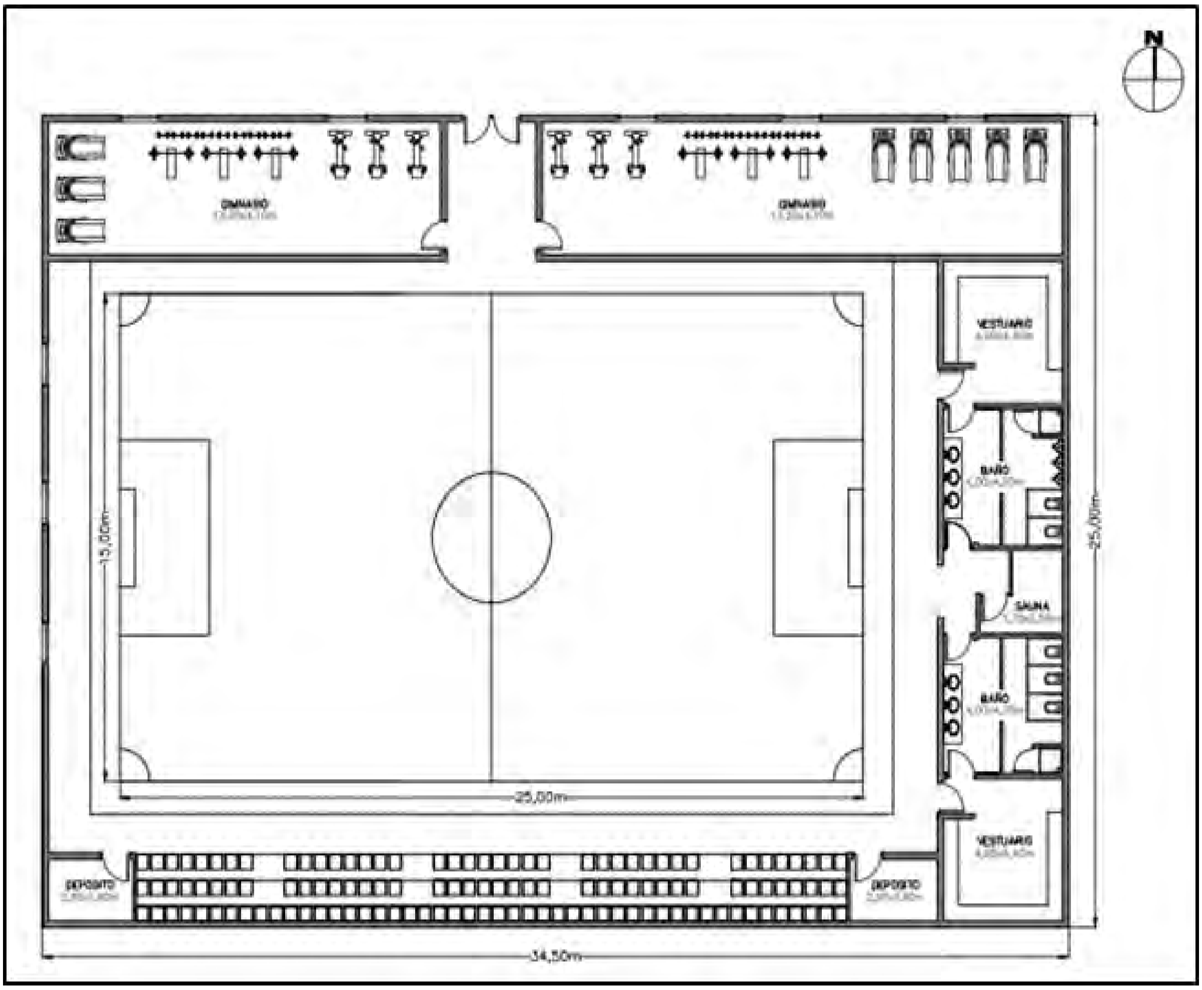


Figure 59: Plan view of the Sports Centre.

4.3.7.2 Specific Description

The building has TEN (10) premises, which will be detailed below:

- TWO (2) deposits materialised in a symmetrical and mirrored manner, each one on one side of the stands sector. They will be 2.85 x 1.90 m.
- TWO (2) gyms materialised in a symmetrical and mirrored manner, both facing the sector of the stands and separated by a corridor with a double door to the outside. The premises will be 13.20 x 4.10 m.
- TWO (2) changing rooms in a symmetrical and mirrored manner, each one in a corner of the building to the east. They will be 4.00 x 4.40 m.
- TWO (2) bathrooms in a symmetrical and mirrored manner each one on one side of the sauna. They will have access through two doors each one that will be facing each other and on each side of the premises. They will be divided into two sectors, one for sinks and one for toilets, showers and urinals.
- The ladies bathroom will have THREE (3) cubicles with a toilet and a shower.
- The men's room will have TWO (2) stalls with toilets, THREE (water closets), and a shower. They will be 4.00 x 4.20 m each.
- The sauna will be 1.70 x 2.55 m.

- ➢ The sports centre court will have dimensions of 29.90 x 20.30 m. The venue will have two goals, a floor suitable for sports (to be defined) and a 24 x 2.06 m sector with three 0.60 m high steps and 128 seats.

The building will be designed with a modular construction system in order to allow its easy transfer from the Continent to Antarctica, and relatively simple to build and assemble, once in the necessary location. The objective of the structure will be to support the forces exerted on it and transmit them to the foundations. It will be built using dry construction methods (sandwich panels) and with a lattice structure system (prefabricated trusses made up of metal profiles). The structural skeleton will be wrapped by the outer walls, which will be fastened by means of threaded steel rods to galvanised structural profiles (purlins). The dimensions, distances and characteristics between these elements must be indicated accordingly in the final project plans. Thin sheet metal profiles, angle profiles, tubular and/or round pipes will be used as stiffeners.

The panels will be made up by injecting a high-density thermal insulating and super-adhesive foam between two sheets: one exterior and one interior. This scheme allows the panel to be resistant and to cover long distances with a smaller support structure.

4.3.8 Workshop

4.3.8.1 General Description

The Workshop building will be a construction located in the south east area of the upper platform of Cape Welchness. It will be located in front of the Vehicle garage, 25 m west and 50 m east from the Sports Centre. It will maintain an E-W alignment with the vehicle garage, the Sports Centre and the Helicopter Hangar. It will occupy an area of 450 m^2. It will be rectangular, 30 m long by 15.00 m wide and 9.00 m high. The flooring will be gabled, having the lowest height at 3.30 m and the highest at 9.00 m. Inside there will be three main premises, called the Ironwork (mechanical workshop), Carpentry and Facilities workshops (Figure 61).

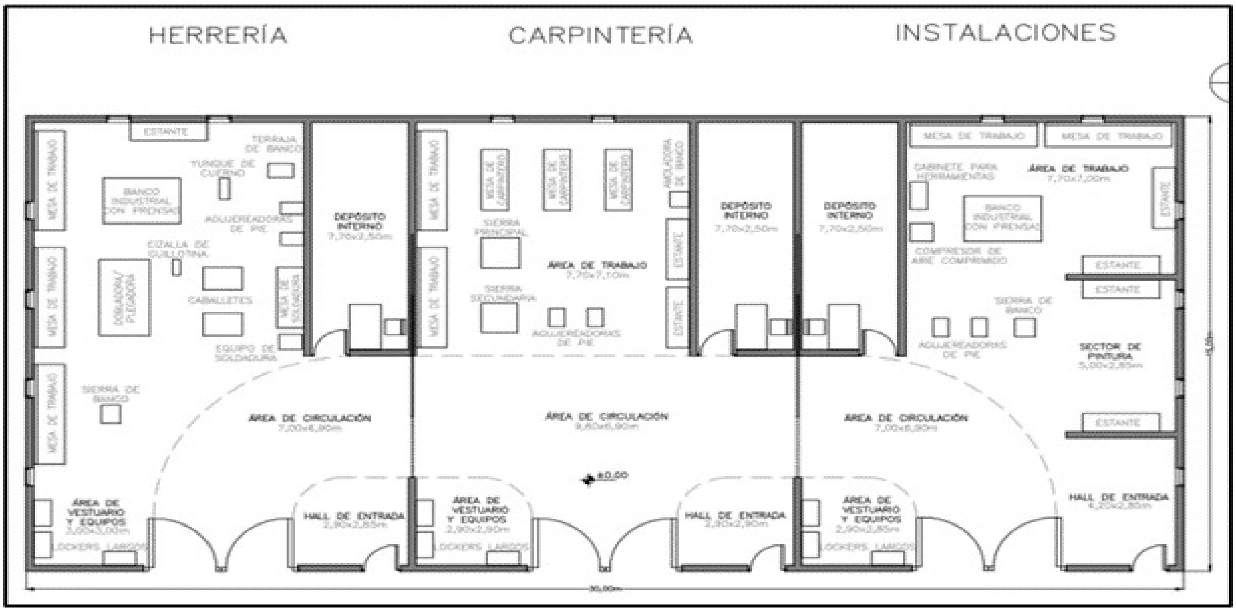


Figure 60: Floor plan of the Workshop.

4.3.8.2 Specific Description

The workshop will have three main premises, one for the ironwork shop, another for carpentry and the last one for installations. The first one must have all the necessary equipment to be able to work with metal and make different types of objects. The second requires similar equipment, but for woodwork. Finally, in the installations sector, maintenance will be given to the other facilities of the Base, be they electrical, sewage, water, etc. (Figure 62).

In addition to the three main premises, the workshop will have three offices, each one dedicated to their administration, which can also function as warehouses and located next to them. Also, on the right side of the three main entrances will be the entrance hall, which will have its own smaller entrance. On the left side, however, there will be a changing room area that will have its own lockers.

In summary, this will have the following itemisation of premises: ONE (1) 54 m^2 carpentry, ONE (1) blacksmith shop of 52 m^2, ONE (1) premises for facilities maintenance of 52 m^2, THREE (3) 19 m^2 offices, and THREE (3) 8 m^2 changing room and equipment areas. Circulations (corridors) will account for 25% of the total area.

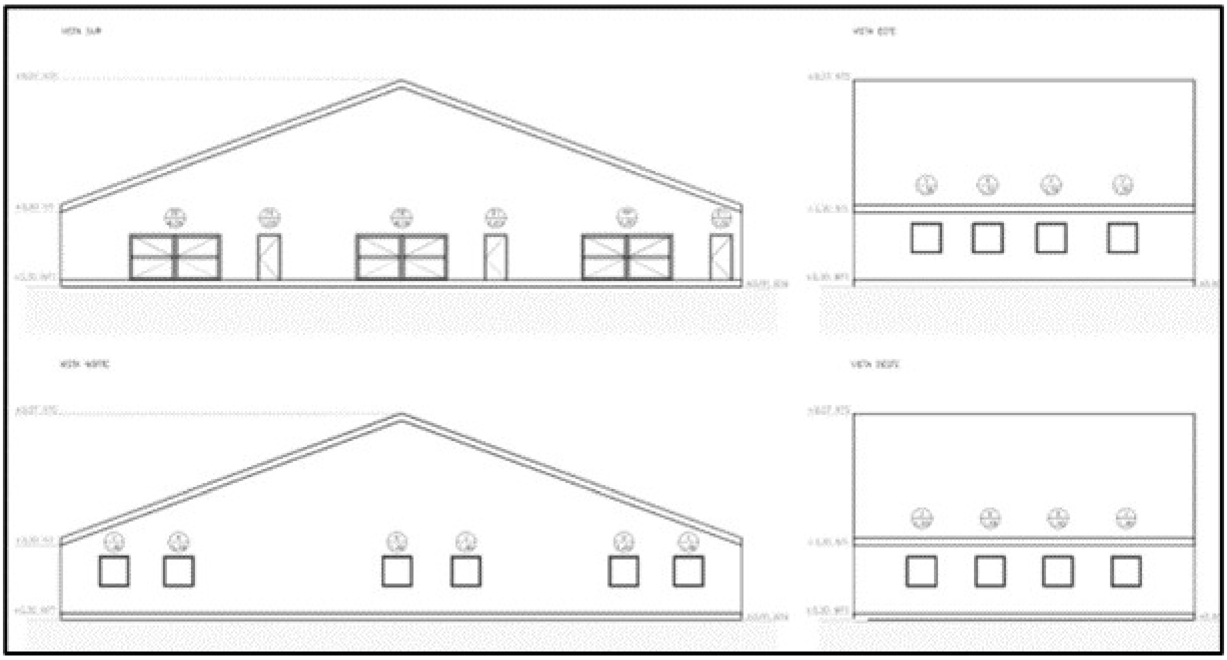


Figure 61: Side view of the Workshop.

The ironworks shop will have THREE (3) work tables, ONE (1) workbench, ONE (1) horn anvil, TWO (2) foot hole punches, ONE (1) industrial bench with vice grips, ONE (1) bender, ONE (1) guillotine shear, TWO (2) sawhorses, ONE (1) welding table and ONE (1) welding equipment. On the other hand, the carpentry will have TWO (2) work tables, TWO (2) shelves, THREE (3) carpenter's tables, ONE (1) bench grinder, TWO (2) saws and TWO (2) hole punchers. Finally, the premises for facilities maintenance will have TWO (2) work tables, FOUR (4) shelves, TWO (2) stand boring machines, ONE (1) bench saw, ONE (1) industrial bench with vice grips, ONE (1) air compressor, and ONE (1) tool cabinet.

4.3.9 Vehicle Garage

4.3.9.1 General Description

In order to protect the machinery used in the maintenance of the base and especially the landing strip, it was decided to build a building for the storage of these called Vehicle Garage. The Vehicle Garage will be located to the south of the vertical tanks and in front of the workshop building, on the intersection of the southern edge of the central platform of Cape Welchness and the moraine of the Rosamaría glacier.

This rectangular-shaped building will have a single floor and will occupy an area of 630 m^2 (42 m long x 15 m wide). Its roof will be gabled, reaching a maximum height of 7.36 m. Its interior will have space to store up to 6 road machinery and will have 4 premises. Access to its interior will be through a door and 7 sliding gates for vehicle entry (Figure 63).

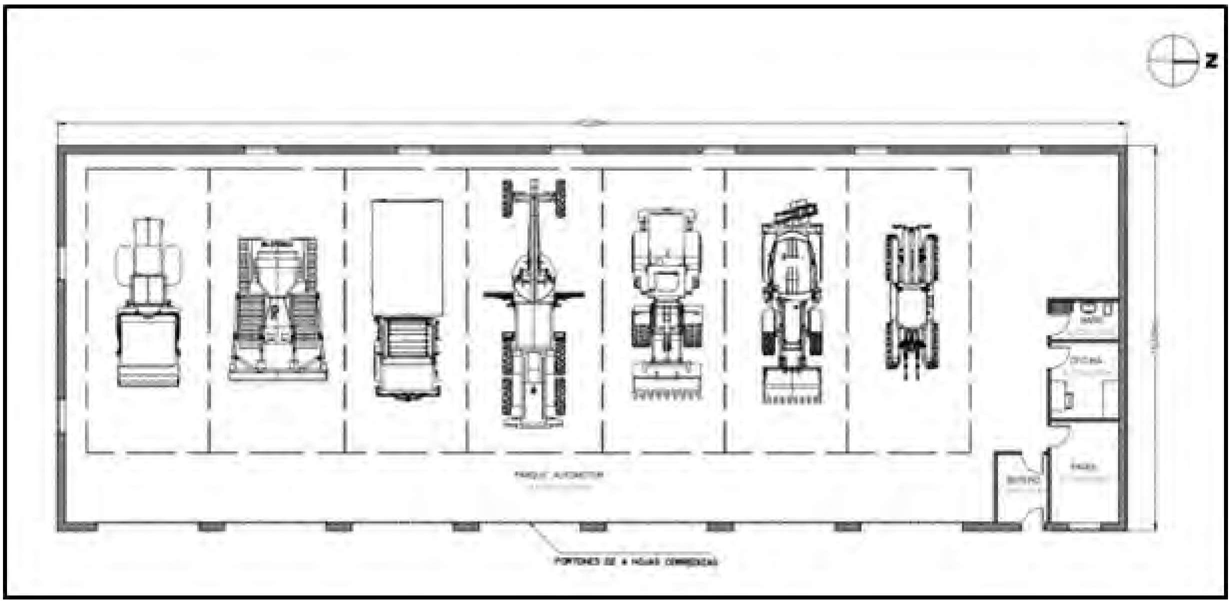


Figure 62: Floor plan of the Vehicle Garage

4.3.9.2 Specific Description

The building must have the following premises that are detailed below: Ground floor:

- ONE (1) bathroom with dimensions 2.70 x 1.50 m.
- ONE (1) office with its respective furniture (desks, chairs).
- ONE (1) Storeroom with dimensions 2.70 x 4.00 m.
- ONE (1) Boot room of dimensions 2.00 x 2.70 m.
- ONE (1) Parking for parking road machines.

The road machines that will be found in the vehicle garage, as previously specified, will be those mentioned below. They will be used to perform different tasks and, depending on the type of needs required, one will be chosen over the other. They will be (Figure 64):

- Road roller
- Bulldozer
- Dump truck
- Grader
- Loader
- Backhoe
- Loader.

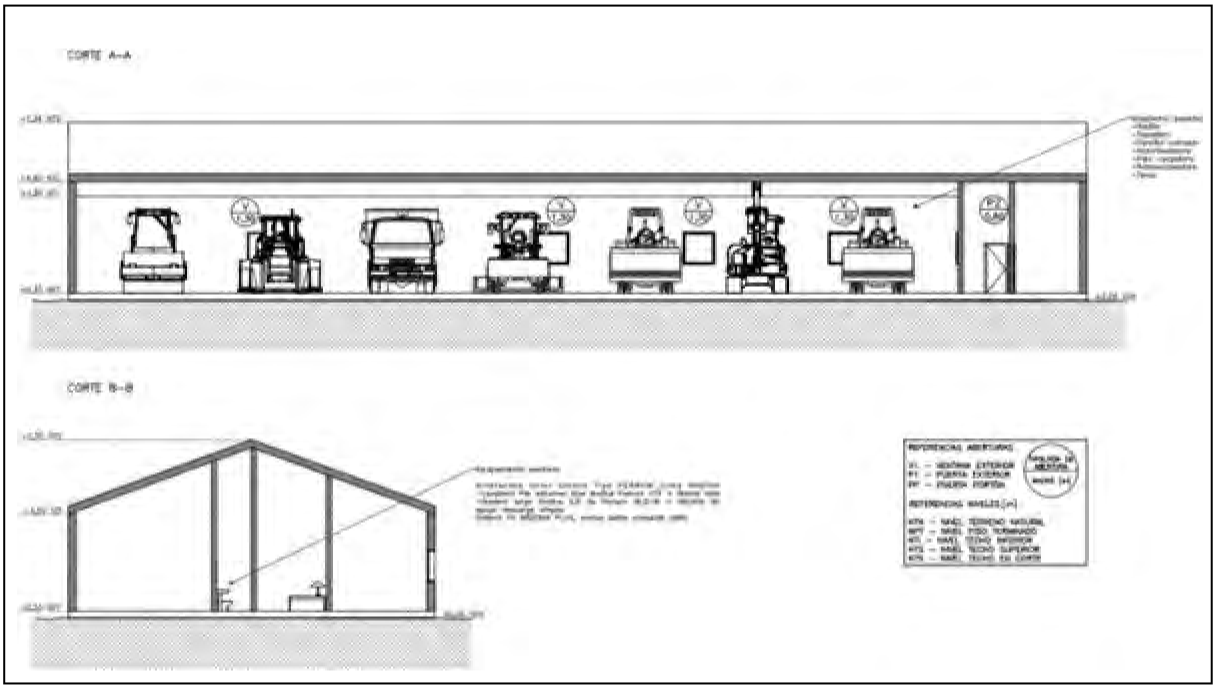


Figure 63: Cutaway plan of the Vehicle Garage.

4.4 Scientific Area

4.4.1 Main House

4.4.1.1 General Description

The laboratory has been projected as an annex to the main house. For this reason, this building continues the line of the Residential House, extending it to the north, on the edge of the upper platform of Cape Welchness. The building will apply the same construction techniques used in the Accommodation Building. The structure will be assembled independently, with a foundation of piles and alumna maintaining the levels of the Accommodation Building. Taking advantage of the difference in height from the ground, one more floor will be added below the level of the Accommodation Building.

The laboratory is projected to have two floors. The upper floor, at the level of the Accommodation Building, will house EIGHT (8) laboratories, and the lower floor will have accommodation with TWELVE (12) rooms with capacity for TWENTY-FOUR (24) people in total and TWO (2) rooms of 36 m^2 each. The building will occupy a minimum area of 462 m^2, which makes a total usable area of 924 m^2 (Figure 65).

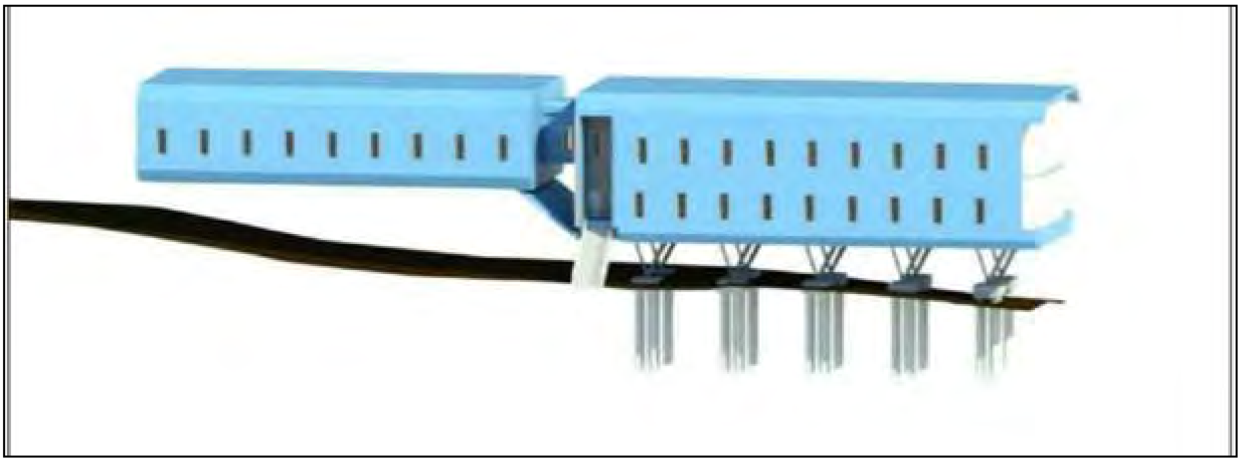


Figure 64: Artist impression of the Laboratory structure.

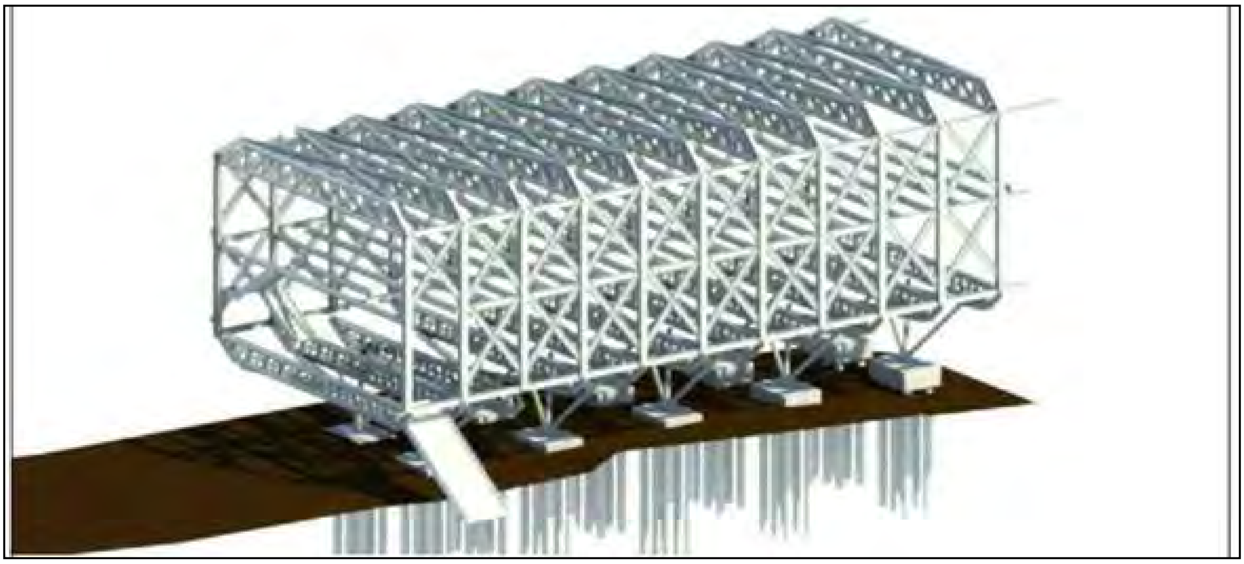


Figure 65: View of the laboratory structure.

4.4.1.2 Specific Description

The building must have the following premises that are detailed below:

Level 0 (Figure 67):

TWELVE (12) double rooms with private bathrooms of 3 x 6 m each, ONE (1) meeting room of 6 x 6 m.

ONE (1) 6 x 6 m library

ONE (1) storage room, laundry room and boot room of 3 x 6 m each,

ONE (1) living room of approximately 3 x 14 m.

ONE (1) entry staircase and ONE (1) access staircase to the 1st floor.

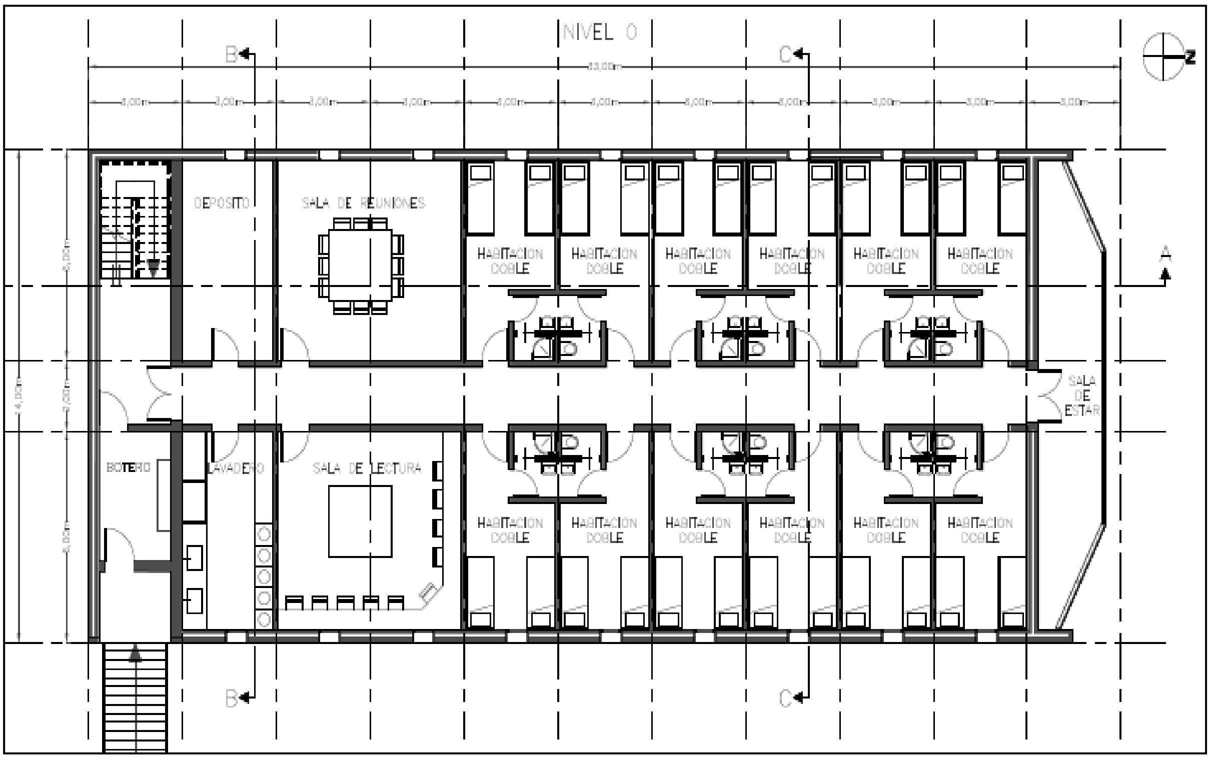


Figure 66: Plan view of Level 0 of the Laboratory Building.

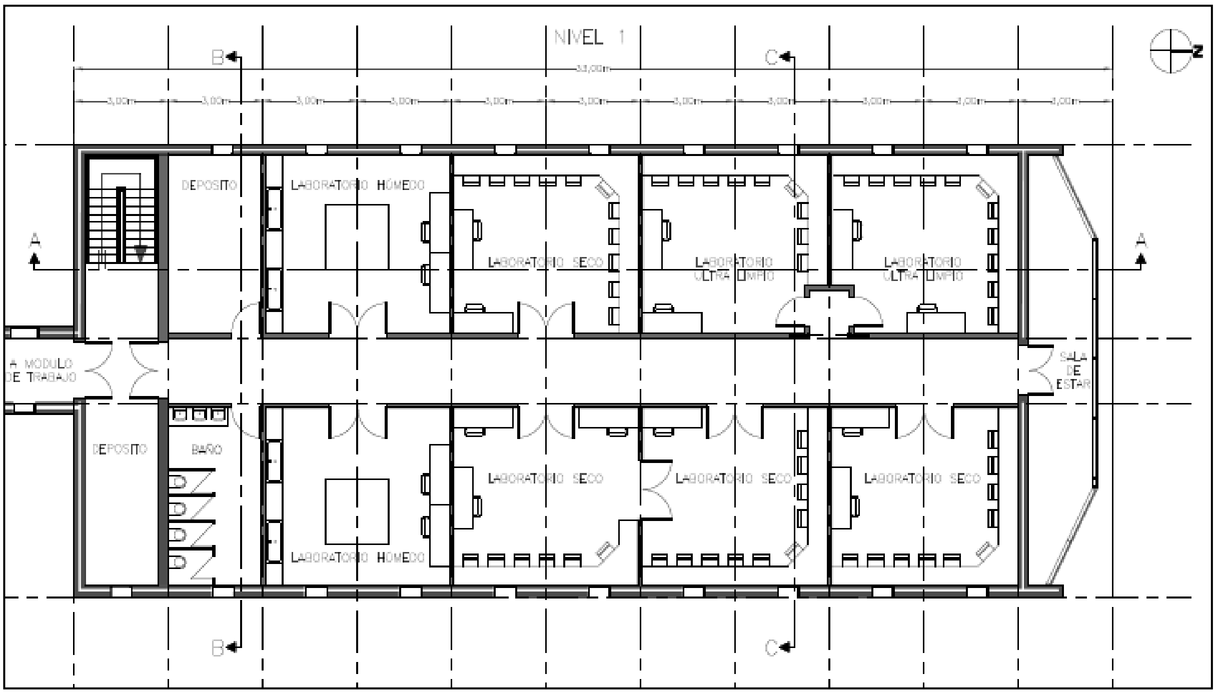


Figure 67: Plan view of Floor 1 of the Laboratory Building.

First floor (Figure 678):

FOUR (4) 6 x 6 m dry laboratories, equipped with their corresponding furniture (chair, community table and perimeter desks)

TWO (2) 6 x 6 m ultra-clean laboratories, equipped with their corresponding furniture (chair, community table and perimeter desks)

TWO (2) 6 x 6 m wet laboratories, equipped with their corresponding furniture (chair, community table, perimeter desks and especially sinks)

ONE (1) tank of 3 x 6 m.

ONE (1) general bathroom with its respective divisions.

ONE (1) living room.

4.5 Construction details

The buildings will have a load-bearing system and an enveloping system (just like the main house).

4.5.1 Supporting structure

Like the foundation system, the supporting structure system and its respective connection with the foundation should be defined in the engineering study, with different proposals for the competent solution of the building having been studied and analysed. Also, it must not pollute the environment, it must be built with low-maintenance materials and be highly optimised in electrical consumption.

In all cases, a new load-bearing structure will be built, whose objective will be to support the forces exerted on it and transmit them to the foundations. The main body will be a main building, basically composed of a panellised manner with dry construction methods and with a lattice structure system (prefabricated hangers made up of full core profiles) similar to Warren. The upper section will be a sloped roof. This system must have a rectangular transverse shape. The structures that support the walls and roofs can be braced by means of cross-beams placed at a certain distance. This lattice system will consist of steel profiles with a galvanised exterior coating, joined at their ends with rigid knots.

The skeleton will be wrapped by the outer walls, which will be fastened by means of stainless steel self-tapping screws to galvanised structural profiles (purlins). The dimensions, distances and characteristics of these elements will be indicated accordingly in the project drawings. We expect to use galvanised folded sheet profiles of angle thicknesses, tubular and/or round pipes as stiffeners.

Once the construction materials have been chosen, the basic drawbacks of these elements must be solved:

- Corrosion (paint, etc.).
- Fire protection (fire protection panels, etc.).
- Lateral bending or buckling due to being a slender element subject to the effects of compression loads.
- Maintenance.
- Need for specialised labour for assembly, for example, on welded joints, resulting in the level of rigidity achieved for the assembly.

Each of the project structures is calculated based on the corresponding regulations in force, establishing the forces acting on the work, defining structural elements and detailing among others the dimensions, heights, spans, layout. It will be complemented with the development of one or more calculation models with software adjusted to the real behaviour of the buildings in second order with obtaining the stresses and displacements to check ultimate and serviceability limit states.

The connection system between the foundation and the load-bearing structure itself consists of an inverted tripodal system of cylindrical tubular profiles (supports) of galvanised ASTM A633 Grade E structural steel with an external epoxy and acrylic polyurethane coating in different layers or a sufficient coating to resist the aforementioned effects. These supports are intended to be able to withstand maximum wind speeds, low temperatures and the effects of possible earthquakes as well as the freezing and thawing cycles of the Antarctic soil. This triodetic system of directions in multipoints to the structure allows counteracting ground movements. These three supports are joined into a composite profile, a central section formed by the union between two U-shaped cold-rolled open profiles connected to generate a single square closed profile. Stiffened on the edges of the trunk, there will be plates at 90º, or angle profiles, divided into a triangular shape with its longest side on the base, which will distribute the loads of this central profile towards said surface, which is directly connected to the anchor plate.

The profiles must be joined to the supporting structure by means of bolts and/or welding; This system must be justified detailing characteristics, sizing calculations, as well as the entire foundation system. Regarding joining methods, for welding without/with filler material, the type of equipment to be used, safety elements and filler material with their respective characteristics must be described, as well as the weld seams; verifying that, in addition to the above, the execution method and related materials are approved by ISO 11611; ISO 9150; ISO 9151; ASME Welding Code; API Welding Code, AWS D1.1 Welding Code, CIRSOC Regulation 301/301-EL, CIRSOC Regulation 304, CIRSOC Regulation 305, etc. for structural welding.

4.5.2 Envelope system

Each of the buildings must be presented with a description of its behaviour in the face of the forces to which it will be subjected, these being:

- Loads: own weight, wind, earthquakes, snow loads, use loads, among others.
- Action against fire.
- Safety of use.
- Water evacuation.
- Level of impermeability of materials used and behaviour against humidity.
- Sound insulation.
- Durability against atmospheric actions and thermal insulation; among others.

The insulating materials to be used in the construction system must ensure as a whole that the enclosures have a thermal transmittance coefficient K less than the maximum admissible coefficient for the comfort level and the winter or summer conditions determined, according to regulations.

4.5.3 Exterior enclosure

The exterior enclosure will consist of insulating panelling injected with high-density polyurethane of different thicknesses, covered with pre-painted galvanised sheet on both sides; together with all the installation accessories necessary to materialise the panelling work for correct assembly. The provision of rock wool panelling is also considered, in order to achieve adequate personnel safety in case of fire.

The modular panelling for perimeter walls, dividing walls and ceilings will be injected with high-density CFC and HCFC-free polyisocyanurate (PIR), with a density of 36–38 kg/m^3 and a transmission coefficient of 0.20 W/m^{2}x ºC; covered with sheets of pre-painted galvanised sheet metal or non-slip fibre multi-laminate, depending on the case, coatings that do not degrade over time and do not absorb humidity or odours.

The panelling is of the refrigerating type with a tongue-and-groove joint, sealed with polyurethane foam at the junctions between panels to form a totally hermetic seal that prevents the development of parasites, fungi and mould. This seal forms a block structure together with the purlin and beam elements that prevents the entry of air from the outside and heat loss from the inside.

Oven-painted galvanised sheet metal profiles in different calibres should be used as a non-structural fastening element, finishing element, materialisation of pre-frames, and closing panels in all those places where the polyurethane is visible. Accessories for fastening ceilings and walls of the plastic mushroom type must avoid thermal transfers in both directions. Plastic mushrooms with threaded rods will be used to fasten the wall panels to perimeter straps, and plastic mushrooms with a cable tension kit to hang the ceiling panels to the secondary roof structure.

As for the profiling accessories, fastening and/or finishing profiling in oven-painted folded #18 gauge galvanised sheet metal, type U, L, Omega or T must be used to make the wall-wall, wall-ceiling, ceiling-ceiling connections and pre-frames or special finishes where the polyurethane is visible. Oven-painted finishing profiles in #18 gauge galvanised sheet metal, folded in the shape of an L, will be used for all the exterior vertices of the floor, both vertical and horizontal, where walls meet walls or where the walls meet the ceiling. And finally, white quarter-round aluminium profiles as sanitary joints, for all the meetings in the wall-wall and ceiling-wall vertices in interior sanitary environments, or environments where cooking and food preparation activities are carried out, for hygiene.

We consider the use of self-drilling screws with hexagonal heads, 3" / 4" / 5” No. 2, direct UX type fastenings for fixing to concrete, POP-type rivets for fastening profiles to the panels, etc.

The type of exterior finish of the sandwich panelling will be obtained through an engineering study corresponding to the orientation of the solar panels. This is because, if it is necessary to locate the solar panels on the surface of the façade, they must have a specific finish that allows them to be anchored.

4.5.4 Packaging and Transportation Parameters

The modular system can be transported by sea using 20-foot containers. The cargo will be protected with packaging and sling-type fasteners suitable for lifting or transporting and pockets on each side to accommodate forklift tines, with standardised dimensions and distance between centres.

The packaging dimensions may not exceed the dimensions of a 20-foot container. The maximum weight will depend on the transport capacity of the ship's cranes (12 000 kg with the crane arm fully deployed; approximate deployment of 16 m, the entire beam).

All the materials to be used must resist extreme temperatures, salt-laden winds due to being close to the sea and be suitable for load handling, unloading and stowage. Each package must be identified and with an attached list of the contents in each one. The packaging will admit disassembly and subsequent reassembly to allow control and verification of the materials to be received.

4.5.5 Engineering and Construction Techniques

In each case, the levels of the land of each building to be built, completions and its profiles will be adapted, generating the correct conditioning of the sector to be worked on, without the possibility of generating landslides or possible flooding due to runoff, in order to carry out the subsequent tasks such as stakeout. After this, the necessary soil movement will be carried out for the correct functioning of the work machines and providing the necessary soil for the fillings. In both procedures the IRAM norms and the contribution of the National Highway Regulations (Argentina) will be applied. The earthworks will extend to an area similar to that established for cleaning.

The completion of embankments and clearings must be uniform and flat, in accordance with the levels stipulated in the work reference plans. A maximum tolerance of 1 cm is established in construction areas and 3 cm in other areas. Excavations may be carried out by hand or by machine. In the latter case, these should have a maximum distance of 30 cm from the final excavation, outlining the last 30 cm by hand.

Regarding the foundations, once the empty spaces are finished, they will be filled with successive layers of at least 20 cm thickness. If conduction trenches should be dug, the filling will be carried out with adequate compaction. All earth movements must be inspected periodically and any loose material that is meaningless or unsafe in the work must be removed and/or eliminated.

The execution of the building should follow the general guidelines that the following construction process describes:

- The corresponding preliminary tasks must be started in order to lay down the foundation. Once this is done, as a third step, the tripod profiling system must be executed, the connection between the foundations and the building structure, which will allow the building to be raised by around 4 m in order to avoid the accumulation of snow around the bottom of the building.
- The structure of the building must continue, which will be composed of a lattice structure system (prefabricated trusses) in the upper and lower sections, linked by pillars on the outer faces. The bracing of the structures can be carried out by means of cross-beams placed at a certain distance.

- This structure will be covered with PIR/PUR type sandwich panels, creating a wall with excellent insulation and protection from the winds; It must be ensured that each time work is started it continues until its total enclosure (Note: the thickness of the panels is under study). Temporary walls may be used to ensure the progress of the works with due structural safety based on the meteorological characteristics of Antarctica.
- Once the exterior enclosure is finished, construction must begin inside under controlled climatic conditions. It is such that the construction of all internal subdivisions with their corresponding facilities and furniture will continue.

4.5.6 Foundation requirements and methodology

The objective of this system is to transmit loads towards the ground, while being compatible with the environment and presenting sufficient structural characteristics. Deep and surface foundation systems will be considered, among others, as well as the possibility of using combinations of these and/or the implementation of additives that provide necessary properties to complement the selected system.

It must present a relative height adjustment system adapted to the chosen foundation, or the connection with the supporting structure, which allows extending the useful life of the building, its maintenance and preserves the consolidated rigidity with respect to the degenerative effects of the climate, settlement over time and possible earthquakes, according to Regulations CIRSOC 101 INPRES and 103 (defining the acceleration of gravity and comparable seismic area, in addition to verifying the stress values for the anchoring system to be verified by the Project Management responding to the Joint Antarctic Command). If the height adjustable system is not deemed necessary, this must be justified by an appropriate study of soil mechanics.

The foundation must be based on a base resting on the roof of the permafrost soil, and must be fixed through a deep foundation system such as anchors, piles or a similar system. Support through this underground system must be sufficient to prevent pull-out and offer support properties. From top to bottom: the connection system with the load-bearing structure must rest on a 90 x 90 cm square metal anchor plate.

The foundation will be buried at least 1.50 m below the level of level ground, exceeding the active permafrost level; the objective will be to anchor to the level/area of firm/effective ground. The well that contains the foundation must be filled with local material or material admissible by the rules of the Antarctic Treaty and cohesion additives if necessary, which provide loads that contribute to cancelling the pull-out effect.

The area studied corresponds to the area where the building will be built.

The number of perforations established by current regulations will be carried out in this area, extending the explorations to the appropriate depth, according to the foundation system, type of structure, surface and underground hydrological conditions and the geocryogenic and geological characteristics of the terrain profile that it is convenient to adopt from the technical point of view.

The results of the soil laboratory study will provide the degree of compactness of the different strata, the composition of each one and determine the vertical subsidence pressure using the Brinch-Hansen equation. The average resistance will then be verified and the respective allowable stress estimated.

The dimensions of the foundations will depend on the proposed type, the total load of the building and the resistance of the soil. The foundation depth must verify the support value of the terrain, and will be located at a depth free from the influence of frost and/or landslides. It must present at least penetration into the permanent permafrost ground level of 1.50 m, considering a section of upper active layer of 0.90 m.

The facilities will be implemented in the central area of the base through different types of foundations. The foundations that will be used are (Table 7):

- Insulated bases with chemical anchors.
- Isolated or combined footings.
- Slab with isolated or combined footings
- Linked beams with footings

This type of foundation will be installed for each building to be built:

Table 7: List of foundations to be used.

No.	Building	Type of foundation to be used
1.	Main house	Chemical anchor base
2.	Scientific laboratory	Chemical anchor base
3.	Emergency house	Chemical anchor base
4.	Passenger terminal	Slab with footings (terminal sector and offices) Linked beam with footings (pump truck sector)
5.	Main power plant	Slab with footings, reinforcement in the generator area Linked beams with footings
6.	Emergency Power Plant	Slab with footings, reinforcement in the area of generators Linked beam with footings
7.	Port terminal	Slab with footings
8.	Existing hangar	Slab with footings
9.	MI-17 Hangar	Slab with footings
10.	Sports centre/Mini stadium	Slab with footings (gym, restroom and stand sector) Linked beams with footings (court sector)
11.	Sewage processing facilities	Slab with footings
12.	Cargo terminal and DNA depot	Linked beams with footings
13.	Vehicle garage	Slab with footings Linked beams with footings
14.	Workshops	Raised slab with footings Linked beams with footings
15.	Workshop	Isolated and combined footings

No.	Building	Type of foundation to be used
16.	Food depot	Slab with footings

4.5.6.1 Insulated bases with chemical anchors

The foundation will be based on bases supported on the roof of the permanent layer of permafrost. Said foundation has different components, the structure corresponding to the house will unload on two profiles placed in the form of a cross on the upper surface of the foundation base, which is projected with an approximate area of 4 m^2. This will bear on the end of the active layer of permafrost to prevent its movement due to the freeze and thaw cycles that occur in this type of soil. Then, from the aforementioned base, a number of threaded rods will be placed, drilling the permanent layer at least one metre deep in order to avoid overturning and tearing, using a chemical anchor to improve the friction of the anchors with the soil that has the particularity of not being very cohesive (Figure 69).

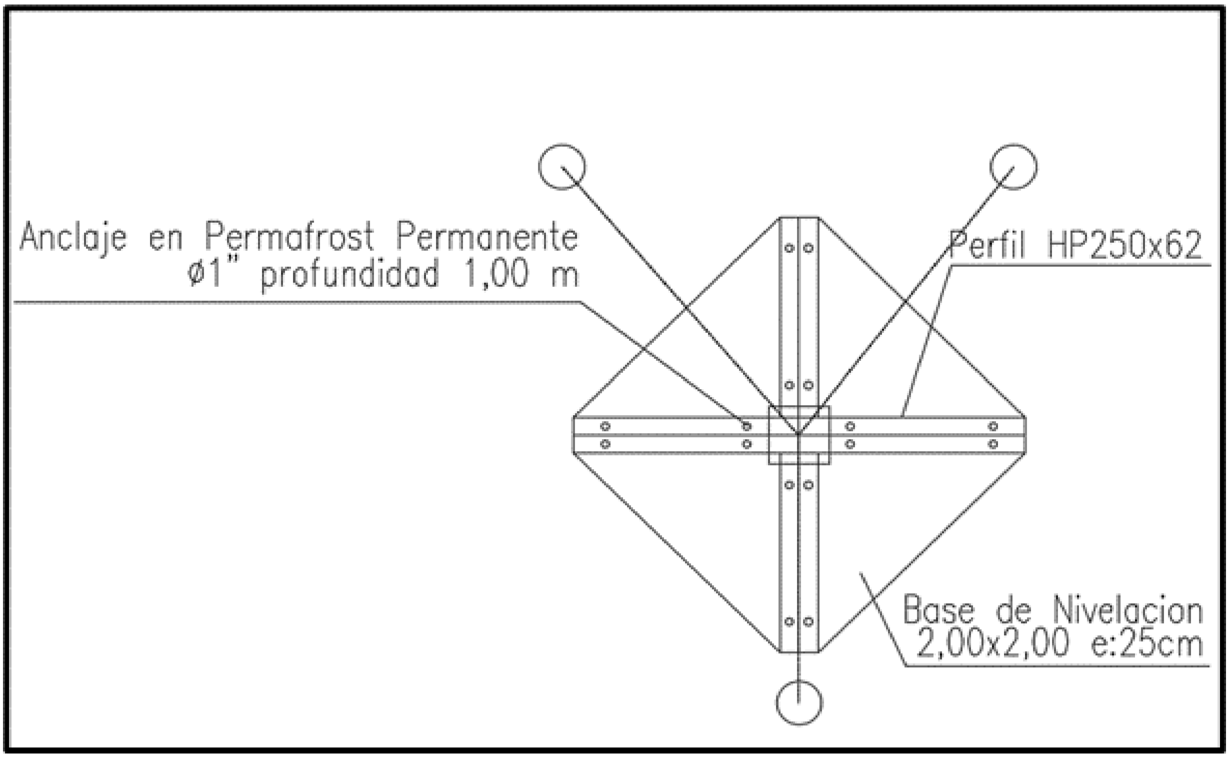


Figure 68: Plan view of the foundation with chemical anchors

Location

- Main house.
- Scientific laboratory.
- Emergency House.

Square metres (area occupied by the bases)

- Main house: approximately 184 m^2.
- Scientific laboratory: approximately 40 m^2.
- Emergency House: Approximately 40 m^2.

Material to be used

- Reinforced concrete (specific weight, 2 500 kg/m^3)
- HP 250 profile.
- Ø1'' threaded rod.
- Chemical anchor type HILTI HIT 200 R or FISHER FIB SB.

4.5.6.2 Isolated or combined footings

The footings will work under compression, by vertical load, depending on the layer in which it is located in the permafrost soil and will be placed symmetrically below the structure with an equivalent distance from each other. The depth of this foundation will be modified depending on the level at which the roof of the permanent permafrost layer is located or where the active layer of the same ends, where the expansion and contraction of the soil occurs. Its main objective will be to divert the loads towards the foundation bed of the permanent layer of permafrost that acts as a concrete. Isolated foundations result from the widening of the lower end of the columns in the plane of support on the ground in order to distribute the contact pressures with it and ensure the stability of the superstructure. If all the footings or some selected ones are connected, they must be joined at their base by means of a reinforced concrete beam to prevent the overturning that can occur, providing overall stability and causing a bending moment opposite to that produced by the loads. external (Figure 71).

This foundation must be verified for slipping, overturning, subsidence, uprooting and load capacity, whose purpose; Among other things, it will save the harmful effects caused by the partial sediment of the selected foundation system, given by the heterogeneity of the soil or the difference in solicitations.

Location

- Workshop (isolated and

combined) Square metres

- Workshop: approximately 170 m^2.

Material to be used

- Reinforced concrete (specific weight, 2 500 kg/m^3)

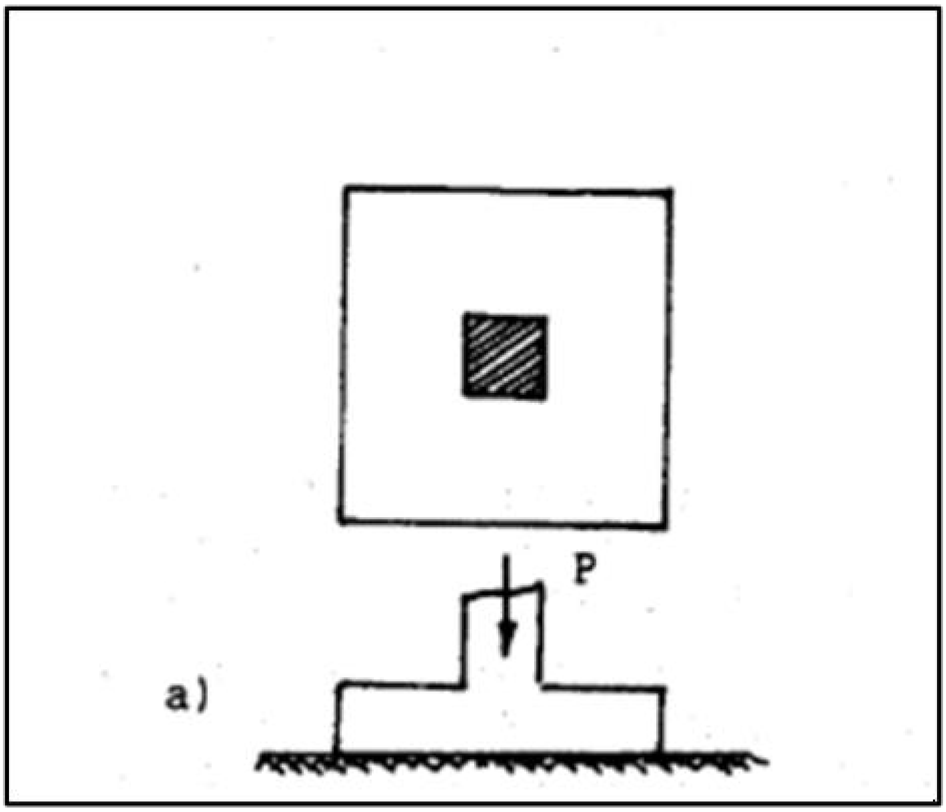


Figure 70: Side and plan view of the Isolated Footing

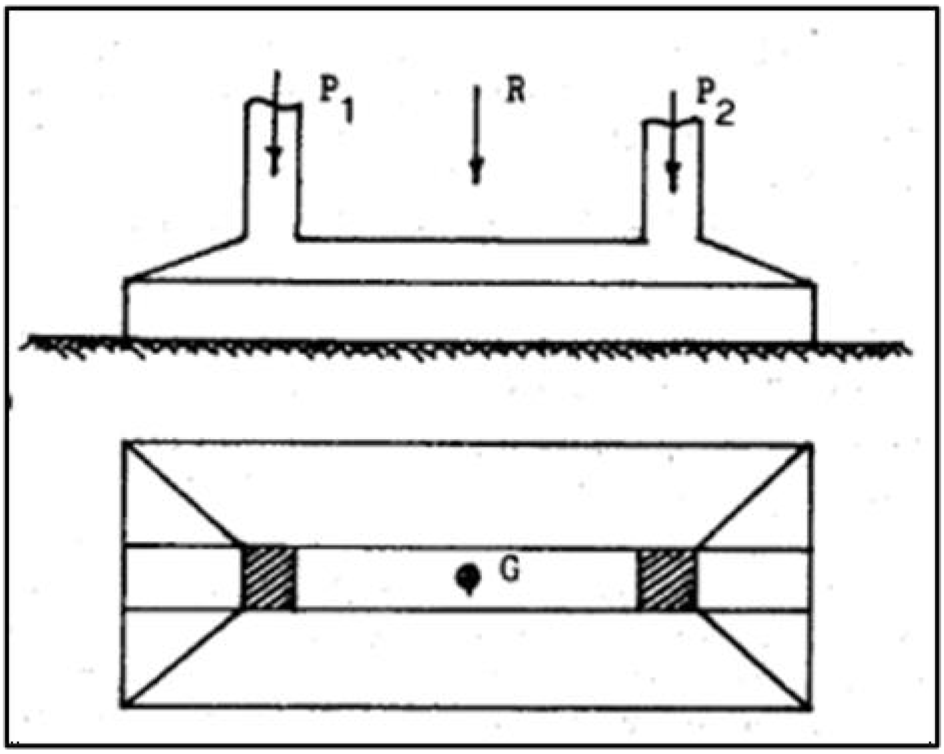


Figure 69: Side and plan view of combined footing.

4.5.6.3 Slab with isolated or combined footings

This foundation must be made up of a superstructure in combination with a platform with footings working in a group, this platform will act as a rigid plane to distribute evenly over the ground and the footings. In the event that the load of a specific section or sections are large enough to cause efforts that put the stability of the platform at risk, there is the possibility of increasing the thickness of the slab in those localised areas. The footing typology will be as described above (Figure 72).

There is also the possibility of raising the stalls from ground level by arranging it on chained beams that are also suspended to encourage wind currents and drag snow under the structure, thus avoiding the accumulation of the latter. As previously mentioned in the type of foundation with footings, the structure must be verified before the same requests.

Location

- Passenger terminal (pump truck sector)
- Main power plant
- Emergency Power Plant
- Existing hangar
- MI-17 Hangar
- Sports centre (gym sector, restrooms and stands)
- sewage treatment plant
- Worksh

ops Square

metres

- Passenger terminal: approximately 75 m^2.
- Main plant: approximately 318 m^{two}.
- Emergency power plant: approximately 44 m^2.
- Existing hangar: approximately 815 m^2.
- Hangar MI-17: approximately 930 m^2.
- Sports centre: approximately 495 m^2.
- Sewage treatment plant: approximately 603 m^2.
- Workshops: approximately 473 m^2.

material to use

- Reinforced concrete (specific weight, 2,500 kg/m^3)

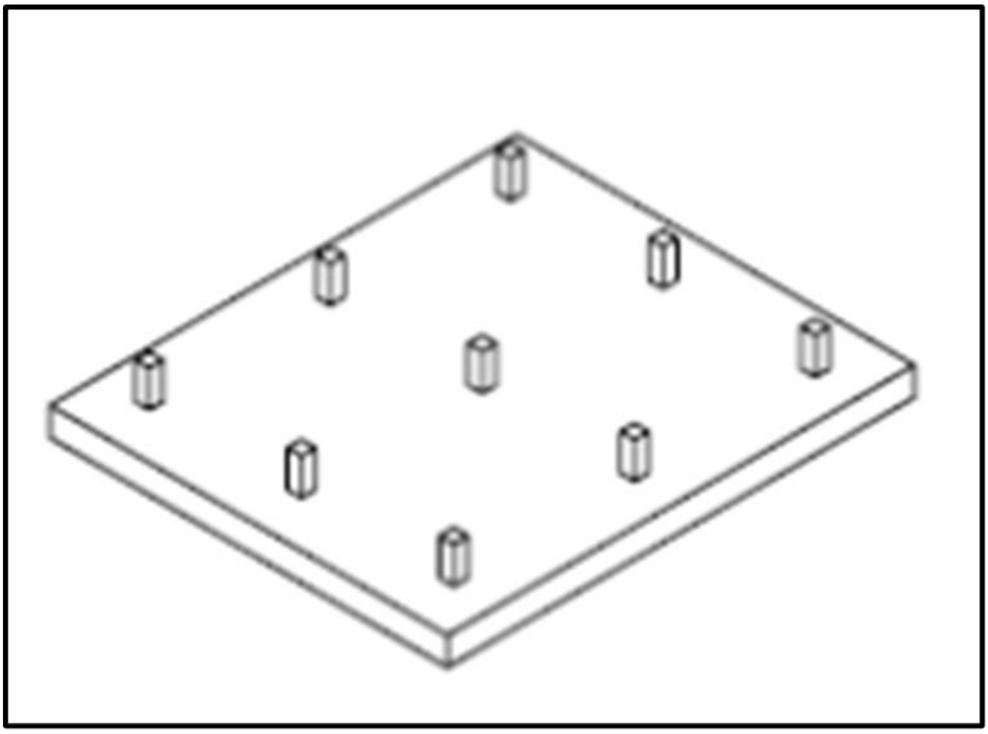


Figure 71: View of the foundation plate

4.5.6.4 5.4 Chained Beams with Footings

This foundation should be made up of footings working as a group, using chained beams to join them, thus working together; avoiding overturning and tearing moments produced by point loads that result in the trunks of the footings. The dimensions of these beams will depend on the structural calculation of the overturning moments to be saved between footings. The type of footing will be as described above. The chaining beams will be used mainly along the perimeter of the structure, arranged to receive the loads of the walls and pupils of this, and this typology can also be combined with a stall arranged on top of this perimeter chaining. As the type of foundation with footings must be verified before the same requests mentioned above (Figure 73).

Location

- Passenger terminal (terminal sector and offices)
- Sports centre (field sector)

Square metres

- Sports centre: approximately 375 m^2.
- Passenger Terminal: approximately 604 m^2.

material to use

- Reinforced concrete (specific weight, 2,500 kg/m^3)

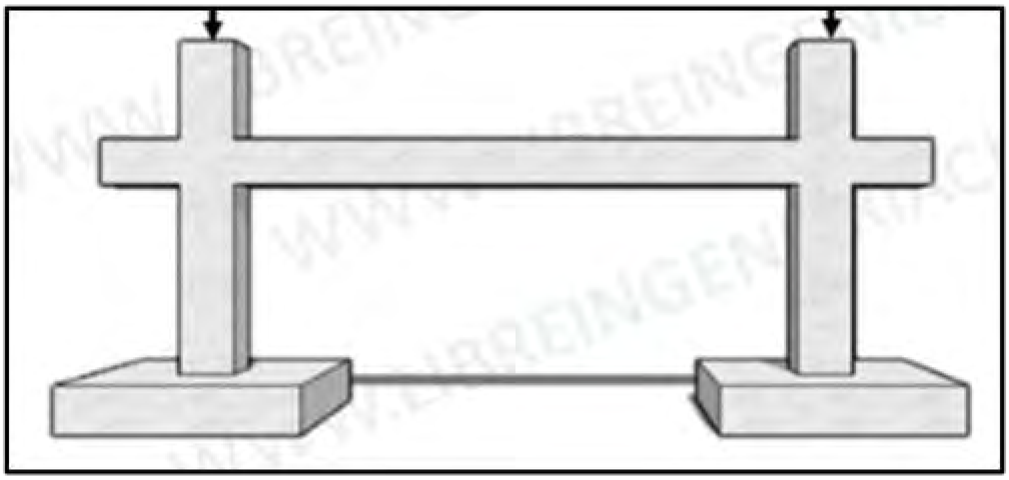


Figure 72: Chained beam with combined footings.

4.5.7 Soil Studies for the Construction of the Main House

Studies were carried out in order to recognize the physical and mechanical properties of the land where the reference work will be built, in order to determine the probable level and type of foundation for said construction. The construction of the Main Modular Housing House of the base has been projected, with a one-story metal structure, with maximum support loads of around 50 tons in compression and 25 tons in traction.

Test of the behaviour of the chemicals for the anchors in low temperatures:

The different chemicals to be used for the anchors were exposed to room temperature in the base, in order to qualitatively evaluate their behaviour.

	Adhesivo: FISHER FIS SB			Adhesivo: Hilti HIT HY 200 R			Adhesivo: Hilti HIT RE 500 V3		
Tiempo (H)	Gelificación	Fraguado	Temperatura (°C)	Gelificación	Fraguado	Temperatura (°C)	Gelificación	Fraguado	Temperatura (°C)
01:00	No	No	-4,7	No	No	-5,2	No	No	-5,2
02:00	No	No	-4,7	No	No	-5,1	No	No	-5,1
03:00	-	-		No	No	-4,7	No	No	-4,7
04:00	Si	No	-4,8	Si	No	-4,7	No	No	-4,7
05:00	-	-		Si	No	-4,7	No	No	-4,7
12:00	Si	Si	-4,7	Si	Si	-4,7	Si	No	-4,7
21:30	-	-	-	-	-	-	Si	Si	-8,5

Trenches in active permafrost:

SEVEN (7) trenches were made to identify the permanent permafrost horizon and the geotechnical profile of the active permafrost. They are designated T1, T2, T3, T4, T5, T6 and T7. In general, profiles T1 to T6 are characterised by the presence of a superficial layer of poorly graded granular material, first frozen and then without the presence of ice (active permafrost), finally permanent permafrost is reached. In profile T7 there is granular material resulting from the weathering of the rock, but without the presence of ice. The profiles found in each trench can be seen below (Figures 74 and 75).

Figure 73: Location of the sampling points.

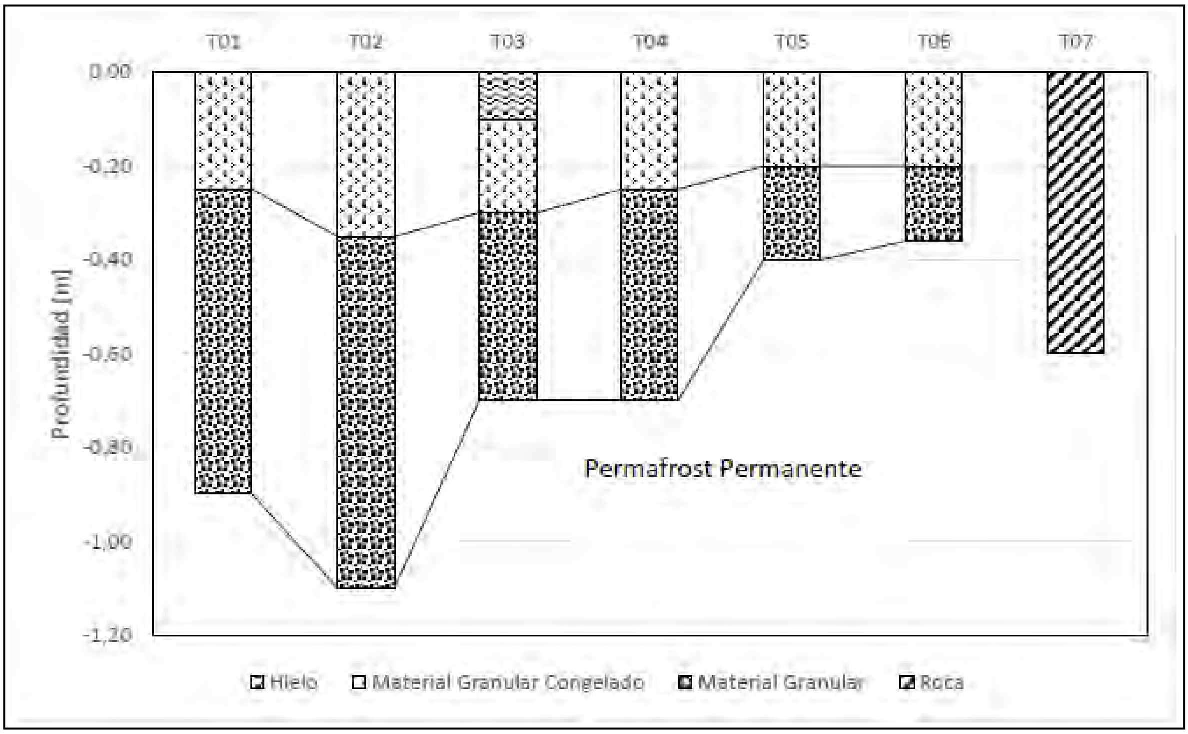


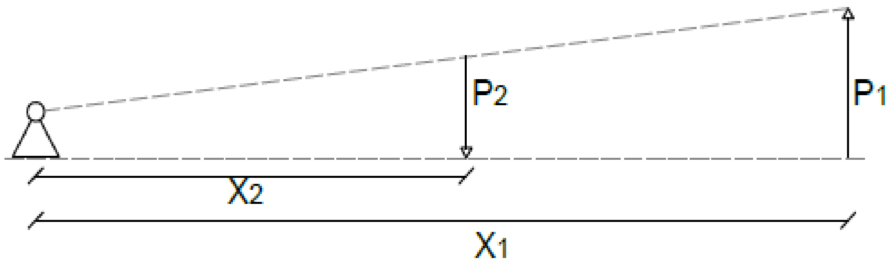
Figure 74: Characteristics of each of the sampled sites.

Tensile tests of anchors in permafrost:

EIGHT (8) 25 mm perforations were made. in diameter with a Hilti TE 70 brand electric hammer with variable depths in the area where the structure and points of interest will be positioned. The perforations were made with compressed air sweeping and final cleaning in order to remove loose material and dust to avoid a decrease in the adhesion of the epoxy adhesives.

Trinchera	Varilla	Coordenadas		Long. Del anclaje [m]	Tipo de Varilla	Temp. amb. [°C]	Temp. Permafrost [°C]	Adhesivo
T01	V1	63°28'38.38"S	56°13'33.34"O	1,45	Varilla Roscada	-16,5	S/D	FISCHER FIS SB
T02	V2	63°28'40.66"S	56°13'32.80"O	0,80	Varilla Roscada	-8,8	-4,2	HILTI HIT RE 500 V3
T02	V3	63°28'40.66"S	56°13'32.80"O	1,55	Varilla de const.	-8,8	-4,7	HILTI HIT HY 200 R
T03	V4	63°28'41.75"S	56°13'34.04"O	1,60	Varilla Roscada	-17,5	S/D	HILTI HIT HY 200 R
T04	V5	63°28'42.96"S	56°13'33.96"O	1,65	Varilla Roscada	-17,5	S/D	HILTI HIT HY 200 R
T05	V6	63°28'44.01"S	56°13'34.62"O	1,55	Varilla Roscada	-21,1	-5,7	HILTI HIT HY 200 R
T06	V7	63°28'44.94"S	56°13'33.21"O	1,50	Varilla de const.	-20,5	-5,2	FISCHER FIS SB
T07	V8	63°28'50.49"S	56°13'40.60"O	0,70	Varilla Roscada	-20,5	-0,8	FISCHER FIS SB

In these perforations, SAE 1040 steel threaded rods and 2 construction rods with thread at one end, 25 mm in diameter, were anchored with the different chemical anchors for the purpose of carrying out tensile tests on them (Pullout). To carry out these tests, a hydraulic jack and a beam supported at a fixed point at one end and on the hydraulic jack at the other were used, as shown in the following diagram:



Load plate tests:

FOUR (4) vertical load plate tests were performed on the permanent permafrost roof, designated PC1, PC2, PC3, and PC4. The methodology used followed the general recommendations of the UNE 103808:2006 Standard. The diameter of the load plate is 300 mm. The reference system was anchored more than 1.00 metre from the dish. (Photo N° 20).

Diamond drill bits:

THREE (3) perforations were made with a 100 mm diameter diamond bit, designated as MD01, MD02 and MD03. Samples of the permanent permafrost were extracted from them, to confirm the continuity of the profiles and carry out determinations and classification in the laboratory. The perforations reached a depth of 1.00 m from the bottom of the trenches, that is, from the top of the permanent permafrost.

Laboratory work:

The following tests and determinations were carried out on the extracted samples:

Granulometry

Through sieve 200

The values obtained are indicated in the corresponding spreadsheets.

Cabinet Works:

Worksheets and graphs of the Laboratory tests have been made, their results have been evaluated, and possible foundation systems for the aforementioned work have been studied in order to formulate the recommendations of this Report.

4.5.8 Description and mechanical properties of the layers

Geologically, this sector of Dundee Island is composed of two units of Triassic and Lower Cretaceous sedimentary rocks. During low tide periods, along the coastal zone, fine-grained marine sediments are exposed, belonging to the Trinity Peninsula Group of Triassic age. The Lower Cretaceous sedimentary package is part of the fill of the Larsen basin (del Valle ef a/. 1997). It consists of fine-grained, well-consolidated, marine clastic sediments exposed on the ESE of Cape Welchness, where they crop out near the eastern limit of the lateral moraine. Complex glacial and fluvioglacial deposits, deposited from the Late Pleistocene to the present, complete the stratigraphic succession.

In general, three geomorphological units of their own character can be distinguished:

1) the lower fluvioglacial plain

2) terrace of the brunette in the background

3) cordon of the lateral moraine of the Rosamaría glacier.

Lithologically, the morainic deposits are diamictitic bodies composed of clasts, formed for the most part by local Cretaceous sedimentary material together with large erratic blocks. Its granulometric composition ranges from coarse gravel to sand and silt. The bottom moraine sector corresponds to the permafrost zone, rich in ice with different types of underground ice, formed as cement or infiltration.

To classify the sampled material, the HRB soil systematisation and the soil classification used in permafrost areas based on the United Soil Classification System, Corps of Engineers and Bureau of Reclamation (Linell and Jonston, 1973) have been used. The classification according to their reaction to freezing (F) can be seen in Table 8.

Table 8: classification of soils in permafrost zones (Linell and Jonston, 1973). G: gravel; S: sand; C; clay; P: poor selection; W: Good selection, H: High; M: Mean and L; short.

Clasificación	Tamaño de particula	% de particulas <2 mm	Tipos de suelos tipicos
F 1	Gravas	3 - 10	GM, GP, GW-GM, GP-GM
F 2	Gravas arenosas	10 – 20 y 3 - 15	GM, GW-GM, GP-GM, SW, SP, SM, SW -SM, SP-SM
F 3	Gravas arenosas sin Limo-Arena	> 20 y > 15	GM, GC, SM, SC
F 4	Arcillas Limos en general Limos arenosos	> 15	CL, CH, ML, MH, SM
F 5	Arcillas, sedimentos de grano fino en capas o bandas		CL, CL-ML, CL y ML, CL, CH y ML, CL, CH, ML y SM

Table: Material sampled in the permanent permafrost

Muestra	Prof,	PT 200	Composición [% en peso]		Tipo de suelo
	[m]	[%]	Sólidos	Hielo	
MD01	0,00 - 1,00	4,54	74,3	25,7	F3 GW GM, SM
MD02	0,00 - 0,30	15,8	69,9	30,1	F2 GP, SM
MD02	0,30 - 0,70	6,7	79,1	20,9	F3 GW GM, SM
MD03	0,30 - 0,70	13,4	94,8	5,2	F3 GW GM, SM

4.5.9 Conclusions

The two chemical adhesives, Fischer FIS SB and Hilti HIT HY 200 R, performed well in terms of open time onset of setting and resistance to ambient working temperatures.

Given the architectural project, the climatic and geographical conditions, the characteristics of the soil found and the logistics of transporting materials to the site, the most reliable solution for founding is to remove the active permafrost up to the permanent permafrost ceiling and from that level. execute 2.00 m perforations. deep, anchoring 25 mm threaded rods. through chemical anchors to the permanent permafrost (all according to stress requirements resulting from the structural calculation). The threaded rods will be fixed to a metallic plate that will provide the necessary support to the compression forces and that will be the starting or fixing of the columns.

4.5.10 Recommendations

foundations

Based on the load plate tests carried out, the corresponding ballast modulus (K) can be calculated:

Ensayo	ME [Kg/cm^2]	K [Kg/cm3]
PC01	2143	95,2
PC02	2500	102,6
PC03	2222	87,0
PC04	2400	64,5

Setting a maximum differential deformation of 2.50 cm, a maximum stress of σmax is obtained = 200 Kg/cm^2 and considering a safety factor of FS = 40, an admissible stress σadm = 5.0 Kg/cm is obtained^2, or 50.0 t/m^2. For tensile tests it is observed that for values close to 10.0 tn. deformations compatible with the structure are obtained.

According to the results obtained in the tensile tests and the previous considerations for the load plate tests, it is recommended to found the structure by means of steel plates anchored in the permanent permafrost, at least 2.00 m. deep, using chemical adhesives suitable for low temperatures, considering an admissible tensile stress of 10.0 tn for each anchor and the collaboration of an admissible compression stress under the plate of 50.0 t/m^2.

Additionally, it is recommended, for the execution of the foundations:

- Carry out the tasks during the summer months, where temperatures are more favourable, which will effectively guarantee reaching the permanent permafrost ceiling.
- Use suitable machinery to carry out the tasks of cleaning and excavating the active permafrost and drilling in the permanent permafrost.
- Use SAE 1040 steel threaded rods, 25 mm in diameter.
- Place paints and/or coatings to protect against corrosion, since the environment is very aggressive for metallic structures.
- Carry out periodic and systematic inspections of metal structures, in order to guarantee their maintenance and durability.

4.7 Airport Area

The Marambio Base runway has been the most important air access point for the Argentine Antarctic Programme since its construction. Much of the logistics movement in the north of the Antarctic Peninsula is carried out from the aforementioned runway. In recent decades, due to the observed impacts of climate change on the permafrost of Marambio Island, the problems for operating there have increased, especially in the summer months, coinciding with the period of greatest activity of the Antarctic programme. This has led to the search for an alternative to this situation and for this reason it was planned to recover the capacity that the Petrel Base had in past decades. Given that the threats of climate change will surely aggravate the effects on the runway of the Marambio Base, it is urgent for the Argentine Antarctic Programme to find a solution to this situation.

4.7.1 General specifications

Runways

The topographical characteristics of Cape Welchness, gather the appropriate aspects to build up to two landing strips with favourable weather and altimetric conditions for a Hercules C-130 type fixed plane aircraft to operate with its best performance and in safe conditions. The C-130 aircraft will be the critical aircraft for this aerodrome and therefore the basis for its study and development.

The direction of both runways, taxiway and operating platforms for the different types of aircraft operating in the area, were adjusted to the design parameters of the International Civil Aviation Organisation (ICAO) and other regulations in force for runways located in the Antarctic Continent, thus allowing other countries to operate and dispose of derivative services such as SAR, cargo and logistics, among others.

The Main Runway with projected orientation 03/21, will reach an approximate operational length of 1,500 metres, the Auxiliary Runway will have a length of 1,200 metres, and a direction 17/35. Both runways will comply with the international regulatory requirements regarding safety spaces at the runway heads and sides.

The runways will be built complying with the aspects and requirements established in the Protocol on Environmental Protection to the Antarctic Treaty, related to the care and preservation of the environment.

The soil of the place is made up according to the "Geocriological-Geotechnical Study for the design of airstrips in Cape Welchness" (Developed by the Argentine Antarctic Institute in November 2005), by medium and fine gravel, sand, little to no existence of clays and in turn, there is presence of dry permafrost at an average depth of 1.40 metres. All this situation makes it possible to determine that a runway at this site will not be strongly affected by climate change as happens at the Marambio Base.

Likewise, the layout of the runways presents differences in levels of up to 5 metres, for which reason a leveling job must be done prior to the layout of the runways. Based on these data, it is studied to reinforce the geotechnical characteristics of the soil through the use of geotextiles and geocells, in order to achieve a greater confinement of the filler material and thus obtain greater bearing resistance of the structural package. In front of the hangar, the taxiway and the platform for aircraft operation were dimensioned, adopting an airplane as the critical aircraft.

Twin Otter, which, although it is not currently operating in the Argentine Antarctic Programme, is expected to resume its operation in the medium term.

On the other hand, this type of aircraft is widely used by other Antarctic programmes, which is why it is not ruled out that they could operate at Petrel Base for various reasons (SAR, mechanical assistance, fuel supply, air evacuations, etc.). The capacity of this area for the operation of medium-sized helicopters such as the MI-171 was also verified.

Flight Tower and Passenger Terminal

It will be located in the current position of Shed I, at the western end of the upper platform of Cape Welchness. It will constitute a single three-story building that will contain all the services of the passenger Terminal itself (with its corresponding bathrooms), fire service (offices and parking for the pumper), communications, meteorology, aerodrome headquarters and control tower.

It will provide the following services:

- Communications and Air Navigation: The communications equipment will be in accordance with ICAO international standards and will be installed in the Flight Tower.
- Aircraft Rescue and Fire Fighting Service (ARFF): There will be a 4x4 self-propelled fire engine, of the OSHKOSCH or ROSEMBAUER type, in compliance with current regulations.
- Passenger terminal: The terminal must have sufficient physical space to house up to 80 people in transit, with adequate heating and toilets. Aspects that will allow passengers to remain concentrated after having checked in.
- Beaconing and runway indication: Initially, a mobile beaconing system of the NAVITRONIK type or similar will be used, with battery and remote control by radio frequency until the most suitable fixed system, resistant to inclement weather, is defined.
- Weather Station: To be located in the Passenger Terminal and Control Tower building. In addition, 1/2 weather stations will be installed as an aid to air navigation. It will provide a forecast service with support from the Marambio Base Meteorological Station.
- Control Tower: To be located in the same building as the Passenger Terminal. It will coordinate the aircraft arriving and departing from the BACP. This location and height allows direct visual control over both runways, the aircraft operating platform, the taxiway and the helicopter operating platform.
- Air Communications: Communications related to the National Meteorological Service and with aircraft in flight or about to land or take off will be carried out and coordinated. It will provide the Aeronautical Information Service (ARO-AIS) and Communications.

Existing aircraft hangar:

The already existing hangar at the base will be used, which has 1,150 m^2 cutlery. Recovery works have already begun on this consisting of repairing the roof, gates and subfloor. It will be used mainly for the storage and maintenance of aircraft. It will be completely reconditioned and put into value. In the same way, the deposits that are inside will be repaired. It will be used for the storage of helicopters and as a workshop for tools and equipment to support the flight. On the west access of the hangar, the necessary works will be carried out to consolidate the land and form the operation platform for helicopters, having 10,000 square metres for the storage and operation of aircraft.

New Helicopter Hangar:

In order to complement the already existing hangar at the Petrel base, the construction of a new hangar was projected in the south-west sector of the upper platform of Cape Welchness. This hangar will be located to the west of the base's Ministadium/Polideportivo. Its expected use will be for the hangarage of a helicopter type MI 171E for supply in Argentina.

JP1 fuel tank and pump

A JP1 fuel for aircraft storage area will be installed. This platform will be located to the south of the Passenger Terminal and relatively close to the taxiway, but maintaining a safe distance. It will also be in an area close to two heliports. Cisterns with a storage capacity of 35 000 litres will be installed there. All will be connected to each other, with the corresponding supply system for the aircraft. This platform will have its spill containment tray. The JP1 fuel will be used mainly for the operation of helicopters and small aircraft (Twin Otter type). The refuelling of large aircraft (C-130 Hercules) is not foreseen, however, the storage capacity of 35,000 litres is the equivalent of a C-130 aircraft fuel tank. This capacity has been calculated as the maximum necessary for a critical situation.

Commissioning equipment

There will be aircraft start-up equipment, complemented by pressurised air equipment, heating equipment with flexible ducts for preheating prior to start-up. These equipment will be found inside the existing Hangar.

Road Park for Runway Maintenance Service

For the works required by an airstrip with these characteristics and in this particular geographical environment, defined road equipment is required, which requires a facility for its guarding and maintenance, located within the airport sector. Said vehicles will be motor graders, backhoes, rollers and dump trucks. Vehicles will be stored in the Vehicle Park or, as long as the hangar is not used for helicopter operations, they can be parked there.

operation platform

The one corresponding to aircraft will be in the sector close to the intersection of both runways. It will not penalize the landing and takeoff operation by other aircraft. There will be a second operations platform in the vicinity of the hangar that will be used by helicopters.

4.7.2 Location and layout of the airport area

The direction of both runways, taxiway and operating platforms for the different types of aircraft operating in the area, were adjusted to the design parameters of the International Civil Aviation Organisation (ICAO) and other regulations in force for runways located in the Antarctic Continent, thus allowing other countries to operate and dispose of derivative services such as SAR, cargo and logistics, among others.

The Main Runway with projected orientation 03/21, will reach an approximate operational length of 1,500 metres, the Auxiliary Runway will have a length of 1,200 metres, and a direction 17/35 (Figure 76). Both runways will comply with the international regulatory requirements regarding safety spaces at the runway heads and sides.

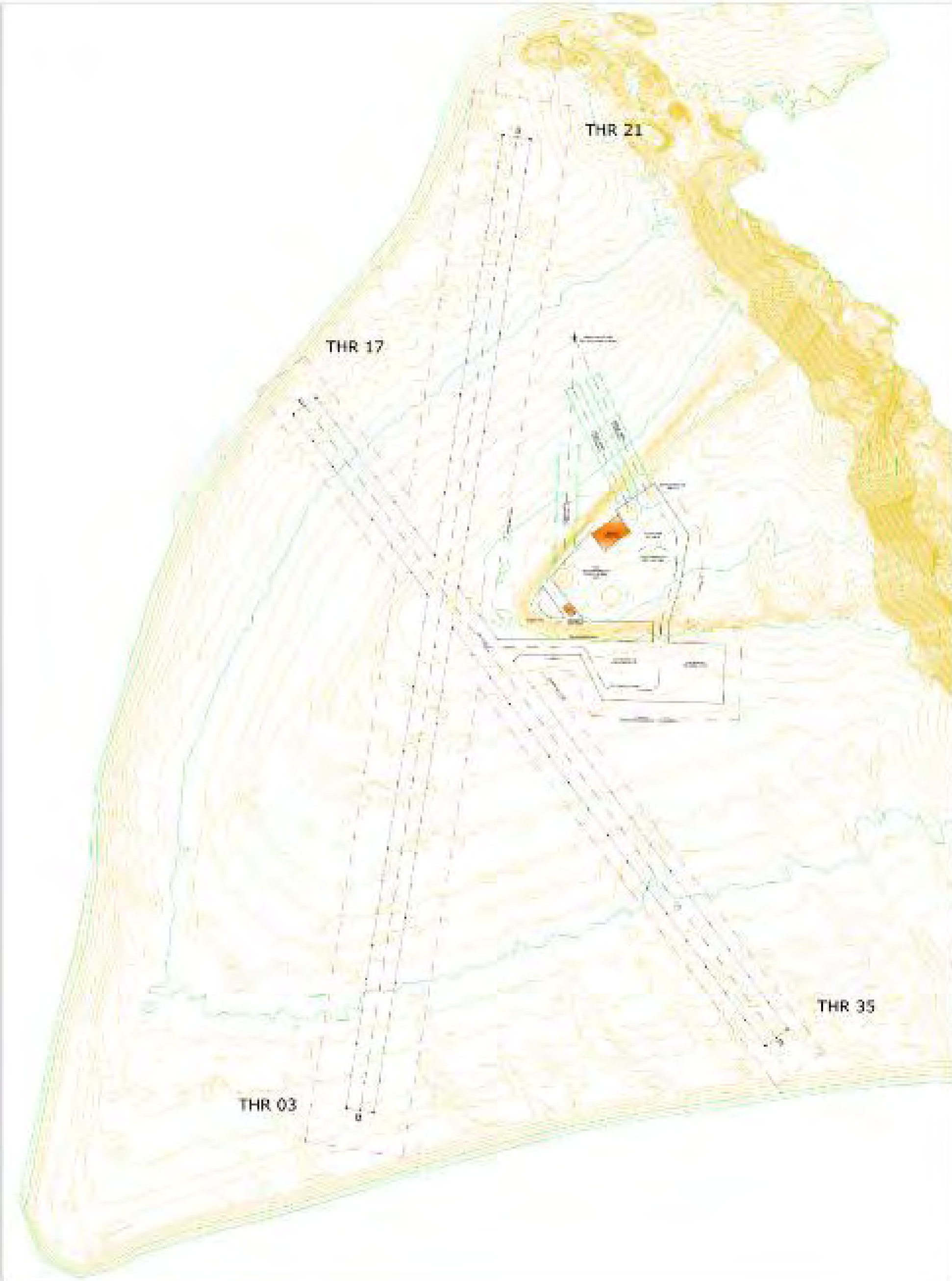


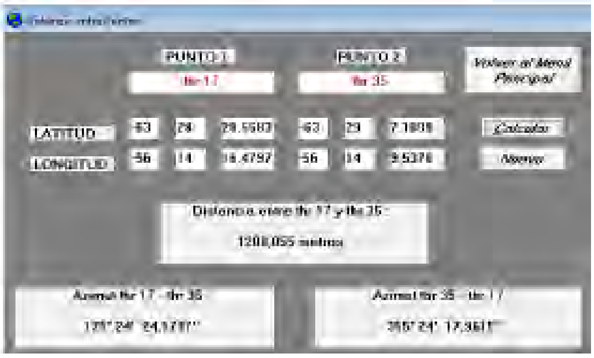
Figure 75: General layout of the airport area.

Physical characteristics of runways (RWY) (Appendix 2, soil study) Surface: natural terrain

ROY 03/21: 1500 by 43 metres wide, precision approach. ROY 17/35: 1200 by 43 metres wide, non-precision approach. Thresholds (THR) determined according to:

- land availability
- Obstacles
- prevailing winds

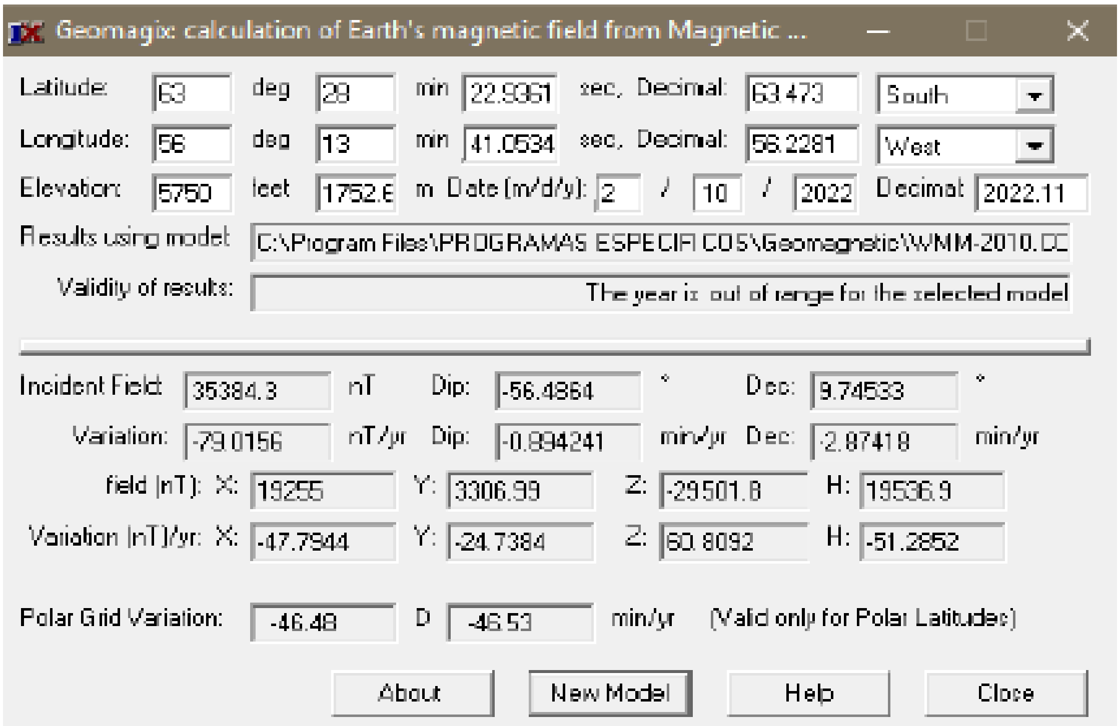
Determination of RWY thresholds



Determined true longitude, considering height above sea level, average temperature, prevailing winds and longitudinal slope of the RWY axes is 2 – 26 according to the reference field longitude that corresponds to the critical aircraft of the aerodrome project, C -130 Hercules:

- Reference field length: 850 metres
- Critical length 1000 metres for 130,000 lbs.
- RWY length availability due to orographic and construction conditions:
- 1500 and 1200 metres.
- Corresponds RWY Number 3 classification (from 1200 to 1500 metres)
- RWY width 43 metres, according to the critical aircraft.
- Wingspan C-130 Hercules: 40 metres
- Corresponds RWY Letter D classification (from 30 to 45 metres)
- Aerodrome reference code: 3D

Correction of geographic course to Magnetic course according to the affectation of the magnetic declination.



Maximum allowed cross sectional wind coefficient

Regarding the orientation of the RWY, analyzing the incidence of the components of wind direction, prevailing winds and intensity, feasible coefficient of use values were obtained, considering a high percentage of time of use of the runway system.

It was determined that, under normal circumstances, the transverse component of the wind that does not exceed the following values:

- ROY 03/21: 37 km/h (20 kts), to operate with a reference field length of 1,500 m or more and 24 km/h (13 kts) estimating some poor braking efficiency condition on the runway due to the coefficient of insufficient longitudinal friction.
- ROY 17/35: 24 km/h (13 kts) in the case of airplanes whose reference field length is 1,200 m or greater than 1,200 but less than 1,500 m.

Note. — Cross-wind component means the surface wind component that is perpendicular to the runway centre line.

RWY 03/21 (PRINCIPAL RWY)

Length: 1500 metres

Width: 43 metres

R mag.: 31°33’18.23” / 211°33’

digits: 03/21 Precision

approaches

ROY 17/35 (AUXILIARY ROY)
Length: 1200 metres
Width: 43 metres
R mag.: 165°39’40.9¨/ 345°39’
digits: 17/35 Non-precision approximations

Pendientes longitudinal y transversal de RWY y TWY

The following values of slopes should be applied to the natural terrain, as graphed below, for the calculation of vertical alignments and cross-sectional profiles of runways:

- ➢ Maximum longitudinal slope: ≤ 1.5% (corresponding to a RWY key 3)
- ➢ Longitudinal slope first and last quarter of RWY: ≤ 0.8 %
- ➢ Transition 0.2% c/30 metres, radius of curvature 15000 metres
- ➢ Convex cross slope ≤ 1.5% and ≥ 1% (corresponding to a key RWY 3)
- ➢ Cross Sections Type of Runway to be Implemented According to Standards

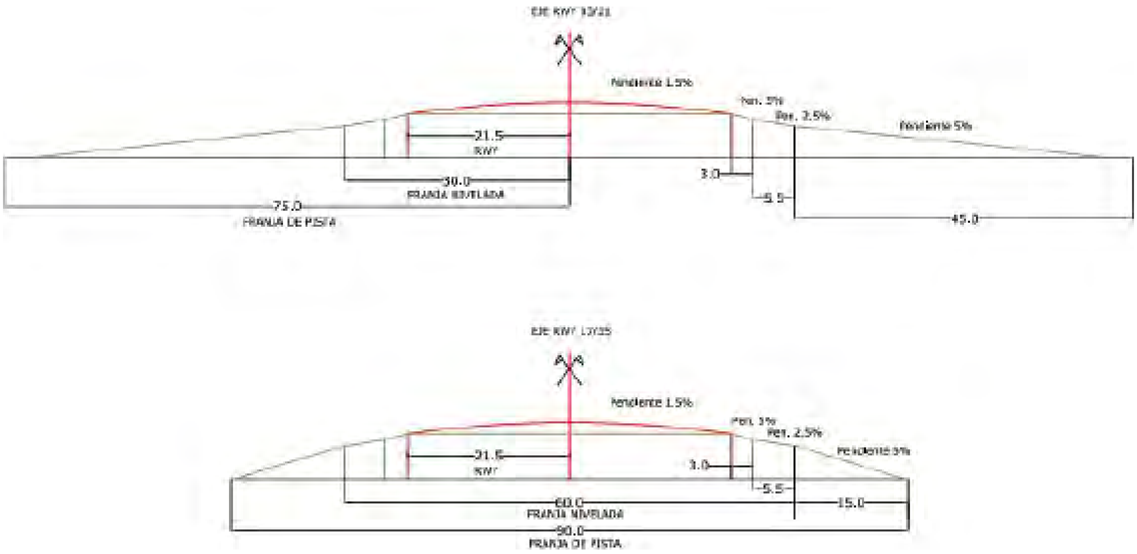


Figure 76: Runway profiles.

Franja from RWY

The strip extends before the threshold and beyond the end of the runway for a distance of 60m parallel to the RWY centre line:

- ➢ RWY Strip Width
    - o RWY 03/21 precision approaches: 75 metres on each side of the axis.
    - o RWY 17/35 non-precision approaches: 45 metres on each side of the axis.
- ➢ level strip

- Length: 30 metres on each side of the RWY centre line and up to 30 metres after each threshold.
- Slopes
  - Longitudinal of RWY: ≥ 1% to ≤ 1.5%, first and last quarter: ≤ 0.8 %
  - Transversal: 2.5%.
- Objects in RWY stripes
  - System of frangible lights and daytime visual signaling cones for RWYs located in the Antarctic environment.

RESA (RWY Extreme Security Area)

It is applied to RWY 03/21 as it is of precision after the security strip corresponding to THR 21. It will have dimensions of 90 metres from the end of the RWY by twice the width of the RWY (86 metres).

Longitudinal / cross slope: +/- 5%.

Rodais (TWY)

- According to the reference code of the 3D Aerodrome.
- Dimensions: 23 metres wide.
- Slopes:
  - Longitudinal slope: 1.5%, slope change 1% every 30 metres, minimum radius 3000 metres.
  - Cross slope: 1.5%.

TWY shoulders and strip

- Franja de TWY: 37 metres on each side of the axis.
- TWY south deal: 34 metres on each side of the axis.

The following distances should be considered in the preparation of the project for the location of constructions and elements close to the maneuvering area environment:

- TWY axis and an object: 37 metres
- TWY axis in APRON and an object: 33.5 metres
- TWY level strip: 18.5 metres on each side of the axis.
- TWY Level Strip Longitudinal Grade: 2.5%.
- TWY Level Strip Cross Slope: +/-5%.

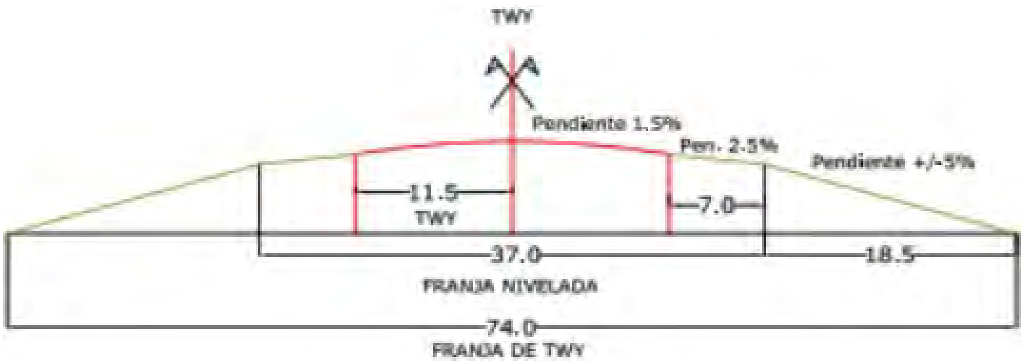


Figure 77: Transversal profile of the type of bearings to be implemented.

RWY holding point

A RWY holding point must be demarcated under the following conditions:

- For RWY 03/21 Precision approach: 90 metres from the RWY centre line, perpendicular to the TWY centre line.
- For RWY 17/35 Non-precision approach: 75 metres from the RWY centre line, perpendicular to the TWY centre line.

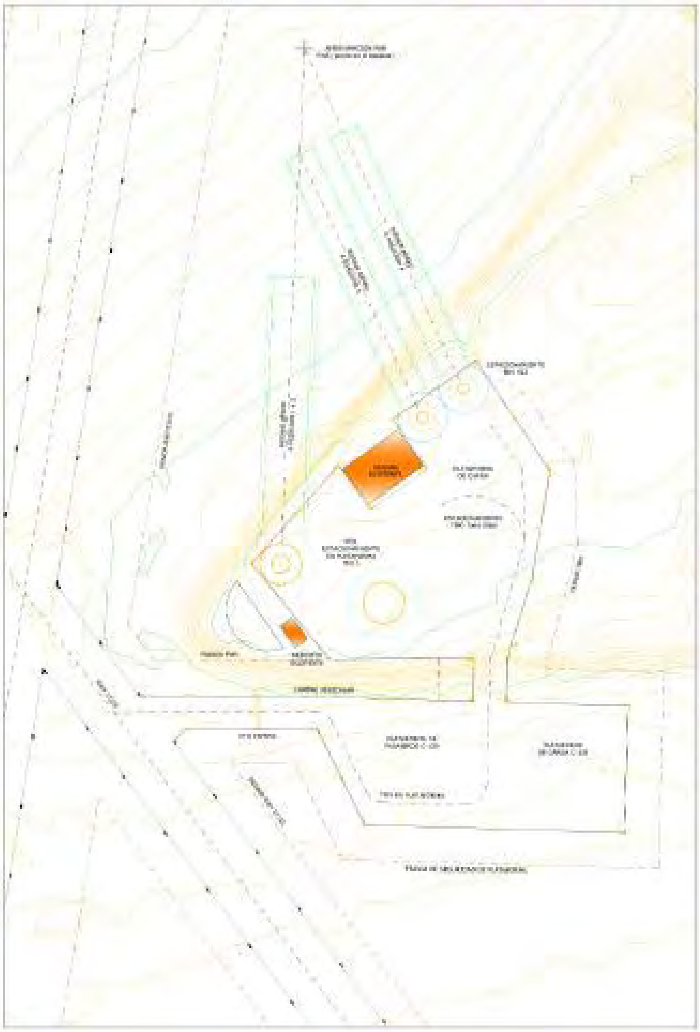


Figure 78: Diagram of the sites for runway operation.

Platforms

The location of two platforms was considered, to operate with helicopters, medium-sised aircraft and two C-130 aircraft simultaneously. Margin considered: aircraft/objects: 7.5 metres.

Areas will be provided for service streets, a manoeuvring area and ground equipment storage. Isolated parking space: Designated 100 metres from the facility or another parked aircraft.

Platform for C-130

A platform for C-130 type aircraft was projected considering an area to operate with passengers and another area to operate with cargo whose dimensions are 190 x 90 metres. Platform slope: (Figure 80).

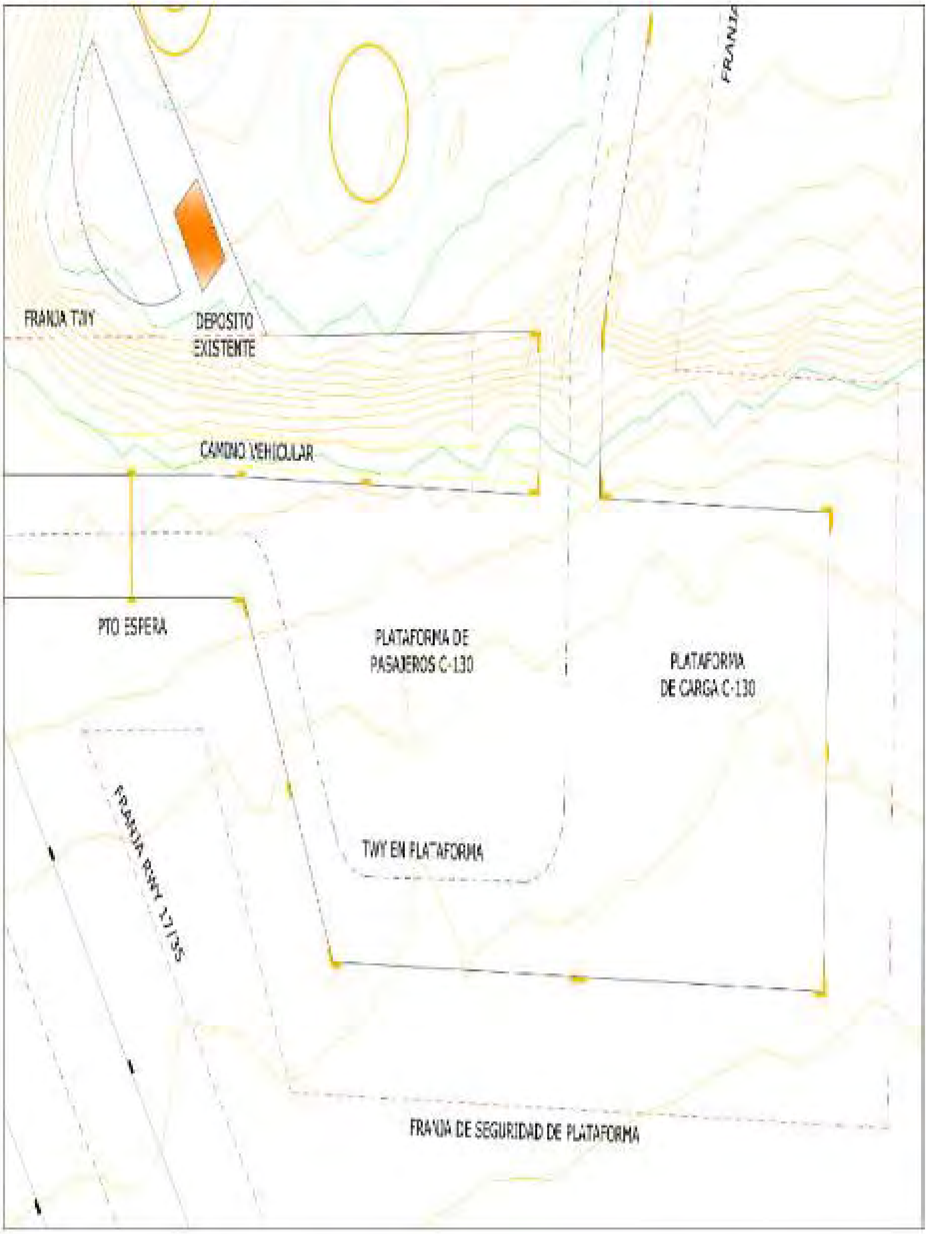


Figure 79: Platform location for C-130.

Platform to operate with Bell 212-412 and Mi 17 helicopters and with aircraft of similar size to Twin Otter

A 200 x 100 metre platform was projected to operate with passengers or cargo with helicopters and Twin Otter type aircraft or similar.

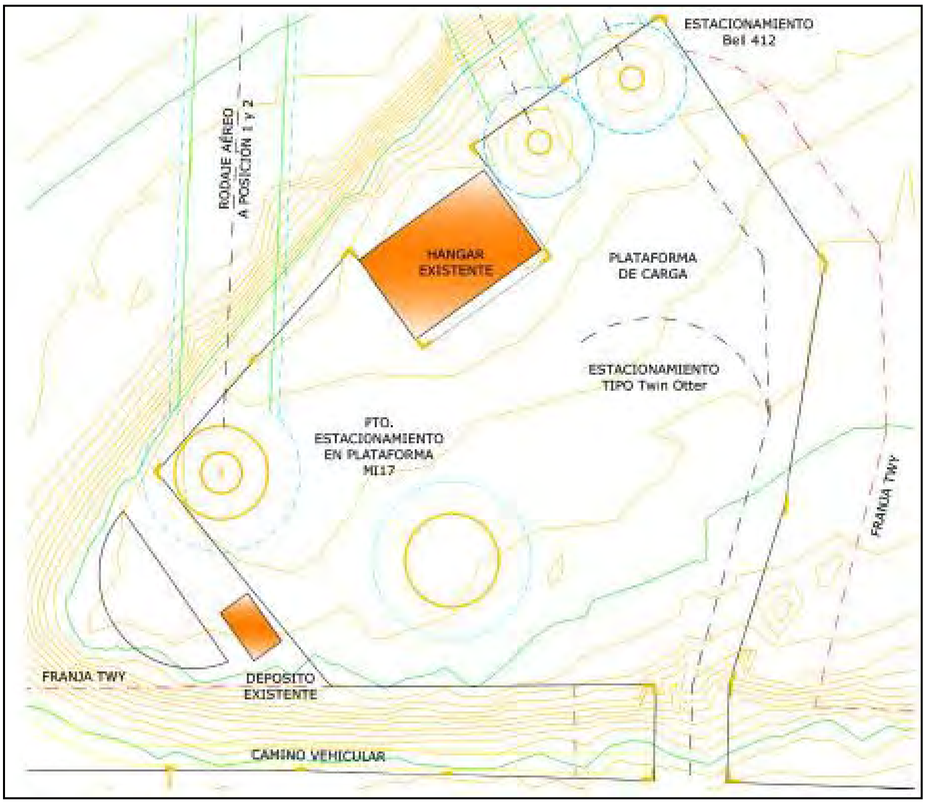


Figure 80: Platform location for M17 and Twin.

ZULU insulated parking stall

A ZULU position was determined at headend 35 . In the event of control due to a report of explosives, illegal interference or due to the need to clear the main runway, the aerodrome control tower will be informed of the designation of this area as the appropriate one for the parking of an aircraft that is known or suspect that it is being subjected to unlawful interference, or that for other reasons needs to be isolated from normal aerodrome activities when encountering an aircraft with technical problems. The isolated aircraft stand is located as far away as possible, more than 100 m from other stands, buildings or public areas, etc. (Figure 82)

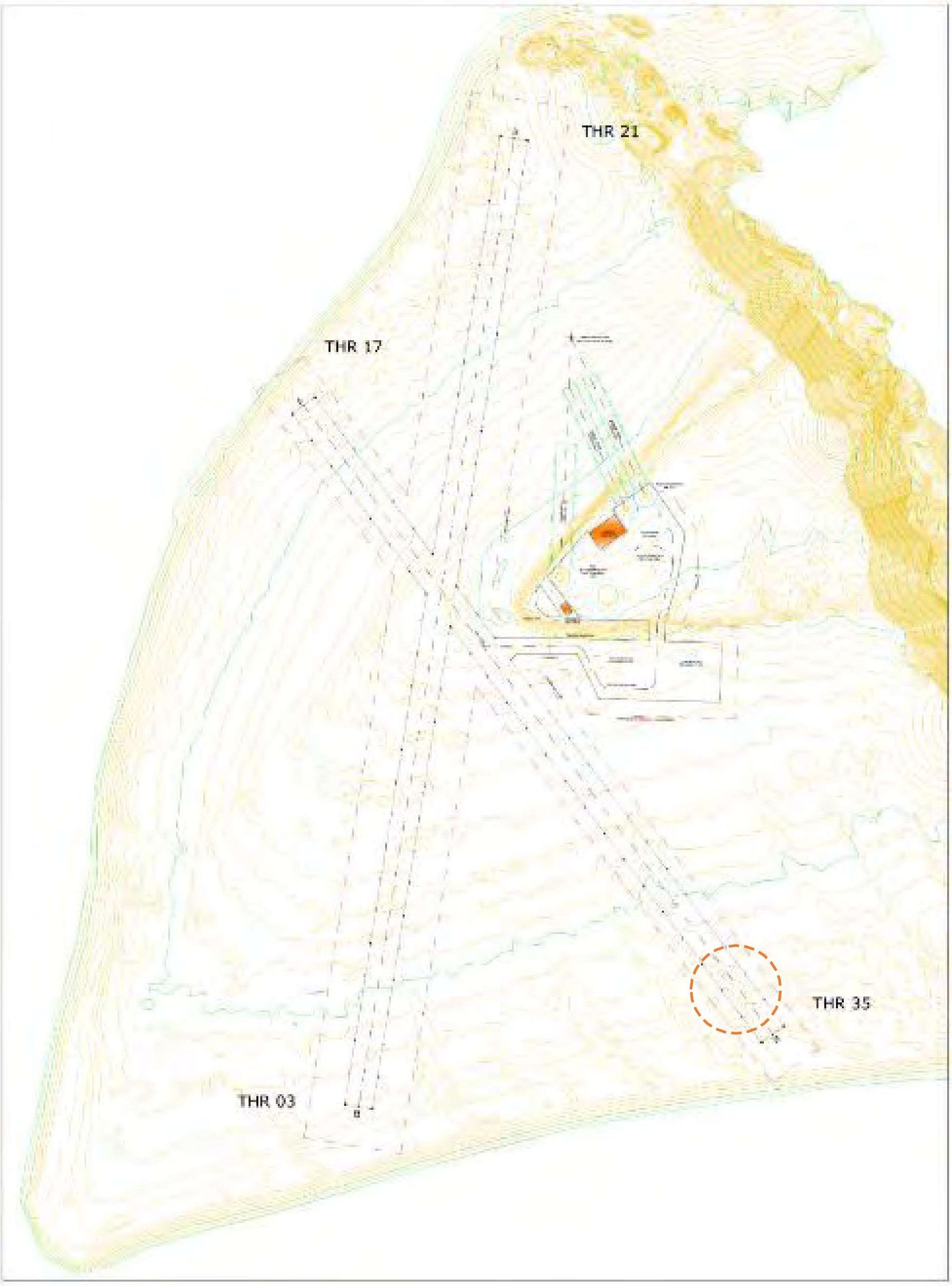


Figure 81: Identification of the isolated parking position, ZULU position.

Application Of Limiting Surfaces

Obstacle Limiting Surfaces

A survey of outstanding objects was carried out, not finding elements that penalised the Obstacle Limiting Surfaces considering the application of the values determined in Table 6 of RAAC 156.

Table 10: Obstacle limiting surfaces for STOL airfield runways.

Superficies y dimensiones	PISTAS DE AERÓDROMOS STOL CLASIFICACIÓN			
	Aproximación visual y por instrumentos de no precisión		Aproximación por instrumentos de precisión	
	Clave 1 y 2	Clave 3	Clave 1 y 2	Clave 3
DE APROXIMACIÓN				
Longitud del borde interior	60	90	90	150
Distancia desde el umbral	30	60	60	60
Divergencia (a cada lado)	10 %	15 %	15 %	15%
Primera sección Longitud Pendiente	3000 6 %	3000 5 %	3000 6 %	3000 5 %
Segunda sección Longitud Pendiente	--- ---	2000 10 %	---- ----	2000 10 %
DE TRANSICIÓN				
Pendiente	20%	20%	14,3%	14,3%
SUPERFICIE DE ASCENSO EN EL DESPEGUE				
Longitud del borde interior	60	90	150	150
Distancia desde el umbral	30	60	60	60
Divergencia (a cada lado)	10 %	10 %	15 %	15%
Pendiente	6 %	5 %	6 %	5 %
Longitud	2000	2000	2000	2000
HORIZONTAL INTERNA				
Altura	75	75 *	75 *	75
Radio	1000 *	2000 *	1000*	2000 *

Survey of Significant Objects

A planimetric survey was carried out in order to determine the layout of the runways and the location of thresholds in order to keep the limiting surfaces free of obstacles.

Likewise, geographic coordinates were determined in the WGS 84 system of the thresholds, obtaining their position and height, geographic headings, and necessary data to carry out a feasibility study for the construction and application of flight procedures and the subsequent preparation of the corresponding cartography (Figure 8283 and 84).

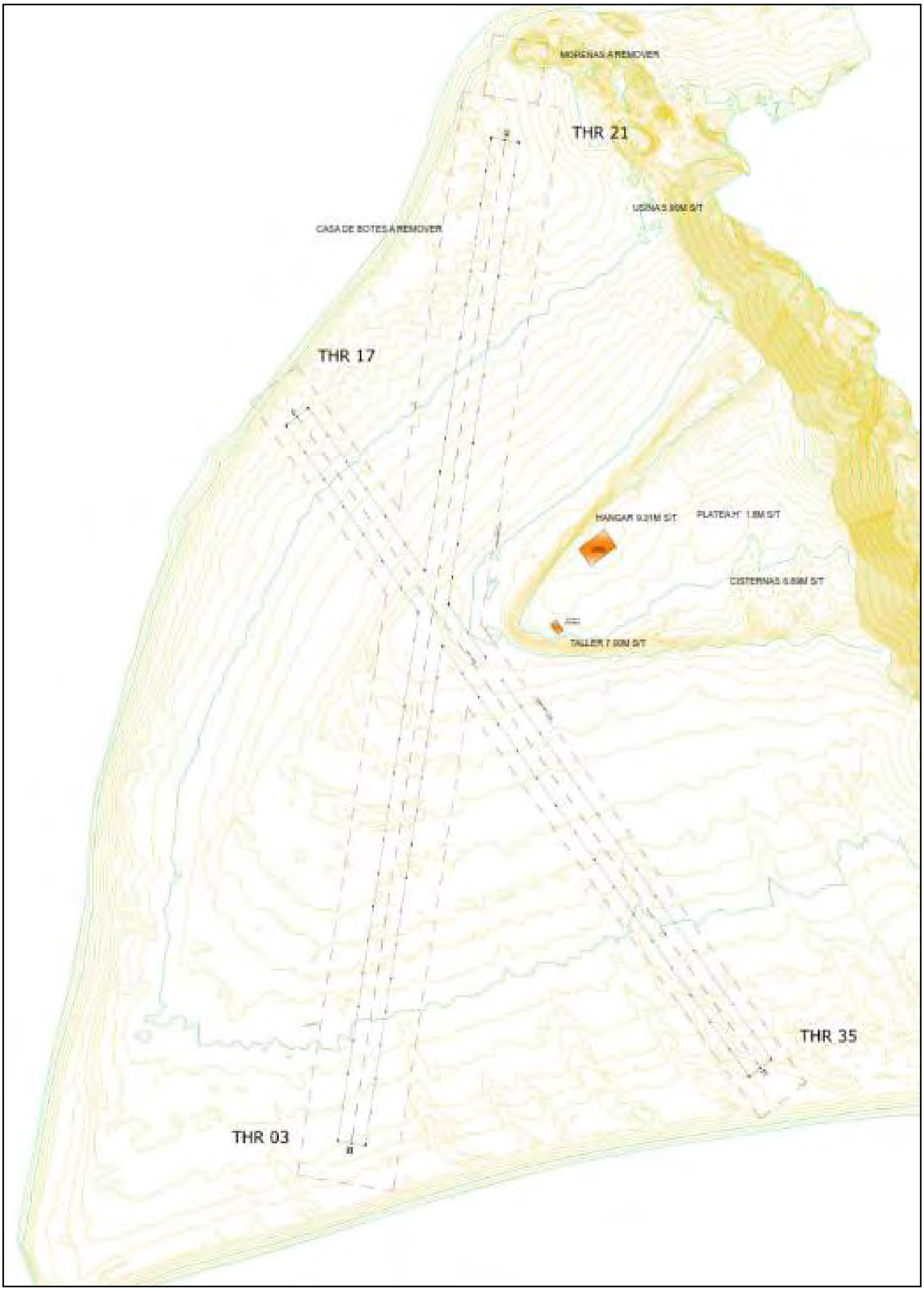


Figure 82: Location of obstacles to be removed.

Obstacle Plan

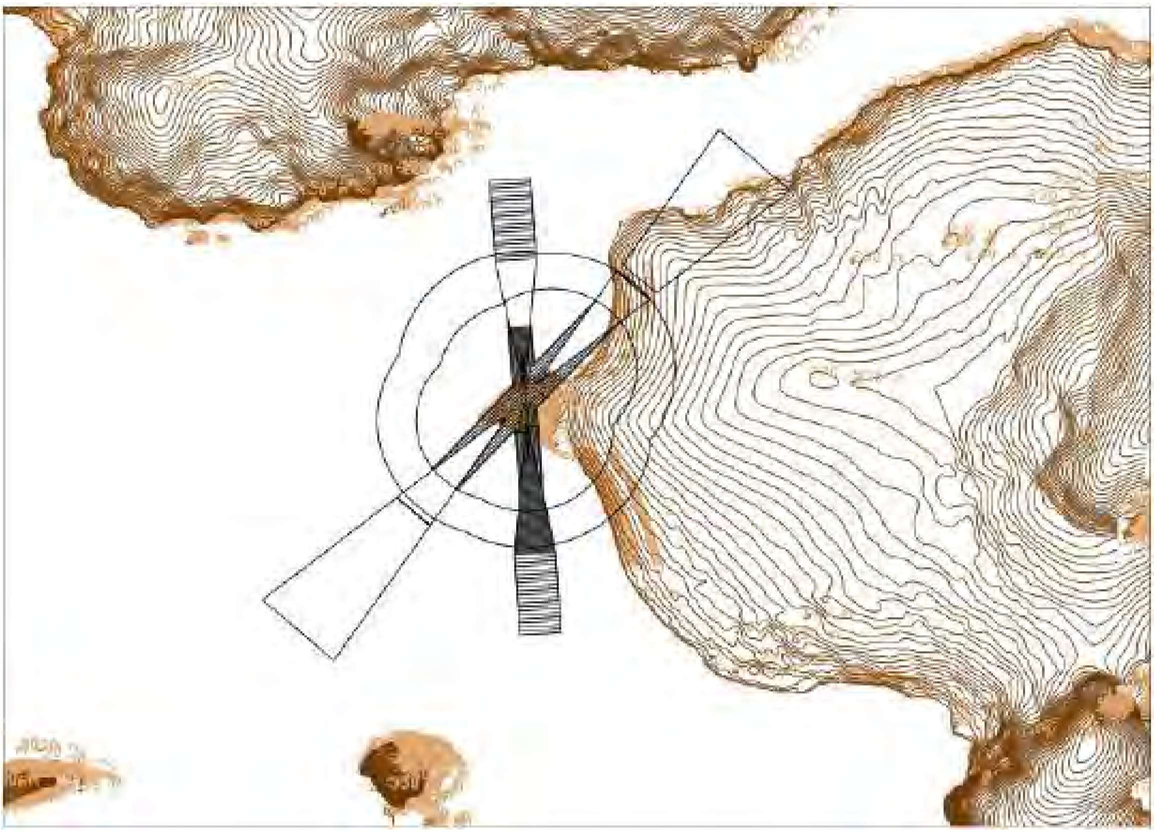


Figure 83: Obstacle plan

Daytime Visual Marking - Night Taxiing Runways, Platforms and Obstacles Visual aids

Daytime visual marking of RWY, TWY, APRON (Figure 85).

