Toitu te whenua
Land Information
New Zealand

Preferred Option for Development of a National Vertical Reference System

OSG Technical Report 16

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Foreword

Land Information New Zealand (LINZ) (Toitu te Whenua) was established in July 1996. It is a government department with roles and responsibilities in the following key areas:

Regulatory Responsibilities	**LINZ Regulatory Groups**
National spatial reference system and cadastral survey infrastructure	Office of the Surveyor-General
Topographic and hydrographic information	National Topographic/Hydrographic Authority
Land Titles	Office of the Registrar-General of Land
Setting rules for rating valuations	Office of the Valuer-General
Crown Property	Office of the Chief Crown Property Officer (Crown Property)
Assisting the government address land related aspects of Treaty of Waitangi issues	Office of the Chief Crown Property Officer (Crown Property)

The main role of the department is a regulatory one, to set guidelines and standards and manage contracts for carrying out the day to day business associated with each of the key areas.

LINZ also offers a range of services to customers related to land titles, survey plans and Crown property. Land Titles and Survey services are carried out by the Operations Group based in LINZ regional offices throughout New Zealand.

LINZ overarching objective is to be recognised as a world leader in providing land and seabed information services.

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PREFERRED OPTION FOR DEVELOPMENT OF A NATIONAL VERTICAL REFERENCE SYSTEM

1 Introduction

The LINZ New Zealand Geodetic Strategic Business Plan identifies three goals relating to heights datums in New Zealand. These are:

- **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 Four**: To support (in the short term) multiple vertical datums and authoritative transformations of heights to an acceptable and defined accuracy.
- **Goal Seven**: To develop a height system to a defined accuracy that enables the generation of orthometric heights from ellipsoidal heights.

To study various options in support of these goals two studies, one internal to LINZ and one external, were undertaken. The criteria, options and recommendations from these studies are reported in:

- OSG Technical Report 10: A Proposal for Vertical Datum Development in New Zealand. By Dr Merrin Pearse, February 2001.
- An Assessment of New Zealand's Height Systems and Options for a Future Height Datum, by Professor John Hannah, Department of Surveying, University of Otago, Dunedin, January 2001.

These two reports may be downloaded from the LINZ Web site at http://www.linz.govt.nz/services/surveysystem/osgpublications/index.html.

The details presented in this paper draw heavily on the above two reports, which should be read in conjunction with this paper.

This paper presents the preferred option for a new vertical datum and geoid model in New Zealand.

2 Problems with the Current Vertical Datum(s) in New Zealand

2.1 *Current Orthometric Datum(s)*

New Zealand, unlike most other countries, does not have a national orthometric datum, but rather 12 separate and poorly linked first order levelling networks tied to 12 different tide gauges, and a multitude of other less significant vertical datums [*Pearse* 2001].

This results in a number of problems with the current vertical datum(s) used in New Zealand that can be summarised as:

- Multiple vertical datums in use that are derived from mean sea level that is not an equipotential surface. [Note: Traditional vertical datums are designed on the assumption that mean sea level is a true level or equipotential surface. However it measurably departs from an equipotential surface which creates anomalies between adjacent or overlapping datums.];

- Precise levelling used to be the method of maintaining, extending or upgrading vertical control networks and datums. However, the cost of precise levelling is now prohibitive compared with newer technologies;

- A subset of users that use ellipsoidal heights. However there is no accurate geoid model in New Zealand to convert between ellipsoidal heights and orthometric heights to satisfy this user group;

- Current vertical datums that are purely land based;

2.2 *Introduction of NZGD2000*

In August 1999 a new geocentric datum for New Zealand, New Zealand Geodetic 2000 (NZGD2000), was implemented. This is a three dimensional datum with ellipsoidal heights determined in terms of the GRS80 reference ellipsoid. Orthometric heights can be derived from ellipsoid heights through the use of a geoid model. However no accurate geoid model exists for New Zealand.

