Toitu te
Land whenua
Information
New Zealand

A Proposal for Geodetic Datum Development

OSG TR2.1
Office of Surveyor-General

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Contents

Foreword

Land Information NZ (LINZ) was established on 1 July 1996 and took over the 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 hydrographic services from the New Zealand Defence Force (to be made contestable from 1 July 1998). From July 1998, as part of the restructuring of Valuation New Zealand, the Office of the Valuer-General will be established within LINZ.

LINZ is focused on advising Government, administering the Crown's interests in land and making Government held land information available to the public. It is the government spatial referencing authority, and the steward and standard setter for core national land databases including: the spatial referencing system, cadastral system, land titles, topography, hydrography, Crown property (excluding the conservation estate) and valuation. Its vision is to provide world class land and seabed information services.

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This document is issued by the Office of Surveyor-General to:

- document proposals for geodetic datum development;
- elicit feedback from stakeholders on these proposals; and
- obtain approval for the final proposals (modified as required on assessment of the feedback) in order to commence the detailed design and realisation of the required geodetic datum.

Revision History

OSG TR2 published 31 March 1998 and circulated for external consultation.

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Datum Project Team

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Executive Summary

The New Zealand Geodetic System Strategic Plan (LINZ, 1998) identified its first goal as:

> ***To provide a cost effective system that can generate up-to-date geometric coordinates of points in terms of an internationally accepted system to an acceptable and defined accuracy.***

Note that this goal does not address the requirements for heighting in terms of an orthometric or mean sea level datum. This is a separate and less urgent goal which will be assessed at a later date.

The following recommendations have been made as preliminary requirements to achieve this goal:

1. ***It is recommended that Land Information New Zealand establish and implement a new official geodetic datum to realise the requirements for three dimensional geometric spatial referencing.***

2. ***It is recommended that the new datum have a geocentric origin.***

3. ***In line with recommendations of the International Association of Geodesy, it is recommended that this datum be based on, and aligned with, the International Terrestrial Reference System (ITRS).***

4. ***Also in line with recommendations of the International Association of Geodesy, it is recommended that the ellipsoid associated with this datum, be the Geodetic Reference System 1980 (GRS80) ellipsoid.***

5. ***It is recommended that the relationship between the new datum and the ITRS be specified at a nominated reference epoch and that all points coordinated in terms of the new datum have coordinates defined in terms of this epoch.***

6. ***It is recommended that the generalised motion of points in New Zealand with respect to the ITRS be modelled to:***

    - ***ensure that observations made at a date other than the reference epoch can be used to generate reference epoch coordinates; and***

    - ***allow up-to-date coordinates at a date other than the reference epoch to be generated from reference epoch coordinates.***

7. ***It is recommended that points coordinated in terms of the new datum not have fixed coordinates but that the coordinates be updated as required to account for new observations, earthquakes or predictable regional mark movement.***

These recommendations are based on an assessment of various options against the geodetic business drivers for Land Information New Zealand (LINZ). Issues which are likely to arise for internal and external spatial data users have been identified. The detailed design of the datum and related systems should take account of these issues and attempt to minimise any adverse effects.

A PROPOSAL FOR GEODETIC DATUM DEVELOPMENT

1 Introduction

1.1 *Responsibility for the Datum*

The New Zealand Surveyor-General is responsible under the Survey Act 1986 for ensuring the provision of, and setting standards for, the geodetic and cadastral survey systems. These responsibilities are also reflected in accountabilities to the Chief Executive of Land Information New Zealand (LINZ). The most fundamental standard of a survey system is the datum.

The geodetic system improves with use. The more people and agencies that are using it and contributing data to it, the better it gets. The principles and design of the geodetic system are based on the efficiencies and long term mutual benefits that result from shared use of the system.

Nevertheless, different users have different requirements and it is not always possible to design a system that meets everyone’s needs. External agencies managing spatial data are free to adopt a different geodetic datum from the one accepted by the Surveyor-General. In practice, these agencies will generally hesitate to do so because of the additional data maintenance costs which result from having to convert authoritative datasets to their own systems.

It is the task of the Surveyor-General to ensure that the geodetic datum meets, and will continue to meet, the requirements of the majority of users. This will maximise its value to the New Zealand economy, maximise the use of the system which increases its integrity, and thus protect the Crown investment in the geodetic system. As a geodetic datum takes a year or two to establish and is expected to last for at least a decade, preferably longer, the Surveyor-General must take not only account of current technical capabilities, but also anticipate likely future developments. A new datum which was designed to only-just meet current requirements, would soon fail to meet new requirements as the spatial data community adapted to new applications and opportunities.

1.2 *New Zealand Geodetic Datum*

A national geodetic datum provides a country with a local implementation of global coordinate systems. It minimises the risk to the Crown of having different and inconsistent coordinate reference systems. It enables a wide range of spatial applications to be supported in a manner that is consistent with international standards and best practice. When New Zealand Geodetic Datum 1949 (NZGD49) was established, it complied with the then current recommendations of the International Association of Geodesy (IAG). It used what could be called the global positioning system of the day - geodetic astronomy - to establish the datum origin and orientation.

As much as the technology of the day allowed, it was an effective implementation of an internationally accepted terrestrial reference system.

Although we now know the difference between the centre of the NZGD49 ellipsoid and the centre of mass of the earth, until the advent of satellite geodesy in the 1960's and 1970's, this difference was not really measurable and was therefore of no practical consequence. The same is true of many other national datums around the world that were developed around this time.

It was only in the late 1980's and 1990's that an increasingly used satellite based geodetic measuring system - the Global Positioning System (GPS) - began to impact on the utility of the national datums of many countries including New Zealand. The inconsistency between NZGD49 and international reference systems started to impact adversely on navigation, scientific applications and on routine spatial data management.

Prior to this, internal distortions of the datum, steadily increasing at the rate of half a metre per decade due to earth deformation, also began to impact on geodetic processing. The introduction of EDM highlighted variations in the definition of scale and the new observations were inconsistent with the distances derived from coordinates of geodetic stations. GPS, with its potential to efficiently meet existing survey accuracy requirements over very long distances, has significantly increased this problem.

In the early 1990's New Zealand could have followed the lead of other countries (e.g., Australia, USA and Canada, European countries, South Africa, etc.) and implemented a new geocentric datum. This decision was deliberately postponed for a number of reasons:

1. The work required to define and implement a new datum (re-observation of the existing network) is largely the same as that required to enable the existing datum to support the efficient use of new technology such as GPS. Either way, the relationship of the existing datum to an accepted international reference system is required. Thus the decision was able to be postponed while this re-observation work was undertaken and the results analysed.

2. From 1993 to 1996, the Department of Survey and Land Information (DoSLI) and subsequently LINZ, supported a postgraduate student with a study award at the University of New South Wales. The topic of research was "A Modern Geodetic Reference System for New Zealand" (Pearse, 1997). As long as an urgent decision was not required, it was prudent to await the results of this research.

3. The business case for survey & title automation and the design of the proposed system depends significantly on the availability of a geodetic datum that allows survey processes to be automated. The distortions in NZGD49 are such that a reasonably high level of experience is required to integrate new geodetic and cadastral survey data into the survey system. This process is not easily automated within the current datum.