The runways, taxiways and aerodrome platforms will be provided with demarcations in accordance with those established in the specifications of RAAC 154 Subpart E considering the following signs:

- RWY Designator Digits: Pair of digits 9 metres high At 6 metres from each threshold.
- threshold signal: The vertices of the RWY and a central dash will be demarcated.
- RWY Border Signal: Dashes or cones every 50 metres
- Señal de borde de TWY: Dashes or cones every 30 metres.
- RWY Holding Point: Cross bar of 1 metre, perpendicular to the axis or cones on edges of TWY.
- platform edge: Cones or dashes will be placed at vertices and midpoints, except in front of hangars.

The signals should be as flat as possible, built of 3 x 1 metre masonry, flush, permanent or, failing that, 0.70 cm high beacons painted in a color that contrasts with the background.

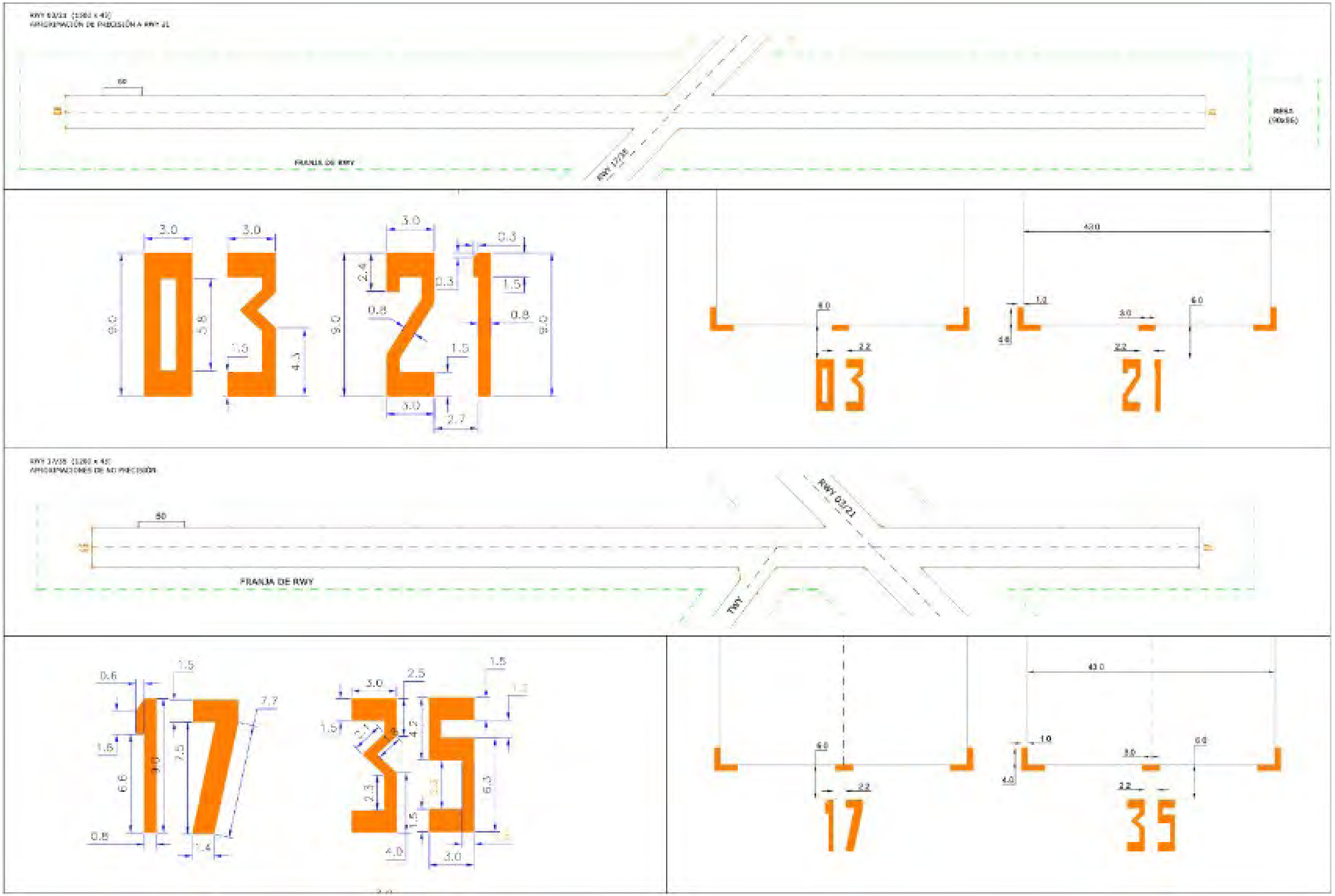


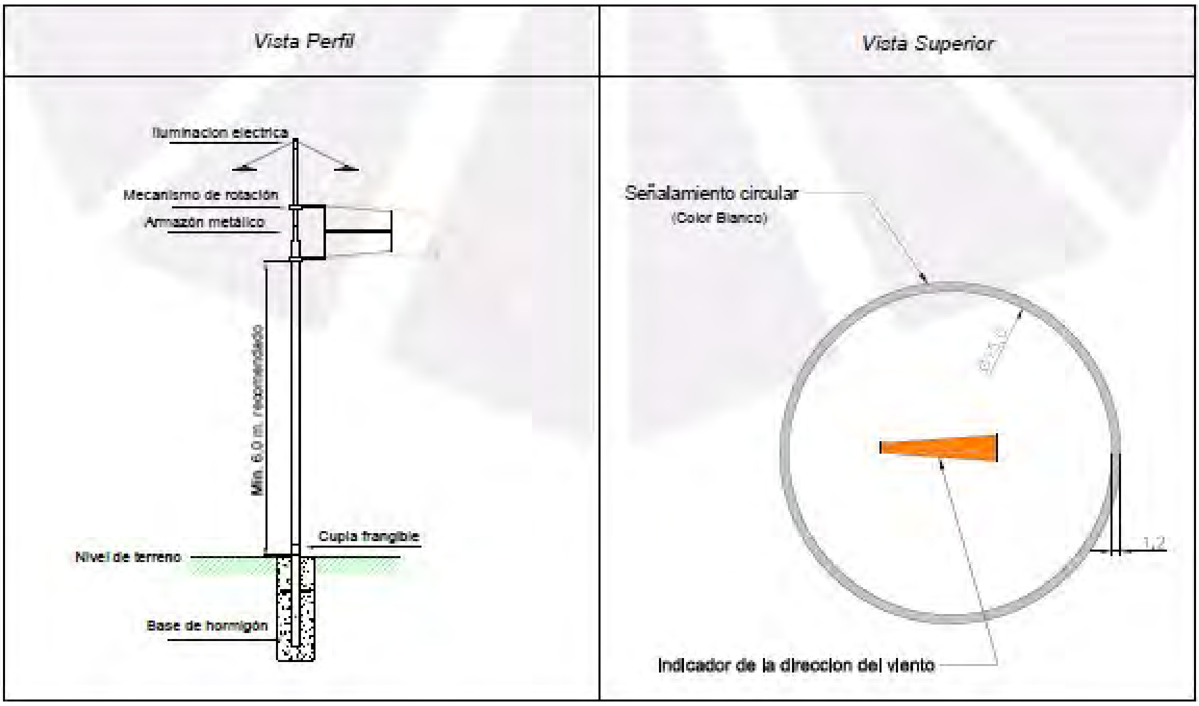
Figure 84: Runway signalling.

wind direction indicator

It must have the shape of a truncated cone and be made of cloth, its length must be at least 3.6 m, and its diameter, at the largest base, at least 0.9 m. It shall be so constructed as to clearly indicate the surface wind direction and general idea of its speed, colored orange so that it can be clearly seen and interpreted from a height of at least 300 m.

It should be located so that it does not suffer the effects of air disturbances produced by nearby objects, if possible, in the first lateral third of the runway axis at no less than 90 metres. Given the particularity of the location in the Antarctic environment, the provision of the wind direction indicator will not be applicable due to the icing conditions to which the fabric that forms it and the turning mechanism will be subjected. The possibility of placing it at the moment should be analysed. prior to operations or may be exempted from its installation, when information on the direction and intensity of the wind is provided by other appropriate means.

Wind Direction Indicator



signal lamp

In the control tower, there will be a signal lamp that must be able to produce red, green and white signals, be able to manually direct itself to the desired target, produce a signal in any color, followed by another in any of the remaining two colors and transmit a message in any of the three colors, using Morse code, at a rate of at least four words per minute.

Lights

Components of visual signaling at night:

- RWY end lights, 6 lights at a distance of ≤3 metres each.
- RWY edge lights, every 100 metres at a distance of ≤3 metres from the edge.

- Wing bar lights.
- Combined end and threshold lights, 6 lights at a distance of ≤3 metres each.
- TWY edge lights, every 30 metres at a distance of ≤3 metres from the edge.
- APRON lighting with projectors.
- There must be night visual beaconing with intensity control with 3 brightness levels.
- Support structures must be frangible 36 cm above the ground or cones of 0.70 cm and one metro de los bordes de RWY per GWY.

Emergency light:

- It should power the border lights of RWY, TWY, APP and thresholds, considering switching to alternative energy in a response time of 15 minutes.

Aerodrome Lighthouse, the need to place an aerodrome lighthouse is exposed due to the following conditions:

- Night operations or instrument flight.
- Flights with visual aids.
- Reduced visibility.
- Difficulty finding the Aerodrome due to the surrounding topography.

Approach lighting system:

As it is not feasible to install a simple reduced approach lighting system – configuration II, said system should be replaced by (RAIL) RWY threshold identification lights and/or RWY threshold identification lights.

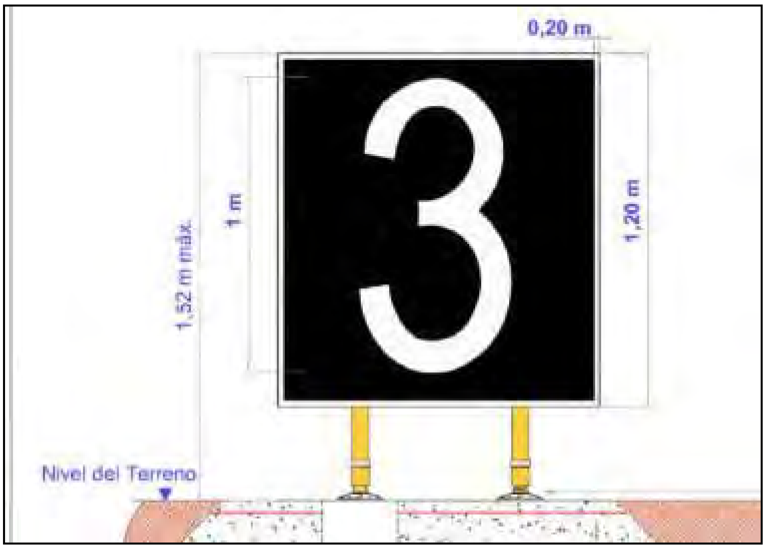
The need to place a visual approach slope indicator system, a 4-element wing bar on the left side of the approach, is exposed, since there is a long RWY.

mandatory signs

The implementation of the following posters should be considered as they are necessary application standards:

- Vehicle entrance.
- Waiting point on TWY.
- Remaining distance.

Rwy Distance Remaining Indicator



Obstacle indicator visual aids

Objects to be pointed out or illuminated:

- All obstacles, located within the distance indicated above, with respect to the axis of a taxiway, apron access lane or aircraft stand access lane will be marked and will be illuminated if the lane taxiway or one of those access roads is used at night.
- Any fixed object, other than an obstacle, located in the contiguous proximity of the limits of an approach, transitional, internal horizontal or conical surface, within the distance between 3000 m and the internal edge of the approach surface, shall be marked. , and will light up if the runway is used at night.
- Vehicles and other mobile objects, which are in the movement area of an aerodrome that are considered as obstacles and will be marked accordingly and illuminated if the vehicles and the aerodrome are used at night or in poor visibility conditions; however, aircraft service equipment and vehicles used only on aprons may be exempted from this.
- Vehicles will be marked with colours, flags and lights, for all conditions of visibility and ambient light. When colors are used to mark moving objects, a single clearly visible color should be used, preferably red or yellowish-green for emergency vehicles and yellow for emergency vehicles. service vehicles.

Obstacle Lights Features:

- Low intensity lights: to illuminate objects whose height is less than 45 metres with respect to the elevation of the terrain, and it is determined through an aeronautical technical study that said lighting is necessary for the safety of air operations.
- Low Intensity Obstacle Lights 21 – 26: Low intensity obstacle lights arranged on fixed objects will be red fixed lights, in no case will they have an intensity less than 32.5 cd of red light.

Aerodrome Infrastructure To Operate With Helicopters

Generalities

The regulations established in RAAC 155 should be applied for the design of surface heliports, aerial taxiing and apron parking positions, the physical characteristics, aids, obstacle limitation surfaces and services that heliports must have, and certain technical facilities and services normally provided at a heliport. These specifications are not intended to limit or regulate aircraft operations.

The particular conditions of the Antarctic environment mean that the heliports in these locations require particular or specific complementary regulations that address operational safety based on the type of aircraft they operate and the particular procedures depending on the environment, especially with regard to availability. data, physical characteristics, obstacle limitation surfaces and visual aids.

Helicopters considered for the project:

- MI 17

- Bell 412 / 212.

Both aircraft are classified as Performance Class 1 Helicopters, whose performance, in the event of failure of the critical power unit, allows them to land in the aborted take-off zone or continue the flight safely to an appropriate landing zone, depending on the moment. in which the failure occurs.

For operations in Ad. the implementation of PBN procedures will be considered, since the aircraft have the corresponding instruments. A point in space called PinS would be determined, located laterally to the RWY axis in order to separate the traffic that operates on the runways and to be able to do so simultaneously.

To do this, you must approach a point called MAPt (Missed Approach Point), it will be determined as a result of the calculations to be carried out in the construction of the procedure, later PinS and from it, carry out an air taxi to the parking position. designated.

Approach, Air Taxiing and Parking for Helicopters Streets and air taxiing

routes for helicopters (Figure 86)

Visual leg of an approximation to a point in space (PinS): This is the leg that corresponds to a helicopter PinS approach procedure from the MAPt to the landing site for a “visually proceed” PinS procedure. The 22 – 26 visual segment connects the point in space (PinS) with the landing site.

The specifications related to air taxi routes are aimed at the safety of simultaneous operations during helicopter manoeuvres. However, the wind speed induced by the rotor downdraft might have to be considered.

The air taxiway is intended for the movement of helicopters above the surface at the height normally associated with ground effect and at a ground speed of less than 37 km/h (20 kt). The width of air taxiways for helicopters are the twice the maximum width of the landing gear (UCW) of the helicopters for which they are intended.

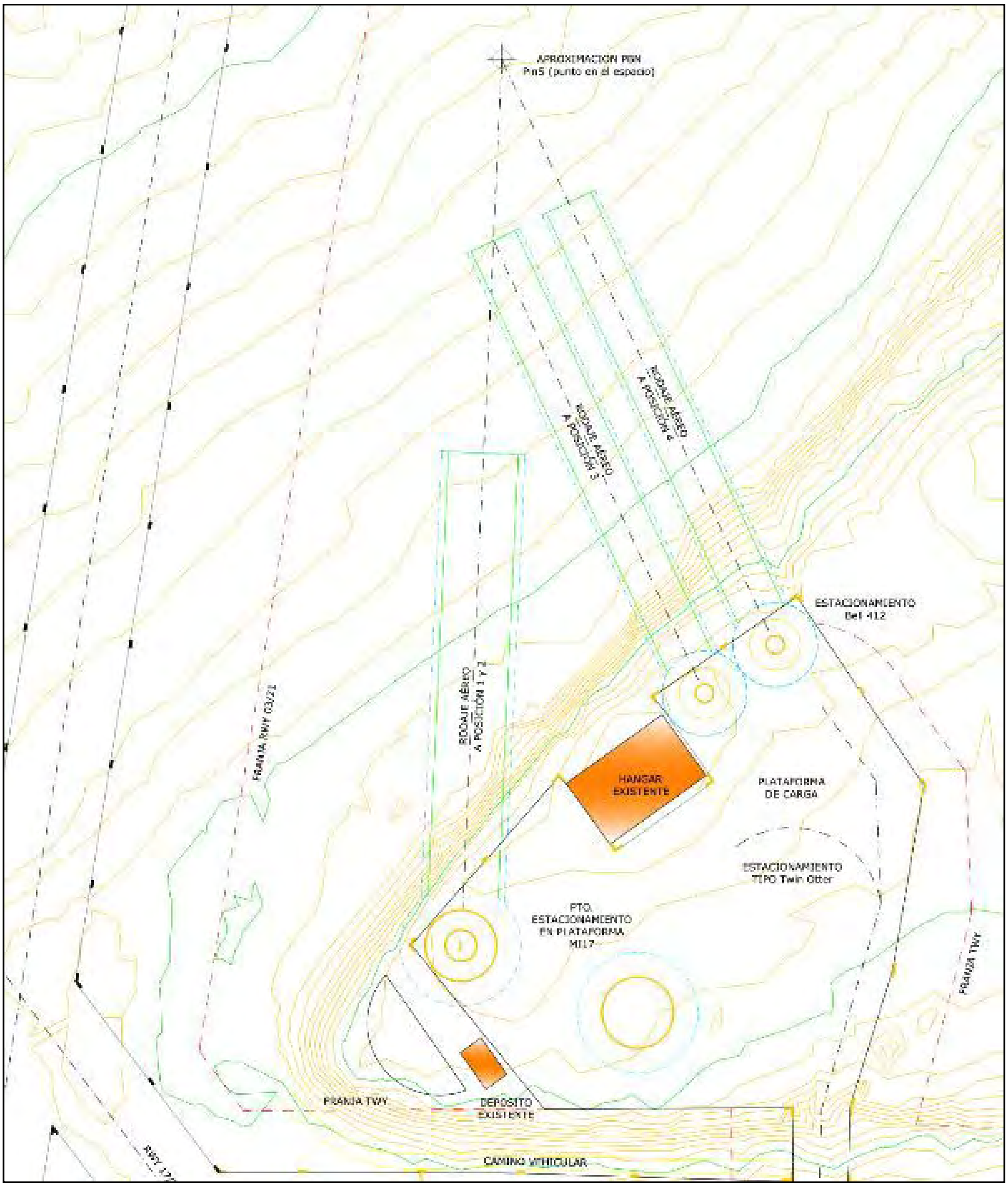


Figure 85: Streets and air taxi routes for helicopters.

The surface of designed helicopter air taxiways is resistant to static charges. The surface slopes of helicopter air taxiways do not exceed the slope landing limitations of the helicopters for which those taxiways are intended. The cross slope does not exceed 10% and the longitudinal slope does not exceed 7%.

Helicopter air taxi routes extend symmetrically on each side of the centre line for a distance equal to the maximum overall width of the intended helicopters. No moving objects will be allowed on an air taxi route during helicopter movements. There are no fixed objects located above the surface of the ground on air taxi routes, except for frangible objects that, due to their function, must be located there.

Objects whose function requires that they be located on air taxiways:

- Objects above ground level whose function requires that they be located on a helicopter air taxiway shall not be located at a distance of less than 1 m from the edge of the helicopter air taxiway; and protrude from a plane whose origin is at a height of 25 cm above the plane of the helicopter air taxiway, at a distance of 1 m from the edge of the taxiway and whose upward and outward slope is 5%.
- Objects above ground level whose function requires placement on a helicopter air taxi route shall not:
  - Be located at a distance of less than 0.5 times the greatest overall width of the helicopters for which it is designed from the centre line of the helicopter air taxiway.
  - Projecting from a plane whose origin is at a height of 25 cm above the plane of the helicopter air taxiway, at a distance of 0.5 times the greatest total width of the intended helicopters from the centre line of the taxiway. aerial taxiing for helicopters and an upward and outward slope of 5%.

The surface of helicopter air taxi routes shall be resistant to the effect of rotor downdraft and the surface of helicopter air taxi routes shall provide for ground effect. When performing simultaneous operations, the air taxi routes for helicopters do not overlap.

helicopter stand

Aircraft parking position that allows the parking of helicopters and, where the operations end or the helicopter makes contact and rises for aerial taxiing operations. The dimensions of the parking stands are 1 "D" for each case, considering "D" the distance that goes from the end of the main rotor to the end of the tail rotor, containing an area within which a circle of diameter can be drawn. not less than the largest helicopter for which it is intended.

A slope shall be applied in either direction not to exceed 2%. The surface shall be resistant to the effects of rotor downdraft and free of irregularities which may adversely affect the take-off or landing of the helicopters and shall have sufficient strength to permit the rejected take-off of helicopters operating in the Performance Class. one.

In helicopter stands, a system of lashing or fastening rings should be available. Operational security area of stand 69. It extends out from the periphery of the stand for a distance of 3 m, each outer side of the safety area is 2 D, there is a side slope rising at 45° from the edge of the safety area up to 10 m, on the surface of which no obstacles penetrate.

Objects whose function requires that they be located in the safety area:

- They shall not protrude more than 5 cm above the plane of the parking stand area and less than 0.75 D from the centre.
- They shall not protrude from a plane whose origin is at a height of 25 cm above the plane of the stand area and at a distance less than 0.75 D from the centre and whose upward and outward slope is 5%.

The surface of the safety area will not have any upward or downward slope that exceeds 4% out of the edge. The surface of the operational safety area will be subject to monitoring of its condition, with constant treatments being carried out to prevent debris from being raised by the downdraft of the rotor.

The parking stands will be designed taking into account that their protection areas do not overlap with each other or with the related taxiing routes and considering that the helicopter will make stationary turns when operating over the stand, therefore, the minimum dimension with the protection area is 2 D.

Obstacle limiting surfaces

In this regard, since the parking stands and air taxiways are protected by the aerodrome's obstacle limiting surfaces, operations will be carried out with procedures designed considering the significant objects that affect it, fulfilling the purpose of defining the airspace that must be maintained. clear of obstacles around heliports so that planned helicopter operations can be carried out safely and to prevent heliports from being rendered unusable by the multiplicity of obstacles in their surroundings.

Likewise, the need is expressed not to allow new objects or extensions of existing ones above any of the indicated surfaces, except when the object is shielded by an existing and immovable object, or it is determined with an aeronautical study carried out by competent personnel who the object will not compromise safety or significantly affect the regularity of helicopter operations.

wind direction indicator

At least one wind direction indicator must be visible from the parking stalls. The wind direction indicator shall be located in a place that indicates the wind conditions on the platform, so that it is not affected by disturbances of the air current produced by nearby objects or by the rotor. The indicator shall be visible from helicopters in flight, while taxiing, hovering or over the movement area.

The wind direction indicator should be so constructed as to give a clear idea of the direction of the wind and its general speed. The indicator must be a truncated cone of cloth and have a length of 2.4 metres, a major diameter of 0.6 metres and a minor diameter of 0.3 metres as minimum dimensions.

It should be located in such a way that it clearly indicates the direction of the wind at the surface and gives a general idea of its speed. The color of the wind direction indicator should be chosen so that it can be clearly seen and interpreted from a height of at least 200 m (650 ft) above the heliport, taking into account the background against which it stands out. If possible, a single color should be used, preferably orange.

The wind direction indicator, in the event that it is considered intended for night use, will be illuminated. Given the particularity of the location in the Antarctic environment, the provision of the wind direction indicator will not be applicable due to the icing conditions to which the fabric that forms it and the turning mechanism will be subjected. The possibility of placing it at the moment should be analysed. prior to operations or may be exempted from its installation, when information on the direction and intensity of the wind is provided by other appropriate means.

Helicopter stand signs

The parking position perimeter sign must be built with a diameter of 1D, yellow color with a line width of 15 cm. If feasible, alignment lines and entry/exit guide lines should be constructed. They would be continuous, yellow in color and would have a width of 15 cm.

4.7.3 Aerodrome Operation

Introduction

The purpose of this section is to detail the characteristics and requirements necessary to carry carried out the implementation of air operations in the AD PETREL project (ANTÁRTIDA ARGENTINA).

This Report is based on the preliminary data available resulting from the survey carried out in February 2022 and other available data such as background information, meteorological data and previous reports made by the crew of the C-130 Weapons System that has a extensive experience in Antarctic air operations.

Based on the product of the compilation of these data, this analysis began in order to provide an initial orientation to the AD PETREL project, which must be complemented later according to the standards of the International Civil Aviation Organisation (ICAO). The BAC PETREL is located at the geographic coordinates S 63º 28' 30'' W 056º 14' 30'' on Dundee Island, 46 NM NE of the MARAMBIO Antarctic Base; Therefore, it is included within the MARAMBIO TMA (MBI) (Figure 87).

The TMA (Terminal Control Area) is a controlled area located at the confluences of the airways, in the vicinity of one or more airports. The TMA allows instrumental flights (that is, they fly based only on navigation instruments, and not on visual references) that depart and arrive from the airways to be under control, and it is in this space that air traffic must be ordered in a manner efficient and safe. It is worth mentioning that this function of ordering transits is carried out by ATCOs (Air Traffic Control Operators), which are the personnel trained to provide said service.

TMA MARAMBIO Circulo de 60 NM de radio con centro en VOR/DME MBI (641405S-0563712W). FL 450 2000FT AGL/AMSL CLASE DE ESPACIO AEREO: A- POR ENCIMA DE FL 195. B- POR ENCIMA DE FL 145 HASTA FL 195. C- DESDE 2000 FT AGL/AMSL HASTA FL 145.	TWR MARAMBIO MARAMBIO TORRE ESPAÑOL H 24	118.10 MHz 118.50 MHz	

CTR BASE MARAMBIO Circulo de 20 NM de radio con centro en VOR/DME MBI (641405S-0563712 W). FL 65 GND CLASE DE ESPACIO AEREO: C	TWR MARAMBIO MARAMBIO TORRE ESPAÑOL HJ	118.10 MHz 118.50 MHz	

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Figure 86: TMA y CTR MBI

The current structure of the airspace of the TMA MBI is that published in the Aeronautical Information Publication (AIP) of the Argentine Republic, and is defined as detailed below (Figure 88). Likewise, in that AIP document, the NAVIGATION CHART EN ROUTE INF-SUP 4 MARAMBIO / ANTÁRTIDA ARGENTINA is published in part ENR 6, currently
valid.

For greater detail, the area of the TMA MBI is expanded below (Figure 878).

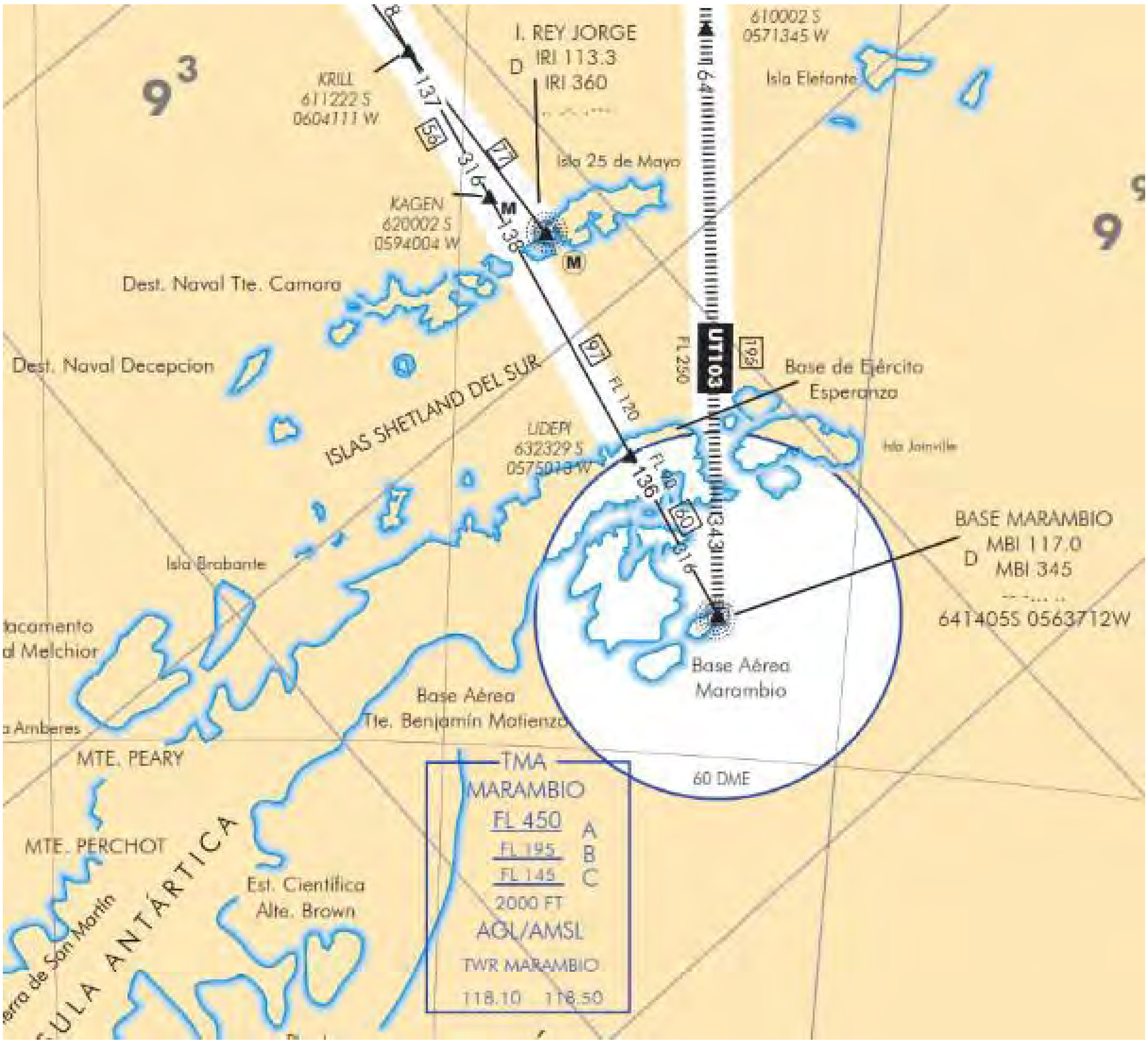

Figure 87: TMA MBI zone.

Likewise, in order to enable the implementation of air operations in instrument flight conditions (IMC) in the AERODROMO PETREL project, the creation of a Control Zone (CTR) is considered opportune. The CTR is a controlled airspace that extends from the aerodrome surface to a determined vertical limit. The CTR is associated with the Control Tower (TWR) and Approach (APP) air traffic services. The function of the CTR is to protect the traffics that operate in the same space, in order to contain the trajectories of the Instrument Flight Procedures (IFP) proposed to the projected runways 17/35 NPA* and 03/21 PA*.

*NPA (Non-Precision Approximation) and PA (Precision Approximation) are detailed in the Appendix 2 “AERODROME APPROACH AND DEPARTURE PROCEDURES”. This way
It is proposed to create a CTR PETREL (Fig. 3) within the TMA MBI with the installation of a VOR DME radio navigation aid to support the approaches, defining it from the centre of said VOR DME.

It can also be defined from the VOR MBI, according to the following detail:

- vertical limit: GND/FL50
- Lateral limit: Between RDL 022 and RDL 345 VOR MBI
- Lateral limit: Between 60 NM ARC and 30 NM ARC from VOR DME MBI

Note: Lateral limits can be determined by geographic coordinates in case of out of service of the VOR DME MBI.

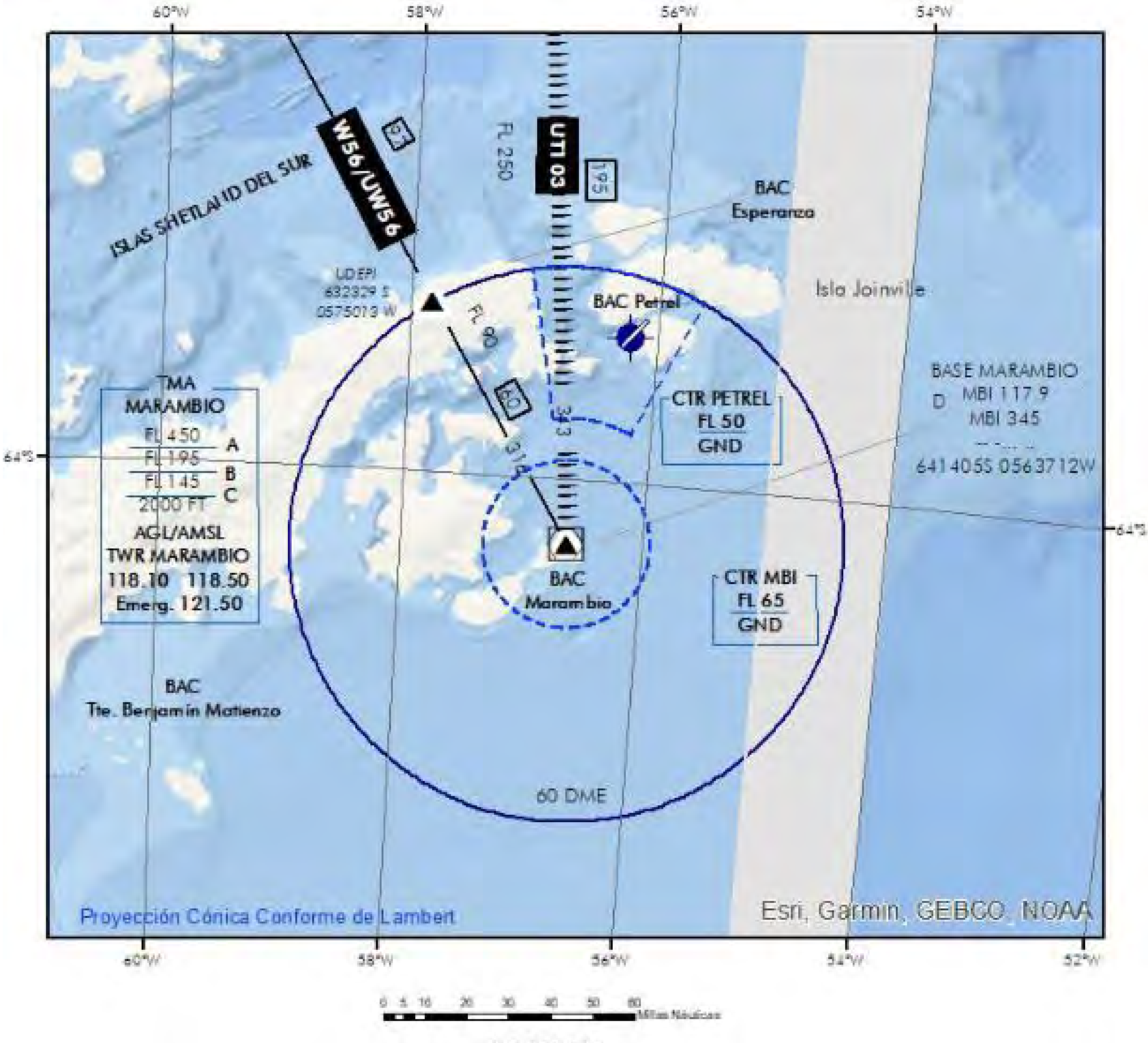

Figure 88: TMA MBI – CTR MBI – CTR PETREL

4.7.4 Approach and takeoff routes

IFPs (Instrument Flight Procedures) are standardised procedures in which aircraft crews fly trajectories with the guidance of onboard navigation instruments, without visual references, and with the corresponding obstacle protection. IFPs can be NPA, APV and PAeleven(Figure 89 90).

According to the configuration of the runways presented in the project, two runways with orientation 17/35 NPA and 03/21 PA are determined. The difference between these lies mainly in the operational advantage they offer for landing, with the NPAs being more limiting in terms of visibility minima. Then the APVs and PAs provide greater efficiency for landing. It is worth noting that the PA needs a suitable infrastructure on the runway.

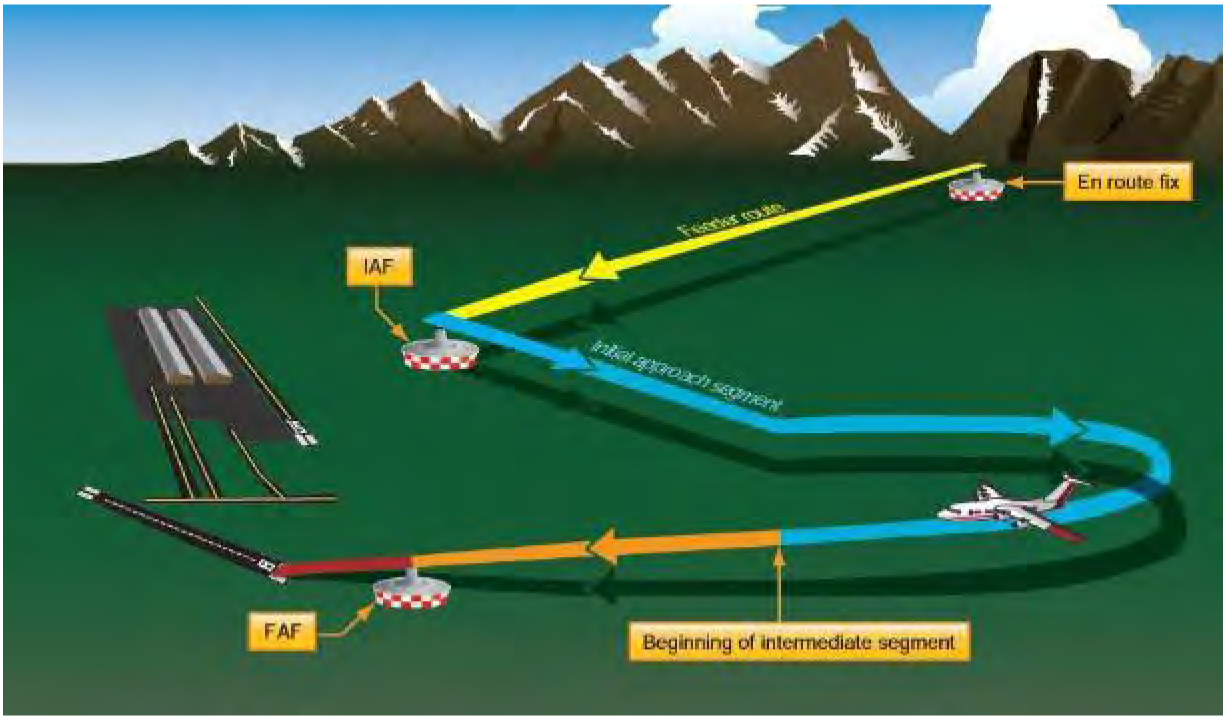

Figure 89: Sections of an IFP.

The criteria for the design of IFPs are described in Doc. 8168 PANSOPS - ICAO. This document details the obstacle clearance areas to achieve safe operations in IMC (Instrument Meteorological Conditions).

Conventional Approach Procedures

IFPs can be developed within the framework of conventional navigation or in the PBN concept (PERFORMANCE BASED NAVIGATION). Conventional navigation includes the support of radio aids on the ground, while the PBN concept does so based on the navigation performance of aircraft supported by satellite systems.

At the PETREL aerodrome, the installation of a VOR DME radio aid is expected to support NPA approaches to both runways. This determination is based on the fact that, before the

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eleven *NPA (Non-Precision Approach), AVP (Vertical Guidance Approach) and PA (Precision Approach).

vulnerability of the signal of satellite systems in Antarctic latitudes, the alternative to conventional navigation is provided by this type of approach.

RNAV and RNP Approach Procedures

The IFPs in the PBN concept (PERFORMANCE BASED NAVIGATION) are developed based on the navigation performance of aircraft supported by satellite systems. In the PBN concept there are two types of navigation specification, RNP and RNAV. RNP requires more requirements than RNAV, but offers greater advantages to the approach (Figures 91 and 92).

The application of both will depend on the capacity of the navigation systems of the aircraft that are approved and that operate at the aerodrome.

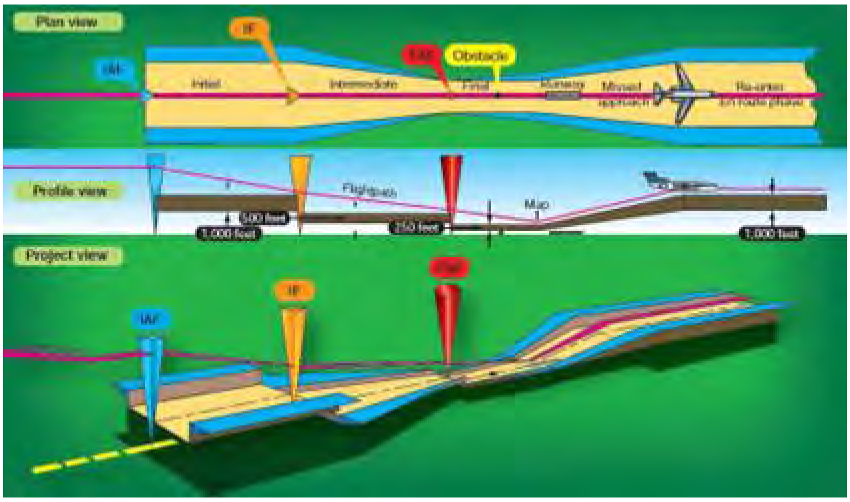

Figure 91: Sections of an IFP and their protection areas

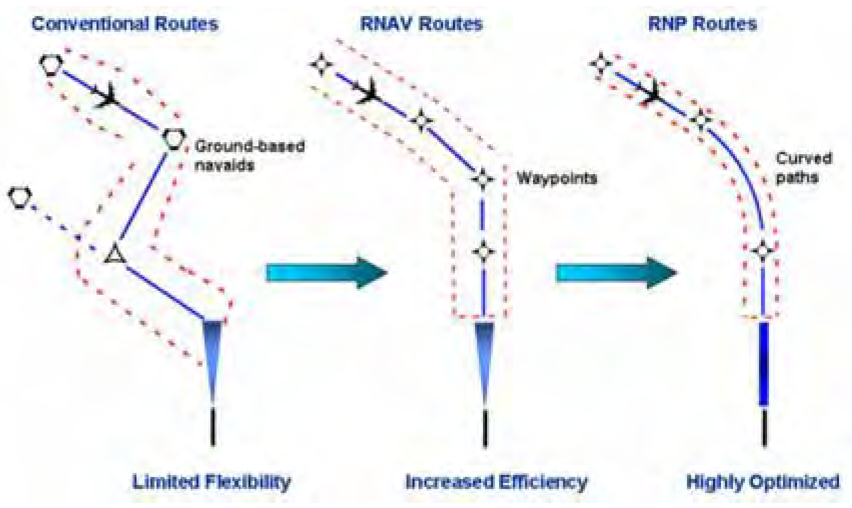

Figure 90: Comparison of obstacle clearance areas between Conventional IFP, RNAV and RNP

For the purposes of implementing air operations, in instrument meteorological conditions (IMC), the AD PETREL project considers: The implementation of IFP in IMC, as well as operations in VMC within the permitted operating margins, to projected runways 17/35 NPA and 03/21 PA.

The projected IFPs are IAC (Instrument Approach Chart, for use during landing), SID (Standard Instrument Departures, for use during takeoffs) and STAR (Standard Arrivals to the Terminal Area, support the transition from the airway to approach) within the framework of the PBN air navigation concept.

Figure 92: Aircraft to be used, C-130 and MI-17

In order to avoid dependence on terrestrial radio aids, the IFP proposals are also oriented to the use of GNSS, and at an advanced stage the possibility of applying GBAS. However, the use of radio aids (VOR) can be proposed for those aircraft without RNAV/RNP capability.

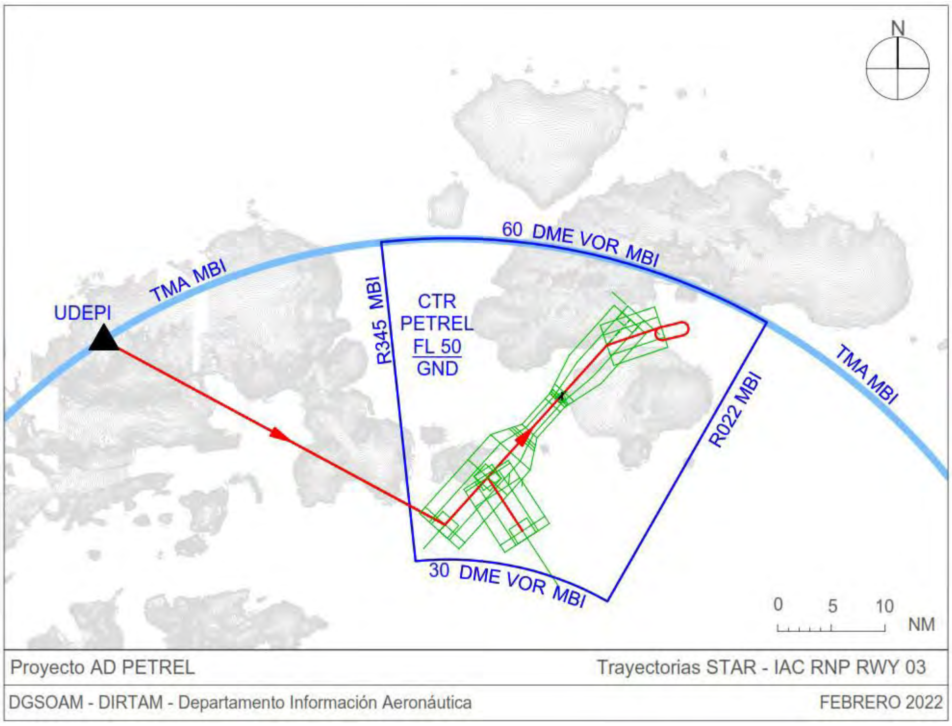

Figure 93: Proposed trajectories for runway 03 PA

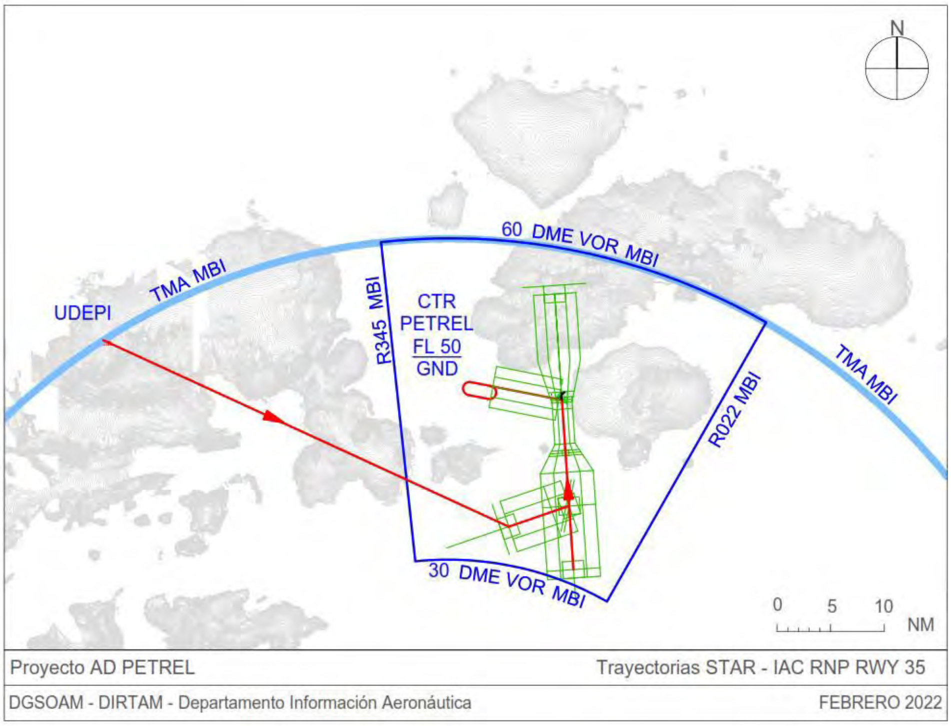

Figure 94: Proposed trajectories for runway 35NPA

Figures 94 and 95 detail the proposed trajectories for runways 03 PA and 35 NPA in red, while the obstacle clearance areas are graphed in green. In this way it is possible to visualize the situation of the trajectories in relation to the surrounding obstacles. TWO (2) hold procedures are incorporated for each IFP. The path from UDEPI will determine a STAR to connect to the IAF (Initial Approach Point of the procedure) of each IFP according to the runway in use. The IFPs are circumscribed in the projected CTR PETREL.

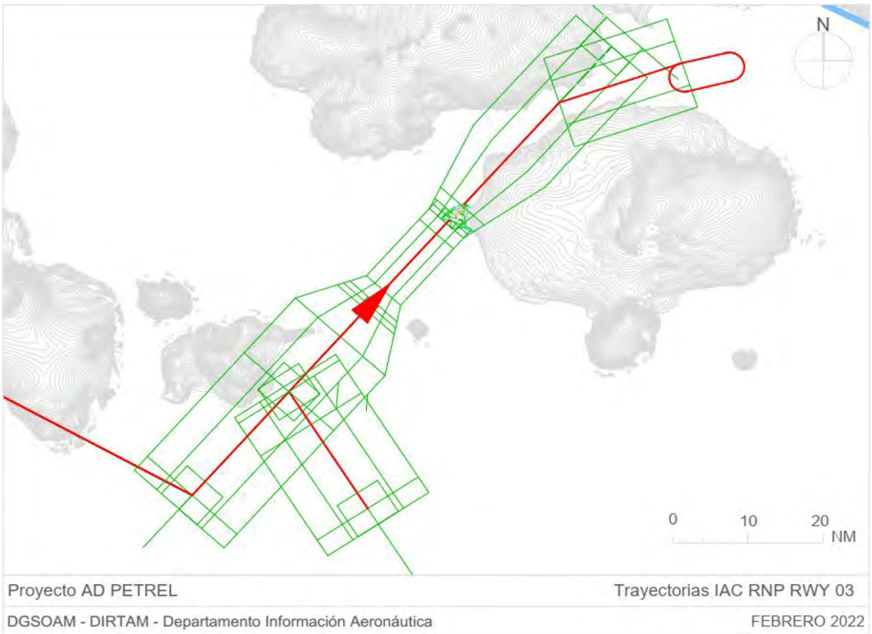

Figure 95: Runway 03 obstacle clearance area.

Figure 96 details the obstacle clearance area of the path to runway 03. Obstacles noted in the initial approach, missed approach and holding segments.

Figure 96: Runway 35 obstacle clearance area.

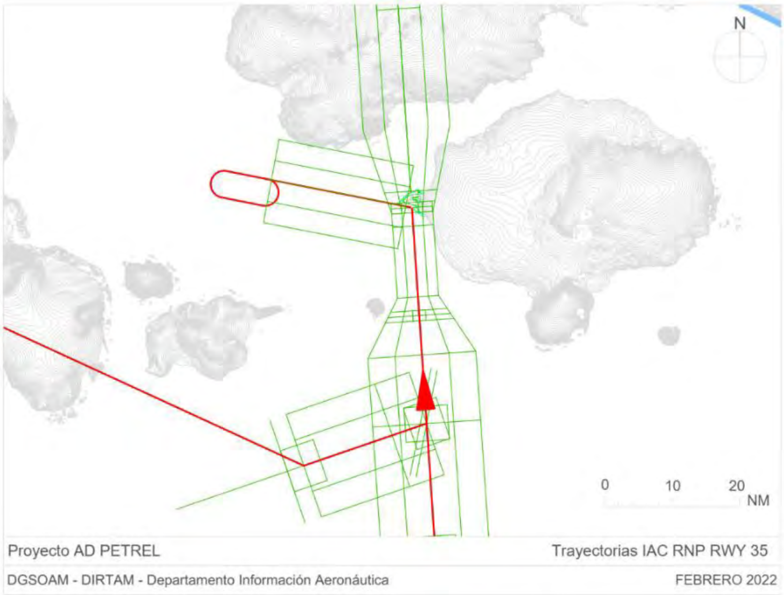

Figure 97 details the obstacle clearance area of the path to runway 35. Notable obstacles in the missed approach segment. The IFPs are projected in the PBN concept and for the RNP navigation specification, therefore it is possible to highlight some issues related to them from the operational point of view. This type of IFP must comply with processes related to implementation, validation on the ground and validated in flight in VMC (Visual Meteorological Conditions), in order to verify the performance of the aircraft in the development of the flight, and ensure the corresponding clearance. of obstacles in all phases of flight. RNP VNAV approaches must be specially validated based on the low temperatures prevailing in the area.

Helicopter Operation

Just like airplanes, helicopters can perform instrument approaches according to the capacity of their navigation systems. Helicopter instrument approach design criteria are also described in Doc. 8168 PANS-OPS - ICAO. It is possible to design IFP for conventional type and PBN helicopters, however, there is the possibility of designing PinS (Point in Space), which have other advantages.

PinS differ from other types of instrument approaches in the infrastructure required at heliports. To implement PinS it is not necessary to operate on a runway or heliport enabled for IFR (Instrument Flight Rules) use. The PinS are applicable to any heliport that complies with the necessary clearance of obstacles according to ICAO Annex 14, both during takeoff and landing. Likewise, there are PinS for departures and approaches, and they can be made up of direct sections, visual maneuver sections and visual flight sections (VFR-Visual Flight Rules).

Below, as an example, an EXIT PinS is detailed (Figure 98) from BAC PETREL to MBI detailing the nominal trajectory in red and the obstacle clearance areas in orange.

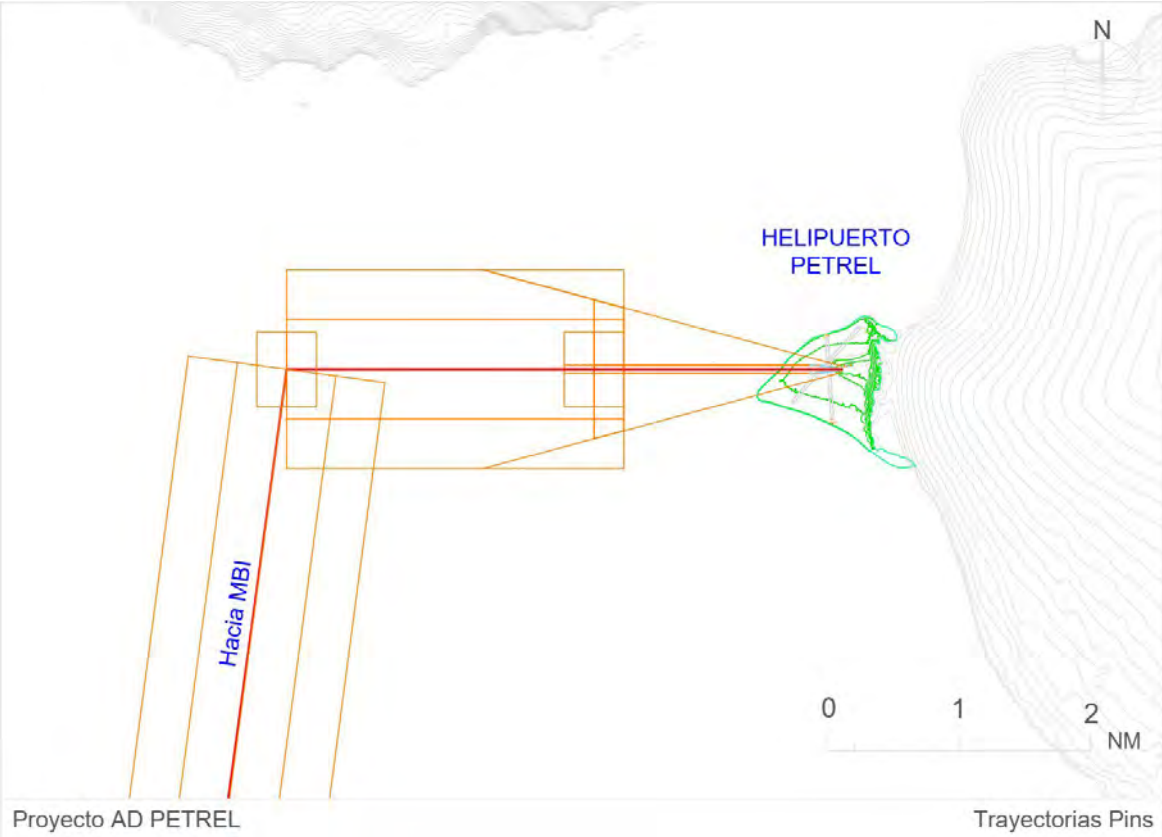

Figure 97: Helicopter departure trajectory from Petrel Base.

4.7.5 Airfield facilities

4.7.5.1 Passenger Terminal and Control Tower

The Flight Tower and Passenger Terminal will be located in the current position of Shed I, at the west end of the upper platform of Cape Welchness. It will constitute a single three-story building, which will contain all the services of the passenger Terminal itself (with its corresponding bathrooms), fire service (offices and parking for the fire engine), communications, meteorology, aerodrome headquarters and control tower.

It will occupy a floor area of 341 m^2 and will have a total of 646 m^2 useful for services. It will provide the following services:

- Communications and Air Navigation: The communications equipment will be in accordance with ICAO international standards and will be installed in the Flight Tower.
- Aircraft Rescue and Fire Fighting Service (ARFF): There will be a 4x4 self-propelled fire engine, of the OSHKOSCH or ROSEMBAUER type, in compliance with current regulations.
- Passenger terminal: The terminal must have sufficient physical space to house up to 80 people in transit, with adequate heating and toilets. Aspects that will allow passengers to remain concentrated after having checked in.
- Beaconing and runway indication: Initially, a mobile beaconing system of the NAVITRONIK type or similar will be used, with battery and remote control by radio frequency until the most suitable fixed system, resistant to inclement weather, is defined.
- Weather Station: To be located in the Passenger Terminal and Control Tower building. In addition, 1/2 weather stations will be installed as an aid to air navigation. It will provide a forecast service with support from the Marambio Base Meteorological Station.
- Control Tower: To be located in the same building as the Passenger Terminal. It will coordinate the aircraft arriving and departing from the BACP. This location and height allows direct visual control over both runways, the aircraft operating platform, the taxiway and the helicopter operating platform.
- Air Communications: Communications related to the National Meteorological Service and to aircraft in flight or about to land or take off will be carried out and coordinated. It will provide the Aeronautical Information Service (ARO-AIS) and Communications.

Dry construction was chosen to minimize environmental impact and optimize insulation, using PIR-type panelling with a thickness of 20 cm on the outside (with a 15 cm air chamber) and 10 cm on the inside. The metal structure is made up of transversal steel frames with a full core located between panels.

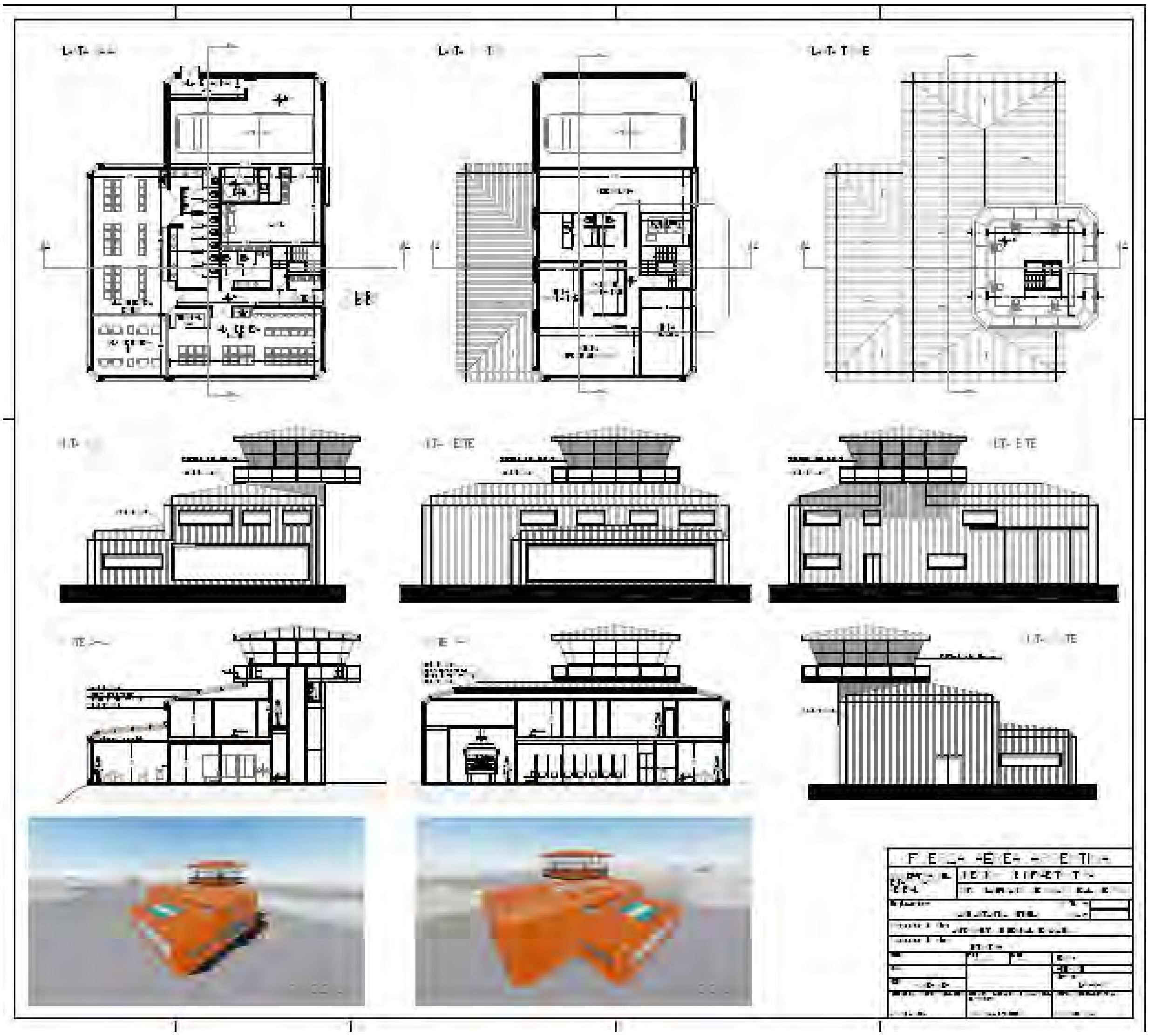

Figure 98: Plans of the passenger terminal and control tower.

The plants were organised in such a way that they are functional for the optimal development of the necessary tasks within an aerodrome in Antarctica. The building is distributed as follows (Figure 99):

- Ground floor: It houses all the public circulation areas of the Passenger Terminal, such as: Entrance Hall 54 m^2, Egress Hall 56 m^2, Preferential entrance / exit room of 24 m^2 and public toilets. Likewise, there is the Fire Service at level /-0.00 to facilitate immediate reaction if necessary and have a direct connection with the slopes.
- Top floor: Developed in 255 m^2, there are all the services of the Aerodrome: Aerodrome Chief's Office, Communications Office, AROAIS Office, Meteorology Office, Communications Rack, and complementary services such as toilets (female and male), office and Tank Room.

4.7.5.2 New Premises in Existing Hangar

The project involves locating new premises inside the existing hangar at the Petrel Antarctic Base, where the MI-171e and Bell 412 weapons systems hangar is planned. The provision of these premises was organised in two facing modules, which are designed to be located on the rear sides of the Hangar, and whose dimensions result in a 3.40m front for each module, 12.40m deep, and a maximum height of 2.40m. ; in compliance with the operational requirement of having a covered area of 84 m^2 distributed on the ground floor, in which spaces were designed for: Workshop, Warehouse, Technician's Room, Driver's Room, and Restrooms (Figure 92).

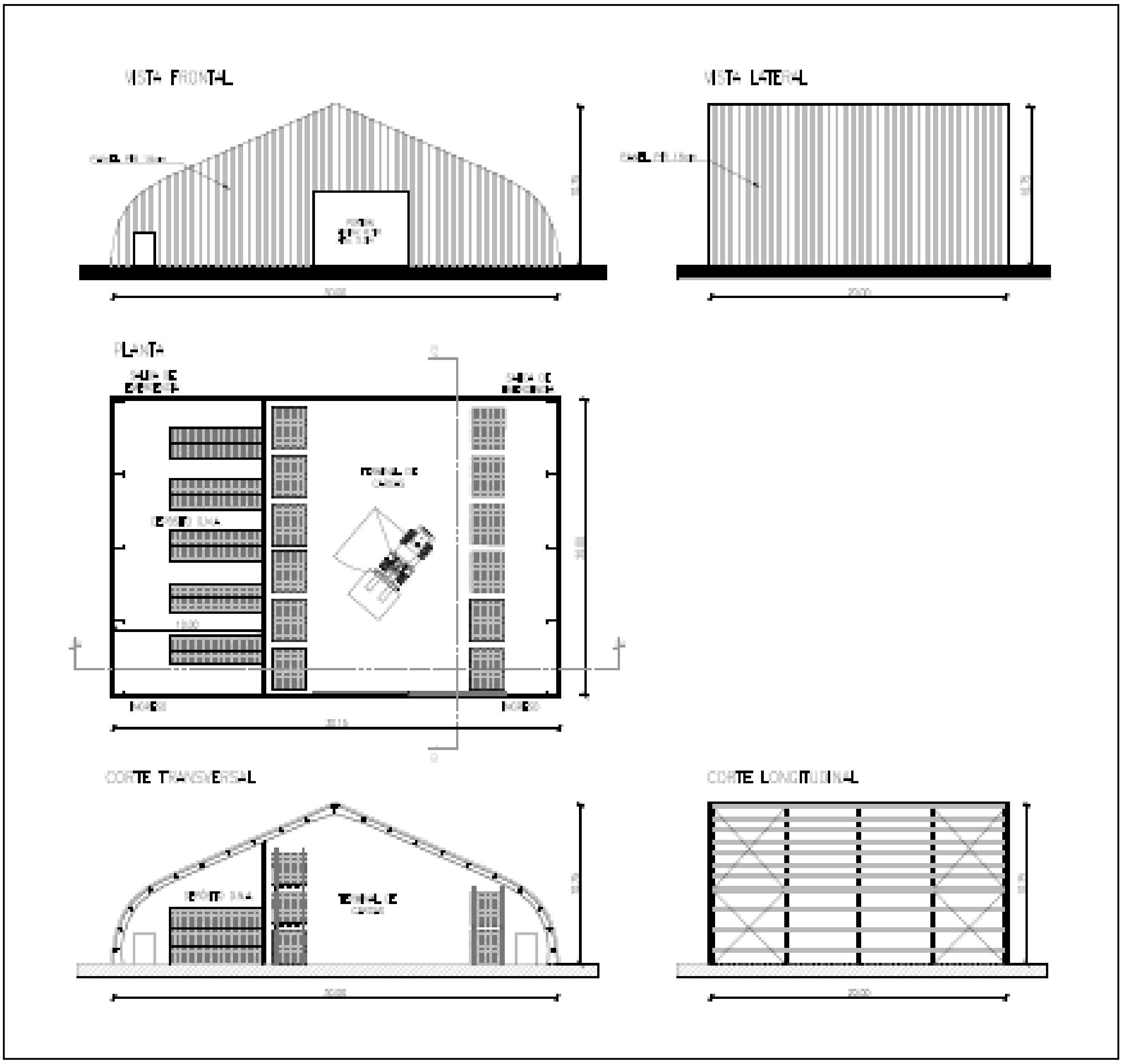

Figure 99: Plan of the Petrel base hangar with the modifications for the new premises.

The aircraft hangarage is planned in such a way as to place the Bell 412 (with folding blades) in the rear sector of the Building, located between the new premises and consequently, the MI-171 helicopter will be arranged in the front sector. The orientation of the entrance gate of the Hangar is towards the East, leaving the rear gate only for emergency exit, in the event of a possible evacuation.

The local modules will be assembled with dry construction technology, and will have a new floating type floor with thermal insulation, which will rest on the existing concrete pavement. The perimeter, internal and ceiling enclosures will be made of gypsum rock plate with thermal insulation. Electrical installations are included, with their corresponding regulatory protection, in addition to the necessary health and data protection, required by the personnel assigned to work in these operational areas.

4.7.5.3 MI-17 Helicopter Hangar

The plant was organised in an area of 1,265 m^2, whose dimensions resulted in 36m for the front, 35m deep, and a maximum height of 12.9m; in the need to hangar an aircraft with the necessary safety distances and free of obstacles. In addition, the operational requirement of having a covered area of 328 m was fulfilled^2 for premises and offices distributed on the Ground Floor and Upper Floor, of which the spaces were designed for: Battery Workshop, Lubricants and Standardised Warehouse, Spare Parts Warehouse, Service Workshop and MI171E/Avionics Store, Float Inflation Workshop, Laboratory, Configuration Service and Workshop, Pilot Room, Technical Office and Library. In addition, it has a health centre for male and female personnel (Figure 101).

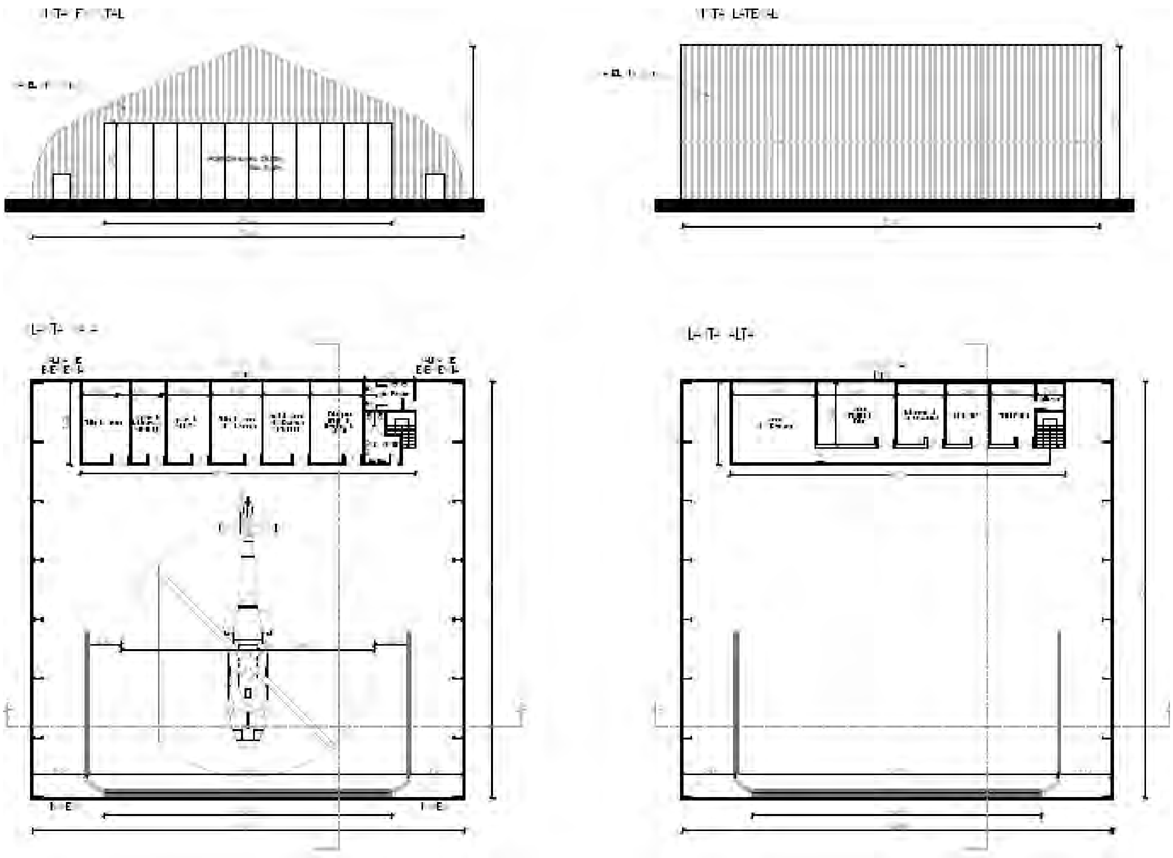

Figure 100: MI-17 hangar plans

The aircraft hanger is through an access gate 24.23m wide and 6.4m high. The orientation of the front of the Hangar is towards the West. At the height that remains above the line of the gate lintel, it allows the placement of tooling elements to carry out hoisting and necessary movements for aircraft inspection/repair work, in addition to other fastening means, considered as protection elements (Lines of life, etc.), for personnel performing maintenance tasks.

The structure was designed in F-36 quality steel, with a full core and with sections of variable heights to optimise its own weight and also save material. 20cm thick P.I.R sandwich panels will be used in the Hangar envelope. the mezzanines

Interiors that function as offices and workshops will also have a metallic structure, and closed with prefabricated gypsum rock panels. The Hangar floor is planned with a substructure and aluminum plates, with thermal insulation.

The main characteristics of the profile of this structure, due to the optimised angle of inclination of the roof, is its resistance to the dynamic actions of winds of up to 300 km/h, also giving it good performance in preventing snow accumulation.

4.7.5.4 JP1 Reservoir and Pump

The JET-A1 Cistern Park is located within the Petrel Joint Antarctic Base, about 40 m SW of the MI Hangar; 170 m south of the cargo terminal and DNA Deposit; 160 m south of the Hangar; 190 m southeast of the Passenger Terminal and 120 m southwest of the sports centre. The location responds mainly to the safety of the facilities, and the possibility of containment in the event of any spill (Figure 102).

Figure 101: Model of JP1 tanks for the Petrel Base.

The base of the park will be 18.00m long and 9.00m wide. On the other hand, the cistern tanks that will store the fuel will be 2m in diameter and 5 m. long. The park will only be used to locate the tanker tanks, store the respective fuel and provide it to the aircraft that require its supply.

The park will have TWO (2) or more horizontal tanks (cisterns) until reaching the storage capacity of 35,000 litres of fuel, the amount necessary to reach the volume of ONE (1) tank of the C-130. It must be possible to access the cisterns by means of a ladder for their control and maintenance.

transfer pump

For the impulsion of the JET-A1 fuel, the proposal of the Base personnel is adopted as a starting hypothesis, this being the use of TWO (2) INDESUR brand double diaphragm pneumatic pumps, Model: D50ALYXN - AB - X.2. Said pumps will carry out the transport of the fluid by means of a pressure change generated by the mentioned diaphragms. They have the characteristic of being of variable pressure and flow and their maintenance is very simple.

plumbing

It was projected that the layout of the drive pipe be made of cryogenic steel type ASTM A333 Grade 6 SCH40 DN 3” Seamless with a minimum thickness t = 5.49mm. This pipe can withstand Antarctic temperatures without the need for an exterior coating and was selected as the solution for a project with similar characteristics at the Petrel Antarctic Base. It must be braced to the ground by means of anchors or metal supports according to the direction of the same and topography of the land.

The characteristics of the pipe and hoses, supports and anchors vary according to the need to be supplied by them, ranging from direction changes, trace continuity, embedment union, etc. These supports were verified through the calculation software RAM Elements V8i, before load combinations such as own weight, overload and rock impact before possible storms. Based on the characteristics and properties of the materials, both the pipes and the hoses, their roughness was taken into account for the subsequent calculation and verification of the pump.

- Steel pipe roughness: 0,000046 m [P]
- Hose Roughness: 0,000010 m [P]
- Steel pipe diameter: 3 inches [C]
- Hose diameter: 2 inches [C]

hoses

For fuel delivery JET-A1 is adopted as the starting hypothesis. Regarding the layout of the suction pipe, it will consist of a triple connection by means of quick couplings that will be connected to Dunlop Antártica Argentina - FT M1174" hoses of DN 2" and the latter connected to each of the Rolling Tanks and another for the connection between this collector system and the fixed pipe itself. All will be divided into a maximum length of 5 m in order to have the characteristic of not taking up too much space and facilitating their handling.

spill protection

The JP1 fuel tank park will have its corresponding anti-spill tray, a necessary condition for the park to be used for fuel storage. A raft with similar characteristics to the one described in the Vertical Tank project will be built.

Rules, regulations and specifications that will govern the work

Law 13,660 and Decree No. 10,877/60 relating to the safety of facilities for the production, transformation and storage of solid, mineral, liquid and gaseous fuels will be used as a reference.

The relevant articles that will condition the project are detailed below: According to

article 321:

"The distance between the different tank walls must be at least one diameter of the largest tank. It will not be able to store more than 10,000 m3".

According to article 322:

The distance between the tanks and:

- Concession limit ½ diameter, with a minimum of 15 metres.
- Public roads 1 diameter, with a minimum of 15 metres.
- Residential houses and neighboring industrial facilities, 2 diameters of the largest tank.

According to article 325:

The pump rooms of fixed fire-fighting installations will be distanced with a minimum of 30 metres.

According to article 329:

The spill containment volume will be equal to the useful volume of the tank plus 10% (110% tank volume).

According to article 602:

The docks that are intended for the transfer of flammable and combustible liquids must be located more than 120 metres away.

According to article 620:

Prior to the transfer, it must be ensured that there are no people smoking and that the hose is connected correctly, that the valves are in a position to operate and that there are no fires or open flames on the dock.

According to article 622:

The transfer will not be possible during electrical storms.

According to article 627:

Trucks and vehicles will only remain at the docks or berths for the time necessary to load and unload, each with its own fire extinguisher.

According to article 1101:

If there is a common place to gather more than 150 people, the tanks must be located more than 150 metres away.

Taking into account the aforementioned, the number of attendees in the sports building will be limited to 150 people.

Construction method and materials to be used

As previously mentioned, this project contemplates the construction of two horizontal tanks of 2.00m in diameter and 5.00m in length. It will be made of 304/l and 316/l stainless steel. The materials that compose it are:

- 2000 x 6000 x 6 mm sheet
- 2000 x 6000 x 4 mm sheet
- Angle profile with equal wings 2 ½" x ¼"

Ambient Condition Systems

Given the characteristics of the network implementation area and the fact that it is a new structure, the building code must be complied with. However, in those points that are not specified, in pursuit of an adequate and efficient solution and design.

In this way, it is understood that when choosing the materials and construction systems, hygiene, health and environmental protection conditions must be guaranteed. This is why it is recommended to complement it with the presentation of an environmental control and effects reduction program.

They stand out:

- Protection against moisture
- Waste collection and disposal
- air quality protection
- Surface and underground hydrology protection
- Protection of landscape, vegetation and fauna
- Protection of archaeological, paleontological and mineral finds of scientific interest
- Energy saving and thermical isolation

4.7.5.5 Commissioning equipment

There will be aircraft start-up equipment, complemented by pressurised air equipment, heating equipment with flexible ducts for preheating prior to start-up. These equipment will be found inside the existing Hangar.

4.7.5.6 Road Park for Runway Maintenance Service

For the works required by an airstrip with these characteristics and in this particular geographical environment, defined road equipment is required, which requires a facility for its guarding and maintenance, located within the airport sector.

Said vehicles will be motor graders, backhoes, rollers and dump trucks. Vehicles will be stored in the Vehicle Park or, as long as the hangar is not used for helicopter operations, they may be parked there.

4.7.5.7 operation platform

The one corresponding to aircraft will be in the sector close to the intersection of both runways. It will not penalize the landing and takeoff operation by other aircraft. There will be a second operations platform in the vicinity of the hangar that will be used by helicopters.

4.7.6 Runway construction and maintenance

The runway construction will have the following stages:

- Stage 1 of the project would include the construction of the main runway 03/21 for precision operations, 2 heliports (for B-412 and Mi-17), with a taxiway, aircraft and cargo apron on the lower peninsular site. Procedure diagrams. Vehicle streets, aerodrome lights. Infrastructure of the passenger terminal, operational offices, control tower and concurrent services. VOR/DME radio. Communications.
- Stage 2 of the project incorporates construction of the secondary runway 17/35 for non-precision operations, 2 heliports (for B-412 and Mi-17), a taxiway and an aircraft and cargo apron on the upper peninsular site.

4.7.6.1 Geological and mechanical properties of the terrain (Initial studies)

In this section of the CEE, the results of the geotechnical investigations carried out since 2006 at Cape Welchness (63°29'S, 56°14'W) on Dundee Island (Antarctica), where it is located, are presented. Petrel Base12. On various occasions, issues of geology, geomorphology and geocryology have been addressed. Its main objective is to determine the geotechnical conditions and assess the possibilities of building airstrips at Cape Welchness. The study area is included within the zone of permanently frozen soils (continuous permafrost), where the upper layers of the same are subjected to multiple freezing and thawing cycles, during which their mechanical properties are significantly modified. Taking into account these particular characteristics of the soil, the proposed style to design the airport facilities was selected in accordance with the geotechnical rules recommended for the polar regions of our planet.

Dundee Island is circular in shape, with a maximum extension of 27 km in an E-direction. W. Currently its 450 km2 they are almost completely covered by glaciers that form ice ravines that fall precipitously into the sea. On the island, one of the few ice-free areas is Cape Welchness, which is located in the western part of the island (Figure 2). This cape consists of a triangular area covering about 2.5 km2. Most of it has a flat surface with a difference in level of a few metres, especially on its two outer edges that border the sea and are eroded by small streams. The eastern part limits with the extensive ice cover of the island, from which it is separated by the crest of the lateral moraine of the glacier called "Rosamaría". The maximum extent of the ice-free flat sector is 1,950 m in a NE-SW direction, and 1,400 m in a NW-SE direction. The environmental conditions, geographical location, local characteristics of the relief and meteorology indicate that Cape Welchness is an appropriate place for the construction of airstrips, usable by aircraft of different sizes.

Geologically, this sector of Dundee Island is composed of two units of Triassic and Lower Cretaceous sedimentary rocks. During low tide periods, fine-grained marine sediments are exposed along the coastal zone, belonging to the Trinity Peninsula Group of Triassic age. The Lower Cretaceous sedimentary package is part of the Larsen Basin fill (del Valle et al. 1997), consists of fine-grained, well-consolidated, marine clastic sediments exposed in the ESE part of Cape Welchness, where they crop out near the eastern limit of the lateral moraine. Complex glacial and fluvioglacial deposits, deposited from the Late Pleistocene to the present, complete the stratigraphic succession.

In general, three geomorphological units of their own character can be distinguished: 1) lower fluvioglacial plain, 2) terrace of the bottom moraine and 3) cordon of the lateral moraine of the Rosamaría glacier. This glacier is in clear retreat and is part of the extensive ice field that covers the island. The ridges of the lateral moraine are located on the W edge of the Rosamaría Glacier, while the bottom moraine is located in the centre of Cape Welchness, forming a flat terrace, where the main buildings and the large hangar of the Petrel Base are located. Lithologically, the moraine deposits are diamictitic bodies composed of clasts formed mostly by local Cretaceous sedimentary material together with large erratic blocks. Its granulometric composition ranges from coarse gravel to sand and

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[12] The study for the baseline is "Geocryological-geotechnical study for the design of the landing strip in the Cape Welchness plain - Dundee Island, Antarctic Peninsula" by Evgeniy Ermolin, Adrián Silva Busso, Rodolfo del Valle and Jorge Lusky* from the Institute Argentine Antarctic of 2006.

limo. The lateral moraines have buried ice cores, relicts of ancient glaciers, and a thin (1.40-2.50 m) active layer of clastic material cemented by ice during seasonal freezing. The bottom moraine sector corresponds to the ice-rich permafrost zone with different types of subterranean ice, formed as cement or infiltration.

The gently undulating lower plain has an area of about
1,500,000m^2, with a maximum length of about 2,500 m in the SSW-NNE direction. It rises between 2-8 m above sea level. It is basically made up of medium and fine grained gravel with sand and a low silt content. Permafrost is characterised by its low subterranean ice content and the thickness of the surface layer that freezes and thaws seasonally (active layer) reaches between 1.5-1.7 m.

The temperature variations in this sector of the Antarctic Peninsula are directly related to the variable anticyclonic conditions during the year and to the moderating actions of the Weddell Sea. According to data obtained during the period 1967-1976[13] extreme temperatures reached an amplitude of 46°C. The absolute maximum was observed in August 1968 exceeding 12.6°C and the minimum was observed on February 12, 1972 with a record of –34.4°C. Average annual temperatures range between -8.5°C and -6.0°C with an average temperature of -6.8°C, average winter temperatures are around -16°C, and average summer temperatures between -1.5°C and –0.5°C.

Depending on the relief conditions of the area, two sectors of surface waters were determined. The first corresponds to the discharge areas of the ablation waters of the Rosamaría Glacier, during the ablation season. This sector can be divided into two water basins referring to the discharge of meltwater. The drainage network of each sector presents dendritic streams with poorly integrated drainage. The SEV data obtained in the sector of the discharge fan of the North stream indicate underground water discharge, corresponding to the formation of a phreatic aquifer in the area.

The second sector is located on the Petrel plain, which consists of a plain with smooth irregularities of a few m of unevenness, especially on its outer edges that border the sea and are eroded by several small dendritic streams. The regime of these streams is transitory, presenting flow only in summer times and according to the meteorological conditions that determine rainfall in this area.

The purpose of the studies was to determine the environmental and geotechnical conditions, and to analyze the possibilities of building airstrips in the flat area of Cape Welchness, on the informally called "Petrel plain", included within the zone of continuous permafrost, on the peninsula. Antarctica. This report presents the construction design of an airstrip in this sector, for which basic studies have been carried out, detailed and precise cartography was made in digital format, geocryological conditions were determined, and the guidelines of the Geotechnics in its various aspects. As a final result, the construction methods of the airstrip embankment in the permafrost zone are proposed, based on the use of local natural stone (aggregate) materials.

[13] The lack of permanent activity at the Base does not make it possible to have a longer time series of meteorological data.

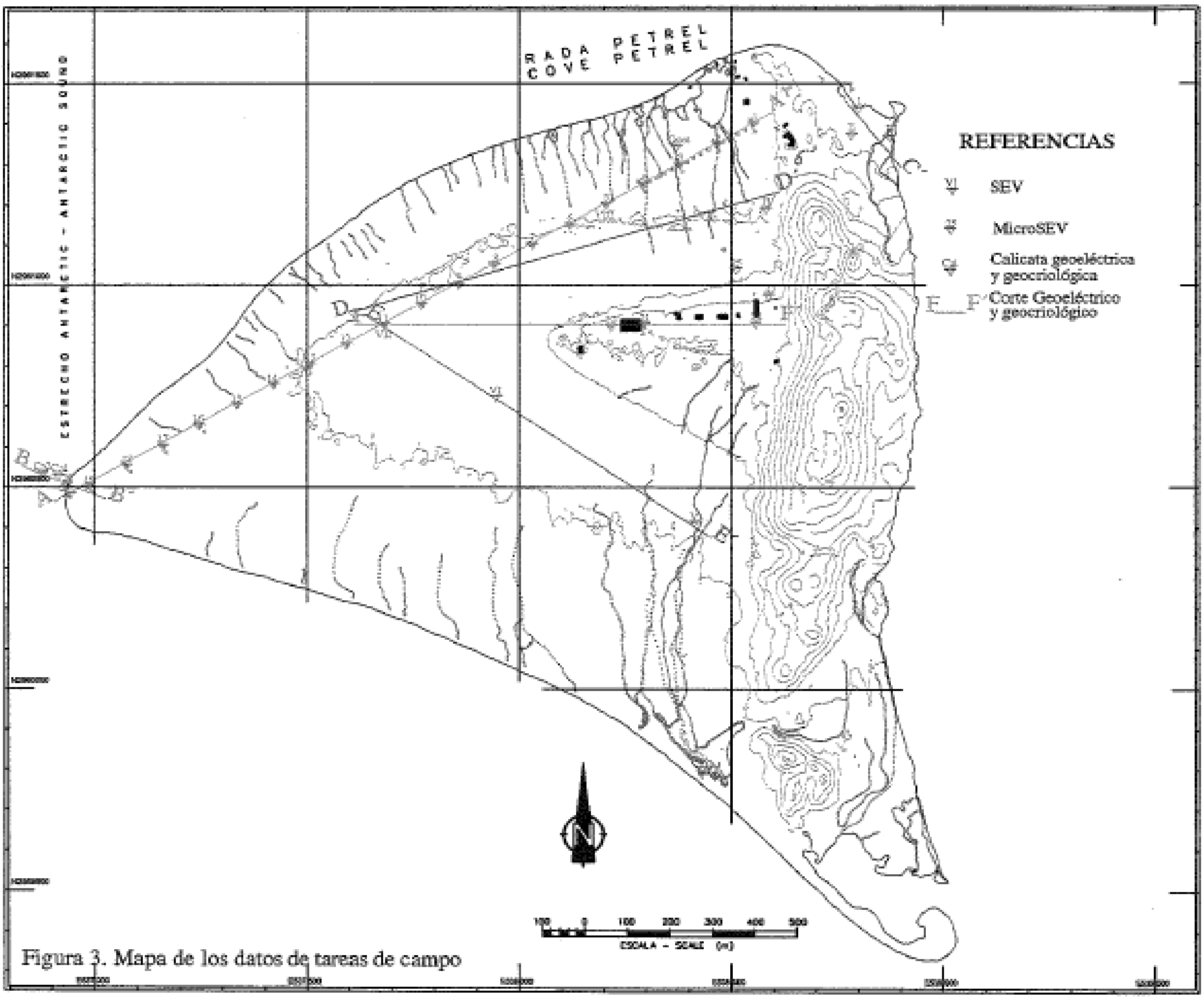


Figure 102: Map of the field task data.

The applied methodology is exploratory and descriptive, and is based on the rules and standards of prospecting and design applied to the construction of airport facilities in the permafrost zone proposed by Gosstroy (1977, 1978). The activities began with field research, then sampling, followed by laboratory analysis, to finally, in light of the results of these, make known the perspective and feasibility of the proposed project for the design of airport facilities in Cape Welchness. (Dundee Island, NE tip of the Antarctic Peninsula), and prepare a final report on the same subject (Figure 103).

field tasks

The field investigations consisted of the following tasks carried out within the zone affected by permafrost: 1) topographic mapping with GPS satellite positioning system,
2) obtaining of main geocryogenic and geotechnical parameters such as: granulometry of the clastic material, total water content in the soil (Wt), total ice content (Hs), and 3) determination of the structure and cryotexture of the active layer and permafrost ceiling, mean depth of freezing penetration, and seasonal thawing.

To this end, the topographic survey and detailed leveling of the area proposed to build the main runway, detailed geoelectric prospecting, and numerous test pits were carried out to analyze the cryogenic and geotechnical parameters of the active layer and the permafrost roof in this sector (Figure 103).

Likewise, samples of the clastic material of the different lithological units were taken to determine the feasibility of their use as aggregates in the construction of the runway embankment. To identify the geological units, the morphology and structure of the active layer and the permafrost, numerous Vertical Electrical Soundings (SEV) were carried out, consisting of a series of apparent resistivity determination□ (a), carried out with suitable geoelectric instruments, by separating increasing between the emission and reception electrodes (“AB”), with constant azimuth and the centre of the segment “MN” fixed, according to the method proposed by Orellana (1982).

The data from ρ_a obtained in each position were represented as ordinates, while the respective distances AB/2 were plotted as abscissas. The scales of both axes are logarithmic. The result is a curve called the “field curve” or “apparent resistivity curve” (ρ_a) that is related to the geoelectric behaviour of the subsoil immediately below the midpoint of the line.

Resistivity is a measure of the difficulty that electric current encounters in its path through a given material. The rocks behave as conductors of highly variable resistivity, mainly due to the fact that their pores are filled with fluids (air and water), coming from the thawing horizon or underground ice in the permafrost zone. The resistivity depends on various factors, one of which is the salinity of the water contained in the thawed sediments or the amount of ice contained in the permafrost. Other important factors, such as the type of sediment, have no influence when it comes to relatively constant areas with respect to lithological variations and without directional anisotropies as in the case at hand.

The electric current enters through an electrode (A), and produces an electric field that is measured by means of two other electrodes (M and N) connected to each other. The data is taken from the ground surface, and results in a “fictional” resistivity that will depend on the true resistivities of each layer and the distances between the electrodes. This quantity is known as the apparent resistivity (ρ_a) which is the experimental variable, which expresses the result of the measurements, and is taken as data for subsequent interpretation.

The purpose of obtaining the SEV is to find out the vertical distribution of layers with different resistivities below the point probed, starting from the field curve. The result is interpreted as a true resistivity curve that is suitable for the different work areas. The comparison of these graphs with others from neighboring boreholes is a method widely used in permafrost areas. This makes it possible to identify different horizons by superimposing records, and thus determine the stratigraphic, structural and geocryological characteristics of the subsoil, and the possible content of water or ground ice.

Laboratory work

The laboratory tasks consisted of tests to classify soils according to the HRB System or "Unified System", with tests to determine the granulometry, total humidity, and optimum humidity. The plastic properties and mechanical resistance of the frozen and thawed soil samples in the work area were also analysed. In addition, tests were carried out to determine the modification of the resistance in samples of aggregates selected as suitable materials for construction, depending on the temperature, humidity and eventual ice content.

The value of the shear resistance of a floor can be determined by means of "direct shear" tests, which is a triaxial test, or simply by measuring the resistance to penetration of the material. This last method, although it is empirical, is based on a number of works carried out both in laboratories testing clastic materials, as well as in the field, which makes it possible to consider it as one of the most feasible and widely used methods in the field. practice.

The determination of the mechanical resistance of frozen soils was carried out in the cold laboratory of LEGAN-DNA (Laboratory of Glacial, Water and Snow Stratigraphy, of the National Antarctic Directorate), in Mendoza, using a "ball penetrometer ” using for geotechnical investigations in the permafrost zone (Kudriavtsev 1961). It is an expeditious method to obtain the mechanical resistance in soils. The device consists of a 20 mm diameter steel ball that rests on the frozen soil sample and is subjected to a 10 kg load for a determined time, or is dropped from a height of 1.0
m. In this test, the relationship between the depth of the mark produced in the frozen soil and the value of mechanical resistance is established.

In the present work, the systematisation of HRB soils was used. The method is shown in Table 11, and allows classifying soils in permafrost or deep seasonal freezing zones.

Table: Soil classification for designs in permafrost zones (based on United Soil Classification System, Corps of Engineers and Bureau of Reclamation, Hennion and Lobaz, 1973). G: Gravel; S: Arena; C: Clay; P: poor selection; W: Good selection; H: High; M: Medium, L: Low

Classification according to reaction to freezing	**Types of soil**	**Weight percentage of particles < 2 mm**	**Typical Soil Types**
F 1	It's important	3-10	GM, GP, GW-GM, GP-GM
F 2	It is important to be sandy	10-20 3-15	GM, GW-GM, GP-GM SW, SP, SM, SW -SM, SP-SM
F 3	Limo-Arena is important	about 20 about 15	GM, GC SM, SC
F 4	clays Silts in general Sandy silts	About 15	CL, CH ML, MH SM
F5	clays, sediments fine grained in layers or bands		CL, CL-ML, CL y ML, CL, CH y ML, CL, CH, ML y SM

Interpretations of geoelectric prospecting and geocryological conditions in the petrel plain

The location of the SEVs was carried out in the most favourable areas according to the physiography of the land, the geological characteristics and the possibilities of construction of future airstrips and logistics facilities (Figure 102). The deep SEVs carried out are enough to support a first approximation of the general characteristics of the permafrost and the geological stratigraphy, being of value because they allow to interpret the arrangement of the resistive levels in depth and to correlate them areally with each other.

The purpose of the microprobes is to support geotechnical studies for the design and construction of the runway and future facilities. A total of 8 vertical electrical soundings of 320 m AB/2 maximum with 15 logarithmic projection points were carried out, they were carried out in the areas where it was possible. In addition, 26 SEVs were carried out with applications for microgeoelectrics with a maximum AB/2 of 30 m with 12 arithmetic projection points, of which SEVs 1 to 19 were carried out in the runway project area in a rectilinear profile every 100 m of distance. separation and leveling with the purpose of supporting the geotechnical study.

A microprobe and two electrical test pits were also carried out in outcrop areas or particular geoforms that are of importance for the understanding of cryogenic and hydrogeological processes. The electrical test pits were made with an AB/2 of 10 m, considering an approximate penetration of 2 to 2.5 m. The coordinates of the SEVs are detailed in the following tables 12 and 13.

Table: Location of vertical electrical macro-soundings AB/2=320m

SEV N°	Latitude	Length	Quota	Place
I	63 28 24	56 13 16.8	1	Costa A° Gabriela Maria
II	63 28 26.1	56 13 18	4	Costa A ° Gabriela Maria. Forehead Brunette
III	63 28 26.2	56 13 11.5	3	Costa A ° Gabriela Maria. glacier front
IV	63 25 32.1	56 13 32.4	10	Place for artificial lagoon. Fund
V	63 28 57.3	56 13 43.8	5	West of the southern beacon plain
VI	63 28 47.4	56 14 17.8	6	Between the south beacon and the hangar
VII	63 28 41.7	56 14 37.8	4.39	On runway at stake 11
VIII	63 28 31.9	56 13 59.7	6.43	On runway at stake 5

Table: Location of microprobes AB/2=30m.

SEV N°	Latitude	Length	Quota	Place
1	63 28 25.3	56 13 34.8	2.61	Runway Stake 1
2	63 28 27.4	56 13 41.1	1.24	Runway Stake 2
3	63 28 28.6	56 13 47.3	2.49	Runway Stake 3
4	63 28 30.2	56 13 53.5	3.26	Stake Runway 4
5	63 28 31.9	56 13 59.7	4.39	Stake Runway 5
6	63 28 33.5	56 14 5.9	5.08	Runway Stake 6
7	63 28 35.2	56 14 12.1	6.05	Runway Stake 7
8	63 28 36.8	56 14 18.4	6.12	Runway Stake 8
9	63 28 38.5	56 14 24.6	5.88	Runway 9 Stake
10	63 28 40.1	56 14 30.8	6.06	Runway Stake 10
11	63 28 41.7	56 14 37.8	6.43	Runway 11 Stake
12	63 28 43.4	56 14 43.3	5.86	Runway Stake 12
13	63 28 45.7	56 14 49.5	5.28	Runway Stake 13
14	63 28 46.7	56 14 55.7	4.45	Runway Stake 14
15	63 28 48.3	56 15 2.1	4.27	Runway Stake 15
16	63 28 50.9	56 15 8.2	3.47	Runway Stake 16
17	63 28 51.6	56 15 14.4	2.8	Runway Stake 17
18	63 28 53.2	56 15 20.6	2.29	Runway Stake 18
19	63 28 54.9	56 15 26.9	1.68	Runway Stake 19
20	63 20 41.1	56 14 9.0	18	South shed door terrace
21	63 28 40.2	56 13 50.0	16	hangar door terrace
22	63 28 40.0	56 13 43.2	16	terrace antennas
23	63 28 39.1	56 13 31.7	13	burnt base terrace
24	63 28 53.8	56 15 26.9	2	South beacon runway
25	63 28 37	56 13 37.2	12	west underground
26	63 28 53.2	56 15 26.2	0	Shore-tidal line
a house	63 28 27.2	56 13 47.9	3	Coastal stream stake 3
Ca1	63 28 51.7	56 15 29.5	0	Triassic Shale Outcrop
Ca2	63 28 51.5	56 15 32.2	0	Triassic Shale Outcrop

Long boreholes were conducted to determine the stratigraphic succession of the local geologic units and the general morphology of the permafrost. The microprobes were carried out to determine the characteristics of the active layer, suprapermafrost aquifer, structure of the upper part of the permafrost and geotechnical characteristics of the frozen and thawed soils. The curves obtained were interpreted based on the field information recorded from the mentioned SEVs. To facilitate the interpretation, the information taken in the SEV macro-soundings between I-VIII will be analysed and finally the micro-soundings that correspond to SEV 1 to 26 will be interpreted.

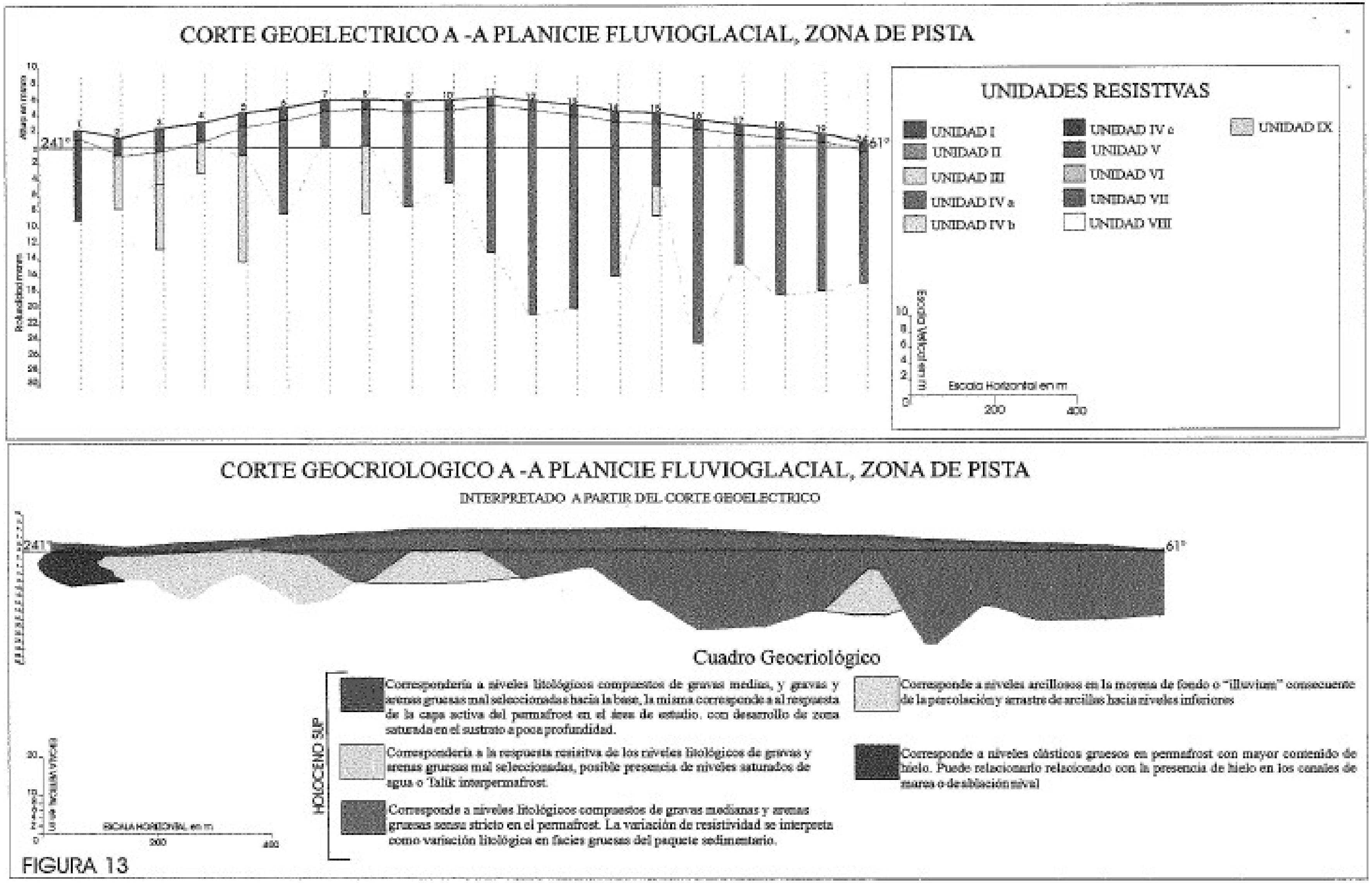


Figure 103: Cross section along transect A-A'

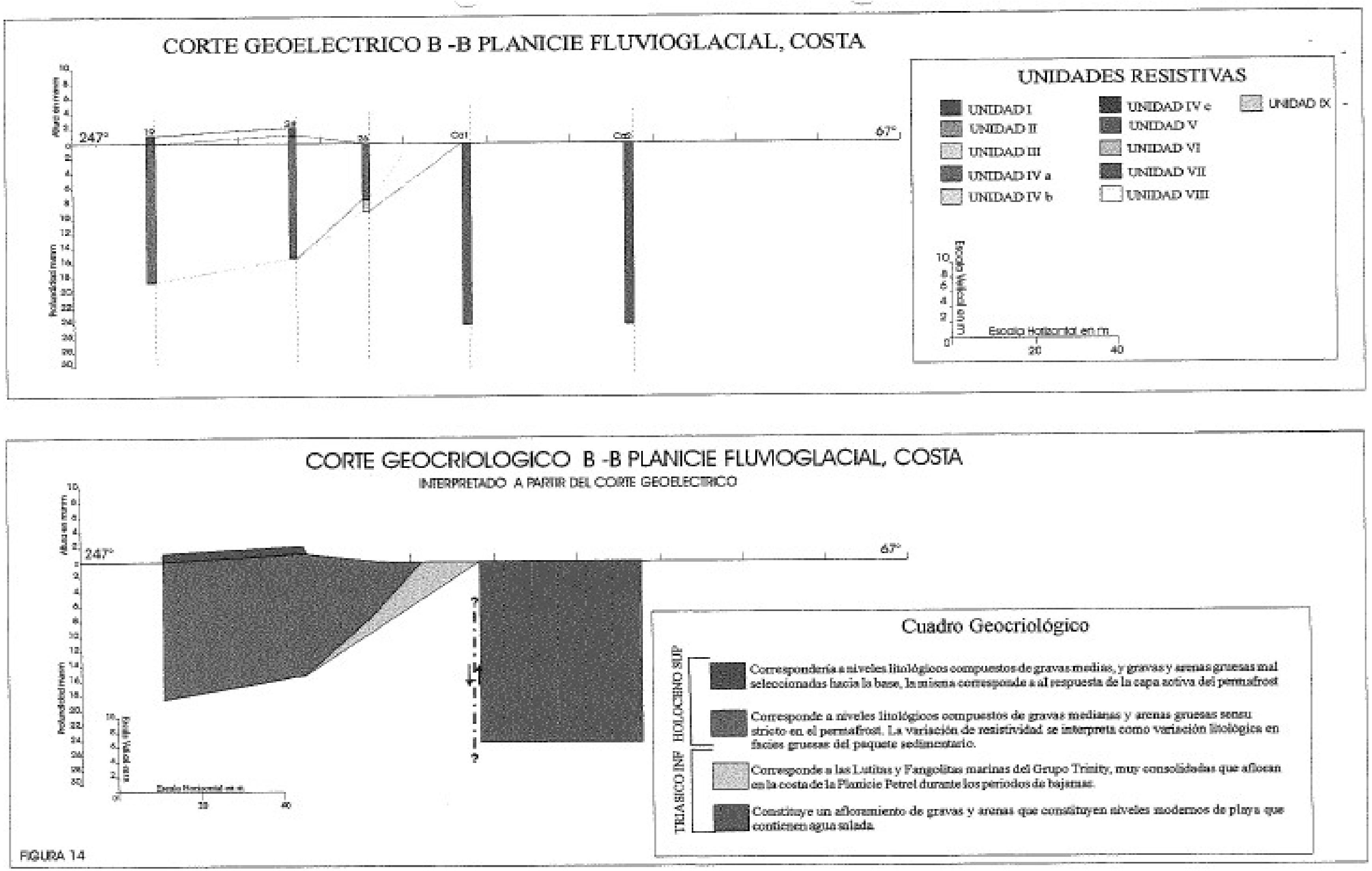


Figure 104: Cross section along transect B-B'

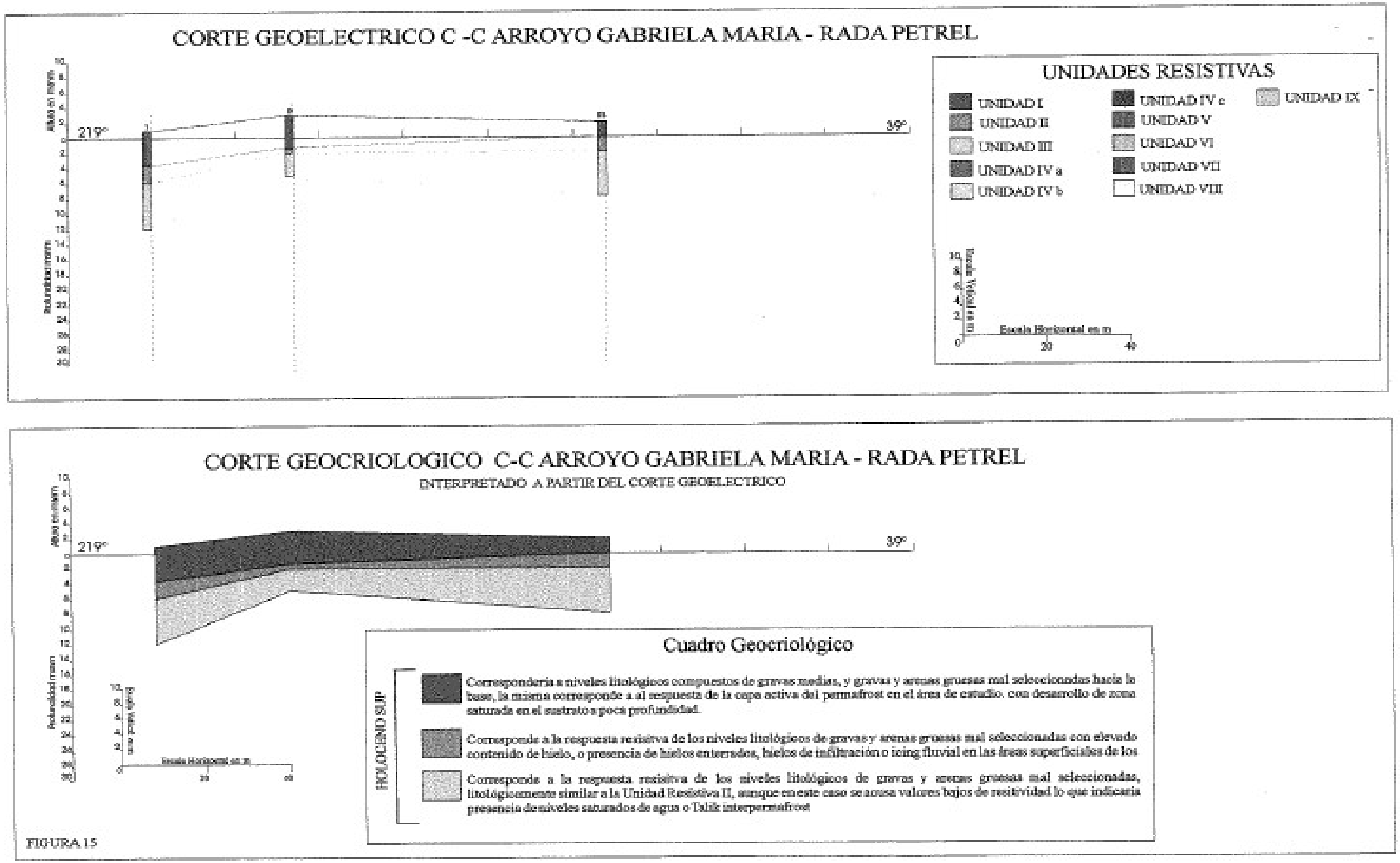


Figure 105: Cross section along transect C-C’

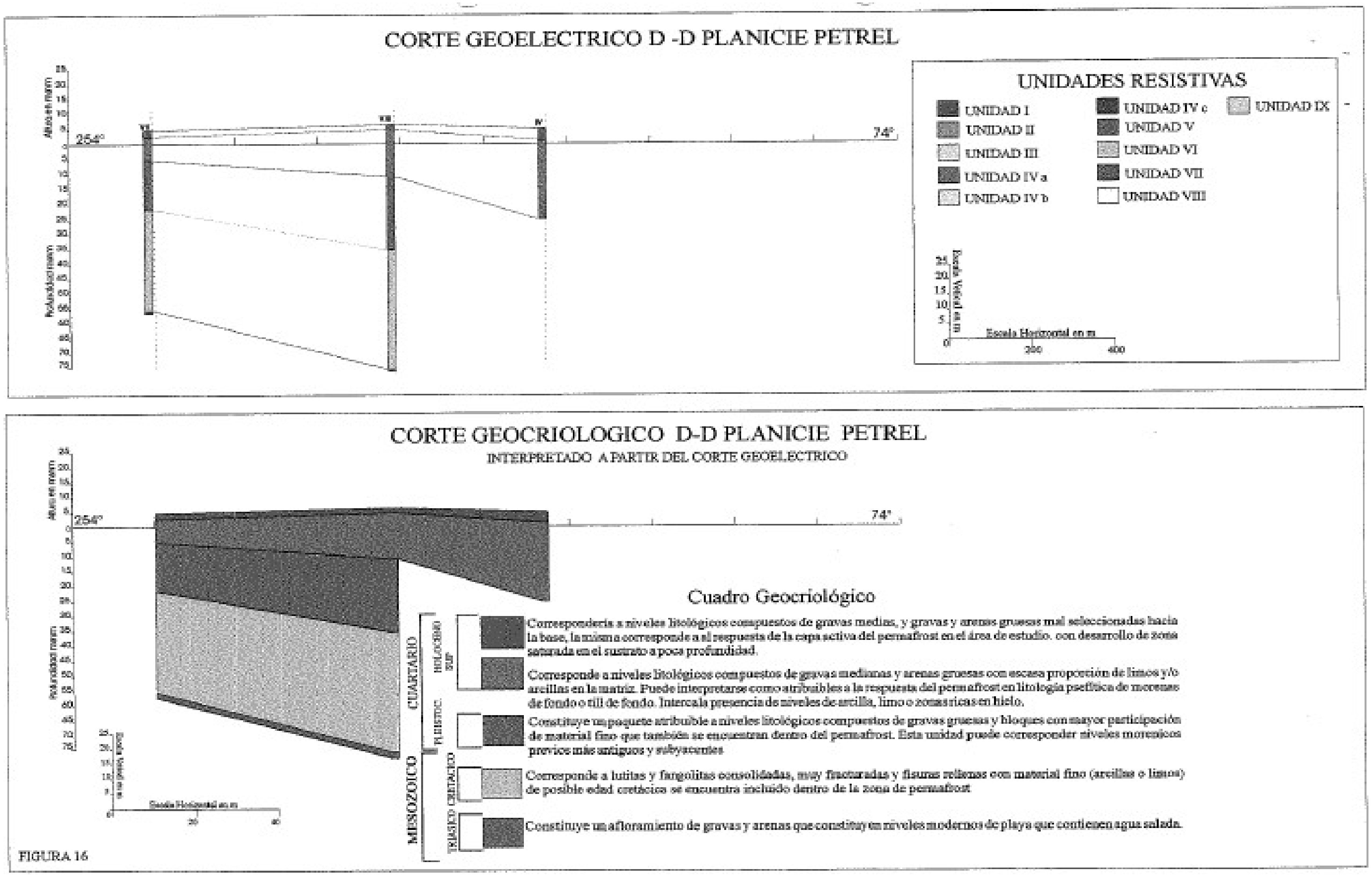


Figure 106: Cross section along transect D-D'

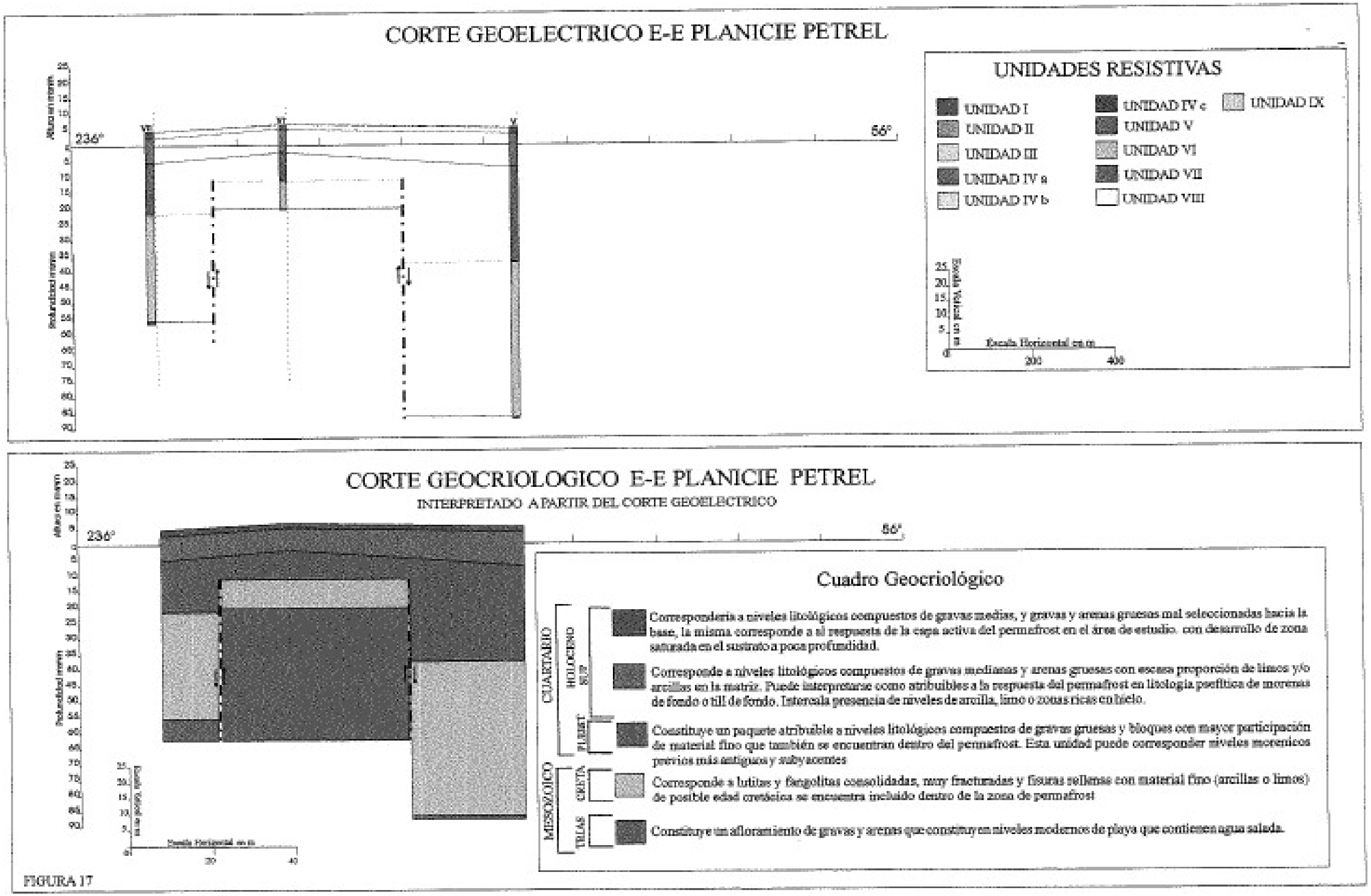


Figure 107: Cross section along transect E-E'

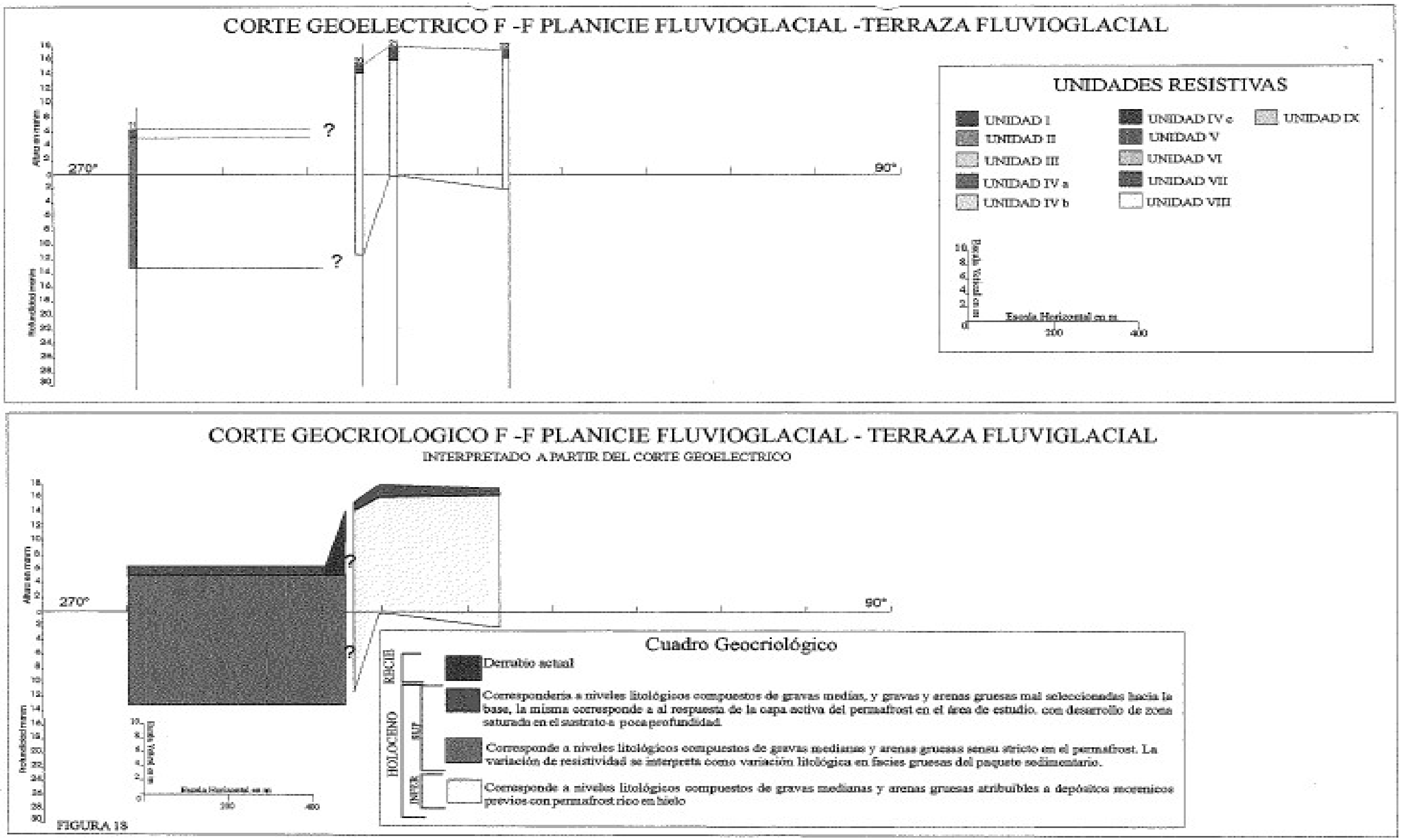


Figure 108: Cross section along transect F-F'

Interpretation of SEVs from macro-soundings

In this area, five resistive units were identified in depth according to table 14:

Table: The characteristics of the resistive units of the macro soundings: thicknesses, resistivities and depths

Thickness approx. (m)	resistivity ohm.m	Depths approx. (m)	Unit
1.57'4.68'	584.47-3089.80.	1.57'4.68'	I
3.93'10.58'	1550.58'6656.77'	5.5'15.26'	II
10.0'18.90'	18.46'143.41'	15.5'34.17'	III
7.08'26.26'	141.56'271.29'	8.65'30.94'	IV
9.24'30.15'	238'528.62'	17.89'61.09'	V
12.97'51.58'	65.88'132.04'	30.86'112.67'	VI
?	1762.13'9895.61'	?	VII

From this we will interpret the following characteristics as possible:

RESISTIVE UNIT I: It corresponds to lithological levels composed of medium gravel, and badly selected gravel and coarse sand towards the base, in general it includes areas of good porosity and permeability. They constitute a set of fluvioglacial and glacial deposits that, considering the lithology of this unit and the resistivity values, allow us to interpret that it corresponds to the response of the active layer and the permafrost roof in the study area. In the SEV carried out towards the area of Rada Petrel (A° Gabriela María), SEV I, II and III, the lowest resistive values between 584.47 - 1035.98 ohm.m are observed, which would indicate an active layer with development of a saturated zone in the shallow substrate. The active layer can allow the development of suprapermafrost waters or surface runoff water infiltration from the channels.

