



Ross Dependency (Antarctica): Current and Future Geodetic Activities

OSG Technical Report 7

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ROSS DEPENDENCY (ANTARCTICA): CURRENT AND FUTURE GEODETIC ACTIVITIES

1 Executive Summary

This reports details the current geodetic activities of Land Information NZ in the Ross Dependency and summaries the work of other New Zealand and overseas agencies. The following recommendations are made for future New Zealand geodetic activities [Note: Section 6 details the recommendations fully]:

- In line with recommendations made by Grant and Belgrave [1996], the New Zealand Geodetic Strategic Business Plan [*Office of Surveyor-General* 1998a], and recognising New Zealand's interest in Antarctica, a new datum, Ross Sea Region Geodetic Datum 2000 (RSRGD2000), should be developed for the Ross Dependency. This will be consistent with the Standing Resolutions from the XXV SCAR Concepcion, Chile, 20 - 24 July 1998 (Resolution 5).
- RSRGD2000 should be implemented by 1 January 2000.
- Consider extensions to the spatial coverage of the present geodetic infrastructure.
- Geodetic data pertaining to Antarctica should be incorporated into the Land Information New Zealand Core Record System (CRS) and Geodetic Database to provide a full record of geodetic data in the Ross Dependency.
- The following maintenance of the current geodetic infrastructure is required:
 - removal of trig beacons;
 - installation of LINZ bronze plaques;
 - update field site records;
 - rationalisation and organisation of field records.
- The continued operation of the Cape Roberts tide gauge should be supported and data incorporated into the New Zealand Tidal Database.
- Land Information NZ should continue to liaise with other groups working on geodetic activities in Antarctica and contribute to the SCAR, GIANT strategy for the development of a spatial infrastructure across all of Antarctica.

2 Introduction

2.1 *Departmental Responsibility*

Land Information NZ was established on 1 July 1996, taking over responsibility for the policy, regulatory and core government service delivery functions of the former Department of Survey and Land Information (DoSLI), the Land Titles Office, and for the purchase of core hydrographic services from the New Zealand Defence Force. In July 1998, as part of the restructuring of Valuation New Zealand, the Office of the Valuer-General was established within Land Information NZ.

LINZ is focused on advising the Government, providing core statutory processes and infrastructure, and administering the Crown's interests in land and making government-held land information available to the public. The department is the government's spatial referencing authority, and the steward and standard-setter for core national land databases including the spatial referencing (geodetic) system, cadastral system, land titles, topography, hydrography, Crown property (excluding the Conservation Estate) and valuation.

The territorial extent over which Land Information NZ has responsibility to provide a spatial reference system has been extended from principally the land mass of New Zealand and the Ross Dependency to include the area of bathymetric obligations within the Government's area of maritime responsibility.

In a review by the Ministry of Foreign Affairs and Trade [MFAT 1996], the New Zealand government has also reaffirmed its involvement in Antarctica. It has defined its strategic objectives as:

“ the conservation of the intrinsic values of Antarctica and the Southern Ocean, for the benefit of the world community and for present and future generations of new Zealanders. The aims are reflected in active and responsible stewardship, that promotes New Zealand's interests by:

- maintaining New Zealand's long-term interest in and commitment to the Ross Dependency;
- keeping Antarctica as a neutral and non-aligned neighbour;
- enhancing New Zealand's economic opportunities within the parameters of the Antarctic Treaty System;
- enhancing New Zealand's leadership in the governance of Antarctica; and
- promoting Antarctica as a natural reserve devoted to peace and science.”

This commitment is further recognised through the development of a science strategic plan in Antarctica by Antarctica New Zealand [ANZ 1998].

2.2 *New Zealand Geodetic Strategic Business Plan*

The geodetic system in New Zealand is the infrastructure that provides the ability to define spatial location for a large part of human activity. Land Information NZ has identified key business drivers that imply a requirement for the development of, and change to, the geodetic system.