4. New datums have been implemented in a number of other countries. As a decision was not urgently required in New Zealand, we were able to study development options, implementation plans and stakeholder responses in these countries and learn from these examples.

With the geodetic work identified above well in hand; with the post-graduate research completed; and with government acceptance of the business case for automation of the survey and title systems; the time has now come for a decision on the datum.

1.3 *Geodetic Strategic Plan*

1.3.1 *Background*

Land Information New Zealand is developing a Geodetic System Strategic Plan which will be completed by 30 June 1998. It identifies requirements for the next 10 years but implementation of the initial parts of the strategy will take three years.

The strategic plan is still in draft form (LINZ, 1998). However, one of the early steps which was identified was the need to make a decision on the type of geometric[1] reference frame required for New Zealand. A number of key decisions were provisionally made in December 1997. This report documents the proposals, and the reasoning that led to them. This document is intended to generate internal and external responses to the recommendations prior to a final decision by the Surveyor-General.

Under the draft Geodetic Strategic Plan, the preferred design of a geometric reference frame will be completed by 31 December 1998 and this design will be put into effect by 30 June 1999.

1.3.2 *Goal*

Goal 1 as defined by the draft New Zealand Geodetic System Strategic Plan (LINZ, 1998) is:

> ***To provide a cost effective system that can generate up-to-date geometric coordinates of points in terms of an internationally accepted system to an acceptable and defined accuracy.***

The strategy statement associated with this goal states:

> *This will provide an accurate geometric spatial reference framework that will cover New Zealand's area of land and seabed interests (which include New Zealand, Pacific Islands and the Ross Dependency in Antarctica) and facilitate the department's commitment to geodetic and cadastral automation. The reference framework will be compatible with the global geodetic network to facilitate the use of modern survey technology and satisfy international commitments and satisfy user needs to work in terms of a global framework.*

[1] See Annex B

Such a system will:

- *reduce the effect of distortions in the official datum to an acceptable level;*
- *reduce the need for multiple coordinate systems;*
- *overcome the limited territorial extent of the current datum;*
- *overcome incompatibility with global datums; and*
- *overcome the inability of the existing system to account for earth deformation.*

This goal was deliberately worded so as not to pre-judge a decision on the datum, while still recognising some of the key outcomes that must be achieved by the preferred option.

1.3.3 *Drivers & Issues*

The draft Geodetic System Strategic Plan identifies a number of departmental business drivers against which proposals for datum development could be tested and a number of issues against which the effects of the proposals could be assessed. The best strategy for achieving the goal will be the one which best addresses the requirements of the drivers. An important consideration will be the extent to which the chosen option can mitigate or address the effects of the issues.

The drivers identified in the Geodetic System Strategic Plan which tend towards development of a new geodetic system are:

- Support geodetic and cadastral automation
- Support increased departmental responsibility (both territorial and functional)
- Simplify the management of digital spatial data
- Reduce risk to Government
- Reduce cost to Government
- Facilitate public usage of the geodetic reference system
- Facilitate the use of international systems
- Reduce client compliance costs
- Meet the changing needs of government
- Accommodate earth deformation

The issues which need to be assessed in considering the implications or effects of the proposals are:

- Education and training
- Resistance to change
- Transitional costs of new technology
- Change in database coordinates
- Continued use of old technology
- Legacy systems

The drivers and issues are further explained in the New Zealand Geodetic System Strategic Plan (LINZ, 1998).

2 Proposal One: Existing vs New Datum

2.1 *Options*

Three options were identified for the type of datum (new or existing) needed to meet Geodetic Goal 1. By default, the authoritative data supplied by LINZ will be in terms of the official geodetic datum. It is also expected that, by default, LINZ will require datum dependent data to be supplied in terms of the official geodetic datum.

2.1.1 *Option 1 - Status Quo*

Under this option, New Zealand Geodetic Datum 1949 (NZGD49) would be retained as the official geodetic datum for New Zealand. Applications requiring use of global reference frames, such as one of the International Terrestrial Reference Frames (ITRF), would be facilitated through transformations which convert between NZGD49 and these global systems. Calculations would continue to be undertaken in NZGD49 with newly observed survey networks distorted to fit the underlying network.

2.1.2 *Option 2 - Computational Datum*

Under this option, New Zealand Geodetic Datum 1949 (NZGD49) would be retained as the official geodetic datum for New Zealand. However computations would be undertaken in terms of a globally consistent and undistorted reference frame. The first step in any computation requiring survey accuracy would be to transform from NZGD49 to the computational datum. The last step would be to transform final results from the computational datum to NZGD49. NZGD49 would therefore represents the “public face” of a more precise system which was generally accessible only to specialised users. This would maintain coordinate accuracy.

2.1.3 *Option 3 - New Datum*

Under this option, New Zealand Geodetic Datum 1949 (NZGD49) would be decommissioned and a new datum would be commissioned as the official geodetic datum for New Zealand. Provision would be made for the receipt and supply of data in terms of other datums, including NZGD49 as appropriate. Transformation between NZGD49 and the new datum would be provided to facilitate the transition from the existing to the new datum. Computations would be undertaken in terms of the new datum.

2.2 *Analysis of Drivers*

Detailed analysis of the drivers in relation to these options can be found in Annex A section 1.1.

Driver	Status Quo	Computational Datum	New Datum
Support geodetic and cadastral automation (See Annex A, Section 1.1.1)	No	Partially	Yes
Support increased departmental responsibility (See Annex A, Section 1.1.2)	No	No	Yes
Simplify the management of digital spatial data (See Annex A, Section 1.1.3)	No	No	Yes
Reduce risk to government (See Annex A, Section 1.1.4)	No	No	Short term - Partially Long Term - Yes
Reduce cost to government (See Annex A, Section 1.1.5)	No	No	Short term - Partially Long Term - Yes
Facilitate public use of the geodetic system (See Annex A, Section 1.1.6)	No	No	Yes but note NZMG is also an issue
Facilitate the use of international systems (See Annex A, Section 1.1.7)	No	No	Yes
Reduce compliance costs (See Annex A, Section 1.1.8)	Some users	Some users	Short term - Some users Long Term - Most users
Meet changing needs of Government (See Annex A, Section 1.1.9)	Unlikely	Unlikely	Potentially
Accommodate earth deformation (See Annex A, Section 1.1.10)	No	With difficulty	Yes

2.3 *Analysis of Issues*

Detailed analysis of the issues in relation to these options can be found in Annex A section 1.2

Issue	Status Quo	Computational Datum	New Datum
Education and training (See Annex A, Section 1.2.1)	Minor but on-going effort	Significant and on-going effort	Significant but decreasing effort
Resistance to change (See Annex A, Section 1.2.2)	Not an issue	Issue for high accuracy users	Issue for low and medium accuracy users
Transitional costs of new technology (See Annex A, Section 1.2.3)	Not an issue	Moderate issue	Not an issue
Changing database coordinates (See Annex A, Section 1.2.4)	Not an issue	Not an issue	Significant issue for external users
Client use of old technology (See Annex A, Section 1.2.5)	Not an issue	Not an issue	Not an issue
Legacy systems (See Annex A, Section 1.2.6)	Not an issue	Not an issue	Significant issue

2.4 *Discussion*

The only option which is able to meet LINZ geodetic and spatial business drivers, particularly in the long term, is the new datum option. The most important of the drivers is the automated geodetic survey, cadastral survey and title systems. With acceptance of the automation business case by government, the department is committed to delivering the benefits promised. These benefits depend, in part, on automation of survey data processing, which in turn, depends on the availability of a geodetic datum capable of supporting survey accuracy.