As observed in SEV IV, V, VI, VII and VIII, the resistivity values are higher (between 1415.62-3049.80 ohm.m) and the resistive unit has less thickness (between 1.57 -2.08m) this can be related to the thicker and better selected granulometry of the fluvioglacial unit and the low subterranean ice content in the upper strata of the permafrost (dry permafrost) being able to develop an active layer of up to 1.5 mbbp that eventually contains the unsaturated zone or saturated suprapermafrost levels.

RESISTIVE UNIT II: Determined only in the area of Rada Petrel on the channel of A° Gabriela María in SEV I, II and III and would correspond to the resistive response of the lithological levels of badly selected gravel and coarse sand with high interstitial subterranean ice content, or presence of buried glacier ice, infiltration ice or fluvial icing in the superficial areas of the riverbeds and even latent ice. It is also part of a set of fluvioglacial deposits that contains permafrost with resistivity values between 1550.58 - 6656.77 ohm.m and thicknesses between 3.93 - 10.58 m, being more powerful in SEV I near the coast. Resistivity variations may indicate changes in interstitial ground-ice content by clastic sediments.

RESISTIVE UNIT III: This unit was also determined only in the area of Rada Petrel on the channel of A° Gabriela María in SEV I, II and III and would correspond to the resistive response of the lithological levels of poorly selected gravel and coarse sand, lithologically similar to the previous Resistive Unit II, although in this case there are low resistivity values between 18.46 - 143.41 ohm.m, which would indicate the presence of saturated water levels or zones of the development of talik interpermafrost in the ablation water discharge sector. This unit has a thickness between 10.0 – 18.90 m. SEV II and III would contain fresh water with resistivities of 143.41 and 52.67 ohm.m and SEV I salty/brackish water with resistivities of 18.46 ohm.m, thus describing a wedge or interface of salty water towards the continent.

RESISTIVE UNIT IV: It corresponds to lithological levels composed of medium gravel and coarse sand with a low proportion of silt and/or clay in the matrix. They are geological units of glacial origin with very continuous and characteristic resistivity values between 141.56 - 271.29 ohm.m recorded in SEV IV, V, VI, VII and VIII with variable thicknesses between 7.08 - 26.26 m that can be interpreted as attributable to the response of permafrost in psephitic lithology of bottom moraines. The resistivity variation is not significant, which shows lithological continuity of the sedimentary package; although the thickness variations are more significant, increasing its thickness in SEV IV and VIII. The presence of levels of clay, silt or areas rich in ice is expected in this unit, which microprobes allow to determine with more precision.

RESISTIVE UNIT V: Verifiable in all the boreholes of the plain zone and Rada Petrel, it constitutes a very continuous and characteristic resistive package with resistivity values that oscillate between 238 - 528.62 ohm.m and would be attributable to lithological levels composed of coarse gravels and blocks with a greater participation of material. fine (as could be observed in geological profiles near the coast) that are also found within the permafrost. This unit may correspond to levels of the oldest previous glacial sediments underlying those observed to emerge on the Petrel plain.

The resistivity variations may correspond to lithological changes and fundamentally to changes in the total ice content at depth. Its thickness is highly variable and oscillates between 9.24 - 30.15 m, being less powerful where the underlying units have higher structural heights, as observed in SEV VI located off Cape Welchness. Part of this and the large erratic blocks outcrop on the coast during the downpours of the sea and seem to rest on the well-consolidated levels of marine shales and mudstones of the Trinity Group of Triassic age.

RESISTIVE UNIT VI: This resistive horizon has been verified in the deepest soundings in the area of the Petrel plain corresponding to SEV V, VI, VII and VIII. Said unit is located within the permafrost zone and has lower resistivity values between 65.88 - 132.04 ohm.m and thicknesses that oscillate between 12.97 - 51.58 m. Outcrops of consolidated shales and mudstones, highly fractured and fissures filled with fine material (clay or silt) of possible Cretaceous age, have been verified on the west ravine of the fluvioglacial terrace and in the moraines with an ice core. For this reason, its presence in the deep geological record in the Petrel plain area is inferred and the resistive response of this unit is attributed to it. As in the previous resistive unit, there is a reduction in thickness in the vicinity of SEV VI located off Cape Welchness as a result of the possible structural control of the 80°N (NE) course of the marine shales and mudstones of the Trinity Group.

RESISTIVE UNIT VII: This resistive horizon, like the previous one, has been verified in the soundings of the Petrel plain area corresponding to SEV V, VI, VII and VIII. It has high resistivities, between 1762.13 - 9895.61 ohm.m, constituting a layer that underlies the previous units. The marine shales and mudstones of the Trinity Group crop out on the coast of the Petrel plain during low tide periods and constitute a group of highly consolidated and impermeable rocks that show evidence of glacial erosion (striations).

Two geoelectric test pits have been made directly on the exposures of the Trinity Peninsula Group at low tide, measuring resistivity values of 69.76 - 89.14 ohm.m in the first 2.5 m of depth. This variation in resistivity is explained by the intense fluvioglacial erosion of the outcrop surface and the presence of salt water in the fissures that decreases the resistivity, although it still constitutes a high value for these conditions. This unit has a main fault direction of 80°N (NE) measured off the coast of Cape Welchness. The resistive response of this unit is attributed to this lithology, which has variations in its structural height, being higher in SEV VI and controlling the overlying clastic sequence.

Interpretation of SEVs from microprobes

The purpose of the microprobes was to carry out a detailed recognition of the first geological levels of Quaternary age, the morphology and structure of the active layer, the development of the unsaturated zone, possibly the suprapermafrost aquifer, the saline interface and the structure of the terrace. fluvioglacial. The places chosen to carry out microprobes were carried out due to their geological and geomorphological location in the study area, generally in the landing strip construction sector.

In addition, they have been used for the recognition of geoforms or specific processes. New resistive units and subunits have been recognised in particular those related to resistive unit I and IV; eventually the resistive unit V when it was reached in depth with the main objective of resolving in this phase of the study the main lithological and geocryological characteristics of the construction area of the future landing strip and supporting civil works. Table 15 details the characteristics of the resistive units and subunits:

Table: The characteristics of the resistive units and subunits: Thicknesses, resistivities and depths

Thickness approx. (m)	resistivity ohm.m	Depths approx. (m)	Unit
1.12'2.39'	1179.91'8091.13'	1.12'2.39'	I
4.92'6.64'	50.0-59.98.	Intercalation	III
7.30'26.90'	112.00'519.90'	8.42'29.29'	IVa
3.80'8.63'	26.82'107.19'	Intercalation	IVb
2.5'10.62'	2069.93'6212.00'	Intercalation	IVc
see macrosoundings	305.08'808.06'	17.89'61.09'	V
7.13'25.40'	1134.75'5959.92'	8.25'27.79'	VIII
1.28	6.19	1.28	IX

RESISTIVE UNIT I: This unit, as in the macro-soundings, corresponds to lithological levels composed of medium gravel, and poorly selected gravel and coarse sand towards the base, generally comprising areas of good porosity and permeability. They constitute a set of fluvioglacial and glacial deposits that, considering the lithology of this unit and the resistivity values, allow us to interpret that it corresponds to the response of the active layer of permafrost in the study area. The microprobes carried out show that the resistivity values in the Petrel plain area (road project) are comparable with the macroprobes with resistivity values between 1179.91–8091.13 ohm.m and thicknesses between 1.12–2.39 m than in SEV 2, 3 with resistivity values between 4000-6000 ohm.m there may be high interstitial ice content due to temporary courses resulting from snow ablation.

SEVs 20, 21, 22 and 23 carried out on the fluvioglacial terrace show similar values to those carried out on the fluvioglacial plain.

RESISTIVE UNIT III: In SEV 2 and 3, a layer with resistivities between 50.0–59.98 ohm.m and thicknesses between 4.92–6.64 m is observed at a depth of 2.06 mbbp, the case of SEV 3 at 25 or 30 m from injection dome. Particularly significant in this unit is the presence of injection domes (see SEV Dome) that present a horizon of 4131.57 ohm.m at a depth of 1.01 m and 1.04 m thick attributable to the presence of infiltration ice in the sediments. Because the latter is evidence of suprapermafrost groundwater and the proximity of snow channels, it is considered that this response corresponds to suprapermafrost aquifer levels in fluvial or fluvioglacial deposits and has been identified as correlative to Resistive Unit III.

RESISTIVE UNIT IV: This unit is recognised in microprobes with greater detail and resolution, being able to divide three resistive subunits IVa, IVb and IVc. The entire unit is of glacial origin and in general the IVa resistive subunit corresponds to lithological levels composed of medium gravels and coarse sands sensu stricto in the permafrost whose resistivity ranges between 112.00–519.90 ohm.m and continuous. The resistivity variation is interpreted as lithological variation in coarse facies of the sedimentary package. SEV 24 carried out on the fluvioglacial plain in the coastal ravine presents a second resistive horizon of 62 ohm.m and 16 m thick, attributable to the response of Holocene moraines, without ice or permafrost but with ingress of salty sea water. SEV 26 was carried out on the coast in the intertidal zone at the foot of the ravine and presented a resistivity of 45 ohm.m and a thickness of 7.30 m, which also indicates ingress of marine salt water.

The resistive subunit IVb and IVc are discontinuous and intercalated within this sedimentary package with permafrost. The IVb resistive subunit has resistive values that oscillate between 26.82–107.19 ohm.m and thicknesses between 3.80–8.63 m, being observed in SEVs 4, 5, 6, 7, 8, 9, 13, 15, 16, 17, 18 and 19. This resistive horizon has been interpreted as a clayey level in the bottom moraine or "illuvium" resulting from the percolation and dragging of clays towards lower levels normally with resistivities of 40-60 ohm.m. This can be seen as shallower levels in SEV 4; and as deeper levels in SEVs 6, 7, 8, 9, 13, 15, 16, 17, 18 and 19. In the particular case of SEV 24, this resistive horizon has values of 3 ohm.m or less and is considered to be the response of the clayey levels in the bottom moraines or "illuvium" that has less resistivity due to the entry of the saline interface of the sea in clays that per se have low resistivity. In SEVs 1, 10, 11, 12, 13, 14 and 26 this resistive horizon is not observed.

The resistive subunit IVc has resistive values calculated between 2069.93–6212.00 ohm.m and in general of little thickness between 2.5-10.62 m. This subunit is clearly observed in SEVs 1, 8, 11 and 14 and is interpreted as thick clastic levels in permafrost with higher ice content. Except in SEV 1 where it is found at a shallow depth, probably related to the presence of ice in tidal channels or snow ablation, in the others it is found towards the base of resistive unit IV almost in contact with resistive unit V.

RESISTIVE UNIT V: This unit has been recognised with the use of macro soundings in the entire study area in the Petrel plain and Rada Petrel. Micro-soundings SEV 10, 12 and 15 on the plain, SEV 26 on the coast, SEV 25 on the glacial subterrace and SEV 20, 21, 22, 23 on the fluvioglacial terrace have reached this resistive horizon at depths less than 25 mbp. Here a very continuous and characteristic resistive package is also verified with resistivity values ranging between 305.08–808.06 ohm.m that would also be attributable to lithological levels.

Composed of coarse gravels and blocks with a greater participation of fine material and found within the permafrost. This unit may correspond to previous, older moraine levels and underlying those observed outcropping on the Petrel plain and it has also been verified that they underlie the sediments of the fluvioglacial terrace with resistive values between 211.36–534.52 ohm.m and in the The coast is shallow and has resistivities of 11.02 ohm.m as a result of the marine salt water interface.

RESISTIVE UNIT VIII: This resistive unit has been determined at the top of the fluvioglacial terrace based on the interpretation of SEVs 20, 21, 22 and 23. It has resistive values that oscillate between 1134.75–5959.92 ohm.m and thicknesses of 7.13–25.40 m. The unit is considered to be of glacial origin and generally corresponds to lithological levels composed of medium gravel and coarse sand in the permafrost whose resistivity can be interpreted as levels with ice-rich permafrost attributable to morainic deposits prior to resistive unit IV and more. modern than the resistive unit V of possible lower Holocene age.

RESISTIVE UNIT IX: Only verifiable in SEV 26 in the intertidal zone is recognised as the first resistive horizon of 6.19 ohm.m and 1.3 m thick. On the coast there are outcrops of thick facies that constitute modern beach levels that contain salt water.

Correlation with the geology, hydrogeology and geocryology of the study area

Based on the interpretation previously presented for the different resistive units, a geocryological characterisation for the region can be carried out according to geological criteria. Figures 104 to 109 show the geoelectric and geocryogenic sections corresponding to the regional distribution of the lithological components, morphology and structure of the permafrost in the study area.

Active Layer and Suprapermafrost Processes

Throughout the study area, it has been interpreted that the active layer and the suprapermafrost processes are involved in the response of the resistive unit I. The latter has been verified in all the macro- and micro-soundings carried out. The thickness of the active layer is relatively constant throughout the Petrel Plain area and reaches a maximum of 1.5 m, being a little deeper towards the Petrel Rada area due to the influence of fluvioglacial processes (Sev I, II and III;SEV 3).

Due to the low moisture content, the permafrost is considered to be of the dry type, where an unsaturated zone is observed up to the top of the permafrost, except in those boreholes where suprapermafrost or closed talik water is found, as can be seen in SEV I, II and III and SEV 3. The active layer is no thicker than 1.46 m with a low moisture content, which is indicated in the microprobes, including the resistive unit I, difficult to identify due to its low moisture content. In the fluvial channel areas, resistive horizons related to suprapermafrost water can be interpreted, defined in resistive unit III with very shallow depths starting at 2 m, which can reach up to 7 m deep in some cases, and may constitute interpermafrost levels. . The existence of injection domes at a depth of 1.01 m in a resistive horizon of 4131.57 ohm.m and 1.04 m thick is attributable to the presence of seepage ice in the sediments. Because the latter is evidence of suprapermafrost groundwater and the proximity of snow channels in fluvial or fluvioglacial deposits, and it has been identified as correlated with resistive unit III.

current beach deposits

The beach deposits are observed in the coastal area, on the intertidal line at the foot of the ravine and includes a permafrost-free zone due to the thermal effect of the sea shield. It is recognised as the first resistive horizon of 6.19 ohm.m and 1.3 m thick and deep on the coast where outcrops containing salt water are observed.

Current ice-cored moraines

In the area of the lateral moraines of the Rosamaría glacier, whose base is found from 10 m above sea level (asl) and which reaches a maximum height of 66 m asl, buried ice is observed from depths between 1, 5-0.7 m covered by poorly selected coarse gravel with erratic blocks. Since these units are not the object of study, no surveys were carried out in them. From observations and experience in similar units in the region, very high resistivity values are inferred, greater than 50,000 ohm.m in the first metres and even higher at depth.

Fluvioglacial deposits on bottom moraines and moraine terrace

This geomorphological and lithological unit has been interpreted as included within resistive units I, II and VIII, although its lithological composition is similar and basically consists of medium and fine gravel with low sand content, and without silt and clay. The resistivity of this unit varies depending on its ice content.

In the Petrel plain area, the fluvioglacial levels are superimposed on the bottom morainic deposits in the entire area of the runway construction. They reach a depth of 1.44 m, and have an equivalent thickness. Within them the active layer of permafrost develops and Resistive Unit I is considered as a characteristic of them. On the coast of the Petrel bay, in the A° Gabriela María, fluvioglacial deposits are more powerful and extend in depth up to 2.00-4.98 m, attributable to Resistive Unit I, and underlie morainic levels rich in ice , which were reworked by fluvioglacial action and are part of the permafrost, and can reach between 5.93–15.26 m deep.

On the moraine terrace, the fluvioglacial levels are found at the top of the sequence with thicknesses and shallow depths between 1.12-1.85 m, and are similar in composition to the plain levels, which in summer contain the layer active. The subterrace presents similar characteristics.

Bottom moraines of Upper Holocene age

In the Petrel plain area, bottom moraine deposits (Upper Holocene) underlie the previous sequence. These form the permafrost zone that presents a resistive response attributed to the Resistive Unit IV in the macro-soundings, and the Resistive Subunit IVa in the micro-soundings, where lithological and ice content variations were identified, such as those indicated in Resistive Subunits IVb and Ivc (Figures 104 to 109).

These deposits are characterised by thick clastic fractions (gravels, blocks) with low clay and silt contents, although they have finer facies intercalations. From the macrosoundings, the sedimentary thickness of this unit was estimated between 10–26.6 m with an average of 13.5 m and a depth of the base estimated at 8.65–30.8 m, with an average depth of 15, 63 m. These values include the resistive responses IVa, IVb and IVc interpreted in the microprobes where the IVa subunit corresponds to "washed" bottom moraine deposits without fine material. The IVb subunit corresponds to very thick clayey levels.

Variable between 3.8-13.2 m with an average thickness of 7.7 m, with depths of 5.02-15.59 m and an average depth of 10.42 m, normally towards the base of the sequence. This resistive horizon has been interpreted as a clayey level in the bottom moraine or "illuvium" resulting from the percolation and dragging of clays towards lower levels. Lastly, the IVc subunit, which is commonly found towards the base of the sequence, has thicknesses measured in a single sounding (SEV 1) of the order of 10 m to 11 m depth; it has been interpreted as variations in the ice content and resembles its response to that of resistive unit VIII (bottom moraine rich in ice). Toward the base, the Unit V resistive response, attributable to Pleistocene bottom moraines, underlies the sequence.

Lower Holocene moraine terrace

The moraine terrace is a 10-12 m high topographical peak located in the Cape Welchness area between the lateral moraines and the Petrel Plain. This unit was explored with microprobes, the response of resistive unit VIII is attributed to it with an average thickness of 16.8 m, with oscillations between 7.13–25.4 m, and an average depth of 18.3 m that oscillates between 8.5-26.8 m from the surface of the unit. It is made up of thick clastic fractions, gravel, blocks and with low clay and silt contents, although with rich levels of ice that give it greater resistivity. Towards the base, the resistive response of Unit V, attributable to Pleistocene bottom moraines, underlies the described sequence. The sub-terrace constitutes a small topographic step to the north with values very similar to those of Resistive Unit IV, probably due to its lower subterranean ice content.

Bottom moraines of Pleistocene age

This unit is very continuous throughout the study area and underlies the entire Quaternary sequence described above. This unit has been recognised with the use of macro soundings in the entire study area in the Petrel plain and roadstead, and with micro soundings in the area underlying the moraine terrace (Figures 104 to 109). This moraine outcrops on the coast at low tide, and is made up of coarse gravel and blocks with a greater share of fine material. These materials are found within the permafrost in the emerged zone. This moraine is the oldest in the work area, it is presumably Pleistocene in age and is correlated with the response of Resistive Unit V, which is recognizable in the macro and micro soundings with mean thickness values of 20.4 m that oscillates between 9, 24–30.15 m, found to an average depth of 32.4 m (between 17.9–42.7 m). It constitutes the substratum of the Holocene bottom moraines in the fluvioglacial plain and the morainic terrace. In the coastal area, it has been verified that it forms the substrate for recent marine beach sediments exposed on the current coast.

Cretaceous sedimentary rocks

These sedimentary rocks were studied by Ramos et al. (1978), who assigned them to the Larsen Basin sedimentary fill (del Valle et al. 1992), and attributed a Lower Cretaceous age to them. They form a relatively thin sedimentary package, compared to other locations in the Larsen Basin, and appear discontinuously in the study area in the east-southeast ravine of the fluvioglacial terrace (approximately 15 m asl) and on the eastern flank of the moraines. sides (approximately 35 m asl). They are formed by fine sandstones and consolidated mudstones, intensely fractured and jointed. Its presence in the deep geological record in the Petrel plain area is inferred and the resistive response of Resistive Unit VI is attributed to it, with an average thickness of 34.4 m and thicknesses that vary between 12.97–51.58
m. It is possible the occurrence of the base of this package in the sedimentary record at depths

averages of 66.8 m from the surface, varying between 30.8-93.8 m in depth as a consequence of the possible structural control exerted by faults arranged in a N 80° (ENE) direction, such as those that affect the marine sedimentites of the Trinity Group Peninsula on the tidal flat surrounding Cape Welchness. The Cretaceous rocks are included within the permafrost in the study area.

Triassic Sedimentary Rocks

Fine-grained marine sedimentary rocks belonging to the Trinity Peninsula Group are exposed during low tide periods on the marine abrasion shelf surrounding Cape Welchness. These rocks are very well consolidated and show evidence of glacimarine erosion (striations). They correlate with Resistive Unit VII, whose base is at an indeterminate depth. It presents the main direction of fracturing and faulting in a N 80° (NE) direction, observed about 200 m away from the western coast of Cape Welchness. Variations in the resistive response of this unit are attributed to internal lithological differences, and to variations in its structural height that control the position of the Cretaceous succession.

geotechnical study

To determine the design and construction style of the airstrip in the permafrost zone it is necessary to establish the following data: 1) mechanical properties of the foundation soils and construction aggregates, 2) total water content (Wt) of the frozen and thawed soils, 3) total ice content (Ht) of the seasonally frozen layer and the top of permafrost, and 4) regulatory depth of seasonal thawing for construction aggregates.

To assess the potential for static and dynamic loading of the runway pavement it is necessary to know the thermal and mechanical properties of the frozen and thawed soil, eg thermal conductivity, mechanical resistance, thawing settlement. In addition, to carry out maintenance tasks on the runway and design its drainage, it is necessary to evaluate the foreseeable changes in geocryological and geotechnical conditions in the construction sector, where the original surface conditions will be modified.

Soil mechanical properties

The original clastic soils usable as a subgrade support or foundation ground in the area of the runway construction have been examined. All test pits and boreholes were carried out along profile A-A´ (Figures 104: runway axis) up to 0.6 m deep. The Figure 109110 shows the variations of the granulometric properties of the soils in this sector. It is observed that the superficial soils up to 0.3 m deep present fractions of gravel and coarse and medium sand, and in the depth interval 0.3-0.6 m the increase of fine fractions (medium and fine sand) is observed. . This inverse vertical selection phenomenon in the active layer of detrital material is explained by the seasonal freezing and thawing processes and unequivocally indicates the implantation of permafrost in the soil.

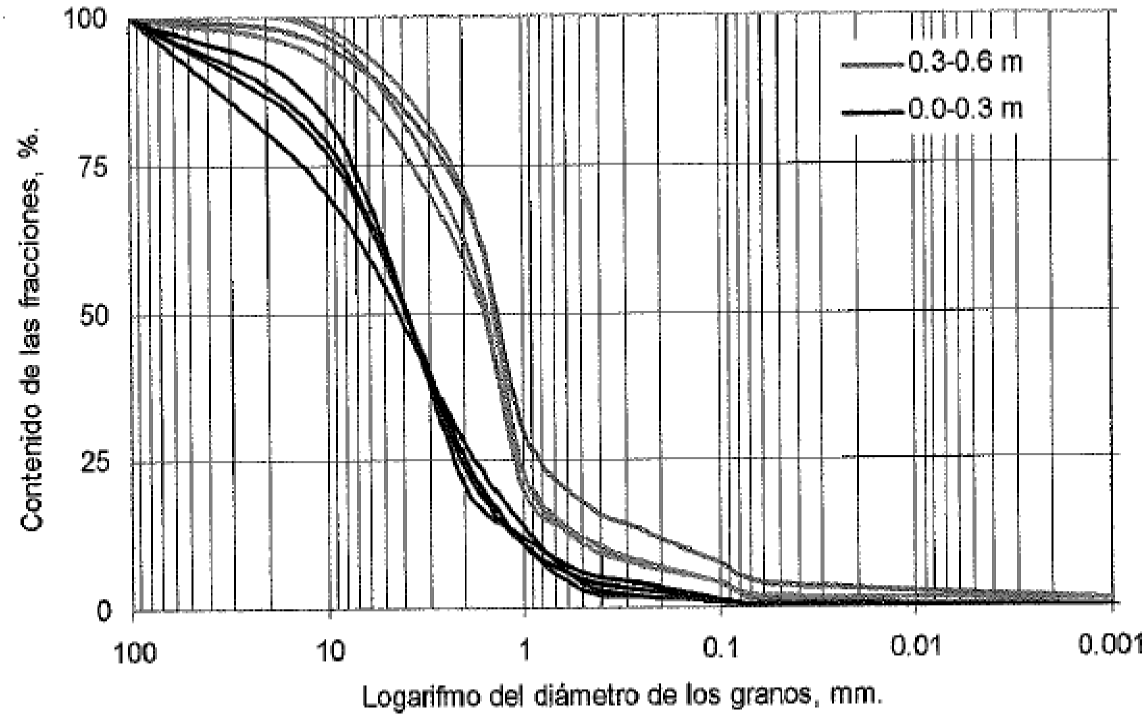


Figure 109: Soil granulometry in the runway sector.

According to the Highway Research Board-H.R.B. (1958), the soils analysed correspond to groups A-1 and A-2, and according to grouping according to the relationship to freezing and thawing, they correspond to group F-1. These granulometric characteristics of the soil determine the excellent conditions of the support layer of the embankment construction. In addition, different types of clastic soil located in three potential sectors of aggregate extraction for the construction of the runway embankment have been analysed. The samples were obtained from cores extracted in pits 0.5-0.7 m deep, which corresponds to the maximum recommended depth for the extraction of aggregates in the region.

The results of the analyzes are shown in Table 16:

Table: Results of the mechanical analysis of the soils in the area of the dam and of the aggregates used in the construction.

Units	A	B	C
Common types of significant component materials	sand is important	stone fragments, gravel and sand	gravels and silty sands
Granulometry: grade N° 4	70	60	90
ours N° 18	55	45	65
ours N° 60	22	18	25
ours N° 230	4	2	12
Effective clast diameter, mm	4.0	5.0	0.7
Volumetric weight of the soil frozen (*ton* m^{-3})	1.75	1.7	1.6
Volumetric weight of the soil thawed (*ton* m^{-3})	1.85	1.84	1.75
Specific weight of dry soil compressed (*Tn* m^{-3})	2.1	2.1	2.0
Classification index according to H.R.B.	A-1	A-1	A-2
Grouping according to reaction to freezing and defrost	F-2	F-1	F-3

The analysed soils are grouped according to their susceptibility to heave ("swell") due to freezing, and to their weakening due to the melting of underground ice. Type C soils show a low susceptibility to frost upheaval and a partial or complete weakening by the action of the melting of subterranean ice during the seasonal thawing period. The aggregates that correspond to Groups A and B are presented as optimal materials for the construction of the embankment. They are characterised by their low susceptibility to lifting due to freezing and their high mechanical resistance, which increases considerably with the decrease in negative temperatures.

Total soil moisture and ground ice content

The studies of the total water content of the active layer and the permafrost roof were carried out between March 11 and 20, 2005 in the test pits located in the runway construction sector. The results obtained and the distribution of total soil moisture (Wt) are shown in Figure 111.

Significant variations have been observed between soil moisture in the superficial zone and in depth. The maximum value of Wt was recorded at points 3 and 4 located in the saturated flood zone during high tide. At points 3 and 4, the increase in soil moisture is observed by 8-9% in the superficial layer and up to 15% in depth of 0.6 m. In the superficial layer the value of Wt varies between 4-8 %. In the depth interval 0.2-0.4 m, a variation between 6-12% is observed and between 0.4-0.6 m depth the total humidity varies between 11-16%.

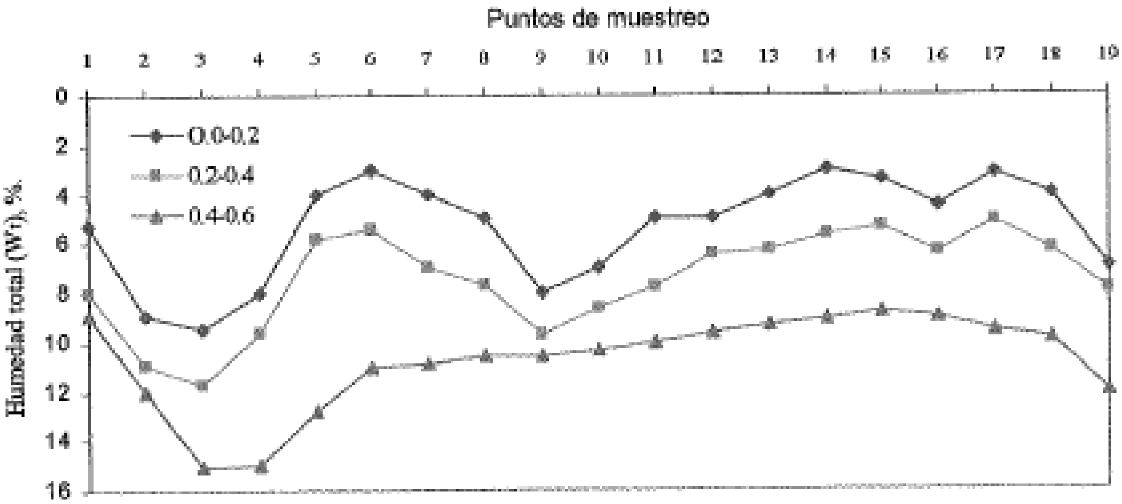


Figure 110: The distribution of the total moisture of the original soils in the runway construction sector.

In the active layer of permafrost during seasonal freezing, the total ice content (h_{you}) depends on the initial soil moisture. For this reason, the value can be modified according to the change in soil moisture before the seasonal freeze. The recorded values of W_{you} of the clastic soils of the active layer indicate favourable conditions for the formation of underground ice in the form of cement and infiltration. The ice content on the permafrost roof does not exceed the values at the base of the seasonal freezing horizon.

Regulatory depth of seasonal thawing

The seasonal thaw reaches variable depths in summer depending on the composition of the soil, the ratio of surface and groundwater, exposure and weather conditions in the seasonal thaw stage. For geotechnical analyzes in cold areas, normative depth values of seasonal thawing are used.

This value is defined as the greatest observed depth where the active layer of permafrost, during the seasonal thawing stage, coincides with the top of the permafrost during the last 10 years. Since there is no database for such a period, the normative depth of thawing was calculated with the data available from the Petrel Meteorological Station, and the properties of frozen and thawed soils, according to the following formulas:

$$H_d = \sqrt{\frac{2\lambda_d \tau_1 t_1}{q} + \left(\frac{Q}{2q}\right)^2} - \frac{Q}{2q}$$

where,

$$Q = \left(0.25 - \frac{\tau_1}{3600}\right)(t_1 - t_c)\sqrt{\lambda_c C_c \tau_1}$$

y

$$q = \rho (w_t - w_n) \gamma_d \left(\frac{\tau_1}{7500} - 0.1 \right) \left(C_d t_1 - C_c t_0 \right)$$

with

$$t_1 = 1.4\, t_p + 2.4$$

$$\tau_1 = 1.15\, \tau_p + 360$$

Table 17 shows the units used and the calculated values of the normative thickness of the seasonal thawing for different types of soils, for example, the sector of the runway, and three sectors of extraction of aggregates for the construction of the embankment.

Table: Seasonal thawing normative depth values, climatic data, and physical and thermal properties of the soil.

Unit	runway area	Sector A	Sector B	Sector C
frozen ($Kcal\ m^{-1} H^{-1} °Ç^{-1}$)	1.7	1.75	1.75	1.8
λ_d-coefficient of thermal conductivity of the soil thawed ($Kcal\ m^{-1} H^{-1} °Ç^{-1}$)	1.75	1.8	1.85	1.85
T_0 – average temperature of the permafrost, (°C)	-3.0	-3.0	-3-0	-3-0
you_p -average air temperature during the time in that stays above 0°C (°C)	1.7	1.7	1.7	1.7
$_c$ – freezing temperature (oC)	-0.2	-0.2	-0.2	-0.3
positive, (hs)	1420	1420	1420	1420
W_{you} - total soil water content, (%)	10	8	8	10
	80000	80000	80000	80000
$C._c$ -heat capacity per volume of soil frozen ($Kcal\ m^{-3} °Ç^{-1}$	450	470	430	440
$C._d$ -heat capacity per volume of soil frozen ($Kcal\ m^{-3} °Ç^{-1}$	510	520	510	520
$^{-3}$	1.7	1.75	1.85	1.8
γ_d - thawed soil density ($ton\ m^{-3}$)	1.8	1.9	1.95	1.9
h_d - standard defrost depth (m)	**0.85**	**0.8**	**0.65**	**0.7**

Mechanical resistance of soils to penetration

From the point of view of mechanical resistance, the soils in the construction area and the future runway embankment can be schematised into two layers that correspond to permafrost (the lower layer) and the active layer (the upper layer of freezing and thawing). seasonal). The lower layer forms a foundation or subgrade, while the upper layer corresponds to the sub-base and base of the embankment.

Two of the most important characteristics that are used to analyze the properties of the soil to be used in the construction of airstrips in the polar regions, are the instantaneous static resistance to impact (Re) for frozen soils and the California support test for seasonally thawed upper layers.

The study of Re is carried out using expeditious and laboratory methods such as the ball pressure monitor, already described. The Re value for permafrost and solid frozen soils of the active layer is stable and is always above 35-40 Kg cm-2 in the negative temperature range of -0.2 ºC (soil freezing temperature type A-1 and A-2) at –3.0 ºC, which corresponds to the average temperature of the permafrost. Permanently frozen soils of this type will form the subgrade layers and the lower subbase of the future runway embankment.

Negative temperatures will favour the static resistance of soils. For its part, this value depends on the density and moisture conditions of the soil in the upper layers, corresponding to the active layer of permafrost. For thawed soils, a support ratio test, known as the "California support value" (CBR), was performed. The CBR test measures the shear strength of a floor under controlled moisture and density conditions. According to the data obtained (Table 18), the capacity of the compacted soils to be used for the sub-base and base of the embankment can be classified as good and very good.

Table: CBR values of the aggregates of the embankment construction.

Units	soil type		
	original floor	Arids B	Mixture of aggregates B and C
soil classification	A-1	A-2	A-2
Grouping according to freezing	F-1	F-2	F-2
Optimum humidity, (%)	7	8	8
Density of compacted soils, Ton m^{-3}	2.05	2.1	2.15
CBR value, (%)	> 70, good	> 75, good	> 85, very good

Potential Runway Layouts

The typical layout of an airport with a runway is shown below. Figure 111. The pavements of the different parts of the airport are divided into three operational areas:

1) Landing runway

2) taxiway

3) trading platform.

These pavements must have specific geometric criteria with respect to their longitudinal and transversal angles, vertical curvature and visual distance. Around the perimeter of these pavements will be located an area free of obstructions for aircraft that accidentally escape the paved surface. The geometric criteria for arctic airports used in Canada are shown in Figure 113.

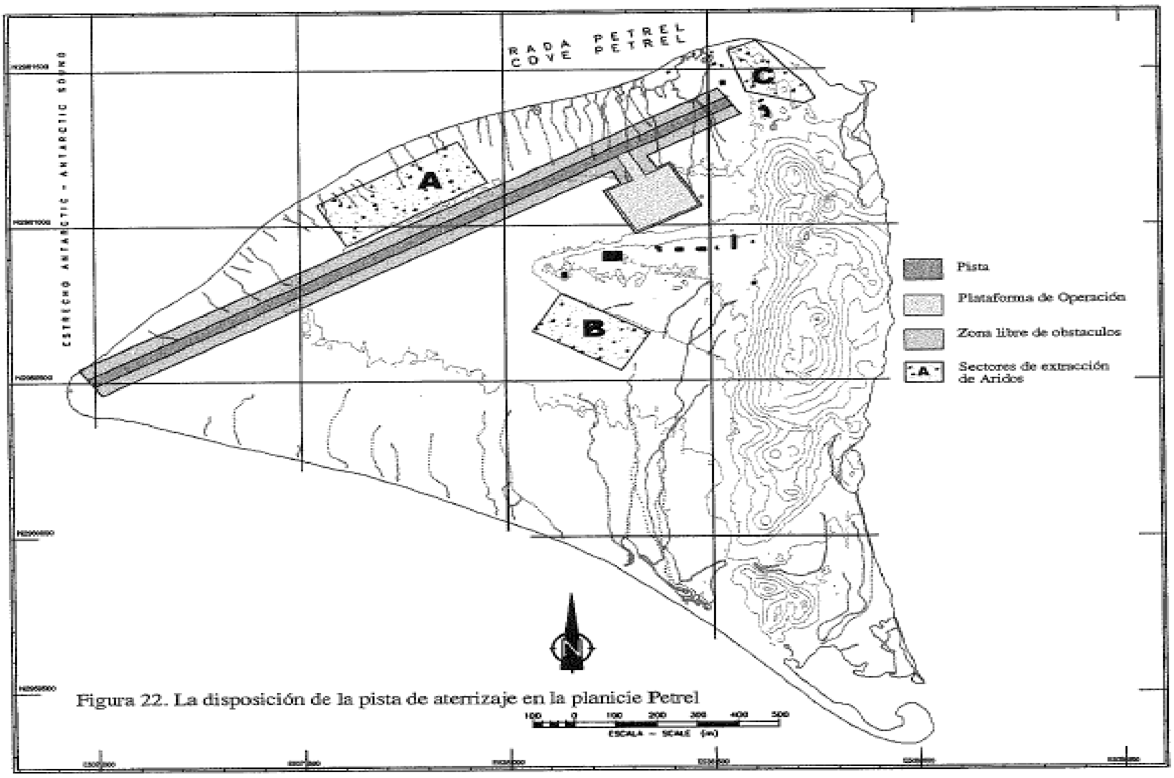


Figure 111: Initial layout of the runway on the Cape Welchness plain.

Airport geometric standards and their specific requirements are classified into four categories. The maximum standard for a class A arctic airport indicates a paved airstrip 2,100 m long and 60 m wide. The minimum standards for arctic airports, classes (B), (C) and (D), require a gravel or pavement surface, with runway lengths of 1500, 900 and 450 m, with widths of 45, 30 and 21 m , respectively.

At Cape Welchness, the layout of a main runway some 1,800 m long in a SW–NE direction is proposed, located on the lower terrace that presents favourable geotechnical and relief characteristics for the potential construction of the airport on it (Figure 111112).

Requerimiento geométrico	Clase de diseño de aeropuerto			
	A	B	C	D
Pista aterrizaje				
Longitud mínima, (m)	2100	1500	900	450
Ancho mínimo, (m)	60	45	30	21
Declive longitudinal máximo G, (%)	±1.0	±1.0	±1.0	±2.0
Cambio máximo en declive longitudinal ΔG (%)	±1.5	±1.5	±1.5	±2.0
Tasa máxima del cambio en declive longitudinal (% por 30 m)	±0.1	±0.1	±0.2	±0.25
Declive transversal máximo (%)	±1.5	±1.5	±1.5	±2.0
Margen de pista aterrizaje				
Ancho mínimo por cado lado del eje de la pista, (m)	75	75	60	24
Longitud mínima desde cabecera de la pista, (m)	60	60	60	30
Declive longitudinal máximo, (%)	±1.5	±1.75	±1.75	±2.0
Declive transversal máximo, (%)	±2.5	±2.5	±2.5	±3.0
Zona libre de obstáculos				
Ancho mínimo por cado lado del eje de la pista, (m)	150	150	150	60
Longitud mínima desde cabecera de la pista, (m)	60	60	60	30
Calle de rodaje				
Ancho mínimo, (m)	22	22	15	11
Declive longitudinal máximo, (%)	±1.5	±1.5	±3.0	±3.0
Tasa máxima del cambio en declive longitudinal (% por 30 m)	±1.5	±1.5	±1.5	±2.0
Declive transversal máximo, (%)	±1.0	±1.0	±1.0	±1.25
Margen de calle de rodaje				
Ancho mínimo del cado lado de calle de rodaje, (m)				
Declive longitudinal máximo, (%)	±2.0	±2.0	±3.0	±3.0
Declive transversal máximo, (%)	±2.0	±2.0	±3.0	±3.0
Plataforma de operación				
Declive máximo, (m)	±1.0	±1.0	±1.0	±1.0
Margen de la plataforma de operación				
Ancho mínimo alrededor de la plataforma, (m)	15	15	10	6
Declive longitudinal y transversal máximo, (%)	±3.0	±3.0	±3.0	±3.0

Figure 112: Geometric criteria for Arctic airports used in Canada

The orientation of the main runway is subject to the S, S-W and S-E directions of the strongest prevailing winds in the area. The length of this potential runway could reach 2,100 m, extending it some 100 m in a N-E direction to the moraine ridge and another 200 m in a S-W direction. In the latter case, they would be reclaimed from the sea near Punta Bajos, at the expense of the intertidal zone, where a terrace of marine abrasion is exposed, some 2.5 m below sea level. This marine terrace is cut in very compact Triassic rocks and prone to erosion. It extends some 200 m offshore, surrounding Punta Bajos, and is suitable for potential extensions of the possible airstrip to the W.

The design of the runway at Cape Welchness and the geometric requirements of future airport facilities are subject to the topography of the land in the sector.

from the lower terrace (Table 19), to the result of the study of the geotechnical conditions in the permafrost zone and the technical requirements of the planned tasks.

Table: Data of the leveling of the axis of the main runway in the Petrel plain

number of points	Distance, m	height in masl	Slope	Degrees
1	0	2.61		
2	100	1.24	-0.014	-0.785
3	200	2.49	0.013	0.716
4	300	3.26	0.008	0.441
5	400	4.39	0.011	0.647
6	500	5.08	0.007	0.395
7	600	6.05	0.010	0.556
8	700	6.12	0.001	0.040
9	800	5.88	-0.002	-0.138
10	900	6.06	0.002	0.103
11	1000	6.43	0.004	0.212
12	1100	5.86	-0.006	-0.327
13	1200	5.28	-0.006	-0.332
14	1300	4.45	-0.008	-0.476
15	1400	4.27	-0.002	-0.103
16	1500	3.47	-0.008	-0.458
17	1600	2.8	-0.007	-0.384
18	1700	2.29	-0.005	-0.292
19	1800	1.68	-0.006	-0.349

Embankment of local materials

The embankment of the runway in cold areas must be designed to withstand adverse conditions such as: lifting of the moist soil due to seasonal freezing, settlement due to thawing of the superficial layers, loss of resistance of the base layers and sub-base of the embankment during and after seasonal thawing and change in surface moisture. In addition, the design of the support layers requires that their load-bearing capacity be determined in order to choose the design safely and economically. In general, load-bearing capacity varies greatly with the various types of soils used for construction. Runways also have to withstand the vibrations of the warm-up period and exhaust from jet engines, as well as the impacts of landing.

The average thickness of the embankment should correspond to the normative depth of seasonal thawing in the region, to avoid the negative effects of ice melting and ablation water drainage. In this case, a very important aspect is to have adequate coarse clastic materials to build the embankment. Aggregates of this type inhibit the formation of underground ice, in addition, they do not favour undesirable uplift due to expansive freezing in the construction sector.

The average thickness of the embankment is estimated at 1.43 m, with a maximum thickness of 2.21-2.96 m between points 2 and 3, which correspond to a sector subject to flooding during high tide (Table 20):

Table: Thickness of the embankment of the landing strip in the Petrel plain

number of points	Distance, m	height in masl		Embankment thickness, m
		original surface	embankment surface	
1	0	2.61	3.7	1.09
2	100	1.24	4.2	2.96
3	200	2.49	4.7	2.21
4	300	3.26	5.2	1.94
5	400	4.39	5.7	1.31
6	500	5.08	6.2	1.12
7	600	6.05	6.7	0.65
8	700	6.12	6.7	0.58
9	800	5.88	6.7	0.82
10	900	6.06	6.7	0.64
11	1000	6.43	6.7	0.27
12	1100	5.86	6.7	0.84
13	1200	5.28	6.7	1.42
14	1300	4.45	6.2	1.75
15	1400	4.27	5.7	1.43
16	1500	3.47	5.2	1.73
17	1600	2.8	4.7	1.9
18	1700	2.29	4.2	1.91
19	1800	1.68	3.7	2.02

All the natural aggregates necessary for the construction of the airstrip are found within the project area. These materials exist in abundance and are of good quality. It is recommended to obtain them from three quarries located at the foot of the moraines. The embankment will extend over 54,000 m^2 and will have an average thickness of 1.43 m. The volume of aggregates to be mobilised will be about 77,500 m^3 (Figures 114 and 115).

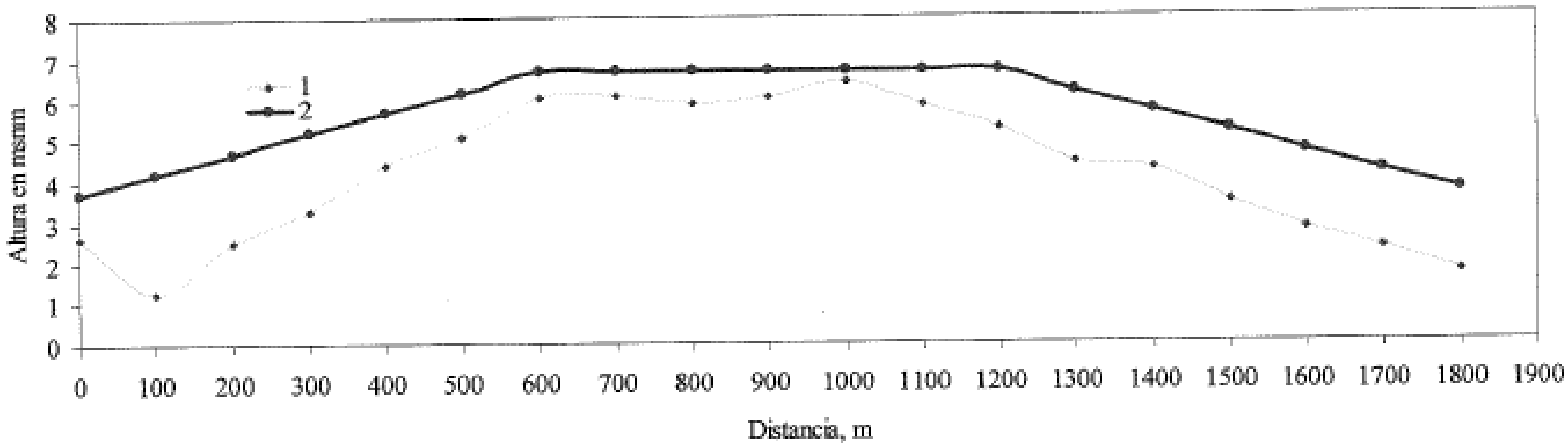


Figure 113: Longitudinal profile of the planned embankment of the landing strip. 1-level of the original surface; 2-level tarraplen

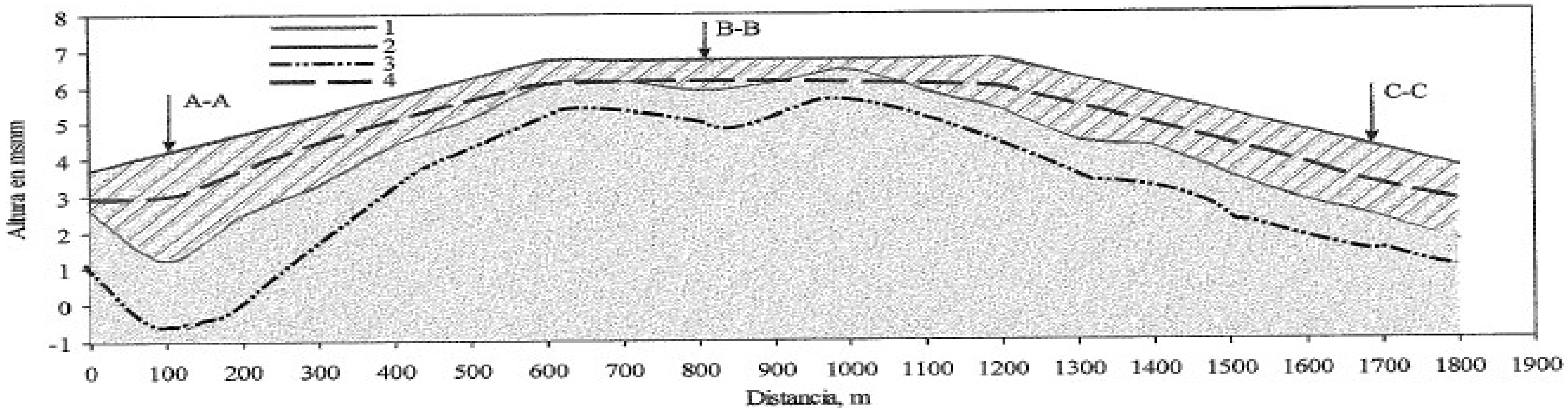


Figure 114: Geocryological longitudinal profile of the embankment. 1-original surface; 2-level of the embankment; 3-permafrost roof; 4-roof of permafrost in
embankment.

Table: Volume of aggregates extracted for the construction of the embankment.

extraction sectors	Size of the sectors, m	Extraction depth, m	Extraction volume, m^3
A	400x150	0.7	42000
B	250x140	0.7	24500
C	180x120	0.5	11000

The appropriate ground for the foundation is the original surface of the ground, which is called "subgrade" and must be properly compacted in the first stage, with an optimum humidity of 7-8%. For the construction of the sub-base of the embankment, aggregates from quarries may be used where coarse gravel with little sand predominates. The aggregates for the base of the embankment will have to be supplemented with the addition of sand and silt from other quarries. This will be necessary to achieve good cohesion and compaction of the embankment surface. The materials (aggregates) used to form the base of the embankment can be mixed with aggregates from quarries B and C in equal proportions.

In all stages of placing the aggregates, compaction must be carried out layer by layer. A good compaction will produce better results in the degree of consistency of the embankment, represented by a lower index of empty spaces, which will result in a higher dry unit weight. When compacting the embankment soil, the following is pursued:

- Improve future responses of cryogenic processes
- Decrease future settlements
- Increase cutting resistance
- decrease permeability

Embankment with rigid pavement[14]

The ideal design for the future airstrip is the construction of an embankment with local materials, specifically designed for a polar region with permafrost development. The embankment shall include a compacted aggregate subgrade and subbase, and a solid top layer of asphalt or concrete. In the case of highways, runways and airport taxiways, a rigid pavement that performs various functions acts as a protective cover for the support layer:

- It supports and distributes the load, with a unitary pressure sufficiently distributed to be within the capacity of the soils that constitute the foundation ground and the sub-base, reducing the tendency to form superficial ruts.
- The pavement waterproofs the surface, favouring the evacuation of moisture from the areas that receive the load and the underlying layers.

Airstrip pavements range from semi-rigid concrete slabs that are laid directly on a sub-base to various types of flexible single and multi-layer pavements. The classic technology of construction of airstrips with solid pavement requires enormous

14 Ultimately this idea was discarded.

quantity of construction materials that must be carried and unloaded in the work zone. Another applicable solution in the construction of the embankment with rigid pavement is the application of stabilising substances to the base soil and the placement of an asphalt pavement that can be manufactured on site, with aggregates taken locally.

Several national products were analysed, for example, those produced by the company Argentina Multsystem S.A. that proposes several state-of-the-art technological solutions for the improvement of asphalt and soil treatment. One of them is the chemical-ionic soil stabilizer called “Etion” and the asphalt cement modifier “Asphaltable”.

Etion soil stabilizer is an aqueous solution of a complex of inorganic salts, added with sulfur surfactant compounds. This solution, when incorporated into the soil, produces electrochemical changes in its structure, conditioning it to achieve high bearing capacity (CBR) and compaction rates, and improve resistance to shear stress. Laboratory tests were carried out with these products to determine the CBR value in aggregates planned to build the embankment of the Cape Welchness runway. The sample was prepared with a mixture of aggregates from two different locations.

The test results were:

- ✓ Soil type according to H.R.B. A – 2
- ✓ Granulometry: sieve No. 4 82 %
- ✓ ours № 18 56 %
- ✓ our number 21%
- ✓ our number 6%
- ✓ Optimum humidity, (%) 8 %
- ✓ Maximum soil density: 2.15 g cm-3
- ✓ ETION® soil stabilizer type (1% solution with water)
- ✓ 5% cement
- ✓ CBR value, (%) > 120%

Likewise, sandy gravels from Antarctica were mixed with Etion, in a low percentage (4-5%), achieving bearing values higher than those obtained by sediments devoid of the additive, which made them suitable for paving. The CBR value of the test was completely acceptable to stabilize the support layer of the embankment. Using this method, it is recommended to increase the thickness of the soil at the base of the embankment, which must be treated by at least 0.3 m of its thickness at the runway heads (impact zones) and 0.15 m at the intermediate sections.

The other product tested (called "Asphaltable") is a chemical compound that improves the quality of asphalt. It is a method for the preparation of cold asphalt concrete, using modified asphalt emulsions as binding material, which replaces the traditional mixing procedure in plants. The great advantage of this type of product is that it produces more flexible mixtures suitable for application in regions with sudden changes in temperature that cause fissures and cracks in the surface layer.

There are also other chemical compounds that modify the properties of asphalt cement, making it possible to prepare special hot asphalt mixes and apply them cold. Appropriate mixtures of these products with natural aggregates give them special properties, prolonging the time available for compaction and improving the quality of the asphalt cement, thereby achieving greater adherence between the asphalt and the aggregate. The time available for compaction is very long, since the densification of the mix is precisely the cause of the elimination of the components that keep the asphalt concrete “workable”. These products are easy to incorporate into asphalt cement. The mixture is made in the tank of the asphalt plant, preventing toxic fumes during its incorporation. They modify the viscosity of the asphalt mix by adding a solvent, which allows working at a lower temperature than the conventional one without losing its plastic qualities.

Tests carried out with asphalt modified with a chemical compound of the "Asphaltable" type, resulted in the fact that it can be applied in successive thin layers from 3 cm thick. Likewise, these products have thermal resins that maintained the temperature for a longer time, making it possible to transport the mixture a long distance from the plant. In addition, its placement was faster and simpler because it required less compaction. The preliminary internal design of the airstrip embankment to be built with these materials is shown schematically in Figure 116.

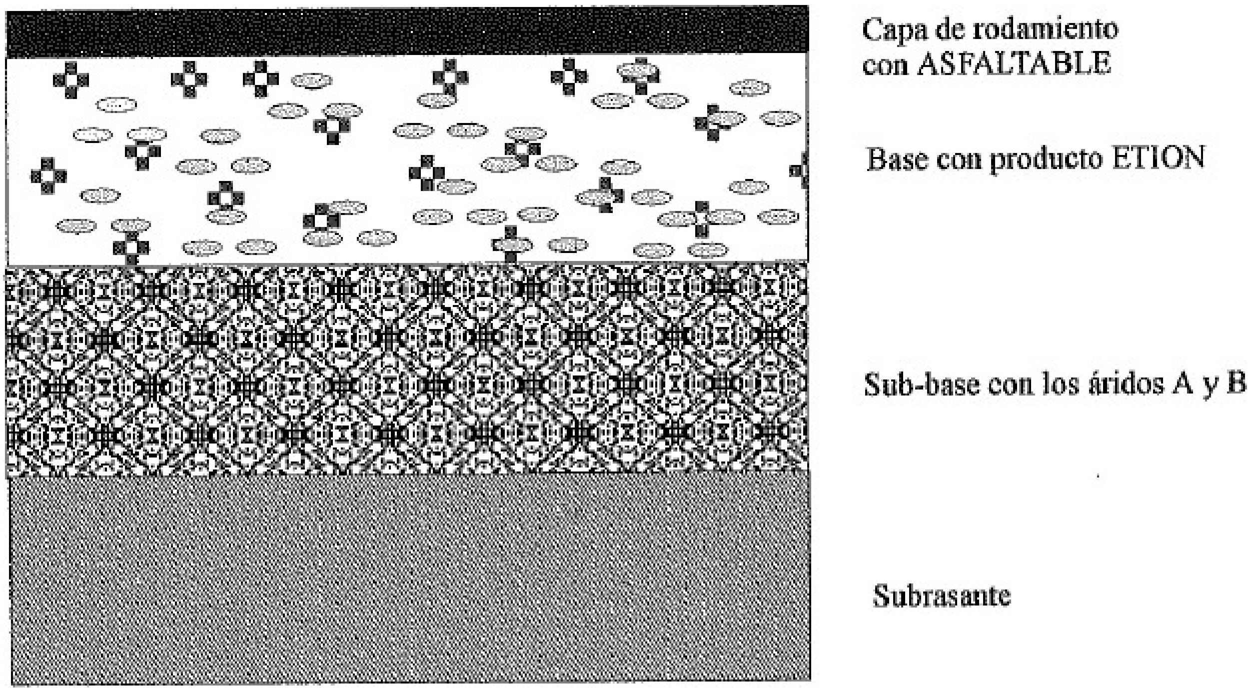


Figure 115: Layout of the runway with rigid pavement.

Drainage in the runway area

Drainage is without a doubt the single most important factor that will contribute to the stability of the runway embankment. Water can only seep into clastic soils under the influence of external charge or an osmotic gradient. The construction of the embankment will imply a superficial natural drainage because it will be higher than the surrounding terrain, and it will be made up of materials that will favour infiltration (in the case of the construction of an unpaved runway) and also the subsequent drainage of water out of the embankment.

The first requirement is that water be kept away or away from building structures, which can withstand erosive damage. Mitigation of these effects requires a series of ditches and gutters along the edges of the runway. The drainage network in the permafrost zone can be calculated according to:

$$A = h_{\max}\sqrt{\frac{K}{W}} = 60m$$

Drainage systems, both surface and underground, must be efficient and stable even during the thawing season. The main structures planned for the drainage network must correspond to the following criteria:

- Meltwater catchment channels should border the upper section, along the embankment to facilitate drainage
- Underground cross channels (runway section between points 2 and 5) should be well insulated from the embankment body to prevent thermoerosion of permafrost
- Off-road drainage cross ditches should not be less than 50m long, less than 0.50m wide at the top and 0.4-0.5m deep
- The drainage ditches should be filled with coarse gravel to ensure good filtering conditions, rapid water evacuation, structural solidity and resistance to erosion.

Figure 117 schematically shows these various drainage characteristics in the runway sector.

Expected changes in geocryological and geotechnical conditions in the construction sector

The construction of the runway with an embankment built with local clastic materials will disturb the initial conditions of the permafrost in this sector. The expected changes can be evaluated with the data on the properties of the aggregates to be used for the construction of the embankment, and the climatic conditions related to the modification of the permafrost in the subgrade, sub-base and base of the embankment. An important characteristic is the depth of freezing (h_c) inside the embankment body after construction. This parameter can be calculated with the data of the thermal properties obtained from the soils and the climatic information collected.

The value (h_c) is expressed according to the following formula:

$$H_c = \sqrt{\frac{2\lambda_c t_c \tau_c}{\rho W_t \gamma_c - 0.5 C_c t_c}}$$

Where:

you$_c$ is the average air temperature during the time it remains below 0 °C (-7.6
°C); *you*$_c$ is rate of freezing, negative degree-days (2200 – 3500 per year); *he*$_c$ is the thermal conductivity of the frozen soil (2.1 Kcal m-1 h-1 °C-1); *C.*$_c$ is the heat capacity per volume of frozen soil (755 kcal m-3 grad-1); *r* is the latent heat of fusion of ice (80000 Kcal Tn-1); W_{you} is the optimum soil moisture (0.07-0.09); γ_c is density of frozen ground (2.0 *you*$_{no}$ m^{-3}).

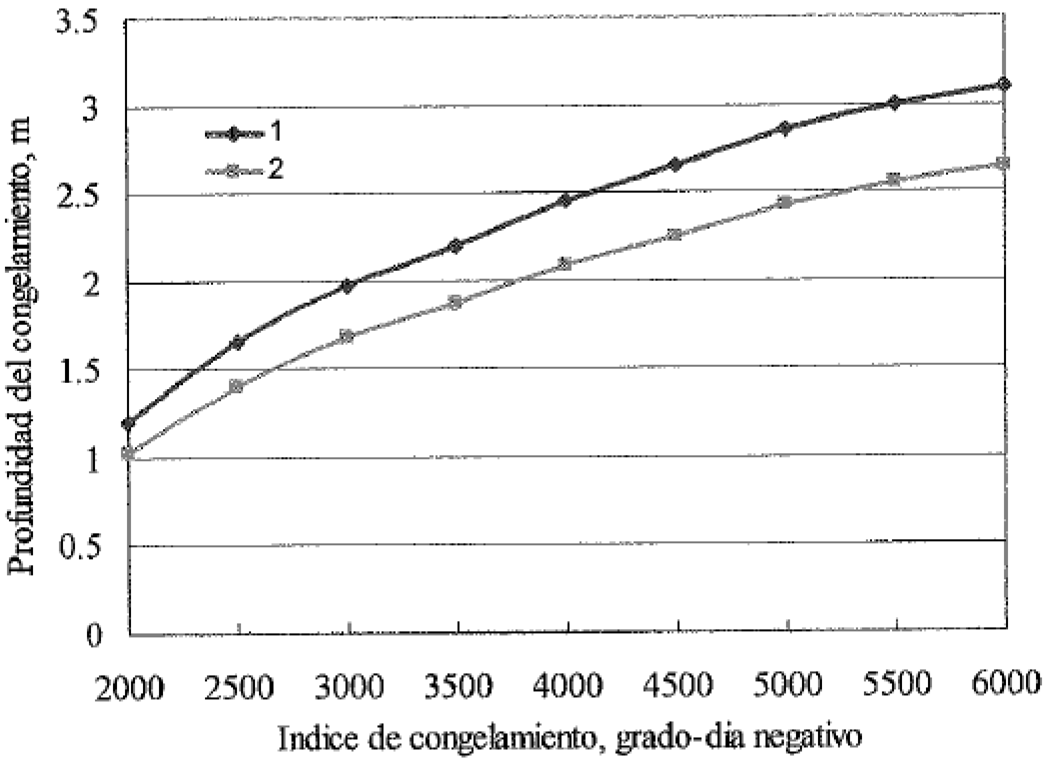


Figure 116: The depth of freezing depends on the freezing index and the humidity of the soils.

Taking into account that there are two values of the optimum soil moisture of the embankment and the period with variable negative air temperatures each year, the potential depth of freezing in this sector can be modified from 1.3 m to 2.1 m per year (Figure 117).

According to this calculation, new permafrost in the body of the future embankment should be formed in the first year after construction in sectors where the thickness of the embankment does not exceed 1-1.2 m, and in the second year the body of the embankment will freeze in its full volume. Figure 118 shows cross sections and longitudinal profile of the embankment after its complete freezing.

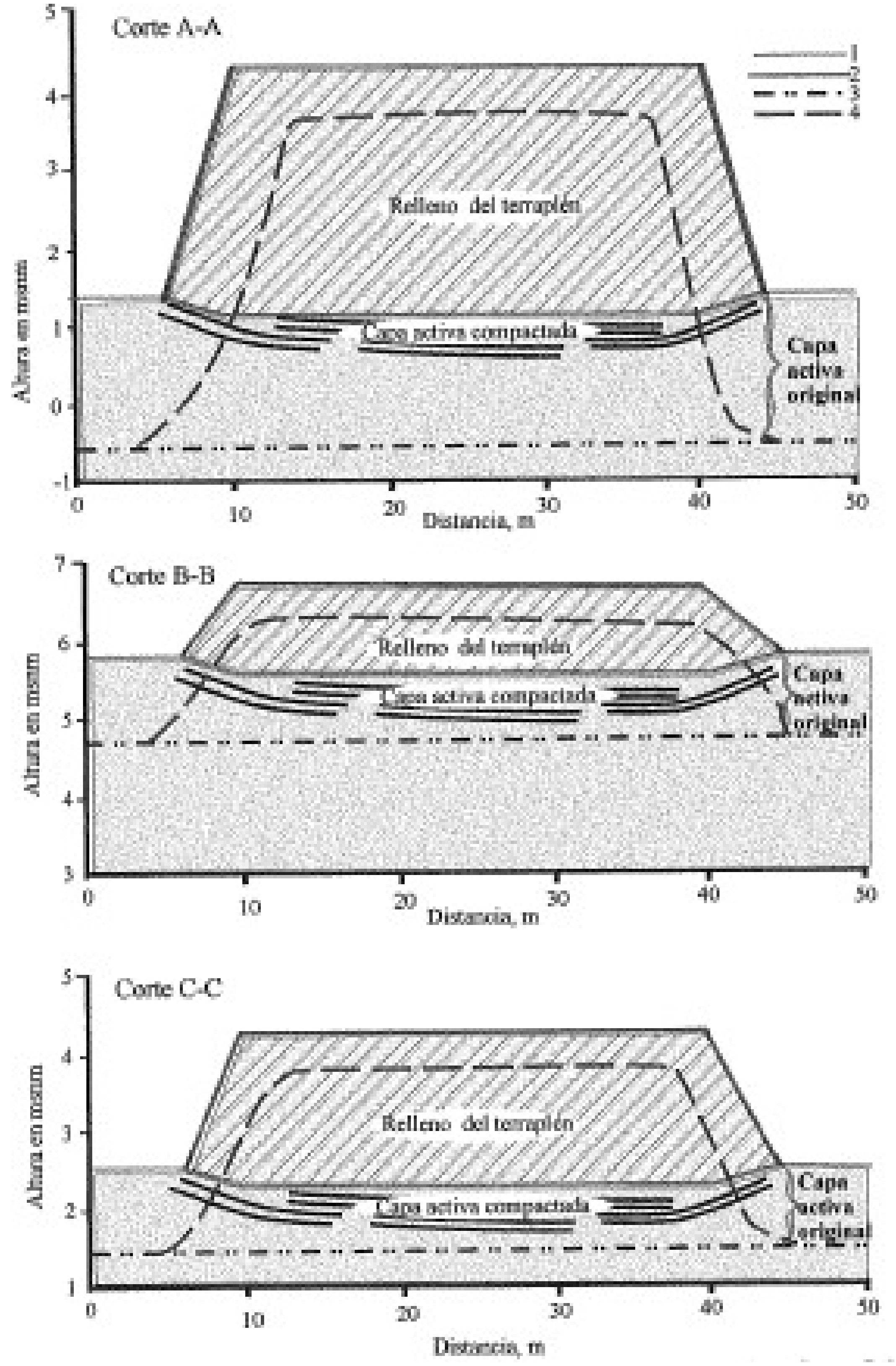


Figure 117: Geocryological cross sections of the embankment. 1-original surface; 2-level of the embankment; 3-permafrost roof; 4-roof of permafrost on embankment

According to the calculations, the seasonal thawing of the upper part of the embankment will be less than 10-15% of the natural terrain (fluvioglacial plain) thanks to the following factors: compaction of the aggregates placed, reduction of W_{you} and decreased snow cover on the elevated runway surface.

4.7.6.2 Methodology for the construction of the embankment and consolidation of the runways

In order to update the geological information for the construction of the runway, during the summer of 2022, measurements and adjustments were made again on the orientation of the runways and on the methodology for their construction. Finally, on the low plain of Cape Welchness, two landing strips were projected, which requires ground movement work to comply with current regulatory requirements in air matters. The following image shows the surfaces to be occupied by the landing strips and taxiways. These surfaces are indicated on the terrain by means of markers with a certain color code as shown in the photos for each runway (Figure 119).

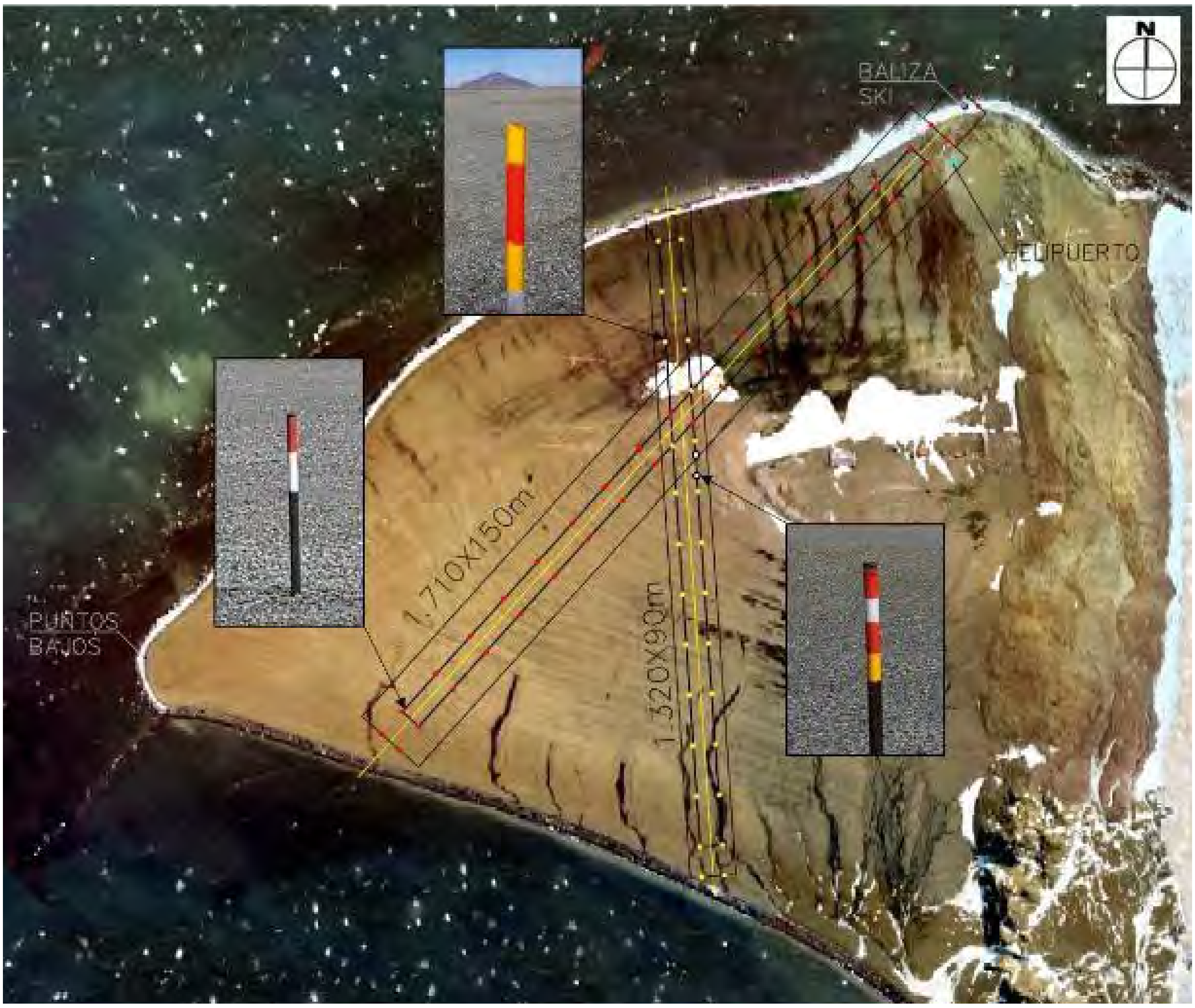


Figure 118: Implementation of the landing strips in the BACP and the type of markers used for their signaling

The first requirement to execute on the strips of runways marked out in the low plain is to compact the natural terrain. For which, a margin must be considered outside the stakes of 10 metres on each side in all cases, on which 3 passages or more will be made with the compactor, and it must be evaluated that the soil has adequate moisture to obtain a greater efficiency. Observing that the ground does not yield, 2 or more passes will be made with the vibrocompactor, having to carry out the same previous evaluations in order to obtain the maximum compaction of the natural ground before starting with the soil fill and leveling.

On both runways, different work requirements must be carried out in order to obtain the desired level of the project. In a smaller sector, the fill and lift must be carried out with added soil from the moraines, and the rest of the layout will require leveling the land in the place that will allow obtaining the lower magnitude lifts and the subsequent profiling of the project (Figure 120).

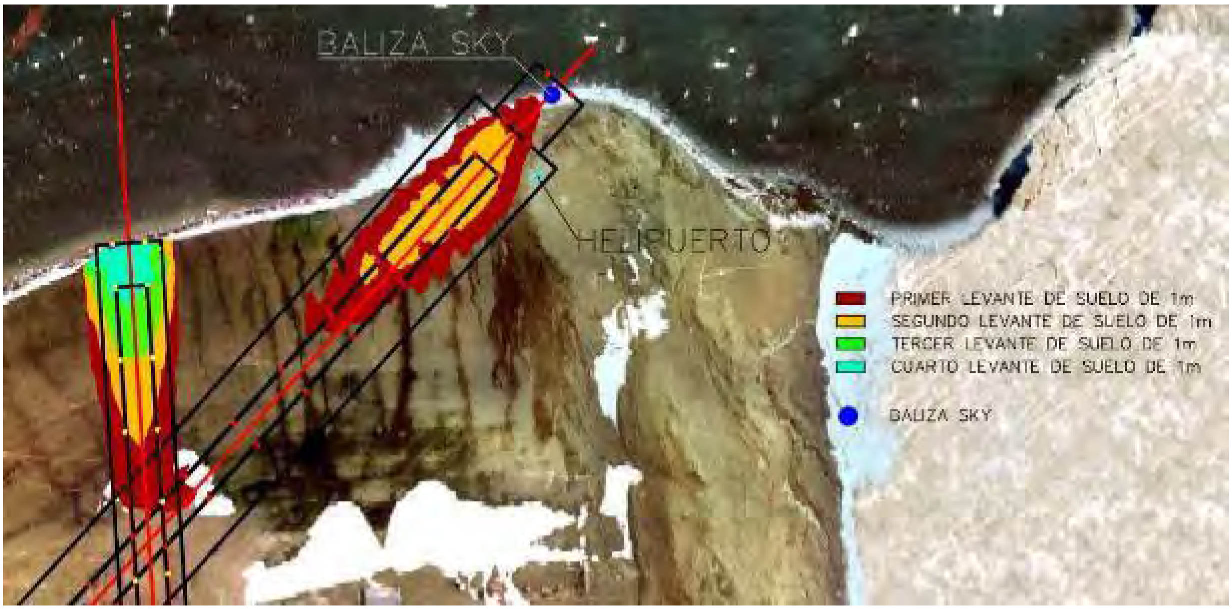


Figure 119: Fill sector and lift with soil contribution from the moraines at the head of runways.

Lift – work sequence (initial stage)

Once the compaction of the natural terrain of the sector where both landing strips will be located has been carried out, the work sequence described below must be started.

Figure 120: Sector to carry out the initial filling.

Main landing strip (low points - sky beacon)

As represented in image 02, the "uplift" of the terrain must be carried out from the foot of the moraines to the 1,200m marker, having to reach the heights with respect to the natural terrain indicated in the following diagrams (Figure 120).

In this sector of the runway, there will be the poles with the following ring-shaped reference painted in yellow where they indicate that the lower edge of the mark is the support point to measure the desired lift (Figure 122). It should be considered that this line made at 70 cm from the natural terrain, for any stakeout that is necessary to carry out.

Figure 121: Marking with a yellow ring to measure upwards the fill height necessary for the project.

The main steps of the sequence to be carried out to achieve a first stage of leveling and preventing the existence of water in the work area are the following:

- Soil extraction.
- Transfer and distribution.
- Leveling and compaction
- Control

soil extraction

The extraction of the contribution soil to raise the most compromised sector of the main runway will come from the area of the moraines that are in proximity to the SKY beacon, having the following important consideration:

- Due to the fact that the moraines present a certain homogeneity by sectors, but not throughout their entire length, one truck from each sector SHOULD preferably be moved ALTERNATELY, in order to allow the soil to be mixed during the spreading and distribution stage in the area to be lifted.
- Another alternative is, if the distance between quarries is greater and this generates longer delays in the work cycle, interspersing the dumping of each truck on the landfill sector, in order to leave the place for when the extraction of soil from the another reference point.

CLARIFICATION: It is important to comply with the observation made above in order to ensure, with the few means available, a more adequate mixture of the soil with the existing material, both due to the size of the particles and the geotechnical characteristics of one sector and another (Figure 123).

Figure 122: Location of the quarry sector.

Transfer and distribution

For the transfer of the supply material, the person in charge or responsible for directing the daily tasks, must study the work cycle to avoid having road equipment and trucks without activity. In other words, their work plan must be adjusted according to the experience they are obtaining, the skill of the operators and difficulties that may arise. Soil spreading should seek to mix the soil from one truckload with another in order to achieve a homogeneous distribution among the different moraine extraction sectors.

Due to the great difference in levels that exists in the lower area in proximity to the Sky beacon, the distribution of the ground must first seek to level the lower ground in order to prevent seawater from continuing to enter the area of the future runway . For which, it must permanently ensure a favourable slope towards the coast, to prevent water from melting snow or permafrost from remaining, without the possibility of being evacuated naturally. (Figure 123).

Leveling and compaction

The layers of spread and leveled soil must not be thicker than 15 cm, in order to allow the compactor roller to act on all the new soil, otherwise there will be sectors of the terrain with poor stability in the future.

Prior to each compaction cycle, the moisture content must be evaluated to obtain greater efficiency in the work of the compactor roller, regardless of the compaction or vibrocompaction stage. A field evaluation is to consider if it snowed the day before and the soil has moisture moving the upper layer, otherwise irrigation with seawater should be carried out prior to compaction work.

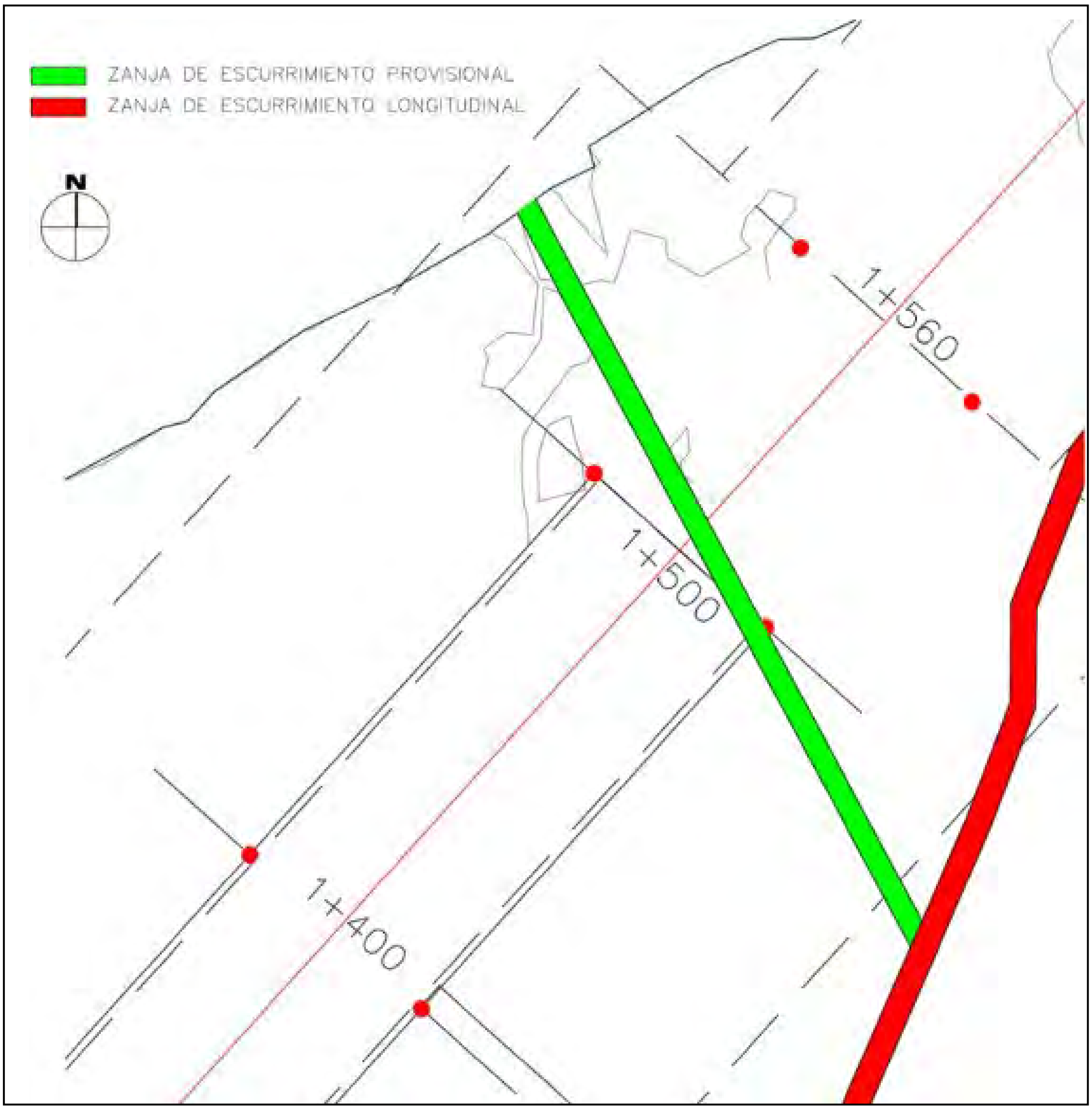


Figure 123: Place proposed for the provisional channel.

Control

Control over each stage of the process and compliance with the recommendations is essential to ensure that both the working time of personnel and equipment, as well as the consumption of fuel and lubricants, are useful and solid progress for the infrastructure to be assembled on the land. worked.

Until a necessary optical level is available at the base to control the heights reached after each stage is completed, the site manager must adopt auxiliary stakes in the field to support himself for final control.

Since it is not the only task at the base that requires the use of road equipment and trucks, it must be planned sufficiently in advance and coordinated with the head of the base, what means will be available the next day, the available personnel and tasks feasible to execute.

Lift – work sequence (final stage)

After having filled and consolidated the lowest sector of the land (near the Sky Beacon), where there is a presence of seawater and also from the melting of the permafrost, the works will be organised as follows:

1) The first work field will be marked, from the foot of the moraines to the progressive 1 500 approximately, depending on the terrain and the filling executed in the first stage, the limit will be conditioned by the previously marked provisional channeling, ensuring the permanent surface runoff towards the sea, with no water remaining stagnant due to the ground movements underway (Figure 125).

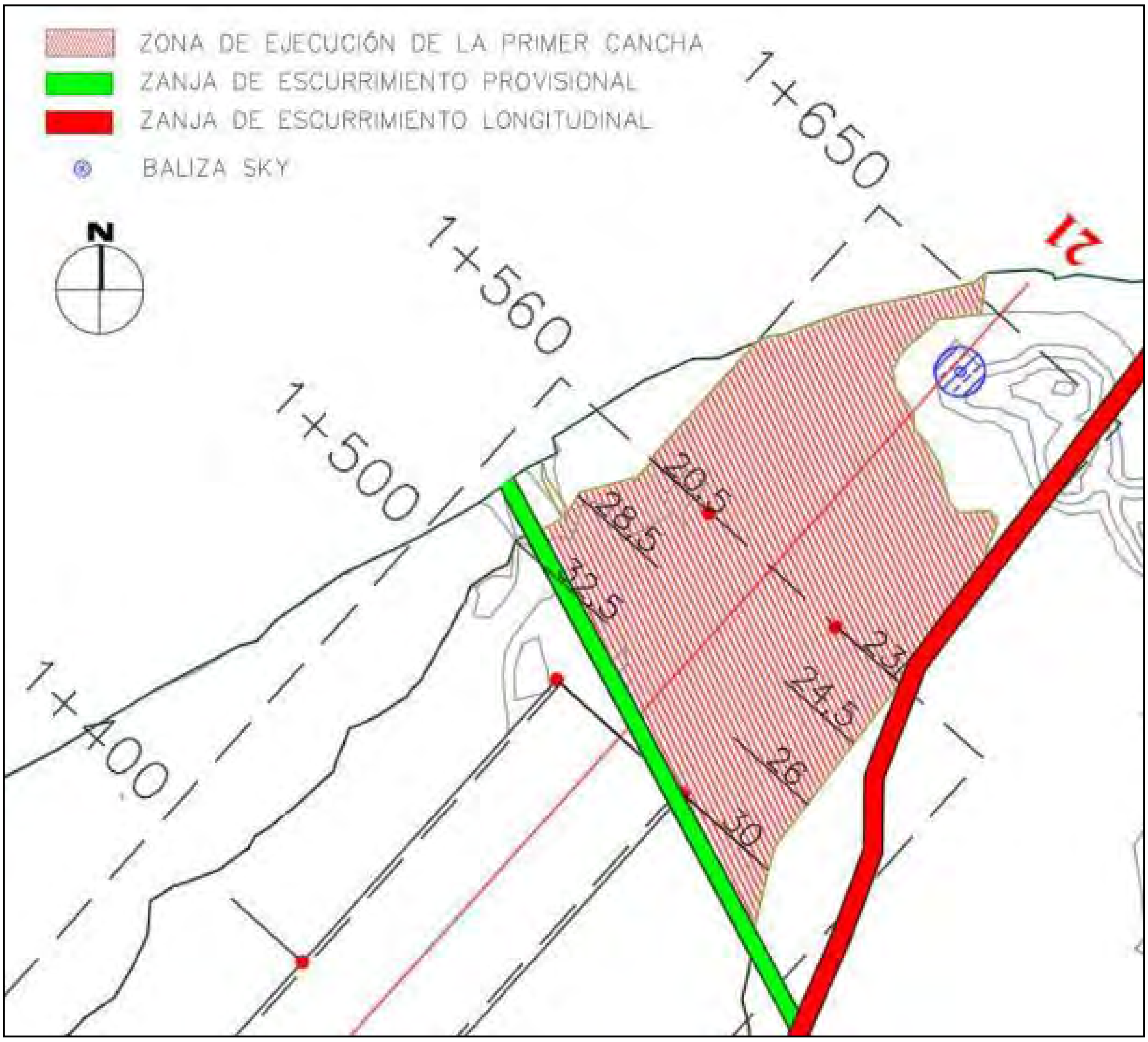


Figure 124: Location of the first court up to the transitory ditch.

The following image illustrates the longitudinal ditch that, as the slopes of the runway sector advance, must be consolidated to ensure the channeling of the water from the snow melt in the summer (Figure 126). In this image you can see the reference distances indicated from the line of existing stakes in the field.

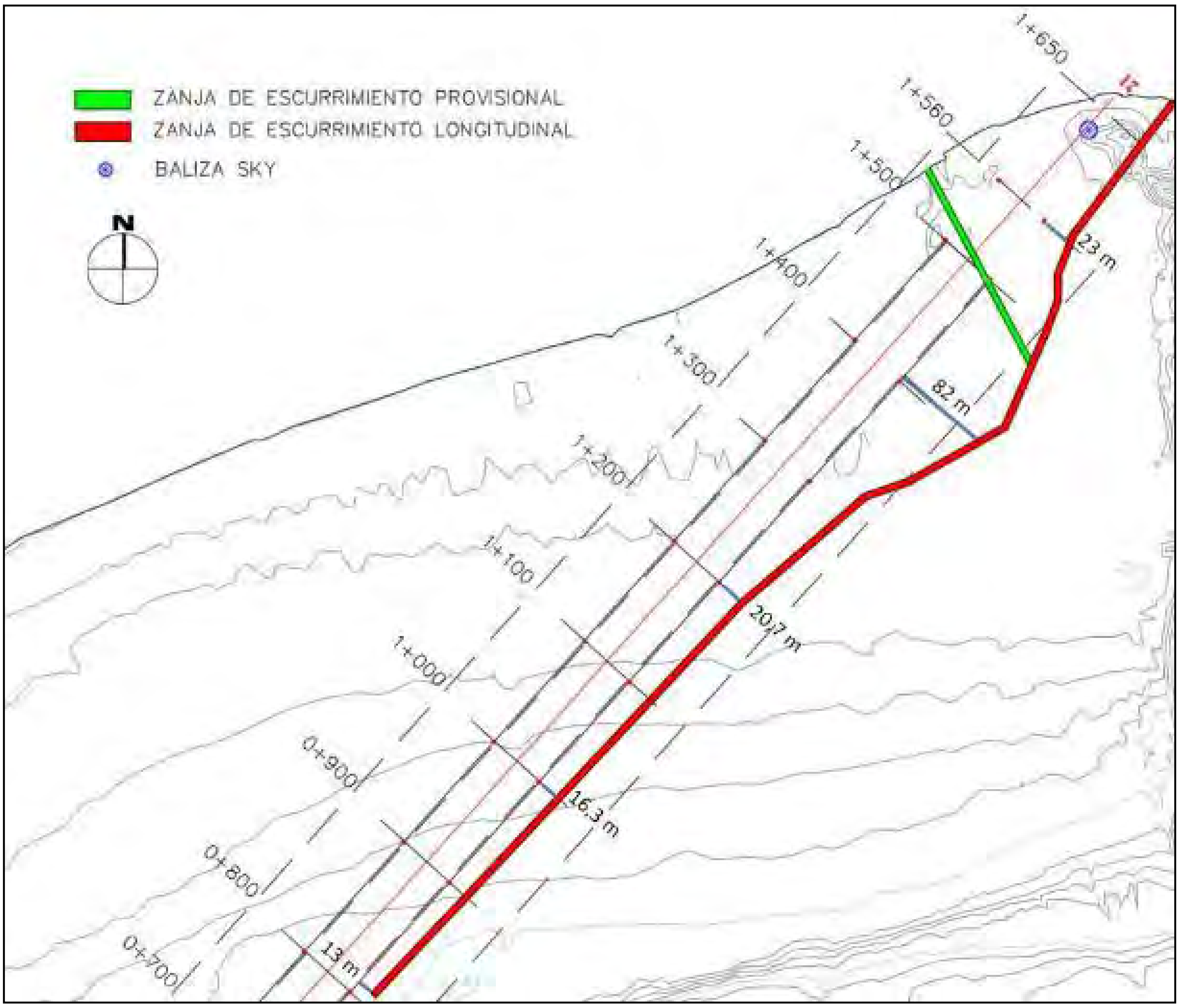


Figure 125: Location of the first court to be raised 1 metre, along with the runoff ditch.

2) The JCB will proceed to load the dump trucks taking into account the extraction of the soil from different moraines in order to facilitate its mixing as mentioned for the first movements, then the motor grader will spread the soil along the first field, in layers not greater than 15 cm thick, the soil distribution being approximately the width of the leaf. Then, the sprinkler truck will pass by to give the new soil enough moisture before compacting, as long as it has not snowed the day or night before.

Finally, the necessary roller passes will be made to obtain the greatest compaction of the fill. The minimum number of passes is 3 and subject to the experience obtained in previous compaction work. This sequence must be repeated throughout the field until reaching a height of 1 metre.

3) Once the construction of the first court is finished, work will begin on the second court, having to circumvent the provisional ditch that divides both eastern sectors. Which will be filled after consolidating the final channeling as mentioned above.

This ditch must have a transversal profile as illustrated in image 09, with a longitudinal slope towards the coast, allowing the free runoff of water, said ditch it should not exceed the width of the roller, which means that it should be compacted along its entire length (Figure 127).

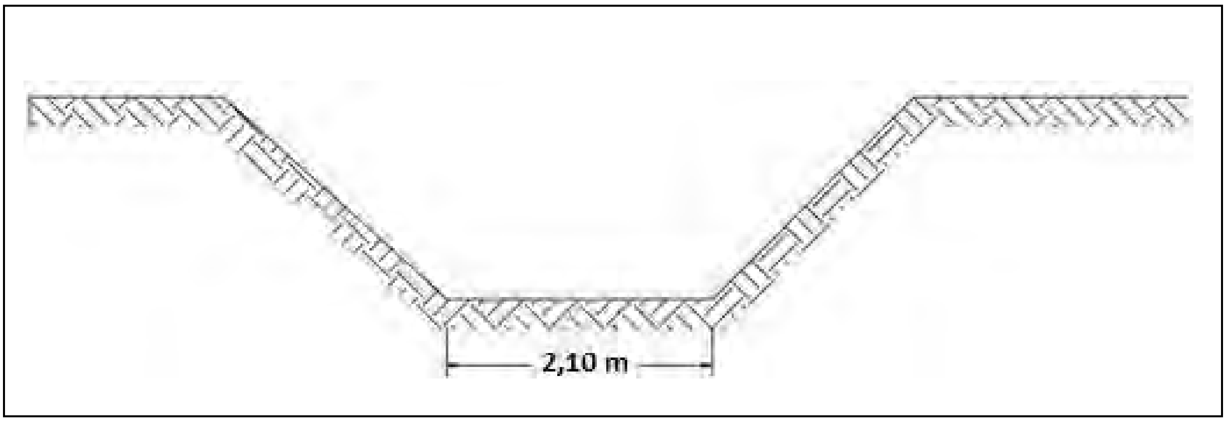


Figure 126: Cross section of the provisional trench with the lateral slope produced by the uplift of the soil.

4) The construction method will be repeated up to survey station 1,200, adjusting the procedure based on the experiences obtained and considering the established project heights for the fill (Figure 128).

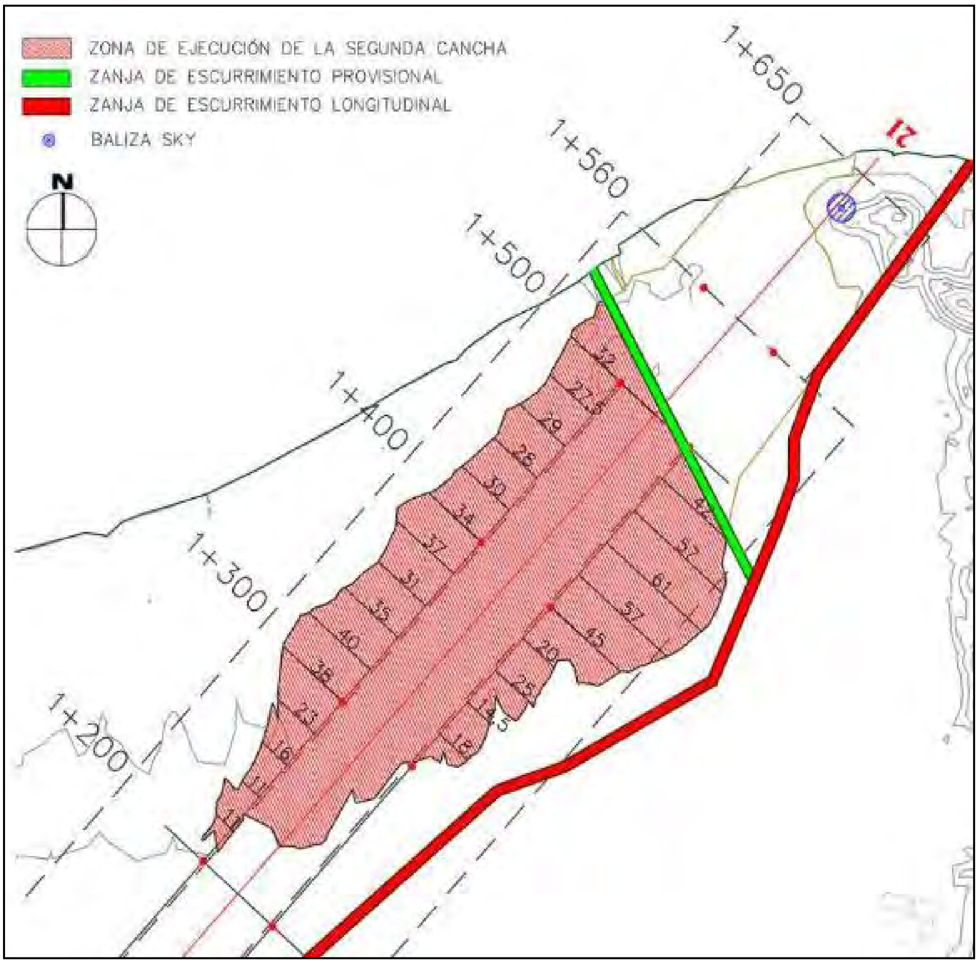


Figure 127: Location of the first field together with the runoff ditch.

5) Lastly, the sector of survey stations 1,200 to 1,560 must be completed with the heights corresponding to Table 22, indicating the ground elevation measurements located on the corresponding markers. For this fill, the ground movement carried out in the previous steps must be considered and fill only the height that is missing until reaching the necessary height.

Table: Measurements to lift with respect to the natural terrain or to the mark on each pole according to the progressive.

JALÓN	IZQUIERDA	POSICION	DERECHA	JALÓN
Marca (70cm)	TN	Levante respecto	TN	Marca (70cm)
---	---	Puntos Bajos 1+200	0,89	0,19
0,23	0,93	1+300	1,5	0,8
1,28	1,98	1+400	2,51	1,81
1,41	2,11	1+500	2,47	1,77
0,52	1,22	1+560 SKY	1,65	0,95

As in the first stage of work, the site manager with the operators must prepare a work cycle to obtain a better performance of the road equipment and vehicles. In turn, the progress of the work must be recorded by means of photographs and writing a report with the weekly exploitation.

Leveling – work sequence

In this stage, the work methodology will be carrying out soil movements from the same place, compensating the fill sectors with the excess coming from the places indicated as clearing (Figure 129).

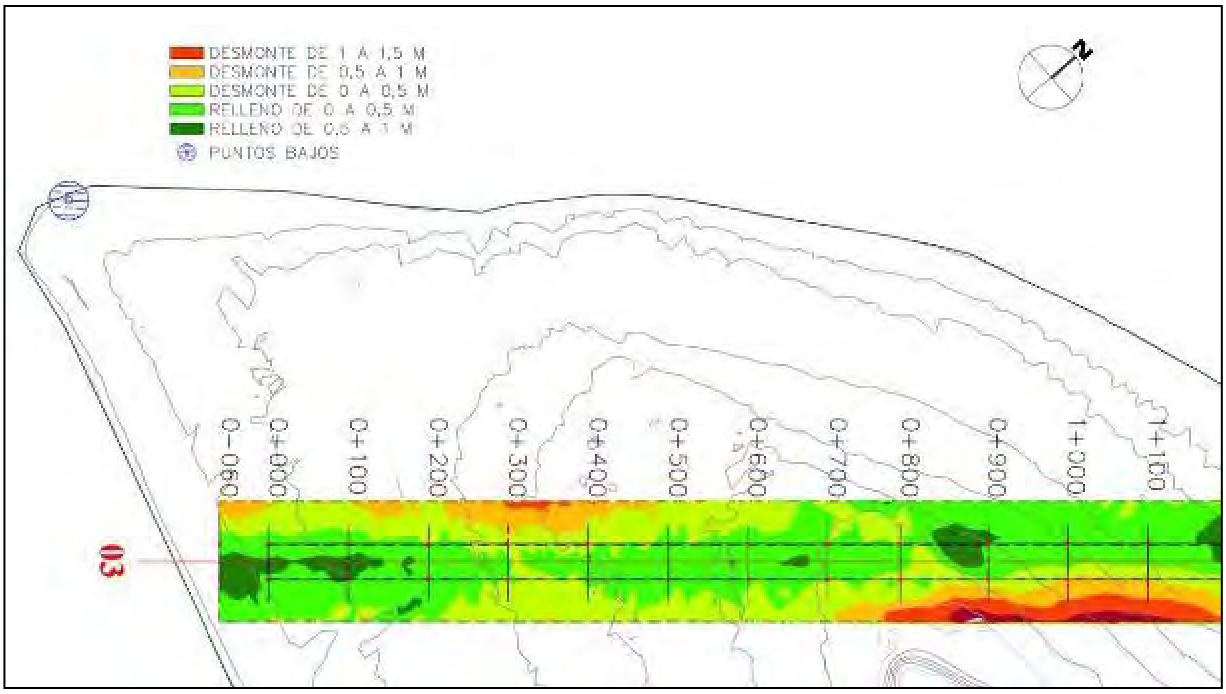


Figure 128: Representative ground movement scheme for surveys 0-060 up to 1 200.

On the markers located in the field -between the progressives 1 100 to 0-060, there are other marks in yellow- that are found continuously from the natural terrain to the even end, an edge that must be taken as the level to be reached with The uprising. Table 02 shows the raising (in black) or lowering (in red) to be carried out in each progressive (Table 23).

Table: Measurements to be carried out for the lift with respect to the natural terrain, marked on the markers in these progressives.

IZQUIERDA	POSICION	DERECHA
TN	Levante respecto	TN
0,75	Puntos Bajos 0-060	0,26
0,38	0+000	0,23
0,51	0+100	0,2
0,22	0+200	- 0,03
- 0,02	0+300	- 0,31
0,09	0+400	- 0,23
0,04	0+500	0,18
0,19	0+600	0,13
0,04	0+700	0,02
0,03	0+800	0,01
0,07	0+900	0,5
0,45	1+000	0,21
0,48	1+100 SKY	0,25

The compaction procedure must comply with all the recommendations made for the previous stages where a contribution of soil is carried out. Having to carry out lifts no greater than 15 cm, control the soil moisture and execute the compaction and vibrocompaction passages, ensuring an embankment with the resistance and stability of the project.

4.7.6.3 Materials and Logistics Requirements

The necessary aggregates (approximately 180,000 m^3) to build the runway embankment can be obtained from alluvial fans located at the foot of the moraine cord. It will be necessary to classify the aggregates by size, and then mix them with special chemical products, in adequate proportions to form the embankment, taking care that the mixture contains adequate amounts of mud to achieve good cohesion of the material (Figure 130).

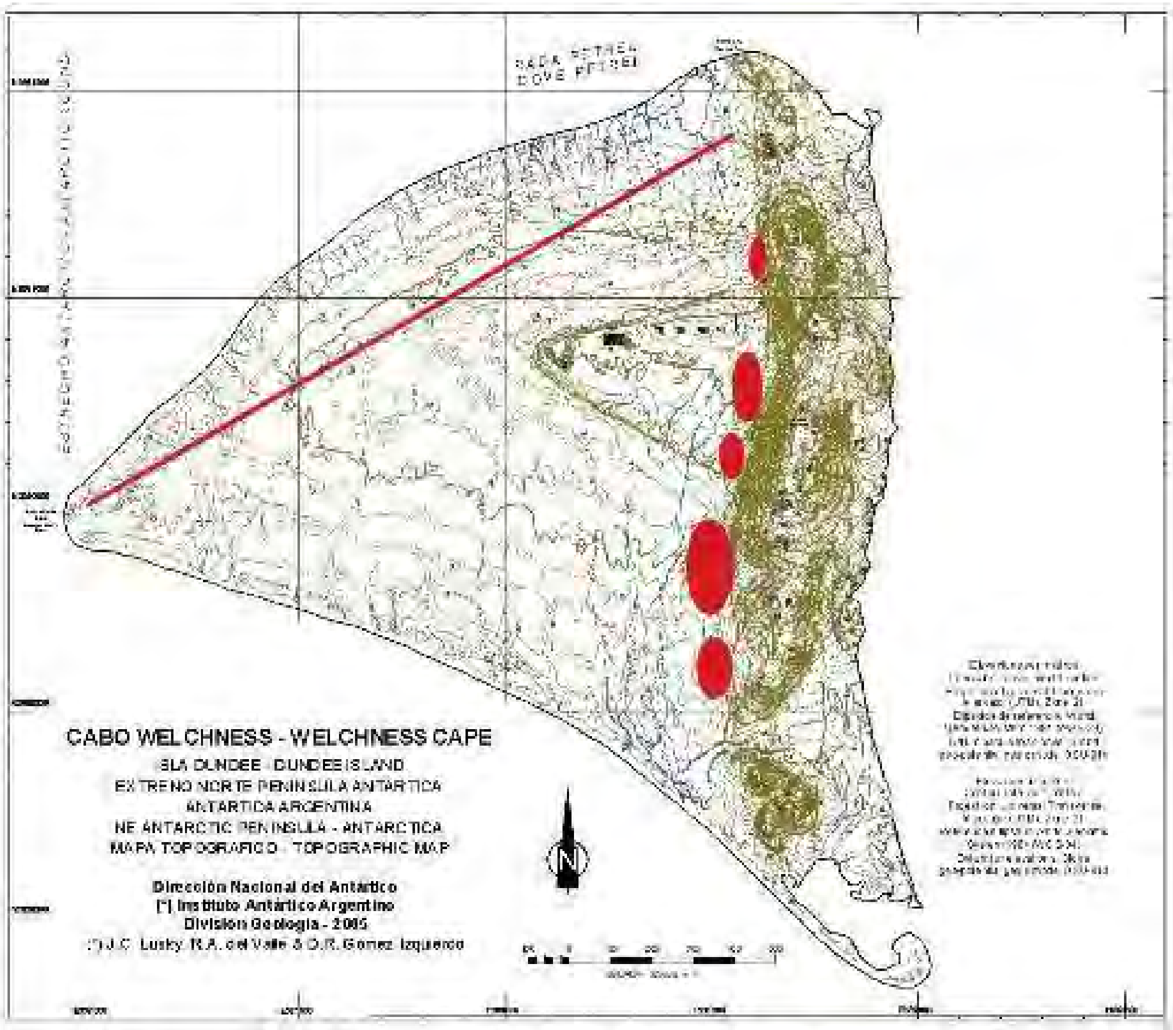


Figure 129: *Alluvial fans located at the foot of the moraine cord*

4.7.6.4 Logistics necessary for its construction

The equipment necessary for the construction of the slopes has the following technical characteristics:

- Astarsa 120 motor grader (UNA): Blade width 3.65 m - Fuel tank 227 L.
- Vibro-compacting roller (ONE): Roller width 2.10 m - Fuel tank 160 L.
- Truck 1518 MB sprinkler (UNO): 5000 L Plastic Tank - 200 L fuel tank.
- MB 1614 truck (DOS): Maximum volume of the box 9 m3 - Fuel tank l50 L.
- JCB 3CX (ONE): Bucket capacity 1.2 m3 - Bucket capacity 0.08 m3 - Fuel tank 128 L.

4.8 Docklands[fifteen]

The construction of a quay with the capacity to moor ships of up to 120 metres in length has been analysed, with a basin of calm waters and protected from ice debris for vessels such as rubber boats or barges.

The possible place for the installation of the wharf is the sector located to the north of Cape Welchness, on the Petrel roadstead. That area is where ships normally operate. The area presents favourable bathymetric characteristics to be counted 250 metres from the coastline, with a draft of 10 metres at the foot of the dock, allowing the mooring and operation of vessels.

From the studies carried out on other docks and existing coastal works in Antarctica, in which the most appropriate construction methods and materials were analysed, it was concluded that it was necessary to use metal sheet piling to meet the demands of the thrust and impacts of the ice.

This material, which is found in the most important docks in Antarctica, will only be placed on the operational perimeter of the dock that is most exposed to ice, providing a metal support structure inside, and filled with compacted soil from Dundee Island.

This work is still under study, since the studies corresponding to the seabed in the northeast area of Cape Welchness have not been completed and because the environmental and economic analyzes carried out to date indicate that its construction is not viable.

The considered coastal infrastructure will have:

- A separate installation for the designated port authority, allowing compliance with the administration, regulation, control and operation of the port system.
- An autonomous system for the transfer of Antarctic Diesel fuel from ship to land, with a bank of pumps, a reduced battery of tankers on the coastline and flexible hoses.
- A containerised or palletised cargo reception service, with capacity for transfer, collection, custody and transshipment.
- Freshwater supply service to ships.
- Reception and dispatch of passengers in transit.
- Launch or removal of small vessels by ramp.

[fifteen] This is the initial proposal for the port area. In the evaluation of alternatives, the construction of the quay was ruled out.

4.9 Services for the New Petrel Base

4.9.1 Energy generation

Considering that the general objective of the remodeling of the Petrel base is to contribute to the fulfillment of the scientific, technical and logistical tasks of the Argentine Antarctic Programme, complying with the provisions of the Antarctic Treaty, the Protocol on Environmental Protection to the Antarctic Treaty and its supplementary regulations. Within this framework, the need arises to have an electricity generation system that satisfies the projected consumption requirements and anticipates consumption increases in the short and medium term. For this purpose, a main system and a complementary one have been thought of.

main system

By motor generators. This method is currently the most reliable.

Advantages	Disadvantages
• Reliability (with the necessary backups) • Ability to meet all energy demand.	• noise generation • carbon dioxide emission • High cost for fuel consumption and associated logistics.

complementary system

Through a photovoltaic solar park

Advantages	Disadvantages
• Reliability (with the necessary backups) • Greater generation during the Antarctic summer, the time of greatest attendance at the Petrel base • Non-polluting	• Generation subject to sunshine hours • It is affected by weather conditions • Low generation capacity in relation to motor generators

The design of an energy network is required in accordance with the parameters of the development of the Petrel base and for this reason the use of clean energy was sought to reduce the consumption of fossil fuels. According to the experiences carried out, the use of wind turbines presents the disadvantage of being highly affected by winds greater than 75 Kn and the constant changes in their power and direction. For these reasons, the wind turbines tested at the bases located to the north of the peninsula and which are normally affected by the low pressure centers that circulate in the 60° parallel zone have suffered serious failures. Logistical and party costs discourage its use until solutions are designed for the problems raised.

Simultaneously, solar energy was chosen due to its low maintenance. The limitation of these is in relation to the hours of sun and its generation capacity. For this, it was considered that the Petrel base will have the highest average number of personnel during the Antarctic summer, that is to say, the peaks of consumption are foreseen at that time. On the other hand, the base projects the most hours of sunlight during this period of the year, guaranteeing a significant amount of energy generated by this means. (See Annex 11 - Solar photovoltaic park). Finally, it was decided to generate electricity with the traditional method of motor-generators complemented with a photovoltaic solar park. It should be noted that the selected photovoltaic solar field will not work with a battery bank, but will be directly connected to the electrical network, thus relieving the r.p.m. of the motor generator and therefore its consumption of fossil fuel.

4.9.1.1 Power generation through generators

4.9.1.1.1 Main Power Plant

The main source of power generation through generators will be the Main Power Plant. It will be built on the current location occupied by the cold room buildings. Said cold room will be dismantled and taken away to the continent. Its foundations will be removed. The building will maintain the line of the buildings located on the northern edge of the upper platform of Cape Welchness. It will be rectangular with a north-facing roof. It will occupy a total area of 262 m^2 (25.55 mx 10.25 m) and will have a maximum height of 10.25 mts.

It will have two floors or levels. On the lower floor, where three generators of 250 KVA each will be located (with characteristics similar to those established in Figure 131). On the side of the building, separated by a fire wall, there will be a plant for melting ice and snow using the heat produced by the electric generators. Next to the ice and snow melting plant, there will be three cistern tanks of 40 m3 each to store drinking water at temperatures above zero, also taking advantage of the heat from the generators. The generator control room will be located on the upper level, together with a small kitchen.

Figure 130: Characteristics of the generator to be installed.

4.9.1.1.2 Auxiliary Plant

The Emergency Power Plant will be located within the Petrel Joint Antarctic Base - in the area where the Emergency Power Plant is currently located, approximately 104 m north of the Photovoltaic Panel Field- 123 m south of the Emergency House, 15 m to the West of the Main Plant and 35 m to the East of the Obrador. The building holding the current emergency power plant will be dismantled and removed.

It will be a building with similar characteristics to the Main Power Plant, rectangular with a pitched roof, but smaller. It will occupy an area of 42.63 m2 (8.70 m long x 4.90 m long) and will have a maximum height of 4.92 m. It will have only one floor. Inside it will be housed a 250KVA generator with its control system and boards (Figure 131). The generator will be used exclusively in emergency situations, or for maintenance reasons. The emergency power plant (and its generator) constitutes the base's redundant power generation system.

4.9.1.2 Power Generation through Photovoltaic Power Plant

The general objective of the activity is to install 576 solar panels at Cape Welchness (Dundee Island) to provide energy to the facilities of the Petrel Base (63°28’44”S, 56°13’53”W). With this work, it is projected to reduce the annual consumption of fossil fuel by 74,000 litres.

Background

Based on the fact that the Marambio Base is located approx. 90km south of the Petrel Base, we will take as a pilot test the work carried out by García et al (2017) through which the feasibility of installing photovoltaic panels at the Marambio Base was determined and which is synthesised in the "Initial Environmental Assessment. Installation of a photovoltaic plant. Marambio Base, Marambio Island (2020)”.

Garcia *et al* (2017) determined that, due to its location, just above the Antarctic Circle (66° 33’ 46”), insolation conditions at the Marambio Base vary enormously between different times of the year. This work showed that the difference between the winter and summer months is extreme, giving days of 20 hours of sunshine in summer and only 4 hours in winter. Considering that the Petrel Base is located north of Isla Marambio, the approximate number of light hours is greater, and the monthly estimate varies between 20 and 5 hours.

At the Marambio Base, the solar elevation in winter months does not exceed 10º, this is observed in the differences that can be observed in the global radiation received in the horizontal plane. The values were measured with a Kipp & Zonen pyranometer from the national meteorological service every 1 minute (García et al, 2017). In the measurement, as a function of time, of global radiation on a horizontal plane, the difference is observed not only in intensity, but also in the number of hours of daily light between the different months shown. These results reflect a global Radiation that exceeds 1000 W/m^2 in the summer period.

Based on these data obtained and within the framework of the IRESUD project, in December 2014 a 1.92 kWp photovoltaic system was installed connected to the 220 V electrical network of the Marambio Base. According to the model, under optimal conditions, the Marambio Base installation, these panels produced some 27,520 kW/hxyear, which is equivalent to an amount of 5,773 litres used by the plant to generate that same amount, equivalent to 28 drums of fuel. The results were encouraging and therefore it could be concluded that the situation was propitious for the use of solar energy at the Marambio Base. This information will be taken as a pilot test for the photovoltaic plant that is intended to be installed at Cape Welchness.

Central Features

After the analyses carried out by specialists in the field in a pilot study including more than three years of measurements at Marambio Base, it can be deduced that the incorporation of electric power generation systems using solar panels, with their corresponding alternating current inverters at Petrel Base, is an extremely viable and timely option. The solar panels are the REC245PE model by REC PICK ENERGY. The factory guarantees a useful life for the panel of 10 years and a stable nominal power for up to 25 years.

A total of 576 panels will be used. The construction of the photovoltaic field will be carried out in two stages.

- Stage I: It will consist of the installation of a first group of panels (200). It will be built during the first year of the project. This construction will make it possible to evaluate in situ the power delivered to the electrical network and the changes and/or modifications to be made in the execution of Phase II of this project.
- Stage II: It will consist of the installation of a second group of solar panels (376), thus completing the projected solar field. This stage will be built during the second year of the project.

If we take the maximum electrical generation capacity of the generators and the electrical generation capacity of the solar panels during each month of the year on Petrel Base, we can infer the energy contribution and the fuel savings of the generators due to their working less.

In this sense, the estimated fuel savings, due to the use of solar panels during stages I and II and with different generator powers (at a similar power percentage, product of base growth) is as follows (Table 24) :

Table 24: estimated fuel savings.

Generator	Line	200 panels	576 panels
120 KVA	Savings (L):	26 010.12	74 909.16
	% of the total	24%	68%
	Equivalent to:	100 drums	262 drums
350 KVA	Savings (L):	26 537.29	76 427.40
	% of the total	8%	23%
	Equivalent to:	92 Drums	267 Drums

It can be seen that the savings in litres is similar in both types of generators, varying only in the percentage of total fuel consumed.

Each solar panel has a size of 166 x 950 x 38 mm with a total area of 1.65 m^2. Likewise, on the side with the solar cells it has a 2.8 cm wide frame edge. Considering these measurements, the panel has a usable area of 1.50 m^2(Figure 124).