3 The Aim of a New Vertical Datum

The aim of a new vertical datum is:

> *'the provision of one authoritative height system for survey marks above a level (equipotential) surface for New Zealand (including the continental shelf), that enables users to generate authoritative heights in terms of the vertical datum.'*

The rational behind this aim is to provide:

- An authoritative height system to avoid confusion – i.e. not to have multiple heights for each mark;
- A system to enable users to obtain heights above sea level or a level (equipotential) surface close to it;
- The ability for users to be able to compute the local instantaneous sea level in terms of the national height datum;
- The ability to correlate or transform between ellipsoidal heights and a level (equipotential) surface;
- The ability for the Crown to analyse data for the Continental Shelf claim.

4 Options

4.1 *Options for Development of a National Vertical Datum*

Hannah [2001] and Pearse [2001] consider various options for a national vertical datum and the issues leading to those options. This paper looks at the pros and cons of the two preferred options. Further background information can be obtained from Hannah and Pearse.

4.1.1 *Option 1a. Ellipsoidal Reference Surface plus Geoid – Orthometric Datum*

Under this option a geoid model would be developed using current available gravity and digital terrain data. This would be based on a recognised global geopotential model such as EGM96 that would define the long wavelength terms. An ellipsoidal height datum (using NZGD2000 ellipsoidal heights) would form the basis of the new national vertical datum from which orthometric heights could be determined using the new geoid model. Determining the offset between the new ellipsoidal datum and marks in each of the existing vertical datums would derive the relationship between each of those existing vertical datums. In addition the offset in mean sea level at each tide gauge could be determined by calculating the geoidal separation at each of those tide gauge reference sites relative to the ellipsoidal datum. Users wanting to know the current or instantaneous sea-level relative to local mean-sea-level can then use tidal predictions.

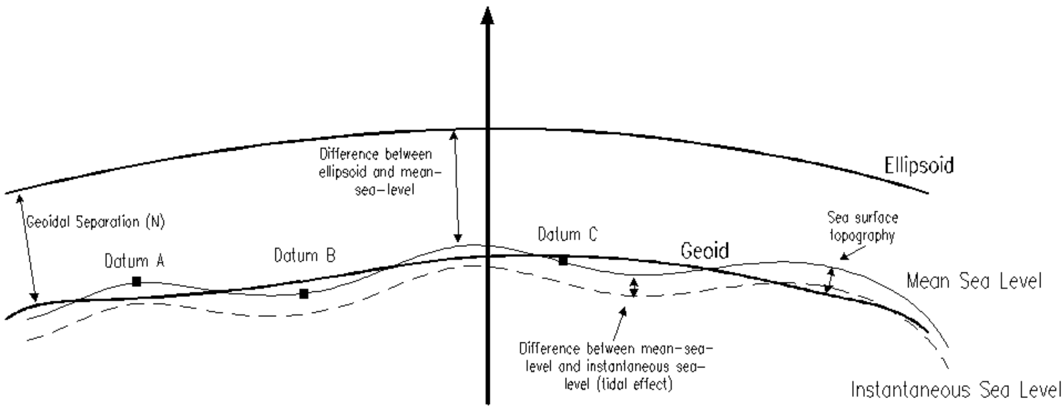

Figure: Relationship between ellipsoid, geoid (equipotential surface proposed for new datum), mean sea level - surface on which current datums are based, and instantaneous sea level.

The advantages of such an approach are:

- NZGD2000 has been developed with good quality ellipsoidal heights;
- We have the global EGM96 geoid model for use in New Zealand now but it is of low precision;

- There is additional new existing information, i.e. gravity data, that can be used to improve EGM96 and develop a more accurate geoid model;
- This is a national, and potentially an international, approach;
- The above defines an equipotential surface that is not affected by current levelling errors due to mark instability, earth deformation, systematic errors, and topographic constraints.

The disadvantages are:

- We currently do not have a national orthometric datum to test the results of any derived geoid model, however the relative height difference between bench marks can be used for limited testing.

4.1.2 *Option 1b. Orthometric Datum plus Ellipsoidal Heights – Geoid Model*

Under this option integration of the 12 separate vertical datums would be carried out initially to define a single national orthometric datum. The difference between this orthometric datum and ellipsoidal heights derived from GPS observations, along with gravity data and a digital terrain model, would be used to derive a Geoid Model.