Although automation is the most important driver, the others are also important for support of national topographic and hydrographic functions, navigation, science, etc. These drivers, at least in the long term, point towards the same solution - a new datum.

The status quo and computational datum options may offer short term advantages to some users but are not sustainable for more than a few years. A new datum is inevitable and the sooner it is implemented, the lower the overall cost to the department and the spatial data community. Several key users have already changed, or are proposing to change, to an internationally accepted datum such as World Geodetic System 1984 (WGS84). This includes other users within LINZ - namely the National Topographic Hydrographic Authority.

The new datum option is the one which generally raises the most significant issues - especially for external users. The drivers, related as they are to core LINZ business needs, play a dominant role in the final decision. However, the issues raised by this option will need to be well managed and opportunities sought, in the design of the datum and associated systems, to minimise their impact.

2.5 *Recommendation*

> ***It is recommended that Land Information New Zealand establish and implement a new official geodetic datum to realise the requirements for three dimensional geometric spatial referencing.***

3 Proposal Two: Local vs Geocentric Datum

Having recommended that a new geodetic datum be established, there are some high level decisions which can be made regarding the key characteristics of this datum. One of these decisions is the origin of the new datum, this being a significant point of difference between NZGD49 and global reference systems.

3.1 *Options*

3.1.1 *Option 1 - Local Datum*

Under this option, the new datum would be designed to provide a best fit, in the average sense, to NZGD49. The origin and ellipsoid would be chosen so that the coordinate differences between the old and new datum would be relatively small (up to say 5 metres). Geoid height variations would be minimised. This best fit would only apply to the 3 main islands of New Zealand.

3.1.2 *Option 2 - Geocentric Datum*

Under this option, the new datum would be based on and would closely match, the International Terrestrial Reference System (ITRS) through one of its reference frames - the International Terrestrial Reference Frames (ITRF). This would be in line with the recommendation of the International Association of Geodesy (IAG) (IAG, 1992). The ellipsoid chosen would be the Geodetic Reference System 1980 (GRS80) ellipsoid as also recommended by the IAG (IAG, 1980). Note that the reference frame associated with GPS, namely WGS84, is consistent with ITRF at the decimetre level and enhancements are periodically made to WGS84 to keep it aligned with ITRS.

3.2 *Analysis of Drivers*

Detailed analysis of the drivers in relation to these options can be found in Annex A section 2.1

Driver	Local Datum	Geocentric Datum
Support geodetic and cadastral automation (See Annex A, Section 2.1.1)	Yes but less efficiently for geodetic automation	Yes
Support increased departmental responsibility (See Annex A, Section 2.1.2)	No	Yes
Simplify the management of digital spatial data (See Annex A, Section 2.1.3)	No	Yes
Reduce risk to government (See Annex A, Section 2.1.4)	No	Short term - Partially Long Term - Yes
Reduce cost to government (See Annex A, Section 2.1.5)	Short term - Partially Long Term - No	Short term - Partially Long Term - Yes
Facilitate public use of the geodetic system (See Annex A, Section 2.1.6)	No	Yes
Facilitate the use of international systems (See Annex A, Section 2.1.7)	No	Yes
Reduce compliance costs (See Annex A, Section 2.1.8)	When dealing with old data - Yes	When dealing with new data - Yes
Meet changing needs of Government (See Annex A, Section 2.1.9)	Least likely	Most likely
Accommodate earth deformation (See Annex A, Section 2.1.10)	Yes but somewhat less efficiently	Yes

3.3 *Analysis of Issues*

Detailed analysis of the issues in relation to these options can be found in Annex A section 2.2

Issue	Local Datum	Geocentric Datum
Education and training (See Annex A, Section 2.2.1)	Significant issue for high accuracy users	Moderate issue for all users
Resistance to change (See Annex A, Section 2.2.2)	No additional issues raised	No additional issues raised
Transitional costs of new technology (See Annex A, Section 2.2.3)	Not a big issue	Not a big issue
Changing database coordinates (See Annex A, Section 2.2.4)	Significant issue for high accuracy users	Significant issue for all users
Client use of old technology (See Annex A, Section 2.2.5)	Not applicable to this decision	Not applicable to this decision
Legacy systems (See Annex A, Section 2.2.6)	Not applicable to this decision	Not applicable to this decision

3.4 *Discussion*

The option for the new datum which best meets LINZ geodetic business drivers is that of a geocentric datum. The primary driver for this decision is not survey automation - it is consistency with international standards and consistency across LINZ's areas of responsibility. In 1949, the datum was developed primarily to meet local requirements. New Zealand's physical isolation meant that the need to comply with international standards was not as strong as it is today. Nevertheless, even then it was recognised that compliance with international best practice and standards would allow efficiencies which it would be foolish not to take advantage of. Acceptance of the geocentric datum option will result in New Zealand's geodetic datum regaining the position it had in 1949 of being compliant with international best practice and standards.

The case for compliance with international best practice, standards and recommendations is much stronger now than it was in 1949. International influences in spatial data are increasing in the following areas:

- Survey technology (data acquisition). Increasing use is made directly of GPS and remote sensing by other satellite systems. These technologies are still developing strongly and their influence is increasing.

- Survey technology (data processing). The increasing complexity of spatial data processing puts heavier reliance on software packages that are designed for, and sold to, a global market. As more countries move to common systems, the cost of being different will increase.

- Global or regional data sets. There is a large investment in multi-purpose global environmental monitoring and global datasets. This data is often suitable for national purposes and can be acquired at little or no cost. Where this data is spatially based, it is almost always in terms of a geocentric datum.

- Survey contracting. Common systems improve opportunities for companies outside New Zealand to compete in New Zealand, keep contract prices down and introduce innovations. They also improve the ability of New Zealand-based survey or spatial companies to compete in overseas markets.

Both options raise issues, as described in section 3.3, but those associated with the geocentric datum are generally more significant. Some users will prefer the local datum option - at least for a few years - as it will tend to minimise their immediate costs. Other users would abandon the New Zealand Geodetic Datum if it were a local datum and a solution similar to the geocentric datum option would probably become the de-facto datum even though not the LINZ "official" datum. This would greatly diminish the main benefit of a geodetic system - that of a multi-user system that maximises benefits for the majority of users and minimises confusion and cost.

These issues will need to be well managed and opportunities sought, in the design of the datum and associated systems, to minimise their impact. One opportunity to minimise the impact may be in the choice of mapping or survey projections associated with the new datum (replacement for New Zealand Map Grid).

3.5 *Recommendation*

It is recommended that the new datum have a geocentric origin.

In line with recommendations of the International Association of Geodesy, it is recommended that this datum be based on, and aligned with, the International Terrestrial Reference System (ITRS).