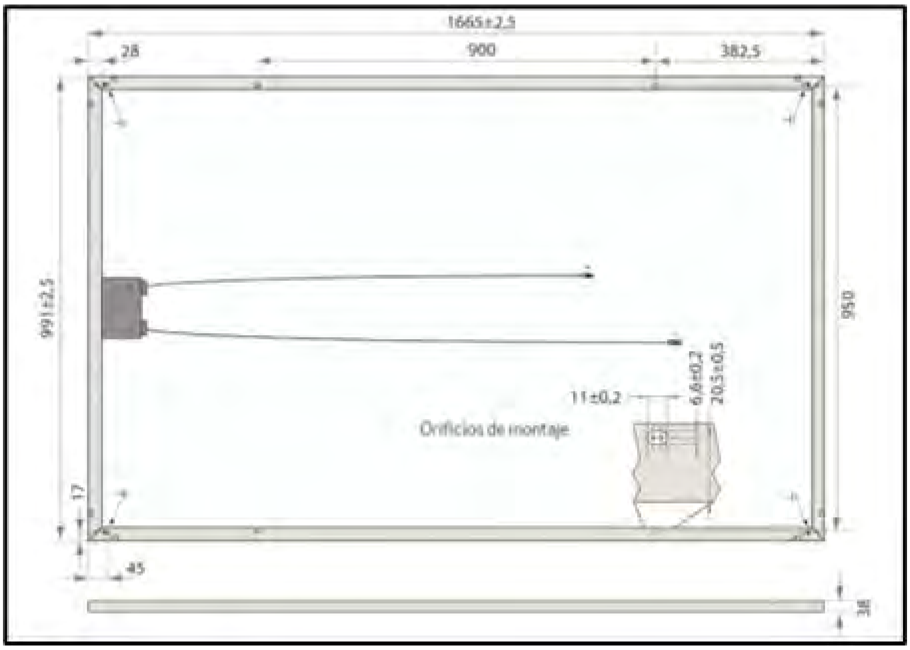


Figure 131: Measurements and characteristics of the panels to be used.

The solar panels will be installed on fixed metal structures. Each structure will contain 12 panels constituting a solar row or table. Each of them will be oriented to the north, keeping the panels at an inclination of 63º. 16 tables will be built in stage I and 32 tables in stage II. Each solar table will be separated from the one in front by a distance of 8 metres to facilitate exposure to the sun and avoid shadows. Laterally, the distance between table and table will be 5 m, which will facilitate the circulation of vehicles and the formation of snow queues.

Since the generators at the base will be working permanently, the photovoltaic field will be connected to the electrical system via inverters. For this reason, the use of a battery field is not foreseen. 3 inverters will be used, each one serving a third of the solar panels, although in the first stage a single inverter will be used for the 200 panels. The inverter will be connected to the general board of the Power Plant. The inverters will be placed at the back of the field of solar panels in a box, for this purpose whose size will not exceed 2 m^3 (2m front, one deep and 1m high).

It is expected that 200 panels will generate 24% of the total energy generated using the 120 KVA generators that the base has. This includes the 200 panels to be installed during stage I of the project. In stage II, adding 356 solar panels and keeping the same generators, it is estimated that 68% of the energy generated will be reached. In stage II, maintaining the 120KVA generators, it is estimated that the 576 panels, during the sunny days in the months of November, December, January and February, would be enough to supply the entire base with energy. Once the 350 KVA generators to be installed during the following stages of the Petrel base development project are installed, the annual percentages will become 8 and 23% respectively. During the summer months, the 576 panels will only cover 40% of the total energy.

Activities to be carried out for construction

The proposed activity consists of four basic tasks:

- **transport of materials**: The materials will be transported from Buenos Aires using the Almirante Irizar icebreaker. Once they arrive at the Base, they will be unloaded to the place destined for their deposit until they are finally taken to the place of installation. The movement in the work area will be carried out by means of the machinery that is usually used for movements within the Base. The packaging of the materials will be carried out in accordance with the directives drawn up by the Air Force regarding manual loading and palletised packaging. The materials to be used in the packaging will consist of cardboard wrappers and plastic film. The packaging material to be used will be the essential minimum, in order to reduce the amount of waste that will be generated. In turn, this waste will be reused to the greatest extent possible and the rest will enter the base's waste circuit.
- **ground preparation**: During this phase, the heights and levels of the foundations will be considered, leading to the excavation for the installation of reinforced concrete footings. For the installation of these it is necessary to place a total of 5 footings for each structure, which must resist the winds during storms. All the solar panels are expected to be installed on a galvanised iron structure, fixed to the ground with reinforced concrete footings. Each of these structures will house 12 panels, constituting a field of panels or row. The materials that make up the structures will be taken to the Petrel base and there they will be assembled and installed.

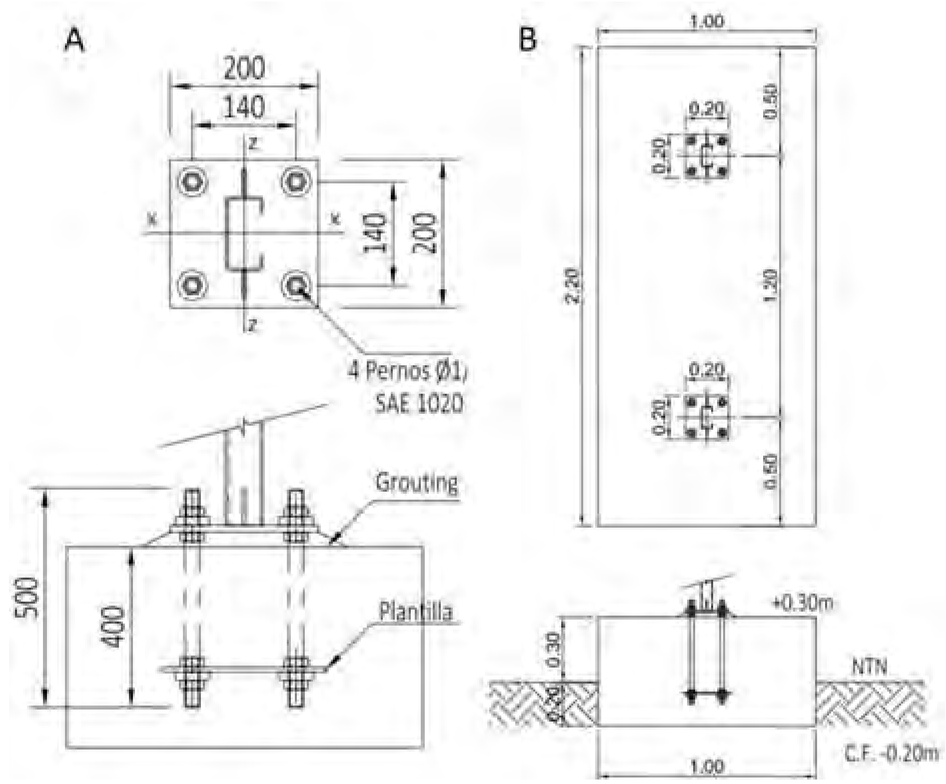
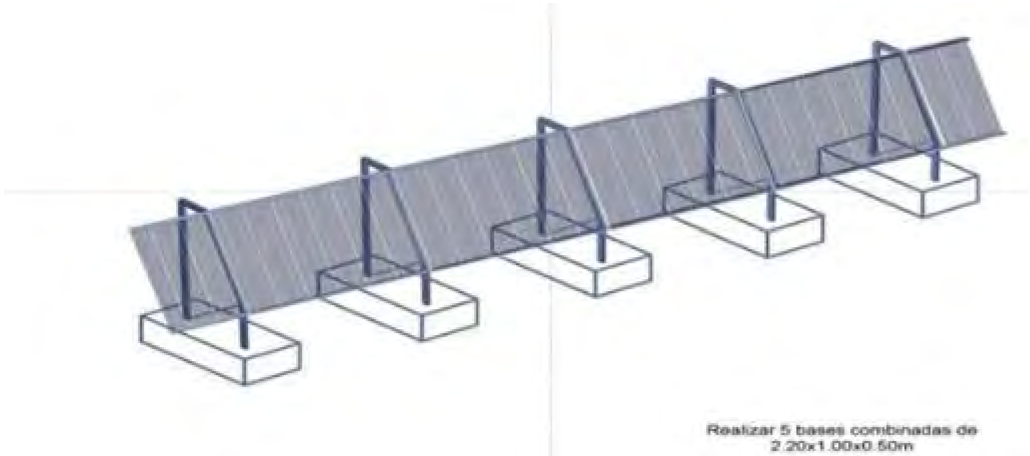


Figure 132: Diagram of the concrete footings to be installed to support the structures of the solar panels.

- **Assembly of the Line of Panels:** Once the piles are in place, the rectangular bases will be installed on them (Figure 133) whose purpose is to support the structures on it (Figure 134) where the photovoltaic solar panels will finally be installed (Figure 135). With the completion of this stage, all the lines of 9x2 panels will be assembled for a total of 4 individual structures, each with 18 panels. Each of them will be oriented to the north, keeping the panels at a 63º inclination. Each solar table will be separated from the front at a distance of 8 metres to facilitate exposure to the sun and avoid shadows. Laterally, the distance between table and table will be 5 metres, which will facilitate the circulation of vehicles and the formation of snow queues.

Figure 133: View of the panel support structure.



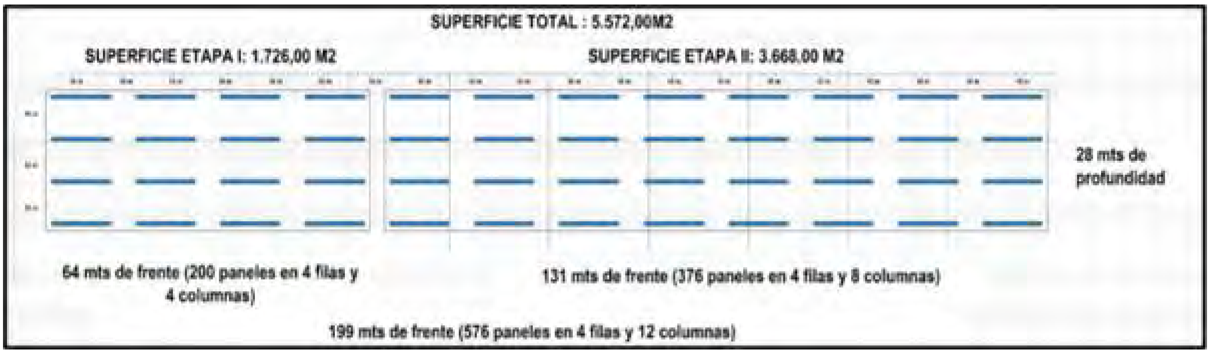


Figure 134: General structure with the location of the solar panels.

- **Inverter Assembly:** In this stage, a fourth annex will be built on an existing platform behind the Main Plant for the installation of the Growatt hybrid inverter with a capacity of 30kW that will supply the energy generated by the solar panels directly to the generators.

- **Start up:** During this phase, all the connections will be made so that the photovoltaic panel system is connected to the Base's electrical network with its subsequent commissioning and control.

As previously indicated, the field or solar facility with the lines of solar panels with a total of 576 panels will occupy an approximate area of 5572 m2 and will be developed 1 m above the natural level of the terrain, mounted on 16 buried piles on which all the structures for the installation of the panels are assembled (Figure 135).

CSFV electricity generation, its relationship with the electricity consumption of the base and its expected performance

Power of the panels and hours of light

The nominal power of the solar panels that the Petrel Base has is 245 Wh. Likewise, it is considered that, due to the latitude of the location of the Petrel Base, the hours of light throughout the year vary, so there is a great difference between the times of the year.

The Petrel Base is located at latitude 63° 28′ 40.61″ S. Accordingly, the daylight hours during the year are as follows:

Table 25: values of daylight hours per month.

HOURS OF AVERAGE LIGHT PER MONTH							
1st Quarter		2nd Quarter		3rd Quarter		4th Quarter	
Month	Hrs light	Month	Hrs light	Month	Hrs light	Month	Hrs light
Jan	19.5	Apr	10.8	Jul	4.5	Oct	12.9
Feb	17	May	7.7	Aug	6.8	Nov	16.1
Mar	14	Jun	5	Sep	9.9	Dec	19

As can be seen, there is a high level of variability in daylight hours. Likewise, a use of 70% of the days for the collection of solar energy was considered.

Electricity generation and fuel consumption at the Petrel Base

The base currently has 150 kVA generators, equivalent to the generation of 120 kVA equivalent to 96 kW hours. In the future there will be 350 kVA generators equivalent to 280 kW. In this way we can point out that the power of the generator for 24 hours will give us what is generated in the full day. However, on that generated power we will apply only a percentage of 70% since that is the power at which they work. Another piece of information that we know is the consumption of the generators calculated per Antarctic month. This average consumption is obtained based on what is consumed in other bases with similar generators.

% of Total Energy Generated annually at the Base that is expected to be generated with the panels

As can be seen in Annex 6 and indicated in the previous point, 200 panels are expected to generate 24% of the total energy generated using the 120 kVA generators that the base has. This includes the 200 panels to be installed during Stage I of the project. In Stage II, adding 356 solar panels and keeping the same generators, it is estimated to reach 68% of the energy generated. In Stage II, maintaining the 120 kVA generators, it is estimated that the 576 panels, during the sunny days in the months of November, December, January and February, would be enough to supply energy to the entire base (Figure 136).

Once the 350 kVA generators to be installed during the following phases of the Petrel Base development project are installed, the annual percentages will go to 8 and 23% respectively. During the summer months, the 576 panels will only cover 40% of the total energy (Tables 26 and 27).

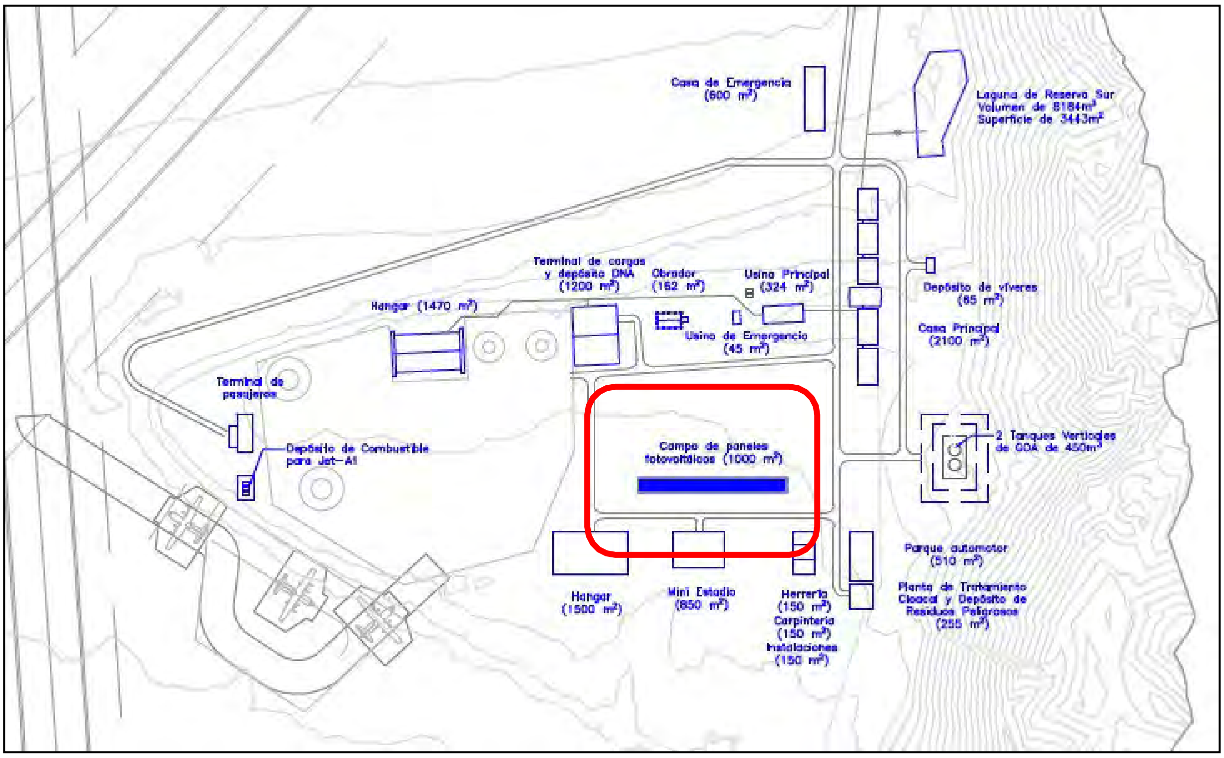


Figure 135: Location of the solar panel field.

Table 26: calculation of the performance of solar panels.

Se considera un rendimiento del 70% x por panel
A los fines de los cálculos se suman las potencias entregadas por día

GENERADOR DE 120 KVA

KW/h: 96 **KW/día: 2304** **70% KW/día: 1612**

				1 panel		200 paneles			576 paneles		
	consumo comb lts	generación/día KW	hs luz	kW x día	70% x día	al 70% potencia	% ahorro	ahorro lts comb	al 70% potencia	% ahorro	ahorro lts comb
ene	7.000,00	1.612,00	**19,5**	4,78	3,34	668,85	41%	2.904,44	1.926,29	119%	8.364,77
feb	8.000,00	1.612,00	**17**	4,17	2,92	583,10	36%	2.893,80	1.679,33	104%	8.334,13
mar	9.000,00	1.612,00	**14**	3,43	2,40	480,20	30%	2.681,02	1.382,98	86%	7.721,33
abr	10.000,00	1.612,00	**10,8**	2,65	1,85	370,44	23%	2.298,01	1.066,87	66%	6.618,28
may	10.000,00	1.612,00	**7,7**	1,89	1,32	264,11	16%	1.638,40	760,64	47%	4.718,59
jun	10.000,00	1.612,00	**5**	1,23	0,86	171,50	11%	1.063,90	493,92	31%	3.064,02
jul	11.000,00	1.612,00	**4,5**	1,10	0,77	154,35	10%	1.053,26	444,53	28%	3.033,38
ago	11.000,00	1.612,00	**6,8**	1,67	1,17	233,24	14%	1.591,59	671,73	42%	4.583,77
sep	11.000,00	1.612,00	**9,9**	2,43	1,70	339,57	21%	2.317,17	977,96	61%	6.673,44
oct	10.000,00	1.612,00	**12,9**	3,16	2,21	442,47	27%	2.744,85	1.274,31	79%	7.905,17
nov	7.000,00	1.612,00	**16,1**	3,94	2,76	552,23	34%	2.398,02	1.590,42	99%	6.906,30
dic	6.000,00	1.612,00	**19**	4,66	3,26	651,70	40%	2.425,68	1.876,90	116%	6.985,97
total	**110.000,00**										

200 paneles	
Ahorro (lts):	**26.010,12**
% del total	**24%**
Equivalente a:	**100 tamb**

576 paneles	
Ahorro (lts):	**74.909,16**
% del total	**68%**
Equivalente a:	**262 tamb**

Table 27: calculation of fuel savings.

GENERADOR DE 350 KVA											
KW/h 280		KW/día: 6720		70% KW/día: 4704							
				1 panel		200 paneles			576 paneles		
						al 70% potencia	%	ahorro	al 70% potencia	%	ahorro
	consumo comb lts	generación/día KW (70%)	hs luz	kW x día	70% x día		ahorro	lts comb		ahorro	lts comb
ene	20.000,00	4.704,00	**19,5**	4,78	3,34	668,85	14%	2.843,75	1.926,29	41%	8.190,00
feb	24.000,00	4.704,00	**17**	4,17	2,92	583,10	12%	2.975,00	1.679,33	36%	8.568,00
mar	26.000,00	4.704,00	**14**	3,43	2,40	480,20	10%	2.654,17	1.382,98	29%	7.644,00
abr	28.000,00	4.704,00	**10,8**	2,65	1,85	370,44	8%	2.205,00	1.066,87	23%	6.350,40
may	30.000,00	4.704,00	**7,7**	1,89	1,32	264,11	6%	1.684,38	760,64	16%	4.851,00
jun	32.000,00	4.704,00	**5**	1,23	0,86	171,50	4%	1.166,67	493,92	11%	3.360,00
jul	34.000,00	4.704,00	**4,5**	1,10	0,77	154,35	3%	1.115,63	444,53	9%	3.213,00
ago	34.000,00	4.704,00	**6,8**	1,67	1,17	233,24	5%	1.685,83	671,73	14%	4.855,20
sep	34.000,00	4.704,00	**9,9**	2,43	1,70	339,57	7%	2.454,38	977,96	21%	7.068,60
oct	28.000,00	4.704,00	**12,9**	3,16	2,21	442,47	9%	2.633,75	1.274,31	27%	7.585,20
nov	20.000,00	4.704,00	**16,1**	3,94	2,76	552,23	12%	2.347,92	1.590,42	34%	6.762,00
dic	20.000,00	4.704,00	**19**	4,66	3,26	651,70	14%	2.770,83	1.876,90	40%	7.980,00
total	**330.000,00**										
							Ahorro (lts):	**26.537,29**		**Ahorro (lts):**	**76.427,40**
							% del total	**8%**		**% del total**	**23%**
							Equivalente a:	**92 Tamb**		**Equivalente a:**	**267 Tamb**

4.9.2 Fuel Storage and Supply Systems

The Antarctic Gas Oil (GOA) fuel facility is essential for the operation of the base since it provides fuel to the generators that produce electrical energy from the base that allows the operation of all its systems.

Related to the above, it is imperative to design storage and distribution facilities capable of being durable over time and, in turn, easy to maintain and quick to put into service, since their operation is essential for the activity and survival of the base.

4.9.2.1 Installation Description

Parts of the Tank (Figure 137 and Table 28):

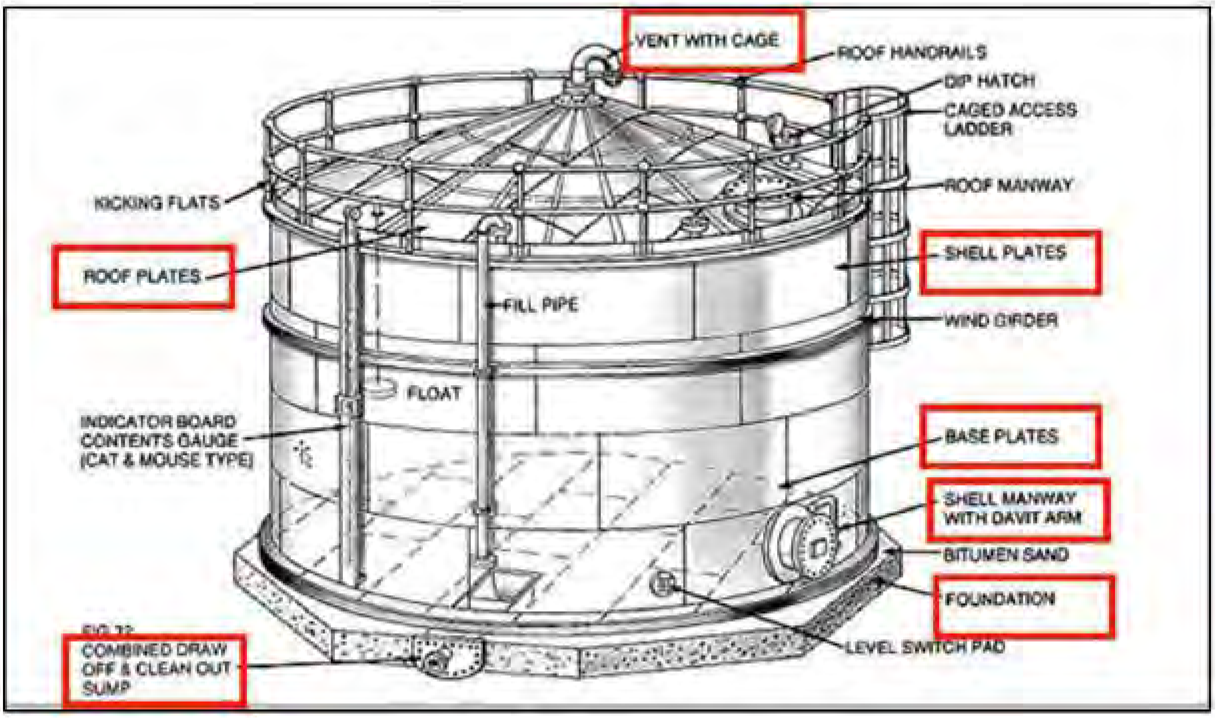


Figure 136: Parts of the tank.

Table 28: parts of the tank.

Ingles	Español	Material
Vent with cage	Ventilación	Acero al carbón
Roof plates	Laminas del techo	Acero al carbón
Shell plates	Láminas de pared	Acero al carbón
Base plates	Laminas del piso	Acero al carbón
Roof handdrails	Baranda de seguridad	Acero al carbón
Caged Access ladder	Escalera de gato	Acero al carbón
Shell Manway with Davit Arm	Boca de acceso	Acero al carbón
Foundation	Fundación	Hormigón armado

Sheet thicknesses

Table 29: thickness measurements of the sheets

Diámetro nominal del tanque (Ver nota 1)		Espesor nominal de lámina (Ver nota2)	
(m)	(ft)	(mm)	(in)
< 15	< 50	5	3/16
15 hasta < 36	50 hasta < 120	6	1/4
36 hasta 60	120 hasta 200	8	5/16
> 60	> 200	10	3/8

Notas:

1. A menos que se especifique otra cosa por el comprador, el diámetro nominal del tanque deberá ser el diámetro de la línea media de las láminas del anillo inferior del cuerpo.
2. El espesor nominal de la lámina se refiere al cuerpo del tanque como es construido. Los espesores especificados están basados en los requerimientos de montaje.
3. Cuando sea especificado por el comprador, lámina con un espesor nominal mínimo de 6 mm puede substituir lámina de ¼ de pulgada.

The thickness of the shell sheets shall be the greater of the required shell product thickness including the corrosion allowance and the required hydrostatic test weight. It cannot be less than the thickness of the following table.

Welding requirements

The welding requirements are based on the API 650 code that establishes the construction and design criteria.

1) Welds allowed

Tanks may be welded with the following processes or a combination thereof.

- SMAW. Coated electrode
- GMAW.MIG
- GRAW.TIG
- OFW. Oxigas
- FCAW. Tubular electrode (Flux cored)
- SAW. Submerged arc
- ESW. Electro slag
- EGW. Electric gas

2) Typical joint types

Welds shall be made in a manner to ensure complete fusion with the base metal, by welding on both sides or full penetration procedures. The edges of the welds must be fused with the surface of the sheets or plates without sharp edges. For vertical joints, the maximum undercut is 0.4 mm of base metal. For horizontal joints, an undercut not exceeding 0.8 mm in depth is acceptable. The maximum reinforcements in each side of the butt joint welds for vertical and horizontal joints will be according to the following table:

Espesor de lámina mm (in)	Máximo espesor del refuerzo mm (in)	
	Juntas verticales	Juntas horizontales
≤ 13 (½)	2.5 (3/32)	3 (1/8)
> 13 (½) hasta 25 (1)	3 (1/8)	5 (3/16)
> 25 (1)	5 (3/16)	6 (¼)

The reinforcement points of the vertical joints of the tank shells must be removed and must not be incorporated into the finished weld when using the manual process. When using the submerged arc (SAW) process, it is not required to remove the weld spots if they have been cleaned and prepared to be involved in the final weld.

a) Vertical shell joints

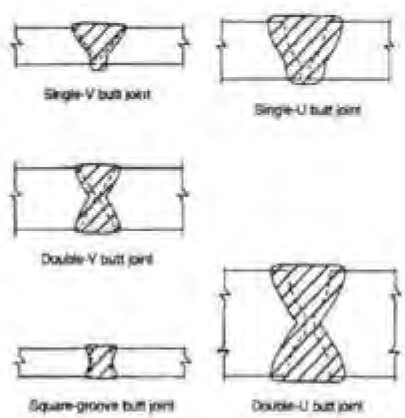
The maximum allowable misalignment for vertical joints shall be less than 1/8” or 10% of the sheet thickness (whichever is less) for sheets larger than 5/8” and 1/16” for sheets up to 5/8” thick.

The following must be met:

- Butt welds shall be full penetration and complete fusion, such as those obtained by welding on both sides or by welding procedures that produce the same quality of deposited metal on both sides of the joint.

- Vertical joints in adjacent rings must not be flush and must be offset by a minimum of 5 times the thickness of the thickest ring sheet in the joint.

Código API 650



Note: See 3.1.5.2 for specific requirements for vertical shell joints.

Figure 3-1—Typical Vertical Shell Joints

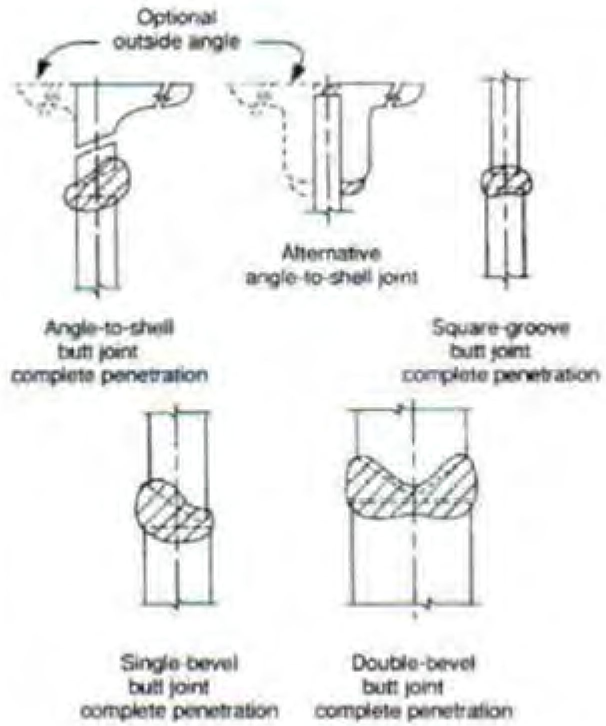
b) Horizontal joints

The maximum allowable misalignment for horizontal joints shall be less than 1/8” or 20% of the top sheet thickness (whichever is less) and 1/16” for sheets up to 5/16” thick.

The following must be met:

- Butt welds shall be full penetration and full fusion, by double sided welding or full penetration procedures. As an alternative, the top corners of the shell can be fitted with lap joints welded on both sides.

- Horizontal butt joints must have a common vertical axis.



Note: See 3.1.5.3 for specific requirements for horizontal shell joints.

Figure 3-2—Typical Horizontal Shell Joints

c) Overlapping bottom joints

Welding should be done in a sequence that produces the least distortion and therefore as flat a surface as possible. The shell-to-bottom weld must be made completely before finishing any bottom joints that have been left open to compensate for distortions and deformations of previously executed welds.

The shell sheets or plates can be aligned by means of metal clips welded to the bottom sheets, and the shell can be welded to the bottom prior to continuous welding of the shell sheets to the bottom sheets.

The following must be met:

- The edges of the sheets must be straight and cut square.

- The triple overlaps shall be at least 300 mm apart from each other, from the tank shell, from the ring butt joints and from the joint between the ring and bottom sheets.

- The sheets require welding on one side only, with a continuous fillet at all bottom joints.

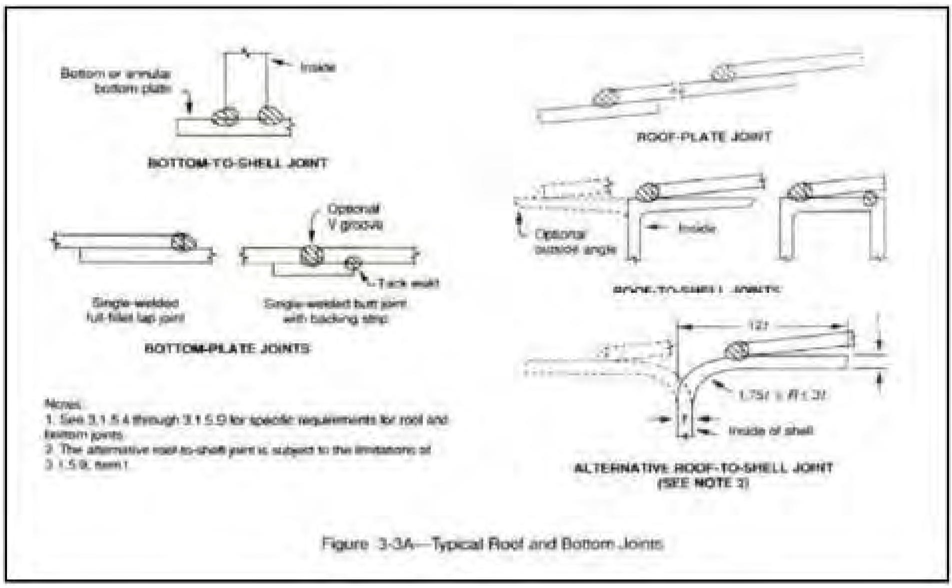


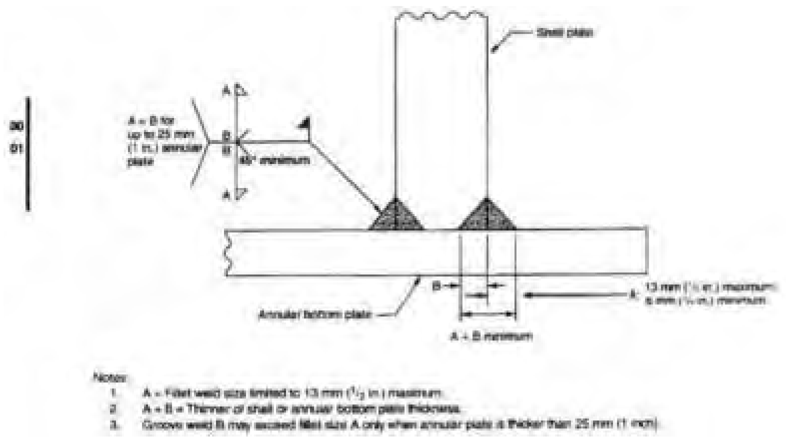
Figure 3-3A—Typical Roof and Bottom Joints

d) Shell-bottom joint fillet welds

The initial pass of welding through the interior of the shell at the shell-bottom union joint must be inspected visually and by one of the following methods: magnetic particles; penetrating liquids; diesel verification; inspection with vacuum box and soapy solution; inner and outer pneumatic test at a pressure of 103 kPa (15 psi).

The following must be met:

- For bottom and bottom ring plates with nominal thicknesses up to 1/2” (12.5 mm), the joint between the edge of the lower shell ring and the bottom plate shall be a continuous fillet weld on each side of the shell sheet.



e) Roof and upper shell angle joints

The following must be met:

- Roof sheets shall be welded on the top side as a minimum with continuous fillets at all sheet joints. Butt welds are also permitted.

- Roof sheets shall be attached to the top corner of the tank with a continuous fillet on the top side only.

- Top angle sections for self-supported roofs shall be joined with full penetration and fusion butt welds.

3) Welding inspection

In accordance with API 650, radiographic testing shall be applied to shell butt joints, shell plate butt joints, and flush butt joint connections. The radiographic method is not used for floor and roof lap joints, top angle joints, underfloor ferrule joints, structural joints, and accessories (inlet and outlet nozzle).

The most common way to verify that there are no leaks from tank floor weld seams is by vacuum chamber testing. These welds are previously visually inspected for slag residue, weld flash, and other defects such as holes, undercuts, and underfills.

Visual inspection of these features also applies to all welds on both sides of the tank shell, as well as fittings and shell-floor joints, where the latter joints are also subjected to an inspection using liquid penetrants.

Once the tank welds pass all inspections, the tank is considered ready for service. If repairs are required during its useful life, similar inspection methods should be used for the particular type of repair carried out.

d. Internal lining

1) Tank bottom corrosion protection

The bottom of the tank must be protected from corrosion in order to avoid spillage of fuel that contaminates the environment. Floor corrosion can be prevented by applying a waterproof coating and using electrochemical protection, when galvanic protectors are attached to the bottom of the tank. Furthermore, the bottom can be effectively protected by means of cathodic protection.

a) Electrochemical protection

Electrochemical storage tank anti-corrosion protection is based on the ability of metals to stop staining under the influence of direct current flow.

The surface of any metal is not homogeneous as far as galvanic characteristics are concerned, and this must be seen as the main reason why metal undergoes corrosion in solutions of electrolytic conductors. In this case only the areas with the most negative potential (anodes) are destroyed while the surface areas with the most positive potential (cathodes) show no destruction.

This method of protection is applied in combination with paint and lacquer coating. This combination of passive protection (paint) with active protection (electrochemical) allows reducing the cost of galvanic protectors and prolongs their useful life.

2) Technological process of applying the corrosion protection coating A primer layer is applied to the prepared inner surface of the tank with a pneumatic spray gun. It is very important to avoid paint drips. This process is intended to ensure the adherence of the paint coating to the metal.

The interior surfaces of the underground and above-ground tanks are covered with paint and lacquer materials in 2-4 layers with successive drying of each layer separately. Upon completion of the work, the acceptance certificate is signed, which must be accompanied by certificates of the materials used.

3) Metal processing before painting

The technological process of preparing the inner surface of the tank differs greatly from that of the outer surface. It is divided into several stages:

- Unloading of petroleum products
- Inner surface cut
- Tank degassing
- Degreasing of the interior surface
- Sandblasting
- Cleaning the interior surface of sand and dirt
- Application of cleaning to corrosion areas
- Washing of the inner surface with hot water
- Drying from the inside at 5-20ºC for 2-3 days (access plates and gate valves are kept open)
- Checking the quality of the preparation work and the suitability for the application of protective coating

e. Estimated sizing

The proposed dimensions for the vertical tank are:

- Diameter: 7.64 m
- Envelope height: 10 m

The proposed materials are:

- Flooring: 6 mm thick sheets 2000x6000 mm AISI 304
- Envelope: 6 mm thick sheet 2000x6000 mm AISI 304
- Ceiling: 4 mm thick sheets 2000x6000 mm AISI 304

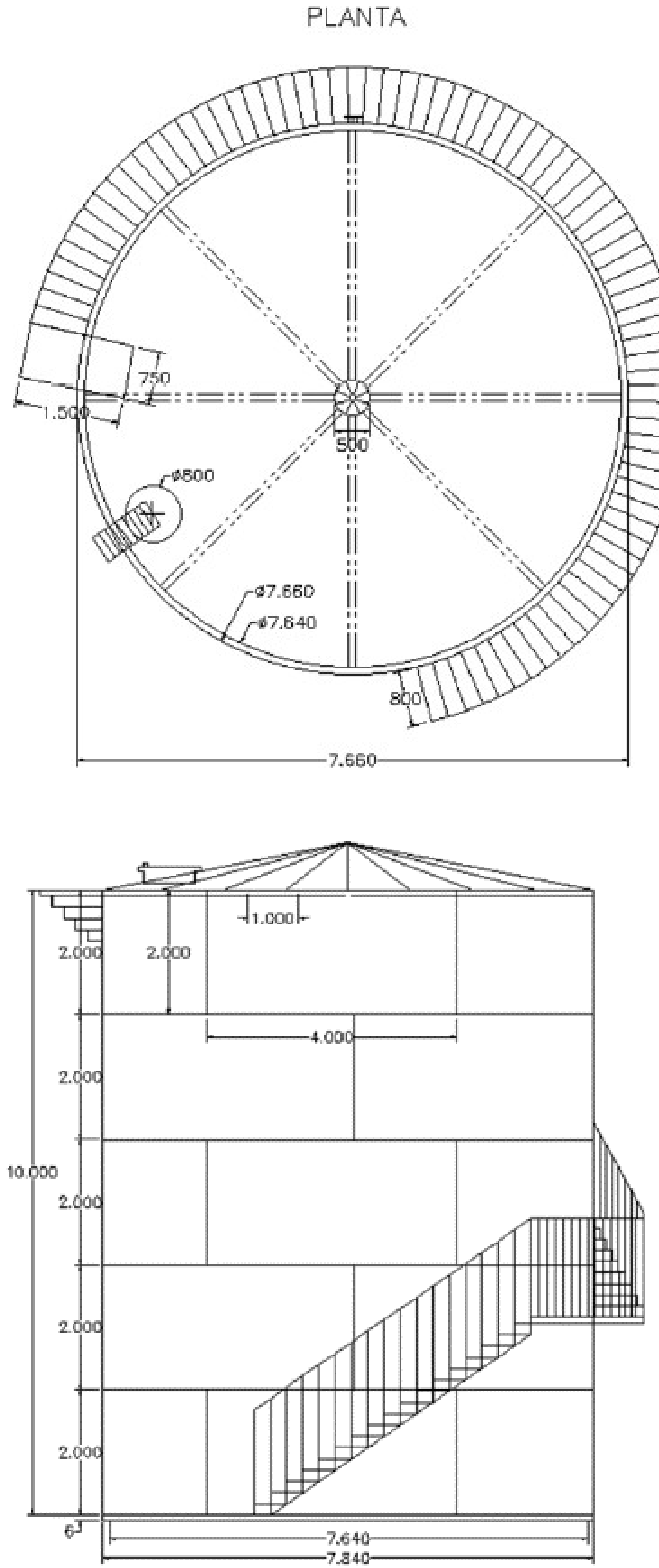


Figure 137: Diagram of the vertical cisterns

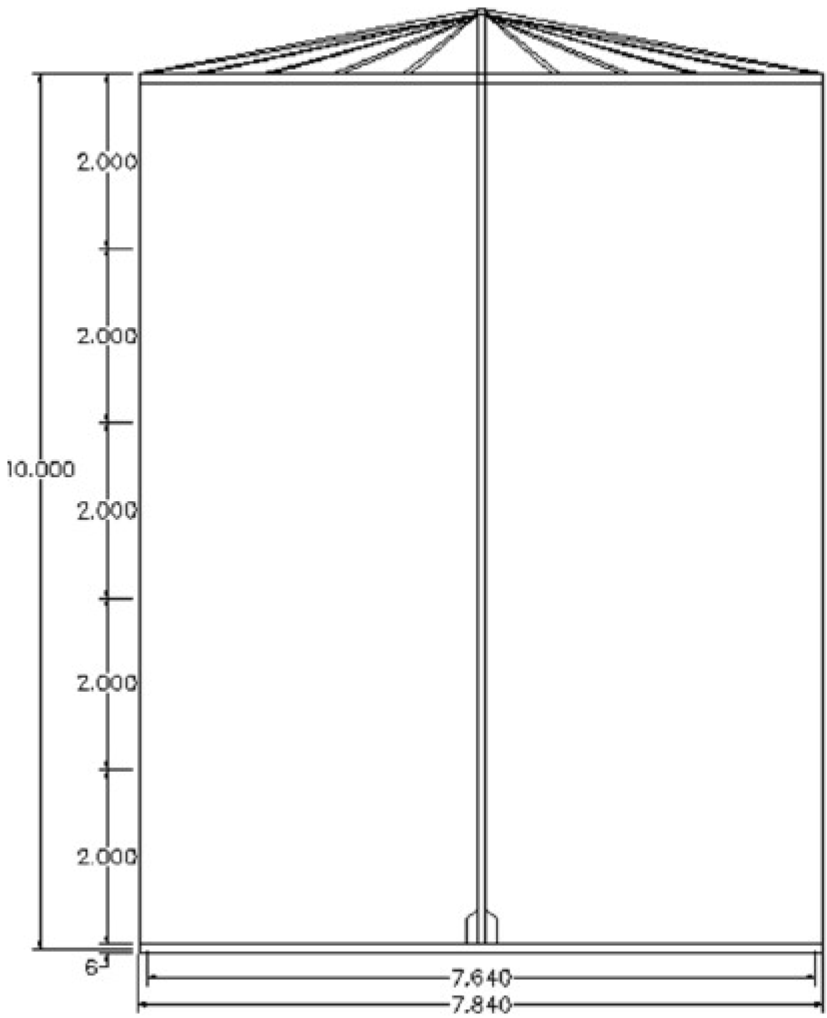


Figure 138: Schematic of the vertical cisterns.

1) Safety distances

After the analysis of the regulations in force in Argentina, using Resolution 1296/2008 of the Ministry of Energy, which corresponds to the minimum conditions that must be met by Biofuel Production, Storage and Mixing Plants in relation to safety in case of fires. Although non-biofuel GOA is stored, the resolution is applicable since it is a similar fluid and complies with internal standards.

According to Article 3 of Resolution 1296/2008, the storage plant was classified as CATEGORY III, and Article 125 determines the safety distances that are:

DISTANCIAS	CATEGORIA III
Distancia entre equipos	1 diámetro no inferior a 2 m
Distancia de zona de operación a almacenamiento de inflamables	15 m
Distancia de zona de operación a almacenamiento de combustibles	10 m
Distancia de zona de operación a pileta de recuperación	15 m
Distancia de zona de operación a cargaderos	10 m
Distancia entre tanques en el mismo endicamiento	1/6 de la suma de diámetros no inferior a 1.50 m
Distancia entre tanques enterrados	no inferior a 1 m
Distancia de la pared del tanque a la pared del endicamiento que lo contiene	no inferior a 1.50 m
Distancia de zona de operación o almacenamiento a quemadores o lugares con fuego	15 m
Distancia de zona de almacenamiento a pileta de recuperación	1 diámetro del tanque mayor, no inferior a 15 m
Distancia de zona de almacenamiento a cargaderos	7.50 m
Distancia al límite de la propiedad	1 diámetro del tanque mayor no inferior a 15 m
Distancia a vías férreas generales	1,5 diámetro del tanque Mayor, no inferior a 20 m
Distancia a casa habitación	2 diámetros del tanque mayor, no inferior a 15 m
Distancia mínima a bosques circundantes	100 m
Distancia de zona de operación a sala de bombas contra incendio	no inferior a 15 m
Distancia de zona de almacenamiento a sala de bombas contra incendio	no inferior a 15 m

2) Anti-spill containment tray

Once again applying Article 27 of Resolution 1296/2008, the liquid contained in the dikes of the overhead tanks must drain with the appropriate slope towards the recovery pool, whose capacity will not be less than TEN PERCENT (10%) greater than the capacity of the largest volume tank. The route of the drainage system will be constructed in such a way as to avoid the propagation of flames and do not expose the tanks. After the aforementioned regulations have been interpreted, it is understood that a dike must be executed of a minimum volume of 500 m^3 for the two vertical tanks. The diking will be carried out by generating a security enclosure through slopes and waterproofing with hydrocarbon-resistant geomembrane and waterproof PVC geomembrane (Figures 140 and 141).

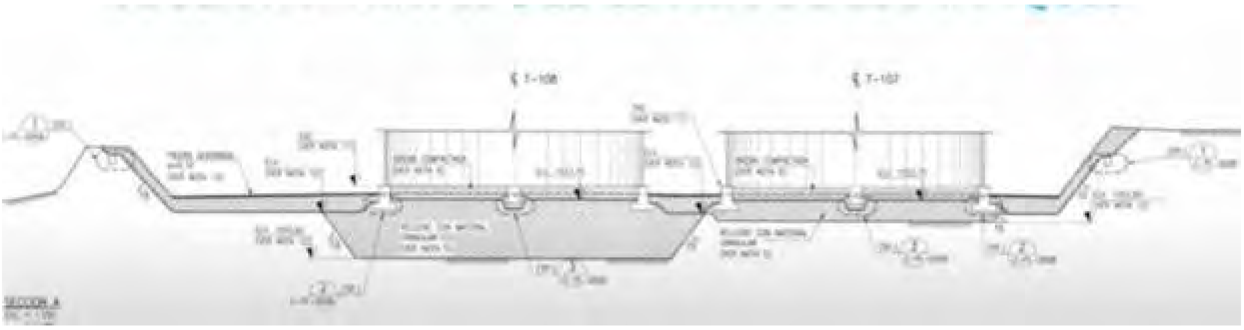


Figure 139: Diking layout

3) Lifting equipment

There are two types of methods known to build API tanks, the traditional method and the Cantoni system. Next, a brief summary and a comparison of each of them will be made. Before making the comparison, it should be noted that a more advanced study must be carried out to determine what type of foundation the storage tank should need. The comparison is already made with the clearing of the terrain, excavation and execution of foundations.

Finally, before carrying out the analysis, the weight of the sheets - both of the envelope and of the floor and roof - necessary for the construction of the tank is determined, which will determine the equipment to be used.

W_en	561,6	kg	Peso envolvente
W_te	374,4	kg	Peso Techo
W_pi	561,6	kg	Peso Piso

a) Traditional system

The traditional system consists of building the vertical tank starting from the base and the first layer of the envelope, for which the use of cranes, heavy machinery and labour is required to position the sheets of the envelope. Then the envelope sheets are welded to the floor and to the adjacent sheets until the first floor of the envelope is finished. After the first level of sheets has been formed, the second level is built using scaffolding and cranes in the same way. Finally, at the end of the construction of the envelope, the roof and its corresponding enclosure are built.

b) Cantoni system

Unlike the traditional system, in this system the first floor of the envelope is built and the roof above. Then the envelope and the roof are raised by means of hydraulic jacks, so that by means of a displacement system the sheets of the lower floor can be inserted and then welded. The welding works are carried out in an air-conditioned cabin located in the ferrule that moves so that the welding is carried out semi-automatically, avoiding work at height.

c) Comparison of systems

	TRADICIONAL	CANTONI
Soldadura temporales	Si	No, se realiza una soldadura definitiva
Tiempo de montaje	Lento	Rápido
Tipo de soldadura	Manual	Semiautomática
Trabajo de mano de obra	Espacio confinado	Salidas de escape, debido a que el tanque esta elevado por gatos hidráulicos
Andamios	Se necesitan andamios internos y externos	No
Trabajo en altura de MO	Si	No, en cabinas climatizadas
Necesidad de grúas	Alta	Baja
Área de trabajo	Alta	Baja, 2 metros alrededor del tanque
Costo	Bajo, solo alquiler de grúas	Alto, alquiler de patentes y equipo
Sistema de elevación	Grúas	Gatos hidráulicos

4) API tank foundations

There are five types of foundation system for API 650 tanks, the type of foundation requires a load analysis and the type of soil where the tank will be located.

The most commonly used systems are:

- Direct support on compacted soil
- Crushed stone ring
- Concrete ring
- Slab
- Slab-on-piles

It should be noted that generally for small capacity tanks, foundation rings are used.

Figure 140: Foundation ring layout

According to the regulations, the foundations are usually around 50 cm at least and ring-shaped, however, a future analysis is necessary and it will depend on the location area. According to Article 27 of Resolution 1296/2008, the foundations must resist up to 8 hours in case of fire.

f. Fire system

Fires where the fuel or diesel is the liquid have a type of fire that is normally extinguished by eliminating oxygen, thus interrupting the combustion chain and stopping the release of combustible vapours.

1) Types of fire extinguishers

The types of fire extinguishers suitable for smothering hydrocarbon flames are:

- Powder extinguishers: use chemical powders (sodium or potassium bicarbonate) to extinguish the fire by suppressing the chemical reaction.

- CO_2 extinguishers: they use carbon dioxide that manages to extinguish the fire by a suffocation effect. It does not produce chemical reactions because it is a non-combustible gas. When using CO_2 it is important to maintain a series of precautions, such as a safety distance of at least two metres from the fire.

- Foam: this is the mixture of foaming agent, air and water in certain proportions. Foam is one of the best resources to extinguish a fire in liquid fuel tanks. In extinguishing a petrol fire, the foam has multiple capacities.

In this section, the most effective solution is the foam for the size of the project. In turn, this type of project is regulated by the NFPA11 standard, which specifies the type of extinguisher and the systems to be used.

2) Protection system with foam chambers on the surface

There are various protection systems for vertical tanks, although in this section the most widely used for API fixed-roof tanks will be developed. The system allows an application of the extinguishing agent with a minimum immersion of the same and a moderate agitation of the fuel. The foam chamber is installed vertically in the tank, between 20 and 30 centimetres below the roof line (Figures 142 and 143).

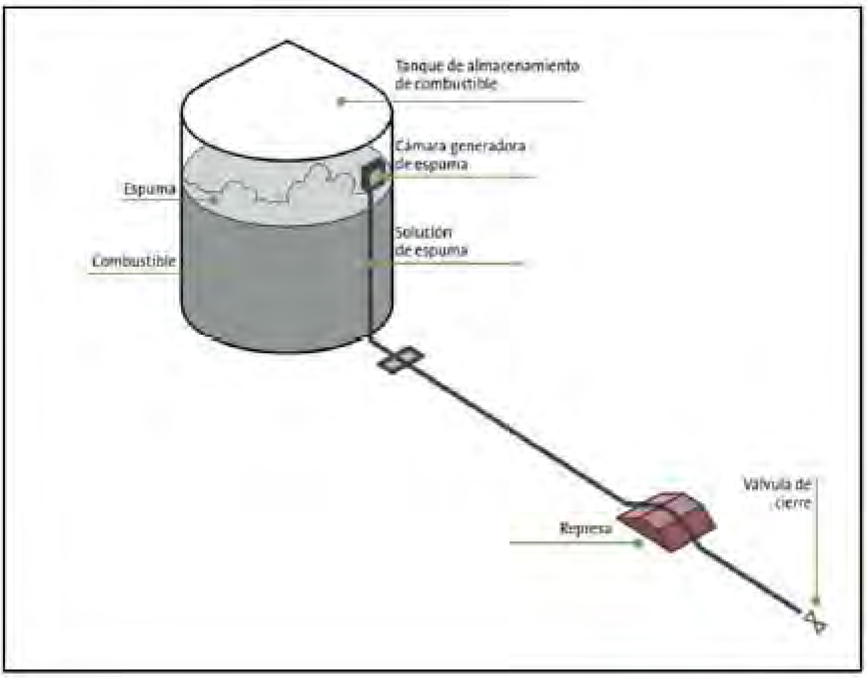


Figure 142: Diagram of the protection system with foam chambers.

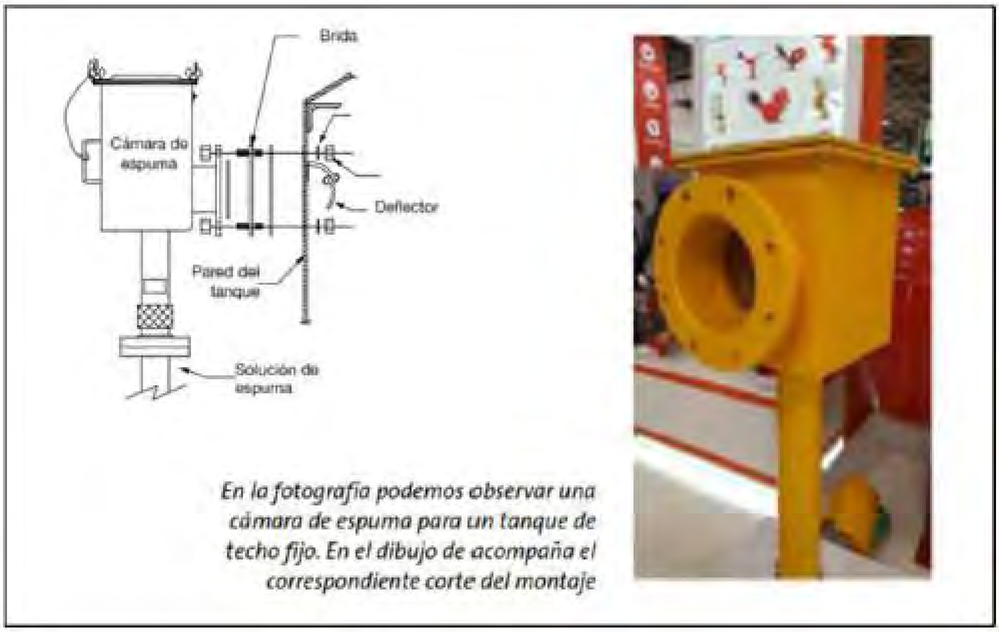


Figure 141: Foam chamber.

TRANSPORT AND STORAGE IN ANTARCTICA

a. Vertical tanks

Vertical tanks are generally used to store large volumes of fluids, these tanks are usually made of carbon steel sheets welded together. By virtue of the aforementioned, the sheets (on the roof, wall and base) can be transported and then welded on site. In this way it allows to occupy less volume in means of transport, facilitating logistics.

It should be noted that to carry out the assembly, machinery is needed, such as a crane (to lift the sheets), hydraulic jacks (to lift the walls) and road machinery to perform earthmoving for the foundation.

b. Horizontal tanks

In the case of this type of tanks, the best solution is to take the already assembled tanks and the sheets of the anti-spill tray separately, in order to weld them in the place where they will be arranged. In this way you avoid the large volume they occupy and thus facilitate logistics.

On the other hand, it is not recommended to weld the tank because the tightness must be guaranteed. In this section, it should be noted that welding in a workshop does not have the same effectiveness as those in the field.

7. Construction steps

In order to carry out the works proposed in this report and meet the self-imposed objectives, a sequence of works must be completed to ensure their continuity, in this way to be able to assemble the vertical tank on the foundation and then be able to carry out filling it without infiltrations.

The following is a brief description of each stage of the procedure of the works:

a. Plans necessary for the execution of the tank

For the execution of the following works, it will be necessary to have the following project plans:

- Plan of implantation of the vertical tank and its setting out
- Foundation plan (concrete ring) and its anchorage
- Plan of the tank bottom, distribution of the plates and overlaps
- Plan of the cylinder, rings, vertical and horizontal welded joints
- Roof plan, plate distribution, support structure
- Distribution plan of accessories, manholes (access), stairs
- Plan of the fire fighting system

b. Clearing of the terrain, setting out at the worksite and earthmoving

The first task to be carried out will be to clean the terrain where the vertical tank will be located, for this purpose earthmoving will be performed to leave the ground flat and to be able to set out the worksite. In turn, the earthmoving will contemplate the anti-spill tray that will be the second containment bottom sealed together with the foundation ring. Once these tasks are completed, the foundation of the tank will be executed.

c. Foundation execution

For the correct execution of the foundation of the vertical tank, it must be designed according to the climatic conditions of the site and the demands of the tank and external environment. At the same time, the reinforcements of the foundation ring, the formwork, vibrators, and the complementary use of additives that solve the inconveniences generated by the conditions of the white continent must be designed.

d. Workshop work on steel plates

The steel plates that have dimensions of (6 x 2) metres must be worked so that they can be installed in the tank, these works correspond to the squaring, bevelling, rolling and verification of the rolling. The squaring and bevelling will be carried out in cases where the dimensions of the plates are not the corresponding ones, requiring cutting with specialised equipment. Rolling is the process to give the plate the necessary curvature, which in this case will be according to the radius of the cylinder. This process is the most delicate of the construction process since it will determine the shape of the tank.

e. Tank bottom assembly

The bottom plates must be distributed according to the corresponding plan, considering the overlaps that must comply with the runoff slope before proceeding with the welding tasks. The headers will be welded sequentially, followed by the longitudinal ones. Welding processes, equipment (manual, automatic, semi-automatic), electrodes, joints, and personal protection elements for the welder must be available.

f. Tank enclosing cylinder mounting

It begins by relocating the centre of the bottom tank and verifying that the layout coincides with the foundation arch. The inner circumference of the edge of the plate should be 2” plus the thickness of the first ring and the distance to the edge should be the same around the entire circumference. The lifting elements will be placed together with their columns. Once the lifting columns are in place, we proceed to locate the plates of the last ring, seating them on the trestles. First the exterior vertical welds are made, then the interior ones, and finally the interior is ground until a uniform surface without porosity is achieved. We proceed to perform tests of its integrity with penetrating inks on the bead and then the internal bead is made.

Once all the vertical joints have been completed, the roundness is verified according to API 7.5.4 “local deviations”. The measurement of the outer circumference will be the nominal one and that will be the measurement until the end. After measuring the circumference, it is prepared for crawling up to a height of 2.40 metres to place the next plate. The vertical welding process is repeated, leaving the closing plate unwelded to verify local deviations and when this is checked, the horizontal seam is started from the opposite side to the vertical closing weld, starting from the outside.

The closure plates are always welded at the same time due to the contraction and expansion processes, the closure is welded verifying that the measurement of the outer circumference is the same as that of the previous ring. The stiffening angle is presented, braced and welded and it is prepared to crawl and install the next ring.

The process is repeated until the second ring. For the first ring, crawl the same way, only to a lower height so that the iron rests on the bottom and not on the trestle. After crawling, the trestles are removed, the plates are placed resting on the bottom and the welds are carried out in the same way. Lastly, the cylinder-bottom weld is made, beginning with the interior seam. Once all these processes are finished, tests are carried out by pouring hot diesel into each seam and observing the exterior to see if there are leaks. From this moment on, the only way to enter the tank is through the manholes.

It begins with the welding sequence of the accessories and the placement of the roof, which requires placement of the columns and beams supporting the roof.

g. Tank roof mounting

Once finished with the placement of the radial beams, the ceiling plates will be installed. A central line is placed first and from there it is distributed to the sides until only the blades remain to be placed. The welding is performed.

h. Final jobs

The supports of the uprights of the fire protection system and accessories will be placed on the roof. Once the hydrostatic test has been performed, no further welding can be carried out. Manhole and nozzle reinforcements are tested for quality. The bottom and top vacuum tests are performed respectively at a vacuum pressure of 4 psi.

- Tank base plate construction
- Construction of the top level wall with sheets
- Construction of the self-supporting roof
- Construction of the rest of the levels
- Final finish
- Antirust paint

h. Fuel Distribution System

Figure 144 shows the fuel distribution system that will connect the vertical tanks, the Power Plant tanks and the supply systems of the future port area.

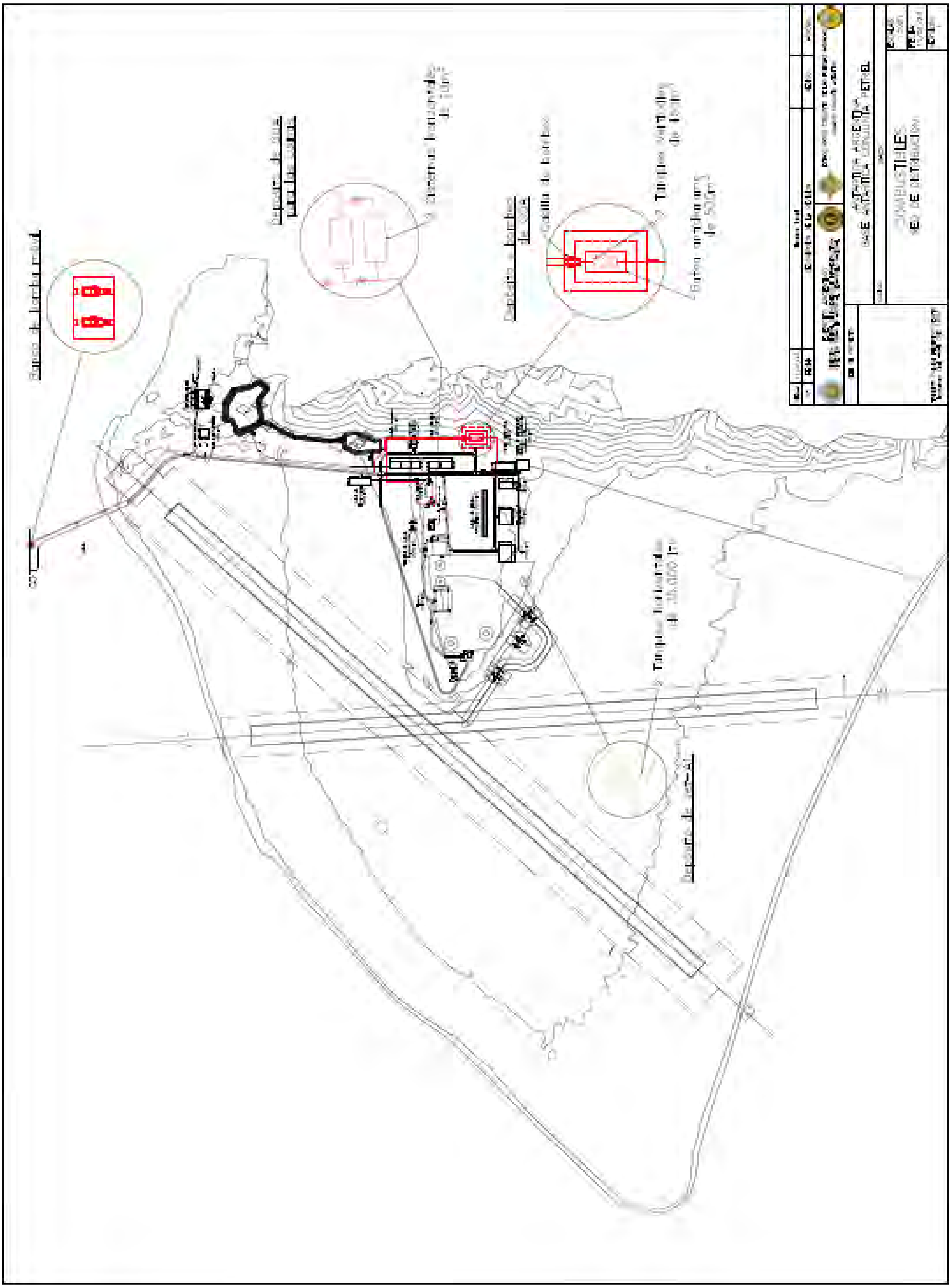


Figure 143: Detail of the general fuel distribution system at the Petrel Base.

4.9.3 Obtaining and Consumption of Water

The lagoons of the Petrel Joint Antarctic Base will be located on the northeast of the plateau (Cape Welchness), at about 20 metres above sea level. The so-called North Reserve Lagoon (LRN) will be larger than the Reserve that is currently there. The Main South Lagoon (LPS) will be a smaller footprint, located at the height of the line of existing buildings.

Both will be connected through a Communication Channel, which will allow maintenance work to be carried out without jeopardising the containment of all the retained water. This will allow the drainage of the liquid by gravity without the need to set up a pumping system. In addition, the LRN will have a type of weir with an open trapezoidal section, which allows direct control and maintenance in the event of any obstruction.

These facilities allow the retention and storage of fresh water from the thaw and melting of the active layer of permafrost and/or snow accumulation. Due to the minerals contained in the soil in the cape, the water collected requires filtering and purification to be suitable for human consumption, but its direct use for cleaning, hygiene and sanitary purposes is allowed.

Considering that the general objective of the remodelling of the Petrel Base is to contribute to the fulfilment of the scientific, technical and logistical tasks of the Argentine Antarctic Programme, complying with the regulations of the Antarctic Treaty and current protocols, within this framework, the need arises to have a system for obtaining, storing, transporting and purifying water in accordance with the parameters of the maximum personnel that the base can support (120 people). To this end, a main system and two alternatives have been conceived.

The system must be capable of: Obtaining, storing, transporting and purifying water throughout the year.

Providing water to:

- Main House/laboratory
- Emergency House
- Main Power Plant
- Cargo terminal and DNA storage
- Hangars
- Passenger terminal
- Workshops
- Sports centre

Auxiliary systems must provide a smaller amount of water, but constantly, so that the base never runs out of water.

4.9.3.1 Sources and methodology for obtaining water

The water containment capacity of the North Reserve Lagoon will increase more than 30 times over, from 1,015 m^3 at 31,740 m^3; and the South footprint will have a capacity of 8,185 m^3. The reservoir surface area will be 8,185 and 3,445 m^2, respectively. The longitudinal slope of the connection channel will be 0.5%, starting from the bottom of the upper end of the channel, at a level of approx. 12.25 m, 1.00 m below the embankment level of the Main South Lagoon, to a lower elevation of 11.35 m above the North Reserve Lagoon. Its section is made up of a base less than 3.00 m and a base greater than 5.00 m with a cross-sectional slope of approx. 1:1. The discharge spillway will be 4.80 m wide (0.80 m at water level), with a difference of 1.00 m with respect to the crest level of the embankment in order to maintain anti-erosion safety. The length of the smaller base will be 2.80 m (Figure 145).

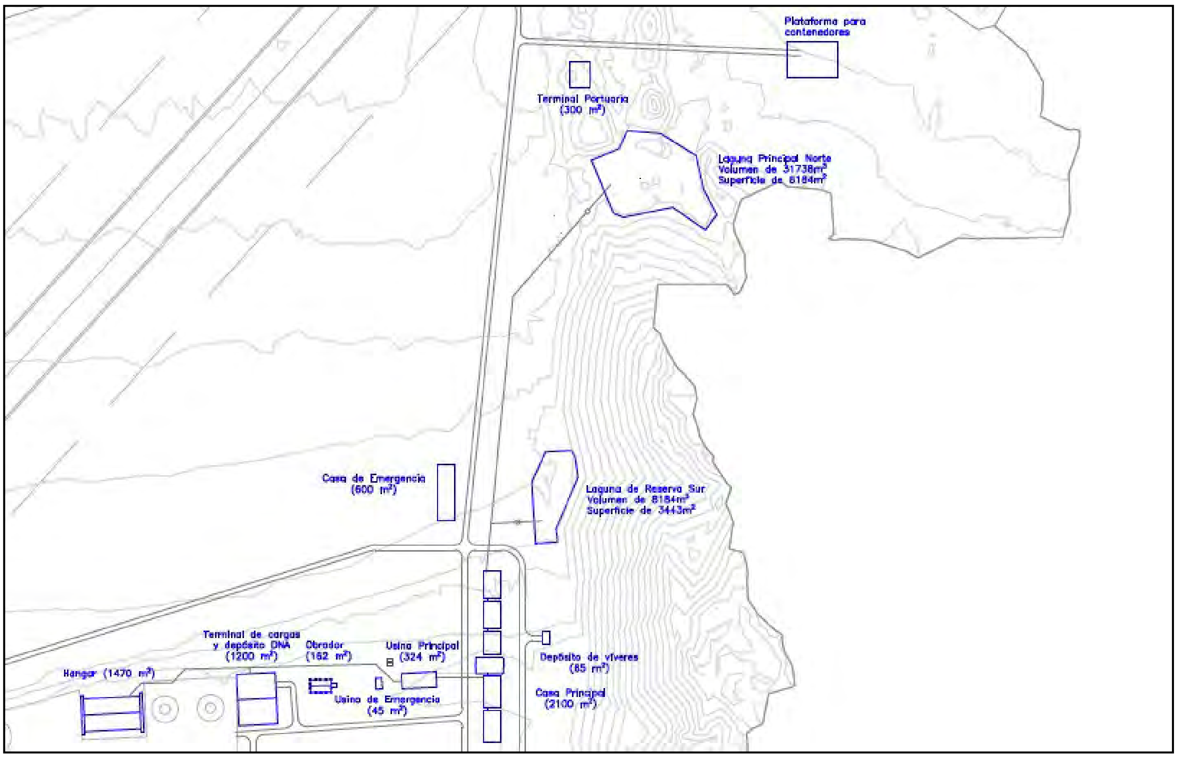


Figure 144: Sketch with location of the lagoons.

Both lagoons as well as their communication channel and the spillway will be protected in order to prevent water infiltration, erosion and undermining of the terrain, and water infiltration into the permafrost, which forms ice wedges and movements in the founding bed of the lagoon, generating instability over time. For this, low-density polyethylene geomembrane (LLDPE) will be used as reinforcement material, which will be placed by means of welded panels. In addition, they must be protected by a security fence of at least 0.80 m in height from the highest point of the fence to the level of the terrain to prohibit the eventual entry of animals. This fence will be a mobile system that can be used during the summer and dismantled in the winter, made up of studs and steel cables, with an external galvanised, acrylic polyurethane and/or epoxy coating in layers.

In summer, the population that will inhabit the base can reach an estimated total of 140 people, so a greater consumption of water must be covered. In winter, although the population could be reduced to an average of 60 inhabitants, the low temperatures can freeze the water to a depth of at least 1 m from the surface of the lagoon, making it necessary to melt snow to make it through this period. For this reason, the aim is also to increase the currently available water reserve capacity.

The lagoon must be complemented with equipment for the transport of water either by gravity or impulsion towards the destination as needed, either the purification plant or the storage tanks, including pipes, hoses, centrifugal pumps, etc. and its corresponding electrical connection.

It is necessary to execute a potable water network at the Petrel Joint Antarctic Base, in order to guarantee access to water for the Argentine Antarctic Logistics Activity (ALAA) and, in this way, meet the needs for planning the Base. It is an execution priority that is rooted in the health, hygiene and sanitation of the staff in daily life and in the event of an emergency.

This supply will be initially through the purification of the thawed glacier water and, secondly, the desalination and purification of seawater. In this way, it would be possible to safeguard its quality and avoid diseases transmitted by water in poor condition.

Two lagoons will be built in the northern sector of the Rosamaría Glacier moraine and another on the moraine near the northern end of the upper platform of Cape Wellchness. Its function will be that of a water reservoir to supply the base. The two lagoons will have their bed waterproofed with virgin polyethylene geomembranes of low density and

molecular weight, in the form of panels. They will be hermetically sealed to achieve low maintenance, allow the reserve of the thawed fluid from the Rosamaría glacier. From there, and through centrifugal impulsion pumps (work and service/reserve pumps), the water will be extracted and led through a pipe to the different buildings for storage.

4.9.3.2 Water treatment and distribution methodology

The water network will have a series of elements, namely:

- Lagoons, where the water will be obtained.
- Pumping plant, where the pumps that remove the water from the lagoon and send it to the network will be found.
- Pipe network, where the water will circulate.
- Storage tanks, located in the buildings that will be in the machine rooms and whose function will be to supply water to it.
- Purification filter, which will make the water suitable for human consumption
- Internal water network, the water network of each building.

Pumping system

There will be two pumping plants. One in the main lagoon and another in the emergency or secondary lagoon. The pumping plants will be made up of a small box in the vicinity of the lagoons, from which the submersible pump will be controlled, which will take the water from the lagoon and drive it through the pipe towards the different buildings, managing to raise the piezometric level of the fluid at heights.

Each pumping plant will have 2 submersible three-phase submersible pumps, one of which will be in operation and the other will be its backup. These will be associated with a flow meter that will report the amount of water that is entering the water network. The control of the operation of each pumping plant (operation of each submersible pump and the flow meters) will be supervised from the control room of the Main Power Plant.

In each pumping plant there will be an air compressor to vent the pipeline. It will be used if it is necessary to empty it for maintenance or other reasons. It is possible that, similar to Base Esperanza, the continuous operation of the submersible pumps is not necessary. In this case, it will be necessary to vent the network.

Water network

Initially, the water will be pumped into two buildings. The Main House and the Emergency House. The Emergency House will have its own pump and storage tanks, as well as its own water treatment plant. From the Main House, the water network will be divided into two main networks that will carry the water to the other buildings on the base

Periodically, water will be pumped through two main networks to the facilities that will have water, which are:

North main network	South main network
• Emergency House • Main Power Plant • Cargo terminal • Hangar	• Carport • Workshops • Sports centre • Helicopter Hangar • Sewage treatment plant

The construction of the water network will be carried out by means of a suspended pipe, with the use of heating tapes, a technology that makes it impossible for the fluid to freeze. Ideally, the pipe is made of stainless steel, such as ASTM 316, or carbon with a respective external coating, wrapped by heating tapes, with a nominal diameter of 3” (inches).

The pipe will be at a height of 60 cm from the ground. The use of expansion joints is also foreseen, to cushion the effect of expansion and contraction of the pipe due to temperatures. The suspension of the pipe will be carried out through metal anchors embedded in the ground similar to support blocks. The supports will be separated from
50 to 80 cm to achieve the stability of the pipe with respect to climatic/meteorological effects such as winds, and possible settlement or outcrop over time. The water network will have its corresponding inspection boxes.

The control of the network will be done from the Main Power Plant and the consumption of the heating tape will be evaluated by sections and the flow of water that circulates through it. Once the water has been made drinkable, the transfer would be divided into 2 lines, one following the line of buildings to the passenger terminal and the other to the Helicopter Hangar.

The pipe should have one or more drive pumps in the event that the topography does not allow the correct operation under pressure of the transfer of water from its collection to the base, or vice versa. It would have an approximate length of 1,600 m (without taking into account the pipeline corresponding to the internal installation of the plant), with valve locks at each entrance and/or exit of the building or dividing the lengths greater than 1,000 m. It should also include purge (drain) valves at low points, air (relief) valves at high points and Duo Check safety (retention) valves, as well as expansion joints, all with flanged ends.

Ideally, the pipe is made of stainless steel, such as ASTM 316, or carbon with a respective outer coating, wrapped by heating tapes, with a nominal diameter of 3” (inches).

4.9.3.3 Water quality

Two OI-501 type water purification equipment will be installed. The first one in the Main House and an alternative one in the Emergency House. The equipment will be reverse osmosis purifiers with the capacity to purify all the water obtained from the lagoons (Figure 146).

Figure 145: Reverse osmosis water treatment plant.

It will have a maximum purification capacity of 1500 litres/hour. Its operation will be automatic and its control panel will be found in the control room of the Main Power Plant. The flow of drinking water and its quality will be controlled.

Storage tanks

Each building that will have water service will have a storage tank in accordance with the estimated consumption in each of these facilities. Shifts will be established for filling each of the water tanks.

They will have a water storage tank, and therefore water and sewer services:

- Main House and Laboratory
- Emergency House
- Main Power Plant
- Cargo terminal
- Passenger terminal
- Workshops

- Sports centre
- Helicopter Hangar

The water network of each building will be supplied from these tanks. The Main Power Plant will have a water storage capacity of 30,000 litres, constituting itself as a water reserve for the base. This building will have a pumping station that will allow it to send water to the two main networks. This procedure will be used in case there are problems with obtaining water from the lagoons, or when the ice/snow melting unit or the desalination plant is being used.

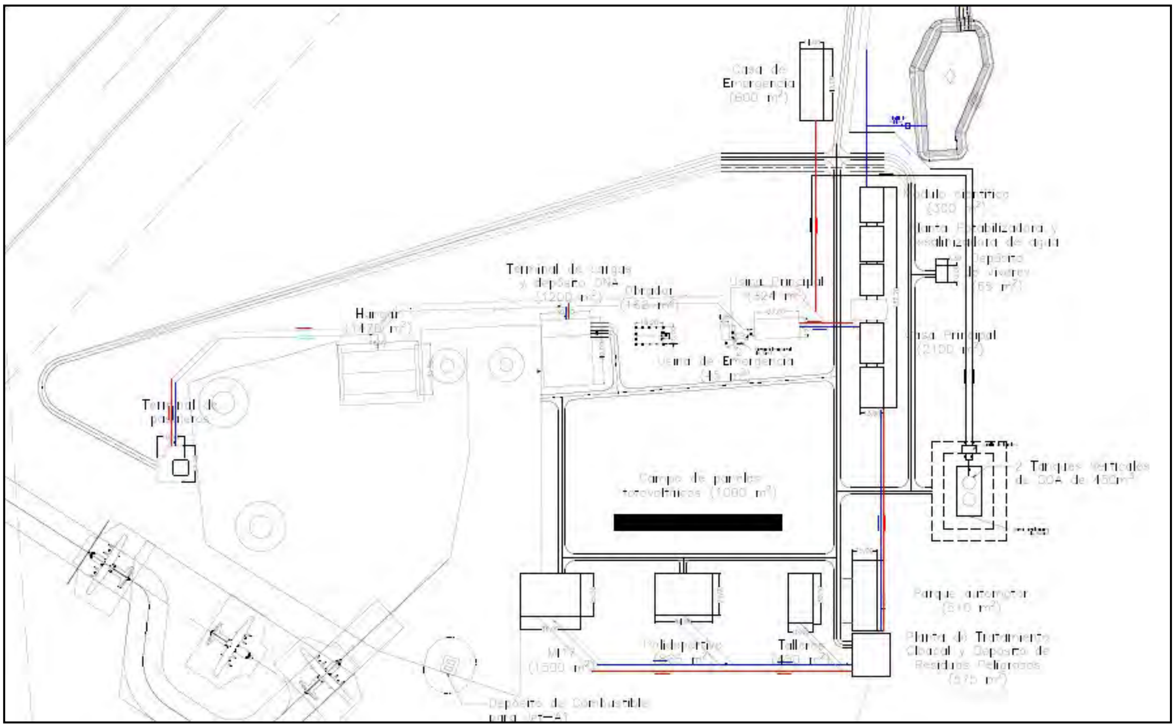


Figure 146: Location of one of the lagoons and the water supply network.

Internal water networks (Figure 147)

They will be specific to each building. Eventually, the networks may have a pressurising pump to raise the output pressure.

Alternative ways of obtaining water

The base will have two alternative ways of obtaining water. These will be used in case of emergency.

The methods will be:

- Obtaining water from the sea
- Obtaining water by melting ice or snow

Obtaining water from the sea

It will be an alternative process. For this, there will be a Karcher WTC 3000 portable desalination plant, which uses the reverse osmosis system to purify the water, retaining particles, microorganisms, viruses, salts and chemical products. It has a performance of up to 3000 l/hr. It will make it possible to obtain water without excess saline components or seawater salts and brine, the latter being returned to the sea. Through a system of pumps, the water is sucked and pumped towards the plant, to later go to the purification plant.

Obtaining water by melting snow or ice

It will be an alternative emergency process in the event of a failure in the system for obtaining water from the lagoons. An ice/snow melting unit with a capacity of 2000 litres will be installed in the Main Power Plant, which will use an electric resistance and a burner for the melting process.

4.9.4 Wastewater management

The decision to remodel the Petrel Base as a central point for the distribution and support of the activities of the Argentine Antarctic Programme, makes it necessary to consider the need for a system that includes the collection, storage, treatment and final disposal of sewage. This situation must be quickly remedied as it is expected that, due to the conversion works at the base, some 50 people attend during the Antarctic summer.

Considering that the general objective of the remodelling of the Petrel Base is to contribute to the fulfilment of the scientific, technical and logistical tasks of the Argentine Antarctic Programme, complying with the regulations of the Antarctic Treaty and current protocols, within this framework, the requirement arises for have a system for the collection, storage, treatment and final disposal of sewage in accordance with the parameters established by the Madrid Protocol and complementary regulations.

For this purpose, a system with the capacity to:

- Collect, store, treat and make the final disposal of liquids throughout the year.
- Vary the amount of liquids to manage, considering the number of staff during the summer and during the rest of the year.
- Given the dispersion of buildings, avoid the freezing of pipes and the normal operation of the treatment plant.

Collect sewage (grey and black water) from:

- Main House/laboratory
- Emergency House
- Main Power Plant
- Cargo terminal and DNA storage
- Hangars
- Cargo terminal
- Passenger terminal
- Helicopter hangar
- Sports centre
- Workshops

4.9.4.1 Effluent network

The sewage network will constitute a system made up of sanitary devices (toilet, sink or washing machine), tanks (septic, decantation and others, pumps, heated pipes and filters. Through it, the collection, storage, transport, treatment and final disposal of grey and black water.

Collection of grey and black water

Each building that has a water service will have a grey and black water collection system. These waters will be conducted to a septic tank where they will be stored. Depending on the calculated volume of grey and black water production, the capacity of the septic tank will be determined.

The capacity of the septic tanks will be directly related to the drinking water storage capacity of each building. They must have at least a volume greater than 10% of the capacity of the building’s water tank. In the same way, the emptying of the septic tanks will be carried out when the water tanks are at their minimum capacity. Said procedure will be automated with the supervision of the staff.

Sewage pumping

The sewage tank will have a grinder pump at its outlet, which will grind the waste and drive it through the pipeline. The grinder pump will have a power of 2 HP and will be three-phase. Its activation will be done automatically as described in the previous point (Figure 148).

Figure 147: Grinder Pump

Collection network for sewage (Figure 149)

The Sewage Network will materialise with a pipe with a three-way route with a diameter of 110 mm covered with expanded polyurethane and fibreglass on the outside. In total it will have an estimated length of more than 1900 m. It will be made up of three main networks that will collect sewage from the different facilities. These are:

Main Network 1:

From the Passenger Terminal, passing through Hangar, Cargo Terminal and DNA Storage and Emergency House to the Main House.

Main Network 2

From the helicopter hangar, passing through the Sports Centre and the Workshops, ending at the Sewage Treatment Plant.

Main Network 3

From the Main House to the Sewage Treatment Plant.

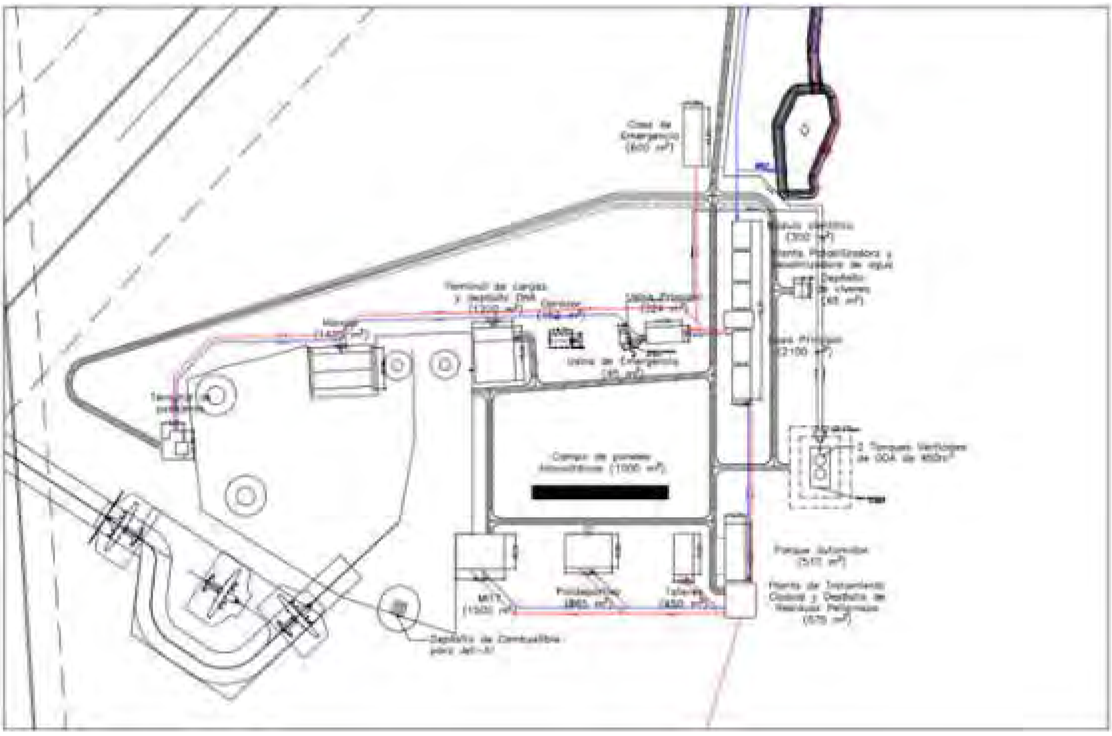


Figure 148: diagram of the drinking water and sewage network.

Materials

The network will consist of a galvanised steel pipe, suspended. It will have a double heating tape system and on it an insulating fiberglass cover. The pipe will be located about 60 cm from the ground level, and the use of this technology will allow the fluids not to freeze due to the low temperatures of the environment.

The suspension will be carried out through metal anchors embedded in the ground, taking into account the climatic effects, such as wind or snowfall, and possible effects of pipe settlement. This system will be made up of metal clamps, steel supports and flanges. Finally, the pipe will have a venting system to ensure that no sewage remains inside the pipes and thus prevent their freezing and subsequent obstruction of the conduit.

4.9.4.2 Effluent treatment system

The main network will lead the sewage to the Sewage Treatment Plant Building, where it will be treated. Inside it, 3 effluent treatment plants (ETPs) will be installed. Each one of them will be activated in a complementary manner in relation to the number of personnel on the base.

This solution was devised because:

- It allows optimisation of the operation of each one of them in its optimal regime.
- It allows deactivating it in case the flow of liquids can be treated by one or two plants.
- It allows an alternative in case any of the plants has a failure and goes out of service.

Building for the Treatment Plant

The dimensions of the plant to be projected will be 22.50 m wide and 25.50 m long, and it will have a covered area of 273.5 m^2. It is expected to treat a flow of 10,800 litres/day, it will carry out the pertinent treatment, purifying and disinfecting the water for its correct deposition (Figure 150).

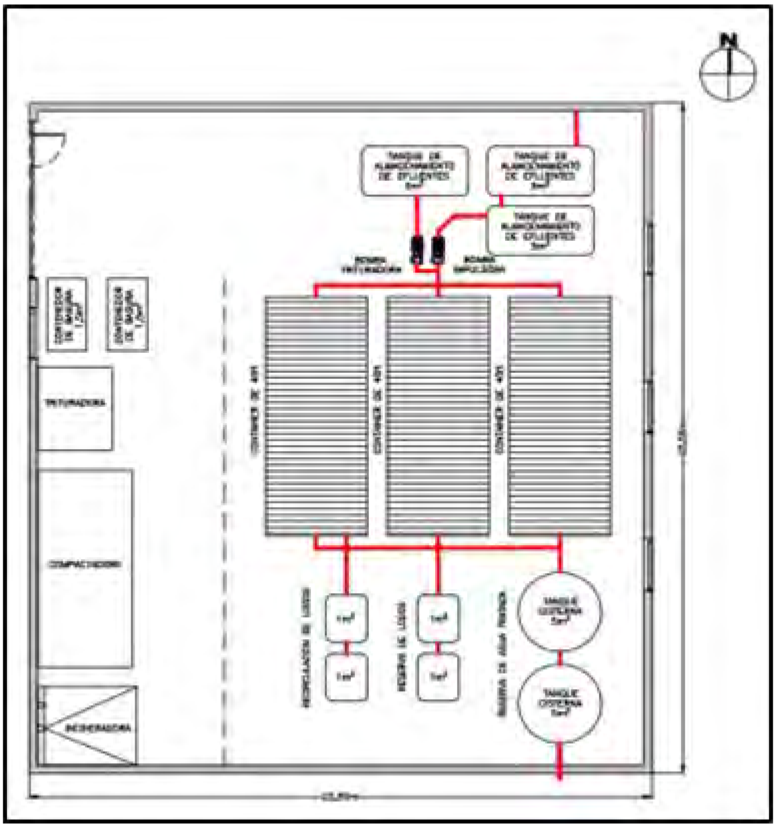


Figure 149: floor plan of the building with the treatment plant

The building will be projected with a modular construction system in order to allow its easy transfer from the Continent to Antarctica, and of a relative simplicity in the construction and assembly, once in the necessary places (Figure 151).

The objective of the structure will be to support the actions exerted on it and transmit them to the foundations. It will be carried out using dry construction methods (sandwich panels) and with a reticulated structure system (prefabricated trusses made up of metal profiles). The structural skeleton will be wrapped by the walls facing the exterior, which will be fastened by means of threaded steel rods to galvanised structural profiles (purlins).

Dimensions, distances and characteristics between these elements must be indicated accordingly in the final project plans. Thin sheet metal profiles, angle profiles, tubular and/or round pipes will be used as stiffeners.

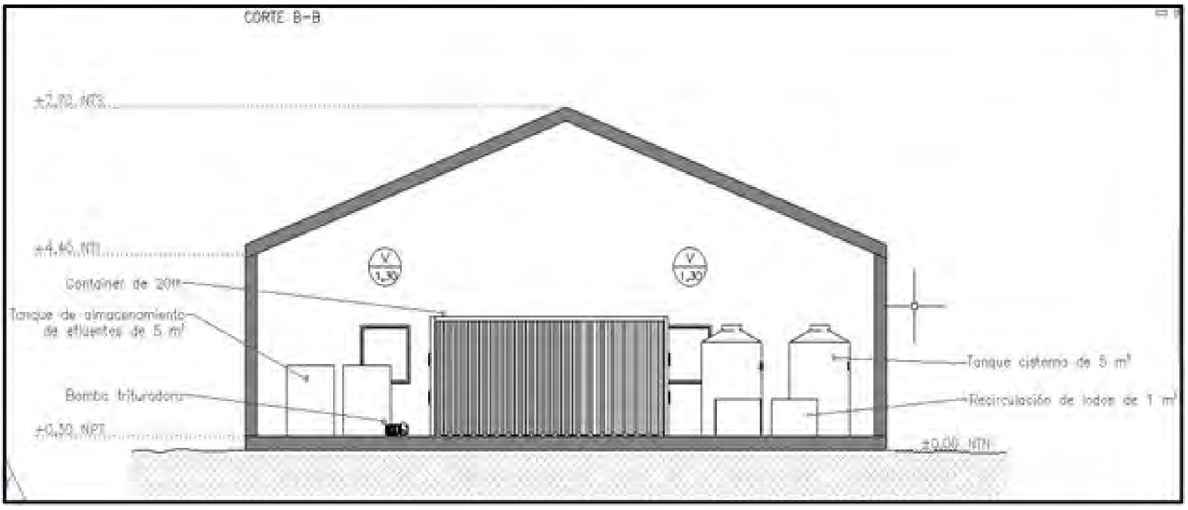


Figure 150: Side view of the building with the treatment plant.

Treatment Plant

The Design and manufacture of the modular and scalable Self-sustaining Biodigester + ETP "Pilot Plant" for the "Petrel" BAC will be carried out. Study of assembly, connection and operation of the equipment (Grey and black water).

The alternative selected for the "PILOT PLANT" of the "Petrel" BAC will be the product of the R&D&i studies carried out by the engagement team, between COCOANTAR, FAUBA, DIGID and DGII. As many aspects as possible related to S&T will be applied, and based on different criteria, whether logistical, environmental or economic; with the safety of people always prevailing in the detection of material or operational failures and above all, as its ultimate goal, to contribute to improving the activity of "Advancing in the Management of Wastewater from Antarctic Stations"

The 2nd Stage of the project will begin during the 4th quarter of 2022, and based on the progress and results, take the equipment during the 2022/23 Antarctic Summer Campaign (transfer the Pilot Plant to the "Petrel" BAC). It is estimated to start with the 2nd stage from the CAV 2023/24. Once all the information from the Pilot Plant has been collected during CAI 2023.

FUNDAMENTAL ASPECTS OF THE PROJECT COMPLETED IN THE PREPARATION STAGE

Within the short and medium term objectives, the following tasks/activities were defined:

- Carry out an analytical, structural and photographic sampling of the current effluent treatment systems of the Esperanza BAC. (completed)
- Investigate and design possible effluent treatment systems for the PETREL Base, for example, the design of a scalable and modular Pilot Plant (Responsible, integral project team FAUBA-DIGID-DGII) (accomplished)
- Sign work agreements (framework and specific) between COCOANTAR and FAUBA (fulfilled)
- Study the rules and laws of the Environment and effluent discharge in the AA (fulfilled)

ASPECTS OBSERVED BY "COMNAP" IN 2014 TO BE TAKEN INTO ACCOUNT

Design parameters:

Tailor-made wastewater management solutions may need to be developed in order to achieve results that meet the requirements from Annex II and III. Mentioned below are the processes that may need to be incorporated to ensure that the results of the process are free of microorganisms. These are:

- Ozone from disinfection/destruction.
- Ceramic microfiltration.
- Inverse osmosis.
- Biologically activated carbon.
- UV disinfection.
- Chlorine disinfection.

System options.

From an engineering operational perspective, desirable unit characteristics may include:

- Compact design.
- Low energy consumption.
- Operational reliability in sub-zero temperatures.
- Combined treatment of black and grey water.
- System location where wastewater streams can be collected using gravity.
- Ease/simplicity of maintenance, including cleaning a system that is closed, to reduce odours.
- Provision for the reuse of treated water for flushing toilets, washing vehicles, etc.
- Minimal need for replacement parts, limited human interventions, or opportunity for human error through, for example, the use of inappropriate chemicals or failure to pay adequate attention to system cleanliness.
- Ease of commissioning in stations that are not occupied throughout the year.
- Ability to "go down" during periods of low demand, e.g. winter.
- Installing kitchen grease traps will likely help, but cannot be expected to solve all of the problems associated with large volumes of grease, oil and grease entering wastewater treatment plants.

Critical aspects

- Effluent monitoring is critically important.
- It is not enough to track and record the results of the system.
- The results need to be analysed for their significance.

- The BOD (Biological Oxygen Demand), TSS (Total Suspended Solids), TN (Total Nitrogen) and *Echerichia coli*, are the emissive parameters most frequently measured in national programmes.
- Measurement of coliform contamination is especially important.

GENERAL WASTE EFFLUENT TREATMENT PROCESS TREATMENT DETAILS

- Degreaser, filter grate or sieve, primary treatment, septic tanks - IMHOFF tank - digester settling tank.
- Retention period: the effluent is retained between 24 and 12 hours depending on the effluent contribution. For 4,500-6,000 litres per day, a retention of 18 hours or 0.75 days is estimated.
- Effluent decantation: simultaneously with the previous phase, a sedimentation of 60 to 70% of the solids in suspension contained in the effluent is processed. This forms a semi-liquid substance called sludge.
- Part of the non-settled solids, made up of oils, greases and other materials mixed with gases, floats and is retained on the free surface of the liquid inside the pit; this liquid is called foam.
- Anaerobic digestion of sludge. Both solids, sludge and foam, are degraded by anaerobic bacteria, causing total or partial destruction of the volatile material and pathogenic organisms.
- Reduction of sludge volume: from the above phenomenon, gases, liquids and a marked reduction in the volume of retained and digested solids result, which acquire stable characteristics capable of allowing the liquid effluent to be treated under better conditions.
- The septic tank must be designed so that its dimensions satisfactorily meet the effluent output and allow simple, economical and safe maintenance.
- The tank volume calculation considers the volume corresponding to the effluent retention period, and the volume corresponding to the accumulation of digested sludge, according to the following expression.

Pre-treatment:

It is the first step after pumping the liquid to the treatment plant, and consists of removing any considerable solid that may enter along with the effluent, such as rags, paper or branches. This is achieved by means of fixed or automatic bars, sieves or perforated baskets, which are usually used in compact plants. Likewise, the pre-treatment can include a desanding process, where sand or small stones that may enter along with the liquid are removed.

Primary treatment:

- The first consists of a primary sedimentation (it is present only in large sewage plants), where fine particles of solids that were in suspension in sewage fluid. These settled particles form a primary mud, which must then be extracted and treated accordingly.

- The second process consists of the equalisation of the effluent. As sewage fluids are not generated evenly throughout the day, it is important to have an equalising tank (also called a homogenisation tank or buffer tank) that cushions flow and load peaks, giving a constant output for the rest of the processes. It is important that this tank is aerated (usually with coarse bubble diffusers), to avoid septicity that can generate bad odours and associated problems.

Secondary treatment:

- It is generally recognised as the most important process in the purification of sewage effluent. It involves the use of biological processes, that is, the use of naturally formed aerobic bacteria that use the polluting organic matter as food and degrade it to form innocuous elements.
- There is a wide variety of possible secondary treatments, although the most common include aeration chambers with activated sludge, SBR systems, MBBR systems, and trickling filters. These processes almost always involve air diffusers, usually fine bubbles. After the microorganisms purify the effluent, it is important to separate them from the liquid, since they can be harmful to watercourses and humans. This is generally achieved by means of a secondary settler, which works similarly to the primary settler, but its function is to separate the biological sludge formed in the aeration chamber and the treated liquid, which goes on to tertiary treatment. Part of the separated sludge is recirculated to the aeration chamber, where it continues with its treatment function, while the rest is sent to sludge treatment.

Tertiary treatment:

- It is the last usual process within a sewage treatment plant. It basically involves the disinfection of the liquid, that is, the elimination of bacteria and other potentially pathogenic microorganisms. Its removal is achieved by adding chlorine. In some modern plants, UV light or ozone disinfection may also be used. The disinfected liquid is now ready to be released into the environment, without representing a source of contamination.

Treatment of sludge:

- The sludge from the primary and secondary treatment must be treated to prevent it from creating problems for the environment. There is a huge variety of treatments, but the most common include aerobic digestion and dehydration, which makes them manageable, to be transported to a sanitary landfill, where they are buried together with urban solid waste.
- In the case of the “PETREL” BAC, they will be taken away to the South American continent for their

final disposal.

SUSTAINABLE PRACTICES IN THE IMPLEMENTATION OF THE SELF-SUSTAINABLE PTERBIODIGESTER AT IN THE “PETREL” BAC

This project takes into account these two pillars considered central to sustainable practices in Antarctica. Treatment and Logistics:

Treatment:

The wastewater produced in the Antarctic bases requires treatment prior to its final disposal, as established by the Madrid Protocol to the Antarctic Treaty signed in 1991 and which entered into force in 1998. However, this Protocol does not establish the parameters to be evaluated in the treatment plants, nor the limits of concentrations allowed in the treated wastewater, which is why different countries have been adjusting their processes, in accordance with their own national regulations.

- Argentina has treatment plants in its permanent bases in Antarctica, but it needs to optimise the processes, to grant them greater robustness and to be able to face local and international treatment standards that are increasingly demanding.

Logistics:

One of the great logistical challenges of the management in the bases of the Argentine Antarctica, lies in the complexity for the supply of equipment, spare parts and supplies for the endowments of the different bases. This manifests itself in the need to arrive by boat or by air, but it also becomes more complex, having to carry out the final disposal of waste on the Antarctic continent. Thus,

- Solid and liquid waste produced by the Argentine bases, excluding treated wastewater, must be classified and stored for subsequent transportation and treatment in our country. For this reason, any reduction that can be achieved in the total volume and mass of waste produced in Antarctica will necessarily generate significant logistical relief.

- Given that a part of the waste produced by the crews in Antarctica corresponds to biodegradable compounds, the proposal to install a “biodigester”, incorporated into the ETP Pilot Plant of “Petrel”, will allow the generation of valuable information related to the capacity of this technology to reduce the amount of solid waste that requires further treatment and transportation to Argentina.

Site selection:

The selection of the terrain for carrying out the work is based on two basic aspects, the first is related to the topography of the area and the second the particular characteristics where the residual effluents originate, generated in each of the facilities at the base. Currently they are discharged without any treatment into the sea. The location and layout of the collectors for feeding the plant must also be determined, as well as the subsequent discharge of the treated effluents at the determined point, following the natural runoff of the slope. To this end, the final location of the ETP Biodigester was defined in the “Petrel” BAC, and thus it was possible to dimension:

Physical location of the project and location plan.

The Treatment Plant, located on the Petrel Joint Antarctic Base, will be located on the elevated plain (E-W direction), sheltered from the prevailing winds (N-S direction), and the formation of the so-called “snow tail” (accumulation of snow behind an obstacle generated by wind vortices).

Location

Each MODULAR CONTAINER (TWO x 20 FEET) that contains the ETP will be in a building with a covered area of 250 m2, with initial dimensions of 16 m (width), 16.50 m (length) and 3 m (height). The liquid to treat will come from the Main House, located 137.5 m from the ETP, in a north-east direction. This is at an elevation of 17.0 m and the ETP at 15.5 m, therefore, there is a positive slope of 1.1%, so that it drains by gravity (Figure 152).

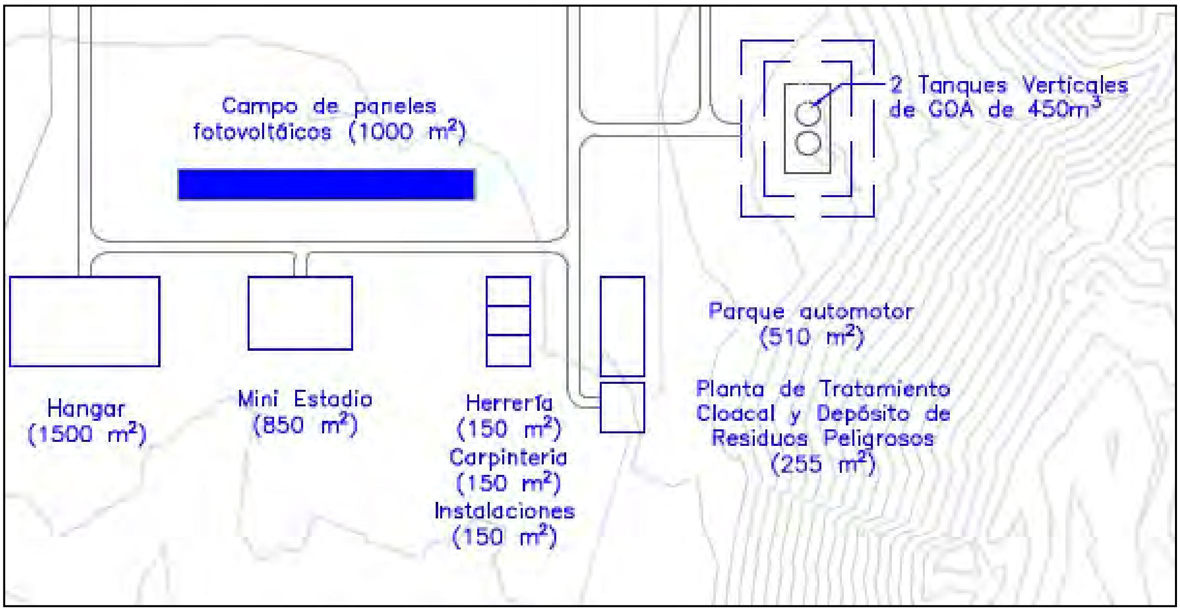


Figure 151: location of the effluent treatment plant.

Minimum residual effluent treatment capacity:

Initially for at least 35-40 people. The outgoing collector from the house will depend on the type of pump chosen. The three ETPs will have a total treatment capacity for up to 120 people.

Pipe (See Sewage network)

The pipe is projected in a 100 mm galvanised pipe, this will depend on the impulsion of the grinder pump located on the Main House. All the piping will have double heating tape, as well, located at about 60 cm from the ground level. Greywater recirculation capacity in each facility.

Frequent environmental characteristics where it will operate (Critical aspects)

- average temperature: -20 degrees Celsius.
- Average wind speed: 100 km/h.
- Maximum speed 250 km/h.

Other relevant aspects to highlight:

The building will be close to another building, the Carport (493 m^2). The choice of this provision is based on the use of energy for heating these buildings. In addition to the generation of EE (PV and wind) of the “self-sustaining ETP”, it is projected that is used as backup energy supply, the Main Power Plant, located 37 m west of the Main House.

4.9.4.3 Effluent disposal sites

The effluents will be disposed of on the south coast of Cape Welchness at a site that meets the requirements established by Annex II of the Protocol:

- This discharge is carried out, if possible, where there are conditions for its initial dilution and rapid dispersion.

4.9.5 Waste management

Waste Management in Antarctica currently has two problems to solve, on the one hand, preventing the volume of waste generated from increasing every day, and on the other, the difficulty and cost of waste disposal logistics from the Antarctic Bases is very significant, therefore, if there is a failure to act responsibly, the degradation of the environment may become irreversible due to the permanent presence of waste in the areas near the Bases. The classification on the basis of waste is essential, but the best waste is the that which is not produced.

For the management of waste for the separation, reduction, collection, storage and elimination of waste, the provisions of the “Waste Management Plan of the Argentine Antarctic Programme” will be complied with, designed by the National Directorate of the Antarctic, which uses the provisions of National Law No. 24,051 on Hazardous Waste. The responsibility for waste management rests with the Head of Base, who designates an Environmental Manager for the purpose of carrying out filing tasks and preparing the Base's environmental supervision records and reports. There are records filed in the Folder of the Environmental Manager. In accordance with the provisions of point 2 of the “Manual of Functions of the Environmental Manager of Antarctic Bases”.

The treatment of waste within the Petrel Antarctic Base will comply with the provisions of the current Legislation for Antarctica. These regulations applied to the activities of the Base are supervised by the active presence of the Environmental Manager, who develops his own tasks, as determined in the Operating Manual of the Environmental Manager. This will be responsible for preparing the corresponding reports for registration, elevation, evacuation and supervision.

The objective of this Management Plan is to establish the guidelines and procedures that must be implemented in the management of waste at the Petrel Base to guarantee compliance with each of the principles emanating from Appendices III and IV of the Protocol to the Antarctic Treaty on Protection of the Environment (Madrid Protocol) and current national legislation and also achieve a reduction in the amount of waste generated and waste evacuated for final disposal.

The general objective is to minimise the impact that waste from human activities can generate in the Antarctic environment by reducing, reusing and recycling waste in order to comply with the principles of Appendices III and IV of the Madrid Protocol. The specific goals foreseen as a result of the implementation of this plan are presented according to the different stages identified in the management of Antarctic waste, as indicated in the following table:

Stage	Targets
Planning	• Organise the activity so as to choose the option that guarantees the least possible waste production. • Guarantee the sufficient supply of elements and the building infrastructure and/or means of transport necessary for the management of waste in Bases, camps and ships. • Verify that no prohibited products are brought into the Antarctic Continent.
Classification	• Facilitate waste management in subsequent tasks.
	• Promote recycling possibilities
Treatment	• Minimise volumes to dispose and/or move. • Ensure optimal sanitary and environmental conditions.
Storage	• Facilitate waste evacuation tasks. • Ensure optimal sanitary and environmental conditions. Reduce the possible dispersion of waste.
Evacuation/transfer	• Minimise the environmental pollution of the Antarctic continent.
Supervision	• Verify the correct implementation of the Waste Management Plan . • Incorporate modifications to the Management Plan, arising from the experience of using this Plan.
Dissemination of Information	• Guarantee the correct implementation of this Plan.

Legal framework

In terms of environmental protection, the Argentine Republic through National Law 24216, of 19 May 1993, approved the Madrid Protocol agreed during the 11th Special Consultative Meeting of the Antarctic Treaty in 1991, which was signed by Argentina on 3 October 1993, thus incorporating it into its domestic legislation. The Madrid Protocol designates Antarctica as a "nature reserve, dedicated to peace and science", and establishes the need to protect the natural and scientific values of the continent. Among its appendices, the Protocol contains one that refers specifically to waste management and another referring to marine pollution, which establishes the guidelines and prohibitions for the discharge of waste into the sea. The disposal of waste at sea, in addition to being regulated by Annex IV of the Madrid Protocol, is in accordance with international regulations for the prevention of marine pollution, known as MARPOL 73/78, which are signed by Argentina. As from 14 January 1998, the Madrid Protocol entered into force, after being ratified by all member countries of the Antarctic Treaty.

Provision No. 87/2000 of the National Director of the Antarctic, of 3 August 2000, defines the scope of the Madrid Protocol, as well as the regulatory aspects of waste disposal and treatment, among other issues.

The aforementioned provision applies to:

- Argentinian citizens.
- Argentinian legal persons, ships and aircraft.
- Foreign citizens who participate in the activities carried out by the Argentine Republic in Antarctica (on board, in bases and in camps).
- Foreign citizens who maintain a permanent residence in the Argentine Republic and
- Foreign citizens, legal persons, foreign ships or aircraft that carry out an activity in the Antarctic Treaty area organised within the Argentine national territory.

In Argentina, the management of Urban Solid Waste (MSW) is regulated by the Minimum Budget Law 25916, which establishes the minimum budgets for proper management of household waste, based on promoting its comprehensive management, promoting its recovery and promote its minimisation in the generation and final disposal. In general terms, they include waste from homes and shopping centres, offices and industries that, given their composition, are comparable to those generated in private homes.

The management of hazardous waste is regulated in a particular way by National Law 24051, promulgated in January 1992, and by its Regulatory Decree No. 831/93. Likewise, in 2002, Law 25612 “Integral Management of Industrial Waste and Service Activities” was enacted, but the instruments for its implementation have not yet been established.

Radioactive waste is regulated by National Law 25279 which approves the “JOINT CONVENTION ON SAFETY IN THE MANAGEMENT OF SPENT FUEL AND ON SAFETY IN THE MANAGEMENT OF RADIOACTIVE WASTE" adopted in Vienna, Republic of Austria, on 5 September 1997. In accordance with the provisions of the aforementioned law, the scientific projects of the National Antarctic Directorate that have required it have a Licence to carry out activities related to the management of radioactive waste, granted by the Nuclear Regulatory Authority, dependent on the Presidency of the Nation.

Given that the scope of application of the Madrid Protocol is the Antarctic Treaty area, that is, south of 60° south latitude, the treatment of waste once it has arrived at continental ports is governed by national or provincial regulations on waste solids or liquids, whether these are dangerous or not mentioned above.

4.9.5.1 Waste Management (during decommissioning, construction and operation)

The first step in waste management at Petrel Base will be its classification into different groups according to its nature. The Madrid Protocol establishes an indicative classification, which has been adapted by the Argentine Antarctic Programme to adequately meet its needs.

The Argentine classification is based on the biodegradation capacity of the residue, the dangerousness and the possible final disposal methods to be used. This classification then establishes six groups, respecting, in general terms, what is established in the Protocol:

Group I: Biodegradable waste (solid): Biodegradable waste belongs to this group, such as food remains, paper, wood and clean rags.

Group II: Non-biodegradable waste (solid): It is made up of those elements with very slow or no natural degradation - non-biodegradable waste - such as plastics (including PVC, polystyrene, polyurethane, and rubber), polyethylene, rubber, ferrous cables, synthetic fibres, ashes from waste incineration from Group I, expired food, metallic containers and treatment residues from Group V.

Group III: Hazardous waste (solid and liquid): Includes hazardous, liquid, solid and gaseous waste established in Law 24051 on Hazardous Waste, which establishes a classification of 46 "Y" categories. The complete list of the classification of hazardous waste as established by the Hazardous Waste Law is found in Annex I of that law. In addition, solid hazardous waste includes all elements that are impregnated with liquid hazardous waste (rags, tow, paper, cans, brushes, treated wood, oil filters).

Group IV: Inert waste (solid): Inorganic solid waste, generically considered as "inert", belongs to this category, in the sense that its degradation does not contribute harmful elements to the environment, although its dispersion degrades its aesthetic value and can cause accidents to personnel. Glass, cans, sheets, remains of metal structures, drums (clean), wires, remains of concrete or concrete, bricks, packing straps, etc. are part of this group.

Group V: Liquid biodegradable waste. (Wastewater and domestic liquid waste): Here we consider wastewater and domestic liquid waste from kitchens, bathrooms, sinks, etc. This does not include liquid waste that may be mixed with hazardous liquid waste, for example, water mixed with oil remains, coming from workshops.

Group VI: Radioactive waste: Radioactive material waste in solid, liquid or gaseous form is defined by Law 25279 as those materials for which no further use is foreseen and which contain radioactive substances with activity values such that they exceed the dose restrictions established by the Nuclear Regulatory Authority for its dispersion in the environment.

Procedures for classification

In each unit of the Base, Ship or in the camp, there must be clearly identified containers in order to accumulate separately the different types of waste produced. The number of applicable groups may vary, according to the activity that is carried out in each premises or dependency of the Antarctic facility, and the existing operational facilities in it for treatment prior to evacuation. In some cases it may be convenient to separate elements of the same group of waste, to facilitate subsequent treatment. For example, glass cans (both residues from Group IV), in order to proceed to compact the cans and grind the glass separately.

All containers where garbage is collected must be labelled with the group number (in Roman numerals: GI, GII, GIII, GIV, GV), clarifying the type of waste that must be deposited in them and identified by a distinctive colour for each group. The suggested colour code for the first 4 groups is as follows:

GROUP	**COLOUR**
1. Biodegradable waste (solid)	black
2. Non-biodegradable waste (solid)	yellow
3. Hazardous waste (solid and liquid)	red
4. Inert waste (solid)	green

<table>
<tr><th>GRUPOS</th><th>GRUPOI (GI) BIODEGRADABLE LIQUIDO</th><th>GRUPOII (GII) NOBIODEGRADABLE</th><th>GRUPOIII (GIII) RSIDUO PELIGROSO</th><th>GRUPOIV (GIV) SOLIDOS INERTE</th><th>GRUPOV (GV) BIODEGRADABLE LIOQUIDO</th></tr>
<tr><td>SE IDENTIFICA CON EL COLOR</td><td>NEGRO</td><td>AMARILLO</td><td>ROJO</td><td>VERDE</td><td>SIN COLOR</td></tr>
<tr><td rowspan="4">RESIDUOS</td><td rowspan="2">RESTO DE COMIDAS</td><td>PLASTICOS/PET</td><td rowspan="4">ACIDOS, GRASAS, COMBUSTIBLES, ACEITES, LUBRICANTES, PINTURAS, LACAS. PEGAMENTO, ALQUITRA Y CUALQUIER TRAPO O SOLIDO IMPRECNADO O SOLOIDOS: PILAS, BATERIAS, RESTOS DE MEDICAMENTOS O PREPARADOS FARMASEUTICOS Y DESECHOS PATOLOGICOS.</td><td>VIDRIO</td><td>AGUAS GRISES</td></tr>
<tr><td>VIVERES VENCIDOS</td><td>LATAS</td><td>AGUS RESIDUALES</td></tr>
<tr><td rowspan="2">PAPEL, MADERA, TRAPO LIMPIO Y CARTON</td><td>ENVASES METALIZADOS</td><td>ALUMINIO</td><td rowspan="2">LIQUIDOS DOMESTICOS PROVENIENTES DE COSINA, BAÑO O LAVADERO.</td></tr>
<tr><td>CENIZAS PROVENIENTE DEL INCINERADOR DEL (GI)</td><td>ESTRUCTURAS METALICAS, CHAPAS, ALAMBRE, MAMPOSTERIAS Y ESCOMBROS</td></tr>
</table>

Once the waste has been classified, the different groups will be treated, stored, disposed of and/or transferred as appropriate to each group and to the place where they are generated.

For the correct management of waste, each Base must ensure that it always has:

- Sufficient containers to adequately store the different groups of waste generated. (Bags, empty drums, drawers, hermetic containers, etc.).
- Procedures and elements to guarantee that the containers in which the waste is stored are perfectly closed to avoid losses and emissions during its transfer. This point is of particular importance in the case of hazardous waste.
- A room with a surface area sufficient to store and handle the containers until they are evacuated. This means the construction or adaptation of a closed premises with an impermeable floor. In those bases that do not have specific facilities

for waste storage, waste must be stored in tents or container-type metallic structures, sheltered from the wind and animals.

- In the case of hazardous waste (Group III), it is advisable to have a separate unit, with an impermeable floor, adequate ventilation, without heating or electricity to avoid accidents. It must also have a fire-fighting system with the corresponding signage and instructions for use and a contingency kit for spills in case of accidents with liquid hazardous waste. This unit must be under strict security conditions in accordance with the danger of each residue.

Management by Groups:

Group I Biodegradable Waste

• Treatment: These residues can be treated on the Antarctic continent in order to reduce their volume. The Protocol allows the use of incinerators that reduce, to the greatest extent possible, hazardous emissions. Accordingly, the use of double-stage incinerators with smoke washing is recommended. This treatment method, in turn, generates a new residue, the ashes, which should be considered as Group II residues.

The remains of poultry products must be incinerated, since they represent a high risk for the local fauna due to the diseases that they can transmit. An alternative to their incineration consists of cooking them in boiling water (100 °C) for a period of more than 10 minutes. This practice eliminates possible viruses, such as the one that causes Newcastle disease.

Pursuant to the provisions of Articles 3 and 4 of Annex III of the Madrid Protocol, open burning as a treatment for waste from this group or any other is expressly prohibited, as is their filling or disposal in areas free of ice or fresh water systems.

• Storage: In the event that these residues are not treated, they must be accumulated in drums in the unit designated for the storage of residues. Once the capacity of each drum is complete, the upper lids must be sealed in order to facilitate their transfer and prevent them from being available to the birds.

• Transport: At the end of the Antarctic campaign, the remains of Group I that are not treated must be evacuated from the Antarctic Treaty area, either by sea or air.

Group II Solid non-biodegradable waste

• Treatment: The treatment methods applicable to the waste of this group have the purpose of reducing its volume. In these cases, compactors, mincers, grinders, slicers and balers can be used.

Some waste from this group can also be reused to store other waste items, such as plastic drums. If they have contained hydrocarbons, they must be washed before being reused. The water from this washing should be considered Group III waste.

• Storage: This waste must be stored in the same way as Group I waste, in the waste storage facility, for subsequent transfer. The dispersion of these residues into the environment must be avoided.