In 1998 a New Zealand Geodetic Strategic Business Plan [*Office of Surveyor-General* 1998a] was developed. The business plan included the provision and development of the geodetic system in New Zealand and the Ross Dependency.

The purpose of the Strategic Business Plan was to articulate a vision and plan for the development of the geodetic system. Business drivers and issues were detailed and a number of short-term (3-year) and long term (10-year) goals identified to enable the business drivers to be satisfied.

The following goals are identified as relevant to geodetic activities in the Ross Dependency:

Goal One: To provide a cost-effective system that can generate current geometric (three-dimensional) coordinates of points in terms of a globally accepted system to an acceptable and defined accuracy.

Goal Two: To provide a cost-effective system that can generate orthometric heights of points in terms of a nationally accepted system to an acceptable and defined accuracy.

Goal Three: To support multiple projections, and authoritative transformations of coordinates between those projections and the official geometric (three-dimensional) datum, to an acceptable and defined accuracy.

Goal Four: To support (in the short term) multiple vertical datums and authoritative transformations of heights to an acceptable and defined accuracy.

Goal Eight: Where appropriate, to contribute to and become an integral part of, the global geodetic system.

Goal Nine: To adapt the design and management of the physical network to take greater advantage of the potential efficiencies offered by new technology.

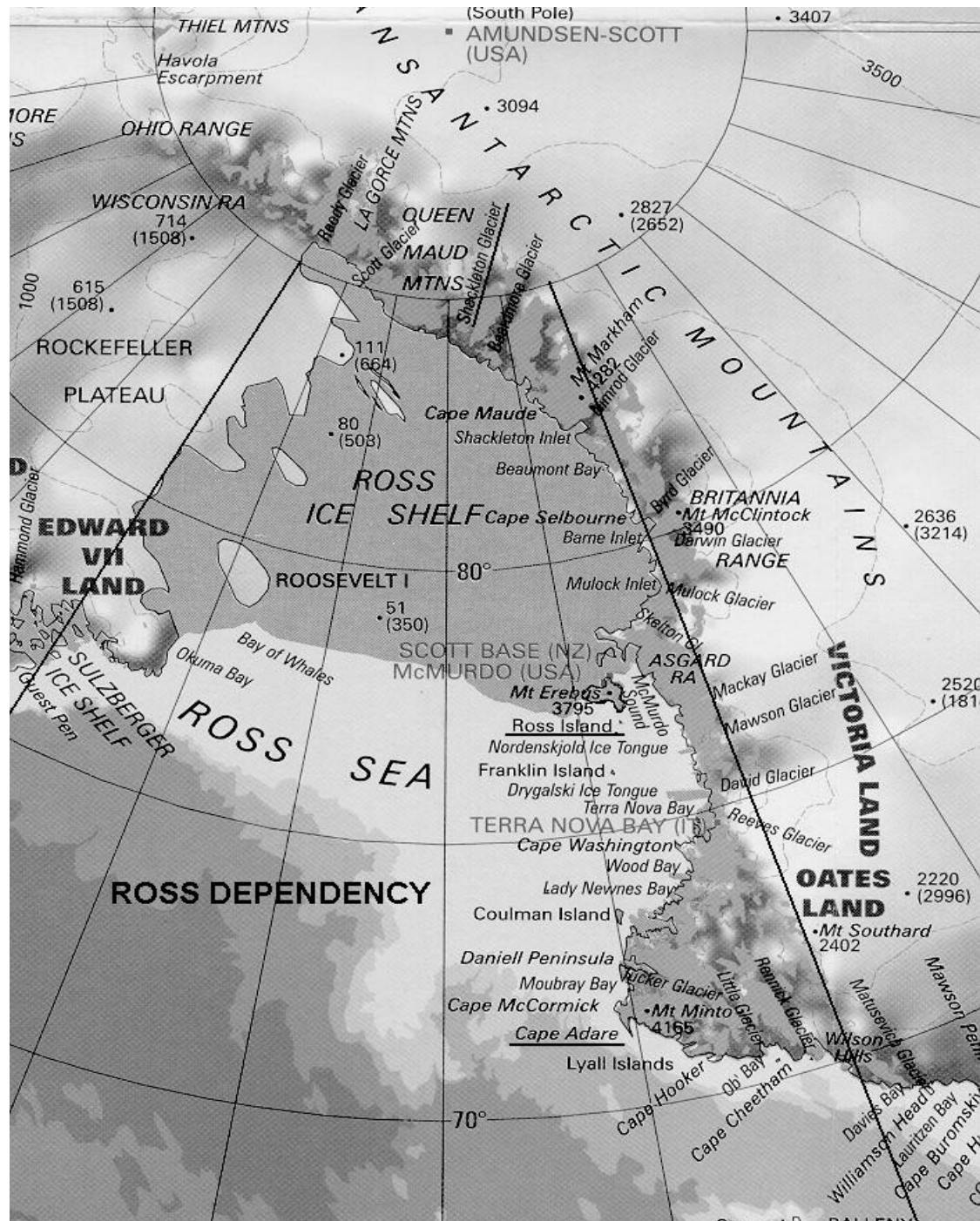
Goal Ten: A user community that understands, accepts, obtains benefit from and uses the New Zealand Geodetic System.