Also in line with recommendations of the International Association of Geodesy, it is recommended that the ellipsoid associated with this datum, be the Geodetic Reference System 1980 (GRS80) ellipsoid.

4 Proposal Three: Method for Management of Dynamics

4.1 *Options*

Another high level decision which can be made regarding key characteristics of the new datum, is that of the management of the coordinate changes, either due to earth deformation, from improved survey information or a combination of the two.

4.1.1 *Option 1 - Static Datum*

Under this option, the new datum is defined by the coordinates of key geodetic stations. The coordinates of these stations are held fixed. NZGD49 is an example of a static datum with the 1st Order trig coordinates being defined in 1949 and subsequently held fixed.

4.1.2 *Option 2 - Semi-dynamic Datum*

Under this option, the datum is defined by its relationship to a dynamic global reference frame at a specified epoch. The datum definition is frozen at this epoch and does not include time dependencies. Coordinates at the reference epoch may change slightly on acceptance of new data in order to maintain the defined relationship between the datum as a whole and the global reference system. Such changes would primarily be as a result of improved accuracy. However, larger coordinate jumps may be required as a result of earthquakes or localised mark movement. Modelling of more uniform time dependencies may be applied during calculations in order to remove systematic errors due to earth deformation. This modelling would be based on a velocity model and would effectively be a time-dependent transformation. All results would be converted back to the reference epoch and expressed in terms of that epoch.

4.1.3 *Option 3 - Dynamic Datum*

Under this option, the datum is defined by its relationship not to a specific reference frame at a specific epoch but continuously to a dynamic global reference system such as the International Terrestrial Reference System (ITRS). Time dependencies are included in the definition such as station velocities, rates of change for transformation parameters, etc. Coordinates, velocities, transformation parameters, etc., change as required to ensure that the datum axes, and thus the coordinates of points, closely maintain their defined relationship to those of the global reference system.

4.2 *Analysis of Drivers*

Detailed analysis of the drivers in relation to these options can be found in Annex A section 3.1

Driver	Static Datum	Semi-dynamic Datum	Dynamic Datum
Support geodetic and cadastral automation (See Annex A, Section 3.1.1)	Yes for a few years	Yes	Yes but difficult
Support increased departmental responsibility (See Annex A, Section 3.1.2)	Yes for a decade	Yes for more than a decade	Yes for the foreseeable future but difficult
Simplify the management of digital spatial data (See Annex A, Section 3.1.3)	Yes for a few years	Yes for more than a decade	Not yet
Reduce risk to government (See Annex A, Section 3.1.4)	No	Yes	No
Reduce cost to government (See Annex A, Section 3.1.5)	No	Yes	No
Facilitate public use of the geodetic system (See Annex A, Section 3.1.6)	Yes for a decade	Yes for more than a decade	No for many users. Yes for cadastral surveyors
Facilitate the use of international systems (See Annex A, Section 3.1.7)	Yes for a decade	Yes for more than a decade	Yes for the foreseeable future but difficult
Reduce compliance costs (See Annex A, Section 3.1.8)	Yes for a few years	Yes for more than a decade	No
Meet changing needs of Government (See Annex A, Section 3.1.9)	Least likely	Likely	Most likely but difficult
Accommodate earth deformation (See Annex A, Section 3.1.10)	No	Yes for more than a decade	Yes for foreseeable future

4.3 *Analysis of Issues*

Detailed analysis of the issues in relation to these options can be found in Annex A section 3.2

Issue	Static Datum	Semi-dynamic Datum	Dynamic Datum
Education and training (See Annex A, Section 3.2.1)	No additional issues raised	Some effort required	Significant effort required
Resistance to change (See Annex A, Section 3.2.2)	No additional issues raised	Not an issue for most users	Significant issue for most users
Transitional costs of new technology (See Annex A, Section 3.2.3)	No additional issues raised	Some software extensions required	Significant issue for software
Changing database coordinates (See Annex A, Section 3.2.4)	No additional issues raised	Not an issue for most users	Most effort to resolve
Client use of old technology (See Annex A, Section 3.2.5)	No additional issues raised	Not an issue	Significant issue for high accuracy
Legacy systems (See Annex A, Section 3.2.6)	No additional issues raised	Need not be an issue	Significant issue

4.4 *Discussion*

The option which best meets LINZ geodetic business drivers is that of a semi-dynamic datum which can be treated as if it were a static datum by many users.

In the long term (a few decades) it seems inevitable that a dynamic datum will become the norm. The International Terrestrial Reference System is effectively a dynamic system and national datums, (if they continue to have a role at all) will need to be dynamic to stay aligned with it. In the short term, a dynamic datum introduces complexity which does not seem to be justified. A semi-dynamic datum (option 2) will provide a smooth transition between the current static datum (option 1) and the future dynamic datum (option 3).

Over the last 5 years, geodetic observations have been collected that are suitable for helping to define a new datum. During this period, significant earth deformation has occurred which cannot be ignored in the development of a datum solution. The static datum option is not appropriate because it would effectively deny the existence of this significant deformation.

The dynamic datum option raises significant issues, as identified in section 4.3, especially for managers of external databases that rely on LINZ data and who would have to cope with significant extra complexity. Note however, that a major user group - cadastral surveyors - would not be adversely affected by a dynamic datum as they could get up-to-date coordinates from the LINZ automated Core Record System and could manage these within a reasonable time-frame without added complexity.

The semi-dynamic datum option raises some issues but these are not as serious as the issues identified for the dynamic datum option.

A number of papers (see Annex C, section 2) have discussed the dynamic datum option. These have made datum users aware that coordinates cannot remain fixed indefinitely if they are to remain useful. However, at this stage, it is considered that the fully dynamic datum option would meet significant (and, to some extent, justified) resistance from many stakeholders and that this would limit the efficiencies that are obtained when a datum is widely used. Therefore, it is considered that the semi-dynamic datum option best manages internal and external requirements.

4.5 *Recommendation*

> ***It is recommended that the relationship between the new datum and the ITRS be specified at a nominated reference epoch and that all points coordinated in terms of the new datum have coordinates defined in terms of this epoch.***
>
> ***It is recommended that the generalised motion of points in New Zealand with respect to the ITRS be modelled to:***

- ***ensure that observations made at a date other than the reference epoch can be used to generate reference epoch coordinates; and***

- ***allow up-to-date coordinates at a date other than the reference epoch to be generated from reference epoch coordinates.***

It is recommended that points coordinated in terms of the new datum not have fixed coordinates but that the coordinates be updated as required to account for new observations, earthquakes or predictable regional mark movement.

Annex A

Detailed Analysis of Proposals

In this annex, the assessment of options against business drivers and issues is documented. The tables in sections 2, 3 and 4 of the main document are based on this reasoning.

1 Proposal One: Existing vs New Datum

1.1 *Drivers*

1.1.1 *Support geodetic and cadastral automation*

This business driver is not satisfied by the status quo option. Automation of geodetic and cadastral data processing cannot be achieved in a cost effective manner under the status quo because of the complexity of the decisions that must be made when fitting new survey data into a distorted and less accurate coordinate system. Maintenance of survey accuracy of coordinates across the whole cadastre of New Zealand cannot be achieved within NZGD49.