• Transport: They must be compulsorily evacuated from the Antarctic Treaty area, either by sea or air.

Group III Hazardous Waste

• Treatment: This waste will not be treated on the Antarctic continent, with the exception of pathological waste, which can be treated by autoclaving or other sterilisation methods.

• Storage: This waste must be stored in a closed unit, for exclusive use and away from daily traffic.

The waste must be contained in special containers for each category "Y", in accordance with the provisions of the National Law on Hazardous Waste. They must be in perfect condition, without deformations or perforations, and be completely hermetic to prevent any leakage into the environment and to ensure the necessary safety and health conditions. They must have a visible identification, stating the Group (III), the "Y" class, the specific content within the category of "Y", the volume and the date of storage, for example: Group III, Y12, Paint, 0.2 m^3, 3 February 2003.

Mixing and close stowage of incompatible elements must be avoided, information that appears in the respective Safety Data Sheet of the substance in question. Pathological or laboratory waste that is not treated by a sterilisation system must be packed in airtight bags and then in sealed and properly labelled containers to facilitate identification.

In the event of incidents involving hydrocarbons, remediation measures must be applied, contained in the corresponding Hydrocarbon Spill Contingency Plan. Aerosol containers, as well as fluorescent lamps or tubes must not be compacted, pulverised or perforated due to the possibility of explosion or implosion with risk to personnel and facilities.

Gas-containing cylinders must be returned for refilling. In some cases, prior venting is required. In other cases, partial content may be reusable, which is why it is a good idea to keep it. In other cases, the release of the content can be highly harmful to the environment. The following table is a general guideline.

• Transport: Hazardous waste will be obligatorily evacuated by sea and as a priority.

Article 32 of the National Law on Hazardous Waste (24051) establishes the prohibition of transporting hazardous waste in airspace subject to Argentine jurisdiction, so the only possible modality for evacuation will be transport by sea.

Group IV Inert Waste

• Treatment: The treatment methods applicable to the waste of this group have the purpose of reducing their volume. In these cases, compactors for sheets, drums and cans and glass grinders can be used. Some waste, such as sheets, can be sectioned.

Efforts are also made to minimise the risks of personal accidents during handling. Scrap in general, including old drums, must not have sharp edges and must be compacted in order to facilitate its transfer by air and its stowage on board.

Any blocks generated or drums compacted must not be taller than one metre.

These residues can occasionally be reused. For example, drums can be used as waste containers. If they have contained hydrocarbons, they must be washed before being reused. The water from this washing should be considered Group III waste. The remains of concrete and wire can be reused as fillers for foundations or foundations.

- Storage: The waste will be packed in the possible cases and will be stored in the waste storage facility, for its subsequent evacuation from the area of the Antarctic continent.

Given the high density of some of this waste, such as construction materials and the remains of structures, it should be ensured that they are stored in a shape and volume equivalent to that of a 205-litre drum, and a weight of no more than 250 kg to allow handling and prevent containers from falling apart. Based on this, if 205-litre drums are used to transport inert waste, such as glass or cement, care must be taken not to fill them to their full capacity, in order not to exceed the final weight. Although the elements of this Group can be stored and packaged together, it is convenient to separate them previously since this practice will facilitate their marketing once they have been evacuated from the Antarctic continent (especially in the case of cans and glasses).

- Transport: Waste from this group will be mandatorily moved outside the Antarctic Treaty area by sea or air.

Group V Wastewater and domestic liquid waste

Although the Madrid Protocol encourages the evacuation of all waste from this group generated there from the Antarctic continent, domestic wastewater and liquid waste can be disposed of within the Treaty Area as long as the regulations emanating from it are respected.

- Treatment: The treatment in bases will depend on the weekly average of people who occupy the Base as established in Article 5 of Annex III.

- Bases with weekly average of more than 30 people: It will be mandatory to treat the effluents at least by maceration. Other treatment methods, such as the Rotary Biological Switch or similar, can also be used in order to reduce the load of pathogenic microorganisms that may affect the marine ecosystem.

Group VI Radioactive Waste (Waste of this type will not be generated at the Base)

- Treatment and storage: These residues cannot be treated on the Antarctic continent. In facilities that generate Radioactive Waste, the registration, classification, segregation, conditioning, storage and transportation of radioactive waste must be carried out, as previously authorised by the Regulatory Authority.

- Transport: All radioactive waste will be evacuated compulsorily. This task will be carried out by the authorised scientist.

Waste evacuation

In the moments prior to its evacuation by sea, the place where the waste is stowed must be carefully selected, trying to use an impermeable surface to avoid seepage into the substrate. It is convenient for the same location to be used each time the waste is evacuated. If the event of not having a fixed waterproof structure, such as a concrete tray, then tarpaulins or plastic sheets can be placed there.

4.9.5.2 Management Diagram

According to what was mentioned in the previous items, waste management at the Petrel Base will be as follows (Figure 153):

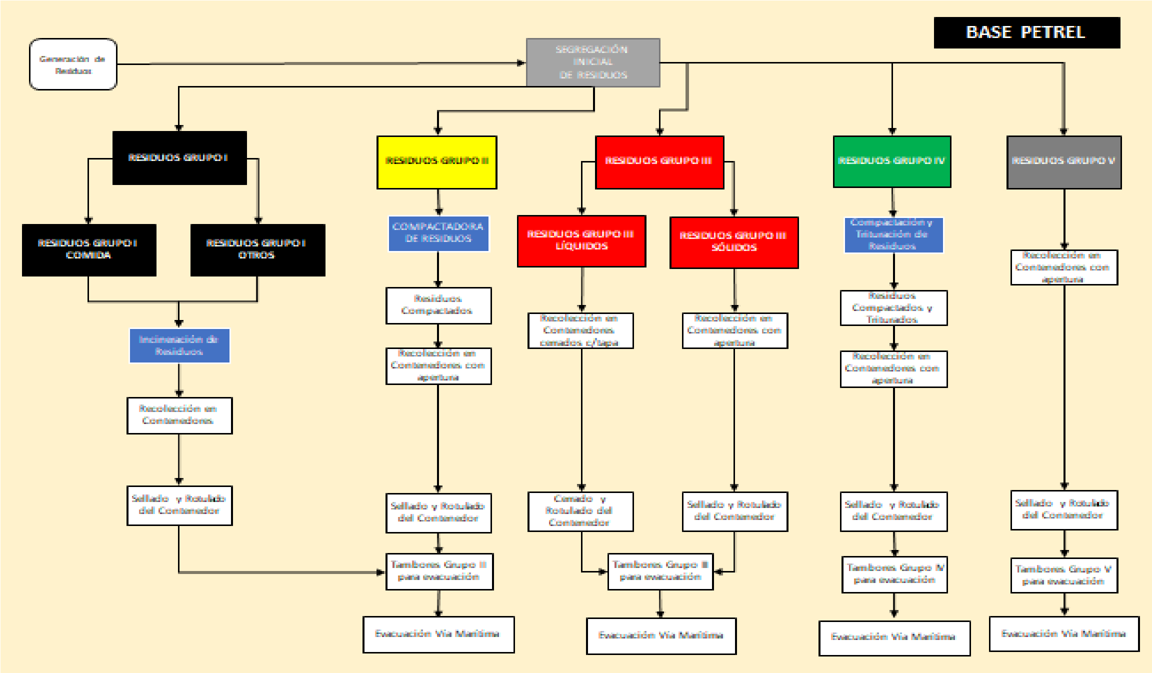


Figure 152: Waste management diagram at the Petrel Base.

4.9.5.3 Activities and Amounts of waste generated

There is no information on this point

At this point, it is important to establish the hazardous waste generation sites, which are the ones that entail a greater risk in their management. The Hazardous Waste generated in the area of the Antarctic Bases comes from the following activities:

Use, Maintenance and Construction of Buildings

- Maintenance work with paints and adhesives. Waste: Y12 (Paint remains)/Y48Y12 (Rags and brushes with paints)/Y48Y13 (Rags and brushes with adhesives and lacquers)
- Changes of Luminaires. Waste: Y29 (Fluorescent tubes).
- Sealing work with asphalt membranes. Waste: Y48Y11 (Membrane remains).
- Maintenance and repair of machines and equipment: Y48Y8 (Filters and oily rags)/Y9 (Fuel with water)/Y48Y9 (Fuel-contaminated rags).
- Preparation of Drums as Containers. Waste: Y9/Y48Y9 (Rags and diatom impregnated in fuels).
- Dispose of batteries of electronic equipment. Waste: Y26/Y29.

Staff medical and dental care.

- Patient medical care. Waste: Y1 (Gauze, syringes, etc).
- Expired pharmaceuticals. Waste: Y2.

Communications and Computer Maintenance.

- Equipment battery replacement. Waste: Y26/Y29.

Generation by the Power Plant

- Maintenance and Control of Generators. Waste: Y48Y8 (Filters and rags with oil) /Y9 (Fuel with water)/ Y48Y9 (rags contaminated with fuel).
- Losses or spills of Fuel. Waste: Y48Y9 (Rags and diatoms impregnated in fuels).
- Replacement of Coolant Liquids. Contaminated packaging. Waste: Y48Y42
- Replacement of Generator Batteries: Waste: Y31Y34

Power Generation for Heating

- Maintenance and Control of Heating Equipment. Waste: Y8 (Used oil) / Y48Y8 (Filters and rags with oil) / Y48Y9 (Rags and diatoms impregnated with fuel).
- Losses or spills of Fuel. Waste: Y48Y9. Management of

Fuels and Lubricants

- Maintenance of the GOA/JP1 Tanks. Waste: Y48Y9Y12/Y48Y12.
- Losses or spills in Supply of GOA/JP1. Waste: Y48Y9 (Contaminated rags, earth and diatoms).
- Losses or spills of GOA in Cisterns or Drums. Waste: Y48Y9 (Contaminated rags, earth and diatoms).
- Losses or spills of JP1 in the supply to Aircraft. Waste: Y48Y9 (Contaminated rags, earth and diatoms).
- Fuel contaminated with water. Waste: Y9.

There is no systematised record of the generation of waste at the base, since it has been activated as a permanent base a short time ago. However, in this campaign, the amount of waste is expected:

Waste generated during removal of current buildings

During the removal tasks of the current buildings, it is estimated that the following amounts of waste will be evacuated:

Building		Group								
		I			II			IV		
		kg	m3	Materials	kg	m3	Materials	kg	m3	Materials
Main House	Accommodation	200	2	Wood - Hardboard	30	2	Expanded Polysterene Cables	400	4	sheet metal concrete rubble
	living room, game room and radio	220	2	wood	30	2	expanded polysterene cables	400	4	Sheet metal rubble
	Mezzanine Bathroom Hall	250	2	wood hardboard	30	2	Expanded Polysterene Cables	200	6	concrete masonry
	dining room	200	2	Wood hardboard	30	1	expanded polysterene cables	100	2	concrete
	kitchen and storage	400	4	wood hardboard	30	2	Expanded Polysterene Cables	200	4	Concrete steel earthenware pipes
Emergency House		200	2	wood hardboard	100	2	expanded polysterene cables copper	3000	8	pipes concrete sheet metal mosaic
Shed I								5000	8	profiles sheet metal concrete
Shed II		1000	4	wood				8000	6	Profiles beam sheet metal
Former power plant		400	2	wood	20	1	wiring	5000	6	concrete steel beams
cold room		300	2	wood	100	4	panels	3000	7	beams sheet metal concrete
Power Plant		1000	5	wood hardboard	30	1	cables expanded polysterene	3000	8	sheet metal beams concrete
Port Department		400	4	wood hardboard				100	2	sheet metal concrete

4.9.5.4 Temporary storage on the premises

In each unit of the Base there will be sites for the temporary storage of the waste generated in those sites. For proper waste management, each unit of the Base must have:

- Sufficient containers to adequately store the different groups of waste generated. (Bags, empty drums, drawers, hermetic containers, etc.).

- Procedures and elements to guarantee that the containers in which the waste is stored are perfectly closed to avoid losses and emissions during its transfer. This point is of particular importance in the case of hazardous waste.

In the case of hazardous waste (Group III), it is advisable to have a separate unit, with an impermeable floor, adequate ventilation, without heating or electricity to avoid accidents. It must also have a fire-fighting system with the corresponding signage and instructions for use and a contingency kit for spills in case of accidents with liquid hazardous waste. This unit must be under strict security conditions according to the danger of each residue.

4.9.5.5 Base temporary storage depot

The Base must have a room with a surface area sufficient to store and handle the containers until they are evacuated. This means the construction or adaptation of a closed premises with an impermeable floor. In those bases that do not have specific waste storage facilities, waste must be stored in tents or container-type metallic structures, sheltered from the wind and animals.

In the event of not having specific facilities for storage, they must be stored in a "sector" (selected and determined) so that this waste remains until its evacuation. In this, wooden pallets will have to be placed as insulation so that the drums or containers are prevented from adhering to the ground, with this we will avoid ruptures when needing to evacuate them.

The following diagram shows the future sites of transitory accumulation of residues at the Base (Figure 154).

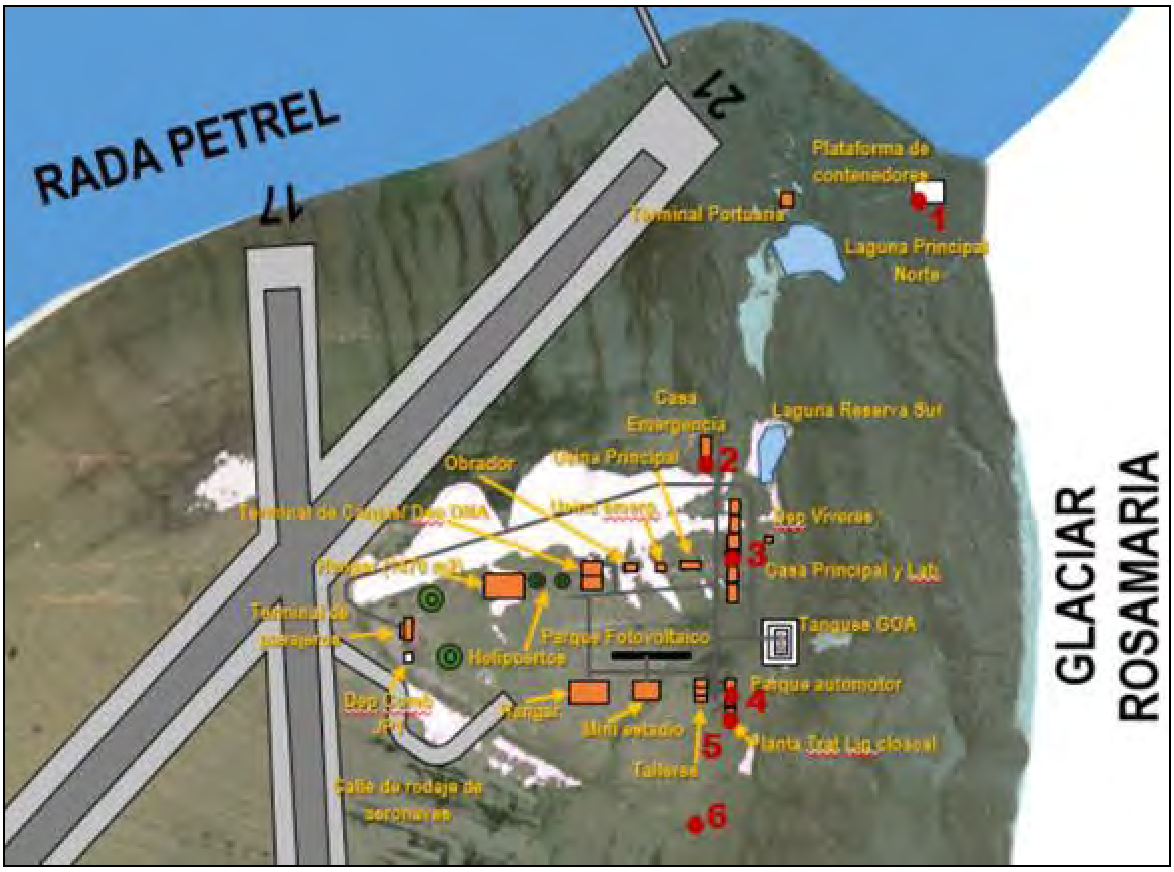


Figure 153: Temporary storage sites for waste generated at the Base. 1 Storage area for Group II and IV waste. 4 Storage area for Group III waste

4.9.5.6 Waste disposal logistics

Every year a tender is carried out to hire transport companies and operators of hazardous and non-hazardous waste in order to ensure the evacuation of existing waste in the Argentine Antarctic bases. In this way you can count on final disposal services upon arrival at port.

Evacuation once a year, during the Summer Antarctic Campaign. Once the waste is removed and the campaign ends, the staff who remain for the rest of the year in one of the six permanent bases restart the waste management cycle. This cycle consists of the classification, storage, labelling and registration of what is generated, so that, despite the difficult winter circumstances, the waste remains in good condition until the following summer and can be removed.

The waste collected at the Base is evacuated to the City of Ushuaia for its final disposal. Transport is carried out by ships participating in the Antarctic Campaign (Icebreaker Almirante Irizar, Avisos, etc.). In this city, different operators receive the different groups of waste (non-hazardous and dangerous) so that the waste is eliminated through authorised treatments. The entire process is controlled by the waste management enforcement agencies in Argentina.

4.9.6 Contingency Plan for Hydrocarbons

The Base does not yet have a definitive contingency plan for fuel management because there are no tankers for bulk fuel storage. Currently, fuel storage is done in 200 litre drums. Specialised personnel are in charge of supplying vehicles and generators with manual pumps from the 200-litre drums. But it must have a Contingency plan whose objective is to prevent and control accidents that involve the use of hazardous materials (hydrocarbons) existing at the base, using the means available at the base, in order to help minimise situations of risk of environmental emergency. The construction of a fuel storage area is planned, with vertical tanks.

4.9.7 Fire Prevention and Fighting Systems

The different units of the Base will have their fire prevention and fighting systems:

Fire Fighting Installations

The pipes of the fire fighting installation must be grooved with “Victaulic” type joints. The main pipe that comes out of the pump room will be 4” in diameter and will run through the entire building before going to a box where it is reduced to 2½". For the connection with the equipped fire hydrants, the diameter of the main pipe must be reduced to 1½” to connect it to the hose. The secondary pipe that will feed the sprinkler network will be 2” in diameter.

Both the pipes and the accessories must be made of black iron according to ASTM. The exposed sections of pipes should be painted with two coats of rust converter and two coats of enamel paint for greater durability. No forge curvatures will be allowed in any pipe, and accessories must be used for all changes of direction. In areas where the temperature is low and there is a possibility that the water could freeze, thermal tapes should be placed in order to keep the water in a liquid state.

The supports must comply with what is specified in Chapter 9, Suspension, Bracing and Securing of the Piping of the NFPA 13 system. All piping must be executed in sight, aligned and suspended from firm structures, using approved and standardised hanging devices. These fasteners should be arranged to avoid proximity to other pipes, hangers, windows, ductwork, electrical fixtures, equipment, ceiling suspension systems, and other obstructions. Pipes shall not be suspended in suspended ceilings.

The valves for outlets must be made of wall-mounted cast bronze with a 45º outlet and a rotating nut with a 1½” fire thread. Check, butterfly and gate valves must have a carbon steel shell and bronze seats, with flanged joints, and these flanges must respond with their counterflange.

The water pump shall comply with NFPA 20 Installation of Stationary Fire Protection Pumps. The electrical panel, accessories, command and specific controls must be available for the correct operation of the pump in accordance with the regulations. (Figure 155).

The pump room must have a pump that keeps the system pressurised (Jockey) and two main pumps that are activated when the demand for water so requires. The capacity, minimum pressure and power of the pump shall be in accordance with the dimensioning of the installation at its furthest point. It is convenient for the reserve pump to be Diesel to ensure its autonomous operation if it should lose its electrical connection at the time of the fire. A water tank or reserve shall be installed that must supply the system for the time established by the standard with a minimum volume of 25 m^3.

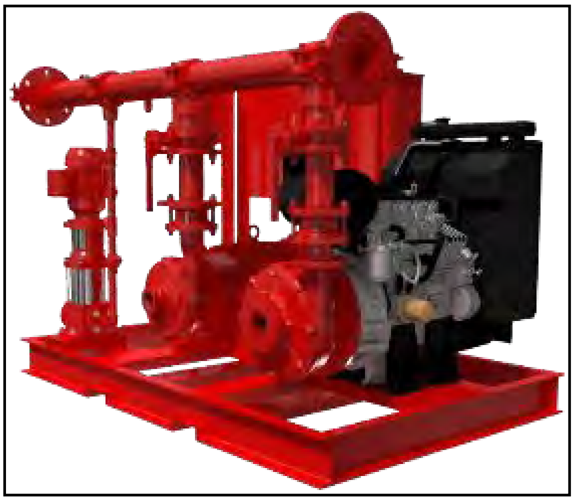


Figure 154: booster pump

The emergency doors and separations of the modules must be firewalls. It is important that doors and hardware are kept in good condition, including intumescent gaskets, door closers, hinges, latches, and glass peepholes. Said fire doors must be at least classified as F60, or that support 60 minutes in contact with fire.

For a correct evacuation plan, the emergency exits must be marked in such a way that it is clear to all personnel which is the escape route. In places where the signal must be visible from a distance or in places with a high density of personnel, signallers with their own light source should be installed. At the same time, the central area of the escape route must be illuminated with a minimum level of 1 lux.

When pipes, cable trays and ducts go through walls that comply with or constitute a fire barrier, the corresponding seals must be made to prevent the passage of fire, with products suitable for that purpose, in accordance with current regulations.

The internal enclosures shall be made of fire retardant material in order to retard the advance of the fire, for which the PIR PUR sandwich panels are indicated since they offer excellent fire performance and are capable of resisting direct flame, since it is a product with little combustibility this means that the general inflammation according to the test is greater than 20 minutes.

The central control and alarm station must be of the “Notifier” or “Simplex” type and its mission will be to control the operation of the installation, give the alarm in case of fire and allow periodic performance tests to be carried out. It must be located in a guard room or sector where there are people 24 hours a day. In turn, red telephones will be installed in each of the corridors for the activation of any emergency that occurs in the modules, said emergency will be received in the room or sector on duty.

Smoke and combustion gas detectors must be installed that are not necessarily visible, as well as temperature detectors wherever it is not appropriate to install smoke detectors, such as service areas like the kitchen, smoking room or garage, where there may be smoke that does not come from a fire.

All detectors, manual push buttons and red telephones installed must be connected to the fire control panel and coded by zones, which will allow rapid identification of the sector where the alarm occurred.

Fire detection and suppression system

This will consist of a set of overlapping subsystems that will provide the ability to detect and suppress fire on time, when it appears. The items necessary for the operation of the global system and their installation are listed and detailed below, such as equipment, pipes, supports, anchors, jacket pipes, insulation and any other detail that is required for the implementation of integral and operational systems.

- Fire Fighting Facilities:
- Fire hydrants
- Fire extinguishers
- Automatic sprinklers
- Inert Gas System
- ASD aspirating smoke detection system

All the artifacts and accessories necessary for the installation, anchoring and support of the pipes and equipment, will be located and installed as the work progresses and according to the advance plan, in order to allow the completion of each phase in the correct sequence. Likewise, all the routes, details, elbows and accessories necessary to coordinate, save or avoid crossings with other facilities or structures.

Installation of fire hydrants

Pipes and Accessories

For the fire hydrant system: All pipes, weld fittings and grooved joint fittings will be made of black iron according to ASTM. Sections of visible pipes should be painted with two coats of rust converter and two coats of enamel paint for greater durability. No forge curvatures will be allowed in any pipe, and accessories must be used for all changes of direction.

Joints

Welded: Both the pipes and the accessories will have chamfered ends for welding as specified in the standard.

Supports

The supports must comply with what is specified in Chapter 9, Suspension, Bracing and Securing of the Piping of the NFPA 13 system. All piping shall be suspended in true alignment using suitable and substantial hanging devices. Wire hangers or strapping will not be allowed. Hangers shall be located so that the pipe and supports are clear of other pipes, hangers, conduit, electrical appliances, equipment, ceiling suspension systems, and other obstructions. Suspended ceiling pipes shall not be suspended.

Testing

The tests to be carried out must comply with what is specified in Chapter 11 System Acceptance of NFPA 14. The fire system pipes will remain charged at the natural working pressure for at least 3 continuous days before covering them and at a pressure of 13.8 kg/cn^2 for 2 hours, verifying that said pressure does not vary in this period and that there have been no leaks along the pipes.

The valves, fire hydrants and any other equipment that is part of the facilities will be calibrated prior to the functional test. Functional tests will be carried out checking manual or automatic start and stop, pressures, flows, etc.

Once the partial tests of all the components of the installations have been carried out, and they have been approved, a general functional test is carried out. The installation shall be made fully operational, verifying the individual operation of all its constituent elements. All equipment and pipes installed will be tested and found to be watertight. All leaking joints will be adjusted or rerun and retested until found to be watertight. These tests must comply with the protocols of NFPA 13.

Valves

For pressure ports: Cast bronze wall outlet with outlet at 45º with
2½" fire threaded swivel nut.

Check valves: They will have a carbon steel shell and bronze seats, with flanged joints, and these flanges must respond with their counterflange.

Butterfly valves: They will have a carbon steel shell, rubber seat and stainless steel butterfly, and these flanged joints must respond to said flanges with their counterflange.

Gate valves: They will have a carbon steel shell and a bronze seat, with flanged joints, and said flanges must respond with their counterflange.

Fire hydrants

They will have the following elements and characteristics:

Fire keys

Interiors: simple, theatre type with 45º exit. They shall be 2” inlet diameter and 1¾” outlet diameter.

Flywheel: Injected aluminum alloy with black epoxy protection Stem: Drawn brass

Bonnet, locking disc and nut: Forged brass

Shell: Cast bronze for valves, fire red synthetic enamel finish. Seal gasket and O-ring: These

shall be located 1.20m above ground level.

Exteriors: double, theater type with 45º exit. They shall be 2½” inlet diameter and 2½” outlet diameter.

Sleeves: these will be made of synthetic fibre without seams or unions on the outside and of polyester elastomer on the inside. Those located inside will be 20 metres long and those located outdoors will be 30 metres long. Work pressure: 15 kg/cm^2 and breaking pressure 45 kg/cm^2. They will be armed with bronze joints adjusted to a mandrel and their diameter will be 1¾" and 2½".

- Ejection lances: The aforementioned sleeves will always have an ejection lance with its corresponding nozzle of 15 mm internal diameter in the jet-mist type discharge.
- Cabinets: The fire keys will be installed in metal cabinets measuring 0.60 x 0.60 x 0.20 metres, with a glass front and stainless steel fillets. They will be built in minimum 20 gauge DD sheet metal (9 mm thick) with pre-painted, pickled and phosphatised treatment by automatic spray. They will be painted with thermo-convertible powder paint, it will have shades on both sides for the positioning of the valve inside the cabinet. The half-moon support to contain the hose will have a quick opening. They will have a "manchon" type lock. Keep in mind that any fire hydrant that exceeds 7 kg/cm^2 of pressure will carry an adjustable bronze pressure regulating device. In the corresponding place, the outlet will be mounted vertically at 1.20 metres from the finished floor level. The outlet will be located inside a 0.40 x 0.60 metre masonry chamber with a metal frame and lid made of 1020 pickled sheet metal painted vermilion red and an easy-to-open stainless steel lock, with the word "FIREFIGHTERS" stamped on it in letters 5 cm high. (Figure 156).

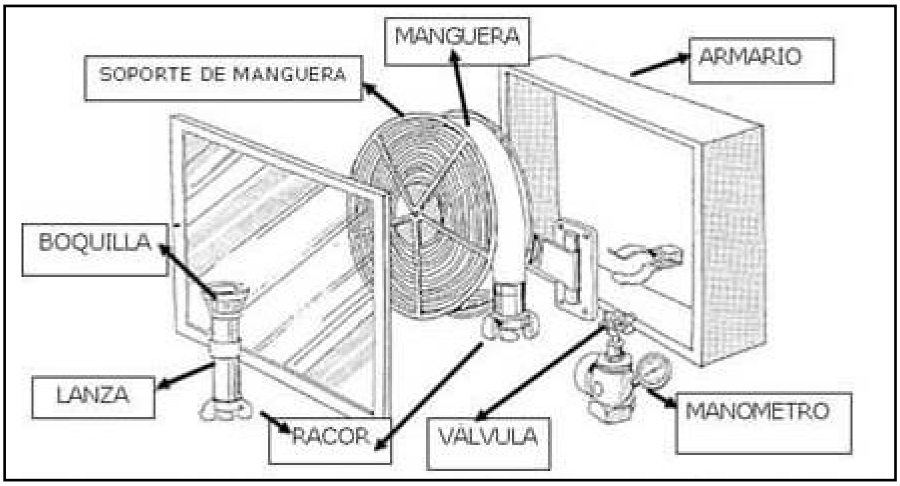


Figure 155: fire cabinet

Installation of fire extinguishers

The extinguishers to be installed must be selected according to the IRAM 3523 capacity standard according to calculation, and according to the fire class in each sector.

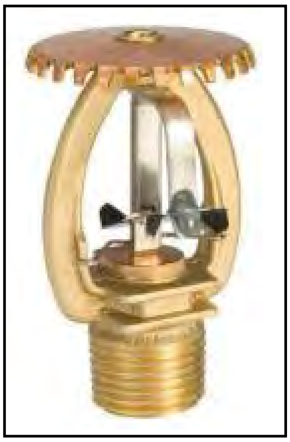
- Manual fire extinguishers according to the IRAM 3509/3565 standard of CO2 capacity according to calculation in electrical machine rooms.
- Manual pressurised extinguishers according to the IRAM 3541 foam (AFFF) standard of capacity according to calculation in places of possible fuel spillage and in uncovered parking lots.

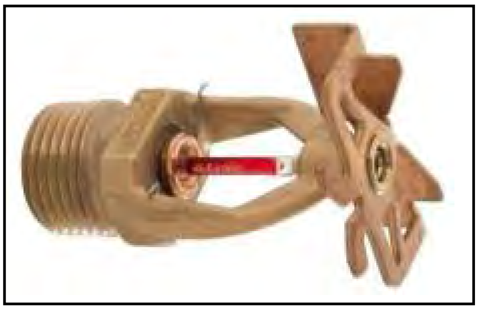
- Manual fire extinguishers according to the IRAM 3504 standard for HCFC 123 or HALOTRON-1 capacity according to calculations at premises with electronic and/or computer equipment.

They must have the IRAM Seal of Conformity and individual certificate. These elements will be suspended on embedded supports, at a height ranging from 1.20 to 1.50 metres from the floor to the base of the extinguisher. The extinguishers will be placed on a beacon plate identifying the type(s) of fire for which it is suitable in accordance with the IRAM 3517 standard. At least one will be placed every 200 m^2 or fraction of each plant.

Automatic sprinkler system

Installation of automatic sprinklers. The installation will be dimensioned using "hydraulic calculation" according to what is requested in Chapter 27 Plans and Calculations of NFPA 13. The different types of sprinkler heads must be supplied by renowned manufacturers in such a way that they do not exceed a coverage area of 37.10 m^2. The sprinkler heads must be placed according to the manufacturer's specific recommendations and/or according to international and local regulations. The sprinkler heads will be made of bronze, with a glass bulb and approved for the wet system, of the pendent, upright or sidewall types, according to what is required, the same throughout the work. The coverage of each type of sprinkler heads shall comply with the spacing of heads as specified in NFPA 13.





Control stations and electronic interior alarms

It will consist of a group of valves and a flow detector. Its mission is to control the operation of the installation, raise the alarm in the event of a fire and allow periodic performance tests to be carried out. It consists of the following elements for all floors:

- Butterfly valve with Tamper Switch. The function of this valve is to block the flow of water to the floor sprinkler installation, for this reason it is of vital importance that it remain fully open at all times. In order to guarantee compliance with this last condition, the valve lever must be effectively secured and thus prevent unauthorised persons from actuating it.
- A flow detector mounted on the distribution pipe of each floor, downstream of the butterfly valve, is in charge of notifying the detection system that the sprinkler network on your floor is in the extinction stage. This is achieved thanks to the fact that when a sprinkler is activated due to a fire, it begins to release water instantly, which causes, through the floor control station, a displacement of water in the direction of the sprinklers. It is in the latter, as is already known, where the flow detector is located, which, upon perceiving the movement of water, closes its contacts, giving notice to the detection system. To prevent false alarms, each detector has a pneumatic delay device adjustable between 0 and 90 seconds (they will graduate between 35 and 45 seconds) before causing the closure of its contacts.
- A manometer for reading pressure located upstream of the butterfly valve allows knowing the pressure available for the floor system. It will be sectioned from the pipe by means of a ball valve.
- A 1” diameter Sure Test type ball valve. It will be arranged in an outlet of the station. This ball valve discharges the test water flow into a 2” diameter pipe, which in turn is connected to the general drainage pipe, also 2” in diameter. The mission of the valve in question is to produce a drainage of water equivalent to that of a sprinkler and thus be able to test the operability of the floor system.

Pumps

The pump shall comply with NFPA 20 Installation of Stationary Fire Protection Pumps. The provision of this equipment also includes the provision and allocation of all its accessories. The electric motor shall be standardised of top quality and 100% armoured. The electrical panel, command and specific controls for this pump must be provided according to

NFPA 20. The command and control panel must comply with NFPA 20 and have certification seals.

High pressure inert gas automatic fire extinguishing system

The criteria adopted for the design of this system arises from the application of the NFPA 2001 Standard Fire Extinguishing Systems with Clean Agents for Inert Gas systems by total flooding, requirements for fires in solid materials.

The system called “HIGH PRESSURE Inert Gas” basically consists of a quantity of heptafluoropropane stored and over-pressurised with extra dry nitrogen at 25 kg/cm^2, 21ºC (360 PSI 70ºF). Storage will be carried out in one or more containers or cylinders suitable for this purpose. The filling of the same will be carried out according to pre-established guidelines of density of the agent inside the container, corresponding to a maximum of 1.121 kg/dm.^{3} and a minimum of 0.65 kg/dm^3.

The amount of Inert Gas necessary for extinction is obtained from the product between the real and total volume of the environment to be flooded and the flood factor. The value corresponds to the volumetric value of Inert Gas in air, which for normal pressure and temperature conditions will be 7%.

This concentration must be reached within the risk area during the first 10 seconds after the agent is discharged. For this purpose, there will be pipes and nozzles sized exclusively for this case and according to the chosen layout.

Both the calculation method and the equations used for sizing the system are totally specific for the flow conditions imposed by the Inert Gas, therefore, comparative analyses can only be performed through the same routine.

The quantity of the resulting Inert Gas according to the applied design concentration is considered the minimum necessary for the risk characteristics. This amount can be increased when the risk involves special conditions such as non-blockable openings during unloading, altitudes greater than 100 metres above sea level, pressures and temperatures other than normal, etc.

Technical characteristics of the materials to be

provided Containers to store the inert gas

Inert gas discharge valve: made entirely of bronze, with pressure opening suitable for a high discharge flow. The shell will be made up of two parts, the lower one has the safety valve, loading mouth and closing device. The upper one with opening pistons and discharge spout.

Flexible discharge hose.

ASD aspirating smoke detection system. An extraction smoke detection system will be used, which has a higher performance than smoke or general temperature detectors. This system will be used at the Main Power Plant as an extra control measure. The control panel will be found in the control room of that building.

Its operating principle is a constant sampling of air from the environment, through capillary tubes with calibrated holes, which run through the protected area. This sampling is analysed by a laser camera, which measures the amount of smoke present in the air and by comparison, based on previously defined thresholds, determines whether there is a fire. These systems are for fire identification by zone and can be taken as peripheral systems of the intelligent control board, reporting its alarm condition to it.

They are generally composed of a detection unit, as well as a duct system, which is connected to the detector. In order to take air samples, there is a fan, which causes the necessary depression so that said sampling can be carried out. The sensors of these systems have the ability to detect at all times any obstruction that appears in the ducts or any rupture or deterioration that they may suffer (Figure 157).

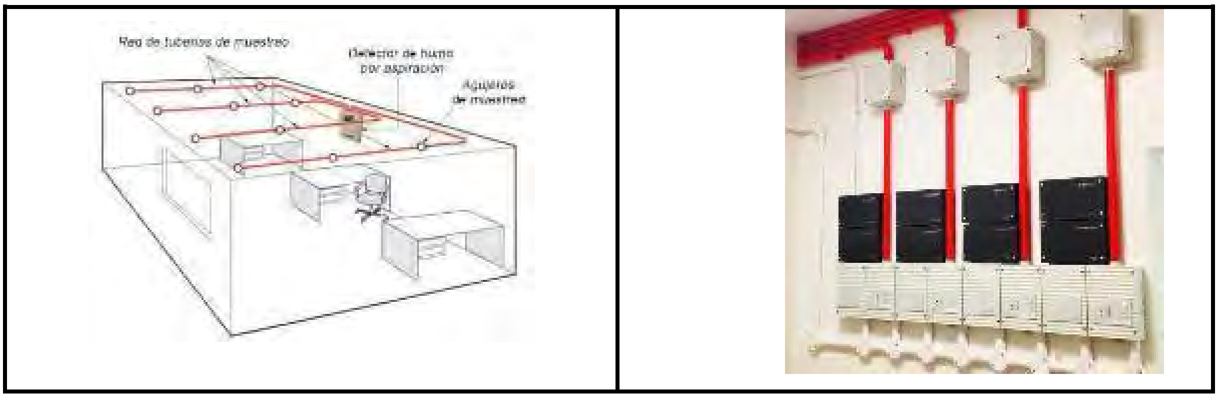


Figure 156: detection sensor diagram.

Structural fire protections Firewalls

Firewalls are fire protection measures in structures, which prevent the structure from collapsing in the event of a high intensity fire and for a prolonged period of time, approximately a maximum of 5 or 6 hours. They must be governed by current regulations that indicate the thickness, fire resistance, separation between the walls and other essential aspects that prevent the spread of fire in other areas and the collapse of the structure.

Function

The main function of firewalls is to act as a protection barrier. In turn, it prevents the spread of fire in the structures and what it does is delay it so that security agencies and other fire-fighting systems such as sprinklers or extinguishers can fight the fire and take evacuation measures for personnel or people who are inside the structure.

Advantages

The advantages of this system are:

- Guarantees the safety of buildings against high intensity fires.
- Efficient and easy-to-install fire-fighting system.
- The materials of firewalls have a great resistance to the transmission of heat and exposure to high temperatures for up to 6 hours.
- This exercises control over the fire and prevents the fire from spreading to other rooms of the structure.

- The finishes of the firewalls are of high quality, providing security in the integrity of people and the building.

Characteristics of the firewall

The firewall must comply with the following:

- It must have a minimum fire resistance of F-120 and its maximum is F-180.
- The material preferably used in firewalls should be concrete.
- The thicknesses of these protection systems are from 15 cm to 30 cm as a minimum, this varies according to the type of structure and the guidelines that must be followed.
- It must have 2 fire doors as a protection element in the structure.
- The minimum resistance of those firewalls that have a resistance of F-120 must be 120 minutes and of F-180 approximately 180 minutes.

Fire doors

Fire doors are specifically designed to prevent the spread of fire and its products for a certain minimum time through the construction elements in which they are integrated. They can be supplied to the site completely assembled, or disassembled, with some components separately (frame, leaf, door closer, etc.). In this second case, they are assembled in situ, to form the complete door. All components must have been fire tested together, or evaluated as capable of working together.

Fire doors are not effective unless they are closed at the time of the fire, so reliable self-closing devices are required to ensure that the doors close each time they are opened. It is important that doors and hardware are kept in good condition, including intumescent joints, door closers, hinges, latches and fire-resistant glass peepholes. Each product must have a classification report after having been tested according to the appropriate form (Figure 158).

Figure 157: image of a fire door.

Flame retardant materials

Flame retardant materials are those that offer resistance to fire and therefore prevent its spread, thus facilitating its extinction. There are flame retardant materials for ceilings, floors and walls, some examples are:

- Insulating foams for walls and floors. They are made of polyurethane and there are two types: self-extinguishing and flame-retardant. The former burn when they come into contact with the fire, however, they go out little by little and stop the flame from spreading. The latter, on the other hand, do not burn at any time. Insulating foams are used for window and door frames, they serve as a filler for construction elements. They are also used in walls and ceilings, since they are insulating. One of the most notable advantages of these foams is that they help reduce energy consumption thanks to their insulation.
- Fibrosilicate plates and plasterboard. These construction materials are protectors of structures (beams, ceilings, wood, etc.). Fibrosilicate and plasterboard plates are composed of a special plaster and fibreglass, which makes them fireproof. Subsequently, these plates can be painted without altering their incombustibility.
- Intumescent paint dilates and swells when exposed to the heat of a fire, creating an insulating barrier with gas bubbles that retard the spread of fire.
- Rock wool plates. Rock wool comes from volcanic rock and has a multidirectional fibrous structure that facilitates the installation of air between the fibres. These plates are fire resistant and also provide thermal insulation.

Fire safety systems for each facility at the Petrel Base

BUILDING	FIRE HYDRANTS	FIRE EXTINGUISHERS	SPRINKLER SYSTEM	AUTOMATIC EXTINGUISHING ASSISTANCE	SMOKE DETECTION SYSTEM
Main House/Lab	X	X	X	X	
Emergency House	X	X	X	X	
Main Power Plant	X	X	X	X	X
Emergency power plant	X	X	X	X	
Supply shed					
Cargo terminal			X	X	
Hangar	X	X			
Passenger terminal	X	X	X	X	
Helicopter Hangar	X	X			
Sports centre			X	X	
Workshops			X	X	
Carport	X	X			
Liquid Sewerage Treatment plant	X	X			
Food Storage					

Extinguishing System in Vertical Tanks

Fires where the fuel or diesel is the liquid have a type of fire that is normally extinguished by eliminating oxygen, thus interrupting the combustion chain and stopping the release of combustible vapours.

1) Types of fire extinguishers

The types of fire extinguishers suitable for smothering hydrocarbon flames are:

- Powder extinguishers: use chemical powders (sodium or potassium bicarbonate) to extinguish the fire by suppressing the chemical reaction.
- CO_2 fire extinguishers: these use carbon dioxide that manages to extinguish the fire through a suffocation effect. It does not produce chemical reactions because it is a non-combustible gas. When using CO_2 it is important to maintain a series of

precautions, such as a safety distance of at least two metres from the fire.

- Foam: this is the mixture of foaming agent, air and water in certain proportions. Foam is one of the best resources to extinguish a fire in warehouses.

liquid fuels. In extinguishing a petrol fire, the foam has multiple capacities.

In this section, the most effective solution is the foam for the size of the project. In turn, this type of project is regulated by the NFPA11 standard, which specifies the type of extinguisher and the systems to be used.

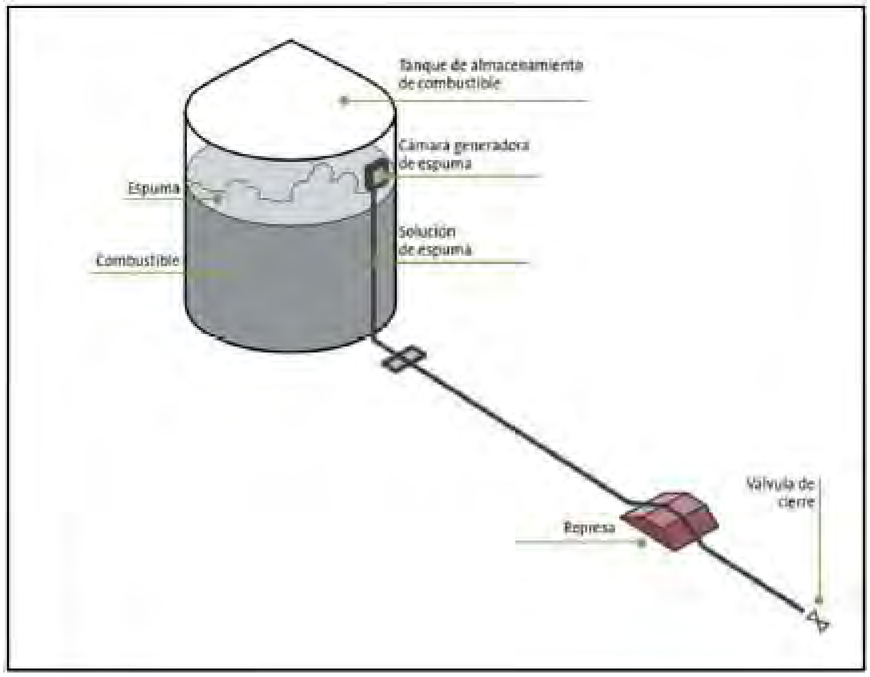


Figure 158: Protection system with foam chambers on the surface.

2) Protection system with foam chambers on the surface (Figures 159 and 160)

There are various protection systems for vertical tanks, although in this section the most widely used for API fixed-roof tanks will be developed. The system allows an application of the extinguishing agent with a minimum immersion of the same and a moderate agitation of the fuel. The foam chamber is installed vertically in the tank, between 20 and 30 centimetres below the roof line.

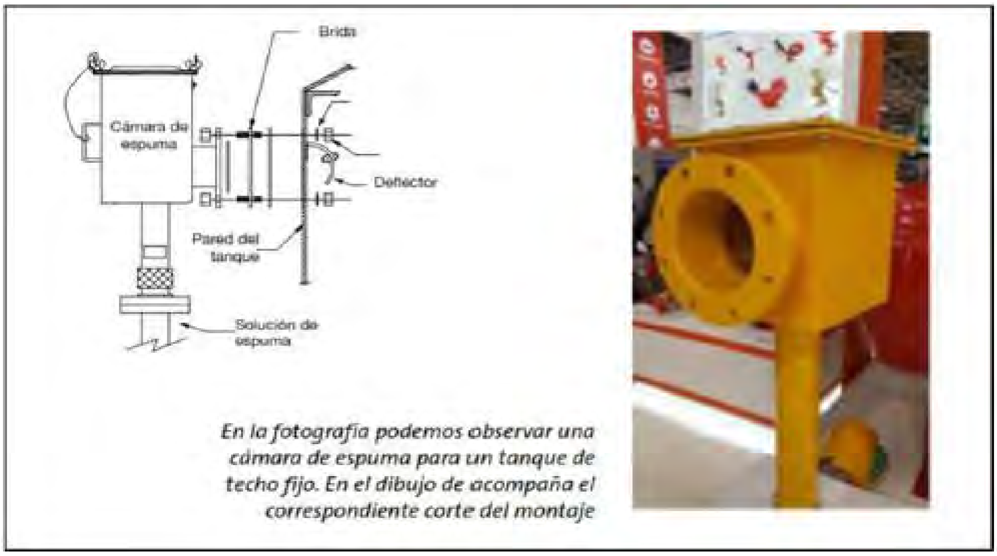


Figure 159: Protection system with foam chambers on the surface.

5 EVALUATION OF ALTERNATIVES

Before considering the environment in which the Petrel Base is located and assessing the environmental impacts derived from the environmental aspects associated with the activities to be carried out for its remodelling, it is necessary to analyse the alternatives that have been taken into account. Article 3.2.a) of Annex I of the Protocol establishes that the draft EMG must include "A description of the proposed activity, including its objective, location, duration and intensity, as well as possible alternatives to the activity, including its non-performance, as well as the consequences of said alternatives."

On the other hand, the Guidelines for Environmental Impact Assessment in Antarctica (Resolution 1 (2016)) specify that both the proposed activity and possible alternatives must be considered together so that a decision can more easily compare the potential impacts on the Antarctic environment and its dependent and associated ecosystems. For this reason, this section of the EMG describes the alternatives considered throughout the design phases of the remodelling of the Petrel Base.

5.1 Not to proceed

At this point, the alternative of not proceeding with the refurbishment of the Petrel Base will be analysed. In this regard, we must take into account the environmental problems that the incident of the fire in the main house and the subsequent irregular use as a temporary base caused at the Petrel Base. As a consequence of this situation, the facilities of the Petrel Base were exposing the surrounding environment to increasing environmental risks and their intensity worsened.

Argentina is an original signatory country of the Antarctic treaty and has ratified the Madrid Protocol and has the following among the objectives of its National Antarctic Policy:

- Strengthen the Antarctic Treaty and its System;
- Promote the protection of the Antarctic environment and its dependent and associated ecosystems;
- Continue deepening the scientific and technological knowledge oriented to the areas that are directly related to Argentina's Antarctic priorities and
- Achieve greater effectiveness of the Argentinian presence, concentrating it on supporting national scientific-technological activity and on the ability to provide other countries with the necessary services and knowledge to facilitate their Antarctic tasks, in cases where it is politically advisable.

During the last few decades, Argentina has on countless occasions evaluated different options to reconstruct and repair the buildings that currently make up the Petrel Base, but in all cases the expected results were not able to eliminate or significantly minimise the environmental risks that the Base posed while, on the other hand, it was not possible to provide research programmes with a place to develop their projects. As such, the state of the Petrel Base did not allow Argentina to meet the objectives of its Antarctic policy and, in particular, its commitment to the protection of the Antarctic environment and its dependent and associated ecosystems, as established by the Madrid Protocol. For this reason, the alternative of simply "not proceeding" was discarded and for this reason this project is presented in order to provide a definitive solution to the environmental problems that the Base currently has.

5.2 Alternatives for choosing the Petrel Base

Argentina has been permanently on the Antarctic Continent for more than a hundred years and has carried out numerous research programmes. However, the Argentina Bases were built many decades ago and therefore, in many cases, a modernisation of the facilities is needed to achieve greater sustainability and a greater capacity to support science. It is for this reason that, in recent years, the Argentine Antarctic Programme has been seeking to significantly increase its scientific activity through an adequate selection system for Antarctic research projects.

In order to achieve this increase, it is necessary to renew the scientific facilities at the bases, a programme that began this year with the construction of three new laboratories at the Esperanza, Orcadas and San Martín bases, and it is also planned to renew the laboratories of the other Argentine permanent bases in the coming years. As a result of these actions, a progressive increase in the number of scientific personnel who will go to Antarctica is expected to carry out research in areas close to the bases as well as in remote areas. This increase in scientific activities and personnel entails a greater logistical effort, especially an adequate use of transport capacities. In addition, it must be taken into account that the change in climatic conditions and new means incorporated into the activity make it necessary to modernise the way of deploying science and the consequent logistical support.

From the analysis of the deployment system of scientific, logistic personnel and cargo, untapped capacities and limiting aspects emerged that affect the harmonious development of transport logistics activities during the Antarctic summer. Basically, from the analysis arises the need to centralise the transport logistics of scientific personnel, logistics and loads for the deployment in Antarctica at a central point that allows us to:

- Make support for scientific activities more flexible, through a rapid deployment, recovery and redeployment of scientists and their teams, the centralisation of samples through a central point for their storage, analysis or expedition to the South American continent
- A better use of resources and transport facilities applied in support of the AAP (PAA in the original), redundant in more scientific activities with the same resources.
- The deployment of science on the Antarctic continent as an opportunity.
- The deployment of logistics personnel and supply of the bases.
- Eventually and with remaining capacities, develop international cooperation activities with other national Antarctic programmes.
- Access by air and sea so as to allow the exchange of scientific personnel, logistics and cargo for the deployment or withdrawal of the Antarctic continent.
- That it has conditions to function as such for a long time and possibilities of growth or expansion (Space).

In light of these aspects, three options were analysed:

- Develop the Marambio base as the central point of the scientific and logistical deployment of the Argentine Antarctic Programme.
- Increase logistics while maintaining the current use of means.

- Develop the Petrel Base as a new central point.

Table 30: Analysis of the proposal for choosing the Base to be strengthened for the AAP.

No. of	Proposal / Aspect to consider (Evaluated according to the possibilities from 1 to 5)	Develop the Marambio base as the central point of the scientific and logistical deployment of the Argentine Antarctic Programme	Increase logistics while maintaining the current use of means	Develop the Petrel Base as a new central point
1	Make support for scientific activities more flexible, through rapid deployment, recovery and redeployment of scientists and their teams; and, the centralisation of samples through a central point for their storage, analysis or dispatch to the South American continent. Major: 5 Non-existent: 0	Its location on the west of the peninsula means greater deployment distances and the impact on helicopter and small aircraft flights due to weather conditions. Assigned value: 3	Limited to the amount of naval assets available, mostly concerned with resupplying the bases. The available aircraft do not have sufficient range to be able to increase the deployment of science. Assigned value 2	Its central location in the north of the Antarctic Peninsula would allow for the deployment, recovery and redeployment of personnel and cargo. Developing storage, science, and accommodation capabilities would facilitate centralisation of operations. Assigned value 4
2	A better use of resources and transport facilities applied in support of the AAP (PAA in the original), redundant in more scientific activities with the same resources. Optimal: 5 Null: 0	Limited access by sea (only RH). Access is limited to the months of December to the end of March. More flight hours can be assigned in support of the scientific act. Limited by extreme weather conditions in the area Assigned value: 2	It can be done by affecting a ship to the scientific act, but it would be limited to the north of the Antarctic peninsula. Assigned value: 2	Petrel allows access to all naval and air resources used on the continent. In the future, developing the aerodrome would allow the link with the South American continent through the use of C-130 aircraft. It has milder weather conditions than Marambio Assigned value: 5
3	The deployment of science on the Antarctic continent as an opportunity. Major: 5 Null: 0	Having helicopters facilitates the deployment to nearby bases. It can also have a small aircraft (Twin Otter) Assigned Value 4	This can only be done from Marambio by helicopter, or using the Frei Base for the arrival of scientists and their deployment on their own ship. Only north of the peninsula Assigned value 3	Greater media access and the possibility of having air resources at the base will enable rapid deployment of science. Assigned value: 5
4	Eventually and with remaining capacities, develop international cooperation activities with other national Antarctic programmes. Major: 5 Null: 0	Its location limits international cooperation in the use of aerial means, or a reduced area close to the base. Assigned value: 3	These activities are taking place Assigned value: 5	Its current easy access and its possibility of increasing it in the future, facilitates international cooperation. Assigned value: 5
5	Access by air and sea so as to allow the exchange of scientific personnel, logistics and cargo for the deployment or withdrawal of the Antarctic continent.	Its limitation is in maritime transport, where only one of the ships used by the AAP can access Marambio Island. The disembarkation or embarkation of passengers and cargo must be carried out with the use of helicopters Assigned value: 3	A transport ship is required to access the bases on the peninsula and release the smaller ships for science. More flight hours of embarked helicopters are required Assigned value: 2	The development of the airfield will enable all naval and air assets to exchange personnel and science at Petrel. Currently, only C-130 Hercules aircraft cannot access Petrel. Assigned value: 5
6	That it has conditions to function as such for a long time and possibilities of growth or expansion (Space). Major: 5 Null: 0	It has possibilities of expansion and operation for a long time Limited to runway condition by temperature. Assigned value: 4	The means are limited to the maintenance of the armed forces. They do not always have the same means. It is planned to incorporate more air and naval resources in the future. Assigned value 3	Once your abilities are developed, you have possibilities for growth (There is enough space) Assigned value: 5

7	Investment to be made None: 5 Maximum: 0	Medium- many facilities already exist Assigned value: 4	High – there is a need for other air and naval means (DC3 Basler and Polar ship)	High – it is necessary to develop the base Assigned value: 1
			Assigned value: 2	
8	Potential environmental impact Null: 5 Maximum: 0	Minimal because it is already an impacted area. Assigned value: 5	The increase in naval and air resources entails an increase in environmental risk. Assigned value: 3	Petrel Base is already an impacted area, although its development would increase this. Assigned Value: 4
	Total	28	22	34
	Maximum value 40 pts	70%	55%	85%

In this regard, it was determined that the Petrel Base is the most favourable proposal. Its geographical situation, its climate, the space of the area and the current and future access of the means used by the AAP make it especially suitable to constitute the central point of the AAP. Only the investment cost needing to be made is unfavourable, although the advantages are many. Its situation, being a base that has already functioned in a permanent manner and therefore has already been impacted, favours its use for this project (Table 30).

The Marambio Base is limited by the limited access of naval resources, a meteorological situation that often blocks the use of the runway and its geographical location. It is favored by its current development and the space for its growth. However, it is an aspect to consider are the annual temperature trends recorded during the last summers that limit the use of its airstrip in the season of greatest demand. Regarding the possibility of having more naval and air means, the possibility of having a greater number to increase scientific activities is limited.

5.3 Alternatives for modernising the Petrel Base

After defining Petrel Base as the place selected to be the future point of entry and exit to Antarctica, by the Argentine Antarctic Programme and from there to project the scientific and logistic personnel and long lines to the rest of the bases and inside Antarctica, some alternatives were evaluated for the development of the base. As a starting point, the base must have port, airport and accommodation facilities and cargo stowage. The port facilities (pier), still under study, can be replaced temporarily with the use of boats, pontoons and smaller vessels that access the Cape Wellchness beach by grounding them or by building a circumstance pier of the "removable" type. The airport facilities will consist of two landing strips, considering the C-130 Hercules to be a critical aircraft and the necessary services and those associated with its operation (passenger and cargo terminal, control tower, fire services, etc.).

Finally, it was considered that it must have the necessary accommodation to accommodate, in an emergency, the entire passenger of a critical aircraft (64 pax plus 6 crew members) for at least 72 hours. From a point of view of the terrain, the firmest ground at Cape Wellchness is known to be the upper platform located in the central area of the cape. It is in this area where most of the buildings will be installed. Based on these design parameters, three basic models were designed, from the simplest design taking advantage of the existing facilities, to the most complex model with the maximum number of facilities, going through another intermediate model.

5.3.1 Proposal 1 – Maximum use of existing facilities

This proposal contains the aerodrome with the two landing strips and a control tower located next to the hangar, it has the pier located on the north coast near the moraine of the Rosamaría glacier. It rests on the current buildings. The main house would be built in the sector where the house that caught fire in 1976, the emergency house for 80 people, and the passenger terminal were located.

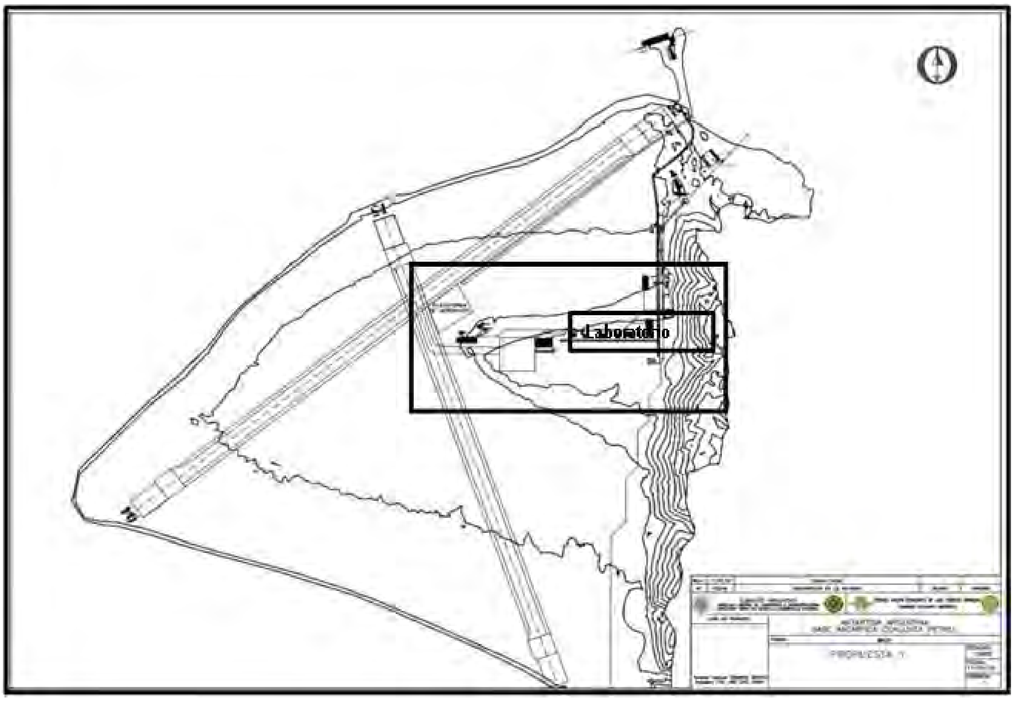


Figure 161: General layout of proposal 1.

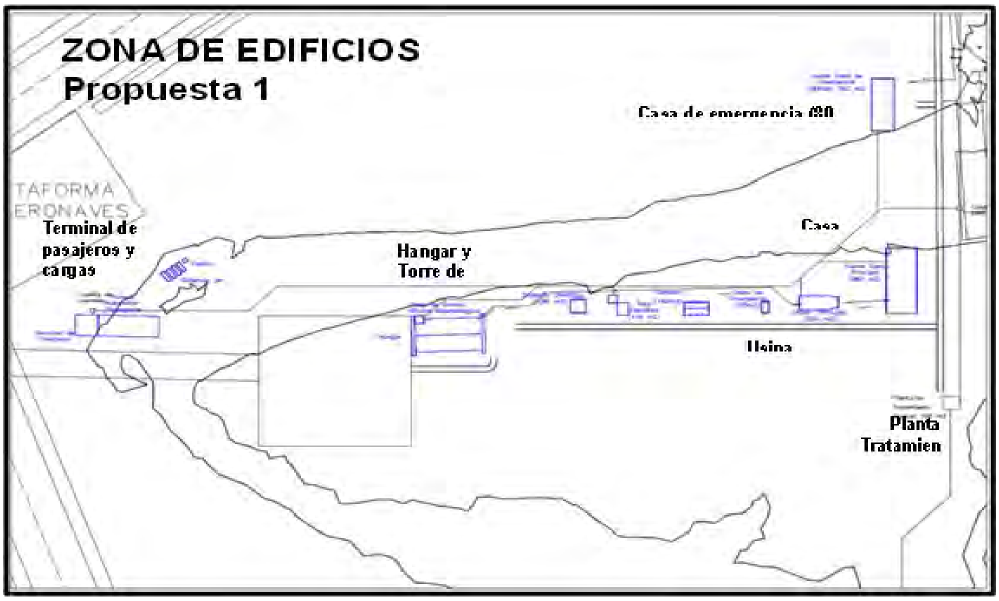


Figure 160: Layout of Proposal 1.

5.3.2 Proposal 2 – intermediate development proposal

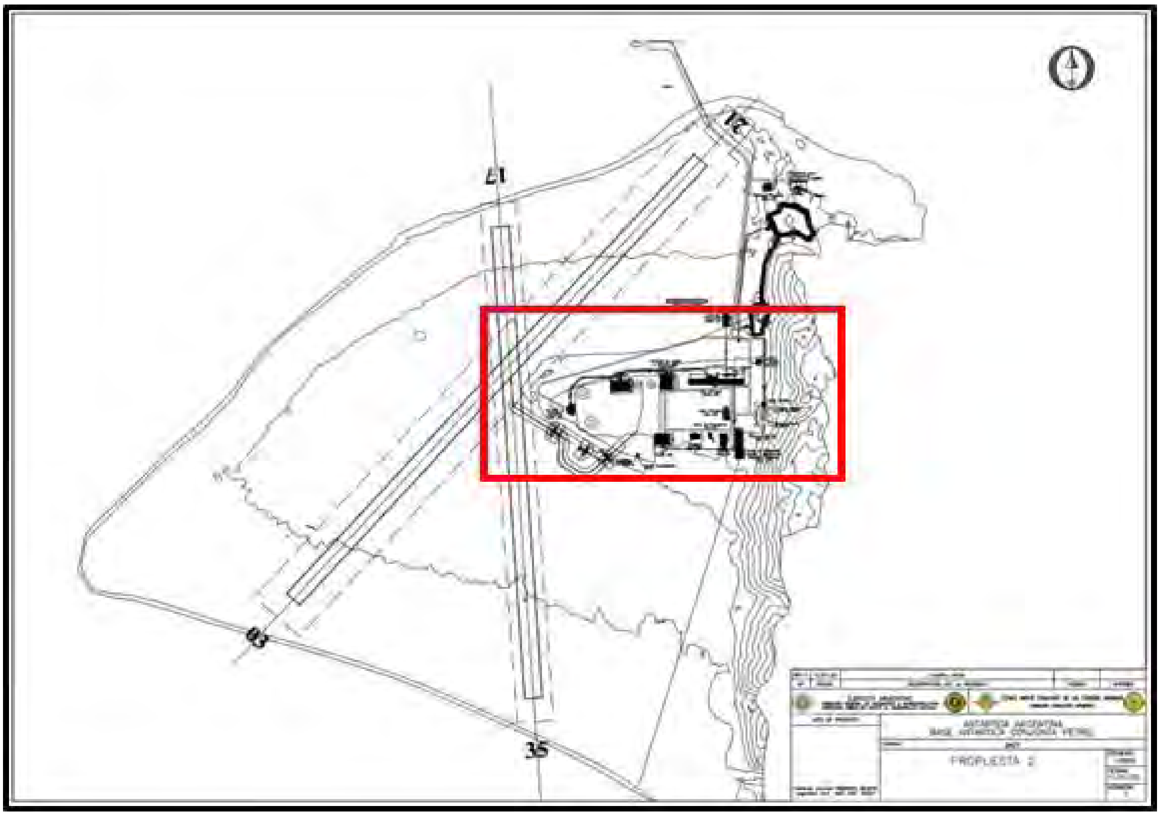


Figure 162: Specific layout of the Petrel Base.

This proposal contains a more developed and complete aerodrome with the capacity to operate helicopters, a pier with similar characteristics to the previous proposal, although with some differences (place and shape) and it has almost all the new buildings. It is characterised by the place where the Main House is located and does not include a place for recreation (Figures 163 and 164).

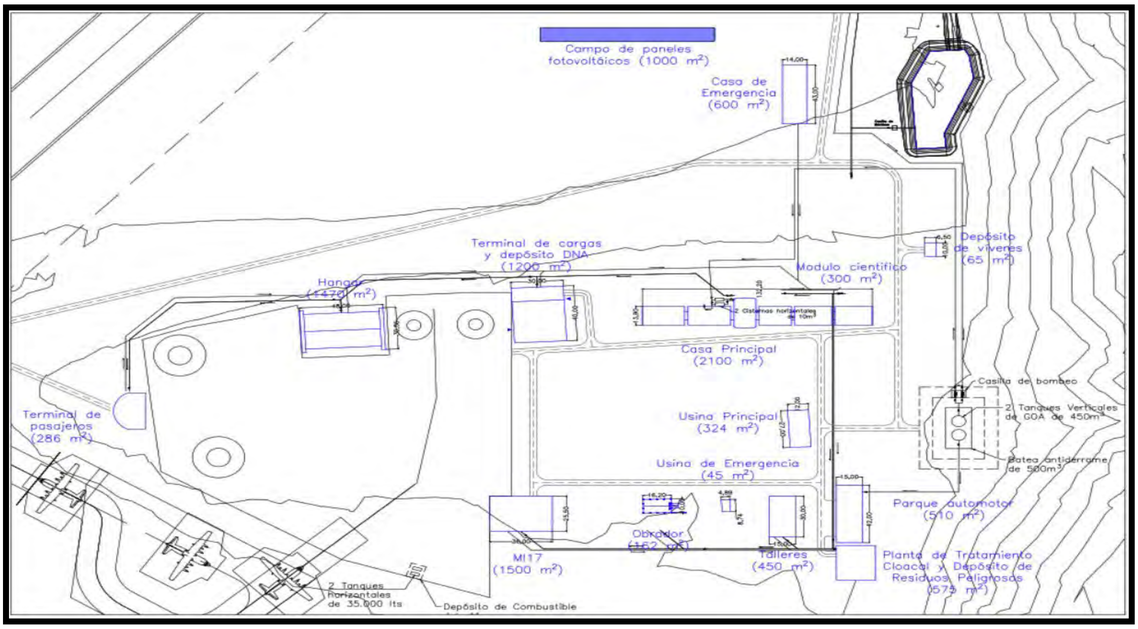


Figure 163: Specific layout of Proposal 2.

5.3.3 Proposal 3 – Maximum development of the base

This proposal contains the aerodrome with all its complete services and with the capacity to house operating helicopters from the base. It maintains the pier (still in the process of study), and all the necessary constructions for the full operation of the base. It locates the Main House parallel to the moraine of the Rosamaría glacier and the construction of a sports centre/mini-stadium as a place of recreation (Figures 165 and 166).

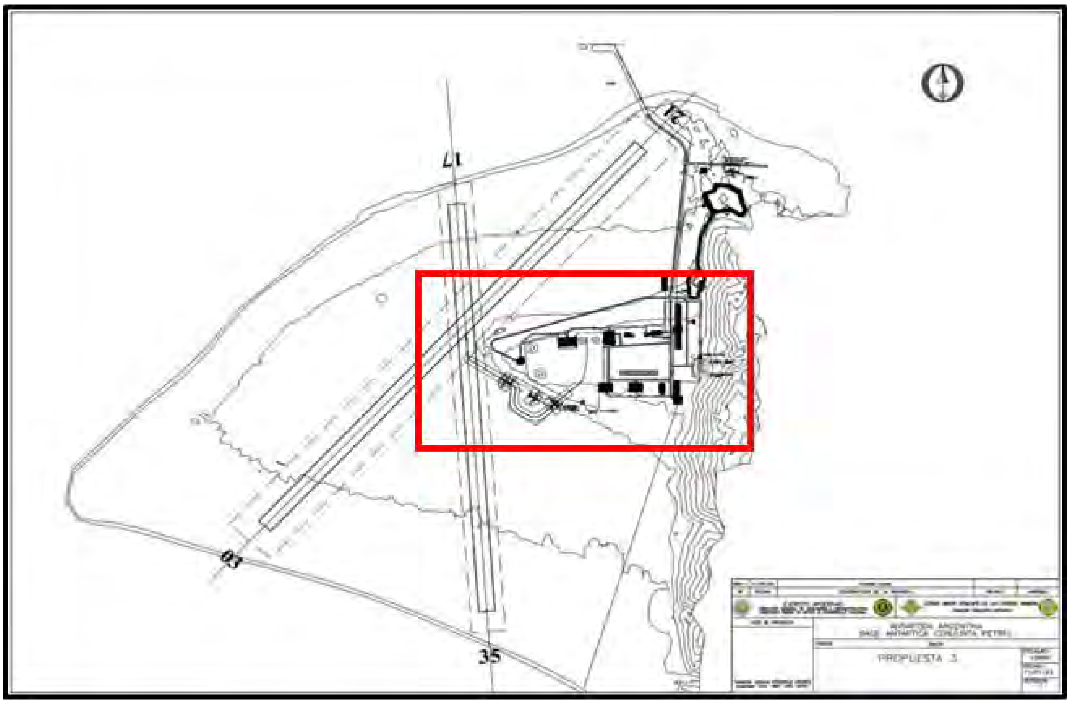


Figure 164: General layout of Proposal 3.

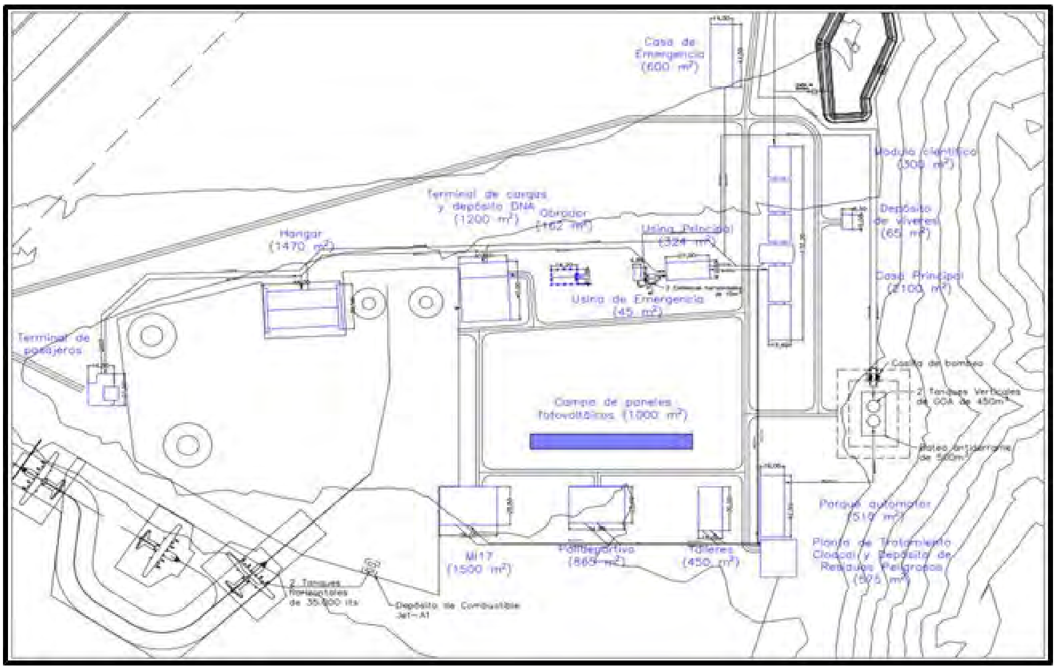


Figure 165: Specific layout of Proposal 3.

5.4 General evaluation of the proposals

The three proposals were evaluated based on the following aspects, which were considered as priorities for the development of the Petrel base.

- The requirements of the Guidelines for the evaluation of the environmental impact in Antarctica (Resolution 1 (2016)) that impose the evaluation of the total project and not only its parts.
- The best use of the zones and the functionality of the base.
- Satisfaction of the requirements determined to constitute the deployment and withdrawal centre for scientists, logisticians and cargo of the Argentine Antarctic Programme employed to select the Petrel Base.

Table 31: Analysis of the proposals.

No. of	Proposal / Aspect to consider (Evaluated according to the possibilities from 1 to 5)	PROPOSAL 1	PROPOSAL 2	PROPOSAL 3
1	Requirements of the Guidelines for the evaluation of the environmental impact in Antarctica (Resolution 1 (2016)) that impose the evaluation of the total project and not only by parts. Greater compliance: 5 Lesser compliance: 0	The design of the base seems to be incomplete and will probably require new facilities in the short term, violating the requirement to evaluate the total project. Assigned value: 1	The design of the base is complete. Assigned Value 4	The design of the base is complete. It has facilities for recreation that can be used as accommodation in case of emergency. Assigned Value: 5
2	The best use of the zones and the functionality of the base Best: 5 Null: 0	Functionality limited to pre-existing installations. The functions must be adapted to the facilities of the base. Assigned value: 3	Acceptable/optimal functionality. It has a greater dispersion Assigned value: 4	Optimal functionality It has a more compact and harmonious design Assigned value: 5
3	Make support for scientific activities more flexible, through rapid deployment, recovery and redeployment of scientists and their teams; and, the centralisation of samples through a central point for their storage, analysis or dispatch to the South American continent. Optimise: 5 Null: 0	Its facilities clear the necessary minimum levels. Their capacities probably cannot be demanded or are exceeded in emergencies Assigned value: 2	Optimal flexibility. Its airport and building capacities are optimal and with remaining capacity, which provides a margin for the growth of activities. Assigned value 5	Optimal flexibility. Its airport and building capacities are optimal and with remaining capacity, which provides a margin for the growth of activities. Assigned value 5
4	A better use of resources and transport facilities applied in support of the AAP (PAA in the original), redundant in more scientific activities with the same resources. Optimal: 5 Null: 0	Limited storage capacity, exchange and distribution of loads. Scientific capacity (limited compared to the other proposals) Assigned value: 2	Optimal scientific and logistics capacity with remaining capacities. Assigned value: 5	Optimal scientific and logistics capacity with remaining capacities. Assigned value: 5
5	The deployment of science on the Antarctic continent as an opportunity. Major: 5 Null: 0	Limited use of helicopters by facilities for guarding and maintenance. May eventually limit scientific deployment Assigned Value 2	Ability to operate up to two lines of helicopters with space for storage and maintenance. Guarantees rapid scientific deployment Assigned value 5	Ability to operate up to two lines of helicopters with space for storage and maintenance Guarantees rapid scientific deployment Assigned value 5

6	Eventually and with remaining capacities, develop international cooperation activities with other national Antarctic programmes. Major: 5 Null: 0	Its remaining capacities are limited Assigned value: 2	Remaining capacities to satisfy international cooperation Assigned value: 5	Remaining capacities to satisfy international cooperation Assigned value: 5
7	Access by air and sea so as to allow the exchange of scientific personnel, logistics and cargo for the deployment or withdrawal of the Antarctic continent. Major: 5 Null: 0	Optimal access by air and naval mode. Limited by its ground capabilities to support these operations Assigned value: 3	Optimal access by air and sea, with the necessary facilities and services to ensure these operations. Cargo exchange and storage capacity. Assigned value: 5	Optimal access by air and sea, with the necessary facilities and services to ensure these operations. Cargo exchange and storage capacity. Assigned value: 5
8	That it has the conditions to function as such for a long time and without the need for growth or expansion (Space). Best conditions: 5 Null conditions: 0	Its operation adjusted to the current level, will entail its growth in the short term Assigned value: 2	With conditions to function like this for a long time, even if their activities increase Assigned value 4	With conditions to function like this for a long time even if their activities increase Assigned value 5
9	Investment to be made Lower Investment: 5 Greater investment: 0	Medium - many installations already exist and just need to be updated Assigned value: 3	High – 90% of the facilities are built Assigned value: 1	High – 90% of the facilities are built Assigned value: 0
10	Environmental impact Null: 5 High: 0	Low environmental impact Assigned value: 3	Limited environmental impact due to being an impacted area Assigned value: 1	Limited environmental impact due to being an impacted area Assigned value: 1
	Totals	23	39	41
	Maximum value 50 pts	46%	78%	82%

Proposal 3, which develops all the facilities that will provide maximum services to science, is observed as the most favourable design. The main difference between Proposals 2 and 3 resides in a more compact design and especially the recreation area constituted in the sports centre or mini-stadium, which will fulfil the double task of recreation for the staff and the availability of a building with capacity that can be used for multiple uses in case of eventualities.

Finally, it can be seen that the total reconversion of the base is convenient over the reconditioning of the current facilities. The main reason is that in a short time it is estimated that its facilities should be expanded for a greater capacity for benefits, thus violating the provisions of Resolution 1 (2016) which stipulates that partial projects should not be submitted.

5.5 Design and location of buildings

If the three proposals presented in the previous point are observed, it can be seen that there are some differences in the buildings, facilities to be developed, as well as their location. Next, the reasons why these variations exist and the choice of the best proposal will be explained.

5.5.1 Runways

The proposals presented are quite similar. The one adopted was the one that corresponds to proposals 2 and three consisting of 2 runways, a main runway of 1500 metres of orientation 03/21 with a lateral security strip of 75 metres on each side and a secondary runway of 1200 metres of orientation 17/35 with a lateral security strip of 45 metres on each side.

In previous studies, the length of the runways was prioritised, obtaining several designs that varied between 1700 for the main runway with orientation 06/24. The secondary runway had an orientation almost the same as the current proposal. Once this proposal has been analysed, although the length of the runway

It was very favourable for the landing of the aircraft, it had a drawback that reduced or penalised the payload of the critical aircraft.

The inconvenience and its solution were the following:

- On the main runway, the end of the runway corresponding to runway head 04 was in front of the moraine of the Rosamaría glacier, forcing a rapid elevation with no escape capacity. In the opposite direction, it forced the aircraft to follow the unevenness of the glacier to access the runway.
- The current design orients runway head 22 towards the coast of the Petrel roadstead, partly avoiding the moraine and the Rosamaría glacier, increasing flight safety. As a counterpart, the total distance of the runway cannot exceed 1,500 metres in length, plus the lateral safety strips in front of each runway head.

For this reason, the current design of the runway is the most suitable for the operation of critical aircraft.

5.5.2 Passenger and cargo terminal and control tower

In Proposal 1, the passenger terminal and cargo terminal are located in front of the intersection of the two landing strips, while the control tower was located next to the Northwest end of the Hangar. In Proposal 2, the passenger terminal contains the control tower and is located in front of the intersection of the two landing strips. In a remote sector is the cargo terminal. The two proposals were analysed based on the operability of the aerodrome and the safety of operations.

No. of	Proposal Aspects to consider (Evaluated according to the possibilities from 1 to 5)	PROPOSAL 1	PROPOSAL 2 and 3
	Situation raised	the passenger terminal and cargo terminal is located opposite the intersection of the two landing strips and taxiway. The control tower was located next to the Northwest end of the Hangar.	The passenger terminal contains the control tower and is located in front of the intersection of the two runways and taxiway. In a remote sector is the cargo terminal.
1	Safety - observation Best: 5 None: 0	The control tower has blind spots. The passenger and cargo terminal obstructs the control tower's view of the runways and aircraft apron. The control tower is located in a position far from the centre of the airfield. The location of the control tower at the Northwest end of the Hangar could produce blind spots on the beach to the south where helicopters could operate. Assigned value: 3	The control tower has 360º visibility without obstacles to observe the landing strips, the taxiway and the beach where the heliports are located. It is centrally located on the airfield. Assigned value: 5
3	Safety - various Optimise: 5 Null: 0	The existence of the cargo terminal in the area close to the runways is not the most convenient place for loading. The airfield fire service (fire engine) would be located in the cargo terminal Assigned value: 3	The cargo terminal is located behind the hangar, constituting an adequate place for their parking. (facilitates the transport of loads to the heliports) The passenger terminal contains the fire service (pumper) Assigned value 5
3	Operability Optimal: 5 Null: 0	The separation between the passenger terminal and the control tower will make it difficult to control personnel in the airfield area, as communication systems must be duplicated. Requires more control Assigned value: 3	The passenger terminal next to the control tower allows centralising the control of the airfield activities. The meteorological service will be located in this building facilitating the observation of the meteorological conditions of Cape Wellchness.
			Assigned value: 5

	Totals	9	15
	Maximum value 15 pts	60%	100%

As a result of what was considered, the construction of the Passenger Terminal containing the control tower was selected, since it facilitates the 360º vision and therefore the control of the operations of the airfield. On the other hand, the cargo terminal located further east removes the cargo in the central area of the airfield and facilitates, in Proposals 2 and 3, the reception and transport of cargo to the heliports.

5.5.3 Main House

The residential houses in the three proposals have differences in location and size.

5.5.3.1 Residential House Size

Proposal 1 presented a residential house of 982 m^2 while Proposals 2 and 3 each presented houses of 2100 m^2. The difference between stowage in the purpose of each project. Proposal 1 is focused on the minimum necessary for the operation of the base and the satisfaction of the indicated operational requirements. In this regard, and by discarding Proposal 1 as a project and promoting the remodelling of the Petrel Base in its maximum development, the house in Proposal 1 is discarded.

5.5.3.2 Location of the Residential House

The location of the residential house in Proposals 2 and 3 still remains to be evaluated. For this, the meteorology, the terrain and the building distribution of the base and its services were analysed (Table 32).

Table 32: analysis of alternatives for the location of the Main House

No. of	Proposal / Aspect to consider (Evaluated according to the possibilities from 1 to 5)	PROPOSAL 2	PROPOSAL 3
	Situation raised	The Residential House is located on the northern edge of the central platform of Cape Wellchness with an East-West orientation	The residential house is located in the Northeast sector of the central platform of Cape Wellchness, close to the moraine of the Rosamarìa glacier, with a North-South orientation.
1	Meteorology Best: 5 None: 0	The East-West orientation of the house faces perpendicular to the strongest winds coming from the south, which could affect its energy efficiency. Having one of the longest faces to the south will affect energy efficiency as it is generally in the shade. Assigned value: 3	The North-South orientation and its proximity to the Rosamaría glacier moraine would protect the residential house from the strongest winds in the area, coming from the south. The reduced face of the house to the south provides a better orientation towards the sun Assigned value: 5
2	Terrain Optimal: 5 Null: 0	Locating the main house close to the edge of the central platform carries the risk that in the future the land will give way and tilt the building. Assigned value: 3	The location of the house on the west side of the central platform, close to the moraine, provides greater security in the stability of the soil. Assigned value 5
3	Constructions currently located in that area Optimal: 5 Null: 0	The construction of the residential house will require the demolition of the emergency house, auxiliary or emergency power plant, cold storage room and workroom. Buildings that will be used during the conversion of the base. Assigned value: 3	The residential house will be built in an area without any other buildings. Only there is the platform of the old residential house (burned down in 1976) that will be demolished. Its construction does not prevent the use of the other buildings on the base Assigned value: 5

4	Environmental impact Null: 5 Maximum: 0	The area is impacted. Only the buildings that currently stand on that location need to be demolished. Assigned value: 4	The area is impacted. The foundation of the old residential house needs to be demolished and removed. Assigned value: 4
5	Building distribution of the base Optimal: 5 Null: 0	The location of the residential house forces a greater building dispersion because it occupies a large space where smaller buildings could be located. It forces the construction of other buildings (Workroom). Assigned value: 4	The lateral location of the residential house allows the construction of other buildings on the central platform. Assigned value: 5
6	Base services No difficulty:5 Difficulty:0	Does not affect the distribution of base services Assigned value: 5	It does not affect the distribution of the services to the base. Assigned value: 5
	Total	22	29
	Maximum value 30 pts	73.3%	96.6%

As a result of what has been analysed, it appears that the location of the residential house in Proposal 3 is the most convenient, since it has a better location according to the terrain, winds and solar orientation; and its construction does not require the demolition of buildings that can be used during the conversion of the base.

5.5.4 Photovoltaic solar facility

During the Petrel base development project, several places were analysed for the installation of the photovoltaic Solar Facility, which will have about 950 m^2. Of four probable location sites, 2 of them were selected for the final evaluation, which appear in Proposals 2 and 3.

In Proposal 2, its installation on the lower platform of Cape Wellchness, to the north of the upper platform, was evaluated. In Proposal 3, its location was proposed in the central area of the upper platform, where the old antenna field to be dismantled is currently located.

The factors that were evaluated for this choice were the following: Type of soil for its implantation, its affectation to the winds, the possible accumulation of snow during the Antarctic winter and humidity during the summer, its proximity to the main power plant (electricity network) and affectation for circulation at the base (Table 33).

Table 33: Analysis of the alternatives of the photovoltaic park.

No. of	Proposal / Aspect to consider (Evaluated according to the possibilities from 1 to 5)	PROPOSAL 2	PROPOSAL 3
	Situation raised	Installation of a photovoltaic solar field on the lower platform of Cape Wellchness, north of the upper platform	Installation of a photovoltaic solar field in the central area of the upper platform of Cape Wellchness
1	Type of soil Best: 5 None: 0	The soil on the lower platform is slightly less firm than on the upper platform (See Annex 3 – Appendix 1, and Annex 6 Appendix 1). This means greater depth and volume of the bases. Assigned value: 4	The soil on the upper platform is firmer. (See Annex 3 – Appendix 1, and Annex 6 Appendix 1). The solar field means less depth and weight of the bases. Assigned value: 5

2	Accumulation of snow in winter and humidity in summer Optimal: 5 Null: 0	According to the reports from the staff in 2022, the area accumulates a long tail of snow as a result of the winds and of being north of the upper platform.	The ground, being at the highest level of Cape Wellchness, accumulates very little snow and is windswept. The soil is drier in relation to the lower platform.
		The soil is more humid in relation to the upper shelf, due to the melting of accumulated snow Assigned value: 3	Assigned value 5
3	Proximity to the Main Power Plant Optimal: 5 Null: 0	The location of the solar field in relation to the location of the power plant in both proposals (2 and 3), is far from the main power plant. Assigned value: 3	The location of the solar field is at a reasonable distance from the main power plant Assigned value: 5
4	Impact on the circulation at the base Null: 5 Maximum: 0	However, the location of the solar field is far from the central platform, the power line must cross over two roads. Assigned value: 4	The field, being in a central sector of the base with roads around it, does not affect circulation in it. Assigned value: 5
5	Building distribution of the base Optimal: 5 Null: 0	Provides more dispersion of the facilities. Assigned value: 4	Contributes to a more compact layout of the base facilities. Assigned value: 3
	Total	18	22
	Maximum value 20 pts	72%	88%

From what is appreciated in the upper matrix, the location of the photovoltaic solar field in Proposal 3 is better than the one corresponding to the one that appears in Proposal 2. As distinctive characteristics, we can say that Proposal 3 presents as superior aspects the lower accumulation of snow in the sector and therefore less dampness on the ground, ease of installation due to a less depth and volume of the bases and proximity to the Main Power Plant to connect its electricity production to the base network.

5.5.5 Evaluation of the non-construction of the runways

An important aspect of the analysis of the alternatives was the decision to build the runways at the Petrel Base. Since 1969, when Argentina founded the Marambio Base, the runway located on the Marambio Island plateau has been the aerial gateway for the activities of the Argentine Antarctic Programme. If the alternative of building the runways at the Petrel Base were ruled out, the Marambio Base runway would continue to be the only entrance for aircraft into an Argentine base.

The problem at present is that Marambio Island and its soils have been suffering the impacts of climate change in recent decades and this has led to the occasional impossibility of using the runways, often at critical moments of the Antarctic campaign or in emergency situations like an aeromedical evacuation. Based on the location of the Marambio Base in general, taking the SCAR Report as a reference, we can mention that in relation to the surface temperature, a significant upward trend has been observed throughout the entire Antarctic peninsula since 1950, with this being more significant in the western and northern parts of the peninsula. Temperatures on the eastern side of the Antarctic Peninsula have shown higher elevations during the summers and autumns, with an average increase of +0.41°C per decade (Turner et al, 2009). In the specific case of the Marambio Base, it has been experiencing a significant increase in the annual average temperature over recent decades of close to +0.7°C (Figure 17). Global results for Antarctica mention that in the last century the average annual temperature has risen approximately +1.2°C (Vaughan et al, 2003).

In the other aspect mentioned, permafrost, according to SCAR (Turner et al, 2009) it is likely that there will be a reduction in the permafrost area, accompanied by subsidence of the soil surface and associated earth movements. It can be determined in a particular way that in Marambio Island a clear positive trend is observed in the increase of the average of

Average annual temperature (Figure 16). However, although Seymour Island is located in the continuous permafrost zone, with ground temperatures close to –5°C and a thickness of approximately 200 metres (Silva Busso, Sánchez and Fresina, 2000), the observed and expected changes in temperatures have significant effects on the dynamics and thickness of the active layer of permafrost (top layer of permafrost that thaws in summer and refreezes in autumn).

The thickness of the active layer is highly variable, and depends on environmental conditions. In the case of Marambio Island, the minimum thickness was detected on the plateau, where it reaches 0.4-0.5 m, while the maximum thickness of 1.5-1.6 m was measured on the gentle slopes to the north and northwest (Yermolin et al, 2002). However, the depth of seasonal thawing on Marambio Island depends on climatic conditions and soil moisture (Yermolin and Skvarca, 2004). It must be taken into account that the thawing thickness (Zd) is calculated using Stefan's equation (Nelson et. al., 1997) and that the higher the temperature, the greater the thawing thickness.

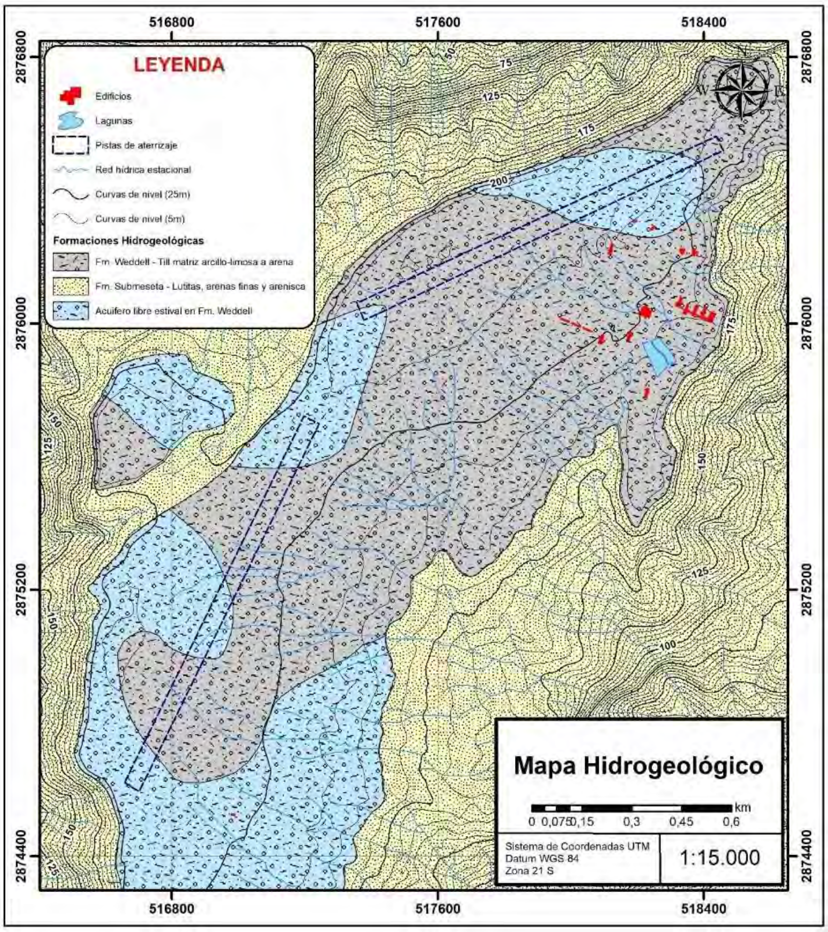


Figure 166: Map showing the location of the free aquifer below the Marambio Base runway (taken from Ormazabal (2022).

In the latest studies carried out (Ormazabal, 2022), it was detected on Marambio Island that the water resulting from the thawing of the active layer together with the ablation of snow precipitations, make up the saturated zone of the soil in which the free aquifer of summer suprapermafrost water can develop and this aquifer is the one that generates flooded areas on the runway and a loss of soil consistency that makes it impossible to operate with large aircraft such as the C-130.

According to Ormazabal (2022) Marambio Island has a high plateau 200 metres above sea level free of permanent ice, topped by a deposit of glacial origin of Pliocene - Pleistocene age, called the Weddell Formation and continuous permafrost develops in these sediments. The active layer thaws during the summer giving rise to the creation of surface water systems and saturated supra-permafrost levels. The freezing and thawing cycles modify the mechanical properties of the active layer and the permafrost roof, so understanding these systems is important, since infrastructure works (buildings, roads, airstrips, etc), in which construction costs, maintenance, and even risks could be reduced.

According to Ormazabal (2022), the free summer aquifer develops in sectors where the thawing of the active layer exceeds one metre. In the study that was conducted, it was possible to observe that the free summer aquifer is discontinuous and is more developed at the southern end of the plateau. It is also developed on the main landing strip, from the centre towards the north runway head. In the rest of the plateau are the sediments of the unsaturated or saturated Weddell Formation, but with an active layer development of about 0.6 metres. These sectors where the permafrost ceiling is raised, prevent the connection of the aquifer and the horizontal flow of the contained water (Figure 166).

The change observed on the island and the expected changes lead to the expectation that the difficulty and restriction of operating on the Marambio Base runway will be increasing, for this reason the alternative of not building the Petrel Base runways (Dundee Island does not have the problems mentioned for Marambio Island) is discarded since it would entail opting to worsen the complications in the future for the airborne entry to the continent.

5.5.6 Evaluation of the non-construction of the pier

As previously presented in this document, the original project included the construction of a pier in the area of the Petrel roadstead. This idea has also been evaluated for many years, seeking to generate an Antarctic Base that has the possibility of having a larger pier that allows the proper operation of larger ships.

Figure 167: Presence of icebergs and ice "rubble" on the coast.

In the first place, the search for a site for the positioning of the pier began. In a first analysis, based on the study of the existing bathymetry of the area, it was observed that on the shore there is a sector of the coast that enters into the sea in the shape of a “tongue”, an approximate distance of 200 linear metres which is very shallow, down to a depth of approximately 3.00 m., leaving sectors with an approximate depth of 7.00 m on both banks.

After what was appreciated in situ, it was observed that the “tongue” acts as a natural defence against the ice falls from the Glacier, the western sector being protected by this defence. The iceberg that could be seen during the inspection denoted that the optimal location of the pier should be to the west of the defense and moving away from La Botera, since the blocks of ice are smaller beyond that sector, so there would be safer navigation.

Finally, various problems began to appear. One of them is that the proposed location does not eliminate the problem of icebergs in the area, which means that the pier may not be operational on many occasions due to the danger of collision with these elements. This situation is also expected to worsen as climate change and glacier retreat release more and more icebergs and debris into the sea (Figure 167).

Figure 168: final schematic of the new Petrel Base.

Another drawback is that the use of the Cofferdam system (cellular cofferdams, containment structures) was considered in the construction system to materialise the structure of the pier, that is to say, a structure formed by contiguous hollow cylinders, joined steel sheet piles, which support the thrusts by means of the friction of its base. The cells will be filled with a material of the highest possible specific weight (mixture of sand and gravel according to availability in the area). This system has two important considerations. One of them is that they do not have all the machinery and equipment to carry it out and another is that the economic costs are outside the values that Argentina can afford.

In this way, it can be concluded that the construction of a pier has numerous obstacles regarding navigation safety issues (icebergs), resources necessary for its construction and economic limitations. The latter are critical, because the necessary investment is not justified given the limitations of use that may arise. For these reasons, the alternative of not building the pier was chosen, leaving the final project without this component (Figure 168).

6 ENVIRONMENTAL CONSIDERATIONS

6.1 General Description of the Area

The Antarctic Continent has always been a great attraction for human beings, for centuries people have visited or lived in it for different purposes, which have changed over time. From whaling and sealing to scientific research, which seeks to understand Antarctic ecosystems and their associated processes. They all have a common denominator, they impact the environment, often significantly. After so many years of Antarctic activity, Argentina is one of the countries with the most environmental problems, as they occupy a central place in Antarctic planning due to the fragility and particularity of Antarctic ecosystems.

The attitude towards environmental problems has changed a lot in recent decades, from the ecological vision of the 1970s and 1980s, this century has moved towards the search for adequate scientific knowledge that allows the right decisions to be made to achieve the solution of these problems. This new approach establishes the need to recognise the “environment” as an object of scientific study, seeking to understand it in depth, which includes its environmental problems.

At present, all Antarctic activities are justified under the gaze of scientific research, which, as mentioned, seeks to achieve in-depth knowledge of Antarctic ecosystems, however, according to epistemological changes in relation to environmental problems, it is necessary to intensify the investigation of the environmental impacts that appear in Antarctica, due to the years of permanence of human beings in such a fragile and particular Continent.

The interaction between the activities that will be carried out at the Petrel Base and the characteristics of the island and the Antarctic environment have some very particular points. Firstly, the environment does not have a significant presence of Antarctic flora and fauna due to the absence of colonies or numerous settlements of birds or mammals, which minimises possible harmful interference with them. Second, the island has a high geological value due to the possibility of studying, among other issues, the retreat of the glacier. Third, since the Base will function as a logistics coordination centre for many activities of the Argentine Antarctic Programme due to the presence of a landing strip, the same large number of people will pass through it, especially in the summer months.

The conjunction of the aforementioned points leads to the fact that the most important environmental aspects (and their derived impacts) in the operation of the Base are those related to the care and preservation of the island's soil, both in its composition and in its structure. The accumulation of waste, the removal of historical waste, the obtaining of water for consumption, the consumption of fuel, the generation of effluents, the use of roads and trails, fuel and effluent spills, the construction and maintenance of buildings, These will be, among others, the causes of the main environmental impacts, in many cases unavoidable, arising from the Base’s activities.

As the island does not have assets of high biological importance, the environmental impacts at stake are soil, water and snow contamination, the modification of the structure and dynamics of the water network, the loss of geological and landscape assets and to a lesser extent measure air pollution. Because the soil is thus one of the components with the highest environmental value on the island, the environmental aspects and impacts derived from the storage, use and distribution of fuel at the Base will be among the most important, followed by those related to the generation and accumulation of all types of waste.

The Base is located in the North of the Antarctic Peninsula, a region with unique characteristics that is undergoing significant processes of change. The Antarctic Peninsula is the northernmost portion of land on the Antarctic continent, which forms a prominent peninsula that extends north from its base and then turns northeast to end at the Trinity Peninsula. It is located in West Antarctica, south of the American continent, surrounded by the Bellingshausen Sea to the west and the Weddell Sea to the east, a sea whose coastline is largely blocked by the Larsen Ice Shelf. Being the northernmost territory of the Antarctic continent, it is also the one with the best climatic conditions compared to the rest of the continent. That is why it is the place with the highest density of Antarctic bases and human activities. On the other hand, it is the region of Antarctica where the effects of climate change are most evident

Although Antarctica is considered to be a pristine environment, some areas of the continent are under constant pressure due to human activities (for example, research, tourism and the logistics associated with these activities). One of the regions that receives the most pressure from human activities is precisely the Antarctic Peninsula and especially its extreme north. The impact of human activities on the Antarctic environment, especially its ice-free zones, where most terrestrial biodiversity is found, has long been a conservation issue.

6.1.1 Location

The Antarctic[16]

The Antarctic continent is largely covered by glacial ice, constituting a whole that is almost circular in shape and about 4,500 kilometres in diameter, almost entirely included within the Antarctic Circle. The surface of the Antarctic, without counting the islands or the barriers, is 13,177,000 km2; with the Sub-Antarctic Islands they add up to about a million more km2. The mosaic image of Figure 169 (Jezek *et al*., 2002) is the most recent satellite reconstruction of the Antarctic continent. The area of interest for scientific research includes oceanographic studies south of the 60th parallel, which covers about 30 million square kilometres (I.A.A., 1997).

From the point of view of physical geography, the Greenwich meridian and its corresponding antemeridian divide Antarctica into two portions: Eastern Antarctica, which includes the lands located to the east of that line, and Western Antarctica, which includes those towards the west, both sectors with very different characteristics. East Antarctica is constituted for the most part by a tabular plateau that occupies almost three-quarters of the entire continent; its coasts are of a remarkable regularity. The relief of Western Antarctica is much more abrupt and its coasts are highly irregular; this part of the continent has a long ledge that juts out into the ocean: the Antarctic Peninsula surrounded by the Bellingshausen and Weddell seas. One of the main characteristics of the Antarctic Peninsula is that it constitutes an extension of the continental region to the north and,

[16] Description written by Silva Busso, A., Fresina, M., Velasco, I., & Rey, C. (2009). The Antarctic Peninsula: a new horizon for water sciences. Water in the North of the Antarctic Peninsula, Félix de Azara Foundation, Buenos Aires, Argentina, Chapter 1, 1–12.

together with the neighbouring island region, it reaches the latitude of 60° south. The fact that most of the continent is covered by a thick ice sheet (Kotlyakov and Smolyarova, 1990) has made it difficult to learn about the subglacial relief. Lythe *et al*. (2001) made estimates assuming a thickness of the ice sheet between approximately 600 and 4000 metres with a marginal length of this layer of more than 20,000 km, most of it in contact with the ocean. Its volume is estimated at 25,400,000 km3, an amount large enough to raise the current sea level by around 60 m if it should melt.

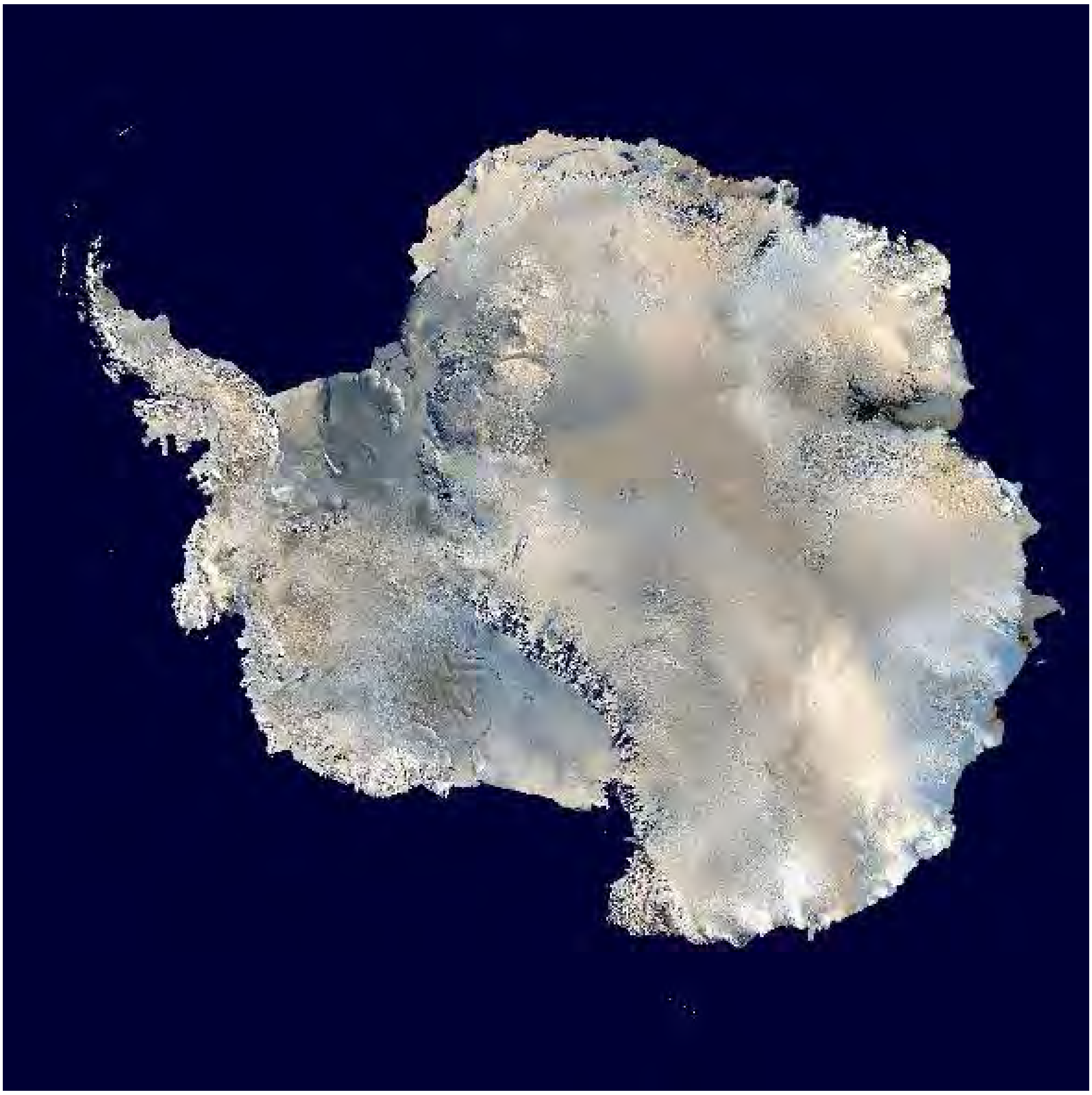


Figure 169: Satellite image of the Antarctic Continent.

Antarctic Peninsula[17]

[17] Description written by Silva Busso, A., Fresina, M., Velasco, I., & Rey, C. (2009). The Antarctic Peninsula: a new horizon for water sciences. Water in the North of the Antarctic Peninsula, Félix de Azara Foundation, Buenos Aires, Argentina, Chapter 1, 1–12.

Within Western Antarctica, between parallel 60º S and the pole, and longitudinally limited by the meridians of 25º and 74º W approximately, is the area that would comprise the Antarctic Peninsula and its insular area, covering an area of 4,000,000 km2 of which approximately 1,230,000 are continental (IAA, 1997). The Antarctic Peninsula (Figure 170) emerges from the continent in a northerly direction and then heads east. The western region of the peninsula is dominated by a plateau relief that generally does not exceed 2,000 metres above sea level. To the east is the mountain range of the San Martín and Trinity Peninsula (in Argentina they are called Antarctandes), which runs along the entire length of the peninsula. The orogeny of this chain is of the same age as the Andes and is considered to be linked to it through an insular arc made up of South Georgia, South Orkney, South Sandwich and South Shetland (Behrendt, 1983) with the highest altitude being that of Cerro Jackson at 4,190 m.

Figure 170: Satellite image of the Antarctic Peninsula.

To the west of the peninsula are the Alexander and Belgrano islands that limit Marguerite Bay and to the north of these two archipelagos appear: Palmer Archipelago and the South Shetland Islands. Separated from the Antarctic Peninsula by the Antarctic Strait, they are in the northernmost part, another group of islands; within the sector, but farther away are the South Orkney Islands, with more than forty islands and small islets. To the east of the peninsula is the Weddell Sea, largely covered by the Filchner Ice Shelf. To the south of the Weddell Sea, in Edith Ronne Land, the Diamante mountain range extends in a north-south direction and reaches its highest point at Cerro Guaraní at an altitude of 3,660 m. The Transantarctic Mountains, located in East Antarctica, form an ice divide causing the ice on the plateau to flow asymmetrically with a main channel towards the Weddell Sea. As the ice in the interior slides towards the edges of the continent, it thins out progressively. Its channelling through valleys and depressions forms discharge glaciers extending out to sea and laterally coalescing, thus forming ice shelves.

The North Antarctic Peninsula (NAP), which encompasses the Bransfield Strait, the southernmost part of the Drake Passage, the northwestern Weddell Sea, and the region north of the West Antarctic Peninsula (WAN) shelf, is primarily important due to the evolution of changes in ecosystems and the dynamics of the cryosphere ocean-atmosphere- related to issues of climate change. The NAP is considered one of the main gateways to the waters surrounding Antarctica and the Antarctic continent, situated in a transitional environment from subpolar to polar influence. In addition, many of the Antarctic research stations are located in the vicinity of the NAP and most polar ships start their Antarctic campaign season from this part of the continent. The area where the Petrel Base is located can be characterised from the biogeographic point of view and from the perspective of environmental domains. Regarding the biogeographical region (Terauds *et al*, 2012) the area of the Petrel Base is located in the region of the “Northeast of the Antarctic Peninsula”. On the other hand, it is located in Environmental Domain A “Geological North of the Peninsula Antarctica” (Figure 171 and 172).

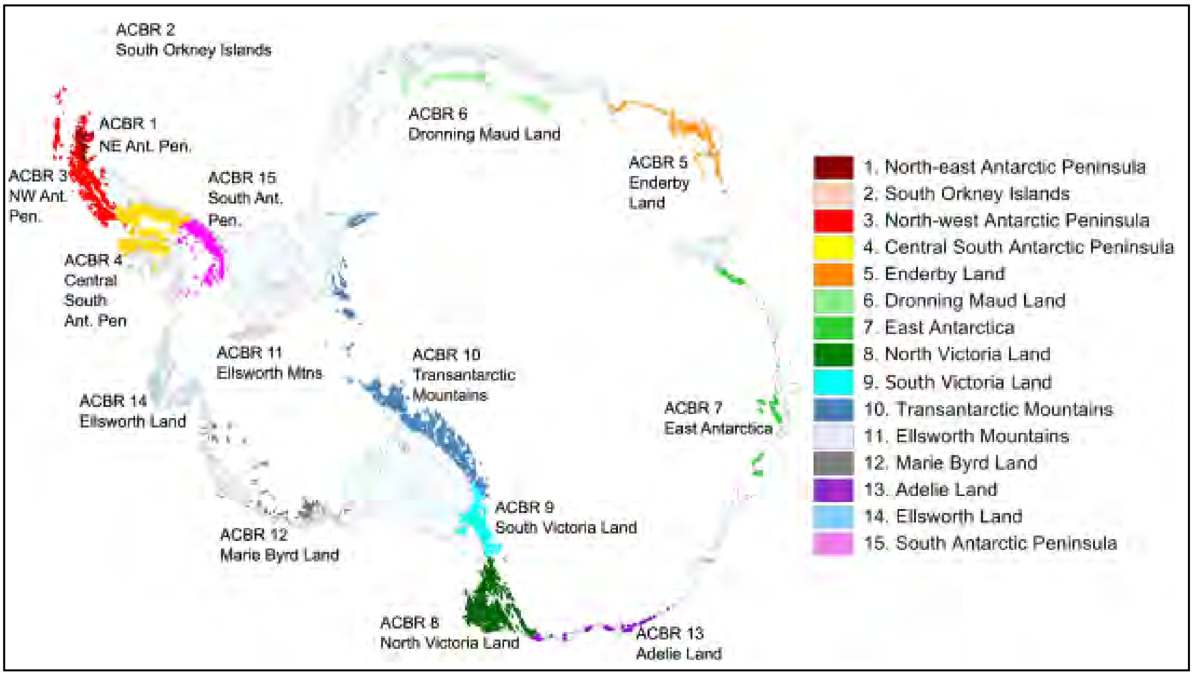


Figure 171: Map of Antarctica showing the 15 Antarctic Biogeographic Conservation Regions.

This domain is characterised according to Morgan et al (2007), as being a small terrestrial environment around the north of the Antarctic Peninsula. The size of the environment (2812 km^2) is very small compared to the other environments (only Environment G is smaller). The environment consists entirely of ice-free land cover and sedimentary geology. Climatically, the environment is warm compared to the other environments. Environment A occupies third place in terms of average air temperature (-10.33°C), second in terms of seasonal variation (-11.68°C) and second in terms of amount of solar radiation (10.28 MJ/m^2/day). The average wind speed in the environment is moderate, occupying eleventh place out of the 21 environments (12.22 m/sec). It is a steep environment, with an average slope of 24.35°, making it the fourth steepest environment on the continent. Among the best-known places covered by the environment are most of Marambio Island, parts of the ice-free peninsulas of Cerro Nevado Island, most of the Hurd Peninsula on Livingston Island, Hope Bay, and other ice-free parts of the Trinity Peninsula and the Nordenskjold coast (e.g., Sobral Peninsula), and other ice-free locations on Graham Land as far south as latitude 66°S (inland Jason Peninsula).

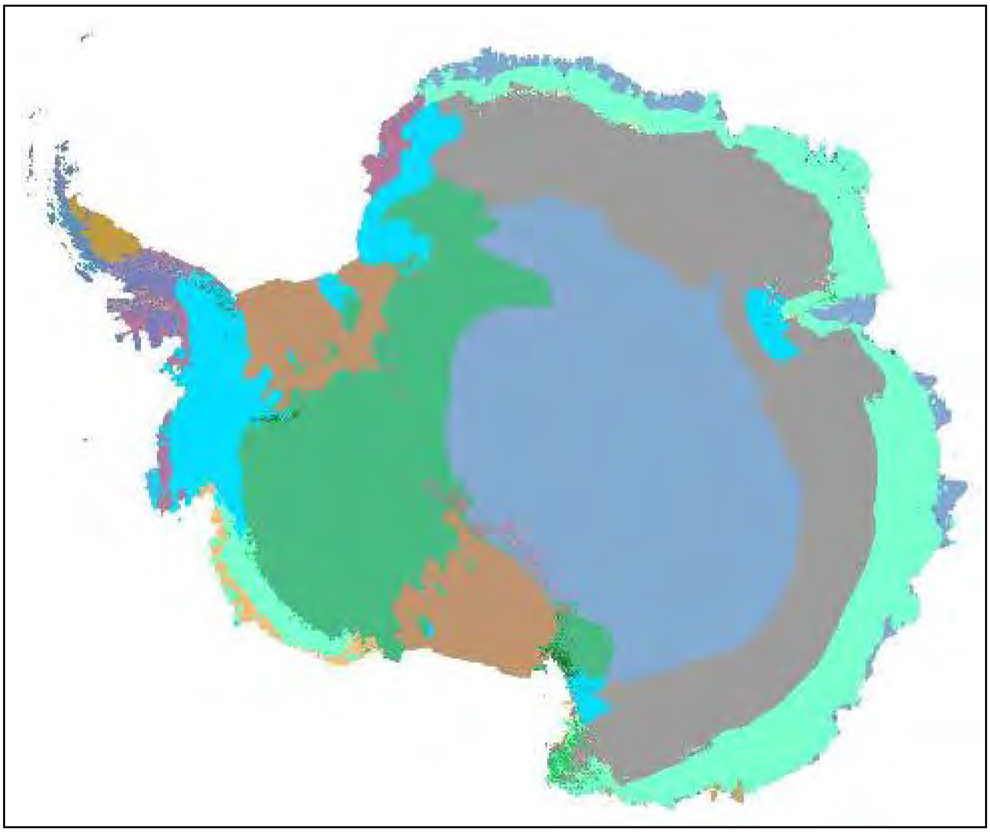


Figure 172: Antarctic Environmental Domains (Morgan et al, 2007)

6.1.2 Regional Analysis

To carry out an environmental characterisation of the environment where the activities of this project will be carried out, we will follow a *"coarse scale-fine scale"* criterion, where we will describe in a sequential way first the environmental conditions and processes of the northern region of the Antarctic peninsula and then in a particular way of the sector where Dundee Island is located, especially Cape Welchness.

6.1.2.1 Climatology of the region

For this point we will take the characterisation made by Silva Busso, Fresina, Velasco & Rey (2009). These authors mention that, in general terms, the Antarctic continent registers the lowest average annual temperatures on the planet, as well as the lowest absolute minimums. One reason is its relative isolation from the world's other oceans as a result of the so-called Antarctic Circumpolar Current that flows around the continent.

In the Antarctic Peninsula, summer temperatures are intensified as a consequence of the greater latitude and the consequent increase in solar radiation, in addition to the thermal effect that comes from exposed rock surfaces. More specifically, the climate in the north of the Antarctic Peninsula between 60° and 64° south latitude, shows, according to Reynols (1981), a gradual decrease in temperature averages from the western region of the Peninsula towards the eastern region. The maritime climate in the west of the Antarctic Peninsula and the pseudo-continental climate in the east have similar vertical temperature gradients (-0.57ºC/100m), between the surface and 1050 m altitude, but the latitudinal gradients are different, -0.77ºC /degree of latitude in the west and -0.85 ºC/degree of latitude in the east. These results would indicate a thermal uniformity that, however, is not such if the average annual temperatures between the W and the E are compared, which differ by 5 ºC, being colder in the W (Reynols, 1981).

The atmospheric pressure reaches its maximum in the Antarctic polar plateau where an anticyclone permanently emits dry and cold winds. Cyclonic systems that form in the ocean cause cloudiness and bad weather in the surrounding seas. In the Antarctic region the direction of the surface winds does not depend on the isobars. Heat loss by surface radiation generates a shallow layer of very cold air that descends at high speed down the slopes between the central plateau and the coastal region. These winds reach strong intensity and their gusts carry snow that reduces visibility, the phenomenon is known as blizzard. The evolution of the climate and especially of the temperature values of the last decades, has been evaluated by Jones, (1995) verifying an increase in the maximum mean thermometric values in the Antarctic continent in the middle and high latitudes. Svarka *et al*., (1998) carried out a comparative study of the thermometric evolution and its relationship with the warming of the region, determining appreciable differences between the eastern and western regions of the Antarctic Peninsula.

In this sense, the increase in the average temperature and especially the average summer temperature has been higher in the last three decades, in the eastern region of the Peninsula and particularly in the area of the Ross archipelago, determining increases of the order of 0.075°C (Marambio Station, 64°S approximately) and 0.083°C (Esperanza Station, 63°S approximately). In the western region, Reymond *et al* (1996) determined an increase of 0.057°C/year (Vernadsky Station, 65° lat. approx.), verifying the most important in the winter mean (0.14°C/year). In the western region, the extent of sea ice seems to be related to thermometric variations, especially in winter when cloudiness is greater than in summer in those regions (Reymond, et al., 1996; King, 1994). Stark (1994) proposes the same causes to explain the warming and also includes the Marguerite Bay area.