2.3 *Scope of this Report*

This reports details the current geodetic activities of Land Information NZ in the Ross Dependency, lying between longitude 150W and 160E, and latitude 60S and 90S, (Figure 1) and summaries the work of other New Zealand and overseas agencies in the

area. Recommendations on future development of the geodetic system in the Ross Dependency, and in particular the opportunities for collaborative work with other agencies, are detailed.

Figure 1. Map of the Ross Dependency region of Antarctica.



3 Geodetic Activities in the Ross Dependency

3.1 *New Zealand Activities*

3.1.1 *Historical Activities Pre 1996*

Prior to 1996 geodetic activities within the Ross Island/Transantarctic Mountains area of the Ross Dependency (Figure 1) by the former Department of Lands and Survey and more latterly Department of Survey and Land Information focused on four areas:

- support to science activities through provision of survey expertise to the New Zealand Antarctic Research Programme (NZARP);
- provision of geodetic control for mapping;
- provision of a control network to enable development of the Scott Base and McMurdo Stations on Ross Island (Figure 1);
- development and maintenance of a spatial infrastructure for the management and administration of the region.

The geodetic activities often concentrated solely on supporting scientific programmes rather than doing so in a way that also contributed to the development and maintenance of a unified spatial infrastructure. This has led to the development of a number of disjointed survey networks and datums within the Ross Dependency, the main one being Camp Area Datum, which is centred on Ross Island and the Dry Valleys area of the Transantarctic Mountains. Many isolated and independent geodetic stations have been located to support specific scientific projects, eg in the Dry Valley area, or for mapping purposes.

Many of the trig stations installed during this period have a trig beacon, consisting of two 44 gallon drums welded together and held in place with wire guys, constructed over the mark¹.

3.1.2 *Activities Post 1996*

3.1.2.1 Geodetic Network

With the trend towards the use of GPS and development of GIS systems and the need for managing and correlating spatially dependent data, there was a recognised need for consistency of spatial referencing of data in the Ross Dependency. The use of GPS for scientific and other activities accelerated the need for a consistent and uniform spatial referencing system in the area. Absolute positioning using GPS can provide spatial referencing at the few 100 metre level. This can increase the risk that experiment designers and data collectors fail to appreciate the significant spatial errors that can result from using GPS. This increases the risk of generating diverse datasets,

inappropriate spatial matching and analysis, and unsubstantiated or spurious conclusions being drawn from the data. While a few 100 metre accuracy may be sufficient for some applications, many applications require higher accuracy for which differential GPS is used. A spatial infrastructure is therefore required to provide a framework so that spatially diverse datasets can be integrated into a uniform system.