It is partially satisfied by the computational datum option because automated processing can be carried out in the computational datum and the transformations can be automatic. However, it is disadvantaged by the extent of extra processing and design requirements. Cadastral survey software would need to apply the same complex transformation models that the LINZ geodetic system used. This would limit the market for cadastral survey software and LINZ would probably need to provide considerable support to this market.

It can be satisfied more easily by the new datum option. The new datum could be designed to maintain spatial accuracy sufficient to enable survey accurate cadastral coordinates to be generated automatically. An accurate coordinate system would reduce the complex judgement required when generating coordinates from new or historical survey data. Similarly, the validation of geodetic data and generation of geodetic coordinates could largely be automated without a large dependency on specialised processes that are only applicable to New Zealand and thus have to be designed and maintained by LINZ. Finally, continued use of NZGD49 introduces data management complexity and ambiguity. GPS data must be transformed (and often distorted) to be in terms of NZGD49. This is a manageable task for geodetic specialists but is little understood by most GPS users.

1.1.2 *Support increased departmental responsibility*

This business driver is not satisfied efficiently by either the status quo or computational datum options because a single datum to cover LINZ's area of territorial responsibility could not be based on NZGD49. NZGD49 does not cover offshore islands, the continental shelf or Ross Dependency. A number of international obligations in terms of air and marine safety require data to be in terms of WGS84. This could be achieved by transformation but with risk of ambiguity or error.

It is satisfied by the new datum option. A new datum could cover all of New Zealand's area of territorial responsibility including the continental shelf, Ross Dependency and, if necessary, the area of hydrographic responsibility in the Pacific. If the datum were geocentric, it would be compatible with the datums specified by international agencies that New Zealand works with and would meet the needs of the hydrographic responsibilities as well as the more traditional responsibilities.

1.1.3 *Simplify the management of digital spatial data*

This business driver is not satisfied by either the status quo or computational datum options. Multiple coordinate systems would continue to be required because the datum would not cover the extent of LINZ territorial responsibilities. This would complicate the management of digital databases that attempt to cover this area of responsibility. Distortions in the current datum would complicate the validation of new geodetic and cadastral observations - particularly under the status quo option. The complex transformations required under the computational datum option would address the datum distortions but introduce a further level of complexity.

The business driver is satisfied by the new datum option. A suitable level of spatial accuracy could be maintained over the whole spatial extent of LINZ responsibility which would simplify system design and automated data processing.

1.1.4 *Reduce risk to Government*

This business driver is not satisfied by the status quo option. There would be continued risks associated with datum ambiguity in the realm of air and marine safety. In addition, there would be risks associated with other crown purchased spatial data being misaligned or poorly aligned with LINZ data. At best this might limit the value of the purchased data. It might also result in risk of consequential damages where the data was relied on by government to make policy or operational decisions.

It is not satisfied by the computational datum option. The complexity of the model and the potential ambiguity between LINZ and other datasets would increase the risks in developing the automated survey & title system, error in air or marine transport safety systems and misalignment of Crown purchased spatial data.

It can be partially satisfied by the new datum option. A new datum would be likely to create initial confusion amongst some spatial data users. However this would decrease with time whereas retention of the existing datum would result in steadily increasing ambiguity and confusion between New Zealand and globally based or generated spatial data.

1.1.5 *Reduce cost to Government*

This business driver is not satisfied by the status quo option. Although there would be no datum development work required, other business drivers, such as automation are also primarily focused on reduced government costs and would not be satisfied. Also there would be increased cost in managing a system which was out of alignment with international trends.

It is not satisfied by the computational datum option. The geodetic work required to generate and maintain a suitably accurate transformation which can account for all distortions would be as great as the work required for a new datum. Extra processing costs incurred by geodetic providers would be passed on to LINZ in contract prices and there would be extra costs to LINZ in validating the data and integrating it.

It is generally satisfied by the new datum option in the long term. The new system would require extra development costs at first. This would be funded partly from automation and partly from existing geodetic funding. The acceptance of the automation business case by government indicates that the longer term benefits to government exceed the cost. A datum capable of supporting automation of geodetic and cadastral survey processing and generation of survey accurate cadastral coordinates is a key component of the automation design. Therefore the new datum option satisfies longer term (3 - 5 years and longer) cost reduction.

1.1.6 *Facilitate the use of the geodetic system*

This business driver is not satisfied by either the status quo or computational datum options. In the past, most users of the geodetic system tended to be either professional surveyors themselves or agencies advised by surveyors. Now, members of the general public are making direct use of geodetic reference frames (sometimes unknowingly). The advent of GPS has lead to a large increase in the number of individuals or agencies able to coordinate points of interest in terms of a geodetic reference frame. For the positioning itself, they often do not need expert help. However, to put their coordinates reliably in terms with other spatial data based on NZGD49 requires expertise. The current datum is not making it easy for these people to take advantage of the efficiency of the new technology.

The business driver is satisfied by the new datum option. For many GPS users, a new geocentric datum would reduce the complexity required to make use of their GPS results. Note however that the existing datum is not the only impediment to efficient use of GPS for non-expert users. New Zealand’s unique mapping projection (New Zealand Map Grid) also causes problems as does the fact that GPS ellipsoidal heights differ from the orthometric heights (i.e., mean sea level heights) of interest to most users.

1.1.7 *Facilitate the use of international systems*

This business driver is not easily satisfied by the status quo option. NZGD49 is specific to the main islands of New Zealand and is not compatible with global coordinate systems, global datasets, or with modern survey technology such as GPS or remote sensing. There are commitments or expectations for NZ compliance with globally consistent reference frames for data associated with hydrographic charting, aeronautical charting, co-ordination of air navigation facilities, defence, definition of the continental shelf, and Antarctic activities.

Neither is it satisfied by the computational datum option. The computational datum could be consistent with global systems but the data in the databases would not be. Where GPS had been used for data collection, it is likely that suppliers would have had to convert it to NZGD49 and that LINZ, in validating the data, would have to convert it back to a global system - not necessarily using the same transformation as was used by the supplier. Data processing could be automated in LINZ systems but would be very complex in user systems. It would be expected that non-expert users of GPS would fail to understand the steps required to correctly process their data.

It can be satisfied by the new datum option. A new geocentric datum would match global coordinate systems. Consistency between GPS observations and data which is in terms of the new datum would reduce the geodetic expertise required by the positioning community.

1.1.8 *Reduced compliance costs*

This business driver is partially satisfied by both the status quo and the computational datum options. Those users with databases based on DCDB data and with moderate accuracy requirements (a few metres) would not need to change their systems. In the short term and for some clients, compliance costs would not rise. However, other users with higher accuracy needs or with other requirements to operate with globally consistent coordinates would continue to have difficulty in spatial alignment of their databases with LINZ data. Under the computational datum option, these users would potentially be able to achieve their accuracy requirements but only by implementing processes peculiar to New Zealand. This would increase software and system design costs. The increased costs would persist for as long as the computational datum continued to be used.

This business driver is not satisfied by the new datum option in the short term because of system changes required to client data and processes to match the new datum. In the long term however, a globally consistent system would:

- enable New Zealand spatial data users to make more efficient use of new technology.
- reduce costs and enhance the competitiveness of New Zealand spatial data service providers working overseas as well as in New Zealand;
- increase competition in the New Zealand spatial market by making it easier for overseas companies to work in New Zealand; and
- increase options and thus reduce costs for software and data systems available for use in New Zealand (without requiring special modification).