The climate of the northeastern region of the Antarctic Peninsula is subpolar, semi-arid, with mean annual temperatures ranging from –5°C to –10°C (Reynolds, 1981). Depending on the area, average summer temperatures are usually between 0°C and -2°C, while winter averages are between -12°C and -17°C, although during the last three decades there has been a significant atmospheric warming of 1.5°C (Skvarca *et al*., 1998). The prevailing winds are from the S and SW sectors, although strong, hot and dry katabatic winds from the WNW sector are sometimes also recorded. Precipitations of 250 mm per year (80% snow and 20% liquid) generally continuous permafrost that ablates part of the active layer during the summer.

To the east of the Antarctic Peninsula, the distribution of heat is fundamentally related to variations in sea ice and cloudiness, in addition to the phenomena of atmospheric circulation of the region (King, 1994). Reynolds, (1981), determined that the average annual temperatures adjusted to sea level in the western region of the peninsula are between -2ºC and -5°C, with isotherms parallel to the coastline, also determined that the average temperatures Summer temperatures tend to be higher in the western region of the peninsula, normally between 0°C and 2°C, while winter averages vary between -6°C and -10°C, on the other hand according to Skvarca *et al*, (1998), the significant atmospheric warming allows calculating a rate of 0.041°C/year.

To the west of the Antarctic Peninsula, a marked oceanic influence is observed since it constitutes a barrier to the circulation of winds coming from the northwest (Raymond et al, 1996). The dominant direction of the wind is WNW and of moderate intensity (compared to the eastern region). The precipitations that are close to 400-450 mm/year, take place during the summer, being fundamentally in liquid form or as snow water. Given the average summer temperatures, the ablation of snow is a constant process during it, in such a way that the contribution in the water basins comes not only from the glaciers but also and to a great extent by direct contribution from the precipitations.

It should be considered in this analysis that the precipitations that are registered in the form of snow are complex to measure due to the way the wind transports it. This normally causes read default errors. It has been observed from the precipitation series of the meteorological stations of the Argentine National Meteorological Service in the vicinity of the southwestern coast of the peninsula, that the precipitations may be higher or have a better record due to the lesser effect of the wind on the Strait of Gerlache. Particularly for the Melchior Base, in said region values of almost 1200 mm per year are recorded.

The presence of surface and groundwater is mainly due to the melting of glaciers, snow or permafrost. Given the particular climatic characteristics of subpolar environments, it is convenient to consider the proposal of Tolstijin and Kiriujin, (1978) (in Mijalov, 1989), which consists of a fundamentally hydroclimatic classification of hydrogeology. The cryological aspects and processes of the region are of importance in the superficial and subterranean hydrological behaviour (Silva Busso *et al.*, 2000 and Silva Busso, 2004). The Antarctic paleoclimate has been the object of study in recent years, mainly from the extraction of ice cores, extracted in deep wells made in the domes or polar caps, allowing us to determine the climatic changes that have occurred during the Quaternary.

The Argentine Antarctic Institute has carried out drilling to extract ice cores in the area of the Ross Island dome (Aristarain and Delmas, 1981; Aristarain et al., 1990) that have allowed analysis of recent climatic cycles. The concept consists of analysing the atmospheric air trapped in the ice bubbles at different depths stored during the moment of precipitation, thus allowing determination of the composition of the original atmosphere and particularly the CO_2 content or other gases that could act with a greenhouse effect (Popov *et al.*, 2002). Drilling carried out for similar analyses in the vicinity of the Vostok station, establish a correlation between changes in temperature and CO_2 content during climatic cycles (Tabacco *et al.*, 2003). CH_4, for its part, seemed to have a higher partial pressure in the ancient atmosphere. This gas is related to ambient temperature and the greenhouse effect, verifying that in the interglacial transitions between 150,000-135,000 years and 18,000-19,000 years, there were strong changes in the concentrations of that gas. Paleoclimate models indicate a climate that is highly sensitive to atmospheric variations.

resulting from changes in the concentration of greenhouse gases (CO_2 and CH_4), and to a change in orbital parameters.

6.1.2.2 Climate change in Antarctica

In this section we will detail the changes that have occurred in the Antarctic Peninsula in the last 2000 years according to what was presented by Turner *et al* (2009). According to these authors, the end of the MHH (*Mid-Holocene Hypsithermal*) was marked by cooler climatic conditions. Numerous studies have identified late Holocene glacial advances, but most are poorly dated or even undated. Some of the supposed neoglacial advances could belong to the Little Ice Age. There is strong evidence that the Prince Gustaf Channel ice shelf began to reform after around 1900 BP, but due to a variable and sometimes large depositional effect (6,000 years) this date is far from certain (Pudsey & Evans, 2001). around 1400 BP, when the climate of Larsen-A, but also in this case the uncertainty about the dating is high (Brachfeld *et al*., 2003).

Numerous well-dated biological indirect records in lakes and elsewhere show a temperature-related decline in production around this time (Björck *et al*., 1991b; Jones et al., 2000; Hodgson and Convey, 2005). After the MHH (*Mid-Holocene Hypsithermal*), Lake Midge (Livingston Island) registers a gradual deterioration of the environment with warm and cold pulses (Björck *et al*., 1991a). There was a warm episode around 2000 BP, and conditions were generally cooler than today between around 1500 BP and 500 BP. Lake Åsa (Livingston Island) shows a clear climatic deterioration, with cold and dry conditions beginning at c. 2500 BP and lasting almost to the present day (Björck *et al*., 1993). Penguin populations declined between c. 1300 and 900 BP and between c. 2300 and 1800 BP at Ardley Island (Sun et al., 2000; Liu et al., 2006).

It is believed that several outlet glaciers or ice shelves, such as Monte Roch, Livingston Island (Björck *et al*., 1996), and the Muller Ice Shelf (Domack et al., 1995) are thought to have advanced during a period roughly corresponding to the Little Ice Age in the Northern Hemisphere. However, the exact timing of these advances is only well delimited in a few places, and many of the many terrestrial records of glacial advance are still undated. Evidence of an LIA from indirect lake evidence. However, Liu et al. (2005) show a decline in penguin populations at Ardley Island on the Ardley Peninsula in the South Shetland Islands, between 1790 and 1860.

Instrumental measurements show the spatial pattern and magnitude of recent rapid regional warming, and in particular the sharp contrast between the west (more warming) and the east (less warming) sides of the AP. In the indirect records, the warming is observed in the increase in the rates of sediment accumulation in some areas of the lake nuclei of the AP (Appleby *et al*., 1995), and in some high-resolution marine cores (for example, Domack *et al*., 2003b). The warming was also detected in a follow-up study of the lakes on the island of Signy, in which the increase in air temperature a significant increase in the number of ice-free days and a fourfold increase in the chlorophyll a content that approaches the productivity of the lakes (Quayle *et al*., 2002, 2004). Few studies have focused on this period of indirect records.

In summary, climatic conditions probably deteriorated after the Middle Holocene, coinciding with the readjustment of glaciers in some regions, although their dating is not well defined, in the Little Ice Age. Rapid climate warming has recently been observed in several AP regions, with receding glacial fronts (Cook *et al*., 2005) and the Signy Island lakes showing a remarkably rapid and magnified response in ecosystem functioning.

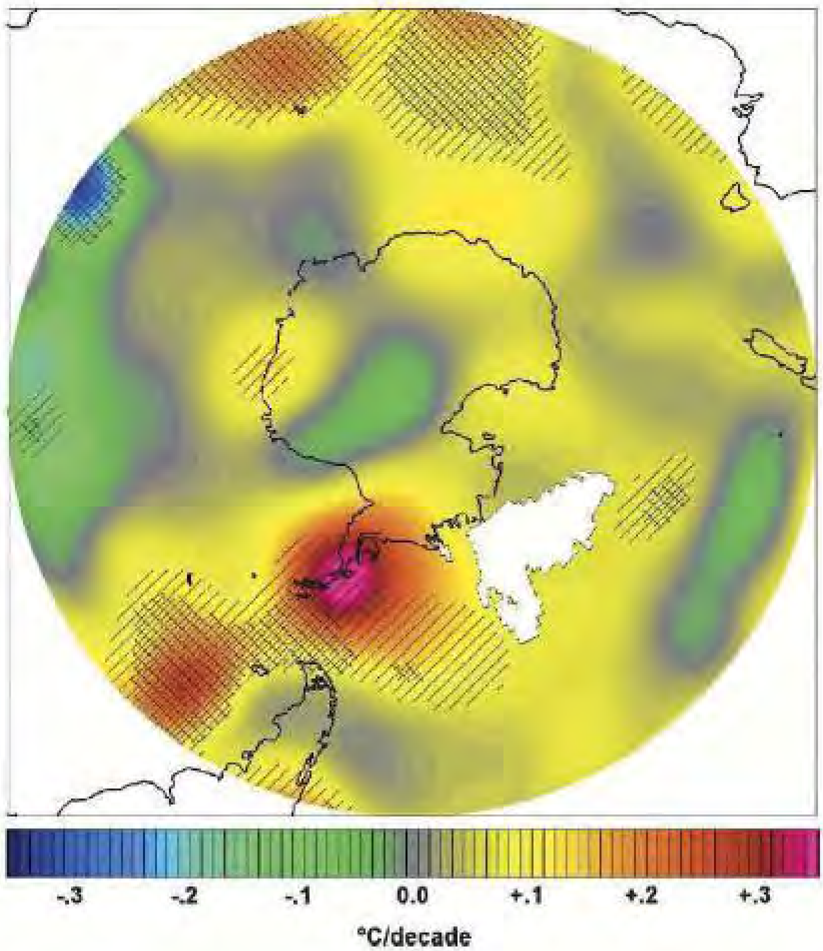


Figure 173: Temperature trends since 1950 (Taken from Turner et al, 2009)

Surface temperature trends from station data since the early 1950s illustrate a strong dipole shift, with significant warming along the Antarctic Peninsula but little change elsewhere on the continent (Figure 173). The largest warming trends in mean annual data are found in the western and northern parts of the Antarctic Peninsula. Here, the Vernadsky/Vernadsky station has experienced the largest statistically significant trend (level
<5%) of 0.53ºC/dec for the period 1951-2006. The Rothera station, about 300 km south of Vernadsky, has experienced a larger annual warming trend, but the shortness of the record and the large interannual variability of temperatures mean that the trend is not statistically significant. Although the region of marked warming extends from the

south of the western Antarctic Peninsula northward to the South Shetland Islands, the rate of warming slows away from Vernadsky/Vernadsky, and the long Orkneys record on Laurie Island in the South Orkney Islands has experienced only one warming of 0.20ºC/decade. This record covers a period of 100 years, instead of Vernadsky's 50 years. For the period 1951-2000 the temperature trend was 0.13ºC/decade.

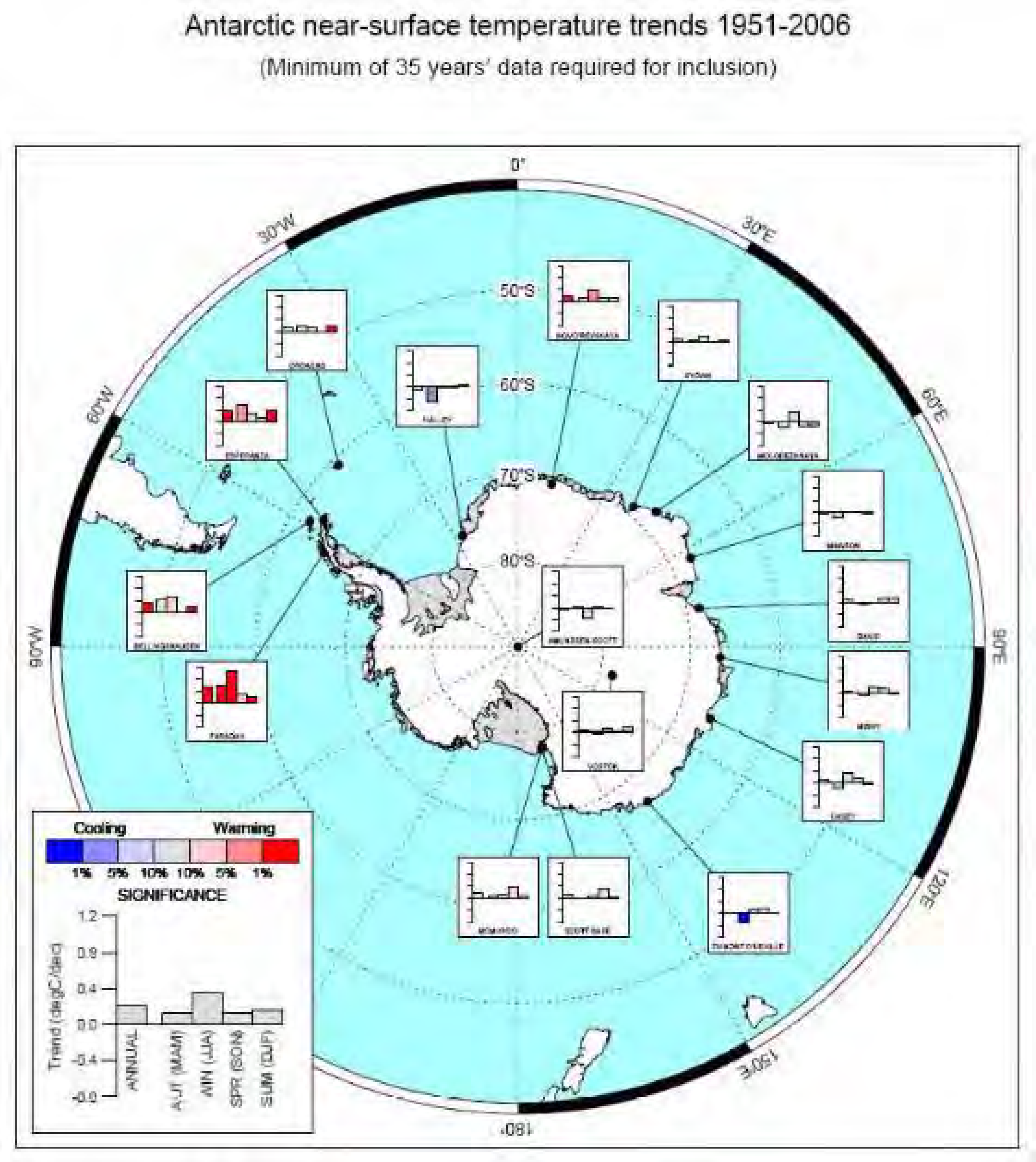


Figure 174: Estimates of annual temperature trends (From Turner et al, 2009)

Determining temperature trends in the interior of Antarctica is difficult, since there are only two stations with long-term records. However, attempts have been made to extrapolate seasonal trends to the rest of the continent. Chapman and Walsh (2007) made estimates of annual trends (Figure 174) and found the greatest warming over the Antarctic Peninsula, but with little warming (~0.1º

C/dec) in West Antarctica and much of East Antarctica. However, they also observed cooling in a strip from the South Pole to Halley Station.

6.1.2.3 Geology

For this point we will take the characterisation made by Silva Busso, Fresina, Velasco & Rey (2009). These authors mention that the Antarctic Peninsula is a strip of arcuate continental crust that is flanked by the oceanic regions of the southeastern Pacific Ocean, the Drake Passage, and the Scotia and Weddell seas (Figure 175). It is an Andean-type orogenic belt, of Mesozoic and Cenozoic age, which reflects subduction of the Pacific Ocean floor below its western continental margin. The oldest known basement outcrops on the southeastern flank of the peninsula, where a set of calc-alkaline plutons indicate late Precambrian-early Paleozoic and Silurian ages. The oldest magmatism is from the Triassic period and reached its maximum activity along the axis of the peninsula during the middle Cretaceous. The volcanic rocks related to this magmatism are known generically as the Antarctic Peninsula Volcanic Group. The geochemical composition and the temporal development of the magmatic activity together with

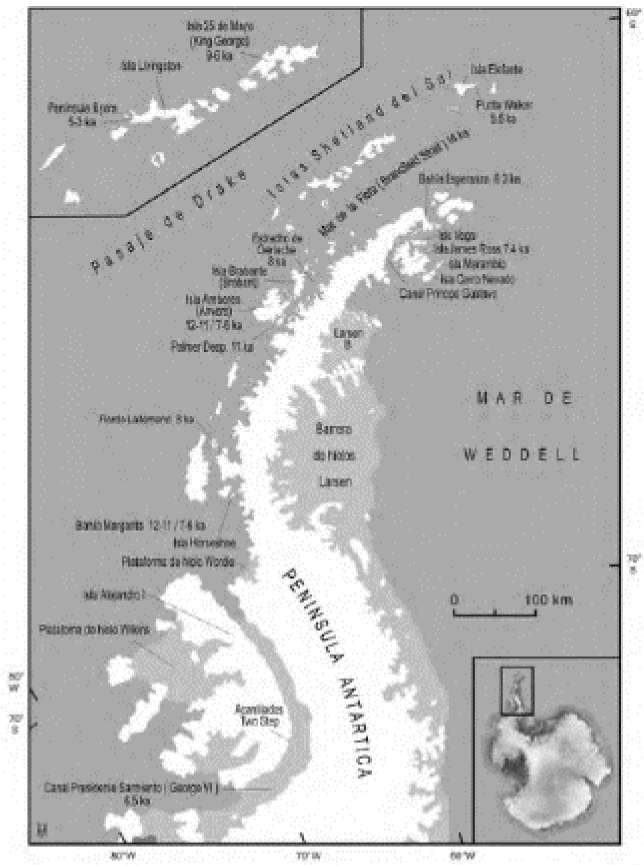


Figure 175: The Antarctic Peninsula region, with some of the locations mentioned in the text. The numbers correspond to the minimum ages for deglaciation, at 14C kiloyears before the present. Depending on the case, e.g. Anvers Island 12,000-11,000/7,000-6,000 years, the first group of numbers refers to the deglaciation of the mid-outer continental shelf areas while the second group refers to the deglaciation of the inner shelf, fjords and bays. According to Ingólfsson et al., (2003).

its areal distribution reflects subduction history, and reconstruction of plate displacements suggests close links with South America.

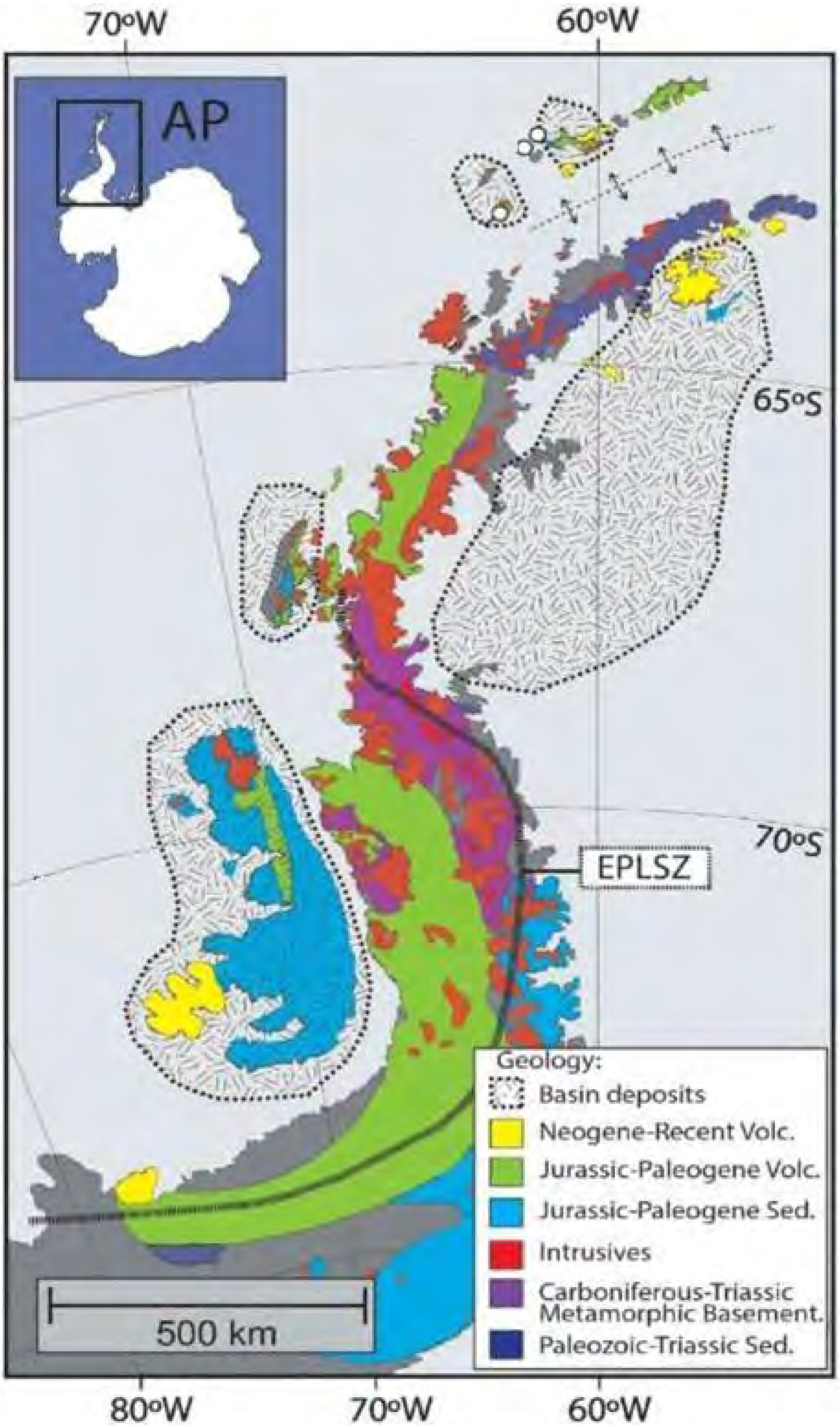


Figure 176: Geologic map of the Antarctic Peninsula showing the distribution of major geological units, modified from Burton-Johnson and Riley (2015). Livingston, Snow, Low, Adelaide and Alexander Islands are indicated by shaded areas with black dotted perimeter. AP, Antarctic Peninsula; EPLSZ, East Palmer Land Shear Zone.

In the northern Antarctic peninsula and adjacent islands (e.g. Laurie and Livingston islands, in the South Orkney and South Shetland islands, respectively), the basement of the Mesozoic-Cenozoic magmatic arc is formed by Permian-Triassic turbidite successions, regionally metamorphosed, which include the Trinity Peninsula Group and the Myers Bluff and Graywacke-Shale formations, in the north of the Antarctic Peninsula, the South Shetland Islands and the South Orkney Islands, respectively. These lithologic units present similar facies associations and area of provenance from a dissected magmatic arc and from a continental area. The turbidite successions represent the deposition in submarine fan complexes formed during the Permian-Triassic, and submarine canyons with debris flows and large slipped blocks, which developed on the Pacific edge of Gondwana before its fragmentation started in the Middle Jurassic. Part of the South Orkney and South Shetland islands and the north of the Antarctic peninsula were fragments of continental crust that originally belonged to the Scotia isthmus that linked Tierra del Fuego with the Antarctic peninsula, and that were displaced to the east by the combination extensive of two backarc basins, now extinct (Figure 176).

Back-arc sedimentary sequences are present along the eastern coast of the Antarctic Peninsula, they exhibit compressional deformation of varying degrees, e.g. Latady basin in the extreme southeast and Larsen basin in the northeast. The Larsen Basin (of the Valley *et al*., 1992) from the Mesozoic-Cenozoic, develops mainly in the area of the continental shelf to the east of the extreme north of the Antarctic Peninsula, and was formed as a result of the Jurassic lithospheric extension, during the early stages of the Gondwana breakup and the subsequent development in a retroarc environment relative to the magmatic arc of the Antarctic Peninsula. The marine fill in the basin is best exposed in the north, in the James Ross Island region, where the stratigraphic record is very complete, spanning the Late Jurassic to the Eocene (Hathway, 2000).

Regarding the raised beaches in the Antarctic Peninsula, Silva Busso, Fresina, Velasco & Rey (2009) mention that raised beach deposits, postdating the LGM in the region of the Antarctic Peninsula and surrounding islands, have been recognised in numerous areas free of ice. In the northern part of the Antarctic Peninsula the postglacial marine limit is located at altitudes between 15 and 20 m above sea level, with the highest limit on James Ross Island at 30 m asl 7,500 years BP, (Hjort *et al*., 1997). To the south it rises to 55 m above sea level, on Horseshoe Island located in Marguerite Bay, the minimum age is 7,000-6,000 years BP.

The north-south gradient in the altitude of the marine limits is in agreement with the conclusions of Bentley & Anderson (1998) and Anderson et al., (2002) that during the LGM the volumes of ice were greater in the southern and central than in the north of the Antarctic peninsula. Evidence on land suggests that the ice cover was greater during the LGM than at present, in the central and southern parts the ice thickness must have exceeded the current thickness by more than 500 m (Waitt, 1983; Bentley & Anderson, 1998), while in the north it was between 150 m and 400 m greater than the current thickness (Ingólfsson et al., 2003).

John & Sugden (1971) and Birkenmajer (1997) mention the existence of coastlines in the South Shetland Islands at elevations greater than 200 masl, Hjort *et al*., (1997) mentions the existence of coastlines at 80 m.a.s.l on James Ross Island. In the James Ross Island Group, at a considerable height, there are a large number of blocks of crystalline rocks from the Antarctic Peninsula. The raised shorelines and erratic blocks seem to indicate one or more Late Pleistocene glacial events prior to the LGM (culminating around 18,000 BP.

6.1.2.4 Glaciology

Antarctic Peninsula

In relation to the glaciology of the Antarctic peninsula we take for reference the work of Silva, Arigony-Neto and Bicca (2019) *"Geomorphological characterisation of the geysers of the Antarctic peninsula"*. These authors mention that the geomorphological classification of glaciers, according to Rau et al (2005), was developed exclusively for the glaciers of the Antarctic Peninsula and that this classification is made on the basis of primary classification, shape, frontal features, longitudinal profile and moraine.

Arigony-Neto & Bicca (2019) establish that the primary classification consists of a characterisation of nine classes of glaciers. Drainage basins are divided into ***(1) uncertain or varied, (2) ice shelf, (3) rock glacier, (4) glaciers and snowfield, (5) ice cap, (6) ice field, (7) mountain glacier, (8) valley glacier and (9) discharge glacier***. Two categories were not used in this classification, the continental ice sheet, because it has a continental proportion and this work makes a more detailed classification, and the ice stream, because it occurs in a zone in the ice sheet, where ice velocities can reach hundreds of metres per year, from the sliding of the basal rock (SIMÕES, 2004) and this work did not measure the speed of movement of glaciers (Figure 177).

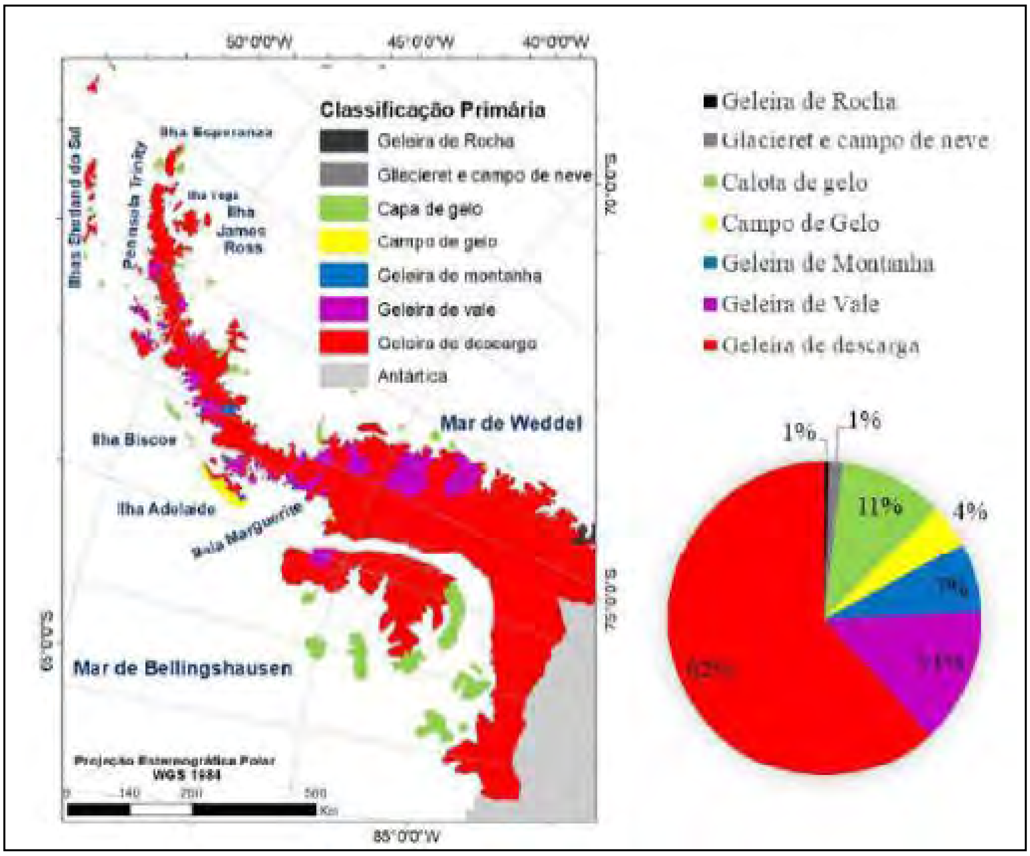


Figure 177: Primary classification of the drainage basins of the Antarctic Peninsula according to Arigony-Neto and Bicca (2019)

According to Arigony-Neto & Bicca (2019), the primary classification of glaciers (Figure 177) showed that 62% of the basins of the Antarctic Peninsula are discharge basins, that is, they drain their masses mainly from the plateau covered with ice, or ice field, or glacial cap, into the ocean or onto an ice shelf. This corresponds to 282,330.22 km^2 of ice surface. The discharge glaciers are distributed throughout the Antarctic Peninsula and represent almost all of the basins studied. This is because the ice mass accumulated on the ice shelf is dumped into the ocean or an ice shelf to the west and east.

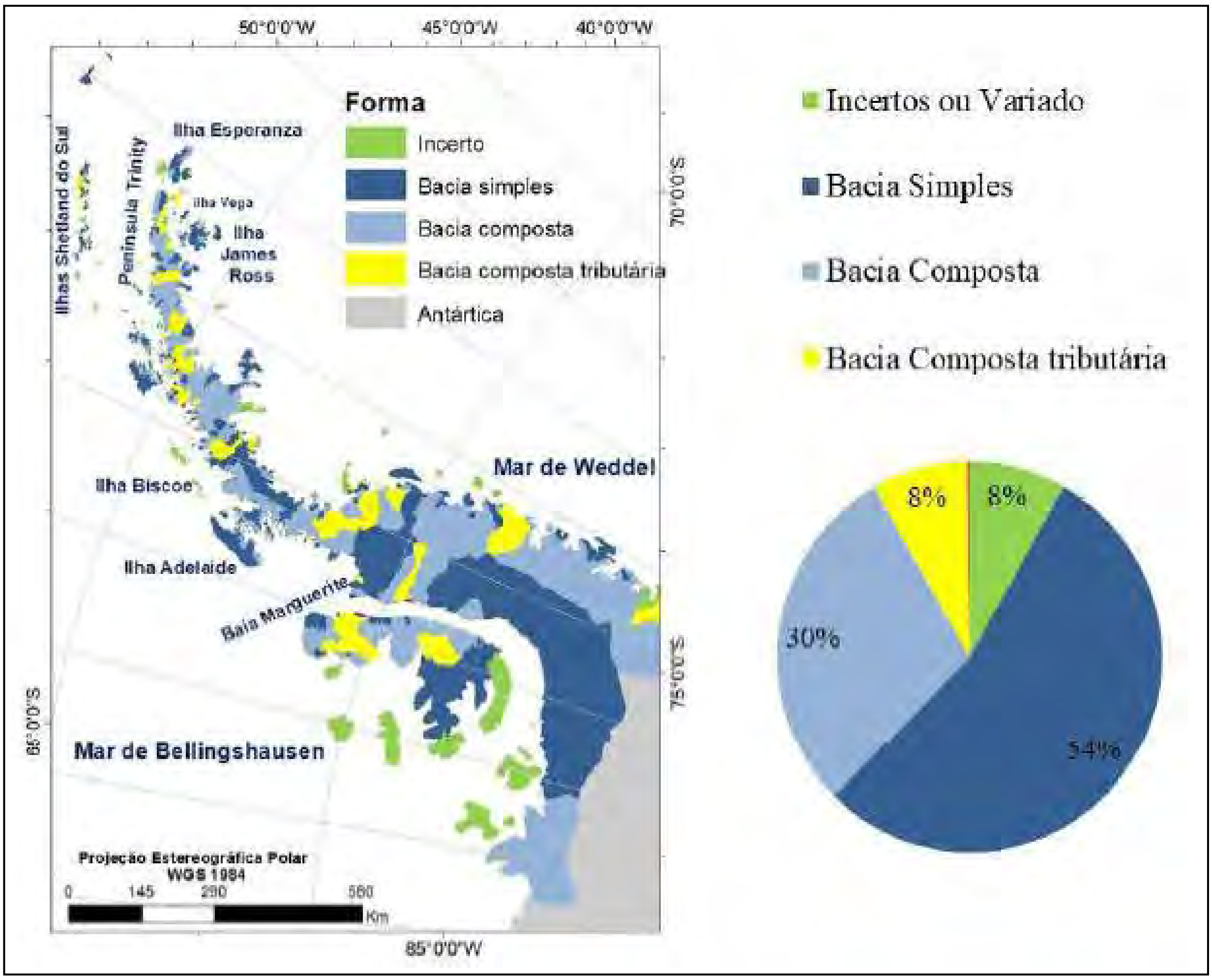


Figure 178: Classification in relation to the morphology of the drainage basins of the Antarctic Peninsula according to Arigony-Neto and Bicca (2019.

The discharge glaciers are distributed throughout the Antarctic Peninsula and represent almost all the basins studied. This is because the mass of ice accumulated on the frozen plateau is dumped into the ocean or an ice shelf on the west and east sides. This inland plateau has an average altitude of 2,800 metres, the main reason for the appearance of this type of glacier. The classification with respect to shape (Figure 178) also followed a pattern. About 54% of the basins present a simple morphology, with a single flow that transfers mass to a single tongue, which represents an area of 143,008.55 km^2; another 30% are from composite basins, glaciers that also have a simple morphology, but in their accumulation zone there may be other glaciers composing the same drainage basin. This classification refers to 141,857.35 km^2 of ice surface.

These authors conclude that in relation to the glaciers of the Antarctic Peninsula, 61% of the basins are discharge basins, 14% comprise valley glaciers, 7% correspond to mountain glaciers, 4% ice fields, 12% ice cap, 1% rock glaciers and 1% glaciers and snowfield. Regarding their shape, 54% are simple basins, 30% compound basins, 8% tributary compound basins, less than 1% are icebergs, glacial cirques, niches and craters, and 8% are uncertain or varied. The classification of the primary characteristics showed that 17% of the glaciers fluctuate, 30% have their calving, 12% calving and lobed, 6% calving and expansion, 5% calving and piedmont, 2% are lobed, 1% expanded, 1% piedmont, 2% confluent, 3% non-contributing coalescing, 3% landslide, 1% normal or various, and 17% feed an ice shelf. In longitudinal features, 50% are cascading, 38% regular uniform, 6% interrupted, 3% ice cascading, 2% protruding, and 1% uncertain or diverse. The fact that most of the glaciers on the Antarctic Peninsula are discharge glaciers shows the vulnerability of these ice masses to climate change. A possible change in its dynamic equilibrium, by melting or accelerating ice flow, for example, tends to increase its potential to drain ice mass from an uplift, inland plateau, ice field, or ice cap into the ocean or an ice shelf.

Trinity Peninsula Zone

To carry out the description of the glaciological region around Dundee Island we will take as a basis the work of Ferrigno *et al* (2006) *Coastal-Change and Glaciological Map of the Trinity Peninsula Area and South Shetland Islands, Antarctica*. According to these authors, the area of the Trinity Peninsula and the South Shetland Islands covers the northernmost part of the Antarctic Peninsula and the adjacent islands, and extends from 60° to 65° South latitude, and from 52° to 67° west longitude. On a map they show (Figure 179) that the northern part of the Antarctic Peninsula, including the coasts of Danco, Palmer and Nordenskjöld. Except for a few small patches of exposed rock, the entire region is covered by glacial ice and permanent snow. In the early 1970s, the most significant glaciological features on the eastern side of the Trinity Peninsula were the Prince Gustaf Ice Shelf, between the Trinity Peninsula and James Ross Island, and the northernmost part of the Larsen Ice Shelf, extending south from Cape Longing. However, a significant retreat occurred during the 1980s and 1990s, culminating in the breakup in 1995 of the Prince Gustaf Ice Shelf and most of the northern Larsen Ice Shelf (renamed Larsen A) (Vaughan & Lachlan-Cope, 1995). Thus, the Prince Gustaf Channel was made accessible to navigation for the first time in history, allowing a ship to transit the channel from north to south and proceed to circumnavigate James Ross Island in February 1997 (Crosbie & Splettstoesser, 1997). These ice shelves had been present since the first visits to the Antarctic Peninsula in the mid-19th century. In fact, oceanographic investigations have indicated that the northern Larsen Ice Shelf had likely been in place since the late Holocene epoch, or for the past 2,500 years (Domack *et al*, 2001). The rest of the eastern coast in the map area is characterised by ice walls, some small ice shelves, and numerous outlet glaciers.

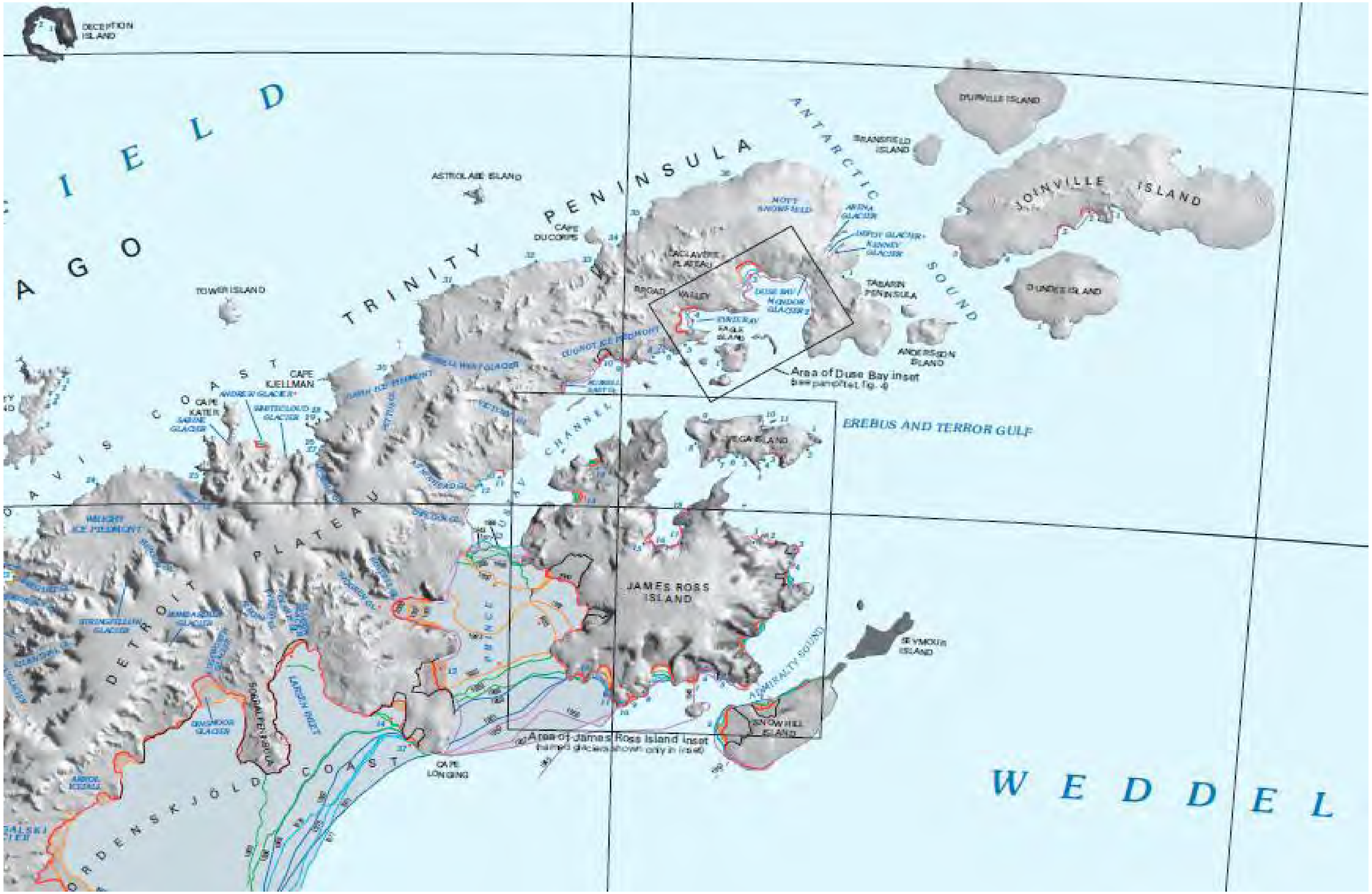


Figure 179: Map showing the dynamics of the northern Antarctic peninsula glaciers (Reproduced from Ferrigno, J. G., Cook, A. J., Foley, K. M., Williams Jr, R. S., Swithinbank, C., Fox, A. J., etc. & Sievers, J. (2006)

The coastline of the western side of the Antarctic Peninsula and adjacent islands appears to be composed mainly of inland ice walls interspersed with floating ice fronts of a few very small ice shelves and numerous small (by Antarctic standards) glaciers with and without names.

6.1.2.5 Soils, permafrost and ground ice

For this point we will take the characterisation made by Silva Busso, Fresina, Velasco & Rey (2009). These authors mention that more than 98% of the Antarctic peninsula is covered by ice and, furthermore, the potential of the discovered areas to obtain geocryological and paleoglaciological data about the environmental history of the permafrost zone and climate is relatively poor. The exposed sectors of ice are key places for the study of the conditions of permafrost formation and cryogenic processes. In the quarter accumulation areas, the main modeller of the relief is and has been the glacial process, followed by fluvial and cryogenic processes. The most widespread glaciogenic forms are characterised by containing underground ice, as well as almost all the deposits present. This determines the appearance of profuse cryogenic manifestations on the surface. Based on the stratigraphic correlation of the moraine deposits, a preliminary chronology was established for the Quaternary in the area. Thus, on Vega Island, four stages of formation of moraines with a core of buried glacial ice were distinguished, which correspond to the main stages of formation of syngenetic permafrost since the last glacial maximum of the Upper Pleistocene.

Geologically speaking, the northern section of the Antarctic Peninsula is composed of different geological units: the Paleozoic Trinity Formation and the Jurassic Monte Flora Formation (Camacho & Fabre, 1957). The first is formed by wacke with abundant layers and veins of quartz. This formation is observed along the coast in this sector of the Antarctic peninsula. To the east there are visible bodies of olivinic diabase and porphyrite intrusions. The Monte Flora formation is made up of sedimentary units (sandstone shales with fossil plants) and volcanic units (multicoloured tuffs and volcanic ash). On the eastern flank there are discontinuous outcrops in the James Ross archipelago (James Ross, Cerro Nevado, Vega and Marambio islands) that correspond to Cretaceous and Tertiary marine sediments and Neogene vulcanites (Nelson, 1966; Rinaldi *et al*. 1978). The first belonging to the James Ross Basin (Elliot, 1988), which constitutes a homocline sequence with a slight inclination to the southwest. These formations are generally very fossiliferous and the material is poorly consolidated. Vulcanites of Pliocene to Pleistocene age outcrop at different levels on James Ross and Vega islands, which are unconformably resting on Cretaceous sediments. These rocks from before the Quaternary period correspond to an epigenetic formation in the Antarctic permafrost zone that can be characterised as dry permafrost.

The quartary rocks in the permafrost zone correspond to the syngenetic formation or ice-rich permafrost. They occur in complex environments such as glacial, fluvioglacial, alluvial, lacustrine, wind and mass removal deposits that form the main features of the periglacial landscape in the exposed ice sectors. Generally speaking, the relief of glacial origin can be differentiated into different units: rocky summits and slopes, lateral and frontal moraines with a core of buried ice, bottom moraines with different types of subterranean ice, terraces and fluvioglacial plains, and the coastal sector with terraces and marine beaches.

Climate data from the Antarctic Peninsula show favorable conditions for the formation and conservation of permafrost, with an evident East-West cryogenic asymmetry. With

With an average maximum height of 2,200 metres above sea level, the axis of the peninsula forms an orographic barrier for the humid winds from the West, which makes it a clear climatological limit. In this way, two characteristic climatic regions are defined: an eastern region, influenced by the Weddell Sea with a markedly continental climate and average annual temperatures ranging from -5°C to -17°C, and a western region, influenced by the winds humid areas of the Bellingshausen Sea and with mean annual temperatures between –1°C and –6°C (Reynolds, 1981). The orographic barrier effect of the Antarctic Peninsula means that, for the same latitude, the average annual temperature difference reaches 8°C. According to a preliminary geocryological study, the -4.0°C isotherm is the limit, in the Antarctic peninsula, between two morphological types of permafrost: continuous and discontinuous.

The upper part of the permafrost presents an active, superficial, semi-permanently thawed soil mantle, subject to summer freeze-thaw pulsations. The development of the active layer and the formation of ice in the period of seasonal freezing are conditioned by climatic parameters and different types of soils related to surface water systems and suprapermafrost water. According to the monitoring of the seasonal freezing-thawing processes, the thickness of the active layer and the thermal regime of the permafrost surface soils are highly variable depending on the environmental conditions of each site.

The stable seasonal freezing of the ground begins at the end of February to the beginning of March, although it varies according to the meteorological conditions of the year. When the degree index, the relationship between days of positive temperatures and days of negative temperatures, exceeds 200°C, the total freezing of the active layer occurs. Total ice content is defined as the percentage of all visible ice types formed by gravitational water and partly by film and crystallisation water. Under seasonal freezing conditions, the formation of underground ice is established according to three factors: thermal regime during the freezing period, soil composition and initial moisture of clastic soils. At the base of the active layer of coarse material contained in the summer ground ice can be modified considerably by changes in soil moisture before the seasonal freeze.

In general, contact or massive cryostructures with cement or porous ice are observed. In the lower levels of the frozen layer of the fine fluvionival or cryoeolic deposits, there is a lenticular or laminar cryotexture with segregation or infiltration ice. In the upper part, massive and massive-porous cryotextures are observed, depending on the initial humidity.

The asymmetry of the climatic conditions of the Antarctic Peninsula predetermines the division of continuous and discontinuous permafrost depending on the temperature and distribution of frozen soils. For continuous permafrost there is a mean annual soil temperature below –3.5°C at a depth of zero annual amplitude between 20-25 metres; for discontinuous permafrost, a temperature between –1.5°C and -3.5°C. The thickness of the permafrost can be found by multiplying the theoretical geothermal gradient value of the site (1°C/33m) by the temperature at the zero annual amplitude depth. According to Kudriavtsev (1978), the difference between the mean annual air temperature and the temperature in depth of the ground with zero annual amplitude is around 2.5°C/3.0°C in arid and semi-arid places (northeast coast and adjacent islands) and around 1.0°C/1.5°C in the humid zone of the western sector. In accordance with this, with average annual air temperatures according to records available from the National Meteorological Service. Marambio would have the base of the permafrost at a depth of about 190-220 m, Esperanza at about 100-120 m, Matienzo at about 40-260 m, South Orkneys at about 50-70 m and Carlini at about 20-30 m, although this number may vary depending on local surface conditions.

6.1.2.6 Bathymetry

Figure 180 shows the general bathymetry of the extreme north of the Antarctic Peninsula. It can be seen that the region around the Antarctic peninsula has a depth that does not exceed 1000 metres. After that the depth increases significantly. The northern end of the peninsula has a greater depth in the space between the South Shetland Islands and the peninsula itself. This situation can be observed between the islands of the extreme north (Dundee, Joinville, etc.) and the Tabarín peninsula (Figure 180).

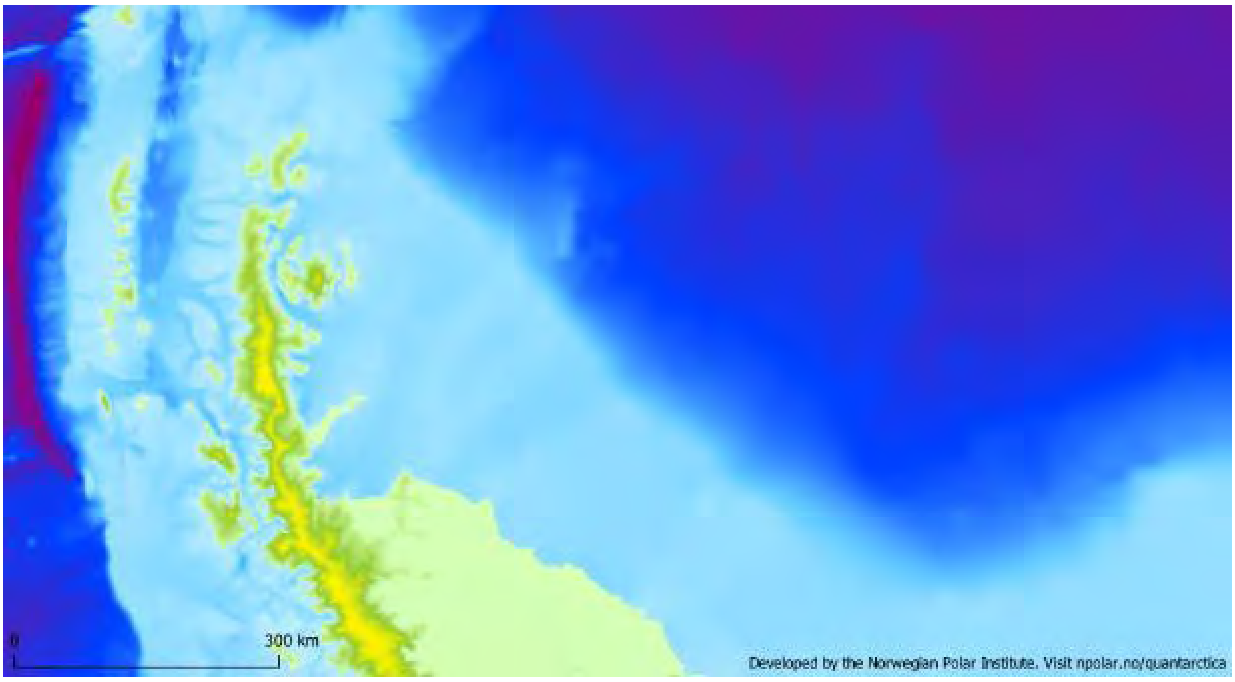


Figure 180: General bathymetry of the northern Antarctic peninsula (Taken from Qantarcica 3.2)

6.1.2.7 Hydrology

For this point we will take the characterisation made by Silva Busso, Fresina, Velasco & Rey (2009). These authors mention that the northern region of the Antarctic Peninsula between approximately 60° and 64° latitude forms a hydrological and hydrogeological environment, where the presence of uncovered areas of ice favors the development of fluvial networks and lake systems. In addition, the region is located in a zone of continuous and discontinuous permafrost, so the water systems have different characteristics from each other. In this region, several study areas have been chosen that characterise a hydrological behaviour that can be typified in particular environments and determine regional variables.

In the Antarctic Continent, the uncovered areas of ice are found mainly in two regions: the Dry Valleys in Victoria Land and the northeast of the Antarctic Peninsula (Guglielmin & Dramis, 1999), the latter being the sector where Petrel Base is located. The surface and subsurface water systems that develop in these regions present, as in the Arctic, particular characteristics of contribution, substrate and regime that clearly differentiate them from those that exist in more temperate regions. In the north of the Antarctic Peninsula, between 60° and 64°, a gradual decrease in temperature averages is observed from the western region of the Peninsula to the eastern region of Reynolds (1981). From the point

In view of global change and its possible consequences on hydrogeology, it is important to mention that the evolution of the climate and especially of the temperature values in recent years has been evaluated by Jones, (1995) verifying an increase in the maximum mean thermometric values on the Antarctic continent in the middle and high latitudes. Svarka *et al*., (1998) carried out a comparative study of the thermometric evolution and its relationship with the warming of the region, determining appreciable differences between the eastern and western regions of the Antarctic Peninsula.

The climate of the north-eastern region of the Antarctic Peninsula is subpolar, semi-arid, and the presence of surface water is mainly due to melting ice. Given the particular climatic characteristics of subpolar environments, it is convenient to consider the proposal of Tolstijin and Kiriujin (1978), which consists of a fundamentally hydroclimatic classification of hydrogeology. The cryological aspects and processes of the region are of importance in the superficial and subterranean hydrological behaviour. In addition, permafrost, because it remains below freezing, contains frozen water in the pores of the rock, making it difficult for groundwater to move. This constitutes a characteristic horizon that behaves like an impermeable level (Silva Busso *et al*., 2000).

The northern region of the Antarctic Peninsula has climatological characteristics that are correlated with the surface and underground hydrological behaviour of the region. From the aspects dealt with in this chapter it can be deduced that climatic differentiation is not the determining factor by itself and that various factors of hydrogeological environments have a particular dynamic. It should be considered that the basins throughout the region are normally mixed hydric environments, that is, they have glacial discharges and a variable importance of precipitation (liquid or snowy) and permafrost ablation. This makes the hydrological study and evaluation methodologies and their relationship with climatic variables more complex.

Due to climatic control over the summer hydrological and hydrogeological system, the conditions to the east and west of the northern region of the Antarctic Peninsula are clearly distinguishable and constitute a first regional criterion to address the analysis. The eastern region of the Antarctic Peninsula, with lower temperatures and scarce rainfall, has characteristics of a subpolar semi-arid zone, with mainly polythermal to cold glaciers (Paterson, 1994). In environments whose main contribution is glacial ablation (Isla Vega) the hydrological dynamics can be characterised by an almost exclusive superficial feeding of the glaciers and whose discharges, in general of several m^3/s, have a high correlation with the average air temperature.

Underground systems are very limited to areas close to riverbeds and bodies of water with little areal development; It is likely that the development of this depends on the angle of insolation and orientation (Silva Busso *et al*., 2003 and Silva Busso, 2003). In areas with no glacial input (Isla Marambio/Marambio) and low rainfall, the control of permafrost ablation over the local hydrological system is evident. The discharge, although of small magnitude, presents a high correlation with the soil temperature. The aquifers in this region develop suprapermafrost and are free, although they are very limited by the characteristics of the permafrost, the chemical composition is variable depending on the sediments that contain them (especially in clastic rock). The possibilities of development of Infrapermafrost aquifers can be considered from the geophysical information, brackish water aquifers are expected at depths greater than 200 metres. The western region of the Antarctic Peninsula, with higher temperatures and more abundant rainfall than the previous one, still has characteristics of a sub-humid subpolar zone. The glaciers are of the temperate type, with superficial discharge and, in particular, an important subsurface infiltration.

6.1.2.8 Limnology

We develop this point from the work *Limnology in the northern area of the Antarctic Peninsula* by Haydée Pizarro and Irina Izaguirre (2009). These authors state that glaciers and precipitation, mainly in the form of snow, provide the water for most Antarctic lakes. Those bodies of water that do not freeze to the bottom during winter, but rather a column of liquid water permanently exists below the ice sheet, are called lakes. In contrast, those bodies of water that freeze completely at the beginning of the winter season are called Antarctic lagoons (Goldman, 1970; Kennedy, 1993).

The lakes located in the vicinity of Argentine bases are mostly shallow bodies of water, whose maximum depths rarely exceed six metres. An exception are some lakes of volcanic origin on Deception Island, which have greater depths. Because they are in the Maritime Antarctic zone, many of the bodies of water located near the Argentinian bases receive marine influence, and their magnitude varies according to their proximity to the sea. This influence is due to the direct action of sea spray, and the activities of fauna (birds and mammals). The vast majority of these lakes thaw at the beginning of the southern summer and remain ice-free until the end of March.

Several studies have shown that bodies of water differ according to their degree of trophism, basically determined by the degree of influence of marine fauna (birds and mammals) to which they are exposed. Lakes that are far from the activity areas of the animals are usually oligotrophic, that is, their waters are more transparent, they have a low concentration of nutrients (nitrogen and phosphorous) and the phytoplankton biomass is relatively less, although the attached algae in the background they are usually very abundant. On the contrary, those bodies of water that are close to nesting areas or that are frequented by animals tend to eutrophicate due to the ingress of nutrients, either directly or through surface runoff. These lakes are more turbid and have a greater development of phytoplanktonic algae, while benthic algae may be limited by the availability of light that reaches them.

The food chains of Antarctic lakes are relatively simple. They are composed of two or three planktonic trophic levels and lack fish. Metazooplankton, generally represented by crustaceans and rotifers, are at the top of the food chain (Hansson and Tranvik 1996). For this reason, the components of the microbial food web are of great importance in the lacustrine plankton of Antarctic lakes (Butler 1999).

The lotic bodies of water (commonly referred to as “streams”) found on the Antarctic Peninsula are of different types depending on their origin. Streams of glacial origin are fed by meltwater from glaciers, while effluents from lakes or lagoons are those that discharge water from these systems into another body of water or into the sea. You can also see areas where flowing water comes from banks of ice or snow. These last bodies of water generally do not have their own channel, while the streams of glacial origin and the effluents of lagoons usually present a well-formed basin, the product of years of erosion and modelling of the landscape.

In the Antarctic Peninsula, different studies were carried out in streams of various origins and general characteristics. Its morphometric and physicochemical aspects and its role functional in the general landscape of each region. In all cases, the epilithon was the biological community that received attention in their study due to the magnitude of its development. In these water bodies, the autotrophic fraction of the epilithon represents the main producing component.

6.1.2.9 Biological situation of the North of the Peninsula

At this point, the biological components present in the northern region of the Antarctic Peninsula will be described in a general way. Instead of opting for a detailed and detailed description of the species, populations and communities present, we are going to mention the general conservation values of the area. The first axis through which we will begin to describe the area of the Petrel Base is that of the Environmental Domains (Morgan *et al*, 2007). It can be seen in Figure 181 that various environmental domains are found in the north of the Antarctic Peninsula. In this area we find Domain A (Northern Geology of the Antarctic Peninsula), Domain B (Geology of the northern mid-latitudes of the Antarctic Peninsula), Domain E (Antarctic Peninsula, Alexander Island and the main ice fields and glaciers from other islands), Domain F (Larsen Ice Shelf) and Domain G (Islands off the coast of the Antarctic Peninsula) (Figure 181).

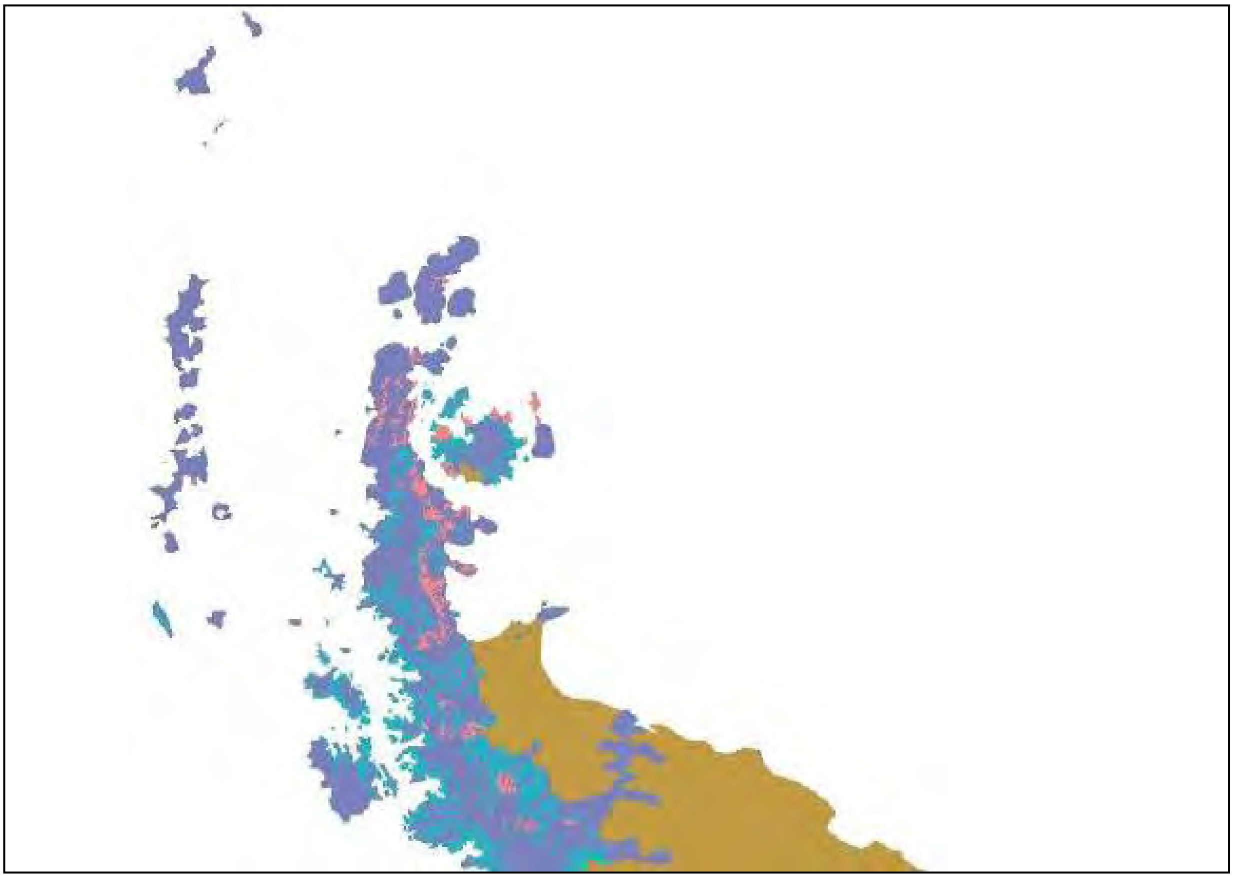


Figure 181: View of the environmental domains present in the north of the Antarctic Peninsula. Taken from Morgan et al (2007)

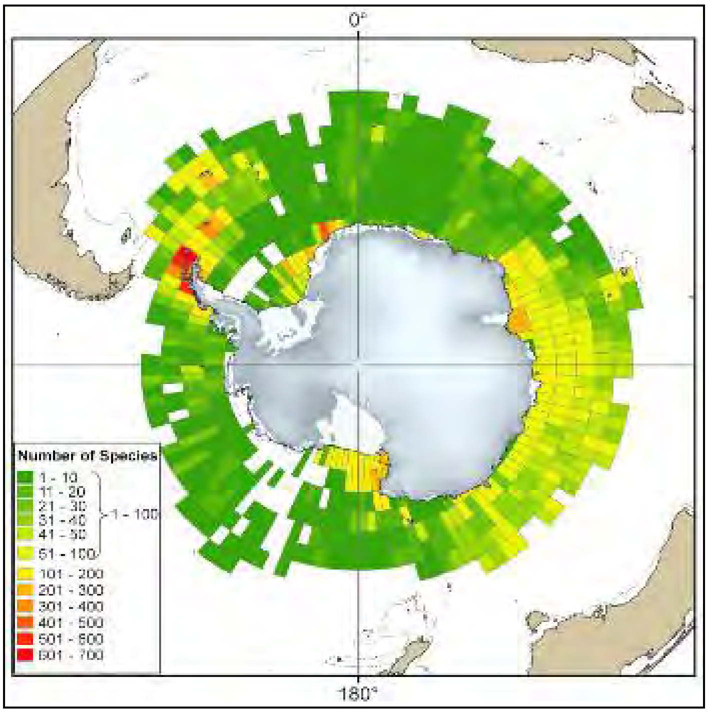
The presence of numerous domains in a limited sector is almost unique and is not found in other sectors of Antarctica. This shows that this heterogeneity of environments is associated with the high diversity of species and therefore their significant conservation value. This situation can be verified by the high number of protected areas in the area (although this is partly due to the proximity to the numerous bases present). In total, these domains include 33 ASPAs and 6 ASMAs, which gives this sector an important degree protection of their terrestrial environments. Figure xxx shows the distribution of the ASPAs in the extreme north of the Antarctic Peninsula.

Taking into account the variables used by Morgan *et al* (2007) to establish the environmental domains, we can establish that the extreme north of the Antarctic Peninsula is characterised by having the highest annual average air temperature, the narrowest annual temperature range is an area of strong winds, it is the region that receives the highest average solar radiation, has the largest percentage of ice-free surface, among other features. Dundee Island, therefore located off the northern end of the peninsula, has the extreme values that characterise this region, therefore.

Figure 182: View of the location of ASPAs (ASPAs) in the North of the Antarctic Peninsula. (Taken from SCAR ADD)

If we look at the area from the point of view of the richness of marine species, we can see that the northern region of the Antarctic Peninsula is of significant importance, both for its conservation and for research, since it is the region with the highest values of species richness. Figure XXX shows the total number of all marine species from the SCAR-MarBIN distribution records found in each grid of 3° latitude by 3° longitude where it was determined that the Petrel Base area is precisely in the sector with the greatest wealth of species (Figure 183).

Figure 183: Distribution of the number of marine species in the



Antarctic convergence area. Taken from Griffiths, H.J. (2010).

The situation mentioned in the previous paragraph establishes that the Petrel Base region is important from the point of view of terrestrial ecosystems as well as from marine ecosystems. It is for this reason that in addition to the protection measures established through the creation of ASPAs, the aim is also to protect this region through the creation of marine protected areas (MPAs). MPAs are a widely recognised area management strategy for improving ecosystem health. They can reduce the cumulative impact of stressors on ocean ecosystems, support ecological spatial connectivity, protect key habitats and biodiversity, maintain ecosystem function, and provide resilience in the face of environmental variability and uncertainty (Figure 184).

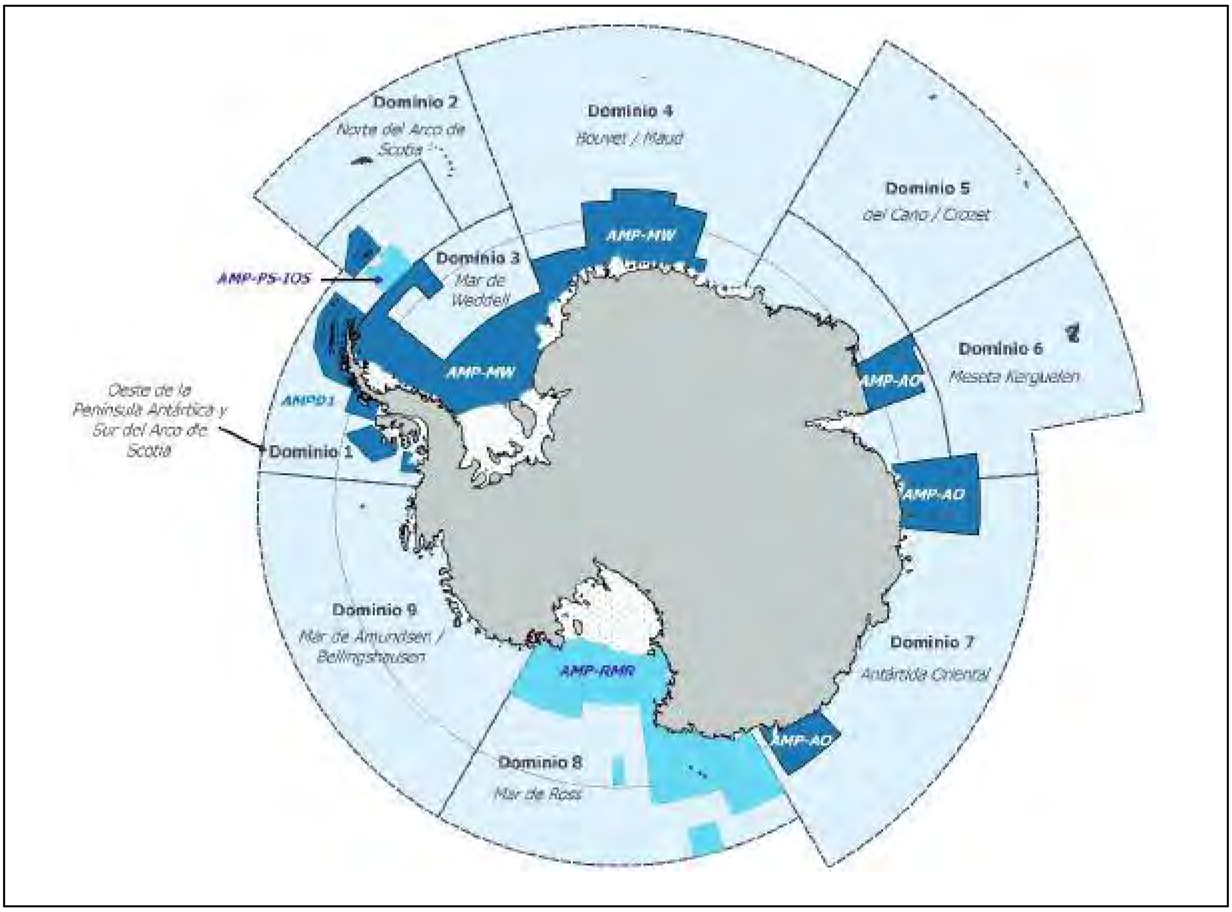


Figure 184: Planning domains and MPAs in the Convention Area. In turquoise are the MPAs adopted by CCAMLR (southern shelf of the South Orkney Islands, MPA-PS-IOS; and Ross Sea region, MPA-RMR). In dark blue are the proposed MPAs that have not yet reached consensus (Weddell Sea AMP-MW; East Antarctica AMP-AO; Domain 1 AMPD1). Taken from Capurro, A. P. (2019). Marine protected areas in Antarctica: analysis of criteria for their designation, with emphasis on the Antarctic Peninsula region.

According to Capurro (2021) the Antarctic Peninsula region is one of the most productive areas in the Southern Ocean, with 70% of the circumpolar distribution of krill and numerous biodiversity hotspots (or areas of exceptional biological value), including a abundance of whales, seals and seabirds that feed mainly on krill. However, the high productivity of the area also results in the largest amount of catches from the krill fishery. Over the past 20 years, these catches have become increasingly concentrated in very small coastal regions during sensitive breeding and feeding periods for krill predators. Although the krill fishing industry is regulated by CCAMLR, it is precisely this concentration of fish catches in space and time that can put undue pressure on krill predators and regulations that are not sufficiently precautionary can be negatively affecting these species.

In the early 2000s, CCAMLR was advancing work on MPAs by conducting circumpolar bioregionalisation studies (identifying priority areas for conservation) and subdivision of the Convention area into nine Planning Domains (or planning domains) for AMP management purposes. In 2011, given the continued activity of Argentina and Chile in the region, they jointly organised an international technical workshop on MPAs for Domain 1 (Western Antarctic Peninsula and South Scotia Arc) which was quickly approved by the Commission and would constitute the cornerstone of the binational AMP proposal. From that moment on, Argentina and Chile (the proponents) undertook to lead the development of the Domain 1 MPA (AMPD1, Figure 184).

If collectively adopted by CCAMLR, the proposed DMPA will protect the sensitive biodiversity of the region now and in the future. Its approximately 650,000 square kilometres would safeguard a wide range of marine habitats and ecosystem processes that support areas of high productivity; krill hatcheries; spawning grounds and recruitment of fish (especially of those species overfished in the past); hot spots for penguins, seals and whales during breeding and feeding; and unique habitats such as seamounts - seamounts that are home to diverse species and support sustainable fisheries. Through a combination of management strategies with and without fishing (Krill Fishing Zone and General Protection Zone, respectively), the D1MPA enables the rational use of marine resources and the establishment of scientific reference zones to increase our understanding of combined effects of fishing activities in a region plagued by environmental uncertainties (Capurro, 2021).

Analysing the Petrel Base region from other conservation tools we can also observe its importance. First we are going to mention what is related to the Areas of Importance for Bird Conservation (AICAs). The identification of Antarctic Key Bird Areas has its roots in the efforts of the Scientific Committee on Antarctic Research (SCAR) Sub-Committee on Bird Biology, which sought to collect data on the distribution and abundance of Antarctic bird species already in the 1980s. The selection criteria applicable to Antarctica were agreed in Tokyo, Japan, in the year 2000, based on the AICAs designation criteria established by BirdLife that are used in the rest of the world. Then, SCAR and BirdLife International organised workshops, through which a first list of AICAs was formulated.

The submitted list of AICAs identifies 204 breeding grounds that meet the global criteria for defining AICAs in Antarctica (Figure 185). The site reports included in the full report (Harris et al., 2015) describe the species that inhabit each AICAs, as well as the main characteristics of the environment, other forms of wildlife in the place and possible conservation problems, and refer to additional data and descriptions. The site reports include maps showing the boundaries of the AICAs in their local context, including important physical features, nearby research stations, and nearby protected areas, as well as references to relevant literature. Figure XXX shows the density of this type of area in the north of the Antarctic Peninsula, which once again shows the high biological value of this region.

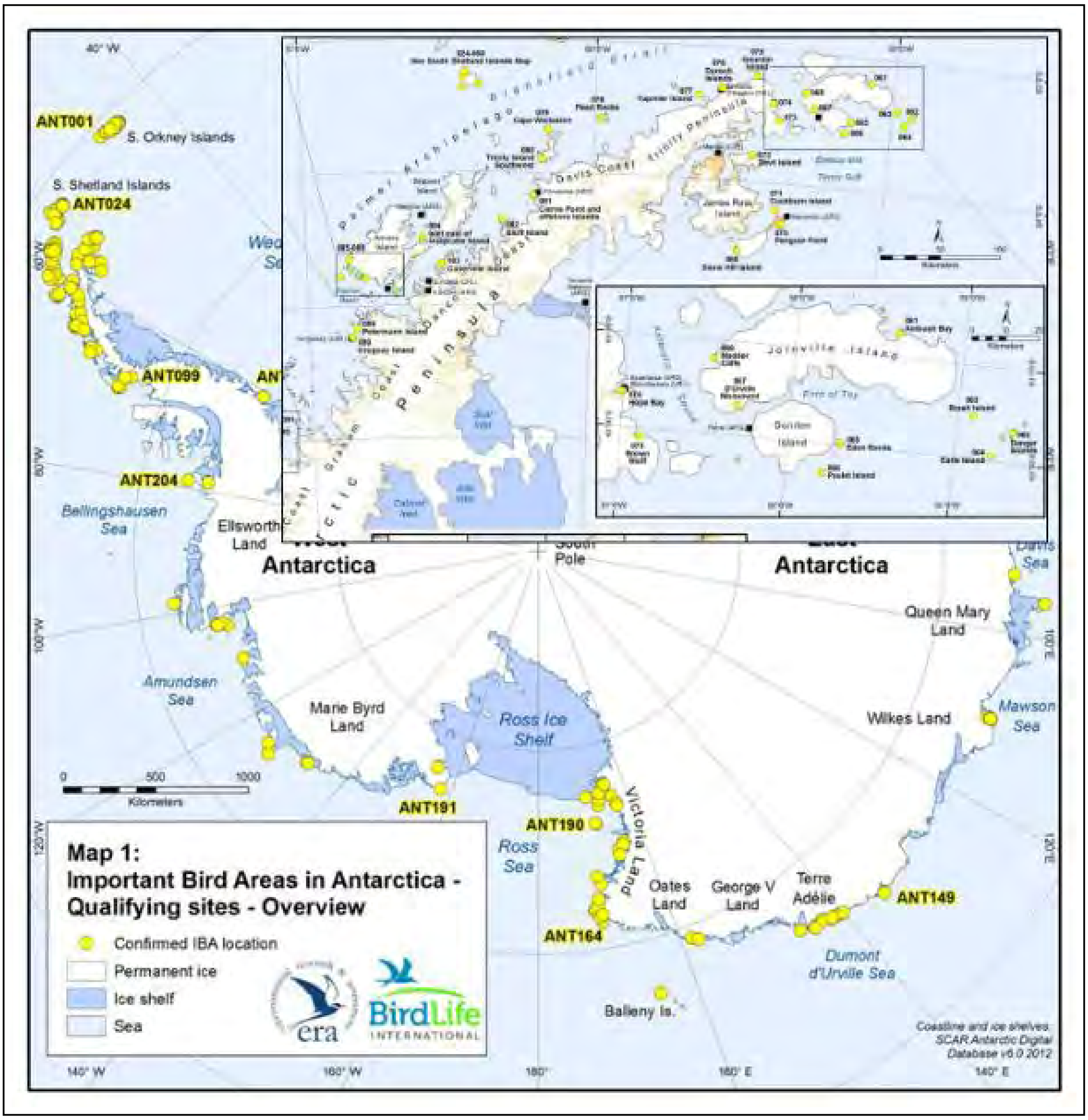


Figure 185: Map with the location of Important Bird Areas in Antarctica (taken from Harris et al, 2015).

Finally, we are going to mention that the region that we have been analysing (north of the Antarctic peninsula) also has a high value in relation to the conservation of marine mammals. Important Marine Mammal Areas (IMMAs) (Corrigan *et al*, 2014) are defined as discrete portions of habitat, important for marine mammal species, that have the potential to be delimited and managed for their conservation. IMMAs consist of areas that may merit protection and/or site-based monitoring. Important in the context of IMMA classification refers to any discernible value, which extends to marine mammals within IMMAs, in improving the conservation status of those species or populations. It can be seen in Figure 186 that the area of the Antarctic Peninsula is associated with an IMMA.

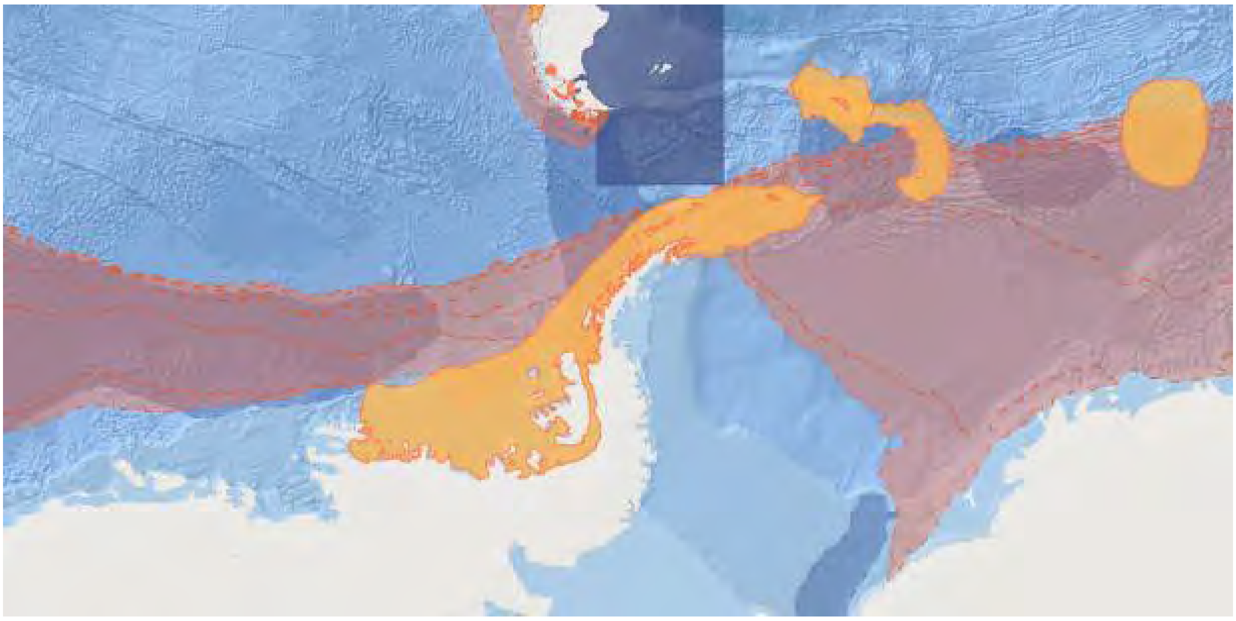


Figure 186: Map showing the location of the IMMA contiguous to the Antarctic Peninsula.

If we do a more detailed regional analysis, it can be established from the work of Capurro (2019) that the northern part of the peninsula is a highly significant region for birds and mammals. Figures 187, 188 and 189 can be seen in the intensity of use in different situations. In all of them, the region at the end of the peninsula (where the Petrel Base is located) has high values.

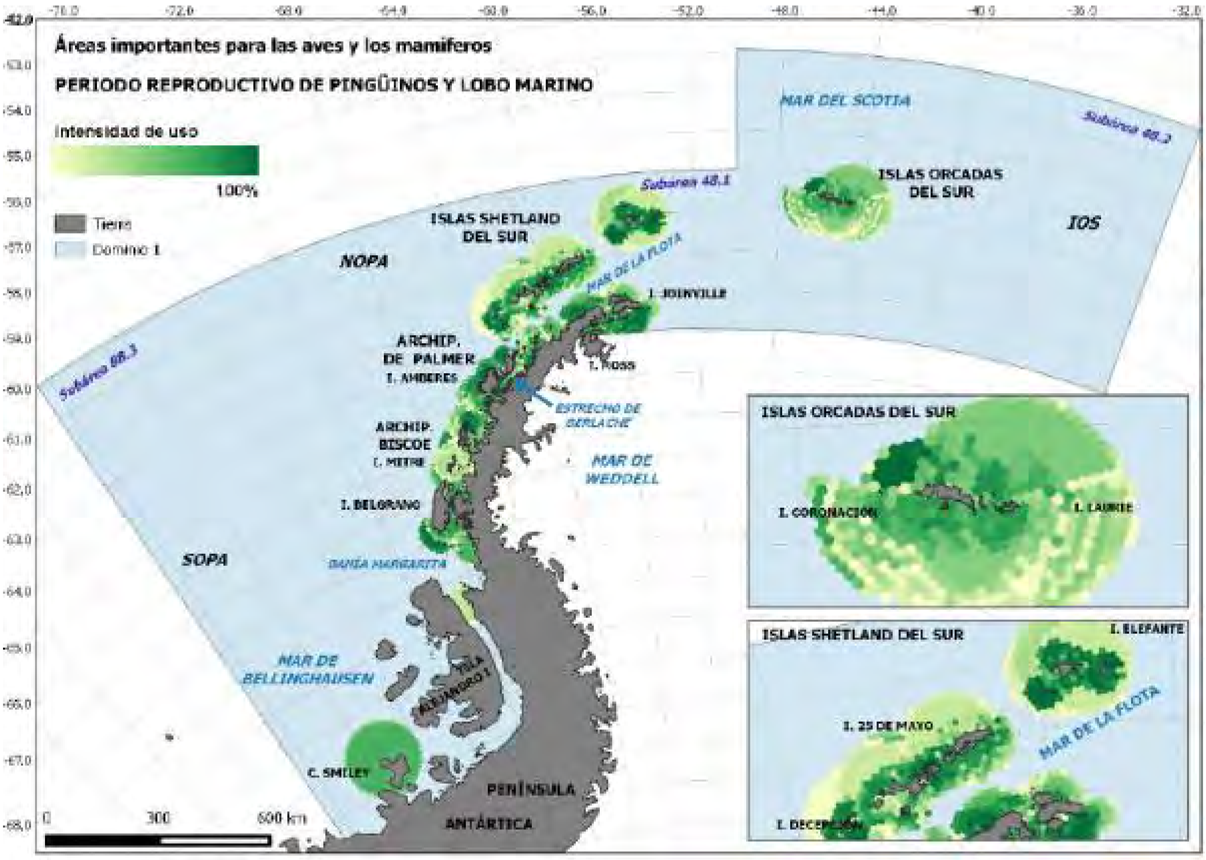


Figure 187: Spatial distribution and reproductive foraging intensity for predators (Reproduced from Capurro, 2019).

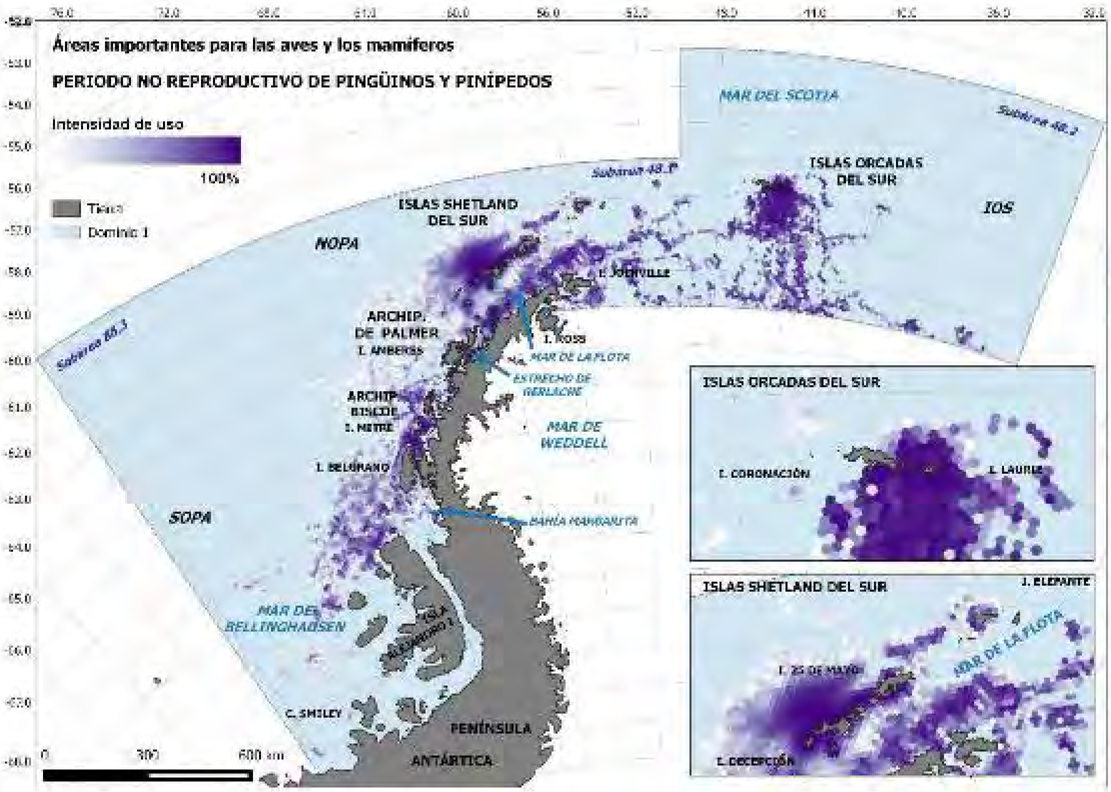


Figure 188: Spatial distribution and intensity of non-reproductive foraging for penguins and pinnipeds (taken from Capurro, 2019).

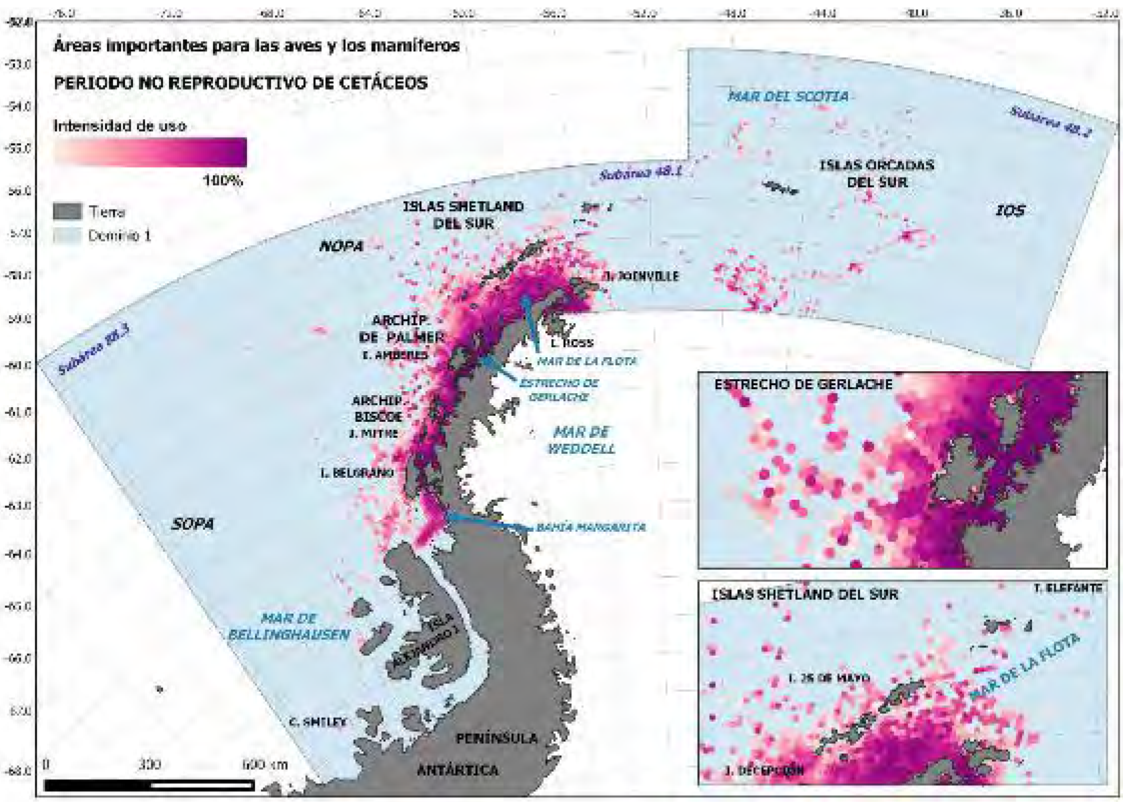


Figure 189: Spatial distribution and intensity of non-reproductive foraging of cetaceans (taken from Capurro, 2019).

6.1.3 Local Analysis

At this point we are going to look at environmental issues at the local level, focusing on Dundee Island and especially Cape Welchness. Given that the Petrel Base has been closed for many years, it is clear that there is a lack of long-term environmental data records, for this reason it is important to take into account that what is going to be described is the state of the natural components of the place to based on the information available, taking into account that the modernisation of the base will allow the resumption of research in the extreme north of the Antarctic peninsula.

6.1.3.1 Local Weather Conditions

This section is based on data observed at the Base Petrel weather station, which has been operated by personnel from the Argentine Navy and the data has been processed by the National Meteorological Service (SMN).[18]. It does not have data between November 1971 and August 1972 or from December 1972. Between January 1973 and January 1974 there is no precipitation information on record. While the work plan is 3 hrs, the digitalised information corresponds to 00 UTC, 06 UTC, 12 UTC and 18 UTC. On the other hand, the available notebooks correspond to the years 1973 to 1976.

Extreme temperatures

The annual mean maximum temperature wave is characterised by positive values in the period between November and February, presenting the maximum in the month of December (2.7°C). May and June present the lowest average values, of the order of -9°C. Considering the variability from year to year, years have been observed with mean monthly temperatures of -12.7°C (May 1967 and June 1969). On the other hand, the warmest month that has been observed was February 1974, which was characterised by a maximum temperature of 4°C (Table 34 – Figure 190).

Regarding the average monthly minimum temperature, it is negative throughout the year. The months of December and January are those with the highest values, -2.2°C and

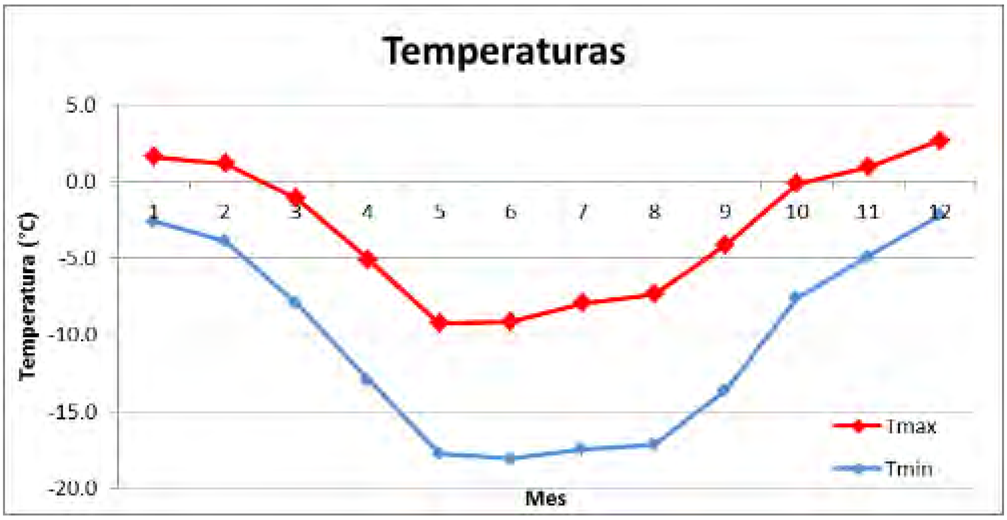


Figure 190: Wave annual temperature maximum and minimum Petrel.

-2.7°C respectively. Between May and August it is below -17°C, with June being the coldest month with -18.1°C. The lowest value recorded was -23.2°C corresponding to the month of July 1976, while the highest value was -0.7ºC in December 1974 (Table 34 – Figure 190).

[18] The meteorological data was analysed by the SMN staff.

Table 34: Maximum and minimum monthly temperature (°C). Petrel 1967-1976.

Variable		Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic	Anual
Temperatura máxima	Media	1.6	1.2	-1.1	-5.1	-9.2	-9.1	-7.9	-7.3	-4.1	-0.2	0.9	2.7	-3.1
	Máximo	3.0	4.0	1.3	-2.1	-3.4	-2.3	-3.7	-4.3	-1.1	2.1	2.5	3.4	-2.3
	Año	1970	1974	1967	1968	1976	1971	1970	1967	1970	1975/76	1970	1969	1970
	Mínimo	0.6	-1.3	-3.6	-8.3	-12.7	-12.7	-14.9	-12.6	-9.5	-4.6	-1.2	1.4	-4.4
	Año	1969	1969	1968/69	1974	1967	1969	1976	1975	1973	1969	1967	1975	1975
Temperatura mínima	Media	-2.6	-3.9	-7.9	-12.9	-17.7	-18.1	-17.4	-17.2	-13.6	-7.6	-4.9	-2.2	-10.5
	Máxima	-1.3	-1.5	-3.2	-10.1	-10.9	-13.8	-12.2	-14.0	-9.6	-4.3	-1.8	-0.7	-9.7
	Año	1975	1974	1974	1968	1976	1971	1970	1967	1970	1976	1976	1974	1970
	Mínima	-3.9	-6.5	-13.1	-15.5	-22.0	-22.6	-23.2	-20.6	-18.6	-13.0	-9.5	-3.7	-11.9
	Año	1973	1969	1969	1969	1967	1969	1976	1975	1973	1969	1967	1967	1969

Regarding the daily extremes, Table 35 shows the values for each of the months. The absolute maximum temperature was 12.1°C, recorded on February 6, 1975, while the minimum was recorded on August 23, 1974 and was -31.5°C.

Table 35: Daily extreme temperatures (°C). Petrel 1967-1976

	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic	Anual
Mínima absoluta	-8.1	-14.9	-16.8	-25.4	-27.6	-29.6	-30.8	-31.5	-29.8	-24	-17.4	-11.2	-31.5
Máxima absoluta	9.8	12.1	11.4	6.6	8.5	5.6	8.0	6.9	6.4	10.3	8.1	10.1	12.1

The average daily thermal amplitude (difference between maximum and minimum temperature) is minimum in January (4.2°C) and reaches the highest values in the winter period. Between April and October it presents values greater than 7°C, and between July and September it exceeds 9°C. These ranges are amplified daily, and it is more noticeable in the months of May to September. Exceptionally, the daily thermal amplitude can exceed 25°C (6 cases). The maximum recorded was 30.5°C and corresponded to July 20, 1968 when the maximum temperature was -0.3°C and the minimum was -30.8°C (Table 36).

Table 36: Maximum daily thermal amplitude (°C). Petrel 1967-1976

Variable		Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic	Anual
Amplitud térmica	Media	4.2	5.1	6.9	7.8	8.5	8.9	9.5	9.6	9.4	7.3	5.8	4.9	7.3
	Máxima diaria	11.5	15.0	17.9	22.1	29.5	26.0	30.5	27.0	24.3	20.8	16.9	13.4	30.5

Table 37 presents the average, maximum and minimum frequency of days with maximum and minimum temperatures above 0°C. In the case of the maximum temperature, the average frequency is maximum in December with 27 days, followed by January with 22.1. The minimum frequencies correspond to the period from May to August with less than 8 days. In the case of the minimum temperature, the frequency decreases significantly with an average frequency of 2 to 3 days in the months of November to March. Between April and September the value is less than one, indicating that only in some years there have been days with minimums above 0ºC.

Table 37: Frequency of days with maximum/minimum temperatures greater than 0°C

		Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic	Anual
Temperatura máxima	Promedio	22.1	17.0	13.6	9.0	4.1	6.4	7.6	6.3	10.8	18.2	19.6	27.0	158.5
	Máxima	28	27	21	14	10	12	14	11	19	26	23	30	189
	Año	1970	1974	1973	1975/1976	1976	1971	1970	1967	1970	1975	1976	1974	1970
	Mínima	16	10	8	3	0	1	1	1	4	7	15	23	123
	Año	1973	1969	1969	1974	1973	1973	1976	1975	1971	1969	1974	1975	1969
Temperatura mínima	Promedio	2.5	3.3	2.7	0.7	0.4	0.3	0.0	0.0	0.2	1.4	2.2	2.7	16.7
	Máxima	7	9	8	2	2	1	0	0	1	5	8	6	31
	Año	1975	1974	1973	1973	1974	1970/71/74	-	-	1968/74	1976	1976	1974	1974
	Mínima	0	0	0	0	0	0	0	0	0	0	0	0	4
	Año	-	-	-	-	-	-	-	-	-	-	-	-	1969

Figure 191 shows the annual maximum (left) and minimum (right) temperature wave for the period 1967-1976 in the three seasons. It should be considered that in Marambio the averages cover 1971-1976. Comparing the annual temperature wave in Petrel with those corresponding to Marambio and Esperanza, it is observed that the average monthly values present the same behaviour in the three seasons, with Marambio being the one with the lowest temperatures and Esperanza the highest. The maximum temperature between Esperanza and Petrel presents differences in general of less than 1°C, with May and June being the months with the greatest difference (1.6°C and 1.8°C, respectively). In the case of the minima, the period with the greatest differences extends between May and August, with differences greater than 2.5° in May and June. In the case of Marambio, the differences are marked throughout the year, being the greatest in the months of April and September, when in Marambio there is a more abrupt change in temperatures.

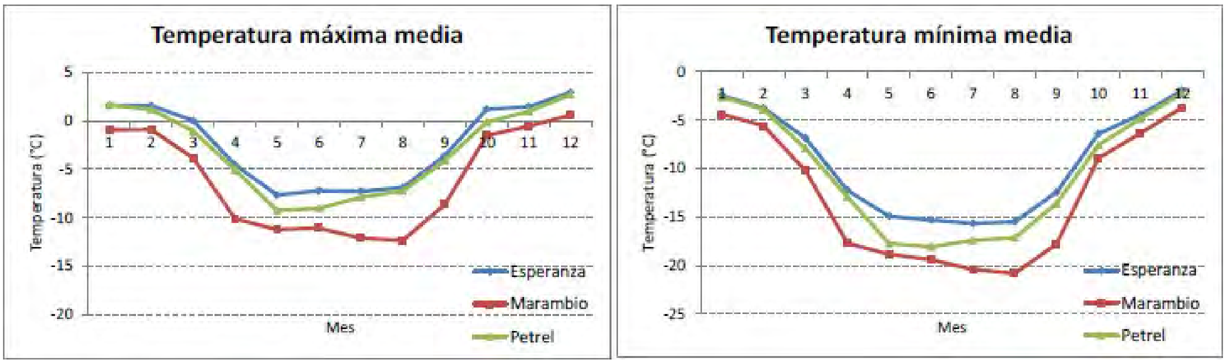


Figure 191: Annual maximum (left) and minimum (right) temperature wave in Petrel, Marambio and Esperanza

Comparing the average monthly values of the period 1967-1976 with those of the decade 2001-2010, an increase in temperatures is observed in both Esperanza and Marambio (Figure 192), especially in the months of January and February, April, May, August and September. In October, on the contrary, a slight cooling was observed.

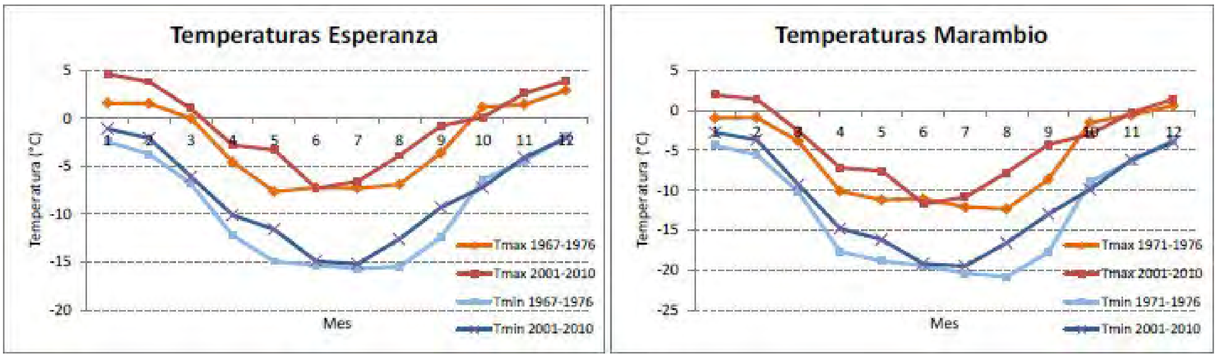


Figure 192: Comparison of the annual wave in Esperanza (left) and Marambio (right) between the periods 1967-1976 and 2001-2010

Analyzing the annual series of extreme temperatures in Marambio from 1971 to 2010, a positive trend of 0.4°C/10 years in the minimum temperature and 0.6°C/10 years in the maximum temperature is found. In Esperanza the values are 0.3°C/10 years and 0.5°C/10 years, respectively. These results have a significance level greater than 95% except for the minimum temperature in Esperanza, which is 90%.

Monthly, although the trends are positive, except in October, in general they are not significant (Table 38). The trends in the month of January are highlighted, which for both seasons and parameters are positive and significant at 95%, and the trends in the maximum temperature in August that present the same behaviour. Then only in Marambio in February there is a significant positive trend in the maximum temperature.

Table 38: monthly trends 1971-2010 (°/10 years).

	Esperanza		Marambio	
	Tmax	Tmin	Tmax	Tmin
Enero	0.8	0.3	0.8	0.4
Febrero	0.6	0.3	0.9	0.7
Marzo	0.4	0.3	0.5	0.4
Abril	0.5	0.6	0.6	0.5
Mayo	1.0	0.8	1.0	0.6
Junio	0.1	0.2	0.1	0.2
Julio	0.4	0.1	0.2	0.0
Agosto	0.9	0.6	1.0	0.8
Septiembre	0.7	0.6	0.9	0.8
Octubre	-0.2	-0.3	-0.2	0.0
Noviembre	0.4	-0.1	0.3	0.3
Diciembre	0.3	-0.1	0.3	0.0

The correlation between the daily values of temperatures in the three stations is greater than 0.9. In the most recent period, a high correlation is maintained between the temperatures in Marambio and Esperanza, therefore, it is highly probable that an increase in temperatures has also been observed in Petrel, particularly in January in both parameters and in August only in the maximum temperature. The decrease in temperatures could be feasible in October, but a small magnitude, which does not present a significant trend. The increase in temperatures in the Antarctic Peninsula has been pointed out in works such as that of William L. Chapman & John E. Walsh (2007) and Vaughan *et al*. (2001).

Regarding the frequency of days with temperatures higher than zero, a similar behaviour is observed between what was observed in Petrel and Esperanza (Figure 193), therefore it is expected that in Petrel in the most recent period there will be an increase in the number of days with temperatures above zero, as was recorded in Esperanza (Figure 193). A marked increase in the frequency of days with a minimum temperature greater than zero is observed during the months of January and February. In maximum temperature, the differences are marked from January to May and there are no changes or they are minimal in June, July and October to December.

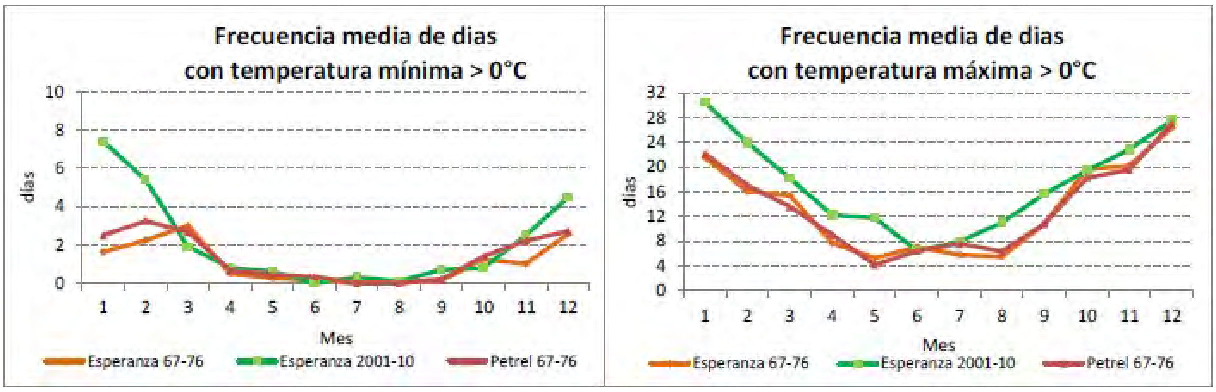


Figure 193: Average frequency of days with minimum (left) and maximum (right) temperatures above 0°C, in Esperanza for the periods 1967-1976 and 2001-2010 and Petrel 1967-1976.

Precipitation

Precipitation in Antarctica is a complex parameter to measure as it is greatly affected by strong winds, which makes it difficult to discriminate between what precipitates and what is deposited by the wind. However, as a guide, Figure 194 shows the average behaviour throughout the year of the precipitation at Petrel.

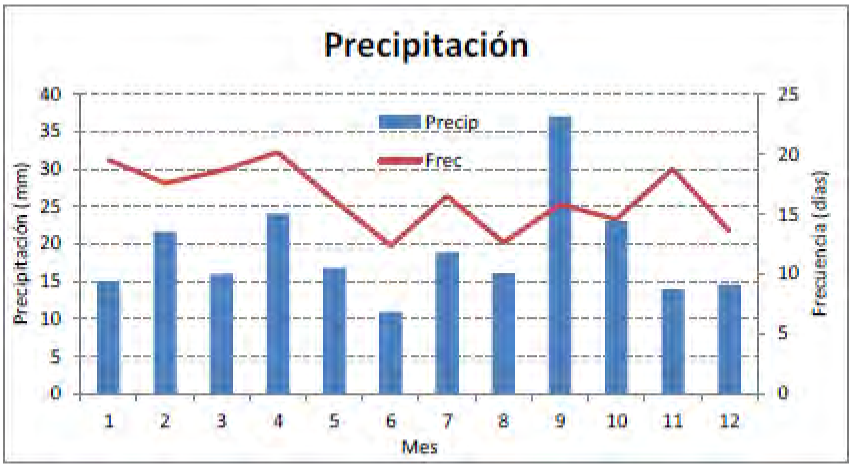


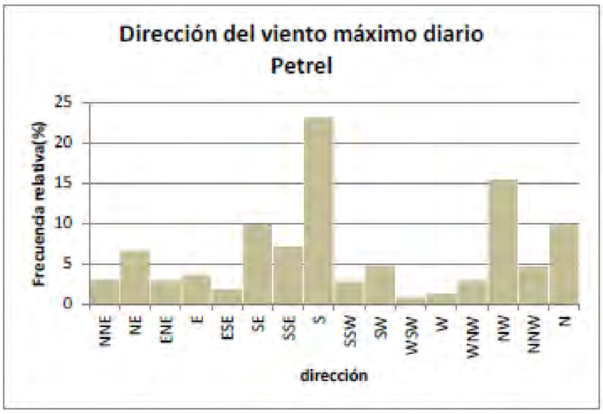
Figure 194: Mean monthly precipitation (mm) (blue bars) and frequency of days with precipitation (red line). Petrel 1967-1976.

Wind

The most frequent direction of the maximum daily wind is from the south during the months of January to July, November and December (Table 39). During the August-October quarter, the NW direction is more frequent. Annually the frequency of winds from the S is greater than 25%, following NW, N and SE (Figure 195 left). Regarding the intensity of the maximum daily wind, the highest frequencies correspond to intensities between 40 and 60 km/h (Figure 195 right). Speeds above 100 km/h were recorded in 2.5% of cases. The extreme cases recorded were: wind from the N sector at 176 km/h on 26 June 1969, N at 167 km/h on 30 September 1968 and N at 157 km/h on 5 March 1969.

Table: Monthly relative frequency of the maximum wind direction (%).

Dirección	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic
NNE	1.2	1.8	4.0	1.5	2.5	3.3	2.2	6.1	4.4	1.9	2.6	3.7
NE	6.1	6.7	6.1	5.2	6.9	6.3	6.6	5.0	7.1	6.8	7.1	9.2
ENE	4.0	5.3	0.0	3.0	2.5	1.5	3.3	4.0	3.1	1.6	4.1	2.8
E	8.1	4.0	4.7	3.4	4.0	4.4	1.8	2.2	2.0	2.3	2.6	4.6
ESE	1.6	0.9	0.7	1.9	1.8	3.3	3.7	4.0	0.7	0.3	1.1	1.8
SE	4.0	11.1	9.7	8.6	14.9	14.8	18.3	13.7	8.5	5.8	3.0	4.1
SSE	4.0	2.7	5.1	14.9	12.0	14.8	6.6	8.3	3.7	2.6	4.5	5.5
S	33.6	25.3	28.2	25.4	27.5	19.6	18.3	14.7	15.3	19.5	22.8	31.3
SSW	8.5	2.7	2.2	3.0	3.3	0.7	0.7	1.1	2.7	1.9	3.7	3.7
SW	10.1	8.9	5.1	3.0	4.3	1.5	2.9	4.0	2.7	2.6	6.7	6.5
WSW	1.6	1.8	1.1	0.7	0.7	0.4	0.0	0.0	0.0	1.3	0.7	1.4
W	0.0	1.8	0.4	0.4	1.8	1.1	0.4	2.2	1.0	4.5	0.4	0.5
WNW	0.4	1.8	1.4	1.5	2.5	3.0	3.3	3.2	3.1	6.2	6.7	0.0
NW	5.7	14.2	14.1	14.6	7.2	17.0	16.5	16.9	23.8	24.4	16.4	11.1
NNW	0.8	3.6	7.6	4.5	2.5	3.7	4.0	1.8	8.5	8.4	4.9	3.2
N	10.1	7.6	9.7	8.6	5.4	4.4	11.4	12.9	13.3	9.7	12.7	10.6



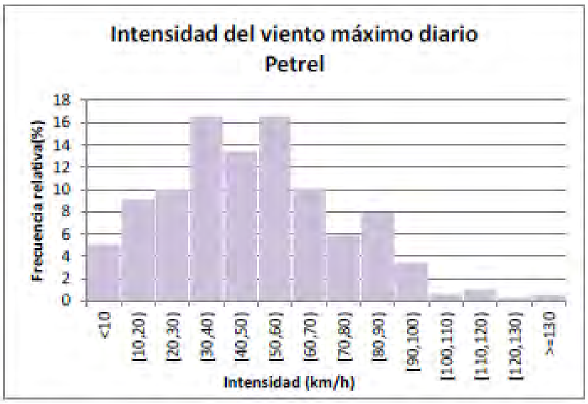
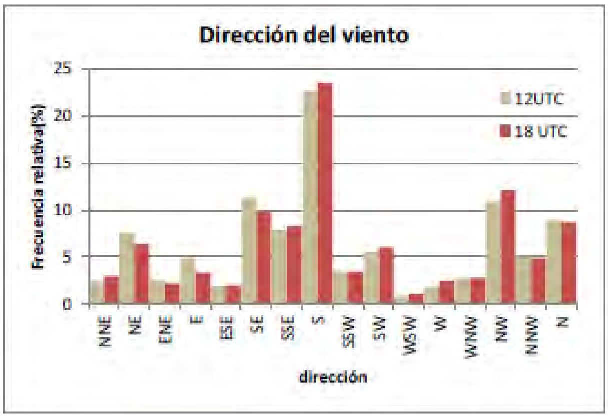


Figure 195: Annual relative frequency of the direction (left) and intensity (right) of the maximum daily wind

Annually, the wind at 12 UTC and 18 UTC presents a similar behaviour both in intensity and direction (Figure 7). The calms represent around 20% of the days and they are more frequent between the months of May and November. January and February are the months in which, in both time slots, the frequency of calm is minimal.

Without considering the calms, in more than 30% of the cases the wind speed is less than 10 km/h, in the range of 10 km/h to 40 km/h the frequency of occurrence varies between 10 and 15% (Figure 196 -right). Speeds greater than 70 km/h occur in less than 5% of cases. Throughout the year, September and October show the highest average speeds (28-30 km/h), while November and January show the lowest (18-20 km/h). A relative maximum occurs in the month of April. The direction of greatest occurrence between December and June is from the South. In July the frequency of winds from the SE increases, which is more frequent at 12 UTC, followed by S. At 18 UTC the frequency of occurrence of winds from the S and SE sectors is similar. In August the frequency of winds from the NW begins to increase and between September and November the wind presents a higher frequency in the S and NW directions (Tables 40 and 41).



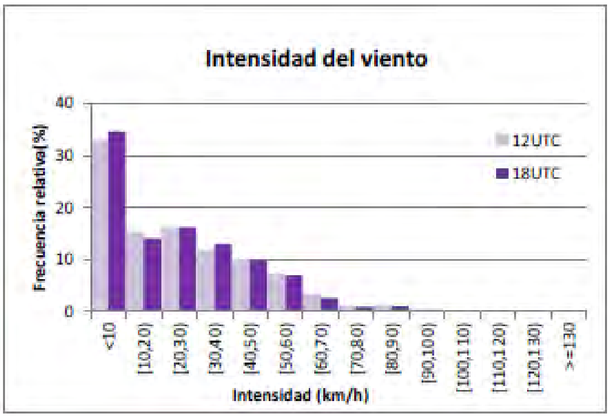


Figure 196: Annual relative frequency of the direction (left) and intensity (right) of the wind at 12 UTC and 18 UTC Table 40: Monthly relative frequency of the wind direction at 12 UTC (%).

Dirección	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic
NNE	0.9	2.6	4.2	1.7	1.8	0.0	2.4	3.2	4.0	1.6	3.2	2.9
NE	7.1	7.1	7.1	7.3	4.6	7.1	7.3	8.6	10.0	7.5	7.8	8.0
ENE	2.8	1.5	2.5	1.3	1.4	2.0	3.4	2.7	2.0	1.6	5.0	4.0
E	8.5	5.6	6.3	4.7	6.5	8.6	1.5	4.1	2.4	4.0	3.2	3.4
ESE	0.9	0.5	0.8	3.9	2.8	4.0	2.9	3.2	0.4	1.6	0.9	0.6
SE	6.6	8.7	11.8	15.0	15.7	16.7	22.0	14.9	7.6	5.2	5.5	6.9
SSE	5.2	8.7	6.7	13.7	12.9	11.6	9.3	6.8	6.0	4.8	4.6	4.0
S	34.4	26.5	24.4	22.3	30.0	19.7	18.0	17.2	15.5	16.3	20.1	31.6
SSW	6.1	4.1	3.4	3.4	4.1	0.5	2.0	2.3	2.8	4.4	3.2	5.7
SW	12.7	9.7	7.6	4.7	6.0	2.5	4.4	2.7	3.6	2.0	6.8	4.6
WSW	1.4	1.5	0.8	0.4	0.5	0.0	0.0	0.0	0.8	1.2	0.5	2.3
W	1.9	4.1	1.3	0.4	1.8	1.0	2.0	0.9	1.2	4.0	2.3	0.6
WNW	0.5	1.0	2.1	1.7	1.8	2.0	4.4	4.1	3.6	6.0	3.7	1.1
NW	2.4	10.7	8.4	9.4	2.8	10.6	9.8	10.4	15.9	19.4	17.8	10.9
NNW	1.4	3.1	8.0	3.0	3.2	3.5	3.4	5.9	10.8	8.7	4.1	1.7
N	7.1	4.6	4.6	6.9	4.1	10.1	7.3	13.1	13.5	11.9	11.4	11.5

Table: Monthly relative frequency of the wind direction 18 UTC (%).

Dirección	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic
NNE	1.4	3.2	3.8	2.3	2.9	2.4	1.8	3.7	2.6	3.1	4.7	4.0
NE	7.4	7.5	3.4	6.5	3.9	8.5	8.8	6.9	8.1	5.0	4.7	6.3
ENE	3.7	2.7	1.7	2.8	2.9	3.3	2.3	2.3	2.1	0.4	0.0	2.3
E	5.1	3.2	2.6	2.3	6.8	6.2	3.2	4.2	0.9	0.8	1.9	4.5
ESE	2.3	2.7	0.9	3.7	1.9	3.8	1.8	3.2	0.0	0.4	1.9	1.1
SE	9.3	7.0	9.4	13.8	12.6	10.0	18.0	15.3	8.5	4.6	4.2	6.3
SSE	3.7	4.3	9.4	12.0	13.1	16.1	11.5	8.8	6.8	4.6	4.2	5.1
S	30.1	30.1	28.6	24.0	28.6	22.3	17.5	17.1	16.6	20.7	21.7	28.4
SSW	8.3	3.2	3.4	3.7	2.4	2.8	1.8	0.5	4.3	3.8	3.8	2.8
SW	10.2	9.1	5.1	6.0	5.8	0.9	4.6	2.3	3.8	5.0	8.5	13.1
WSW	1.9	1.6	0.9	0.5	1.0	0.9	0.5	0.0	0.9	1.1	1.4	2.8
W	1.9	3.2	1.3	2.8	1.5	1.4	2.3	3.7	1.7	5.4	1.9	1.7
WNW	0.5	2.7	2.1	1.8	1.5	1.4	3.2	3.7	4.7	5.0	5.2	0.0
NW	1.4	10.2	12.8	11.1	5.3	10.0	9.7	15.7	16.6	20.7	17.0	11.9
NNW	2.8	4.8	5.6	2.3	3.4	2.8	6.0	4.2	8.1	10.0	4.2	1.7
N	10.2	4.3	9.0	4.6	6.3	7.1	6.9	8.3	14.5	9.6	14.6	8.0

Comparing the behaviour of the wind in this region is complex since the wind is greatly affected by the orography. It is noted that gusts of more than 200 km/h have been recorded at the stations closest to Petrel, which indicates that records of this magnitude could also be possible in Petrel, depsite the fact that in the measurement period there are no records of this magnitude. With regard to direction, there are no factors that indicate that there could be a change in this parameter.

Cloud base height

The average monthly frequency of days with cloud base height (plafond) less than 100 m for each of the hours analysed is generally between 1 and 3 days (Figure 197-left). The lowest frequencies occur at 06 UTC, which throughout the year remain below 2 days. The average frequency at 12 UTC and 18 UTC shows a similar behaviour, with two maximums, one in February-March and the other in August. Between October and January the average frequency is maintained for all hours below 2 days.