On 1 July 1996 Land Information NZ was established taking over responsibility for the policy, regulatory, and core government service delivery functions of the former Department of Survey and Land Information (DoSLI). The provision of direct survey field support to the New Zealand Antarctic Research Programme then ceased as it was outside the mandate of the new department.

In 1996 prior to the formation of the new department, a review of Ross Dependency survey requirements was carried out by *Grant and Belgrave* [1996] which identified the limitations with the current survey infrastructure. These limitations include:

- the inadequacy of the system to meet present and future needs;
- maintenance being carried out in an ad hoc manner;
- the development of a myriad of horizontal and vertical datums and coordinate systems which differ from WGS84 by several hundred metres;
- lack of a clear picture of the current geodetic system.

In the review the need for a survey infrastructure and a programme to enhance and update it was developed. Two options were considered as to how future needs could be met:

- integrate existing survey datums and maintain the infrastructure;
- start from scratch with a modern GPS-based survey system.

It was recommended that any new reference system be compatible with the World Geodetic System 1984 (WGS84). This recommendation is consistent with the arguments developed in the New Zealand Geodetic Strategic Business Plan [*Office of Surveyor-General* 1998a] and a report 'A Proposal for Datum Development' [*Office of Surveyor-General* 1998b] for the development of a new datum in New Zealand. The latter report recommends that the new datum in New Zealand be based on the International Terrestrial Reference System (ITRS) and thus be compatible with WGS84.

Grant and Belgrave [1996] suggested a survey maintenance programme to enhance and develop the existing survey infrastructure through to 2002. It was recommended that the programme commence in 1996/97 with the establishment and survey of a primary network (1st and 2nd Order 2000 stations) to connect all horizontal and vertical datums in the Ross Dependency together in terms of the ITRS with a follow up survey in 1997/98 to complete the field work. This programme was approved by

Land Information NZ and the 1996/97 survey undertaken in conjunction with the US Geological Survey (USGS). As a result of the collaborative efforts considerably more field work was accomplished during the initial field survey than initially planned. Accordingly, it was considered unnecessary to carry out further field work during the 1997/98 field season and until all data had been processed, the unified datum developed, and any remaining requirements identified.

In 1997/98 and subsequent years, USGS continued with their field surveys as part of their ongoing mapping requirements and as part of a joint USGS and Ohio State University (OSU) scientific project to study uplift and deformation of the Transantarctic Mountains (TAMDEF Project). Where practicable, this additional work has been tied into the New Zealand survey network and the data has been made available to Land Information NZ for integration into the current datum project.

Progress by Land Information NZ towards continued maintenance of the Ross Dependency survey infrastructure as proposed by *Grant and Belgrave* [1996] and processing of the data and development of a new datum has slowed. This has been principally because of the greater priority to develop a new datum for New Zealand to support the *Landonline* automation programme.

3.1.2.2 Cape Roberts Tide Gauge

Victoria University Wellington (VUW) has operated a tide gauge at Cape Roberts since 1990. This has provided a valuable, (possibly the longest such record in Antarctica) of sea level and tidal monitoring in the Ross Sea region. Until 1997 annual ties were made between the gauge and a reference bench mark by the former Department of Survey and Land Information. This tide gauge has operated successfully with the exception of 18 months loss of data due to hardware problems.

The operation of this site provides an important reference data set for development of tidal models and determination of sea level for future hydrographic charting in the Ross Sea as proposed by the department. An assessment of the data from this site will be carried out and a formal agreement arranged between VUW and the department for the ongoing maintenance and operation of the gauge and supply of data.

3.2 Overseas Activities

New Zealand has maintained a close relationship with other agencies working in the Ross Dependency and Antarctica and in particular, with the United States Antarctic Programme (USAP) since 1957.