1.1.9 *Meet the changing needs of Government*

Although the future needs of government are not known for certain, it is possible to say that this business driver is unlikely to be satisfied by either the status quo or computational datum options. NZGD49 is an inflexible system and there is very little scope for modifying it to meet new requirements.

This is potentially satisfied to some extent by the new datum option. A new datum can be designed to maximise flexibility to support potential future requirements.

1.1.10 *Accommodate earth deformation*

This business driver is not satisfied by the status quo option. The definition of NZGD49 is such that no account can be taken of earth deformation except at a local level. The impact of earth deformation on the datum is at least 2 - 3 metres and increases by half a metre per decade.

It is partially satisfied by the computational datum option. The coordinates in LINZ databases would not account for earth deformation but the transformations could include dynamic components to ensure that deformation was accounted for in computations. Accounting for large scale deformations associated with earthquakes would be difficult.

It can potentially be satisfied by the new datum option. A new datum would at least account for the deformation that had occurred since 1949 and, depending on design, could accommodate future deformation.

1.2 *Issues*

1.2.1 *Education & training*

Under the status quo option most users already have procedures in place which work with the current datum. There would be an increasing requirement to educate users in the relationship between NZGD49 and global reference systems such as GPS and other globally-based systems are increasingly used. These specific education and training issues related to management of modern data within a conventional datum are common to many other countries. However, the number of countries that would share these issues with New Zealand would decrease over time as other countries change to new geocentric datums.

The computational datum option will impose significant requirements for education and training. By adopting a solution specific to New Zealand, we would not be able to take advantage of training resources developed overseas. Education & training requirements would be on-going.

The new datum option would also impose significant education and training requirements. However, many users are familiar with global reference systems already. An increasing number of other countries are adopting new datums and so facing the same requirements. New Zealand could take advantage of training resources (i.e., on the internet) developed overseas such as those developed in Australian by the Inter-governmental Committee on Surveying and Mapping (ICSM). The education and training requirements would diminish with time as the most important datasets were migrated to the new datum.

1.2.2 *Resistance to change*

This is not an issue for the status quo option as it involves minimum change.

For the computational datum option, it would not be an issue for medium to low accuracy users who would be able to continue to use NZGD49 as if nothing had changed. For users seeking sub-metre accuracy, the computational datum option might encounter significant resistance as a system which requires changes to data processing but which does not achieve any consistency with international systems.

The new datum option may encounter resistance from some medium to low accuracy users who may not see significant short term benefits from the change and who might be faced with higher costs to manage their systems. On the other hand, high accuracy users, users wishing to use internationally consistent systems and software, and users who have already migrated or are planning to migrate to systems such as WGS84, would welcome the decision. Many high impact LINZ users fall into this category. The issue could partially be overcome by education, training and by the presence (whether provided by LINZ or others) of support to users facing adverse effects of change.

1.2.3 *Transitional costs of new technology*

This is not an issue for the status quo option as it involves retention of the existing datum and coordinate systems. There would be no dependency or requirement for the use of new technology.

The computational datum option would involve changes to processes for high accuracy users and there would be costs associated with these changes.

This would not be a significant issue for the new datum option because it does not require implementation of new technology except for some software functionality which is widely available.

1.2.4 *Change in database coordinates*

This is not an issue for either the status quo or computational datum options as both involve retention of the existing datum and coordinate systems.

This would be an issue for the new datum option. There is a potential shift of over 200 metres in changing to a geocentric datum. Continued minor coordinate changes in LINZ databases would be expected as new survey data was integrated. Other changes in coordinates due to the effects, for example, of instability of survey marks would also occur. The impact of the initial 200 metre shift might be minimised by appropriate choice of mapping projections - i.e. one in which the 200 metre change in latitude and longitude was largely countered by an equal but opposite shift in the projection origin. There would also be opportunities for 3rd party service providers to manage changes for clients and minimise the impact on their spatial data systems.

1.2.5 *Continued use of old technology*

This is generally not a datum issue. Use of old technology should still be possible under any of the datum options. Note however that the computational datum and new datum options (2 and 3) might require new or upgraded software - in the case of option 2 to handle the transformations to and from the computational datum and to a lesser extent with option 3 to support the new datum. Note however that most modern survey or GIS software already support global datums.

1.2.6 *Legacy systems*

There are issues for the status quo or computational datum options from old cadastral datum surveys but the issues would not increase under these two options as they involve retention of the existing datum and coordinate systems.

It is an issue for the new datum option. Paper records containing data in terms of the old datum would not be able to be converted to the new datum without full capture of data attributes. These paper records will be likely to have continuing relevance, either in paper or image form, for decades.

2 Proposal Two: Local vs Geocentric Datum

2.1 *Drivers*

2.1.1 *Support geodetic and cadastral automation*

This business driver can be satisfied under both options. New incoming geodetic data will almost all be in terms of a geocentric datum so automated processing of geodetic data would be easier under the geocentric datum option than under the local datum option.

2.1.2 *Support increased departmental responsibility*

This business driver is not realistically satisfied under the local datum option. The need for a single datum to cover LINZ’s area of responsibility could be satisfied in theory by a best fit local datum which covered this wide area. In practice it would only be a best fit within the main islands of New Zealand. It would also not be consistent with international obligations, international positioning standards, or with the requirements of hydrographic or aerocharting users.

It is satisfied under the geocentric datum option. A single datum can cover all areas of responsibility and would be consistent with international standards and obligations.

2.1.3 *Simplify the management of digital spatial data*

This business driver is not satisfied under the local datum option. Data management would continue to use procedures and tools specific to New Zealand. While many international software developers provide support to existing national datums, they might choose not to invest in a new "orphan" datum just to satisfy the small New Zealand market. It is also likely that management of multiple coordinate systems in LINZ databases would need to continue. A datum optimised for use within the main islands of New Zealand would be unlikely to be suitable outside of this area if it were extended to cover the Ross Dependency, offshore islands or areas covered by hydrographic charting and bathymetry.

It is satisfied under the geocentric datum option. International best practice for data management could be applied. Also, related to the discussion in section 2.1.2 above, the availability of a single datum which covers all areas of responsibility would allow data management in different areas to be aligned and thus simplified.

2.1.4 *Reduce risk to Government*

The local datum option generates risks associated with development of a new system which is out of alignment with international developments. Increased software and system design costs could be expected. Ambiguity in the areas of air and marine safety would be a significant potential risk. In addition, there would be risks associated with other crown purchased spatial data generated, in part or whole, from global positioning or remote sensing systems, being misaligned or poorly aligned with LINZ data. At best this might limit the value of the purchased data. It might also result in risk of consequential damages where the data was relied on to make policy or operational decisions.

It can be partially satisfied by the geocentric datum option. A geocentric datum with associated coordinate shifts of approximately 200 metres would be likely to create initial confusion amongst some spatial data users and this might lead to a short term increase in risk. However this would decrease with time whereas a best fit datum would result in steadily increasing ambiguity and confusion between New Zealand and globally based or generated spatial data. This problem would not relate to hydrographic or aeronautical applications where global reference frames are already in use.