The maximum frequencies observed at the monthly level correspond to the month of February at 12 UTC with 13 days and at 18 UTC with 11 days, marking the interannual variability during this month (Figure 197-right). Between March and May and November-December the maximums do not exceed 6 days while in the winter quarter there are maximum frequencies of more than 8 days at 18 UTC.

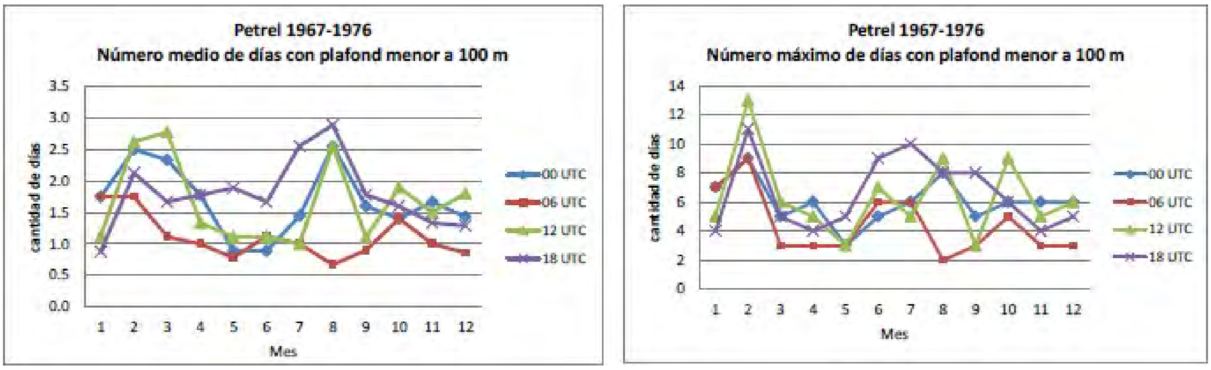


Figure 197: Mean (left) and maximum (right) number of days with ceiling less than 100 m for 00 UTC, 6 UTC, 12 UTC and 18 UTC

Visibility less than 500 m

The average number of days with visibility reduced to less than 500 m varies throughout the year, staying mostly in the range of 1 to 2 days (Figure 198-left). The highest frequencies correspond to the cold half and in the winter quarter there is a difference between the hours, the reduction in visibility being more frequent at 00 UTC. The maximum monthly frequency corresponds to the month of July at 00 UTC with 11 days, so in general they are in the range of 3 to 6 days (Figure 198-right).

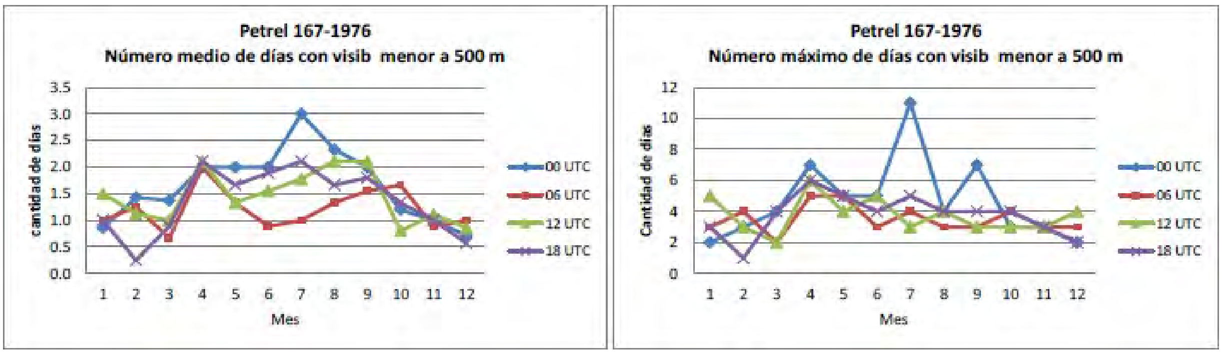


Figure 198: Mean (left) and maximum (right) number of days with visibility less than 500 m for 00 UTC, 6 UTC, 12 UTC and 18 UTC

Blizzard

The average monthly frequency of blizzards increases from January until it reaches its maximum in the months of August and September (more than 6 days), then it drops markedly until it reaches its minimum in December-January (around 1 day) (Figure 199-left). The behaviour is the same at the different times, varying the values reached that are higher at the times of 12 UTC and 18 UTC and lower at 6 UTC. The maximum monthly frequencies are between 10 and 11 days, registered between May and September. (Figure 199-der). Between November and February there have been no months with more than 6 days with a blizzard.

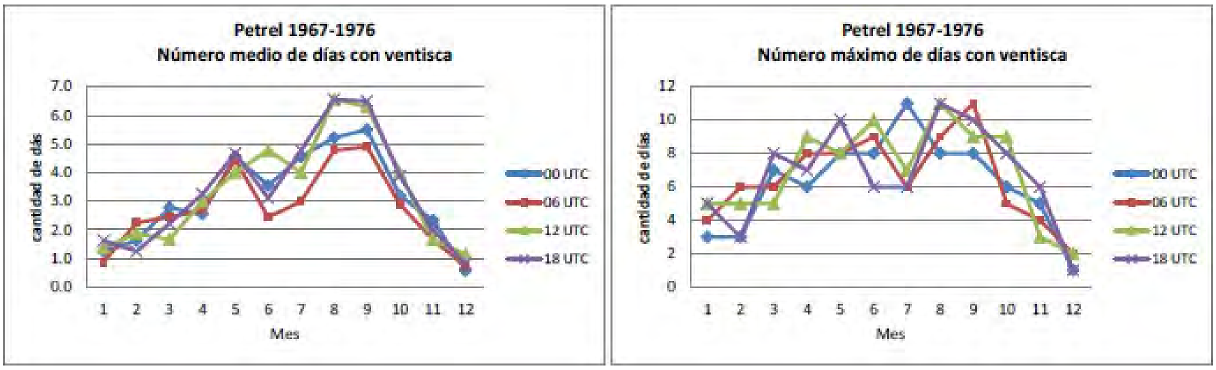


Figure 199: Mean (left) and maximum (right) number of days with blizzard for 00 UTC, 6 UTC, 12 UTC and 18 UTC

6.1.3.2 Local geology[19]

Dundee Island is located at the NE tip of the Antarctic Peninsula, where it forms part of the Joinville Island group (Figure 200). Dundee Island is circular in shape, with a maximum extension of 27 km in an E-W direction. There is very little exposed rock and the island rises to c. 624 m in a soft shield of snow and ice that dominates the island. The coastline is made up of rocky unbroken ice cliffs and a prominent low-lying triangular promontory (Welchness) at the western end. Currently its area of 450 km^2 is almost completely covered by glaciers that form ice ravines that fall precipitously into the sea. On the island, one of the few ice-free areas is Cape Welchness, which is located in the western part of the island. This cape consists of a triangular area covering about 2.5 km^2. Most of it has a flat surface with a difference in level of a few metres, especially on its two outer edges that border the sea and are eroded by small rills. The eastern part limits with the extensive ice cover of the island, from which it is separated by the crest of the lateral moraine of the glacier called "Rosamaría". The maximum extent of the ice-free flat sector is 1,950 m in a NE-SW direction, and 1,400 m in a NW-SE direction. The environmental conditions, geographical location, local characteristics of the relief and meteorology indicate that Cape Welchness is an appropriate place for the construction of airstrips, usable by aircraft of different sizes.

[19] This point is complemented by the geological descriptions presented in the item "*4.6.6.1 4.6.6.1-Geological and mechanical properties of the terrain (initial studies)*" and presents the information collected by the Argentine Antarctic Institute in numerous Antarctic campaigns in the region.

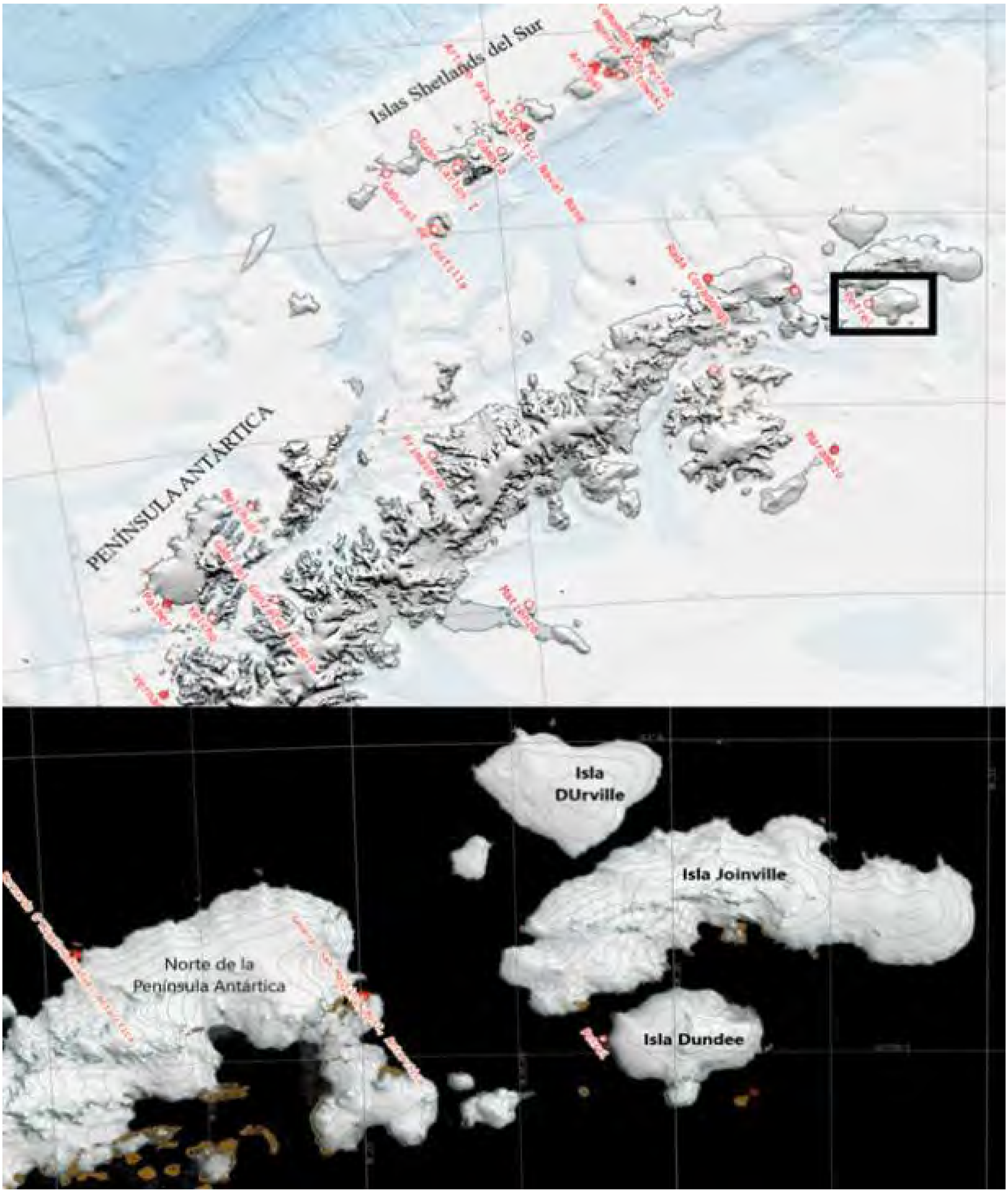


Figure 200: Geographic location of the Argentine Petrel Base (Dundee Island, Joinville Archipelago). Modified from Antarctic Digital Database (ADD).

The area is located at the NE tip of the Antarctic Peninsula, where there are large glaciers and the history of relief formation during different stages of the Quaternary glaciation is documented, together with the development of permafrost in ice-covered coastal areas, which contributed to modeling the particular environmental conditions in this sector of the island.

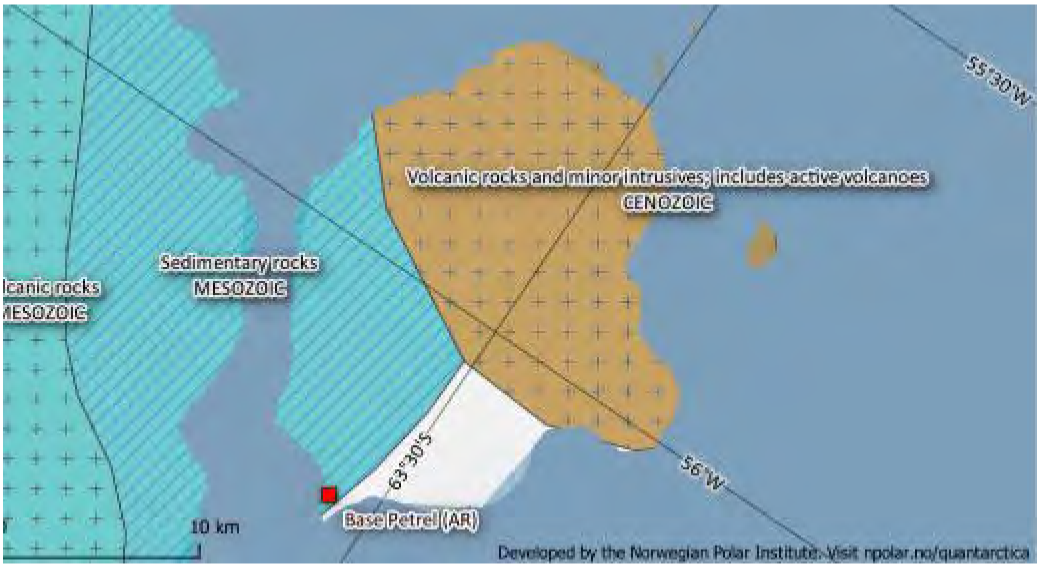
Cape Welchness consists of a gently undulating outer platform, triangular in shape and low in height above sea level (between 1-7 metres above sea level, which includes a marine terrace ascended up to 15-16 masl with a much smaller surface and equally triangular and flat. The lower shelf presents irregularities of a few metres of unevenness, especially in its

Figure 201: Dendritic cover of the outer plain.

external borders that run down to the sea and are eroded by temporary streams. The outer plain has an average elevation of 4 m above sea level, is gently undulating, and has an area of approximately 1,500,000 m^2, with a maximum length of 1,900 m in the E-W direction (in the direction of the observer's line of sight). The detrital cover is mainly made up of fluvio-glacial sediments (in the centre of Figure 201 a broken and laminated block can be seen due to repeated freezing and thawing). In the SE sector of the upper terrace, well-bedded sedimentary rocks from the Lower Cretaceous era are exposed, tilting 10-12° to the SE (Figure 202).

Figure 202: Late Cretaceous sedimentary rocks exposed on the upper terrace.

Geologically, this sector of Dundee Island is composed of two units of Triassic and Lower Cretaceous sedimentary rocks. During low tide periods, fine-grained marine sediments are exposed along the coastal zone, belonging to the Triassic era Trinity Peninsula Group. The Lower Cretaceous sedimentary package is part of the filling of the Larsen basin (del Valle *et al*. 1997), consisting of fine-grained, well-consolidated, marine clastic sediments exposed in the ESE part of Cape Welchness, where they crop out near the eastern limit of the lateral moraine. Complex glacial and fluvioglacial deposits, deposited from the Late Pleistocene to the present, complete the stratigraphic succession.



In general, three geomorphological units with their own character can be distinguished: 1) lower fluvioglacial plain, 2) terrace of the bottom moraine, and 3) ridge of the lateral moraine of the Rosamaría Glacier. This glacier is in clear retreat and is part of the extensive ice field that covers the island. The ridges of the lateral moraine are located on the W edge of the Rosamaria Glacier, while the bottom moraine is located in the centre of Cape Welchness, forming a flat terrace, where the main buildings and the large hangar of the Petrel Base are located. Lithologically, the morenic deposits are diamictitic bodies composed of clasts formed mostly by local Cretaceous sedimentary material together with large erratic blocks. Its granulometric composition ranges from coarse gravel to sand and silt. The lateral moraines have buried ice cores, remnants of ancient glaciers, and a thin (1.40-2.50 m) active layer of clastic material cemented by ice during seasonal freezing. The bottom moraine sector corresponds to the ice-rich permafrost zone with different types of subterranean ice, formed as cement or infiltration.

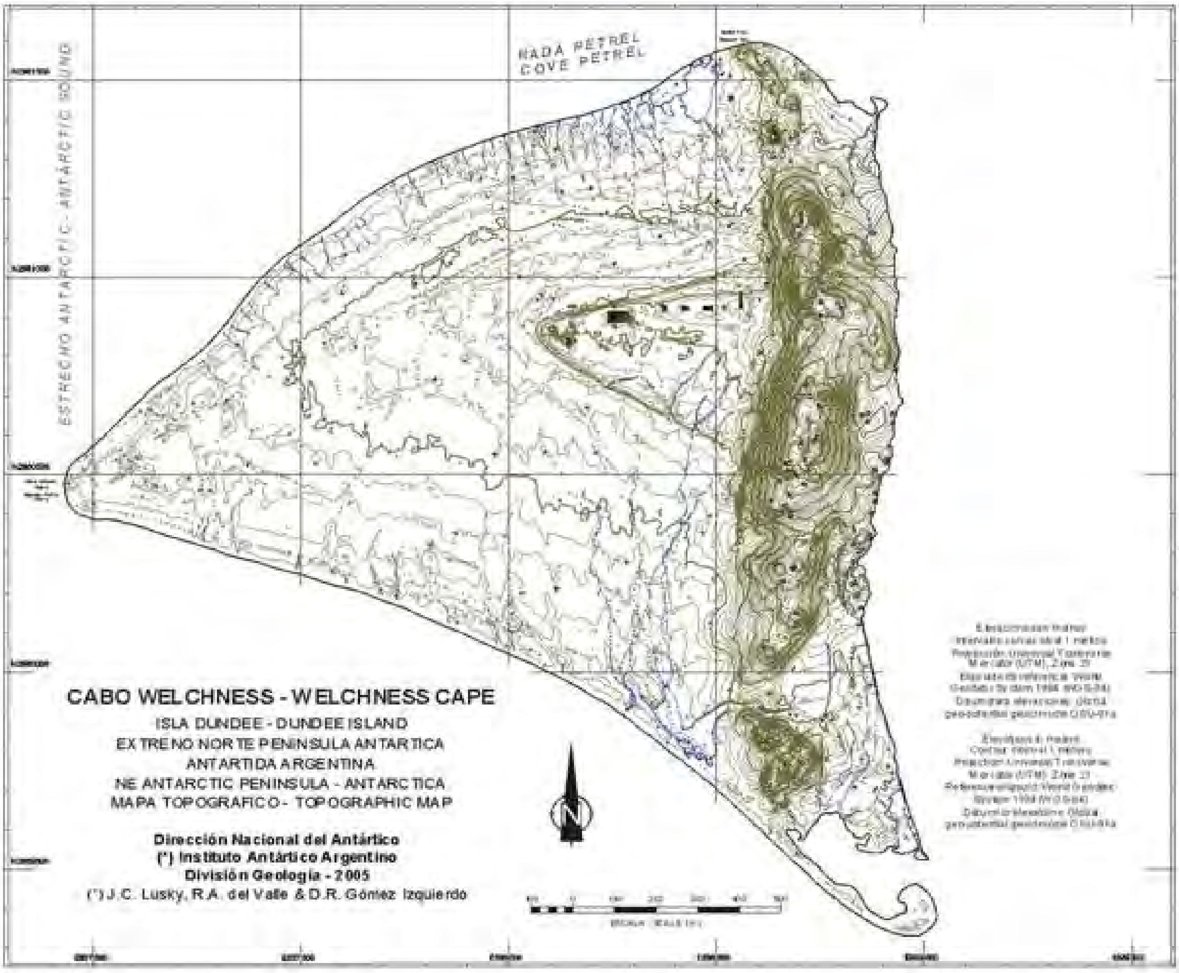


Figure 203: Distribution of rills at Cape Welchness

The gently undulating lower plain has an area of approximately 1,500,000 m^2, with a maximum length of about 2,500 m in the SSW-NNE direction. It rises between about 2-8 m

Figure 204: Record of outcrops with bivalves.

above sea level and is basically made up of medium and fine grained gravel with sand and a low silt content. Permafrost is characterised by its low subterranean ice content and the thickness of the surface layer that freezes and thaws seasonally (active layer) reaches between 1.5-1.7 m. On the marine terrace up to 15-16 metres above sea level (upper shelf) sedimentary rocks from the Lower Cretaceous outcrop that contain marine fossils, for example, moulds of large bivalve shells (Figure 204).

The triangular plain is bounded on one side by a high ridge of glacial sediments ("moraines"), approximately N S in development, parallel to the local edge of the Dundee Island ice field, and is bounded by the sea (Antarctic Strait and Petrel Roadstead) on its other two sides (Figure 205).

Figure 205: The image on the left shows the moraines that limit the plain and the image on the right shows the location of the Antarctic Strait.

Moraines have an ice core and a glacial gravel cover, where the stony materials are cemented by ice. Thermokarstic collapses are common at the foot of the moraines and allow us to observe that the massive ice core lies below the gravel cover. Ice-cemented sediments are capable of flowing downhill and slide slowly due to the slope of the terrain and the static or dynamic load to which they are subjected. The photo shows a destabilised 3x3 m concrete plate. The ability of ice to flow is mainly due to its property of melting and sliding when subjected to pressure. The slopes of the terrain favour this flow (Figure 206).

Figure 206: Images of the moraines where the ice core can be seen, and especially in the photo on the right, the thermocratic subsidence.

A few metres below sea level, the rocky substratum ("bedrock") of the lower terrace is exposed at low tide, forming a flat, terraced platform, which extends up to about 200 m from the shoreline adjacent to Punta Bajos (Figure 207). At low tides, in the area of the sea adjacent to Punta Bajos, a flat terrace of marine abrasion is exposed at a depth of about 2 m below sea level. The marine terrace is cut into compact and erosion-prone sedimentary rocks, which are well stratified in thin banks (0.2-0.8 m) that evenly slope between 15-70 to the SE. This submarine terrace extends to about 200 m offshore, surrounding Punta Bajos, and is suitable for extending the runways towards the sea.

Figure 207: View of the “bedrock” on the right and of the shallow area on the coast.

6.1.3.3 Glaciology

For a description of the Glaciology of Dundee Island, we will take in a general way what is established by Silva, Arigony-Neto & Bicca (2019) in the geomorphological characterisation of the glaciers of the Antarctic Peninsula. These authors point out that on Dundee Island we find a glacier that can be classified as an ice field since they are generally formed in extensive areas of basins or on plateaus, which allows the formation of a continuous mass of ice on the relief, without interruption by glacial channels. The ice fields have an area of less than 50,000 km². It is a single basin since they are fed by a single catchment mass, with a single accumulation zone (RAU *et al*, 2005).

These authors also point out that since the glacier ends in the sea, then it is classified within the “calving and lobe” class. Calving is a classification for a normal basin whose termination extends into a lake or into the sea, producing icebergs and growlers in its loss of mass, whereas, in a floating basin, the termination is floating in the sea and the rough line of calving may be detectable. Finally, they point out that it is uniform and regular, since it is a basin without marked changes in the surface profile of the glacier, and it can form on vertical slopes (Figure 208).

Figure 208: Satellite image of Dundee Island where the ice cover can be observed and the presence of Cape Welchness on the left as the only ice-free surface.

6.1.3.5 Local bathymetry

Figure 209 shows the bathymetry of the area around Cape Welchness surveyed by the Argentine Naval Hydrographic Service. In Figures 210 and 211 the depth values around the coasts of the Cape can be observed in more detail. In both cases, the low depth determines, at times of low seas, a large surface is exposed.

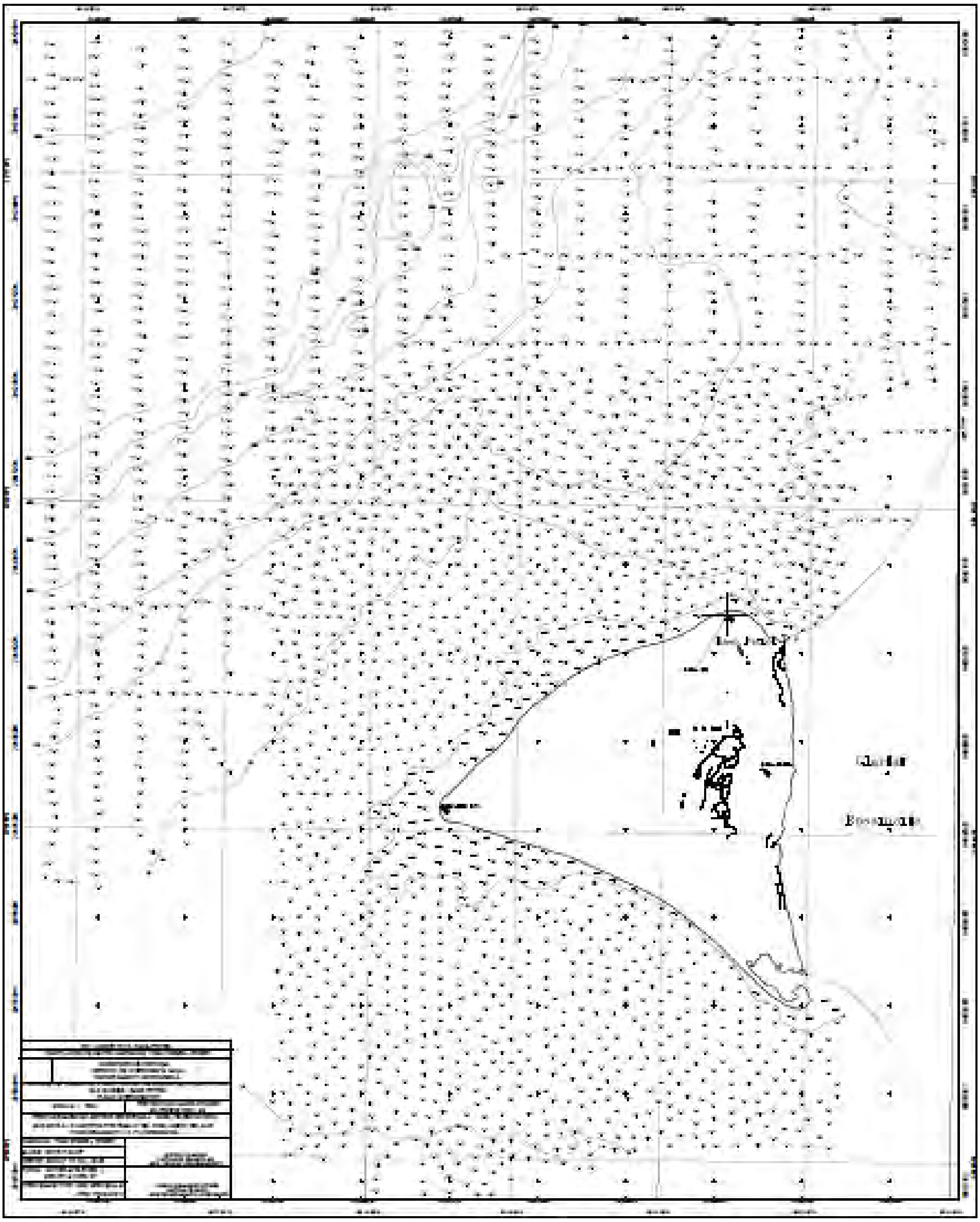


Figure 209: General map of the bathymetry of Cape Welchness.

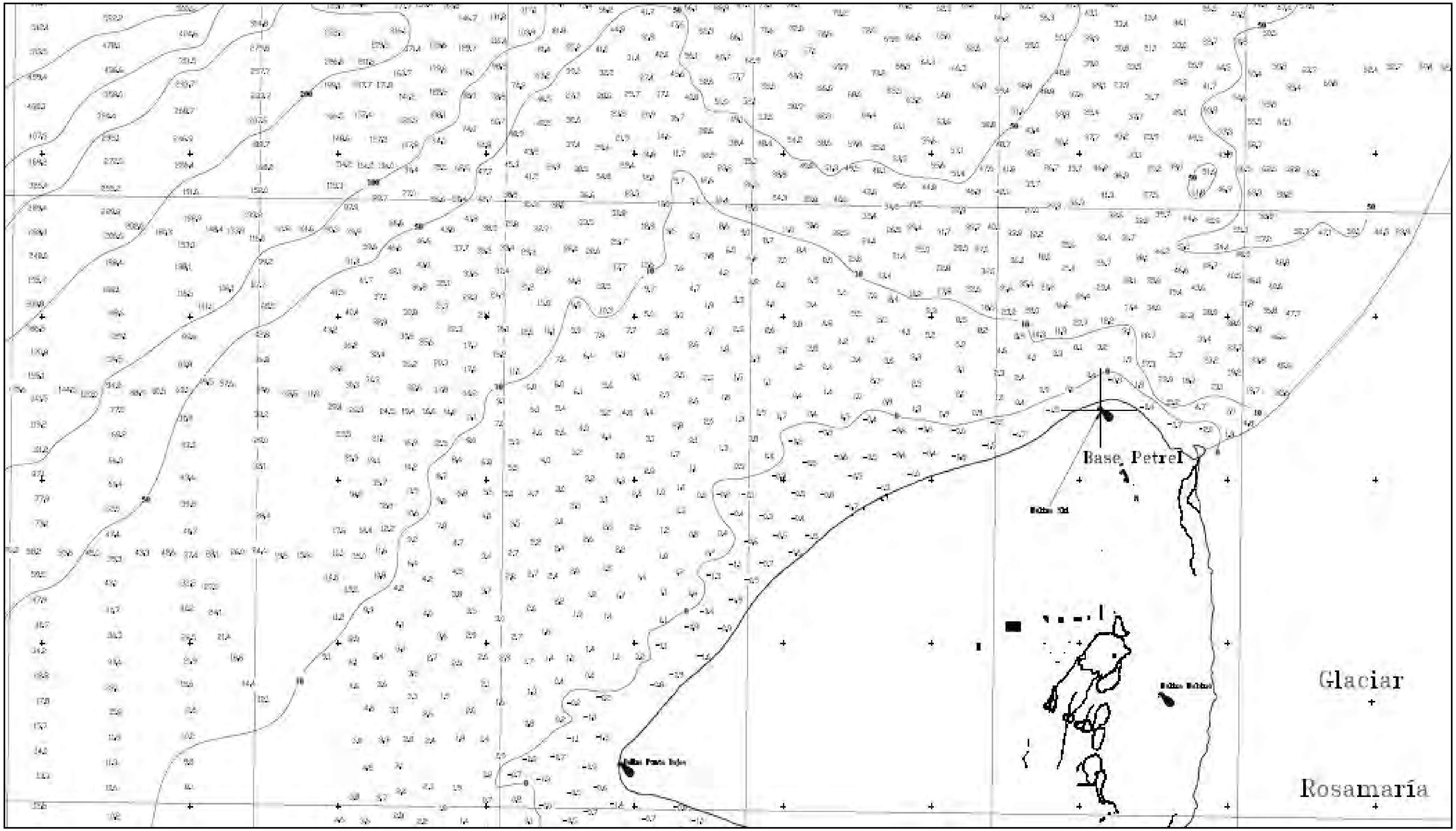


Figure 210: Bathymetric map of the northern area of Cape Welchness.

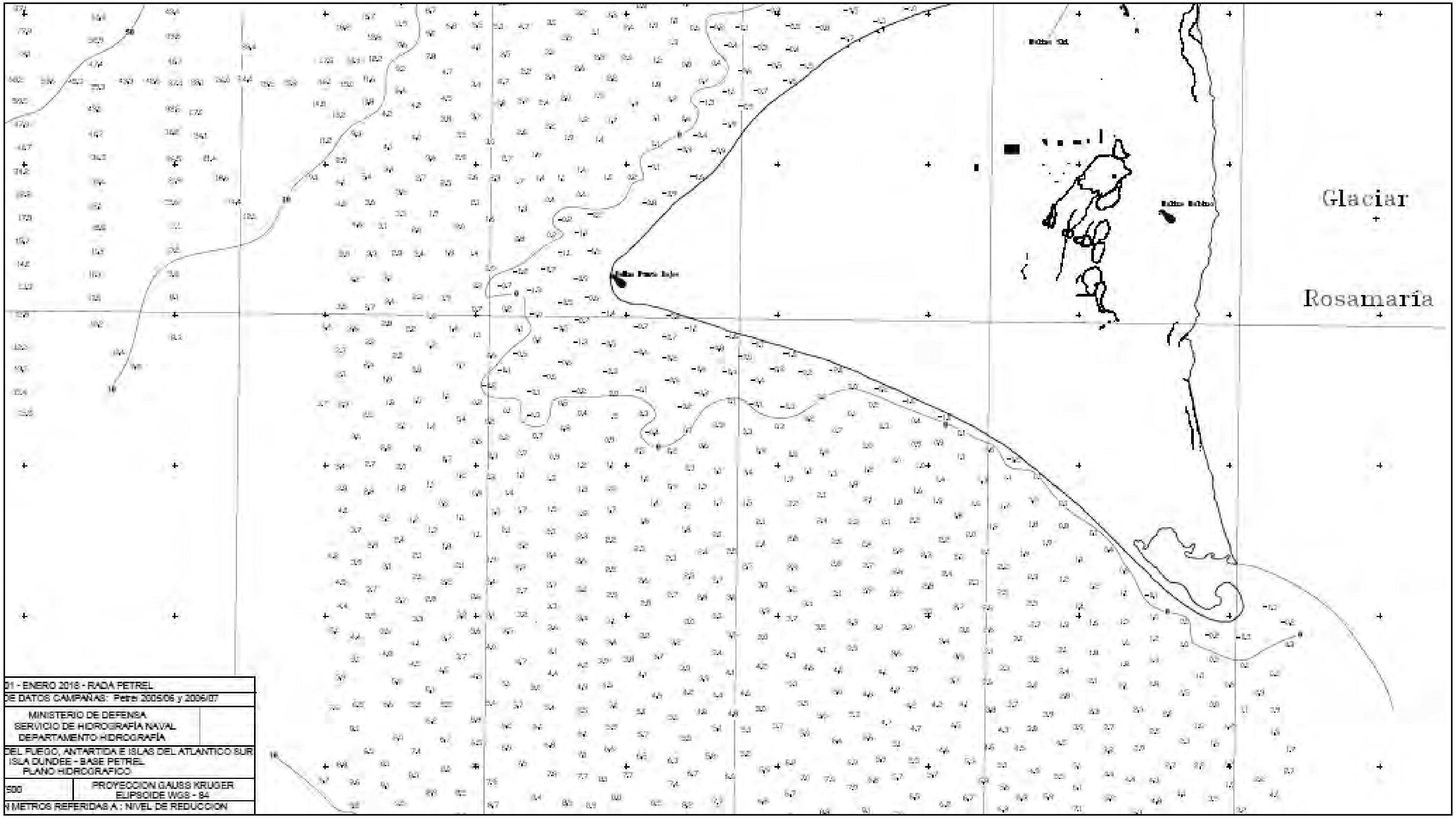


Figure 211: Bathymetric map of the northern area of Cape Welchness.

6.1.3.6 Local hydrology

The northern region of the Antarctic Peninsula has climatic characteristics that allow the development of surface and underground water systems during the southern summer months. The behaviour of this water system is correlated with regional and seasonal climatic conditions. In these environments, the dynamics of the glacial and geocryological ablation processes are related to the surface and subterranean water dynamics, so the understanding of the different hydrological processes is in line with them. Due to the important climatic control over the summer hydrological and hydrogeological system, the conditions to the east and west of the northern region of the Antarctic Peninsula are clearly distinguishable.

Cape Welchness has these mentioned characteristics, since in the summer months it has, especially in the lower plain, an important surface water system develops, especially on the south coast (Figures 212 and 213).

Figure 212: Image in which the glacial melt lagoons on the southeast coast of Cape Welchness can be seen

In Figure 214 the rills generated in the summer months can be seen in blue. A more important presence can be clearly seen to the south of Cape Welchness, where natural bodies of water are also generated. In this sense, it is also important to highlight that it must be evaluated how the construction of the runway will interrupt the runoff to the north of the Cape and mitigate this problem.

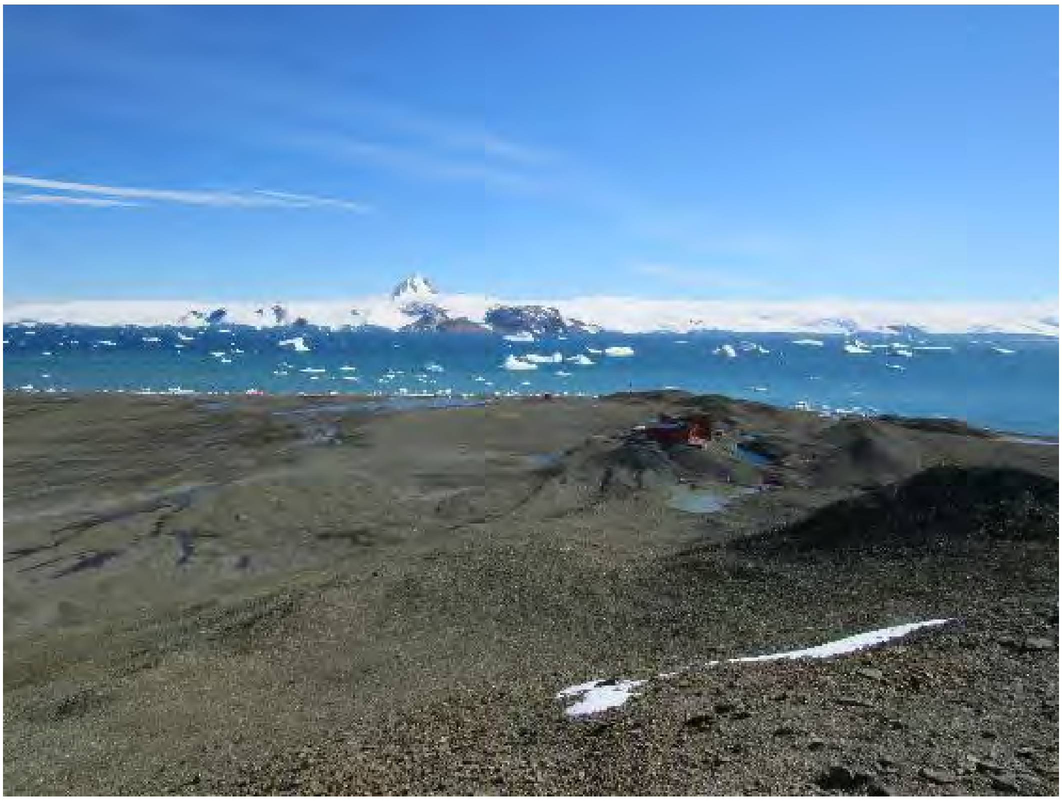


Figure 213: Image where you can see the surface water network on the northeast coast of Cape Welchness

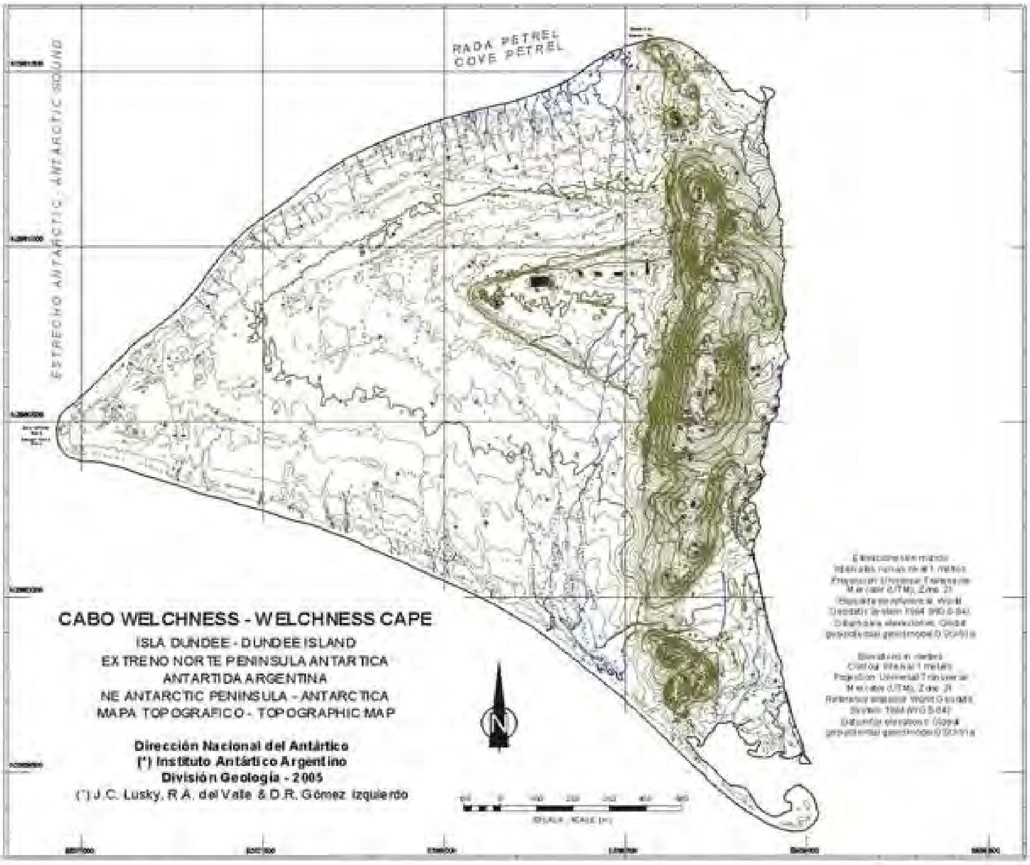


Figure 214: Map of Cape Welchness where the watercourses generated in summer are shown in blue.

Many of these courses have been maintained over time and for this reason in the SE sector of Cape Welchness there are active temporary streams that have eroded channels more than 2 m deep (Figure 215).

Figure 215: Image where you can see a deep channel of one of the streams.

2021/2022 Summer Antarctic Campaign Survey

During the 2021/2022 Summer Antarctic Campaign, a survey of the surface water system of Cape Welchness was carried out in order to assess the impacts of the construction and operation of the runway. On the cord of the lateral moraine up to Punta Bajos, 70 dry channels, rills and natural lagoons were identified, most of which have a direct discharge into the coastal waters surrounding the cape. The power supply of this network is seasonal due to the melting of the moraine ice cores, the permafrost and the snow accumulated during the winter or episodes of intense snowfall. Figure 216 shows a rill typical of those found on the moraine margins.

Figure 216: Image where the rills descending from the lateral moraine can be seen.

These are resting, drinking and bathing areas for several species of birds and mammals, as well as nesting areas for skuas. During the survey, eight pairs of skuas were recorded with a total of approximately twelve chicks distributed in seven rills, with the exception of one, all located on the south coast (Figure 217).

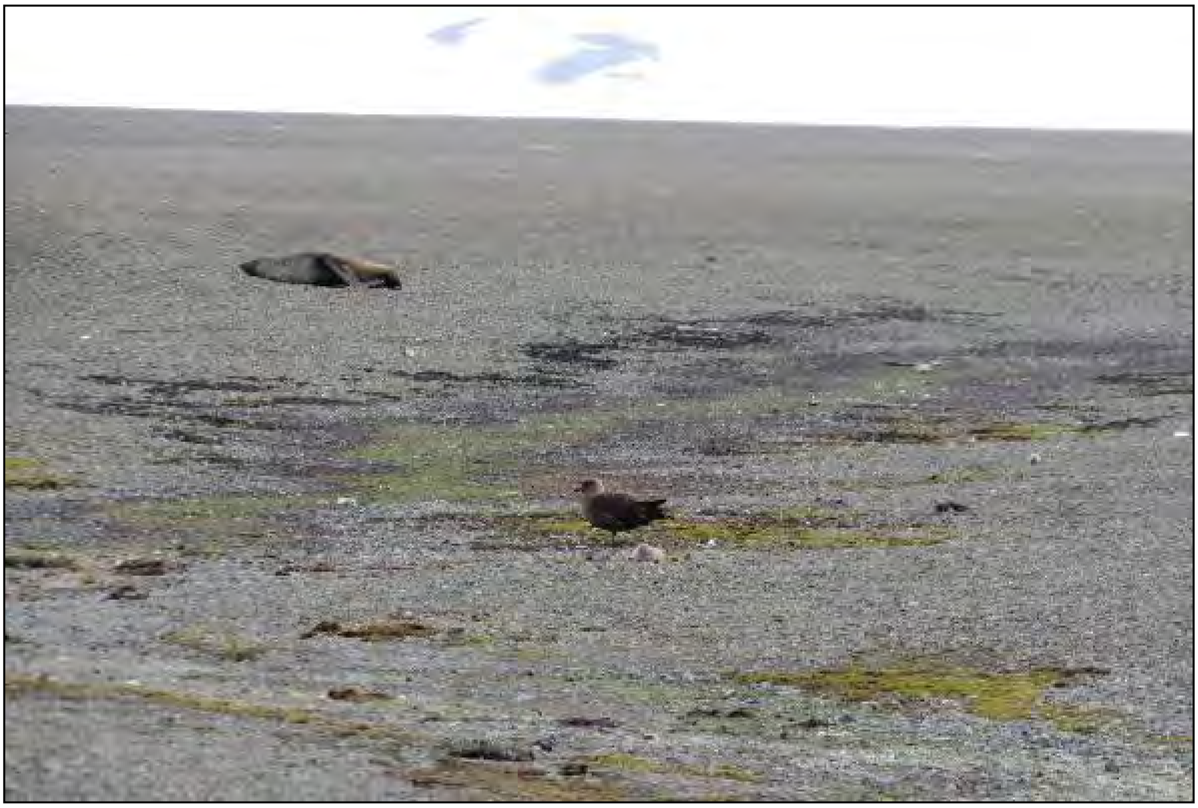


Figure 217: : image where you can observe the fauna and flora associated with a rill on the south coast.

Of the total channels observed, at the time of sampling, only 25% (17) had water on their surface or moist substrate, these are the so-called deep rills. They were in relation to the lateral moraine cord; the upper terrace being the watershed. In these rills, mosses and microbial mats or mats develop (Figure deep streams) (Figure 218).

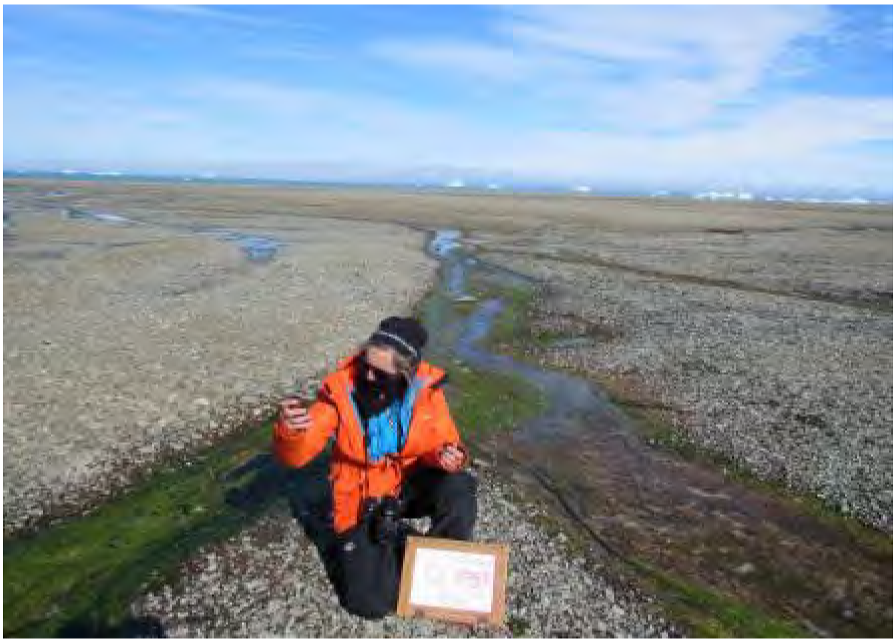


Figure 218: Deep rills off the southeast coast of Cape Welchness.

The remaining 75% corresponded to the channels that are located in the direction of Punta Bajos passing the upper terrace. These have a seasonal spring regime and develop in relation to the coastal margin, they are usually the resting places chosen by marine mammals and pinnipeds, with mosses and lichens as the dominant vegetation (Figure 219).

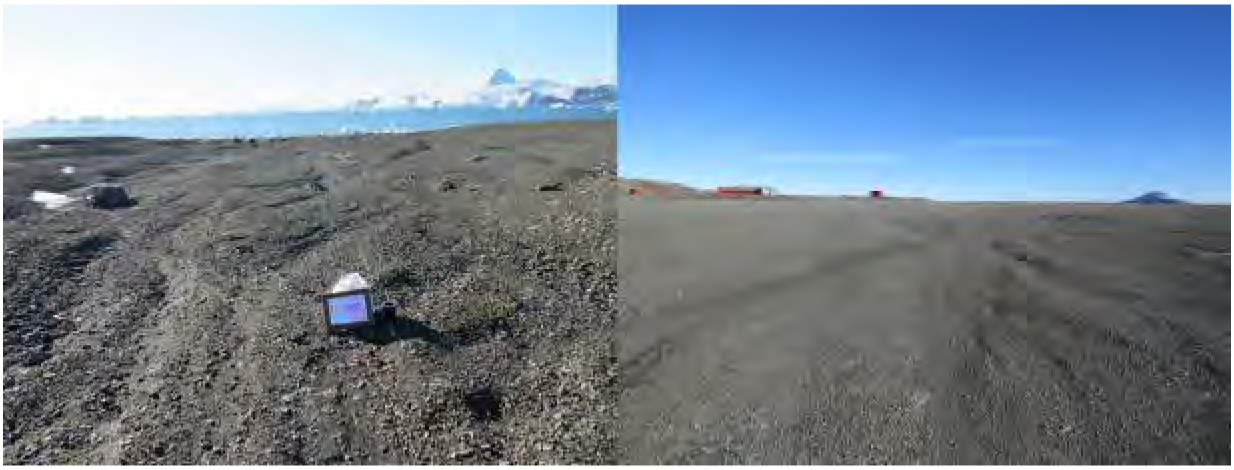


Figure 219: Images where two dry riverbeds on the north coast can be seen.

Finally, in the fjords that are formed facing the glacier, there are profuse rills and glacial lagoons, whose development was accelerated due to the glacial retraction of recent years due to the effect of climate change (Figure 220).

Figure 220: Glacier valley behind the moraines. Composite image, not to scale. February 2022.

6.1.3.7 Flora and Fauna

Initial Survey Antarctic Summer Campaign 2014/2015

During the 2014/2015 Summer Antarctic Campaign, some flora and fauna surveys were carried out at the Petrel Base in order to assess the impacts of a future reactivation of the Base. The results of those censuses determined that, in the area, represented by around 2,500m^2, several different animal and plant species stood out. Their presence was scarce, but at the same time diverse. From the faunal point of view, the presence of Weddell seals could be observed in the sector called “La Olla” (portion of frozen sea at the foot of the Rosamaría glacier). They never exceeded 25 specimens. Among these, some leopard seals were also present alternately. It should be noted that these settlements are more than a hundred metres from the main house and had no interaction with human beings under any point of view, except for the landing and takeoff of the helicopters that arrived at the base. Apparently, the arrival of these individuals at the sector is in order to rest. It is also important to note that after a series of storms the ice pack at the location broke up and was moved by the sea currents. After this happened, the seal population did not return to the location, realising that it could be a transitory settlement.

The greatest diversity comes from the side of flying birds, such as: Southern giant petrels (passing through the coastal sectors of the base), terns, being the leading species together with skuas (nesting), kelp gulls (rare), cormorants and Wilson’s petrels, both very rare. Apparently, according to the tours carried out around the base, some of these species, such as terns, would be nesting near the slopes of the moraine arch and in some cases, such as skuas, on the ground, in the disused alternate runway. Among the penguins we can highlight the larger number of Adélie penguins, who are distributed in a very dispersed way, and the Gentoo or Chinstrap in very low numbers (one or two specimens). It should be noted that many of them are far from the base, more than one hundred and fifty metres away, and rarely approach the main house out of curiosity. In the case of the Adelia, close to the base, they never exceeded 30 individuals. Something similar happened on the southern coastal sector, evidencing a series of individuals, but all highly dispersed and without the presence of nests in any case. On the Antarctic and/or Active Strait, a group of transiting whales was sighted from the coast, of which the species cannot be specified (Figure 221).

Figure 221: On the left image of Ross seals resting in front of the glacier. On the right is a picture of a skua nesting in the runway area.

From the point of view of the flora, the presence of mosses and lichens (the species could not be identified) was evidenced on the surface covered by Cape Welchness, both at sea level and between the cracks that exist between each of the morainic arches at different heights. They are almost imperceptible to the human eye and in some cases they are accidentally trampled because they are confused with the ground, because they have similar characteristic colours (Figure 222).

Figure 222: Presence of mosses and lichens in different sectors of the base area.

2021/2022 Summer Antarctic Campaign Survey

During the 2021/2022 Summer Antarctic Campaign, some flora and fauna surveys were carried out at the Petrel Base in order to assess the impacts of a future reactivation of the Base and with the aim of contributing to the development of the baseline. This work was very important since there were no continuous records of fauna at the cape because the base had been closed for many years. From the point of view of flora, on the surface covered by Cape Welchness the presence of mosses and lichens was evidenced (the material has been collected and systematic identification is underway) both at sea level and between the crevices that exist between each of the moraine arches at different heights.

Figure 223: Layout of the grid used to survey Cape Welchness.

To study the area, the Cape was divided into 13 sectors in order to characterise each of them environmentally (Figure 223). Each of these quadrants were characterised in a general way, finding that they can be classified in some of the following environments: coast, terrace and moraines. Table 42 describes each of these quadrants.

Table 42: environmental description of each of the quadrants studied.

Cuadrantes	Ambiente	Sustrato	Cuerpos de agua salobre (chorrillos, laguna costera)	Flora	Pendiente	Actividad antropica asociada al cuadrante	Conexión con el mar
4 (oeste)	costa	arena fina con grava muy chica.	vinculo directo con glaciar, presencia de chorrillos de origen glaciario, presencia de lagunas mixtas temporales	musgos y otros asociados a chorrillos y laguna costera	2	media, conexión con chorrillos y lagunas de efluentes de casa principal	rada, mar contenido normalmente calmo
3	costa y terraza	arena fina con grava muy chica.	laguna costera permanente-durante el verano- chorrillos sin descarga al mar	musgos y otros asociados a chorrillos y laguna costera	1	alta, presencia de casa de bote, costa usada para desembarco, helipuerto, descanso de barriles de combustible	costa
2	costa	arena fina con grava mediana y presencia de bloques.	sin cuerpos de agua visibles en el verano	sin vegetacion	3	baja	costa, dinámicas de mar abierto
1	costa	arena y grava chica en su mayoria y presencia de bloques	sin cuerpos de agua visibles en el verano	sin vegetacion	3	baja, presencia de baliza en desuso	costa, dinámicas de mar abierto, confluencia de antartic y active
8	costa	grava grande, grava chic.	sin curpos de agua visibles en el verano	sin vegetacion	2	baja, se observan restos historicos de brea	costa, dinámicas de mar abierto, confluencia de antartic y active
9	costa	grava grande, grava chic.	alta presencia de chorrillos de origen permafrost	musgos y otros asociados a los chorrillos	2	baja	costa al antarctic, dinámica de mar abierto
12	costa	arena gruesa + grava gruesa y fina	chorrillo de origen permafrost, laguna costera de origen mixto que no desemboca en el mar	asociada a cuerpos de agua, mata microbiana, musgo y liquenes	2	media, presencia de residuos historicos en vinculo directo con fauna	costa al antarctic, dinámica de mar abierto
13 (este)	morena y costa	grava fina en costa	sin cuerpos de agua visibles en el verano	sin vegetacion	3	media, presencia de residuos historicos en vinculo directo con fauna	costa al antarctic, dinámica de mar abierto
13 (oeste)	tipo fiordo, conjuncion entrada a glaciar, morena, chorrillos de origen glaciario, laguna y costa	arena fina y pebbles	laguna costera permanente en verano, contacto directo con glaciar, chorrillos de origen glaciario con pluma al mar	asociada a cuerpos de agua, mata microbiana, musgo y liquenes	1	presencia de residuos historicos	conexión directa con el mar
5	terraza	pebbles	sin curpos de agua visibles en el verano	musgo seco y liquenes de bajo desarrollo	0		sin conexión directa con el mar
6	terraza	grava y pebbles	sin curpos de agua visibles en el verano	musgo seco y liquenes de bajo desarrollo	5	alta, presencia de edificaciones, transito de transporte de carga, transito de personal	sin conexión directa con el mar
10	terraza	arcilla y pebbles	alta presencia de chorrillos de origen permafrost	musgos y otros asociados a los chorrillos	0	con basura antropica, marcas de transito de personas y transporte	indirecta a traves de chorrillos
11	morena	rocas de diversos origenes	con lagunas de origen permafrost y chorrillo de origen permafrost de gran tamaño	mata microbiana y musgo asociada a cuerpos de agua	10	en chorrillo principal presencia de basura antropica	sin conexión directa con el mar
7	morena	rocas de diversos origenes	con lagunas de origen permafrost	mata microbiana y musgo asociada a cuerpos de agua	10	sin actividad antropica destacable	sin conexión directa con el mar
4 (este)	morena	rocas de diversos origenes, con presencia de limo y bloques	sin curpos de agua visibles en el verano	mata microbiana y musgo asociada a cuerpos de agua	5	alta, presencia de lagunas de efluentes y de utilizacion de agua tecnica y de consumo	sin conexión directa con el mar

The survey of the macrofauna was carried out during 17 days, recording the species (quantity), the site and the use of the habitat (feeding area, reproduction, rest or passage) at different times of the day (morning, afternoon and night). A total of 22 visual surveys were carried out at three different sites: moraine (n=2), terrace (n=20) and coast (n=20). Seventeen species of seabirds and pinnipeds were identified, in a total of 6517 observations.

using the site for rest, feeding or as a reproduction site. The most abundant species was the Adélie penguin, *Pygoscelis adeliae*, with a total of 2544 observations, of which 2267 were feathered specimens observed in groups on the coast. The next species with the highest number of observations was the fur seal, having been recorded 2,294 times. *Arctocephalus gazella*, all of them particularly thin juvenile individuals, resting on the coast or on the banks of streams.

Figure 224: Birds present at Cape Welchness

Among the most common flying birds the skuas (*Stercorarius antarcticus*) and the terns (*sterna vittata*). Tern and skua nests were found on the upper terrace, the fluvioglacial plain (or middle terrace), in the glacial moraine facing the Rosamaría glacier, and in the meltwater lagoons that form at the southern end of the cape. The individuals were concentrated on the southern coast facing the glacier. This sector hosts skua nests with populations of more than 20 individuals and terns (based on moraines) of more than 100 individuals. Feeding on the coast, it is common to see Wilson's petrels (*Oceanites oceanicus*) and terns, and among the birds of passage are the Antarctic Shag (*Leucocarbo bransfieldensis*), southern giant petrel (*macronectes giganteus*), Snow petrel (*pagodroma nivea*), cape petrel (*Daption capense*) and Kelp Gull (*Larus dominicanus austrinus*) (Figure 224).

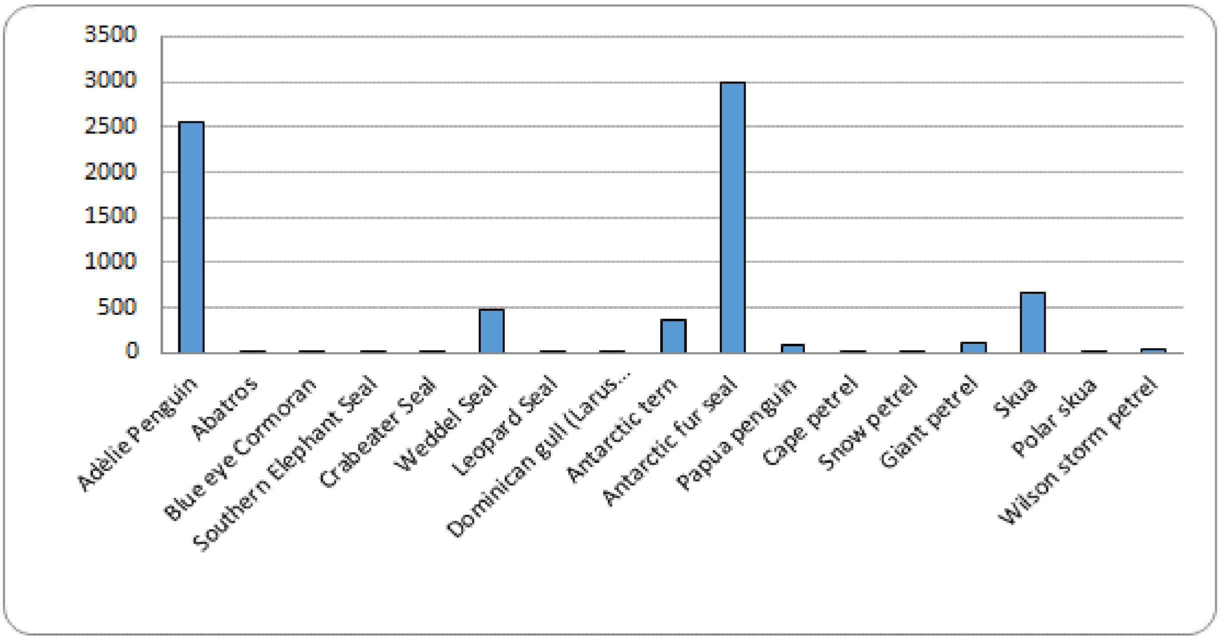


Figure 225: Total number of each of the bird and mammal species recorded in summer 2022.

Regarding the spatial distribution of the fauna, taking into account the environments (coast, moraines and terraces), Table 43 shows the total number of each of the species observed in each type of environment.

Table 43: distribution of macrofauna species in the environments.

Especie	Costas	Morena	Terraza	Total
Pingüino Adelia (*Pygoscelis adeliae*)	2482	54	24	2560
Albatros	1			1
Cormorán antártico (*Leucocarbo bransfieldensis*)	12			12
Elefante Marino (*Mirounga leonina*)	29		1	30
Foca cangrejera (*Lobodon carcinophagus*)	12		2	14
Focas Weddel (*Leptonychotes weddellii*)	465		19	484
Foca Leopardo (*Hydrurga leptonyx*)	4			4
Gaviota cocinera (*Larus dominicanus austrinus*)	15			15
Gaviotin Antártico (*Sterna vittata*)	278	78	20	376
Lobo fino antártico (*Arctophoca gazella*)	2776	5	215	2996
Pingüino Papua (*Pygoscelis papua*)	79	2	1	82
Petrel damero (*Daption capense*)	3			3
Petrel de las nieves (*Pagodroma nivea*)	2			2
Petrel gigante (*Macronectes giganteus*)	101	3	1	105
Skua (*Catharacta chilensis*)	560	21	82	663
Skua Polar (*Catharacta maccormiki*)	1			1
Petreles de Wilson (*Oceanites oceanicus*)	55			55
Total	6875	163	365	7403

Among the flightless birds, about a thousand specimens of juvenile Adélie arrived at the cape in the middle of the campaign. Predation of Adélies by skuas and southern giant petrels was also observed, mainly on the coastal margins and occasionally in the lower terrace area, where vagrant Adélie individuals would be found. Southern giant petrels inhabited the cape for several days in groups of up to 40 individuals.

Figure 226: Nesting areas of skuas (Stercorarius antarcticus) and gulls (Sterna vittata).

Marine mammals used to rest along the shoreline and in the channels; Several species were found and their tendency was to increase, reaching almost 500 individuals in one day. The first days the coast was visited and inhabited mainly by Weddel Seals (*Leptonychotes weddellii*) and crabeaters (*Lobodon carcinophagus*) with the latter on the ice packs. After the first two weeks, almost simultaneously with the arrival of the Adélies, the number of Antarctic fur seals increased (*Arctophoca gazella*) reaching 400 specimens in one day (Figure 226).

Figure 227: Some of the species found at Cape Welchness were skuas, southern giant petrels, Antarctic fur seals and Weddell seals – February 2022.

As observed in the Summer 2014/2015 survey, the flora on the cape were mosses and lichens, the latter developing over the entire surface, even in dry places. In addition, the presence of microbial mats in the lagoons and rills was recorded. Being the presence of water one of the most important factors in the development of the flora and with the objective of identifying the vegetated zones, the GPS positioning of 68 channels and rills of the cape was surveyed and samples were taken from the accompanying vegetation (mosses and lichens).

Figure 228: Survey of flora in riverbeds and rills – February 2022

Lichens were the dominant group, with development observed in 38 of the 68 channels, of which only 7% were channels with water or in their field capacity. The second dominant group were mosses, found in 31 (of 68) channels, of which 55% corresponded to channels with water or in their field capacity; it was common to find dormant mosses recognisable by their brown colouration. The last group corresponds to the microbial flora associated with permanent or transitory freshwater, registered in 17 (of 68) channels, with 82% of channels with water or in their field capacity.

Figure 229: In the image you can see a folder of mosses recorded on the south coast.

6.1.3.8 Conservation objects in the area

Various conservation objects can be found in the local area of Dundee Island. In relation to the ASPAs, it can be seen that the area is only close to ASPA No. 148 Monte Flora, in Bahía Esperanza, some 40km away (see Figure 229). This protected area aims to preserve the Monte Flora fossil formation, of significant importance for the evolutionary history of Antarctica.

The figure that does have an important presence in the vicinity of Dundee Island are the Areas of Importance for the Conservation of Birds (AICAs). Although the island does not have AICAs, they are present on nearby islands. Thus, for example, we have the 065 - Eden Rocks and 066 - Isla Paulet, very close to Dundee Island. There are 3 AICAs on Joinville Island, two on the outside of the Tabarin Peninsula and three more (062, 063 and 064) west of Dundee Island (Figure 229).

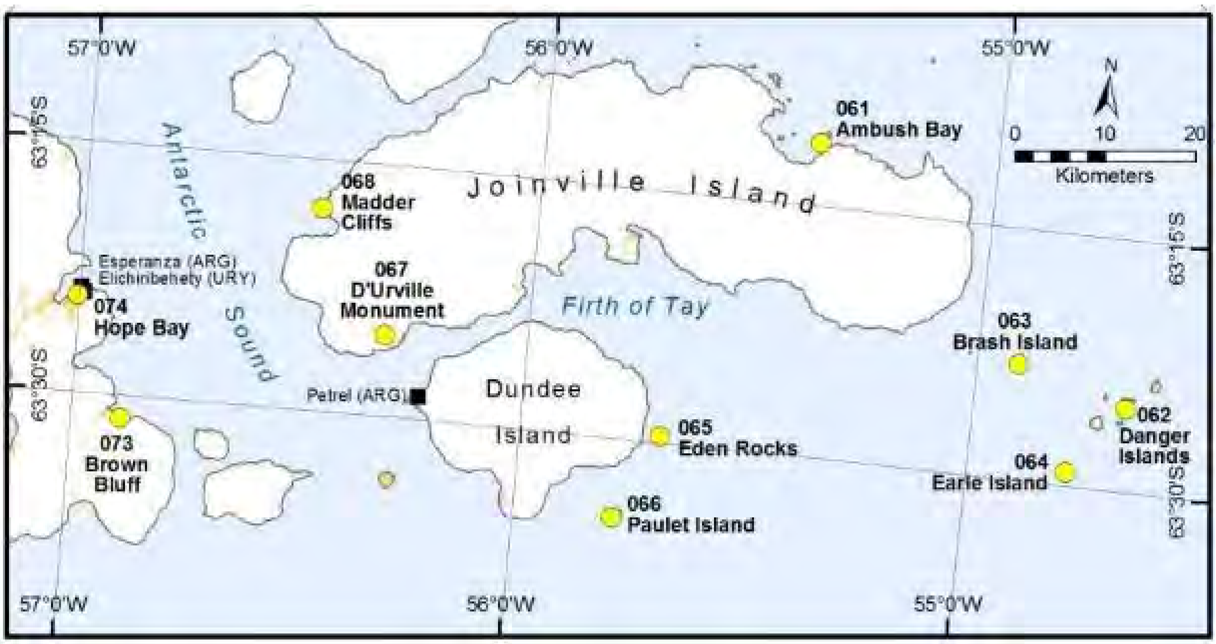


Figure 230: location of the AICAs in the vicinity of Dundee Island. Taken from Harris et al (2015)

Taking into account the closest AICAs we can mention 065 Eden Rocks. It is classified by the presence of the Adélie penguin colony (*Pygoscelis adeliae*) and comprises two rocks that rise to about 90 m and the intermediate sea. Two large colonies of Adélie penguins breeding at Eden Rocks were recorded in 1996, with approximately 20,000 pairs in the western colony and 26,750 pairs in the eastern colony (a total of between 44,249 and 49,460 pairs). Other confirmed breeders in the area are the Cape petrel (*Daption capense*) and the skua (*Catharacta spp.*.). Occasional visitors include the southern giant petrel (*macronectes giganteus*), the snowy skua (*Chionis albus*), Wilson's storm petrel (*Oceanites oceanicus*) and the Kelp Gull (*Larus dominicanus*).

Regarding AICA 066 Paulet Island: Paulet Island is located about 5 km southeast of Dundee Island, east of northern Trinity Peninsula, in the Gulf of Erebus and Terror. The extinct and ice-free volcanic cone is 1.7 km in diameter and rises to 350 m in height (ATS Visitor Site Guide: Paulet Island, accessed 08/06/2010). The IBA is classified on the basis of Adélie penguin colonies (*Pygoscelis adeliae*) and imperial cormorant (*Phalacrocorax [atriceps] bransfieldensis*) present and the great concentration of seabirds, and includes the entire island.

The southern and western slopes of the island are covered with scree. A flat terrace to the north and northeast, access to which is restricted to visitors, is frequently submerged at high tide. Historic Site and Monument No. 41 is located on Paulet Island, and comprises a stone hut, rock cairn and tomb from the Swedish South Pole expedition of 1901-2004.

According to Harris *et al* (2015) approximately 100,000 breeding pairs of Adélie penguins were recorded breeding around meltwater lakes and on ridges north-east of Paulet Island in 1999. In 2007, approximately 465 breeding pairs of tufted imperial cormorants were recorded breeding among Adélie penguins. More recently, the Antarctic Site Inventory reported 548 imperial cormorant breeding pairs in January 2012. Previous records indicate that most cormorants nest on a nearby basalt stack and cliff on the north coast. It was estimated that 300 pairs of Snow Petrels (*pagodroma nivea*) were breeding on Paulet Island in 1992. The Kelp Gull (*Larus dominicanus*) is also a confirmed breeder, while the snowy plastron (*Chionis albus*) and Wilson's storm petrel (*Oceanites oceanicus*) are frequently observed and may breed in the area.

Another nearby AICA, located on Joinville Island, is 067 - D'Urville Monument, it is a small ice-free zone (127 ha) to the southwest of Joinville Island, on the northern shore of Activey Strait in front of Petrel Roadstead. The IBA is classified based on the concentration of seabirds present (particularly the Adélie penguin (*Pygoscelis adeliae*)) and covers the ice-free area of the site. Approximately 10,000 Adélie penguin pairs and more than 670 Gentoo penguin pairs (*Pygoscelis papua*) are reproduced in the D'Urville Monument.

6.1.4 Problems and Threats

In order to analyse the impacts of the renewal of the Petrel Base, we will first establish the context in which the region is immersed. In order to value the real impact of the proposed activities on the conservation values of the area in the short, medium and long term, it is necessary to describe the processes that may could current conservation or future threats in the area.

Antarctic ecosystems (terrestrial and marine) are being affected by global forcing (Morley et al, 2020) and local forcing (Grant et al, 2021) that manifest themselves, in both cases, in impacts observed in past decades or in threats predicted for the next decades. These groups of global factors have been causing changes in the Antarctic environment and in its dependent and associated ecosystems and have generated, in recent decades, new environmental problems. In addition, the best available science predicts that the situation will worsen in the coming decades if mitigation measures are not taken in the corresponding areas. Next, we will carry out a brief analysis of the environmental pressures of the Northern region of the Antarctic Peninsula in order to establish the context where the actions of this project will be carried out and especially in order to obtain a general diagnosis of how these processes will affect the submitted project.

6.1.4.1 Anthropic processes

We are going to describe the anthropic processes that exist in the northern region of the Antarctic peninsula in order to establish the pressures that human activities exert on the area of influence of the Petrel Base. The entire Antarctic continent is under pressures caused by environmental factors that act as forcing factors of change that make it necessary to assess the current threats in the area where each activity is going to be carried out, especially to make an adequate valuation of the cumulative environmental impacts.

According to Capurro (2021) the western Antarctic Peninsula is experiencing the fastest environmental change on the continent (and one of the most critical in the world). Sea surface temperatures in some coastal regions have already reached temperatures initially predicted for 2100 and coupled with an atmosphere that has warmed by almost 3°C since 1951, these changes have been linked to the collapse of several Antarctic ice shelves, the retreat of most glaciers and the exposure of new terrestrial habitats. In fact, the year 2020 marked a new temperature record of 18.3°C (64.9°F), registered during the austral summer at the Esperanza station in Argentina, very close to the Petrel Base.

These trends are causing environmental changes that seriously affect the entire ecosystem, from seabed communities to top predators. For example, krill densities in the region have declined dramatically, and the population has already shifted its distribution south and closer to the Antarctic ice shelves. Climate change is not only disrupting the krill-centric food web, it is also opening up new fishing grounds and allowing fishing activities for longer periods as ice (in all forms) recedes. In addition, current krill fishing regulations do not take climate change considerations into account, posing additional challenges for the conservation and management of the Southern Ocean (Capurro, 2021).

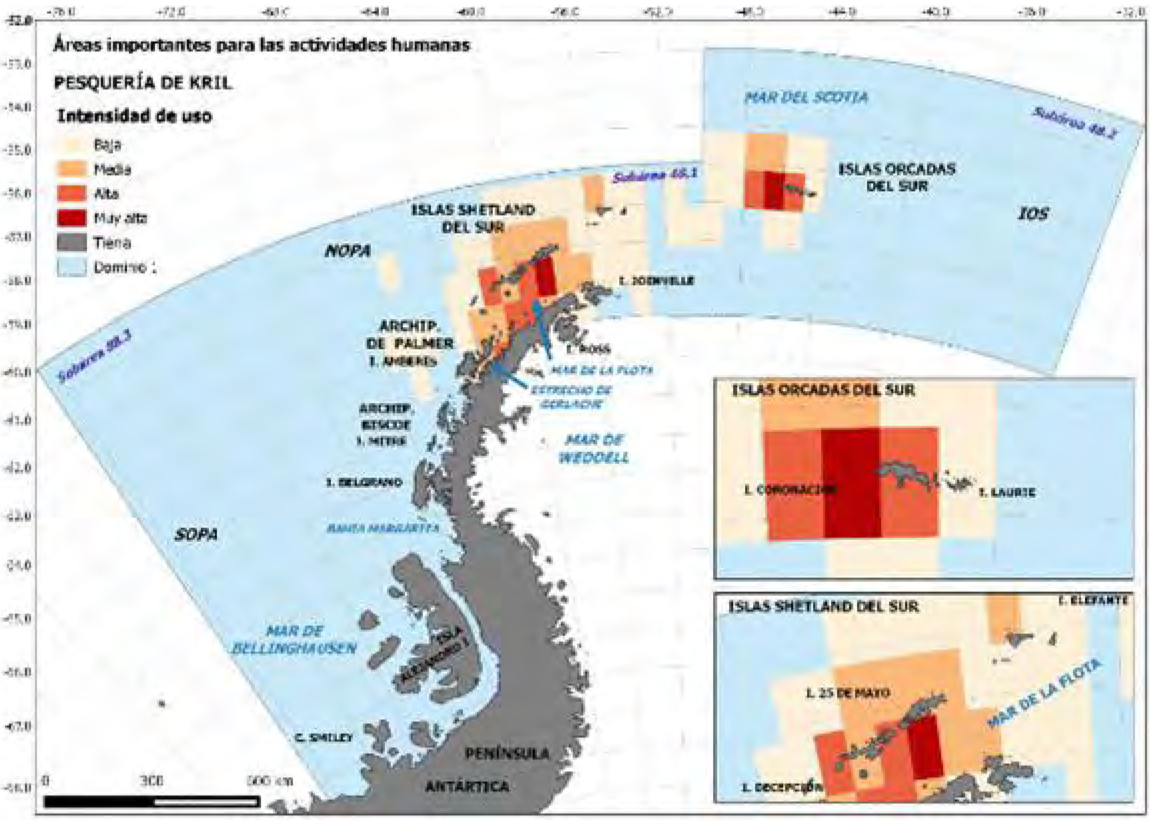


Figure 231: Spatial distribution and intensity of use of the krill fishery (taken from Capurro, 2019).

If we take Capurro (2019) as a reference, we see that, regarding human activities in the region, as usually happens, the highest concentration of these within Antarctica is in the Antarctic Peninsula region. For example, in the first place when analysing the krill fishery we mention that although it began in 1961, it intensified from the 1970s. During the last ten years, probably due to the decrease in the extent of sea ice, the spatial distribution of the fishery has shifted towards the south and today it is mainly concentrated in the following regions: i) Bransfield Strait, between the northern tip of the Antarctic Peninsula and the South Shetland Islands; ii) northwest of Coronation Island in the South Orkney Islands; and iii) north of the South Georgia Islands. In Figure 230 you can see the intensity of use of krill fisheries in the north of the peninsula.

Another very important human activity in the area is maritime transport. In this sense, Capurro (2019) mentions that, in terms of the intensity of maritime transport, it is observed that some sectors were more intensively used by boats. For example, in the NOPA region, the surroundings of the South Shetland Islands, reaching Deception Island, and the west of the Antarctic Peninsula, especially in the Gerlache Strait, stood out. Figure 231 shows this situation and the high intensity in the area near Dundee Island.

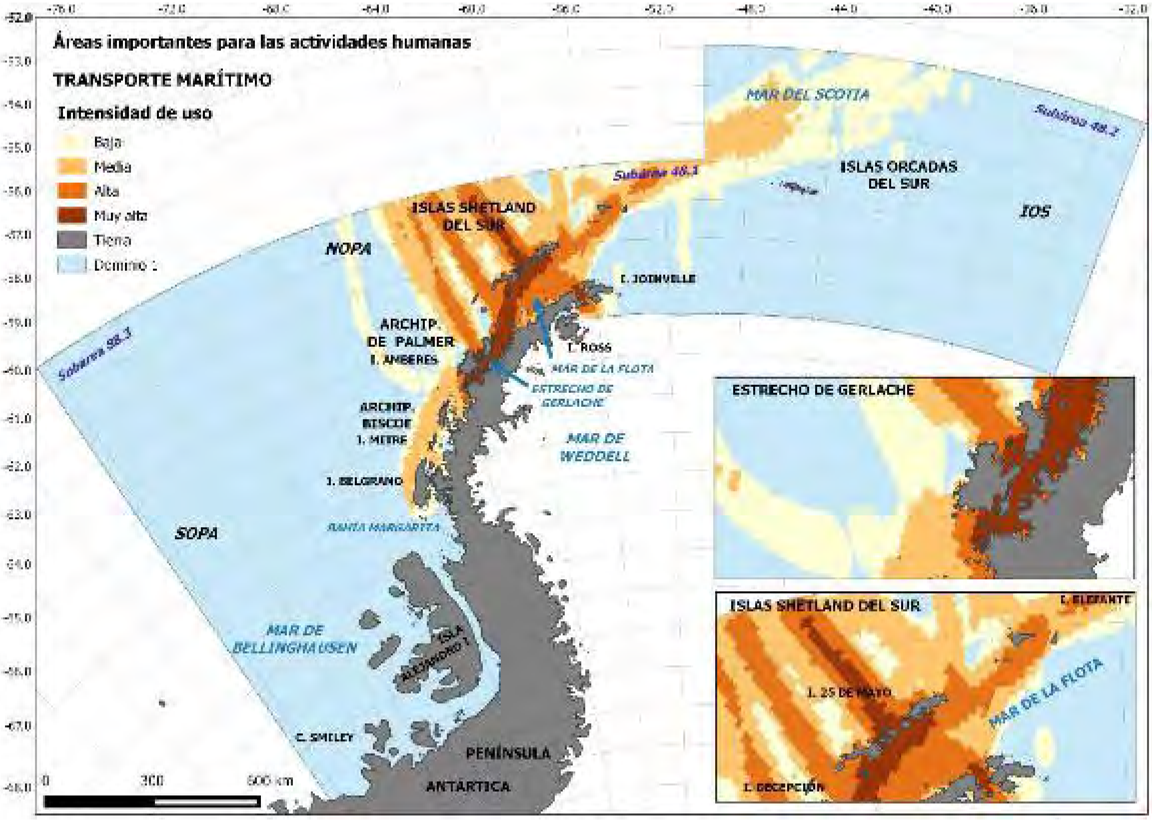


Figure 232: Spatial distribution and intensity of use of maritime transport (taken from Capurro, 2019).

A human activity of significant importance in the Antarctic Peninsula, and particularly in the North of it, is tourism. The region receives more than 95% of all Antarctic tourism each year, which in the season prior to the COVID-19 pandemic consisted of more than 74,000 visitors during the austral summer, a growing trend that continues to increase (Figure 232).

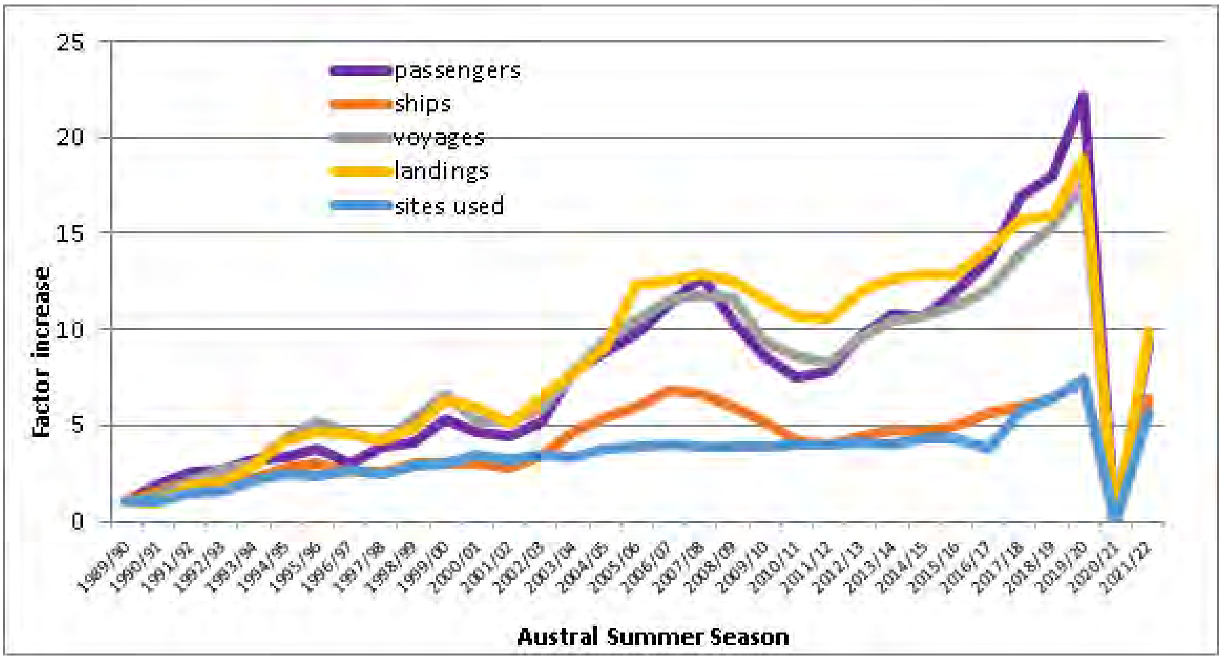


Figure 233: Antarctic tourism development since 1989 (Taken from IAATO ATCM44 ip43)

According to the IAATO (ATCM44 ip 043) making a comparison of the increase factor in different aspects of this activity (number of passengers, ships, trips, landings made and places used). Although the COVID-19 pandemic caused IAATO Operator expeditions during the 2020-21 season to be limited to two individual expeditions and 15 clients in the Antarctic Peninsula. However, during the 2021-22 season, all traditional commercial maritime tourism with landings around the Peninsula was carried out by IAATO Operators. Figure 232 provides a detailed view of the number of passengers, trips, landings, venues, and vessels over the past five seasons showing industry growth over the period 2016-2021.

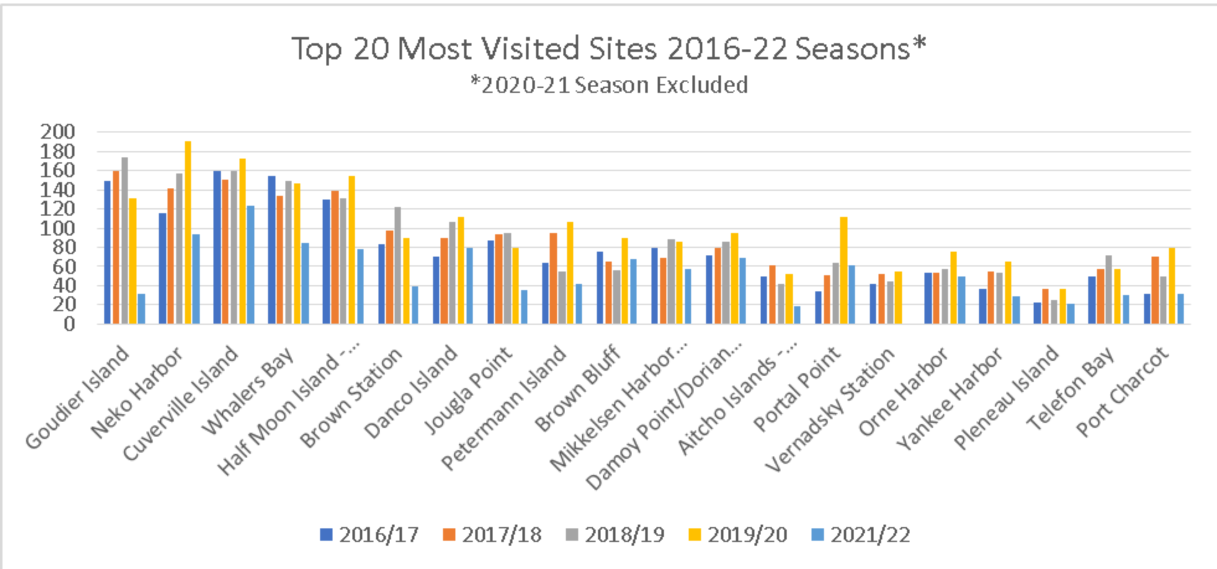


Figure 234: The 20 most visited sites in the period 2016-2020 according to IAATO (Taken of ATCM44 ip43).

According to IAATO (ATCM44 ip 43) it was observed in recent years that while overall levels of tourism continued to increase prior to the COVID-19 pandemic, the increase is not uniform across all visiting places. A few sites remain very popular with a further increase in activity, while other sites saw a decline in activity. The pattern of concentrated increase is believed to be explained in part by the popularity of these sites for reliable access, ease of visitor management, and aesthetic value and historical interest (Figure 233). Additionally, factors such as ice patterns and weather greatly contribute to site selection and visiting patterns, allowing or restricting access.

The growth and diversification of Antarctic tourism in recent decades have been the subject of numerous studies. However, the environmental impacts associated with this activity have received less attention despite the increasing number of studies examining environmental issues related to Antarctic tourism. In addition to raising important research questions, the possible negative effects of tourist visits to Antarctica are also a topic debated by the Antarctic Treaty Consultative Parties (Tejedo *et al*, 2022). The cumulative impacts of tourism have received little attention, and there has only rarely been talk of comprehensive, long-term monitoring programmes, leading one to assume that such long-term programmes are rare. And more importantly, there are not always connections between research and policy or management (Tejedo *et al*, 2022).

An analysis carried out by Tejedo *et al* (2022) allowed the identification of a wide range of potential and measured impacts derived from Antarctic tourism activities. They took three large groups of activities: land, sea and air. Actual negative impacts have only been confirmed as deriving from tourism activities in a very limited number of cases, which largely focused on effects on soil and vegetation (due to trampling), disturbance of macrofauna (mainly penguins and seabirds, but also in relation to some marine mammals), the possible introduction of non-native species and pollution (for example, marine debris or greenhouse gases). However, in many cases the magnitude of these impacts on Antarctic ecosystems has not been adequately quantified.

Potential negative environmental impacts from Antarctic tourism include chemical pollutants; impacts on geology, geomorphology and soil; limnological and microbiological consequences; and social impacts/human dimensions. In other topics, such as terrestrial fauna and alien species, there is more variability in the results, since numerous studies on these topics have not been able to demonstrate that the presence of tourists generates negative impacts on the environmental component analysed.

Finally, we can conclude that, although there is discussion about the real impact of Antarctic tourism, if it is confirmed that the North of the Antarctic Peninsula has the highest number of visits by tourism, the environmental impacts derived from this activity are more significant in this area and their sum as cumulative impacts with the presence of Antarctic bases. This is a significant point since the presence of scientific stations and their national research programs is also concentrated in the north of the Antarctic peninsula.

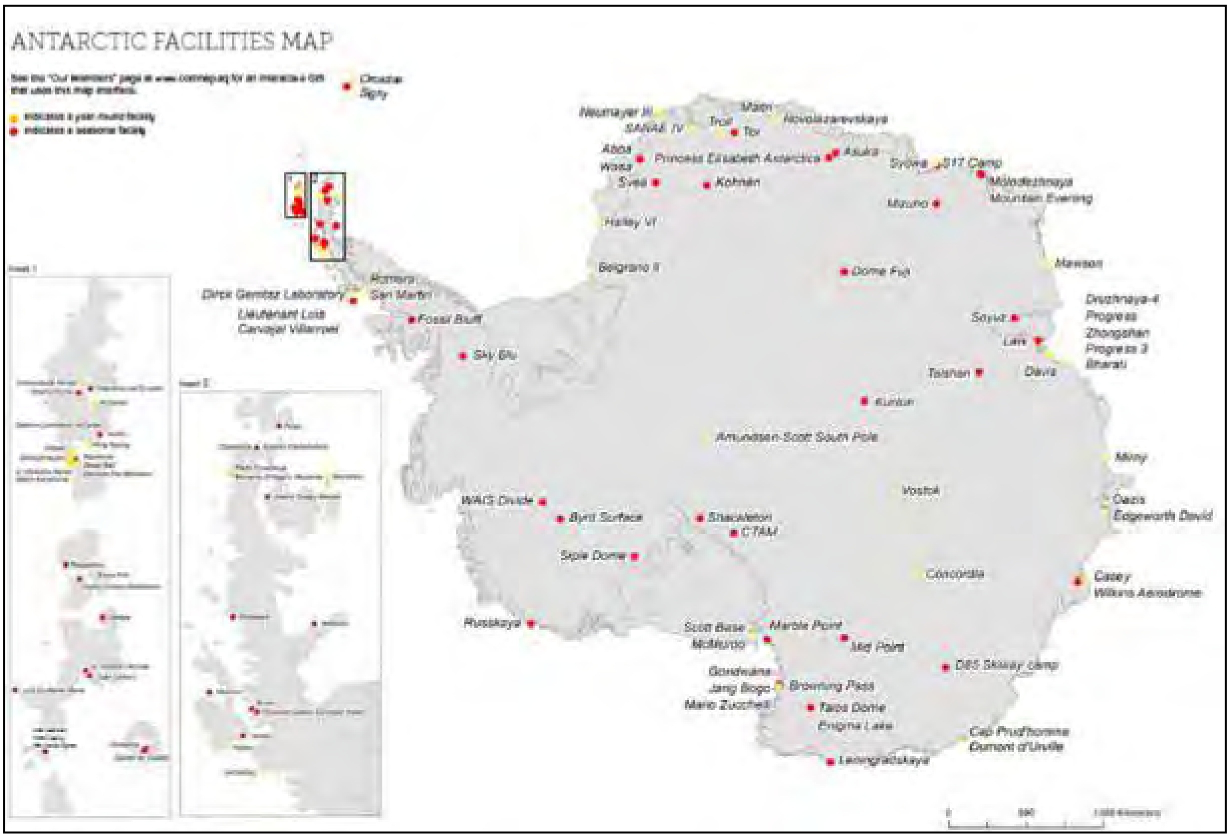


Figure 235: Map with the location of the Antarctic facilities (Taken from COMNAP Antarctic Facilities Map)

According to Pertierra *et al* (2027), from a general point of view, Antarctica is subject to less human activity than most other areas on Earth; however, at a finer spatial scale, many ice-free coastal areas are under increasing pressure from human activities and substantial human impacts have been recorded, including habitat destruction and wildlife disturbance (Pertierra et al, 2017). These authors mention that “The Antarctic Peninsula obtained some of the highest footprint values, and in particular the ice-free areas of the South Shetland Islands and the north of the Antarctic Peninsula, where numerous stations and places of visit are concentrated”. The Petrel Base is therefore located in one of the areas with the greatest impact from human activities (science, tourism, fishing, etc.) and therefore the actions of this project will not have effects on pristine or low-impact ecosystems. (Figure 234).

In relation to human activities in the area, Pertierra *et al* (2027) mention that "In particular, the surroundings of the Frei, Escudero, Bellinghausen and Great Wall stations on the Fildes Peninsula (King George Island, South Shetland Islands) show the largest group of pixels in the Antarctic Peninsula region with a footprint score of 90+ in a 4.5 km area^2. This paper shows that human footprint scores remained moderately high along the western side of the Antarctic Peninsula, but decreased south of 67°S latitude. In contrast, footprint values on the eastern side of the Antarctic Peninsula were substantial only at latitudes above 65°S” (Figure 235).

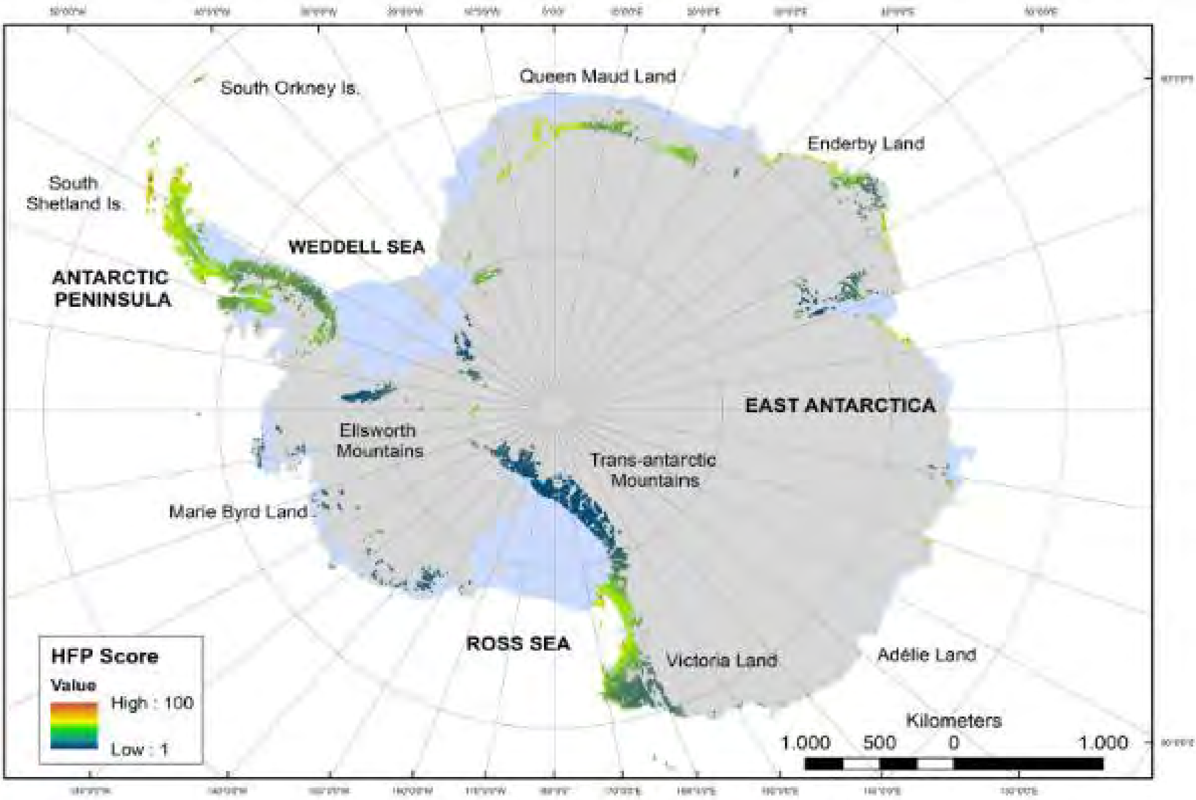


Figure 236: Footprint of human activities in Antarctica (Taken from Pertierra et al, 2017)

Finally, we can affirm that the northern region of the Antarctic Peninsula is a biodiversity hotspot highly threatened by climate change and subject to increasing pressure from other human activities, and has been identified as a priority area for conservation (Capurro, 2021). The region where the Petrel Base is located has the highest values of pressure from human activities (scientific stations, research tasks, logistics, tourism and fishing) (Figure 236).

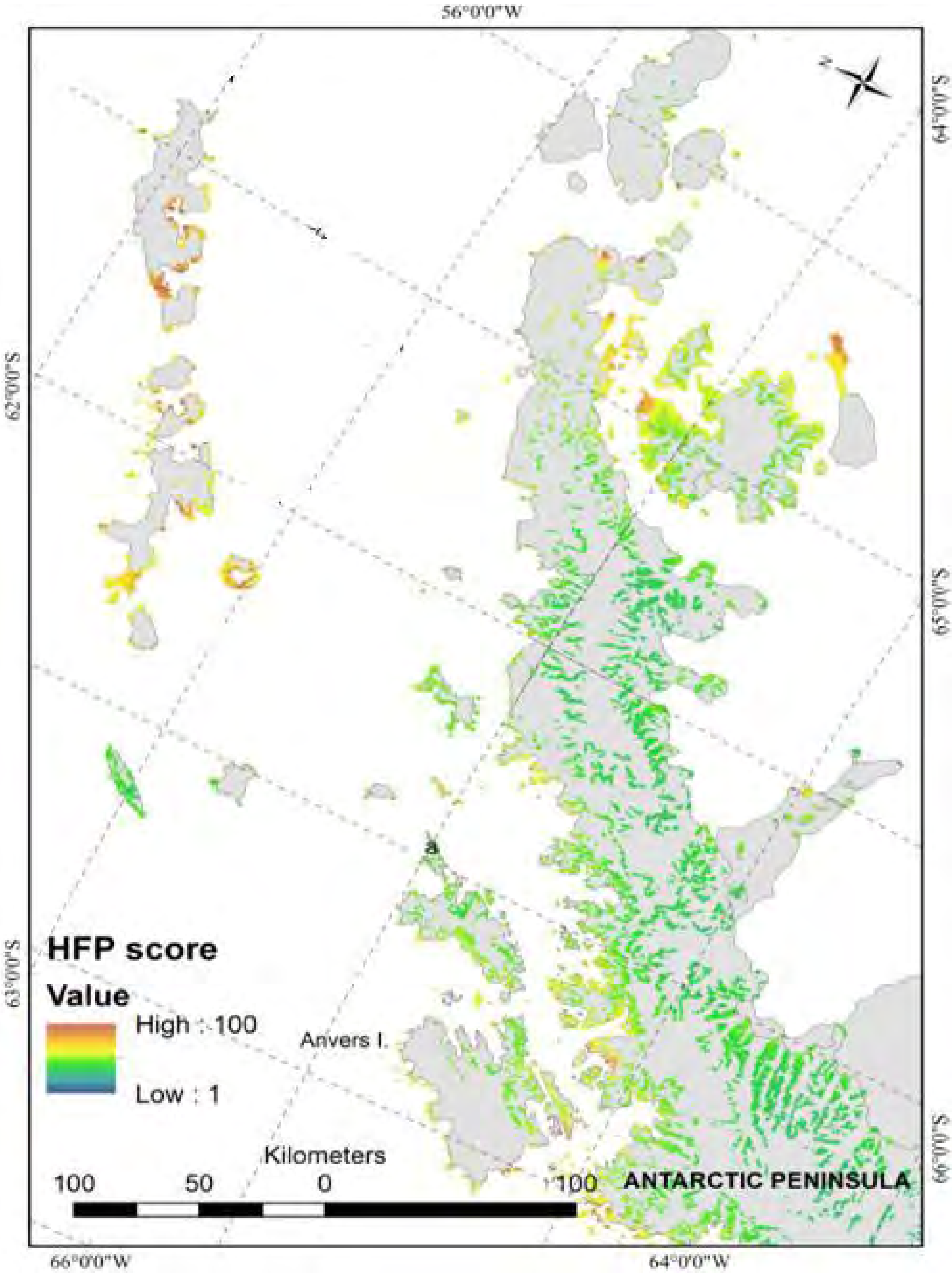


Figure 237: Footprint of human activities in North Antarctica (modified from Pertierra et al, 2017)

6.1.4.2 Problems and threats of non-native species

Biological invasions constitute one of the most important threats to biodiversity worldwide, risking the survival of species and are responsible for great changes in the structure and functioning of ecosystems, for this reason non-native species are one of the main threats to biodiversity worldwide. In the case of Antarctica in 1964, the Antarctic Treaty System (ATS) established the prohibition of the introduction of non-native species to the Antarctic continent, in the “Agreed Measures for the Conservation of Antarctic Fauna and Flora”, measures that already are not in force and that indicated a series of exceptions to this prohibition, such as sled dogs. Finally, the “intentional” introduction was prohibited from the entry into force of the Protocol to the Antarctic Treaty on Protection of the Antarctic Environment. Despite Antarctica’s isolation and harsh climatic conditions, invasion of species is now recognised as a serious risk to the region: Antarctic ice-free areas and surrounding sub-Antarctic islands are home to a large proportion of the seabird species of the world, and their terrestrial biotas, despite not having a large number of species, include a large proportion of endemic and well-adapted taxa (Resolution 4 - 2016) (Figure 238).

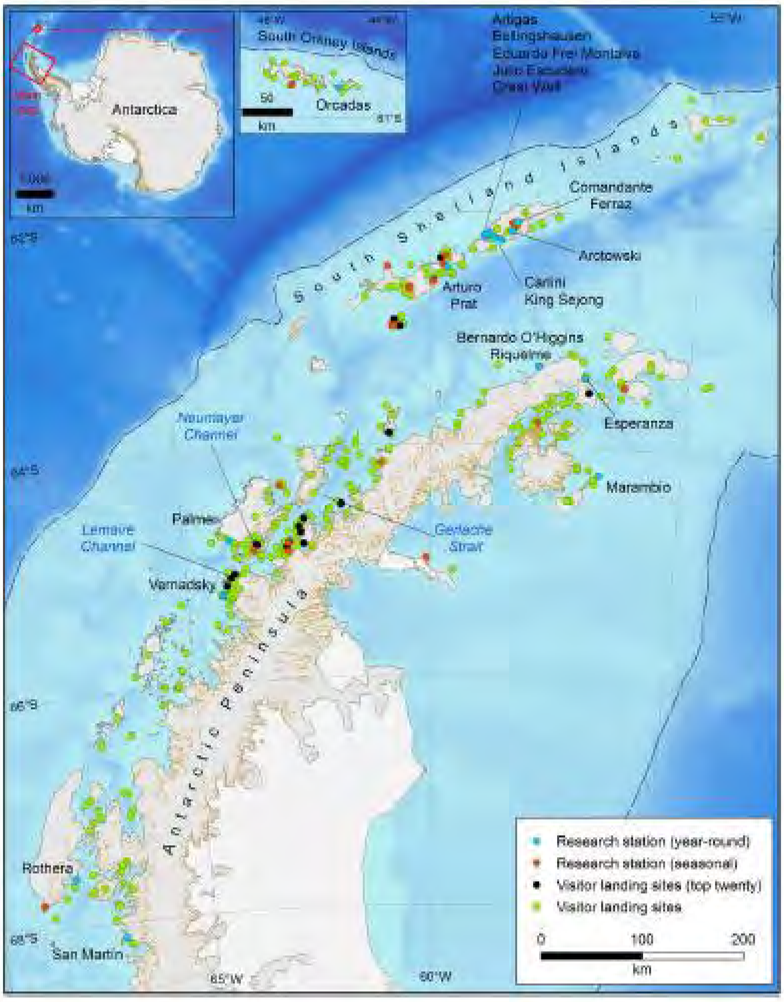


Figure 238: Map showing the presence of scientific stations and tourist visit sites in the north of the Antarctic Peninsula (Taken from Hughes et al (2019)

This situation occurs, because despite the prohibition of the Protocol, currently the introduction of non-native species in an “unintentional” way and their establishment in Antarctica represents one of the most important threats to its biodiversity, both at the species level individuals as well as at the level of functioning and structure of ecosystems. There are two causes of this situation. On the one hand, it must be taken into account that climate change is manifesting itself at great speed in some sectors of Antarctica, which is why it is probable that the number of introduced species will increase and that colonisation by non-native species will be favoured, with the consequent increase in their impact on ecosystems, as can already be seen in the sub-Antarctic islands. The other cause is the increasing movement of people by ships and planes to Antarctica to carry out different tasks (logistics, research, tourism, etc.), which can potentially transport exotic organisms or their propagules (McCarthy, Peck, Hughes, Aldridge, 2019)

So the probability of such invasions depends on the number of propagules of alien species entering the region (which potentially increases with the number of visits), their probability of establishment (which increases with climate change), and the extent to which these established species can spread and disrupt local ecosystems. Understanding the initial phases of spread and establishment is especially important for applying management measures that minimise the risks posed by invasive alien species because the invasion process is contingent; that is, a species cannot spread to a new area if its propagules have not arrived and established themselves (Chown et al, 2012). The conclusion in relation to this problem is that a species cannot spread to a new area if its propagules have not arrived and established themselves.

The process of arrival and establishment of non-native species through human activity in Antarctica is relatively well understood. Propagule pressure, from seeds, plant fragments, live invertebrates, and fungi, is applied via a variety of vectors, including migratory human visitors. Anthropogenic pathways include National Antarctic Programmes and tour operator aircraft and ships, which in a matter of hours or days can traverse the waters surrounding Antarctica. Routes often consist of multiple visit points, some even starting in the northern hemisphere, as many programs and operators have bipolar interests, allowing propagule transport of cold-adapted taxa across hemispheres (Bergstrom, 2021).

One of the most frequent and effective ways of introducing non-native species is by human transport. Clothing (clothing pockets, boots, velcro closures on garments), personal equipment (backpacks, bags, camera cases, tripod) as well as scientific instruments and work tools can function as effective vectors for the transport of larvae of insects, seeds, or propagules that may develop in the conditions of the Antarctic environment, especially from the effects of climate change, and thus become an invasive species. Recent work, including the International Polar Year project “Aliens in Antarctica” has identified the main pathways and vectors of unintentional introduction of ENN in the region.

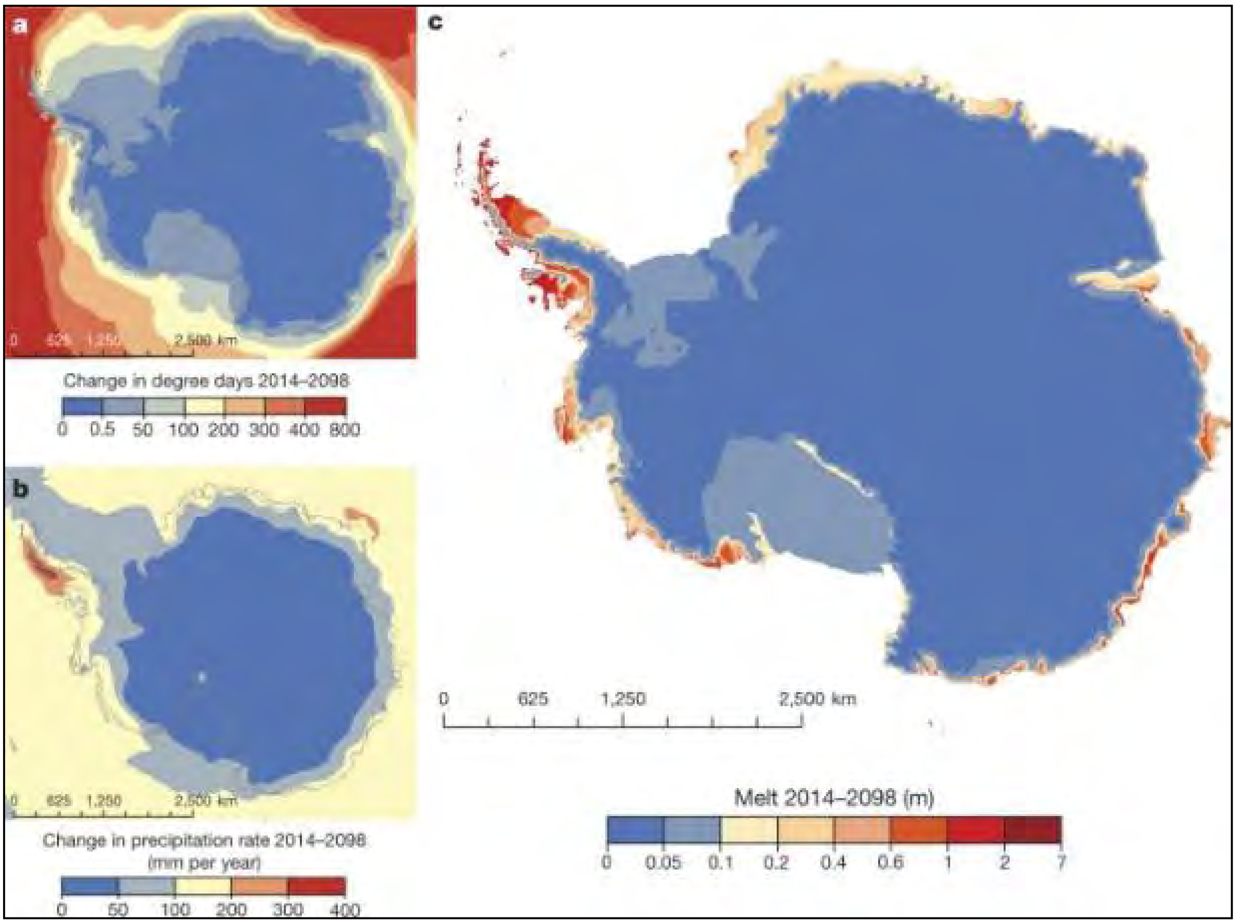


Figure 239: Changes in temperature, precipitation and ice melt in Antarctica. In all three cases it is observed that the most serious situation is in the north of the Antarctic Peninsula. Taken from Lee et al (2017)

The foregoing is aggravated by the situation of global forcing changes in the southern oceans such as the ozone hole, changes in wind systems and in temperature regimes that have among their consequences in Antarctica the loss of sea ice, the retreat of glaciers and the acidification and warming of the ocean (Morley et al; 2020). This global situation intersects with the situation of local drivers of change (activities or processes that cause physical or ecological changes) and that influence Antarctic ecosystems (Grant et al, 2021). Among the most significant effects pointed out by this work is the potential increase in the invasion of species.

In a particular way we can analyse the situation of the Antarctic Peninsula and which is indicated as one of the regions with the highest risk of settlement of non-native species (especially the north of it). This is because, on the one hand, it is one of the regions of the planet with the greatest effect of climate change. Global results for Antarctica mention that in the last century the average annual temperature has risen approximately 1.2°C (Vaughan et al, 2003), but nevertheless the Report of the SCAR Antarctic Scientific Research Committee we can mention that in relation to the temperature surface, a significant increasing trend has been observed across the entire Antarctic Peninsula since 1950, being more important in the western and northern part of the peninsula (Figure 238).

Temperatures on the eastern side of the Antarctic Peninsula have shown higher elevations during the summers and autumns, with an average increase of +0.41°C per decade (Turner *et al*, 2009). This situation would worsen according to most climate change scenarios studied. Cumulative degree-days in ice-free Antarctica calculated using climate forecasts for 2100 suggest that the risk of alien species establishment remains highest in the Antarctic Peninsula area species (Chown *et al*, 2012).

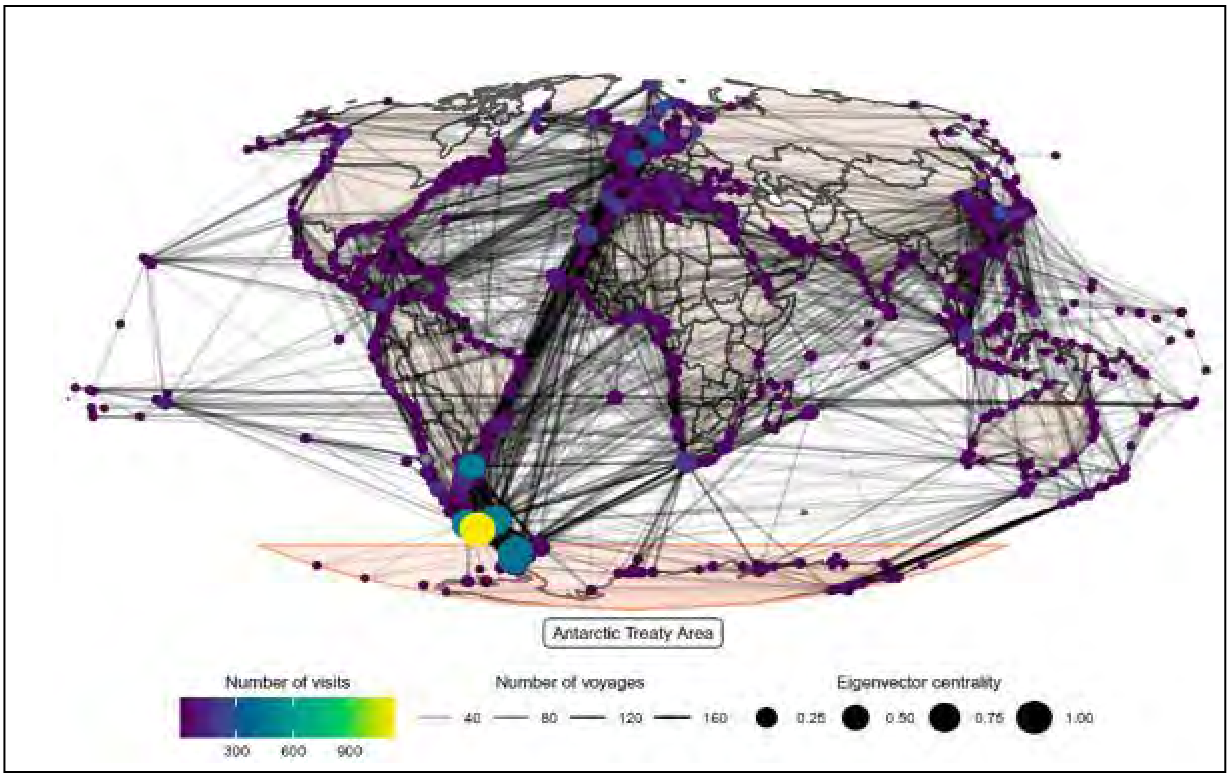


Figure 240: Global port-to-port traffic network of all ships that visited Antarctica from 2014 to 2018. Ships connect Antarctica with all regions of the world, with major hubs in South America and particularly strong connections across the Atlantic to Europe. The lines represent trips between places, and the darker lines indicate more trips, but the lines do not reflect the distance travelled. Taken from McCarthy, Peck, & Aldridgea (2022)

In relation to the other causal component of the problem, the number of visits. The Antarctic Peninsula is the region of Antarctica with the largest number of bases, with the largest number of tourist visits and with the highest intensity of air and navigation traffic (McCarthy, Peck, Hughes, Aldridge; 2019) (Figure 239). This transforms this region, especially in the north of the peninsula, into the region with the greatest potential risk of settlements of non-native species. This situation was reflected when calculating a risk index, based on the pressure and origin of the propagules, and the climatic suitability of the ice-free areas of the continent, which indicated that the coast of the Western Antarctic Peninsula and the islands off the coast of the Peninsula have the highest current risk of establishment of exotic species (Chown *et al*, 2012).

It should be borne in mind that invasive species are those non-native species that are expanding their range in the colonised Antarctic region, which causes the displacement of native species and causes significant damage to biological diversity or to the functioning of ecosystems. On the other hand, non-native/exogenous species are understood to be organisms that occur outside their current or previous range and potential for natural dispersal, whose presence and dispersal in any biogeographic region of the Antarctic Treaty area is due to non-intentional human action.

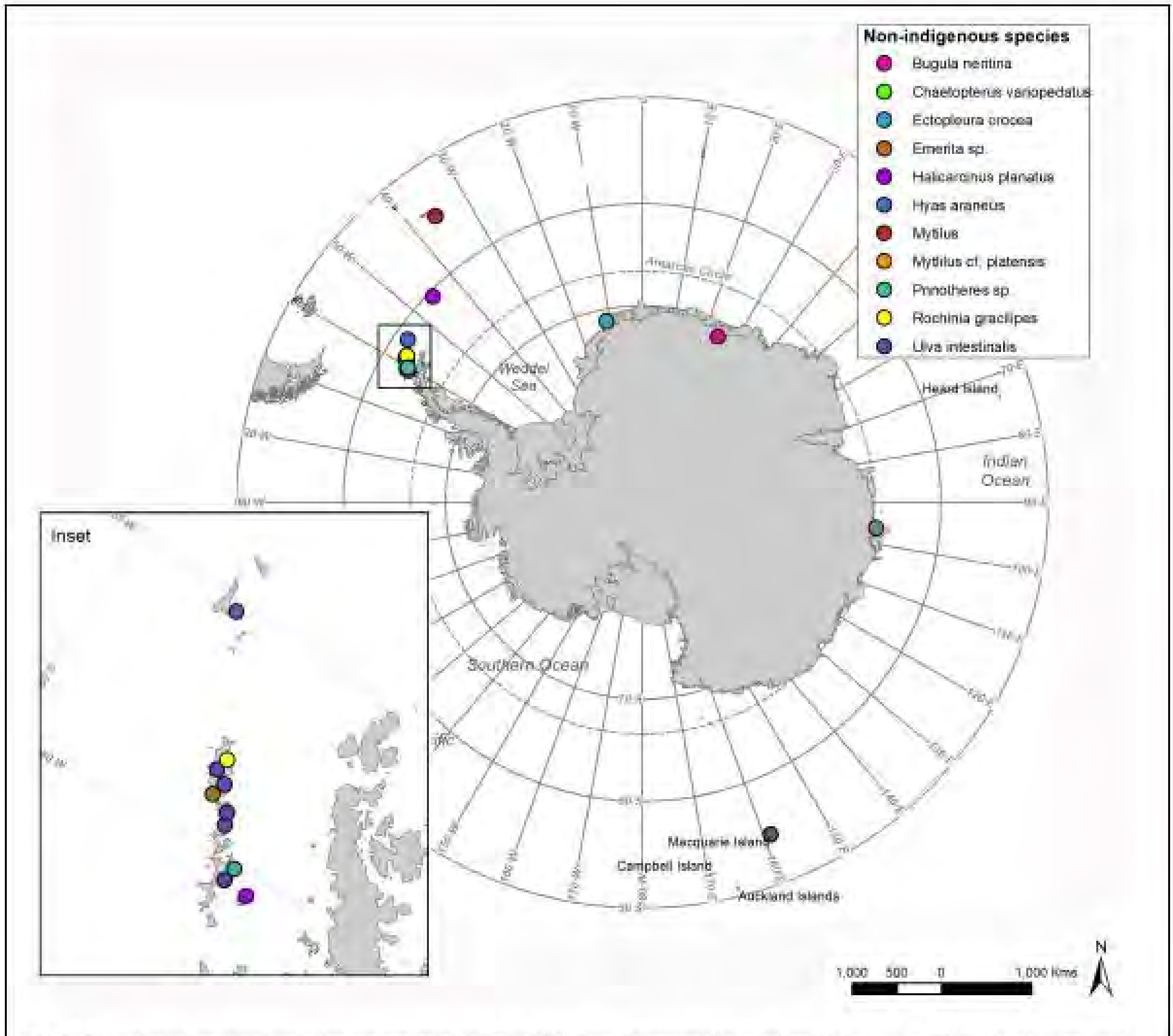


FIGURE 3 | Locations of records of non-indigenous species within the MEASO region. References cited in text and McCarthy et al. (2019). Map produced using data from the SCAR Antarctic Digital Database.