Geodetic survey activities in the Ross Dependency by overseas agencies include:

- **US Geological Survey (USGS)**

- running and maintenance of GPS permanent tracking stations at McMurdo and South Pole that contribute data to the IGS;
 - provision of control for USGS aerial mapping and satellite imagery;
 - absolute gravity measurements which contribute to vertical uplift and vertical datum studies.
- **US Geological Survey/ Ohio State University** - joint scientific programme, funded by the National Science Foundation (NSF), using precise positioning with GPS to study uplift and deformation of the Transantarctic Mountains.
 - **University Navstar Consortium (UNAVCO)** - provide support to the US (and in several cases NZ) scientific programmes including the operation of a GPS permanent tracking station at McMurdo that broadcasts GPS Real Time Range corrections.
 - **Jet Propulsion Laboratory (JPL)** - support two projects that operate 5 GPS permanent tracking stations in the Transantarctic Mountains to study uplift and deformation of the mountains.
 - **Antarctic Support Associates (ASA)** (Contractors to NSF) - provide a surveyor at McMurdo and South Pole to carry out survey work associated with engineering and facilities management, and support to the US scientific programme.
 - **Italian Antarctic Programme** - provide a GPS permanent tracking station and tide gauge at Terra Nova Bay (Figure 1) and carry out some precise GPS and other geodetic measurements (eg gravity) as part of their scientific programme and the USGS/ Ohio States TAMDEF project.

The overseas agencies working in the Ross Dependency have traditionally been willing to support and contribute data to Land Information NZ for the datum project and to support the NZ Antarctic Programme. Specifically:

- USGS and the Italian programme make all data from the TAMDEF Project available to Land Information NZ to enhance and develop the new datum;
- data from the McMurdo, South Pole, and Terra-Nova Bay GPS permanent tracking stations are freely available for use on the datum project and to enhance the spatial infrastructure;
- UNAVCO have assisted with and provided data to several NZ science programmes.

The exchange of geodetic data in Antarctica is also facilitated through the Scientific Committee on Antarctic Research (SCAR), Geodesy and Geographic Information (GGI) working group, Geodesy in Antarctica (GIANT) sub group. New Zealand is a

member of this group which provides a forum for geodesy groups working in Antarctic to exchange information, collaborate on projects, and set standards for the development and integration of all geodetic data in Antarctica.

4 Future Geodetic Requirements in The Ross Dependency

4.1 Spatial Infrastructure

Through the SCAR GIANT working group there is coordination of geodetic activities in Antarctica and an aim to develop an Antarctica wide geodetic infrastructure [*refer internet site <http://www.scar-ggi.org.au/geodesy/giant.htm>*]. New Zealand contributes to this overall infrastructure. A 1998-2000 geodetic programme has been developed by GIANT and its objectives are to:

- provide a common geographic reference system for all Antarctic scientists and operators;
- contribute to global geodesy for the study of the physical processes of the earth and the maintenance of the precise terrestrial reference frame;
- provide information for monitoring the horizontal and vertical motion of the Antarctic.

There are significant efficiency gains through the provision of a uniform common survey infrastructure as detailed by *Grant and Belgrave* [1996]. Future requirements include the provision of an infrastructure in the Ross Dependency that will support:

- continued mapping (both topographic and hydrographic);
- the ability to spatially reference different data sets into a common GIS system¹ ;
- the NZ Antarctic Programme whose uses will include spatial referencing for safety, rescue, environmental protection, navigation, monitoring change, and science.

Land Information NZ's activities in the Ross Dependency must now focus on the development of an infrastructure that satisfies Primary Users as discussed in the New Zealand Geodetic Strategic Plan² [*Office of the Surveyor-General* 1998a]. A survey infrastructure that supports Primary Users through core Government activities (i.e. mapping to support science and hydrographic charting to meet Government objectives and reduce risk to Government from its activities in Antarctica) will often support other Secondary Users such as tourists and research.