2.1.5 *Reduce cost to Government*

Both the local datum and the geocentric datum options will require essentially the same geodetic cost to develop.

The geocentric datum option might impose short term costs associated with conversion of the topographic database to the new datum and obsolescence of existing paper map stocks. This could be minimised by an appropriate choice of new mapping projection. Consistency with international reference systems would reduce on-going costs associated with processing of new data and allow better alignment of topographic and hydrographic data.

2.1.6 *Facilitate the use of the geodetic system*

This business driver is not satisfied under the local datum option. For the same reason that GPS users require a new datum (see Annex A, Section 1.1.6) they also require it to be geocentric.

The geocentric datum option will satisfy this business driver by facilitating the use of efficient GPS technology by non-expert individuals and agencies.

2.1.7 *Facilitate the use of international systems*

This business driver is not satisfied under the local datum option. The best fit local datum would be a non-standard system applicable only to New Zealand.

It is satisfied under the geocentric datum option. An ITRF based datum is the standard recommended by the IAG.

2.1.8 *Reduced compliance costs*

This business driver is partially satisfied under the local datum option. For clients dealing primarily with old data, especially if paper based, the local datum would allow them in many cases, to continue with existing processes and data as if the datum had not changed. However, there would be an on-going cost associated with processing of new data from global positioning and remote sensing systems. This cost would be likely to increase with time as use of new technology became more prevalent.

It is also partially satisfied under the geocentric datum option. In this case, costs associated with processing of new data would be reduced and remain at a lower level. Costs associated with processing of historical data would be increased compared with current levels.

2.1.9 *Meet the changing needs of Government*

Future needs are likely to be in the direction of increasing inter-dependence of nations in the international community, and an increasing opening-up of national systems to international competition. The local datum option would represent a deliberate choice not to comply with international technical standards and would therefore be least likely to satisfy this business driver. The geocentric datum option would be aligned with international and national trends and would be most likely to satisfy the business driver.

2.1.10 *Accommodate earth deformation*

Both the local datum and geocentric datum options can allow this business driver to be satisfied. However, as data on earth deformation will be generated in terms of one of the International Terrestrial Reference Frames, the utilisation of this data would be somewhat easier in a datum which is based on ITRF - i.e., the geocentric datum option.

2.2 *Issues*

2.2.1 *Education & training*

For many low accuracy users, the local datum option would not require additional education and training. For some high accuracy users, the implementation of a new datum, unique to New Zealand would require an intensive education programme although many would already have the basic skills to understand the issues. All education and training resources would need to be developed in New Zealand with LINZ having to make a significant contribution.

Under the geocentric datum option an education and training programme would be required by all users. Resources developed overseas, including Australia, could be adapted to New Zealand requirements.

2.2.2 *Resistance to change*

Most resistance to change will be associated with the decision to change the datum. Neither the opponents, nor the supporters of change are likely to be satisfied with the local datum option under which the datum is changed but the old type of datum origin is retained. Therefore this decision will have little impact on the degree of resistance to change.

2.2.3 *Transitional costs of new technology*

This is not a big issue for either the local datum option or the geocentric datum option because neither has significant demands for new technology in order to be implemented.

2.2.4 *Change in database coordinates*

Under the local datum option, coordinate changes could be limited to a few metres. This would have some advantages for users only requiring accuracy at this level (e.g. users with GIS based on topographic data). For higher accuracy users the similarity of the coordinates could cause confusion.

Under the geocentric datum option, coordinates in terms of latitude and longitude would change by about 200 metres. The extent of change to projection coordinates (e.g. NZMG) would depend on the choice of projection in the new datum. It could be limited to a few metres. Alternatively it could be made deliberately larger to avoid any ambiguity.

Under the local datum option, geoid heights within the main islands of New Zealand are in the range of -10 to +10 metres. Ignoring these heights may affect relative horizontal position by about 1.5 ppm.

Under the geocentric datum option, geoid heights within the main islands of New Zealand are in the range of 0 to +40 metres. Ignoring these heights may affect relative horizontal position by up to 7 ppm.

2.2.5 *Continued use of old technology*

This is generally not a datum origin issue. Use of old technology should still be possible under either of the options. Any software that has the current ellipsoid defined in the code will need to be changed under the geocentric datum option. However this will be less significant that the changes resulting from the decision to have a new datum.

2.2.6 *Legacy systems*

Most of the issues relating to legacy systems will be associated with the decision to change the datum. The choice of datum origin will have little impact on the cost of converting or maintaining these systems.

3 Proposal Three: Method for Management of Dynamics

3.1 *Drivers*

3.1.1 *Support geodetic and cadastral automation*

This business driver would only be satisfied by the static datum option for a limited time (a few years). As distortions due to earth deformation increased with time, the level of error would start to interfere with automated processing and human judgement might be increasingly relied on. The business case for automation relies on a decreasing requirement for manual processing - not an increasing requirement.

It is satisfied by the semi-dynamic datum option. Where significant and appropriate, earth deformation could be accounted for during automated data processing.

It is satisfied by the dynamic datum option but the level of complexity required would exceed the capability of the current design for automation. While it is clear that the dynamic datum option is capable of being implemented, (the International Terrestrial Reference System is effectively a working example) the best mechanism for implementing it in a local datum is not yet clear and further research would be required before the best model could be agreed on.

3.1.2 *Support increased departmental responsibility*

Given that the new responsibilities in hydrographic charting and boundary delimitation do not require centimetre or decimetre accuracy, this business driver would probably be satisfied by the static datum option for a period of at least 10 years. New Zealand’s area of responsibility covers at least 3 tectonic plates and errors due to earth deformation would eventually exceed specifications.

It would be likely to be satisfied by the semi-dynamic datum option for well over a decade. The main effects of earth deformation could be removed. Eventually, the global systems adopted by international consensus would diverge from the system that the New Zealand datum was based on.

It is likely to be satisfied by the dynamic datum option for the foreseeable future. However, in the short term, this model might involve un-necessary complexity.

3.1.3 *Simplify the management of digital spatial data*

This business driver would only be satisfied by the static datum option for a limited time. As distortions due to earth deformation increased with time, the level of data processing complexity would increase.

It would be likely to be satisfied by the semi-dynamic datum option for well over a decade. A reasonably constant processing regime could apply during this period.

It would not be satisfied by the dynamic datum option which would involve a high level of complexity right from the start for managing coordinates. This would not impact on cadastral survey users who could get up-to-date LINZ coordinates from the automated system. However, it would increase the complexity required of the automated system in order to generate those coordinates and would also complicate the management of external spatial databases.

3.1.4 *Reduce risk to Government*

This business driver would not be satisfied by the static datum option. It would increase the risk of another change of datum within 10 years with consequent expense in migrating spatial databases to the new datum and confusion and ambiguity in the use of spatial data at that time.

The semi-dynamic datum option would satisfy the business driver of reduced risk by providing a datum that was likely to be reasonably long lived (one or two decades) and which would be able to smoothly upgrade to a full dynamic model at the time when that option becomes more technically viable.