Figure 241: Map showing the location of sites where non-native species have been detected in Antarctica (modified from Morley et al (2020).

The first introductions of non-native organisms to Antarctica and sub-Antarctic islands date back to the 18th century, at the hands of the first explorers and sealing expeditions. Since then, numerous species have been deliberately or accidentally introduced to areas near and south of the Antarctic Convergence. Although most of them failed to develop south of 60 degrees south, some of them have successfully established themselves on the Subantarctic islands, causing significant impacts on local species. Thus, although only two non-native plant species (genus Poa) have been persistently established in the South Shetland Islands and on the coasts of Punta Cierva (Antarctic Peninsula), more than 100 non-native vascular plants are present in practically all the subantarctic islands. Something similar occurs with terrestrial invertebrates: while there are numerous non-native species on the sub-Antarctic islands, only two non-native species (a worm and a midge) have managed to colonise, although without invading, Antarctic coastal habitats. Likewise, there is evidence that seems to indicate that some microorganisms have been introduced to the Antarctic fauna and have spread as a consequence of human activities. The problem of non-native species is perhaps the greatest environmental pressure in the northern region of the Antarctic Peninsula due to environmental changes and the greater presence of human activities (Figure 240).

6.1.5 Impacts and threats of Climate Change in the Area

Climate Change is pointed out as the most significant environmental pressure in this region of Antarctica. Since in 2009 the Scientific Committee on Antarctic Research (SCAR) published its historic report “Antarctic Climate Change and the Environment (ACCE Report)” (Turner *et al*. 2009), this organisation has been detailing the observed impacts of climate change in Antarctica and also establishing future threats from different climate scenarios. The latest SCAR update, “Antarctic Climate Change and the Environment: A Decadal Synopsis and Recommendations for Action” (Chown *et al*, 2022), shows that this problem has worsened significantly in recent decades and that important changes are expected in the coming decades. Without a doubt, the greatest global forcing on the Antarctic continent are associated with the climate system and its changes.

However, in order to frame the current environmental problem (understood within the framework of complex systems due to their multi-causality and the different levels of analysis required), we would like to mention that although climate change is one of the greatest concerns in the world, various research studies have shown that although climate change is a major problem, habitat modification and resource use are the main drivers of diversity losses (Caro et al, 2022). Although habitat modification appears to have less of an impact in Antarctica, concerns have been raised about increased stress on Antarctic systems due to global environmental change and increasing interest in the region's resources (fisheries and mineral resources), but it should not be overlooked that increasing ice-free surface and human activities are likely to increase, potentially modifying these habitats (Chown *et al*, 2012).

The Antarctic Peninsula has been identified as one of the areas of our planet that has warmed the fastest in the last 50 years (Vaughan et al. 2003). There is increasing evidence that Antarctic lakes are sensitive indicators of climate change (Quayle et al. 2002), as well as valuable centres of biodiversity (Vincent & Laybourn-Parry 2008). Below we will briefly describe the impacts and threats of climate change for the Antarctic Peninsula in accordance with the provisions of the latest SCAR report, “Antarctic Climate Change and the Environment: A Decadal Synopsis and Recommendations for Action” (Chown *et al*, 2022).

This report mentions that there is very clear and compelling scientific evidence that, due to the current trajectory of emissions of CO_2 and other human-induced greenhouse gases, the atmosphere and ocean will continue to warm, the ocean will continue to acidify, the patterns of atmospheric and oceanic atmospheric and oceanic circulation, the cryosphere will continue to lose ice in all its forms and the sea level will rise. Although uncertainties remain about various aspects of the Earth System, what is known is indisputable. The trends, based on observations and confirmed by modelling, will accelerate if high rates of CO_2 and other greenhouse gas emissions continue.

6.1.6 Changes in Temperatures and Precipitation

According to the latest SCAR report (Chown *et al*, 2022) the global mean surface temperature has increased in the last 50 years at a rate than in any other period of at least the last 2000 years (medium confidence), due to human influences on climate [IPCC AR6 WGI 2.3.1.1.2; Cross section Box TS.1]. Global mean surface temperature is 1.09°C warmer (for 2011-2020) than the 1850-1900 baseline, assessed across multiple data sets. These authors also mention that surface warming has been more pronounced on land than in the ocean. For the period 2011-2020, the global air temperature at the land surface (LSAT) has increased by 1.59°C (1.34-1.83) since 1850-1900 [IPCC AR6 WGI 2.3.1.1.3], compared to an increase of 0.88°C (0.68-1.01) in the average annual temperature of the sea surface (TSM).

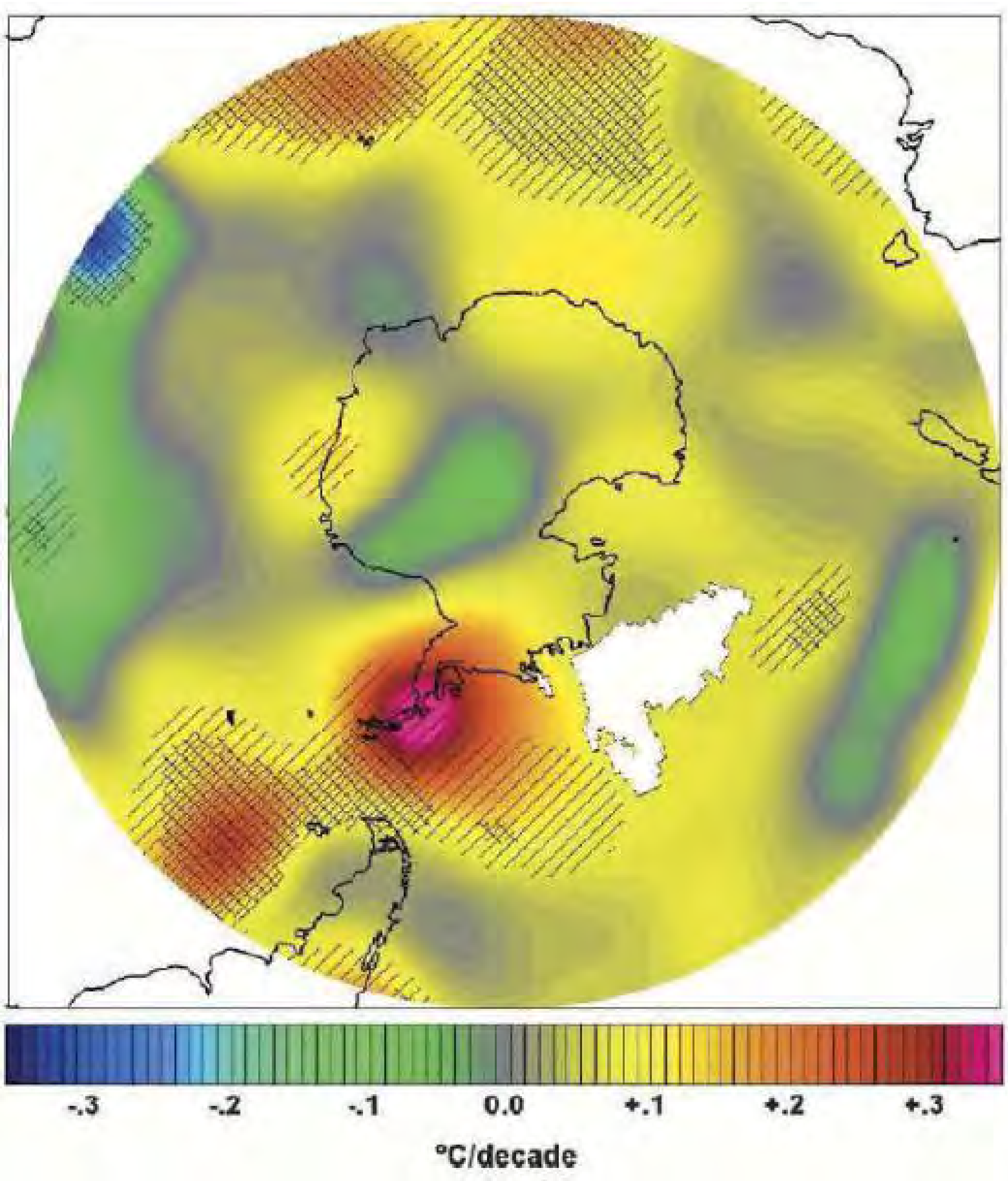


Figure 242. Estimation of temperature trends. Taken from Turner et al. (2009)

According to Turner et al (2009) warming on the western side of the Antarctic Peninsula has been greatest during the winter season, with an increase in winter temperatures in Vernadsky of +1.03ºC/decade between 1950 and 2006 (Figure 241). In this area there is a high winter correlation between sea ice extent and surface temperatures, suggesting more sea ice during the 1950s and 1960s and a progressive reduction since then. King and Harangozo (1998) found a number of ship reports from the Bellingshausen Sea in the 1950s and 1960s, when sea ice was well to the north of locations found in the period of satellite data availability, suggesting some periods of greater extent of sea ice than in recent decades. However, data on extent, however, data on sea ice extent prior to the late 1970s is very limited, so we have largely circumstantial evidence for a sea ice maximum in the mid-century at this time. At the moment it is not known if the warming in the Peninsula is due to natural climate variability or anthropogenic factors.

Temperatures in the eastern part of the Peninsula have risen more during the summer and autumn months, with Esperanza experiencing a summer increase of
0.41ºC/ decade between 1946-2006. This increase in temperature has been related to a strengthening of the westerly winds that has occurred as the SAM has passed into its positive phase (Marshall *et al*., 2006). The intensifying winds have caused more relatively warm maritime air masses to cross the peninsula and reach the low ice shelves on the eastern side.

According to Chown *et al.* (2022) in Antarctica, surface warming trends have shown large spatial and decadal variability. Some areas have warmed by more than 0.2°C per decade since 1981, while other areas have shown no significant change over the same period [IPCC AR6 WGI Figure 2.11]. Since the 1950s, near-surface air temperatures in the west and north of the Antarctic Peninsula and in West Antarctica (eg, in North Antarctica) are most likely. West Antarctica (for example, Vernadsky Station warmed by 0.46 ± 0.15°C per decade between 1951-2018) (medium confidence) [IPCC AR6 WGI Atlas 11.1.2]. The centennial-scale warming trend for the Antarctic Peninsula is most likely an emerging signal compared to natural variability, while the West Antarctic warming trend is at the upper end of centennial-scale trends for the last 2000 years (medium confidence). During the same period, no significant changes were observed along the eastern Antarctic peninsula [IPCC IE6 GTI Atlas 11.1.2].

Regarding precipitation, according to Turner et al (2009), net precipitation (in climate models it is precipitation minus evaporation and ablation) over Antarctica is an important factor in the mass balance of the continental ice sheet. Surface sublimation and snowblowing processes also contribute to determining the local mass balance of the ice sheet, but these factors have an important influence on the mass balance.

Specifically in the north of the Antarctic Peninsula, Carrasco and Cordero (2020) determined that there was a global increase in precipitation from 1970 to the early 1990s and a negative trend between 1991 and 1999 with a decrease in rainfall. On the other hand, although there was also an increase in precipitation events from 1970 to the early 1990s, there was a decreasing trend of precipitation events during the 2010s. This entails that the positive trend in the accumulation of precipitation registered during this period is due to the increase in extreme precipitation events. Analysis of the type of precipitation shows an increase (decrease) in snow (rain) episodes from the mid-1990s to the mid-2010s during the summer season. These opposing trends are related to the summer cooling that affects the Antarctic Peninsula region.

These same authors have pointed out that the increasing trend in rainfall was interrupted by a downward trend from the early 1990s to the early 2000s. The ENSO index (SOI) reveals that during the 1980s and 1990s El Niño episodes prevailed, which entails a decrease in precipitation, although it also entails an eastward shift of the Amundsen Low Sea (ASL), favouring precipitation near the Antarctic Peninsula. The decreasing trend of precipitation during the 1990s coincides with the prolonged episode of El Niño 1991-1994 and the strong El Niño event in 1997/1998. The positive trend in precipitation resumed in the early 2000s. La Niña episodes have prevailed from the early 2000s to the mid-2010s, entailing an overall increase in precipitation. However, it also entails a westward shift of the ASL, which may be related to the fact that the total annual number of precipitation days (events) did not increase during this period.

According to Turner *et al* (2009) the predicted change in precipitation depends on and is greater in winter than in summer. According to Chown *et al.* (2022) Land precipitation is projected to increase in the 21st century under very low conditions (likely range: -0.2-4.7%; SSP1-1.9) and high (probable range: 0.9-12.9%; SSP5-8,5) [IPCC AR6 WGI Box TS.6]. Precipitation is also very likely to increase over Antarctica in 2100 by about 5%, 12% or 25% under the low (SSP1-2.6), moderate (SSP2-4.5), and high (SSP5-8.5) GHG emissions scenarios, respectively, relative to 1995-2014 [IPCC AR6 WGI Atlas 11.1.4].

According to Chown *et al.* (2022) the greatest increase in mean precipitation is projected for the coastal areas of West Antarctica and the Antarctic Peninsula [IPCC AR6 WGI Atlas 11.1.4]. Changes in precipitation in the Southern Ocean will result in increased snowfall [IPCC IE6 GTI Atlas 11.1.4]. However, models in the predicted changes in the seasonality of rainfall in the Antarctic region [IPCC AR6 WGI Atlas 11.1.4] in the Antarctic region [Box 8.2, Figure 1 of IPCC AR6 GTI]. What happens with precipitation trends in the form of rain is very important due to its effects on soil dynamics and in species due to its impacts on infrastructure, and particularly in the case of Petrel, on the runway.

6.1.7 Rising sea levels

All the Scientific Stations that are close to the coast in Antarctica will be subject to the threats posed by the rise of the sea level, therefore, it is very important to plan the new activities taking into account the projected heights. According to Chown *et al.* (2022) the Antarctic ice sheet contains enough water to contribute, if fully melted, about 58 m of global mean level rise. Such a significant mass loss is not expected even on models extending up to 2300 (DeConto *et al*. 2021). However, land ice (Antarctic, Arctic, and mountain glaciers) loses mass at an accelerating rate (Hugonnet *et al*. 2021), endangering some 800 million people due to sea level. 800 million people at risk from sea level rise [IPCC AR6 WGII].

These authors indicate since 1901, the global average sea level has risen 0.20 m (0.15-0.25), at a faster rate than in any other century of the last three millennia (high confidence) [IPCC AR6 WGI 2.3.3.3; 9.6.1.1]. Since at least 1971, the increase has been attributed to human activities (very likely) [IPCC AR6 WGI 3.5.3.2]. Change during the 20th century has been dominated by ocean thermal expansion (thermosteric sea level rise) and mass loss from glaciers and the Greenland ice sheet [IPCC AR6 WGI 9.6.1.1]. Antarctica's contribution to the increase has so far been quite limited, but has increased recently. In total, mass loss between 1992 and 2020 has contributed 7.4 mm (5.0-9.8) to global average sea level rise. [IPCC AR6 WGI 9.4.2.1].

Antarctica is expected to contribute 0.11 m (probable range: 0.03-0.27) in the low emissions scenario and 0.12 m (probable range: 0.03-0.34) in the high emissions scenario (medium confidence) [IPCC AR6 WGI Table 9.8]. Thermal expansion of the oceans is expected to contribute greatly to future sea level rise from the ocean and, in the high emissions scenario, from mass loss from glaciers and the Greenland ice sheet [IPCC AR6 WGI Table 9.8].

Antarctic contributions are expected to be rather small due to increased snowfall associated with warming air temperatures, which will offset the loss of mass from glaciers, compensating for loss of mass from increased ice drainage to the ocean and surface meltwater runoff in all the SSS in all SSP scenarios for the 21st century. Antarctica could even contribute negatively to global average sea level rise up to 2100 (medium confidence) [IPCC AR6 WGI 9.4.2.3].

High uncertainty surrounding low-probability, high-impact ice sheet processes, including sea ice sheet instability and sea ice cliff processes, means that Antarctica may contribute significantly more to the rise of sea level in the 21st century [IPCC AR6 WGI 9.4.2.3] than expected [IPCC AR6 WGI 9.6.3; Table 9.4].

Finally, according to DeConto and Pollard (2016) the polar temperatures of the last million years have been, at times, slightly warmer than today, but the global mean sea level has been between 6 and 9 metres higher in the last Interglacial (between 130,000 and 115,000 years ago) and possibly higher during the Pliocene (about three million years ago). In both cases, the Antarctic ice sheet has been implicated as the main culprit, pointing to its future vulnerability. Here we use a model that combines ice sheet and climate dynamics—including hitherto underestimated processes linking atmospheric warming to hydrofracturing of reinforcing ice shelves and structural collapse of sea-terminating ice cliffs which is calibrated with Pliocene and Last Interglacial sea level estimates and applied to future greenhouse gas emission scenarios. Antarctica could contribute to raising sea levels by more than 1 metre between now and 2100 and more than 13 metres between now and 2500, if emissions are not reduced. In this case, atmospheric warming will soon become the dominant factor in ice loss, but prolonged warming of the oceans will delay their recovery for thousands of years.

6.1.8 Glacier retreat

According to Turner *et al* (2009) the ice cover of the Antarctic Peninsula is a complex alpine system of more than 400 individual glaciers that drain a high and narrow montane plateau. The tidal/marine glacier systems of this region (excluding the ice shelves and ancient tributary glaciers of the Larsen A, B and Wordie ice shelves) cover an area of 95,000 km^2 and an average net annual accumulation of 143 ± 29 Gt/year). Changes in the ice margin around the Antarctic Peninsula based on data from 1940 to 2001 revealed that of the 244 marine glaciers draining the ice sheet and associated islands, 212 (87%) have shown global retreat from their earliest known position (which, on average, was 1953). The other 32 glaciers have shown global advance, but these advances are generally small compared to the scale of the retreats observed.

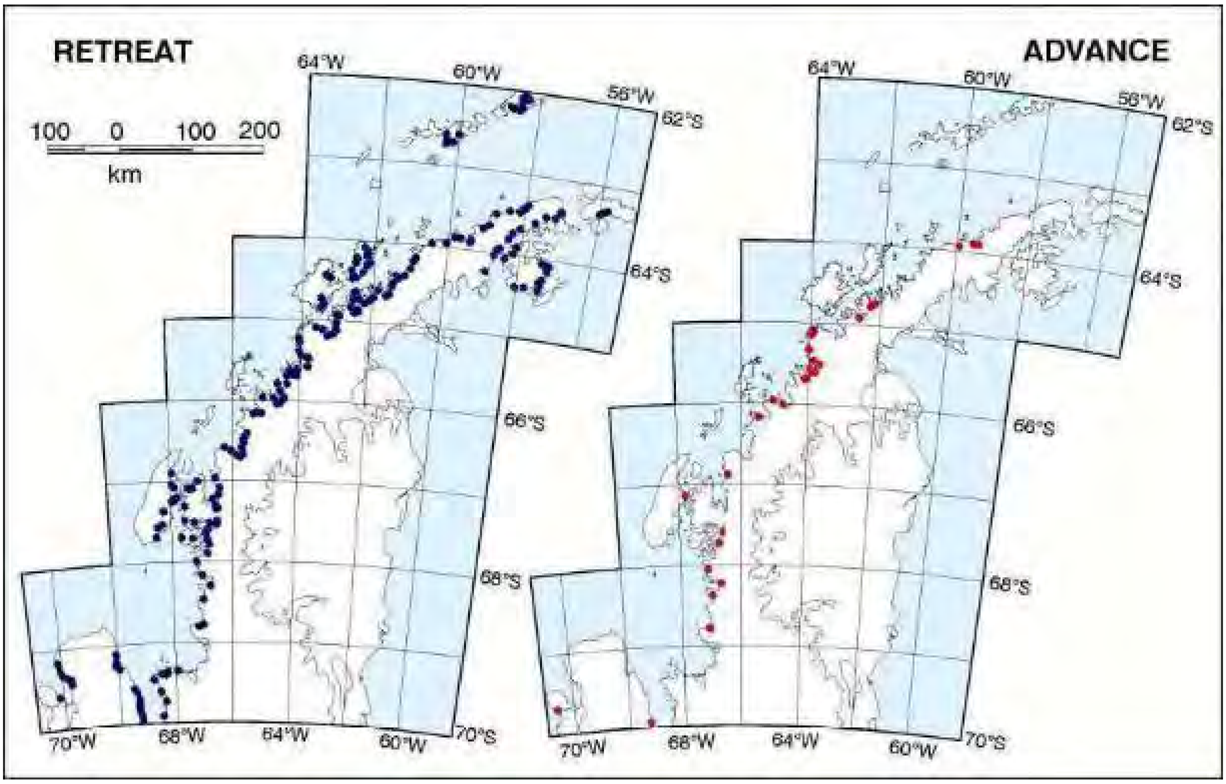


Figure 243: Global change observed in the glacial fronts since the first records. (DeCook et al., 2005).

Turner et al (2009) the glaciers that have advanced are not grouped in any pattern, but rather are located uniformly along the coast (Figure XXX). Examination of the chronology of changes along the peninsula indicates that from 1945 to 1954 there were more glaciers advancing (62%) than retreating (38%). Since then, the number of retreating glaciers has increased, with 75% retreating in the period 2000-2004. The results indicate a transition between medium advance and retreat; a southward migration of that transition at a time of receding ice shelves and progressive atmospheric warming; and a clear regime of retreat of the ice shelves that now exists across the entire Antarctic Peninsula (Figure 242).

The rapidity of the migration suggests that atmospheric warming may not be the only driver of glacier retreat in this region. Glaciers with fully embedded marine caps show unusually complex responses to changes in mass balance, as in addition to normal forcings, they are also subject to oceanographic forcings and subglacial topography. Future analysis of changes in all boundary conditions may reveal why glaciers have responded in this way.

6.1.9 Permafrost stability

Since facilities in Antarctica generally sit below the active layer of permafrost, what happens to their dynamics is very important. According to Turner et al (2009) permafrost temperatures and depth of the active layer are sensitive indicators of climate because they integrate different climatic factors (i.e., air temperature, seasonal snow cover, wind) that interact with each other and with the soil surface features (i.e., vegetation, surface microrelief). Permafrost temperatures and the thickness of the active layer respond to climatic variations on different time scales because the permafrost thermal regime reacts: a) seasonally above the zero annual amplitude (ZAP) depth, b) annually in the AAP, and c) from years to millennia at a progressively greater depth. The thickness of the active layer responds seasonally to the climatic climate.

In the other aspect mentioned, permafrost, according to SCAR (Turner *et al*, 2009) it is likely that there will be a reduction in the permafrost area, accompanied by subsidence of the ground surface and associated mass movements. The change is most likely in the northern Antarctic Peninsula and in the South Shetland and South Orkney Islands and in the coastal areas of East Antarctica. So forecast changes entail risks to the infrastructure and therefore become critical when analysing long-term infrastructure projects.

Based on the changes in the observed and expected climate on Seymour Island, it was possible to determine in a specific way that a clear positive trend can be observed in the increase in the average annual average temperature. However, although Seymour Island is located in the continuous permafrost zone, with ground temperatures close to –5°C and a thickness of approximately 200 metres (Silva Busso, Sánchez and Fresina, 2000), the observed and expected changes in temperatures have significant effects on the dynamics and thickness of the active layer of permafrost (top layer of permafrost that thaws in summer and refreezes in autumn).

The thickness of the active layer is highly variable, and depends on environmental conditions. In the case of Marambio Island, the minimum thickness was detected on the plateau, where it reached 0.4-0.5 m, while the maximum thickness of 1.5-1.6 m was measured on the gentle slopes to the north and northwest (Yermolin *et al*, 2002). However, the depth of seasonal thawing on Marambio Island depends on climatic conditions and soil moisture (Yermolin & Skvarca, 2004). It should be noted that the thawing thickness (Zd) is calculated using the Stefan equation (Nelson *et al*, 1997) and that the higher the temperature, the greater the thaw thickness. However, it should be noted that according to the SCAR report (Turner *et al*, 2009) there has been no evidence of a major reduction in the permafrost area in the last 100 years (p. 345), but notes that the melting of permafrost should be a concern for COMNAP due to the impact of this process on the bases.

Regarding future projections, Turner et al (2009) mention that, although a significant reduction in the permafrost surface is expected in the next 100 years, thawing of the ground can cause subsidence of about 15,000 km^2 of the ice-free regions of Antarctica. Areas especially sensitive to this effect, known as thermokarst, are found in coastal areas such as Casey Bay, near Molodezhnaya Station (70.5ºS, 12ºE), the Pennell-Borchgrevink coasts in northern Victoria (70.5-73ºS, 165-171ºE), the Scott Coast in the area of McMurdo Sound (74-78ºS, 165ºE), and throughout the Antarctic Peninsula and its offshore islands (55-72ºS, 165ºE). (55-72ºS, 45-70ºO).

They also mention that in recent years there have been significant changes in hydrological and geomorphological processes as a consequence of unusual summer warming. For example, in the McMurdo Dry Valleys (MDV), the average summer temperature (December-January) between 1994 and 2003 was -0.19ºC, and during that period there were 30 days of the year when the average daily temperature was above 0ºC. Between December 2000 and January 2001, the average temperature was 1.5ºC, and there were 43 days in which the average daily temperature exceeded 0ºC. This prolonged warming caused rivers to rise and inland lakes to expand. (see also Foreman et al., 2004). These extreme events can have long-lasting effects.

Turner *et al* (2009) state that around 90% of the summer bases in Antarctica are located in areas sensitive to the formation of thermokarst and the loss of mass. For this reason, the effect of climate warming on permafrost thawing should be a reason why permafrost melting should be of concern to the Council of Antarctic Programme Managers (COMNAP). In this sense Chown *et al.* (2022) project permafrost to thaw in all regions where it is present (high confidence) [IPCC AR6 WGI TS 4.3.1]. Simulations predict continued warming and permafrost degradation, but there is great uncertainty about the magnitude and timing of the predicted changes [Smith et al. 2022]. The total ice-free land area in Antarctica is expected to increase under future climate scenarios by up to 25% by 2098 [Lee et al. 2017]. Changes in ice cover are expected to be more pronounced along the north of the North Antarctic Peninsula and offshore Antarctic islands, so this aspect is central to Petrel Base.

6.1.10 Seismic movements and Tsunamis

One of the risks that must be evaluated for the construction of the new Petrel Base is to determine the state of the seismic risk situation in the northern part of the Antarctic Peninsula. For this we will take the report of the Argentine Antarctic Institute “Evaluation of seismic hazard in the region of the extreme north of the Antarctic Peninsula and surrounding seas” prepared by Zambrano, Zakrasek and Lirio (2022).

These authors mention that the Scotia Arc includes the development of a series of islands and continental blocks that allow the southern tip of the Andes to continue with the Antarctic Peninsula (Ramos 1999) (Figure 243). Geological and geophysical studies indicate that this configuration represents the scenario of fragmentation and dispersion of continental blocks that were driven by an eastward-directed sublithospheric mantle flow from the early Paleogene (eg: Alvarez 1982, Barker 2001). It also represents the circumpolar sector with the highest concentration of seismiotectonic activity around the Antarctic Continent, where the high seismicity level and distribution of seismic foci are the product of intense deformation along plate margin segments.

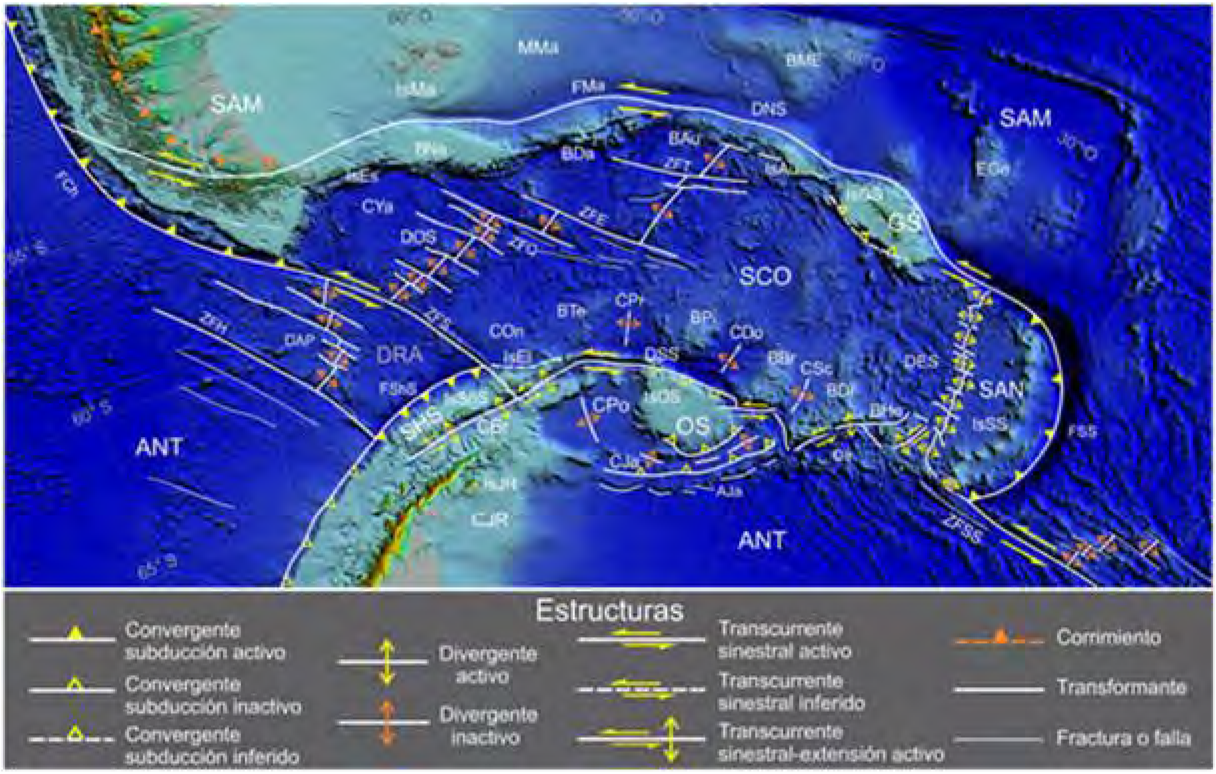


Figure 244: Main structural guidelines and tectonic regimes (active and fossil) in the Scotia region and extreme north of the Antarctic Peninsula. SAM: South American Plate; ANT: Antarctic Plate; SCO: Scotia Plate; SAN: Sandwich Plate; DRA: Drake Plate (formerly Phoenix Plate); SHS: South Shetland Plate; OS: South Orkney Islands Block; GS: South Georgia Islands Block; MMa: Falklands Plateau. IsEs: Staten Island; IsMa: Falkland Islands; IsAu: Aurora Islands; IsGS: South Georgia Islands; IsSS: South Sandwich Islands; isOS: South Orkney Islands; IsEl: Elephant Island; IsShS: South Shetland Islands; IsJR: James Ross Island; CJR: James Ross Basin; CBr: Bransfield Basin (in the Bransfield Strait); CPo: Powell Basin; C.J.: Jane Basin; COn: Ona Basin; CPr: Protector Basin; CDo: Dove Basin; CSc: Scan Basin; CYa: Yaghan Basin; BNa: Namuncurá Bank; BDa: Davis Bank; BAu: Aurora Bank; BME: Maurice Ewing Bank; EGe: Georgias Northeast Elevation; BHe: Herdman Bank; BDi: Discovery Bank; BBr: Bruce Bank; BPi: Pirie Bank; BTe: Terror Bank; FMa: Falklands Trench; FCh: Chilean Trench; FSS: South Sandwich Trench; FShS: South Shetland Trench; AJa: Jane Arc; DNS: North Scotia Ridge; DSS: South Scotia Ridge; DOS: West Scotia Ridge; DES: East Scotia Ridge; DAP: Antarctic-Phoenix Ridge; DIr: Irizar Ridge; ZFH: Hero Fracture Zone; ZFS: Shackleton Fracture Zone; ZFSS: South Sandwich Fracture Zone; ZFQ: Quest Fracture Zone; ZFE: Endurance Fracture Zone; ZFT: Tehuelche Fracture Zone. Based on Yamin and Anselmi 2020, Torres Carbonell et al. 2014, Patterson et al., 1999, Ramos 1999, and citations within these works. (Figure modified from Zambrano et al. 2022).

Therefore, the seismic activity in the Scotia region is linked to the sudden and gradual release of the deformation energy that is concentrated in the main structural lines that affect the terrestrial lithosphere, product of the dynamics of the tectonic plates (Figure 243). It is observed that the foci of greatest concentration of seismicity occur especially at the intersections of the main tectonic structures, but also at the margins of some continental blocks where they make contact with said structures (Figures 243 and 244). Depending on the orientation of the regional stress field, they usually represent critical areas of deformation accumulation and seismic potential energy during the phase prior to the seismic event.

The earthquakes produced in those structures or rheological contrasts characterised by low thresholds of resistance to brittle-ductile deformation, will result in average moderate or intermediate magnitude (Mw~5). At the level of the lithospheric elastic thickness, they correspond to zones of low emission of radiated seismic energy. On the other hand, those structures or rheological contrasts characterised by a high threshold of brittle-ductile resistance, can eventually generate large-magnitude earthquakes due to the greater capacity for elastic deformation. At the level of the lithospheric elastic thickness, they correspond to zones of high emission of radiated seismic energy.

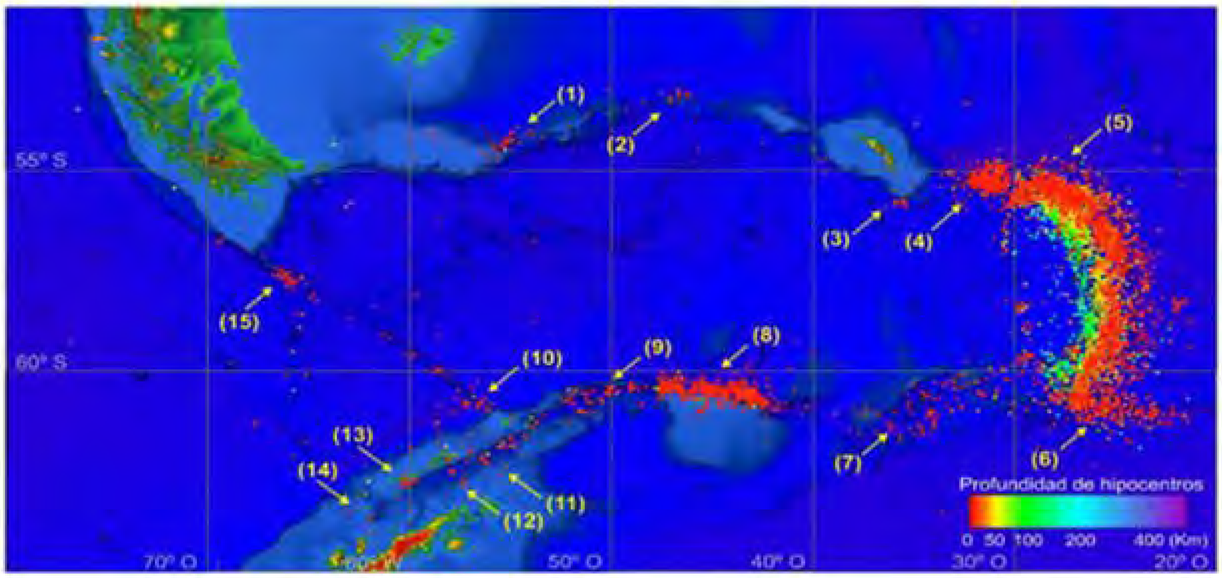


Figure 245: Manifestation of seismic activity in the Scotia region during the period 1996-2016. Note the distribution of the epicentres around the main regional structures. Note the appearance of clusters focused at the intersection of the main structures and at the margins of the continental blocks (indicated by arrows). These represent episodic and abrupt release foci of seismic energy accumulated during the pre-seismic deformation stage. In Bransfield Strait, earthquake swarms are associated with tectonic activity and centres of volcanic activity distributed along the rift. (1) Northeastern end of the Namuncurá bank; (2) Aurora Bank; (3) Southeastern end of the South Georgia Islands block; (4) Northern end of the East Scotia Ridge, west of the triple point determined by the Scotia, Sandwich and South American plates; (5) Northern end of the East Scotia ridge, west of the triple point determined by the Scotia, Sandwich and South American plates; (6) South Sandwich Fracture Zone, east of the triple point determined by the Sandwich, South American and Antarctic plates; (7) Irízar Ridge; (8) South Scotia Ridge, north of the South Orkney Islands block; (9) South Scotia Ridge, north of Powell Basin; (10) Intersection between the South Scotia Ridge and the Shackleton Fracture Zone (Elephant and Clarence Islands sector); (11) Bransfield Rift (Bridgeman Island sector); (12) Bransfield Rift (Isla 25 de Mayo sector); (13) Bransfield Rift (Deception Island sector); (14) Bransfield Rift (Isla Baja sector); (15) Intersection between the Shackleton Fracture Zone and the Antarctic-Phoenix Ridge (fossil). Information on seismic events extracted from the open access databases GEOFON of the GFZ German Research Centre for Geosciences (https://geofon.gfz-potsdam.de), and IRIS Incorporated Research Institutions for Seismology (https://ds.iris.edu)

In order to identify areas of potential seismic risk in the Scotia region, as a first step we can establish a distinction between areas of high and low emission of radiated seismic energy:

A) Deformation concentration zones characterised by a high emission of seismic energy (Figures 243 and 244):

- Northern end of the East Scotia Ridge, west of the triple point determined by the Scotia, Sandwich and South American plates.
- Northern end of the East Scotia Ridge, east of the triple point determined by the Scotia, Sandwich and South American plates.
- Wadati-Benioff zone of the subducted South American plate.

- Eastern sector of the South Sandwich trench, on the South American plate.
- South Sandwich Fracture Zone.
- Irizar Ridge.
- South Scotia Ridge, on the northern margin of the South Orkney Islands block.

B) Strain concentration zones characterised by low seismic energy emission (Figs. 1, 2 and 3):

- Northern margin and eastern end of the Namuncurá bank.
- Northern sector of the Aurora bank.
- South-eastern sector of the South Georgia Islands block
- East Scotia Ridge.
- Wadati-Benioff zone of the subducted South American plate.
- South Scotia Ridge, north of the Powell Basin.
- Intersection between the Shackleton Fracture zone and the South Scotia Ridge (Elephant and Clarence Islands sector).
- Bransfield Rift. The areas with the greatest seismicity are concentrated in the vicinity of the islands: Bridgeman (northeast sector), 25 de Mayo (central-northeast sector), Deception (central-southeast sector) and Baja (southeast sector).
- Intersection between the Shackleton Fracture Zone and the Antarctic-Phoenix Ridge (fossil).

Based on the seismic records, it is observed that the occurrence of the most relevant seismic events (high magnitude earthquakes and focused cumulus) are located in the critical sectors of deformation of the Scotia Arc structure, linked to different tectonic regimes: convergence in the South Sandwich Trench, strike-slip fault in the South and North Scotia ridges, and divergence in the Bransfield rift. Most of them correspond to episodic foci of abrupt emission of seismic energy. Two classes of seismic cumulus formation can be distinguished: a) cumulus led by high-magnitude mainquakes ($M\_w \geq 7$) produced mainly in the South Sandwich Islands region and north of the South Orkney Islands block, and b) seismic swarm-like cumulus of low to intermediate magnitude (Mw <~ 5.5-6) associated with the Bransfield rift, particularly in the Bridgeman Island sector, in the 25 de Mayo Island sector, in the Deception Island sector, and in the Isla Baja sector (Figure 244). Seismic swarms have also been observed on the margins of the Namuncurá, Aurora and Davis banks and in the extreme southeast of the South Georgia Islands block, all of them related to the transpressive strike-slip fault that is developed in the North Scotia Ridge. Another sector that observes seismic swarms is associated with the transtensive deformation that develops in the Irízar Ridge (Figures 243 and 244).

The geodynamic analysis and characterisation of seismic activity in the region of the extreme north of the Antarctic Peninsula and surrounding seas, recognises at least three main seismic hazard zones, dominated by different tectonic regimes: convergence in the area of the South Sandwich Islands, strike-slip fault in the area of the South Orkney Islands and divergence in the area of the South Shetland Islands. The zoning and ordering that was obtained based on the seismic hazard level is consistent with the degree of seismic hazard that can be expected to be observed according to the associated geotectonic environment (Frisch *et al*. 2011).

However, when evaluating the vulnerability of human settlements (human lives) and building infrastructure elements (permanent Antarctic bases and Antarctic scientific laboratories) to the generation of seismic shocks and/or to mass removals of the terrain and/or to the advance of tsunamis resulting from a seismic event, the location with the highest seismic risk includes the South Orkney Islands (high seismic risk). The permanent Argentine base Orcadas is located in this archipelago, at 4 metres above sea level, immersed in a zone of high seismic danger.

7 ENVIRONMENTAL IMPACT ASSESSMENT

Article 8 of the Protocol establishes that the activities to be carried out in Antarctica will be subject to the procedures established in Annex I on the prior evaluation of the impact of said activities on the Antarctic environment or on the dependent or associated ecosystems. For its part, Article 1 of Annex I mentions that the environmental impact of the proposed activities, mentioned in Article 8 of the Protocol, will have to be considered before they start, in accordance with the appropriate national procedures. And also that, if it is determined that an activity will cause less than a minimal or transitory impact, said activity may be initiated without delay.

From all of the above, it is clear that an objective methodology must be available to assess the environmental impacts of activities and determine the degree of impact, within the scope of the Antarctic treaty, three categories are considered:

a) less than a minimal or transitory impact;

b) a minimal or transitory impact; or

c) more than a minimal or transitory impact.

In Resolution 1 (2016) “Guidelines for Environmental Impact Assessment in Antarctica” it is established that an activity is an event or process that results from (or is associated with) the human presence in Antarctica or that can lead to that presence. An activity can consist of several actions; for example, an ice drilling activity may require actions such as equipment transportation, camp setup, drilling power generation, fuel management, drilling operations, waste management, etc. The activity should be analysed considering all the actions that each phase involves (for example, construction phase, operation phase, and decommissioning phase).

One of the important issues highlighted in this document is that understanding the ways in which a proposed activity may interact with the environment (i.e., its environmental aspects) is an important step in identifying and addressing potential environmental impacts. According to the aforementioned Resolution, the following definitions are used:

- An environmental aspect could include a result or addition to the environment (for example, emission of pollutants, noise or light, human presence, transfer of non-native species, direct contact with wildlife or vegetation, leaks or spills of hazardous substances, etc.) or an extraction from the environment (for example, use of lake water, collection of moss samples, extraction of stones).
- A number of component parts or actions may be involved in a single activity, each of which may have various environmental aspects associated with it. For example, the general activity of building and operating a research station may involve the use of vehicles, which may directly interact with the environment by compacting the soil, producing emissions into the atmosphere, generating noise, etc.).
- The identification of issues should include not only normal operating conditions, but should also take into account, to the greatest extent possible, abnormal conditions (eg startup or shutdown) and emergency situations.

- An environmental impact (synonym: effect) is a change in the values or resources of the environment that can be attributed to human activity. It is the consequence of an interaction between an activity and the environment, and not the interaction itself. An impact can also be defined as the result of the interaction between an activity and an environmental value or resource.

The evaluation of environmental impacts of an activity is built in a four-stage process that is summarised below: 1) Considering the actions that make up the activity, 2) Identification of the environmental aspects involved, 3) Analysis of the environmental findings, 4) Determination of the significance of the impabt, the Risk Factor and implementation of Mitigatation Measures (if necessary). On the other hand, identifying potential impacts involves determining which component(s) of the environment are likely to be affected by an activity or action. An activity will not result in an impact to an environmental value or resource if there is no process of interaction, or "exposure". It should also be considered that a single environmental aspect could have several related environmental impacts.

7.1 Identification and Quantification of Impacts

7.1.1 Characterisation of the Impacts[20]

The identification of environmental impacts consists of characterising all the changes in the environmental values or resources resulting from an activity. Only when the impact is identified can an assessment of its significance be made. In the case of this new methodology proposed for the Argentine Antarctic Programme, each impact will be identified by the following characteristics in a summarised manner:

- Activity: Set of actions within a process that are carried out to fulfil a specific stage of the process. The name of the activity that contains the aspects and impacts to be valued must be stated, together with the process in which it is included. An activity can consist of several actions; for example, an ice drilling activity may require actions such as equipment transportation, camp setup, drilling power generation, fuel management, drilling operations, waste management, etc.
- Exposed Environmental Component: including the physical and biological features that could be directly or indirectly affected.
- Environmental Aspect: environmental aspects (synonym = cause) are those elements or derivatives of activities with a possible impact on the environment. For its survey, each and every one of the processes involved in the activities, their raw materials, their products and their residues, as well as the elements and machinery used, are taken into account. The identification of issues should include not only normal operating conditions, but should also take into account, to the greatest extent possible, abnormal conditions (eg startup or shutdown) and emergency situations.

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twenty This methodology for the evaluation of environmental impacts was designed for this project and it was presented by Argentina in the last ATCM XLIV - CPA XXIV in Berlin through the informative document *IP035 "New methodology for the quantitative assessment of the environmental impacts of the Argentine Antarctic Programme*".

- Environmental Impacts: an environmental impact (synonym: effect) is a change in the values or resources of the environment that can be attributed to human activity. It is the consequence of an interaction between an activity and the environment, and not the interaction itself. An impact can also be defined as the result of the interaction between an activity and an environmental value or resource.
- Type of impact: establishes whether an impact is direct or indirect according to the following characterisations. A direct impact is the change in environmental values or resources as a result of the consequences of the interaction between the exposed environment and an activity or action (for example, the decline of a limpet population due to an oil spill, or the decline of a population of freshwater invertebrates due to the extraction of lake water). An indirect impact is a change in environmental values or resources due to the interaction between the environment and other impacts, both direct and indirect.

7.1.2 Impact Quantification

- Extent: Area or volume where changes are likely to be detectable.
- Intensity: measure of the change caused to the environment due to the activity (can be measured or estimated by means of, for example, number of species or individuals affected, concentration of some pollutant in a body of water, erosion rates, mortality rates, etc.).
- Duration: period during which the changes in the environment are likely to occur.
- Probability: it is the possibility of occurrence of the impacts during the project.
- Legal Aspects: degree of compliance or non-compliance of the environmental impact with respect to the applicable regulations.

7.1.3 Analysis and Evaluation of Impacts

In this second stage, the significance value of the surveyed environmental impacts is established. With the information collected or supplied, the extent, intensity, duration, probability and legal aspects are valued according to the following Table 44:

Table 44: rating scale from 1 to 4 for each of the elements analysed to identify an impact.

	Very low	***Low***	***Medium***	***High***
	1	***2***	***3***	***4***
Extension	***One-off:*** *Within the limits of the base.*	***Local:*** *It exceeds the limit of the base, but within the area of influence (e.g. sea shelf).*	***Regional:*** *Within the biogeographic region.*	***Continental:*** *Antarctica and waters south of 60°S.*
Duration	***Limited:*** *The impact lasts a maximum of 3 months.*	***Short term:*** *The impact lasts between 3 months to 1 year.*	***Medium term:*** *The impact lasts from 1 to 10 years.*	***Long term:*** *The impact lasts for more than ten years.*

Intensity	***None:*** *No changes in environmental components or ecological processes are detected*	***Low:*** *Low-magnitude, short-term changes in natural values or ecological processes*	***Medium:*** *The changes produced in the natural values or ecological processes are reversed in the medium to long term.*	***High:*** *Changes in natural values or ecological processes are not reversed*
Probability	***Unlikely:*** *occasional or no occurrence.*	***Low:*** *unlikely to occur in normal operating situations.*	***Medium:*** *Likely occurrence if no action is taken*	***High:*** *Unavoidable occurrence during the project.*
Legal	***Without regulations:*** *Does not have legal requirements*	***Compliant:*** *It does not constitute an infringement if the legal requirements that it has are met*	***Local non-compliance:*** *Constitutes a serious infringement or non-compliance with the requirements of national laws*	***International non-compliance:*** *It constitutes a serious infringement or non-compliance with the requirements of the Antarctic treaty.*

- ***Unmitigated significance:*** result of the mathematical formula of the qualification between the results of the extension x intensity x duration x probability x legal aspects, the significance of the impact is obtained by multiplying the impact score of each characteristic (for example, 2 x 2 x 2 x 2 x 2=32). The overall impact score range is between 1 and 1024, considering that a score of all the minimum scores in each evaluation criterion is equal to one (that is, 1 x 1 x 1 x 1 x 1 = 1) and a maximum score is equal to 1024 (that is, 4 x 4 x 4 x 4 x 4 = 1024). This provides a simple means of impact comparison. The higher the number, the greater the environmental impact.

Significance = extent x intensity x duration x probability x legal aspects (a)

- Original risk (12): once the analysis of impacts based on extension x intensity x duration x probability x legal aspects has been carried out, the prioritisation of the risk area is determined, which makes it possible to determine which ones require immediate treatment. There are three levels of impact significance (Low, Medium and High) that correspond to those described in Article 8 (1) of the Protocol (Table 45):

Table 45: assessment of the risk of impacts.

COLOR		DESCRIPICIÓN	FACTOR DE RIESGO
Bajo	***VERDE***	Los impactos tienen niveles aceptables y se gestionan con la aplicación de las medidas de mitigación y los procediemientos y directrices ya establecidas.	Menos que un impacto mínimo o transitorio (1 a 102.4) **(0%-10% de la escala)**
Medio	***AMARILLO***	Los impactos necesitan la implementación de medidas de mitigación y el monitoreo durante el proyecto.	Un impacto mínimo o transitorio (102.4 a 204.8) **(10%-20% de la escala)**; y
Alto	***ROJO***	Los impactos poseen una significancia que se necesitan la aplicación de medidas de mitigación y el monitoreo por parte de organismos externos	Más que un impacto mínimo o transitorio (204.8 a 1024) **(mayor a 20% de la escala)**.

- ***Mitigation measures:*** That is, the use of practices, procedures or technologies in order to minimise or prevent the impacts associated with the proposed activities. The modification of some component of the activity (and, therefore, the consideration of environmental aspects and impacts), as well as the establishment of supervision procedures, are effective forms of mitigation. Mitigation measures will vary depending on the activity and the characteristics of the environment.
- ***significance with mitigation***: result of the mathematical formula of the qualification between the results of the extension x intensity x duration x probability x legal aspects but after having taken into account the mitigation measures applied.
- ***mitigated risk***: level of significance of the impact after the application of the mitigation measures.
- ***Degree of Impact***: final level of significance in relation to the three categories established in Annex I of the Madrid Protocol (greater than, equal to or less than minimum or transitory).

If a given action presents a Medium or High level of significance, it will require the implementation of Mitigation Measures. That is, the use of practices, procedures or technologies in order to minimise or prevent the impacts associated with the proposed activities. The modification of some component of the activity (and, therefore, the consideration of environmental aspects and impacts), as well as the establishment of supervision procedures, are effective forms of mitigation.

After this first analysis, the mitigation measures are considered in the matrix, and from these measures the Level of Significance with mitigation is calculated, which is the result of the mathematical formula of the rating (a) with the new values of extent x intensity x duration x probability x legal aspects, but after taking into account the mitigation measures applied. With this new calculation, the mitigated risk is finally obtained, level of significance of the impact after the application of the mitigation measures and the one that is compared again with.

7.2 Climate Change Risk Assessment[twenty-one]

The impacts of the risk of damage due to climate change are a growing concern as they reduce the predictability of future infrastructure needs and increase the vulnerability of populations and assets worldwide. Particularly climate change is a growing threat to the Antarctic Contain, which affects the present ecosystems, but also poses challenges for the bases and their structures in the medium term. In this regard, Resolution 1 (2016) - Guidelines for Environmental Impact Assessment in Antarctica states that "where appropriate, assist proponents to give consideration to the possible implications of climate change for proposed activities and their associated environmental impacts". An important concept in this sense is the vulnerability of the bases or constructions present in Antarctica. Vulnerability is determined based on the nature, magnitude, and rate of climatic variation to which a structure is exposed, its sensitivity, and its adaptive capacity. For these reasons, the Environmental Management and Tourism Programme of the National Directorate of Argentina set out the objective of being able to establish a methodology that allows incorporating a risk analysis into its initial environmental impact assessments that allows recommending adaptation measures to the proponents of the activity to minimise the effects of climate change threats. Considering the risk of damage and climate change in the design and construction of projects is important to increase their resilience.

7.2.1 Methodology Guidelines

To establish the methodology, the definitions and guidelines established by the IPCC (IPCC 2014) were followed. Risk assessments, by nature, are oriented towards finding solutions, determining the most appropriate measures to reduce and/or mitigate risks and provide a diagnosis that allows identifying opportunities in terms of resilience. This Methodology was designed in this first stage to be applied mainly to infrastructure projects, but it is expected to be extended to all types of activities in the future.

According to the United Nations Office for Disaster Risk Reduction, disaster risk refers to the possibility of death, injury or destruction and damage to assets in a system, a society or a community in a specified period of time, determined based on hazard, exposure, vulnerability and capacity.

The methodology is based on the determination of the components of the risk of damage due to climate change: Hazard, Exposure and Vulnerability:

- The threat component in this context refers to naturally occurring phenomena that pose a threat to population or property and could therefore cause damage, economic loss, injury, and loss of life.

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21 This methodology for the evaluation of environmental impacts was designed for this project and it was presented by Argentina in the last ATCM XLIV - CPA XXIV in Berlin through the informative document *IP040* *"Methodology for assessing vulnerability to climate change in environmental impact studies"*

- The exposure component refers to the spatial and temporal coincidence of people or assets (both physical and environmental) and natural hazards.
- The vulnerability component refers to how likely an entity is to be harmed or damaged. In the case of assets, systems and people, it is their intrinsic, internal, individual and combined characteristics that, by nature, make them prone (or, conversely, resistant) to suffer damage.

Based on these concepts, a risk assessment was designed that allows the consideration of the potential for damage due to climate change of a particular project. At this stage of development, we propose a qualitative approach to determine the nature and scope of disaster risk through the analysis of possible threats and the evaluation of existing conditions of exposure and vulnerability that in concert could cause damage to people, property, services, livelihoods and the environment. The objective of the methodology was to establish specific measures to reduce the risk identified in the evaluation, adaptation measures, to be included in the recommendations together with the mitigation measures.

7.2.2 Qualitative methodology

The methodology used is based on the information and specific knowledge on the design of the project provided for the preparation of the preliminary environmental impact assessment and the scientific knowledge available on climate change in Antarctica, especially the Report on climate change and the Antarctic environment of SCAR 2009, and its subsequent regular updates by SCAR. In accordance with the methodology used, the following concepts involved are determined following (IPCC 2014):

- Environmental Factor: environmental variable that has an impact on the activity being assessed.
- Observed impacts: Refers to changes in the physical environment or biota resulting from already observed climate change and its effects on natural and human systems from extreme weather and climate events and climate change.
- Threats: natural or man-made phenomena that have the potential to cause harm to people or property.
- Exposed values: elements of the analysed activity that could suffer damage due to the threats of climate change.
- Risks: “The potential for consequences where something of value is at stake and where the outcome is uncertain (...).
- Hazard: Potential occurrence of a physical event or trend of natural or human origin, or a physical impact that may cause loss of life or property.
- Vulnerability: attributes of exposed elements that can increase (or decrease) the potential consequences of a specific climate hazard.
- Adaptation: Process of adjustment to the actual or projected climate and its effects. In human systems, adaptation aims to moderate or avoid harm or to take advantage of beneficial opportunities.

The qualitative methodology adopted to assess the effects of climate change on activities involving infrastructures is then intended to establish the components and relationships observed in Figure 1 to propose adaptation measures that fundamentally reduce vulnerability and thus the structure has greater resilience.

7.3 Analysis of Environmental Impacts

7.3.1 ID

The approach we use to assess and value environmental impacts is based on an analysis of the processes involved and then within them the determination of the activities to be carried out. Once the main activities have been established, the associated environmental aspects and impacts are established. The works to be carried out at the Base can be divided into the following major phases:

- Preparation stage: studies
- Stage 1 Petrel, permanent base
- Stage 2 Habitability and services
- Stage 3 Provision of services to own people
- Stage 4 Provision of services to third parties

Preparation stage: Studies

The objective of this phase is to plan the development of the base, solving implementation problems, establishing the different phases, material requirements, execution times. Although decisions will be made throughout the base modernisation process, it is during this phase that the most crucial decisions will be made, relating to the design parameters to be implemented and the capabilities to be developed to meet the needs of the Argentine Antarctic Programme.

Stage 1 Petrel, permanent base[22]

The objective of this phase will be to change the situation of the Petrel Base before the Antarctic Treaty community, from a temporary base to a permanent base, assigning staff for the winter. This staff, together with a summer work team, will need to start the conversion activities of the base. The objective of the stage responds to the need to maintain the operational base throughout the year, to carry out maintenance and improvement activities. Its permanent operation will also facilitate the sending of the different organised groups to carry out the environmental and design work of the base.

Stage 2 Habitability and services

The objective of this phase is to increase staff accommodation capacity, while ensuring enough space for storing the materials and machinery necessary for development of the base. For this, the construction of a new residential house will begin, the commissioning of the base hangar, the use of the old buildings, the removal of those structures in

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22 Although the vast majority of the processes and actions of this stage have been included in this draft EMG, Argentina submitted a specific Initial Environmental Assessment that is available at IEE - Works of Repairs and Maintenance at Petrel Base, Dundee Island. Summer and Winter Campaign Antarctica 2021-2022.

disuse or without current purpose and the environmental remediation of the base through the collection, classification, storage and removal of the historical residues of the base.

Stage 3 Provision of services to own people

The objective of this phase is to launch the use of the base as a scientific centre and to use the base as a passenger and cargo transfer terminal for the Argentine Antarctic Programme.

Stage 4 Provision of services to third parties

The objective of this phase is to enable use of the base as a transfer terminal for passengers and cargo to other Antarctic programmes with the surplus capacities of the base.

In order to analyse environmental aspects and impacts, the activities necessary to carry out these phases were grouped into the following processes:

- Repair, Maintenance and Demolition of Original Facilities
- Construction of New Facilities
- Construction, use and maintenance of the airport area
- Construction, use and maintenance of the photovoltaic plant
- Construction, use and maintenance of lagoons.

7.3.2 Environmental Impact Assessment Matrices and Mitigation Measures

Based on the analyses carried out, the corresponding matrices of environmental impacts and their corresponding mitigation measures have been established. They are attached as appendices to this document in the following order:

- Environmental Impact Assessment Matrix for the Repair, Maintenance and Demolition of Original Facilities (Annex 2);
- Environmental Impact Assessment Matrix for the Construction of New Facilities (Annex 3);
- Environmental Impact Assessment Matrix for the Building, use and maintenance of the airport area (Annex 4);
- Environmental Impact Assessment Matrix for the Building, use and maintenance of the photovoltaic plant (Annex 5) and
- Lagoon Maintenance Environmental Impact Assessment Matrix (Annex 6). for the Building, use and

7.5 Environmental Impacts of Climate Change on the project

In principle, the proposed activity has a minimum approximate useful life of about 30 years, therefore, taking ATCM 1 (2016) on guidelines for Environmental Impact Assessment in Antarctica as a reference, it is necessary to assess the possible risks that the change will have on the proposed activity. For the analysis of this interaction between climate-future and the new facilities of the Petrel Base, we will take as a general reference the Report on climate change and the Antarctic environment of the Scientific Committee on Antarctic Research (SCAR) (SCAR, 2019; Turner et al, 2009) and especially the latest report by Chown et al (2022) "A decadal synopsis and recommendations for action" by SCAR. To specifically analyse the parameters that are fundamental and that act as determinants of the useful life of the proposed activity, among them the expected trends in temperatures, precipitation, sea level rise, glacier retreat and the expected changes in the dynamics of the permafrost for the zone of the extreme North of the Antarctic Peninsula where the Petrel Base is located. The methodology for carrying out this analysis was described in point 7.2 of this evaluation.

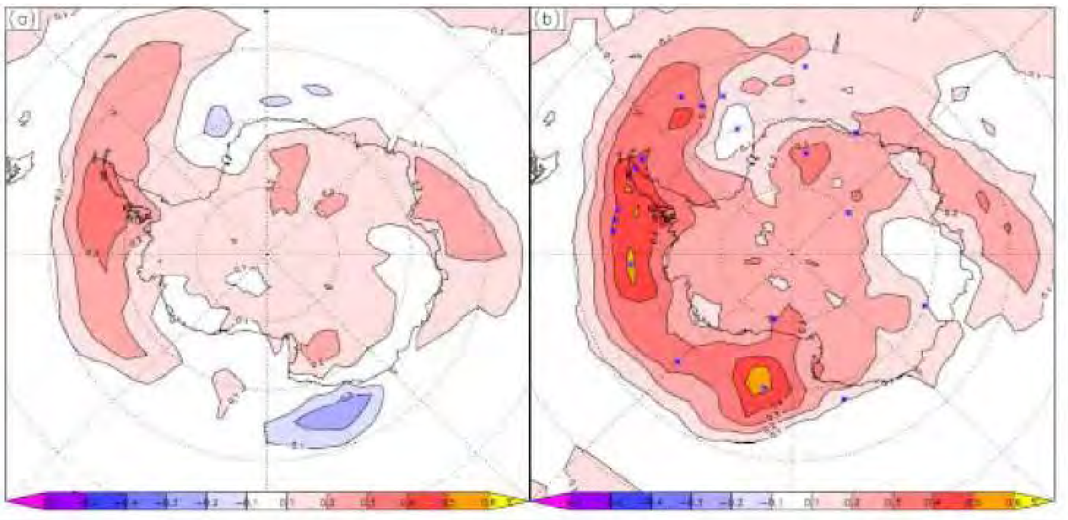

Figure 246: Annual average temperature trend from 1960 to 2000 (Turner, 2009). The Petrel Base area is within the region with the highest record of change increase.

Analysis of Environmental Factors involved

Based on the location of the Petrel Base, in general terms and taking the SCAR Report as a reference, we can mention that in relation to the ***surface temperature*** a significant increasing trend has been observed throughout the entire Antarctic Peninsula since 1950, which is more significant in the western and northern part of the peninsula, that latter location being precisely where the Base is located. Temperatures on the eastern side of the Antarctic Peninsula have shown higher elevations during the summers and autumns, with an average increase of +0.41°C per decade (Turner et al, 2009) (Figure 245). In the specific case of the Petrel Base, although we do not have updated data, we can take as a reference what is being recorded at the Esperanza Base located a few kilometres away. In this site, a significant increase in the annual average temperature was recorded over the last decades close to +0.7°C (Figure 246), however global results for Antarctica mention that in the last century the average annual temperature has risen approximately 1.2°C (Vaughan et al, 2003).

Another important factor is the dynamics of the permafrost, especially the thickness of its active layer, according to SCAR (Turner et al, 2009) it is probable that there is a reduction in the permafrost area, accompanied by subsidence of the soil surface and associated earth movements. The change is most likely in the northern Antarctic Peninsula and in the South Shetland and South Orkney Islands and in the coastal areas of East Antarctica, thus affecting the Petrel Base area. According to SCAR, forecast changes entail risks for the infrastructure and therefore become critical when analysing infrastructure projects in the medium and long term.

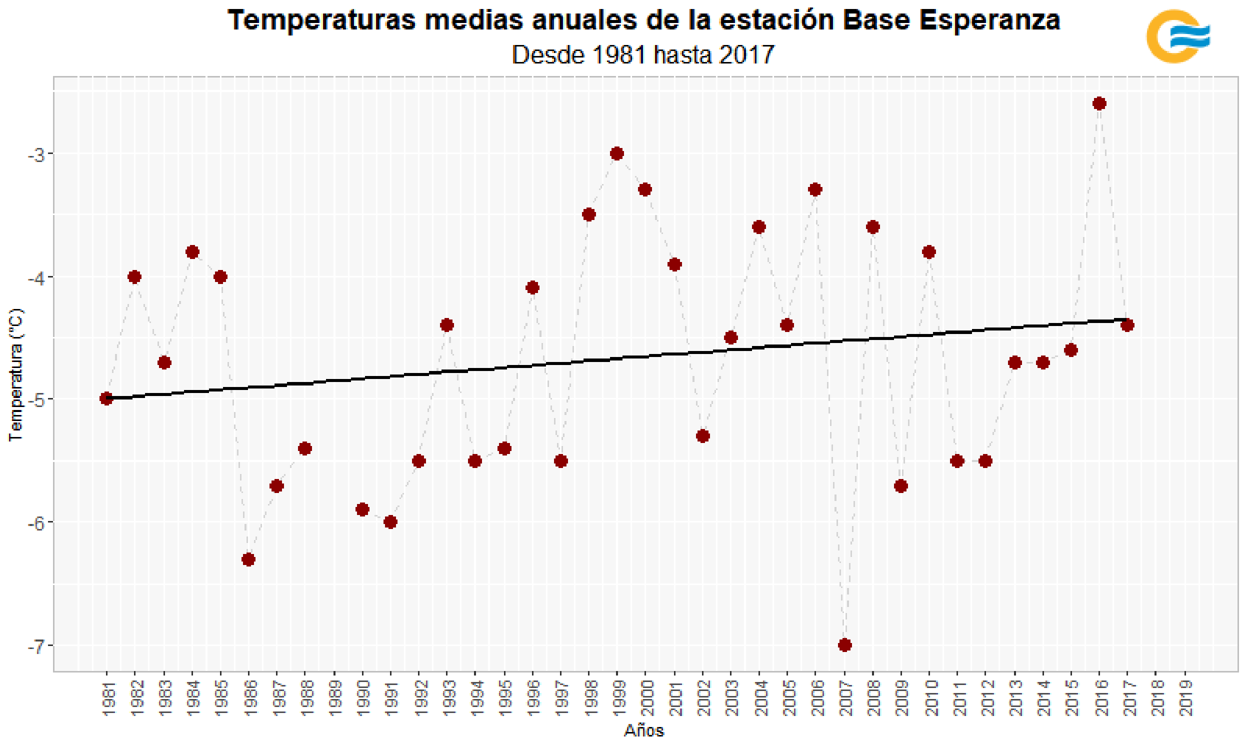

Figure 247: Average annual temperature trend at Base Esperanza (Source SMN).

In particular, it can be determined that in the Dundee Island area (taking Base Esperanza as a reference) there is a clear positive trend in the increase in average annual temperature (Figures 246 and 247) in recent decades. The geographical location in the extreme northeastern part of the Antarctic Peninsula, the existence of glaciers and the history of relief formation corresponding to stages of Quaternary glaciation and development of permafrost on the uncovered ice surface contribute to the particular environmental conditions of the this sector of the island where the Base is located.

The thickness of the active layer is relatively constant throughout the Petrel Plain area and reaches a maximum of 1.5 metres, being a little deeper towards the Petrel Roadstead area due to the influence of the fluvioglacial process (Instituto Antártico Argentino, 2006). Thus, observed and expected changes in temperatures have significant effects on the dynamics and thickness of the active permafrost layer. The thickness of the active layer is highly variable, and depends on environmental conditions. However, the depth of seasonal thawing on the island depends on climatic conditions and soil moisture (Yermolin & Skvarca, 2004). It should be taken into account that temperature and precipitation variations can have significant consequences then on the dynamics of the active layer.

It should be noted that the thawing thickness (Zd) is calculated using the Stefan equation (Nelson *et al*, 1997) and that the higher the temperature, the greater the thaw thickness. However, it should be noted that according to the SCAR report (Turner et al, 2009) there has not been evidence of a major reduction in the permafrost area in the last 100 years (p. 345), but it points out that the melting of the permafrost should be a concern to COMNAP due to the impact of this process on the grassroots. So the threat of further melting of the permafrost increasing the depth of thawing is what has the effect of risking a lower possibility of support of the pillars buried in the ground. The threat of the thermoerosion phenomenon due to increased seasonal thawing and melting of underground ice exposes the danger of affecting the stability of the built infrastructure in the medium and long term.

This context is important in terms of analyzing the vulnerability of the structures to be installed (buildings, solar panels, runway, etc.) in the face of the climate change scenario expected for Dundee Island, if the impacts on temperatures already observed are maintained. According to the SCAR report, an average annual temperature change of about 0.25°C per decade is expected in the Base area (Figure 247). Expected future changes will expose the structure to certain risks (eventual consequences of danger) and therefore, in order to reduce vulnerability to exposure to these dangers, it is necessary to make recommendations for its installation.

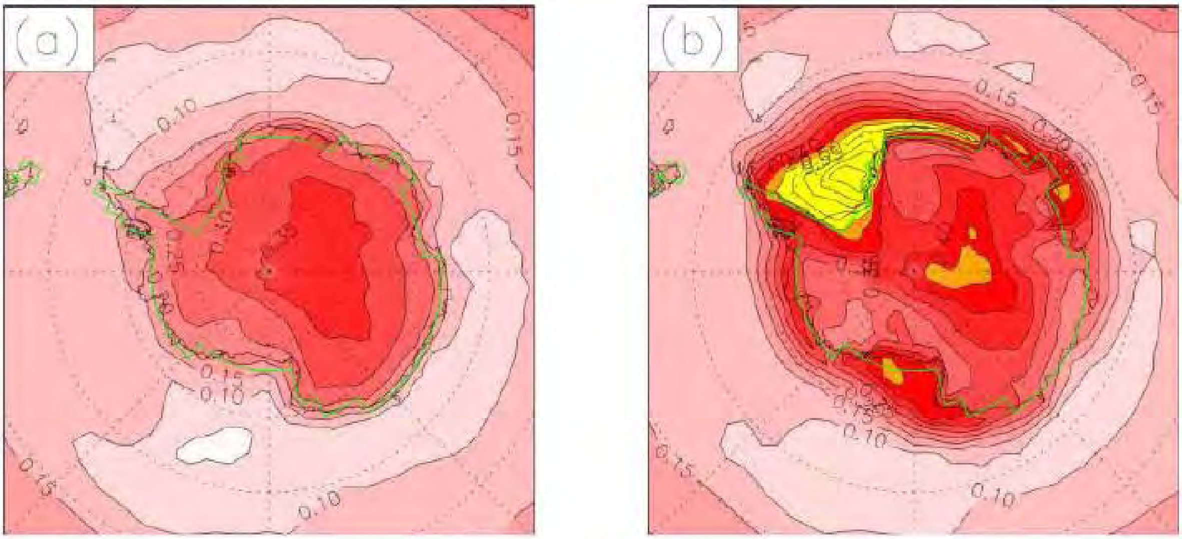

Figure 248: Expected changes per decade in °C for Antarctica based on the SCAR report (Turner, 2007).

What will happen with changes in precipitation in the area should also be taken into account. For the north of the Antarctic Peninsula, Carrasco and Cordero (2020) determined that there was a global increase in rainfall from 1970 to the early 1990s and a negative trend between 1991 and 1999 with a decrease in rainfall. On the other hand, although there was also an increase in precipitation events from 1970 to the early 1990s, there was a decreasing trend of precipitation events during the 2010s. This entails that the positive trend in the accumulation of rainfall registered during this period is due to the increase in extreme rainfall. Analysis of the type of precipitation shows an increase (decrease) in snow (rain) episodes from the mid-1990s to the mid-2010s during the summer season.

These opposing trends are related to the summer cooling that affects the Antarctic Peninsula region.

According to Turner et al (2009) the predicted change in precipitation depends on and is greater in winter than in summer and that the greatest increase in mean precipitation is predicted for the coastal areas of West Antarctica and the Antarctic Peninsula. According to these authors, changes in rainfall in the Antarctic Ocean will translate into an increase in snowfall. What happens with precipitation trends in the form of rain is very important due to its effects on soil dynamics and in species due to its impacts on infrastructure, and particularly in the case of Petrel, on the runway.

According to the document ATCM42_wp001_rev1 “The Antarctic Peninsula and a 1.5C scenario” the temperatures of the Antarctic Peninsula will increase by an amount greater than the world average in the 1.5°C scenario. That warming has already been surpassed in the northern peninsula, despite the recent lull in rising temperatures. Regional temperatures could increase beyond current levels by between 1ºC and 2ºC during winter and between 0.5ºC and 1ºC during summer. A 1°C warming will lead to an increase of between 50% and 150% in the number of days per year with temperatures above 0°C, that is, a minimum of 25 to 80 days and a maximum of 35 to 130 days per year in the north of the Antarctic peninsula. While there was a 10-20% increase in precipitation, which is becoming more extreme, it is unlikely that there will be much more than current levels. The largest circulation change affecting the peninsula is a weakening of the circumpolar westerlies in response to ozone recovery. Increased levels of water runoff—rain and snow/glacial melt—and/or melting of any thin layer of sediment can considerably alter the geotechnical properties of ice-free terrain, despite occurring during limited periods of the year.

Another significant aspect to take into account in a coastal base such as Petrel is that it will occur with the rise in sea level. All the Scientific Stations that are close to the coast in Antarctica will be subject to the threats posed by the rise of the sea level, therefore, it is very important to plan the new activities taking into account the projected heights. According to Chown *et al* (2022), the Antarctic ice sheet contains enough water to contribute, if fully melted, about 58 m of global mean level rise. Such a significant mass loss is not expected even on models extending up to 2300 (DeConto *et al*. 2021). According to DeConto & Pollard (2016), Antarctica may contribute to raising sea level by more than one metre between now and 2100 and more than 13 metres between now and 2500, if emissions do not decrease.

Climate change is a phenomenon that has the potential to cause damage to assets, and in this specific case, the increase in temperatures, the increase in the thickness of the active layer of permafrost, changes in rainfall and the increase in the level of sea in the Dundee Island area will expose the structures that make up the new Petrel Base. Based on the impacts already observed and future scenarios, it is expected that the infrastructure of the new Base will be exposed to risks and dangers that make all the structures unstable or suffer partial collapse. In this way and in order to take into account the threats of climate change for the proposed activity, the threats, risks, exposed values, hazards and adaptation measures to be taken into account to reduce vulnerability are described in Table 46 of the photovoltaic plant during its useful life.

Table 46: Assessment of the impact of climate change on the activities of the Petrel Base renovation project.

FACTOR AMBIENTAL	IMPACTOS OBSERVADOS	AMENAZAS	VALORES EXPUESTOS	RIESGOS ASOCIADOS	PELIGROS	VULNERABILIDAD	MEDIDAS DE ADAPTACIÓN
Temperatura Media Anual	Ha ascendido +0.7°C en los último 40 años.	Se espera que la temperatura media anual continue aumentando 0,25 °C por década.	Estructura de sostén de las construcciones.	Riesgo de daño a la estructura por aumento de la acumulación de agua sobre el terreno y la afectación al permafrost	Presencia de zonas de acumulación de agua entre los pilares de la estructura.	Las fundaciones que sostienen los edificios está influenciadas por la firmeza del suelo.	**Adaptación 1:** No interrumpir los cursos superficiales y evitar la formación de colas de nieve para evitar la acumulación no natural de agua y se debe eliminar las posibles concavidades donde se acumula la nieve.
Temperatura Media Anual de los veranos australes	Aumento de los procesos de termokarst y termoerosión por aumento del descongelamiento estacional y fusión de los hielos subterráneos.	Se espera que las aguas supra-permafrost incrementen la termoerosión del suelo.	Estabilidad del terraplen de la pista.	Que por aumento de los fenómenos de termokarst y termoerosión aumente la inestabilidad del terraplén.	Que la inestabilidad del terraplén sean tan grande que que la pista no pueda utilizarse.	Ubicación de la pista sobre un terraplén con permafrost en su interior que es afectado por la temperatura.	**Adaptación 2**: El espesor promedio del terraplén debe corresponder a la profundidad normativa de descongelamiento estacional en este sector, para evitar los efectos negativos de la fusión y drenaje.
Produndidad del permafrost	Ha aumentado el espesor de la capa activa por aumento de la temperatura.	Que la profundidad de descongelamiento sea cada vez mayor debido al aumento de la temperarura.	Pilares enterrados de sostén de toda la esturctura	Riesgo de daño a las estructura por aumento de la termoerosión del permafrost.	Espesor de la capa activa del permafrost mayor a la profundidad de enterramiento de lo pilares	El sostén de los pilares enterrados en el permafrost para su fijación en el suelo depende de la profundidad de la capa activa.	**Adaptación 3:** Realizar un enterramiento a no menos de 1,50m de profundidad por debajo de la capa activa.
Nivel del mar	El nivel del mar ha ascendido en promedio unos 0,2m.	El nivel del mar puede subir hasta 0,7m según distintas proyecciones.	Todas las edificación que están por debajo de los 2 m.s.n.m.	Riesgo de daño a la estructura por quedar sumergidas en agua.	Que el nivel del mar alcance niveles superiores a la cota inferior de las estructuras de la base.	Imposibilidad de traslado de las estructuras por el tipo de fundación utilizada.	**Adaptación 4:** Construir todas las estrucuras por encima de la cota de 2 m.s.n.m.
Aumento del número de días con precipitaciones	El número de días con precipitaciones en forma de lluvia ha aumentado entre un 30-40%.	Que la cantidad de precipitación liquida aumente a más del 50%.	El tarreplen de pista tiene por debajo un permafrost de tipo seco debido al bajo contenido de humedad.	Que se modifique la estructura del terraplen por cambios en la humedad del suelo y por acumulación de agua.	Que la humedad del terraplen provoque la saturación del permafrost y por lo tanto la acumulacion de agua en los meses de verano.	El terreno de fundación (es la superficie original subrasante) debe tener un valor óptimo de humedad de 7-8 %.	**Adaptación 5:** El espesor promedio del terraplén debe corresponder a la profundidad normativa de descongelamiento estacional en este sector, para evitar los efectos negativos de la fusión y drenaje.
Aumento del nivel de escurrimiento de agua	Se ha observado un aumento de la precipitación y del derretimiento de la nieve.	Se espera un aumento en las precipitaciones y del derretimiento de la nivel/glacial además del derretimiento de la capa delgada de sedimento.	Todas las estructuras que están sustentadas con fundaciones dentro del suelo.	Riesgo de daño a la estructuras por deblitamiento de las fundaciones.	Que las propiedades geotécnicas del terreno no permitan sostener las estructuras.	La estabilidad de las fundaciones depende de las propiedades geoténicas del suelo.	**Adaptación 6:** asegurar que las fundaciones se fijan sobre el sustrato que está por debajo de la capa activa del permafrost.

FACTOR AMBIENTAL	IMPACTOS OBSERVADOS	AMENAZAS	VALORES EXPUESTOS	RIESGOS ASOCIADOS	PELIGROS	VULNERABILIDAD	MEDIDAS DE ADAPTACIÓN
Perdida del hielo marino costero	Aumento de la exposición de la costa y los ambientes costeros a los efectos de las olas.	Incremento de la pérdida de hielo marino costera y una mayor exposición de las costas a los efectos del océano generando erosión costera.	Instalaciones y estructuras costeras.	Que la erosión costera por aumento de la exposición a la olas afecte las fundaciones de las estructuras costeras.	Que la estabilidad de las estructuras se vean seriamente afectadas hasta inutilizarlas.	Dificultad del traslado de las instalaciones.	**Adaptación 7:** no ubicar instalaciones cercanas al a costa para evitar que sean afectas por la erosión costera.
Retraccion del glaciar	Se ha observado que en el norte de la península antártica la superficie libre de hielo ha llegado hasta el 3%.	Un aumento mayor de la superficie libre de hielo.	La fauna y flora nativa que habita estas áreas libres de hielo.	Que la superficie libre de hielo sea colonizada por especies no nativas.	Que el aumento de las actividades humanas en la isla incremente el riesgo de transporte especies no nativas.	Las actividades humanas y las especies nativas conviven es las áreas libres de hielo.	**Adeptación 8:** aplicar todas las medidas establecidas en el Manual de Prevencio de Especies No Nativas del Programa Antártico Argentino.
Agua superficial por ablación	La temperatura anual promedio ha aumentado +0,7°C en las últimas décadas, aumentaron las lluvias y disminuyó la nieve caida.	Se espera que siga el aumento de las lluvias, la disminución de la nieve caida y una aumento de las temperaturas promedio.	Laguna de obtención de agua de consumo.	El suministro de agua depende la acumulación de agua de deshielo en las lagunas.	Que la cantidad de agua por ablación de nieve disminuya significativamente y las lagunas no retengan agua suficiente.	Que el régimen de estos chorrillos transitorio, presentando caudal sólo en épocas estivales y según las condiciones meteorológicas determinadas.	**Adaptación 9:** que las lalgunas a utilizar no dependan de zonas de descarga de aguas de ablación de glaciar Rosamaría durante el tiempo de ablación.
Superficie cubierta por vegetación	A medida que aumenta la superficie libre de hielo ha ocurrido un aumento de la superficie cubierta por vegetación.	De continuar las tendencias de temperatura segruirá en aumento la superficie cubierta por vegetación.	Vías de circulación y espacios en torno a las instalaciones.	Que por el aumento de superficie con vegetación ocurra intromisión perjudicial o toma durante las actividades de la base.	Que la vegetación crezca sobre rutas de circulación o especios operativos alrrededor de las instalaciones.	Que las actividades de la base transcurren sobre las áreas libre de hielo donde puede crecer la vegetación.	**Adaptación 10:** monitorear de forma permanente las zonas de crecimiento de vegetacion.
Superficie de las lagunas paraglaciares	Aumento de la superficie de las lagunas paraglaciares debido al aumento del derretimiento de los glaciares.	Incremento de la superficie de las lagunas por intensificación de los procesos de derretimiento de glaciares por el aumento de temperaturas.	Instalciones ubicadas en la cercanía de las morrenas de recesión.	Que las lagunas del sistema paraglaciar inunden instalaciones cercanas.	Que el crecimiento de la laguna debilite la zona de fundación o asentamiento de alguna instalación.	La estabilidad de las fundaciones depende de las propiedades geoténicas y humedad del suelo.	**Adaptación 11:** no ubicar instalaciones en la zona cercana del frente de las morrenas.
Frecuencia de eventos extremos de tiempo y temperatura	Se ha registrado un aumento de la frecuencia de eventos extremos de temperatura y tiempo	Que continue la tendencia de aumento de evetos extremos de tiempos meteorológico.	Personas trabajando en la Base.	Que las personas estén expuestas de manera más frecuentes a eventos severos.	Que aumente la frecuecia de heridas o enfermedades por exposición a eventos severos.	Las personas pueden sufirir heridas heridas o enfermedes asociadas a eventos severos.	**Adaptación 12:** generar un sistema de alerta para evitar la exposición de las personas a eventos severos.

7.6 Cumulative Impacts

Cumulative impacts arise from the interaction between impacts caused by past, present, and likely future activities. These impacts result from the successive, incremental and/or combined effects of an activity or project when added to the effects of other existing and already planned undertakings.

Article 3 of Annex I to the Madrid Protocol considers the cumulative impacts of both the activity alone and in combination with other activities in the Antarctic Treaty area. This is a complex evaluation due to the multiplicity of variables that are involved in the process, and the significance of the impact arises from a multiscale analysis that will consider the actions to be carried out, the processes of the receiving environment, the spatiotemporal scope and the thresholds of assimilation.

Cumulative impacts may arise, for example, from air emissions, oil spills, and effluent discharges during the construction and operation stages of the Base. Generally, these activities are summarised in:

- Activities related to the logistics of the Base (planes, ships, trucks, etc.)
- Activities related to scientific deployment (near and remote camps, sea or air research, permanent scientific research structures).
- Tourism activities that take place around the area.

The northern part of the Antarctic Peninsula, the area of influence of the Petrel Base, is currently the most impacted region of the continent and with the greatest anthropic pressure. Not only because of the consequences of climate change, but also because the largest number of scientific stations, research tasks, logistics tasks, and tourism and fishing are concentrated there.

Among the cumulative impacts that were identified as products of the remodelling and commissioning of an aircraft runway at Cape Welchness, the following stand out:

Impacts to:

- the atmosphere (GHG emissions and particulate matter, also due to noise and vibrations).
- to the terrestrial environment (loss of soil quality, alteration of the glacial moraine, changes in the topography of the landscape and in the landscape value, alteration of the surface water network, changes in flora and microfauna, loss of habitat for nesting birds and marine mammals).
- to the marine environment (acceleration of coastal erosion processes, alteration of the physical-chemical composition of the water, alteration of the benthic diversity that inhabits the intertidal platform, alteration in the coastal planktonic community, loss of habitat for marine mammals and loss of feeding areas for seabirds).

The design of the station has greater energy efficiency (through the installation of the field of photovoltaic panels), improvements in the treatment of effluents (with the commissioning of a new treatment plant), and the possibility of developing new projects of scientific research in the area (facilitated by the possibility of air transfers and the installation of a laboratory module). Likewise, the activity will result in an improvement in waste treatment with a view to reducing the impact of contamination and the risk of environmental incidents.

The change in status of the Petrel Base will represent a small fraction of the total impact that this region of Antarctica regularly receives. On the other hand, the remodelling of the Petrel Base as a permanent base with a runway for large aircraft will enable it to recover its capacity to function as a logistics operation centre for the distribution of scientific groups working in the eastern Antarctic Peninsula within the Argentine Antarctic Programme or in collaboration with it. In this way, the logistics that today are carried out from the Marambio Base would pass into the hands of the Petrel Base, the latter being more efficient in terms of fuel demand and flight hours, ultimately, making overall less impact on the environment.

One of the most significant aspects among the cumulative impacts in the new Petrel Base is the interaction of the presence of the landing strips, an area that has a high number of movements of aircraft and vessels of all kinds. In principle, the most significant thing in the area is the direct interaction of the take-off and landing routes of both runways with the presence of colonies of fauna on the nearby islands. It is clear that when considering the construction of both runways, future operations to be carried out on them and associated human activities (scientific research and logistics activities, including infrastructure construction and support), we must take into account the disturbances caused by air operations and their environmental impacts such as noise, particle emissions, oil spills and the increase in human presence as long-term impacts.

The approach and takeoff routes were defined taking into account the CPA guidelines for the operation of aircraft near concentrations of birds in Antarctica, included in the Annex to Resolution 2 (2004), especially taking into account:

- Flight altitude over bird colonies higher than 2,000 feet;
- Landing site with a linear distance greater than ½ nautical mile;
- Passage over areas of concentration of wildlife is not foreseen
- Maintain a vertical separation from the shoreline of 2,000 feet whenever possible.

In this sense, it can be seen in Figures 249 and 250 that for both runways the approach and takeoff times do not overlap with the presence of the AICAs located in the Nearby Islands. Likewise, it has already been mentioned that there are no ASPAs in the area, being the only one presenting ASPA No. 148 Monte Flora in Bahía Esperanza, but which has paleontological values. Argentina will monitor changes in the area due to the operation of the aerodrome to modify its approach and takeoff routes with the aim of minimising the environmental impact on nearby bird and mammal colonies.

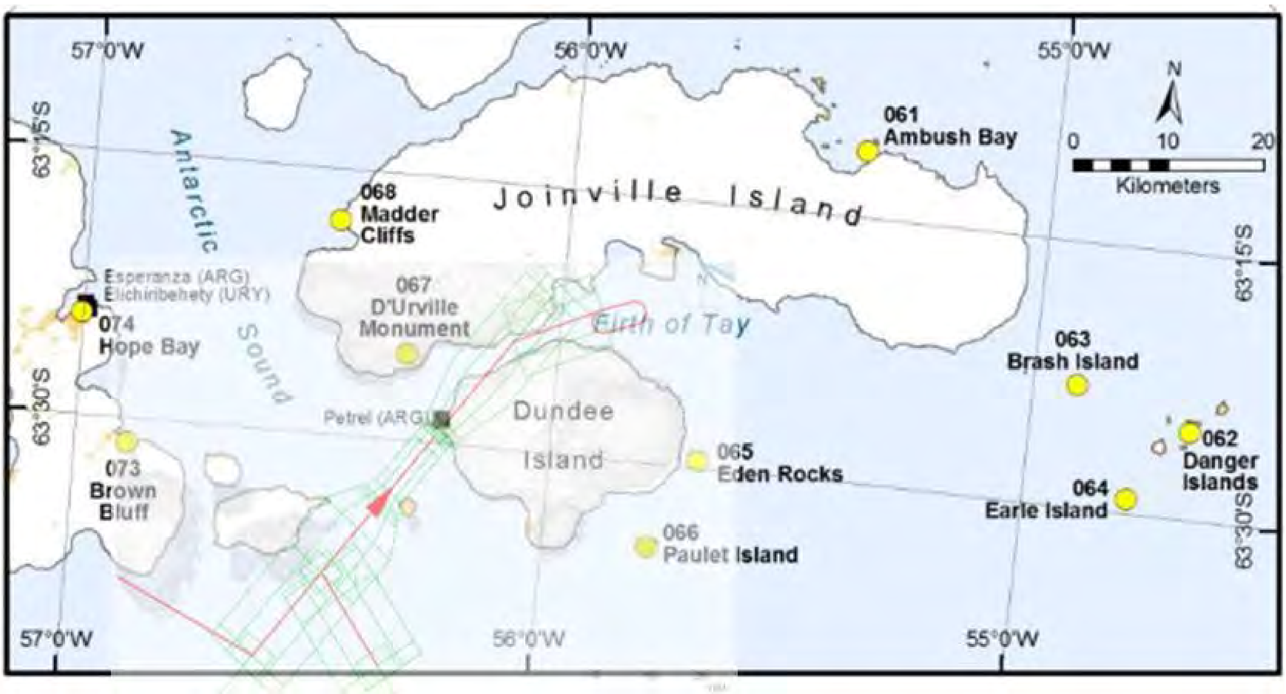

Figure 249: Overlapping of the approach and takeoff routes from Runway 03/21

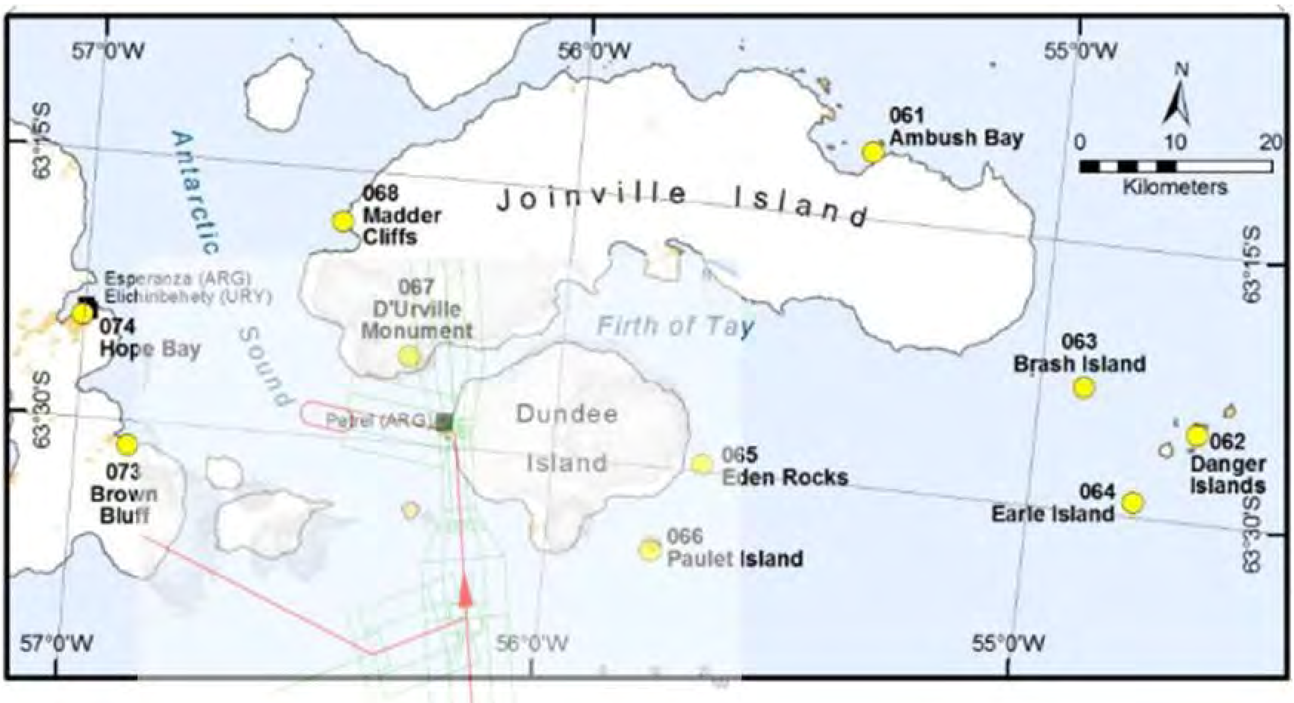

Figure 250: Overlay of approach and takeoff routes from Runway 17/35

8 MONITORING AND FOLLOW-UP PROGRAMME

Resolution 1 (2016) that establishes the guidelines for the Evaluation of Environmental Impacts in Antarctica establishes that when necessary, the monitoring objectives must be clearly established, establish verifiable hypotheses, select the key parameters to be monitored, evaluate data collection methods, design a statistical sampling programme, and decide on the frequency and schedule of data collection and recording. The implementation of such monitoring programmes is a further step, which can begin once the planning stage is complete, even if the activity has not started.

On the other hand, Article 5 of Annex I of the Protocol mentions that "Procedures will be established, including the appropriate observation of fundamental environmental indicators, to evaluate and verify the impact of any activity that is carried out after the conclusion of a Global Environmental Assessment." It is also important to note that the monitoring programme through indicators allows for the ongoing review of the proposed activity as established in Article 5 b) when mentioning that the purpose is to "provide useful information to minimise or mitigate impacts, and when where appropriate, information on the need to suspend, cancel or modify the activity."

The approach that we will adopt in this monitoring programme is based on the monitoring of three central questions 1. How are project activities affecting the environment? How are the project activities carried out? How is climate change affecting the project? and finally, What is the result of the application of mitigation and adaptation measures?

We understand that, although the monitoring or follow-up of a Global Environmental Assessment entails carrying out scientific measurement programmes, it should not be forgotten that ultimately the most important thing is to follow up on how the environmental impacts of the proposed activities are managed and have been minimised its effects and therefore make measurements of other aspects not related to natural values.

8.1 Monitoring Programme

General Objective of the Monitoring Programme

Obtain regular and verifiable information on the impact of the activities for the renewal of the Petrel Base, through the establishment of environmental condition and performance indicators, to monitor the effects on the environment of the project and assess the need to suspend, cancel or modify activities.

Specific objectives

1. How are the project activities affecting the environment?: Obtain regular and verifiable information on the environmental condition of the ecosystems present in the area of the Petrel Base and its zone of influence, through field sampling and the collection of information from a database, to evaluate the changes observed in the environment and its relationship to project activities.
2. How are the project activities carried out?: Obtain regular and verifiable information on the environmental performance of the activities carried out for the construction and use of the Petrel Base, through the implementation of a set of indicators of

environmental performance, to assess the degree of compliance with the mitigation measures established for the project.

3. How is climate change affecting the project?: Obtain regular and verifiable information on climate trends in the area by collecting data and collecting information in databases to determine the impact of climate change on the Base and evaluate the efficiency of the proposed adaptation measures.
4. What is the result of the application of mitigation and adaptation measures? Prepare an annual report based on the analysis of the information obtained to assess the status of the environmental condition and performance of the project activities.

8.2 Specific Monitoring Programmes

8.2.1 Environmental Condition Monitoring Programmes

An Antarctic Base is immersed in an environment that has natural characteristics and that, in turn, are related to the environment of the area. All this set that was described in the environmental characterisation of this EMG, it is necessary to permanently evaluate both the state in which they are and how they evolve over time (short, medium and long term). The state of the characteristics of the environment is called environmental condition and a correct follow-up of the same allows to ensure the fulfilment of the objectives and above all things to evaluate the affectation due to the environmental impacts received.

The objective of this programme is to “Obtain regular and verifiable information on the environmental condition of the ecosystems present in the area of the Petrel Base and its zone of influence, through field sampling and the collection of information from a database, to evaluate the changes observed in the environment and their relationship to project activities. The environmental condition refers to the state of the environment in which the project is going to be carried out, both its baseline condition or starting environmental situation as well as the biological processes that integrate it and its trends over time.

The ecosystems present in the area of influence of the activities of this project are made up of numerous and diverse structural, functional, and compositional components (Noss, 1989). The environmental condition of an environment seeks to establish or measure the state of these components to assess, among other things, whether they are being affected by natural or anthropic processes that put present natural values at risk.

Of all the components of the environment present in the Petrel Base area, the greatest interest will be placed on those natural values that may be affected by environmental impacts derived from the activities to be carried out for the renovation and use of the new Base. That is why of all the possible elements to be used for the measurement of the environmental condition, environmental indicators will be used to measure the state and processes of the affected components. The results obtained should help to discriminate the impact of ecological and anthropic processes on the environment of the reserve and warn about their potential negative effects:

Data Collection

The information to obtain the environmental condition indicators must be obtained from the results of the monitoring programmes established in the Annual Antarctic Plan. They must cover the main values present, such as: soil, water, flora, fauna, climate, etc.

Source of information

Established monitoring programmes should be based on the following types of information:

- Field data collected or measured as part of the programmes implemented in the RND.
- Official data from different national and international organisations (e.g.: National Meteorological Service, Naval Hydrographic Service, National Geographic Institute, SCAR, COMNAP, etc.) and data from NGOs.
- Satellite and Aerial Images provided by national and international space research agencies (e.g.: CONAE, INPE, NASA, NOAA, etc.).
- Data Characteristics: from the agreed records, the information for the subsequent calculation of the indicators is obtained. The data used can be classified into:
  - Direct measurements or calculations: absolute basic data and information.
  - Relative measurements or calculations: data or information compared to or in relation to another parameter.
- Indicator Categories: of the types of Environmental Condition Indicators (ICAs), they can be established according to the scale that involves the following categories:
  - Global or National ICAs (ICAsG or ICAsN): provide information on the global or national environmental condition.
  - Regional ICAs (ICAsR): provide information on the environmental condition of the region where the Petrel Base is located.
  - Local ICAs (ICAsL): provide information on the local environmental condition of the main characteristics present at the Base.

Aspects to consider

For each indicator to be measured, the following points will be established:

1) Environmental component
2) Environmental Parameter
3) Environmental impact
4) Measurement objective
5) Variables to measure
6) Indicator Type
7) Measurement frequency

Ecosystem Component	Environmental Component Exposed	Environmental Parameter	Environmental impact	Measurement Objective	Variables to Measure	Measurement Frequency
Atmosphere	Air	Air quality	Alteration of the composition of the air due to the emission of pollutants.	Determine the presence of pollutants in the air and trends of change in composition	Suspended particles, NOx, microplastics, etc.	Annually
Land	Soil	Topography	Alteration of the substrate and landscape due to the installation of buildings (building foundations)	Registers changes in the landscape structure due to the presence of buildings.	Detailed digital elevation model for the preparation of a topographic map,	Annually
		Topography	Alteration of the relief due to the presence of the slope of the runway (embankment).	It records changes in the landscape structure due to the presence of the runway.	Detailed digital elevation model for the preparation of a topographic map,	Annually
		Landscape	Alteration of the landscape due to the circulation of machinery and vehicles.	Determine changes in the slaughter area used.	% area sacrificed for road use.	Annually
		Soil structure	Alteration of the soil due to the intrusion of anthropic elements (building foundations)	Record of alteration of water retention in the soil due to the presence of foundations.	Soil temperature and humidity monitoring.	Permanent
		Soil quality	Soil contamination (due to the use of fuels, vehicle circulation, etc.).	Analysis of soil quality by detecting contaminants.	Presence and quantity of hydrocarbon derivatives in the soil.	Annually
		Soil quality	Soil contamination due to the presence of residues (historical and current).	Record of waste sites at Cape Welchness	Amount and type of waste.	Permanent
	Surface water	Drainage networ	Alteration of surface water courses due to the presence of buildings and the runway.	Analyse the modification of the surface drainage network.	Cape Welchness surface watercourse map.	Annually

		k				

		Drainage network	Water pollution by anthropic elements (hydrocarbons, micro plastics, etc.)	Analysis of soil quality by detecting contaminants.	Presence and quantity of derivatives of hydrocarbons and heavy metals.	Annually
		Drainage network	Generation of artificial accumulation sites for snow and/or surface water.	Record the places with accumulation of water in summer.	Map of water accumulation sites.	Annually
	Fauna	Diversity	Alteration of distribution patterns of birds and mammals in the Cape due to increased human activities.	Establish changes in spatial use by species.	Evaluate habitat use patterns of species.	Annually
		Population dynamics	Alteration of the population dynamics due to the increase in human activities.	Establish changes in the number of individuals by species.	Monitor population sizes and reproductive success of bird and mammal species	Annually
		Introduction of species	Introduction of non-native species.	Determine the presence of non-native species	Quantity and sites with non-native species	Permanent
		Taking of species	Incidents with species of birds and mammals during air operations.	Determine number of bird strike events in air operations	Record of incidents during landing and take-off of aircraft	Permanent
		Physiology	Alteration of the physiology of fauna due to environmental contamination	Determine the presence of contaminants in the tissues of birds and mammals	Analysis of the concentration of essential elements, heavy metals and determination of the presence of microplastics.	Annually
	Flora	Diversity	Alteration of the distribution patterns of the flora in the Cape.	Establish changes in spatial use by species.	Locate patches of vegetation and georeference them using GPS.	Annually

		Distribution	Alteration of the distribution of flora due to the harmful interference of human activities.	Determine t he interaction of flora with human activities	Maps of vegetation	Annually
Marine	Flora and Fauna	Composition	Alteration of the distribution and diversity of coastal fauna and flora due to the presence of human activities.	Establish changes in the spatial use by coastal species in the discharge zone.	Study of the diversity, structure and spatiotemporal fluctuations of the marine microbial community and larval stages of crustaceans and fish	Annually
		Physiology	Alteration of the benthic fauna and flora of the coast due to pollution (effluents, hydrocarbons, etc.)	Determine the presence of contaminants in fauna and flora tissues	Analysis of the concentration of essential elements, heavy metals and determination of the presence of microplastics.	Annually
Cryosphere	Glacier Environm ents	Permafrost	Modification of the active layer of permafrost due to the presence of the new facilities.	Set changes to the dynamics of the active layer at the sites of the new facilities	Depth of the active layer, soil temperature.	Annually
		Ice-free area	Modification in the ice-free area and the interaction with human activities.	Determine the effects of glacier retreat.	Map glacial fronts and margins.	Every 3 years
		Sea ice	Alteration of coastal sea ice due to ship activity.	Analyse changes in coastal sea ice in the vessel unloading area.	Coastal sea ice map.	Annually
	Paraglacial lagoons	Volume of the lagoons	Alteration of the accumulation of water in the paraglacial lagoons.	Analyse the dynamics of the lagoons in front of the glacier	Lagoon map and volume estimation.	Annually
		Water quality	Alteration of the water quality of the lagoons in front of the moraines.	Analysis of soil quality by detection of contaminants.	Presence and quantity of derivatives of hydrocarbons and heavy metals.	Annually

8.2.2 Environmental Performance Monitoring Programmes

The evaluation of environmental performance measures seeks to determine “the measurable results of the management that an organisation makes of its environmental aspects.” In order to evaluate the performance of an organisation, “environmental performance indicators” are established that allow gathering information on the effort of the organisation and the operations that are carried out. In this way, an attempt is made to carry out measurable monitoring of the environmental performance of the Petrel Base through objective and verifiable information in order to assess compliance with the mitigation measures.

The objective of this specific programme is to “Obtain regular and verifiable information on the environmental performance of the activities carried out for the construction and use of the Petrel Base, through the implementation of a set of environmental performance indicators, to assess the degree of compliance with the measures mitigation measures established for the project.”

Regarding the characteristics of each indicator, the following is established:

1- Data Characteristics: the information for the subsequent calculation of the indicators is obtained from the aforementioned records. The data used can be classified into:

- Direct measurements or calculations: absolute basic data and information.
- Relative measurements or calculations: data or information compared to or in relation to another parameter.

2- Indicator Categories: of the general categories for Environmental Performance Evaluation, those of the Environmental Performance Indicators (IDAs) type are established, and within this category:

- Management Performance Indicators (IDGs): provide information on management's effort to influence environmental performance.
- Operational Performance (IDOs): provide information on the environmental performance of an organisation’s operations.
- Environmental Conditions (ICAs): provide information on the environmental condition of the area where the organisation’s activities are carried out.

3- Measurement Frequency: according to the type of measurement, the measurement frequency can be annual, quarterly or monthly.

4-Data Collection: the information to obtain the indicators comes from the different records kept by the different dependencies of the Base. The main ones are:

- Arts and records of the Environmental Manager Manual.
- Report on Waste to DNA storage.
- Maintenance Records of the Different Rooms (Plumbing, Electricity, etc.).
- Monthly Report on Transportation.
- Monthly Report on the Power Plant.
- Cargo manifests.
- Internal Inspection Reports.

- Records of Water and Effluent Analysis.

➢ Staff reports.

➢ Weather reports.

5-Information Evaluation and Results Report: the information obtained will be evaluated every six months in order to compare it with the established environmental performance criteria. With an annual frequency, a report will be prepared based on the results obtained in the calculation of the indicators. The aforementioned report and its communication provide useful information for all interested parties in relation to environmental performance.

6-Environmental performance indicators:

OBJETIVO / PROCESO	*ACCIÓN DERIVADA*	*INDICADOR*	*UN. De MEDIDA*	*Medición*		*Categoría*		*Frec.*
				Directa	*Relativa*	*IDGs*	*IDOs*	
Gestíon Integral de los Residuos Generales	Relevamiento de el 100% de los sitios con res. históricos	Cantidad de sitios con RH / Cantidad al año 2014	% de sitios remanentes		x		x	Anual
	Evacuación de Residuos Históricos y domicialirios	Cantidad de Parsonas en la Base	Personal en la Base	x		x		Mensual
		N° de arribos de buques logísticos	N° arrivos	x			x	Mensual
		N° evacuaciones de residuos	N°	x			x	Mensual
		Residuos GI generados	M3	x			x	Mensual
		Residuos GI generados / cantidad de personas en la base	M3/ personas		x		x	Mensual
		Residuos GI evacuados / N° de arribos de buques logísticos	M3 / N° arrivos		x		x	Mensual
		Área de sacrificio por Instalaciones / área total de la Base.	%		x	x		Anual
	Ejecutar plan de Gestión de Residuos	Residuos G II Generados	M3	x			x	Mensual
		Residuos G II generados / cantidad de personas en la base	M3 / personas		x		x	Mensual
		Residuos G II evacuados / N° de arribos de buques logísticos	M3 / N° arrivos		x		x	Mensual
		Residuos G III generados / cantidad de personas en la base	M3 / personas	x			x	Mensual
		Residuos G III evacuados / N° de arribos de buques logísticos	%	x		x		Mensual
		Residuos G IV generados	M3	x			x	Mensual
		Residuos G IV evacuados / N° de arribos de buques logísticos	M3 / N° arrivos		x	x		Mensual
		Residuos NP generados / Residuos NP Evacuados	Tamb / Tamb		x	x		Anual
		Residuos NP Acumulados	M3	x			x	Mensual
		Residuos RP generados / Residuos RP Evacuados	Tamb / Tamb		x	x		Anual
		Residuos Peligrosos Acumulados	M3	x			x	Mensual

Minimizar impacto por generación de efluentes cloacales	Inspecciones, mantenimiento preventivo y correctivo	Vol. de efluentes generados / cantidad depersonas en la base	Lts / personas		X		X	Mensual
		Calidad de los efluentes generados	Apto/No apto	X		X		Anual
		Nº de perdidas o derrames de efluentes	N • derrames	X			X	Mensual
Prevención de Accidentes y Dderrames	Inspecciones, mantenimiento preventivo y correctivo de combustibles	Nº de derrames o perdidas de cumbustible	N• derrammes	X			X	Mensual
		Consumo de GOA Usina (Grupos Electrógenos)	Lts.	X			X	Mensual
		Consumo de GOA Base	Lts.	X			X	Mensual
	Comprobar los planes PREVAC e Hidrocarburos	N° de situacion de emergencias registrados	N• situaciones	X			X	Mensual
		Nº de prácticas preaccidente	N• prácticas	X			X	Mensual
		Nº de prácticas contraincendio	N• prácticas	X			X	Mensual
		Nº de prácticas combustible	N• prácticas	X			X	Mensual
		Registro de Capacitaciones	N° Capacitac.	X			X	Trimestral
Asegurar provisión de agua potable	Realizar análisis de potablidad	Consumo de agua / Personas en la Base	Litros / personas		X		X	Mensual
		Resultado de analisis de agua de consumo	Mensual	X			X	Mensual
		N° de muestras	Cantidad de muestras	X			X	Mensual
	Optimizar el funcionamiento del derretidor.	Consumo de combuistible derretidor / Consumo de agua de la base	Lts/ Lts		X		X	Mensual

8.2.3 Climate Change Monitoring Programmes

The objective of this programme is to “Obtain regular and verifiable information on climate trends in the area by collecting data and compiling information in databases to determine the impact of climate change on the Base and evaluate the efficiency of the measures of proposed adaptations.”

The variables to monitor are those mentioned in Point **Error! Reference source not found.** when analysing the impact of climate change on the project:

- Average annual temperature
- Average summer temperature.
- Depth of the active layer of permafrost.
- Average value of sea level rise.
- Number of days with rain.
- Amount of annual rain fall.
- Amount of annual snowfall.
- Geotechnical properties of the soil.
- Location of the glacier front.
- Number of extreme weather events.

The sources of information will initially be international databases and then, as progress is made with the base project, the meteorological station that is to be installed.

9 KNOWLEDGE GAPS

The Petrel Base renovation project has a very important scope and therefore the processes and activities that make up each part of it are complex. Having all the detailed information to evaluate each aspect to take into account is not always an easy task. For this reason, we believe that there are knowledge gaps that can be filled as the project progresses, especially in the items that we develop below.

9.1 Project Stages and Schedule

The scope and activities that have been outlined in this EMG draft depend on numerous variables, including securing funding at the right times and also the circulation of this draft. Given the intrinsic terms of the project (about 4 years), contingencies may cause the schedule and the stages originally proposed to be reviewed, facts that will be permanently notified and reported by Argentina to the Environmental Protection Committee and all parties.

9.2 Design of the Facilities

At the time of preparing this draft EMG, the Petrel Base renovation design is at a stage where all major and minor elements of the proposed new base are clearly defined and projected to scale with supporting documentation and specifications. The same situation occurs with the construction of the landing strip and with the photovoltaic plant. While no significant modifications are expected throughout the project, minor changes may occur between the circulation of this draft EWC and the completion of the procurement processes. However, these are not expected to have any material effect on the impact assessment in the draft that we have submitted.

9.3 Lack of knowledge in environmental description

A central aspect in an environmental impact assessment such as this draft is the detailed description and diagnosis of the environment in which the activities are to be carried out. In this case, we find that by locating the Petrel Base in the North of the Antarctic Peninsula, sufficient and significant information is available to describe the region and/or the surrounding area.

The situation is different when we analyse the situation on a local scale, given that the irregularity in the use of the Petrel Base has not made it possible to have continuous and updated time series of information (such as current meteorological and climate data), as if they exist in other Argentina Base. An attempt has been made to solve this situation by carrying out campaigns starting in the summer of 2022 that seek to collect information on the state of the environment and its processes on Dundee Island and Cape Welchness. Although there may still be knowledge gaps, we consider that the environmental information significantly related to the project has been compiled.

9.4 Removal of the facilities

The deconstruction methodology for the renovation of the Petrel Base has been presented based on the best current knowledge on the state of the current buildings. But we believe that at the moment of beginning the removal, new obstacles may arise that force us to reconsider the activity in order to meet the objective of minimising the environmental impact of the removal of the old buildings.

9.5 Interaction of the runway and the moraine

The site for the installation of the runway means the close interaction in one of its runway heads with the moraine of the Rosamaría Glacier. While the glacier is dynamic (especially in recent decades due to climate change), the moraine ridge is much more stable. As presented in this EMG draft, the characteristics of the moraine ridge have been evaluated in great detail for many years. However, some important questions remain open and need to be addressed in the near future, in part by implementing site-specific tests.

One of the most important issues is to consider that the moraine closest to the runway head is made up of an upper layer of arid rubble of different sizes. However, studies have shown that below the rubble layer there is an ice layer that lies on top of the bedrock and incorporates scattered rubble. Given the dynamics of this moraine system, it is necessary to permanently evaluate what happens to these ice cores when the moraines are removed in such a way that the ice is exposed. The need to build a permanent runway using material from the moraine is supported by the fact that it has a lower environmental impact than other options.

This form of construction has already been used by other countries, but nevertheless we must not fail to keep in mind that the modification of the moraines entails monitoring the water dynamics of the area to prevent bodies of water from forming on the runway.

11 CONCLUSIONS

This draft of the Global Environmental Assessment (EMG) presented the activities associated with the renovation of the Petrel Base facilities and the construction of the runway and a photovoltaic plant. The environmental impacts probably derived from the environmental aspects associated with the proposed activities were evaluated together with the proposed mitigation, adaptation and follow-up measures.

From this draft EMG it can be concluded that the proposed activities are likely to have an impact ***greater than minimal or transient on the environment*** due to the duration, scale and intensity of the activities and their associated impacts. The most significant potential impacts that are expected to arise are:

- Emission of Greenhouse Gases;
- Modifications in the physical landscape, in watercourses and snowmelt waterways and alteration of the permafrost;
- Alteration of the moraine due to removal and movement of aggregates;
- Noise pollution due to noise generation;
- Contamination of soils and water courses due to spills of dangerous substances;
- Alteration of the substratum due to the introduction of anthropic elements;
- Alteration of the distribution of fauna and flora due to the increase in human activities;
- Introduction of non-native species due to increased human activities; and
- Modification of the landscape due to the increase in the sacrifice area.

Table 47: summary of the level of impact of the activities.

Nivel de impacto	N	Promedio	Moda	N	Promedio	Moda
BAJO	102	63	48	200	55	96
MEDIO	83	148	144	9	139	128
ALTO	24	269	288	0	0	0
TOTAL	209	121	48	209	59	96

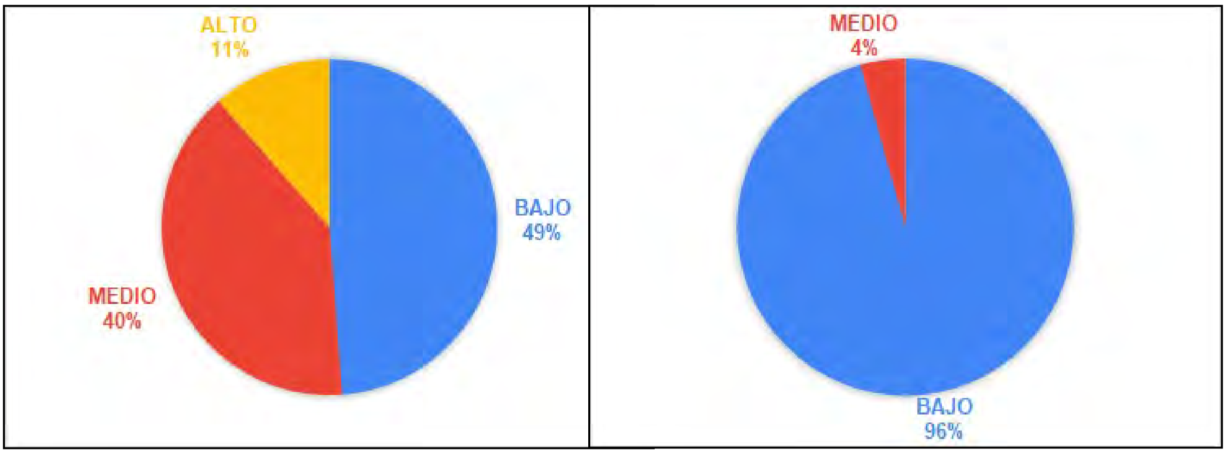

Figure 251: Percentage of the different levels of environmental impact. On the left without the application of the mitigation measures and on the right after the application of the mitigation measures.

Of a total of 209 environmental impacts estimated in the original assessment, 102 were low risk, 83 medium risk and 24 high risk. After the mitigation measures were proposed, finally 200 were low risk, 9 medium risk and none high risk (Figure 248 and Table 47).

The renovation of the Petrel Base, by changing it from a summer station to a permanent station, and the replacement of its facilities is aimed at improving the environmental performance of the activities that Argentina carries out there. The current situation of the Petrel Base,
- which has been reached due to non-regular use of the same, raised the need to address the emergencies that arise from the environmental aspects and impacts associated with the conditions of the Base. The state of the facilities exposes the natural values of the island to risks associated with the management of waste, fuels, among others. These conditions initially raised the need for its general repair. In this way, the objective of eliminating or mitigating the associated environmental impacts is sought through energy efficiency, sustainability, operational efficiency and risk reduction.

- Reduction of the contribution to global climate change thanks to the use of renewable energy generation (solar panels);
- Replacement of buildings for new facilities with greater energy efficiency and greater sustainability;
- Reduction of environmental pollution through a new wastewater treatment plant;
- Better facilities and procedures for waste management;
- Improvement in the entire fuel supply and storage system;
- A significant improvement in the facilities for scientific research through better laboratory spaces and better facilities;
- Better facilities for staff residence.

The proposed mitigation and adaptation measures, as well as the monitoring plans for the condition and environmental performance, as well as all the requirements that have been taken into account for the design of the new facilities and the procedures for the dismantling of the old buildings are considered adequate and sufficient to manage the aspects and impacts that have been foreseen.

Established monitoring programs (environmental condition, environmental performance, and climate change) can adequately verify the magnitude of anticipated impacts, detect impacts that are more significant than anticipated, and provide early detection of unforeseen impacts. Review and reporting of monitoring results are significant elements in ensuring that mitigation activities and measures can be modified as necessary to manage environmental impacts on an ongoing basis.

Thus, it is concluded that the proposed activities without the application of mitigation measures are likely to have a greater than minimal or transitory impact on the Antarctic environment. It is considered that the proposed activities should continue, given the improvements in environmental performance and the scientific support and environmental protection that they will allow to be achieved.

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