¹ The lack of physical and manmade features in Antarctica, particularly in those areas covered by ice and snow, means that spatial referencing relies heavily on a survey infrastructure.

² The support of the Antarctic Research Programme through the provision of field survey expertise, as was provided prior to 1996, is now outside the business activities of the department. However there is opportunity for the science community to arrange the provision of these services through agencies such as UNAVCO or ASA.

4.2 *Topographic Mapping*

Current New Zealand science activities in the Ross Dependency have focused on Ross Island and the Dry Valleys area of the Transantarctic Mountains. The current New Zealand geodetic network and topographic mapping programme also focuses on these areas.

Discussions with Antarctica New Zealand suggest that the New Zealand scientific effort over the next 5-10 years may tend to expand northwards to the northern Victoria Land area of the Transantarctic Mountains. The US research programme is also tending to expand southwards towards the Shackleton Glacier area (Mullins (USGS) personal communication).

There is a desire by USGS to continue the joint NZ/US mapping programme (memo of understanding being developed between the two departments) and that this mapping should occur where the science programmes are focused. The geodetic infrastructure will need to be extended to support these future mapping and science programmes.

4.3 *Hydrographic Charting*

Land Information NZ has taken over the purchase of core hydrographic services from the New Zealand Defence Force. Hydrographic surveys are proposed to be contracted out in the future for surveys at the entrance to the Ross Sea in the Cape Adare, Cape Hallett, and Possession Island areas (Figure 1). Geodetic control is required to support this new initiative. In addition, some permanent control is required for forward planning in the event of New Zealand lodging a claim for an Exclusive Economic Zone in the Ross Dependency and potential claim for the continental shelf under the International Law of the Sea .

The survey infrastructure in this area of the Ross Dependency should form part of the overall geodetic infrastructure. Tidal observations in the Cape Adare, Cape Hallett, and Possession Island areas will be required. Observations made at the Cape Roberts and Terra Nova Bay tide gauges will be used to help model tidal flow in the Ross Sea Region for charting and tidal prediction purposes.

4.4 *Science*

A survey infrastructure that supports mapping and hydrographic charting will also support spatial referencing for many scientific applications. Specialised control may be required for specific scientific applications such as deformation monitoring. The use of GPS by scientists to provide the positional basis for data collection plays a prominent role in Antarctica because of lack of topographic features in many areas to reference data. This is particularly true in the work of monitoring ice cap thickness and ice flows.

4.5 *Other*

While there is currently no specific ownership of the Antarctic Continent there is no need for a cadastral system. However, there is a requirement to map and define rights over specific areas of land. This is currently restricted to the survey and defining of Scientific Sites of Special Interest, i.e. historic sites, which have conditions such as restricted access imposed on them. While it is unlikely in the future that Crown or company ownership of land will be permissible, it may be possible that the issue of rights (i.e. mining leases or fishing rights) over specific areas will be considered. The issue of such rights must be accurately spatially referenced. Any spatial infrastructure must accommodate the potential future need to accurately locate areas where special rights are granted or restrictions imposed. Such spatial referencing will need to be of a type consistent with international standards. Hence there will be a need to ensure that the Ross Dependency spatial referencing system is not inconsistent with or unable to support international standards.

5 Future Land Information NZ Activities and Opportunities

5.1 *Geodetic Network*

The costs to Land Information NZ of contracting field surveys in Antarctica to NZ Survey Companies is high. This can be due to the time delays in transport to and from Antarctica, time delays in the field, harsh operating conditions, and high costs of helicopter support. USGS have a commitment to ongoing geodetic activities in the Ross Dependency and have expressed a willingness to continue to collaborate with Land Information NZ (Hothem personal communication).