Such an approach would have the following advantages:

- The current height system would not be changed too much (i.e. levelling errors could be distributed into the geoid model;

The disadvantages of this approach include:

- It would produce a distorted geoid model due to the inclusion of possible levelling errors;
- It is expected that the unification of the existing 12 vertical datums would take time and be costly without bringing significant improvements to the orthometric height datum.
- Analysis will be more complicated because of the various and unknown distortions (eg levelling errors) incorporated into the geoid model;
- It won’t result in a true level (equipotential) datum as it will be distorted by long range systematic errors in the levelling;
- It may ultimately conflict with more accurate models.

4.2 *Options for Orthometric Datum Zero*

Having decided on an option for development of a national vertical datum a further consideration is the choice of the orthometric datum zero. Three logical options are available. Background information can be obtained from Hannah [2001] and Pearse [2001].

4.2.1 *Option 2a. Zero Height at One Tide Gauge.*

Under this option the height at one tide gauge would be set so that the orthometric height is zero. This is perhaps the simplest option to implement but the adoption and assumption of zero height at one tide gauge would be influenced by any biases and errors in the data at that site. Such biases and errors include:

- Errors in the determination of mean-sea-level at that site;
- Vertical crustal deformation and/or sea level change that may have resulted since the determination of mean-sea-level;
- Instabilities in the tide gauge or ground reference mark to which the tide gauge is tied;
- Effects of sea surface topography on the resultant mean-sea-level at that site.

An added issue is that the assumed value of zero height would drift away from the physical value due to influences such as sea level change. This may result in the need to change the zero height value from time to time.

4.2.2 *Option 2b. Zero Height Derived from the Mean of a Number of Tide Gauges*

This option is similar to 2a above except that datum zero is based on the mean of two or more tide gauges. This option would help to lessen (but not remove) the biases and errors in the data as described for option 2a. Any ongoing changes in sea level would also affect the determination of the zero height value.

4.2.3 *Option 2c. Adopt an Equipotential Surface Corresponding to Zero Height.*

A global geopotential model (eg EGM96) would be used to define the equipotential surface corresponding to zero height. This would leave the national vertical datum independent of (but close to) the local mean sea surface, while providing alignment with the global mean sea surface inherent in the geopotential model. This would remove the biases and errors described with options 2a and 2b above.

Adoption of this option should be dependant on such a defined geopotential model being close (few decimetres) to mean-sea-level, i.e. that any global geopotential model adopted does not itself have a large bias across New Zealand. A further consideration is the effect on zero height of a revision of the EGM global geopotential model or its determination using a new locally derived geoid model. However the average effects of any changes across New Zealand would be expected to be small.

5 Preferred Option for Development of a National Vertical Reference System

The adoption of option 1a, development of a geoid model using available gravity and digital terrain data is the preferred solution for development of a national vertical datum. Option 2c, the use of an equipotential surface corresponding to zero height is proposed as the orthometric datum zero. The final selection of this option is dependent on this surface being close to mean-sea-level.

Based on this solution the following methodology is recommended for the development of a national vertical reference system in New Zealand:

1. Provide a policy statement on the development of a national (ellipsoidal) vertical datum in New Zealand.

2. Determine a local geoid model based on existing gravity data and digital terrain models.

3. Use a global geopotential model to define a geopotential surface (eg EGM96) that forms the basis for zero height.

4. Fit the local geoid to the International Geoid model (eg EGM96). This method will work offshore where the international geoid can be used with a more detailed model onshore.

5. Determine an accurate separation between the ellipsoidal heights and each separate existing vertical datum to determine the relationship between each of the existing datums. This will allow unification of the individual orthometric height datums relative to the vertical ellipsoidal datum. In a similar manner determine the height separation between the ellipsoid and local mean-sea-level at each tide gauge to determine the relationship of sea level and the geoid.

6. Test the model at selected sites by comparing the orthometric derived heights using the geoid model with levelled heights. Refine the geoid model as necessary.

6 References

Hannah, J. 2001: An Assessment of New Zealand's Height Systems and Options for a Future Height Datum, *Contract report published by Department of Surveying, University of Otago, Dunedin*.

Pearse, M. 2001: A Proposal for Vertical Datum Development in New Zealand. *Land Information New Zealand OSG Technical Report 10.*