There is opportunity for the NZ scientific programmes to use the resources of UNAVCO and the ASA surveyors for field support which may be a more economical alternative than contracting dedicated NZ staff or companies. Any use of these services in Antarctica should be arranged through the appropriate channels, and in the case of both organisations, planned well in advance of the field season so that special arrangements can be made.

Because of the close working relationship between the NZ and US Antarctic programmes there is the potential to work collaboratively and to contract USGS for future survey and maintenance of the survey infrastructure in the Ross Dependency. In accepting any offer to work collaboratively, Land Information NZ should be able to be seen to be contributing to the overall geodetic programme in the Ross Dependency that supports both the NZ and US Antarctic programmes. There is also the possibility of contracting NZ science programmes to Antarctica to make geodetic survey observations during their field campaigns where they are in areas of interest to LINZ.

It is the intention of USGS to extend the GPS permanent tracking network with the installation of a permanent tracking station at Cape Roberts collocated with the Victoria University tide gauge. This would provide a key site for the integration of the vertical (orthometric) height network with the proposed new geocentric datum. Data from the Cape Roberts site would provide a valuable extension to the present survey infrastructure and would be an important data source for the hydrographic charting proposed in the northern Ross Sea Region.

5.2 *Maintenance*

The use of the Global Positioning System (GPS) eliminates the usefulness of the current trig beacons (two 44 gallon drums welded together and held in place with guy wires). The Environmental (Madrid) Protocol to the Antarctic Treaty³ sets out strict guidelines for the environmental protection of Antarctica. Senior staff of both the US

³ The Environmental (Madrid) Protocol to the Antarctic Treaty was concluded at Madrid in 1991. New

Zealand ratified the Protocol in 1994.

and NZ Antarctic programmes have expressed a desire that the survey beacons, and associated material, be removed as their continued existence is contrary to the Environmental Protocol. There is an urgent need to remove these beacons and clear waste material at many trig sites.

5.3 *New Datum*

In line with the development of a new datum in New Zealand, Land Information NZ should complete the adjustment and unification of geodetic data in the Ross Dependency. The new datum for the Ross Dependency should be compatible with New Zealand Geodetic Datum 2000 (NZGD 2000), being geocentric and ITRS based. Any new datum in the Ross Dependency should be ITRF96 at a reference epoch of 1 January 2000 and its relationship to Camp Area Datum and World Geodetic System 1984 (WGS84) defined. This agrees with recommendations made by GIANT.

Because the deformation rates in the Ross Dependency are very low, c. 1mm/year, no account needs to be made of the dynamics in a new datum as in the case of New Zealand Geodetic Datum 2000. Observations made by other agencies should be integrated into the new datum to enhance the spatial infrastructure and this data made available through the Land Information NZ Geodetic Database and the Land Information New Zealand Core Record System. In this way, NZ can be seen to be making a major contribution to the spatial infrastructure of the Ross Dependency building on its own efforts and work as well as that of other agencies.

5.4 *Mean Sea Level*

New Zealand and the US have attempted to install tide gauges on Ross Island to monitor tidal flows on several occasions in the past without success. Victoria University have successfully operated a tide gauge at Cape Roberts for 9 years, providing arguably the longest and best sea level records in Antarctica. Victoria University have offered this record to Land Information NZ and the data will be incorporated into the NZ Tidal Database. LINZ should contribute to the operation of this gauge and a formal arrangement entered into with Victoria University to ensure the ongoing operation of the gauge.

The future development of the spatial infrastructure in the Ross Dependency should be seen as a collaborative effort between NZ and other nations agencies working in the area. New Zealand's strength will be in the integration of all data and provision of an integrated datum with contributions from a number of sources. New Zealand will also be seen as an active participant in the ongoing maintenance and development of the infrastructure.

6 Recommendations for Future Work

6.1 *Datum Definition*

In line with recommendations made by Grant and Belgrave [1996], the New Zealand Geodetic Strategic Business Plan [*Office of Surveyor-General* 1998a], and recognising New Zealand's interest in Antarctica, a new datum, Ross Sea Region Geodetic Datum 2000 (RSRGD2000), should be developed for the Ross Dependency. This will be consistent with the Standing Resolutions from the XXV SCAR Concepcion, Chile, 20 - 24 July 1998 (Resolution 5).

The new datum for the Ross Dependency should have the following characteristics:

- it will be know as 'Ross Sea Region Geodetic Datum 2000' (RSRGD2000);
- the ellipsoid associated with RSRGD2000 will be the Geodetic Reference System 1980 (GRS80 ellipsoid);
- RSRGD2000 will be based on and aligned with the International Terrestrial Reference Frame 1996 (ITRF96) which has a geocentric origin and will be defined at epoch 1 January 2000;

6.2 *Datum Implementation*

RSRGD2000 should be implemented by 1 January 2000. This would provide a single authoritative datum for the Ross Dependency and incorporate data from other agencies such as USGS operating in the area. Data from the Cape Roberts tide gauge and proposed new GPS permanent tracking station should be integrated so that the vertical (orthometric) and RSRGD2000 datum can be integrated.

6.3 *Extension of the Geodetic infrastructure*

Extension of the present geodetic infrastructure will need to be considered and implemented to support:

- planned hydrographic charting by Land Information NZ in the Cape Hallett, Cape Adare, and Possession Islands area of the Ross Sea;
- extensions to the topographic mapping north and south of the present area of coverage;
- other users such as Antarctica NZ and the Antarctic Science Programme requiring access to a spatial infrastructure.

6.4 *Update of the Geodetic Database to Incorporate Antarctic Data*

Geodetic data pertaining to Antarctica should be incorporated into Land Information New Zealand Core Record System (CRS) and the Geodetic Database to provide a full record of geodetic data in the Ross Dependency. Where available, this should include site details.

6.5 *Ongoing Maintenance of the Geodetic Infrastructure*

The following maintenance of the current geodetic infrastructure is required:

- **Removal of trig beacons:** all Land Information NZ trig beacons should be removed by 2005;
- **Installation of LINZ bronze plaques:** many of the New Zealand survey marks in Antarctica are not identifiable as official Land Information NZ survey marks. Land Information NZ bronze plaques should be installed adjacent to high integrity survey marks and stamped with the geodetic code to aid identification;
- **Update field site records:** many sites have several NZ and/or US marks and many of these do not have site records (ie N7 or equivalent cards). Site and mark details should be completed or updated for high integrity marks and incorporated into the geodetic database;
- **Rationalisation and organisation of field records:** there is an urgent requirement to organise existing field records for ease of access in the future.

New Zealand should liaise with the USGS geodetic programme in the Ross Dependency to carry out the above maintenance programme. It is recommended that Land Information NZ provide resources during the 1999/2000 and 2000/2001 field seasons for maintenance of the New Zealand network.

6.6 *Cape Roberts Site*

With the Cape Roberts tide gauge and proposed collocation of a GPS permanent tracking station, there is the potential to link the vertical (orthometric) and new geocentric datum. This site will provide valuable data for the proposed hydrographic charting programme being developed by the department. It is recommended that:

- data from the Cape Roberts tide gauge be incorporated into the New Zealand tidal database so that it is available for use by the department and other agencies;

- Land Information NZ ensure the continued operation of the Cape Roberts tide gauge by Victoria University and provide funding for hardware upgrades, and ongoing operation and maintenance of the gauge;
- support the installation of a GPS permanent tracking station collocated with the tide gauge by USGS and contract to purchase data from this site for inclusion into RSRGD2000.

The above recommendations should also be considered in relation to the Terra Nova Bay tide gauge.

6.7 Liaison with Other Organisations

Land Information NZ should continue to liaise with other groups working on geodetic activities in Antarctica and contribute to the SCAR, GIANT strategy for the development of a spatial infrastructure across all of Antarctica.

7 References

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