The dynamic datum option would not satisfy this business driver because it would put New Zealand at the leading edge of datum development and management. In the long term, this option is likely to be adopted by many countries. In the short term, there would be significant risks involved in leading the way.

3.1.5 *Reduce cost to Government*

This business driver is not satisfied by the static datum option. Some of the cost savings available from survey automation might start to be reversed after a few years and a further datum change would be likely after about 10 years.

The semi-dynamic datum option would satisfy the business driver of reduced cost in the long term by providing a datum option that would be likely to be reasonably long lived and which would support increased automation of geodetic and cadastral survey data processing and validation as time goes by. In the sort term, some extra development cost is required for LINZ automated systems but this cost is avoidable for external systems that do not require survey accuracy. Overall, the semi-dynamic datum (option 2) provides the lowest cost by acting as a smooth transition between the current the static datum (option 1) and the expected future dynamic datum (option 3).

The dynamic datum option would not satisfy this business driver. Development of the processes required to manage a dynamic datum would impose an additional cost both on LINZ systems and client systems.

3.1.6 *Facilitate the use of the geodetic system*

This business driver would be satisfied by the static datum option for a period of at least 10 years. As GPS continues to deliver higher and higher accuracy and a wider range of applications are found for this technology, a number of users will find that this option does not meet their requirements.

The semi-dynamic datum option would satisfy the business driver well for over a decade. Many non-expert users could continue to use it beyond this time without changing their processes. Users with higher accuracy requirements could continue to use the datum efficiently by taking advantage of the dynamic models. Their timing in taking up this option would be their business decision.

This business driver would generally not be met by the dynamic datum option because of the immediate extra complexity required by all users whether they needed the high accuracy offered or not. If the automated survey and title system supported the dynamic datum option, the cadastral surveyors could take advantage of its superior coordinate accuracy by only using up-to-date coordinates.

3.1.7 *Facilitate the use of international systems*

This business driver would probably be satisfied by the static datum option for a up to 10 years. Eventually however, the static datum would diverge from the International Terrestrial Reference System (ITRS).

It would be likely to be satisfied by the semi-dynamic datum option for well over a decade. The dynamic transformations could maintain the relationship between the datum and the ITRS.

It would be likely to be satisfied by the dynamic datum option for the foreseeable future. However, in the short term, this model might involve significant complexity.

3.1.8 *Reduced compliance costs*

This business driver would probably be satisfied by the static datum option for a few years. It would involve the least change to existing processes. Eventually however, survey accurate users would be faced with higher compliance costs to incorporate new data with the New Zealand static datum.

It would be likely to be satisfied by the semi-dynamic datum option for well over a decade. Medium to low accuracy users could ignore the dynamic models. Survey accurate users could use these models to facilitate their data processing.

It would not be satisfied by the dynamic datum option. Management of the dynamics would impose a cost on those external users who have spatial database management requirements not directly supported by LINZ but who wish to keep their databases aligned with LINZ databases.

3.1.9 *Meet the changing needs of Government*

The static datum option would be least likely to satisfy the changing needs of government because it would be based on fixed data and procedures. Any change in accuracy required by government or future alignment with the ITRS would be difficult to achieve without a further datum change.

The semi-dynamic datum option is likely to satisfy the changing needs of government because it provides a transition from the static spatial systems of the past to the more adaptable systems of the future.

The dynamic datum option is the most adaptable model but for some period of time, it is likely to provide more flexibility than required at significant cost.

3.1.10 *Accommodate earth deformation*

This business driver will not be satisfied by the static datum option. The fixed coordinates of some stations would preclude modelling of the relative or absolute motions of those stations.

It would be satisfied by the semi-dynamic datum option for well over a decade. Eventually the dynamic transformations might become an inefficient means of modelling earth deformation.

It would be satisfied by the dynamic datum option for the foreseeable future.

3.2 *Issues*

3.2.1 *Education & training*

The static datum option would not require additional education and training (over and above that required for the a new geocentric datum) as it is the current model.

For geodetic users and, to a lesser extent, other survey accuracy users the semi-dynamic datum option would require some education on the use of dynamic transformations. However, medium to low accuracy users could treat it as a static datum.

Under the dynamic datum option a significant education and training programme would be required by most users.

3.2.2 *Resistance to change*

The static datum option would not invoke additional resistance to change (other than that caused by the datum change itself) as it is the current model.

The semi-dynamic datum option would not invoke much extra resistance as those users not wanting dynamic modelling could ignore it.

The dynamic datum option would cause the greatest resistance to change as it is the greatest change from the current system. This need not affect cadastral surveyors as the automated system could manage the changes for them. Other spatial data users would be significantly affected and the department would not have the resources to offer significant support to them.

3.2.3 *Transitional costs of new technology*

The static datum option would not invoke additional transitional costs as it is the current model.

The semi-dynamic datum option would require some additional software to be developed to apply the velocity model (dynamic transformation).

The dynamic datum option would require a significant development effort in the Core Record System in order to support automatic or semi-automatic geodetic processing.

3.2.4 *Change in database coordinates*

The static datum option would not invoke additional resistance to change as it is the current model. Coordinates of stations (other than the defining stations) would change from time to time as new surveys were incorporated into the system. However, these changes would be relatively small (few centimetres).

The semi-dynamic datum option would not invoke much extra resistance as those users not wanting dynamic modelling could ignore it. There would still be some minor coordinate changes at all stations but this also happens occasionally now for all but 1^{st} order geodetic stations.

The dynamic datum option would cause the greatest resistance to change with coordinate changes of the order of 0.5 metres/decade or more. This need not affect cadastral surveyors as the automated system could manage the changes for them. Spatial data users that were merging LINZ and other spatial data would be significantly affected and the department would not have the resources to offer significant support to them.

3.2.5 *Continued use of old technology*

For the static and semi-dynamic datum options this is generally not an issue. Use of old technology should still be possible under either of the options.

For the dynamic datum option, use of current or old GIS may be difficult for users requiring survey accuracy.

3.2.6 *Legacy systems*

The static datum option would not raise additional issues as it is the current model.

The semi-dynamic datum option need not raise additional issues because, for many users, it could be regarded as equivalent to a static datum. Those users requiring higher accuracy (specifically LINZ) would be replacing legacy systems anyway.

The dynamic datum option would cause problems with legacy systems because it is unlikely that many such systems would be able to manage the time aspects well.

Annex B

Key Terms & Definitions

Ellipsoidal Height	Height above the surface of the datum ellipsoid. The ellipsoid varies from mean sea level surface by tens of metres. Therefore, the ellipsoid is not a level surface.
Geometric Reference Frame	The term "geometric reference frame" is used to describe a reference frame where the orthogonal reference frame axes are not dependent on the local direction of the gravity field. Reference frames that use cartesian coordinates (X, Y, Z) or ellipsoidal coordinates (latitude, longitude, ellipsoidal height) are examples of geometric reference frames. Frames that use orthometric height or astronomic latitude and longitude are not geometric reference frames. The latter could be described as gravimetric reference frames.
Global Positioning System (GPS)	This system was designed principally to support military and civilian navigation. However the system is increasingly used for survey applications ranging from geodetic, through cadastral survey, to GIS data capture. Use for cadastral survey is still limited but will increase as GPS becomes integrated with conventional field technology. GPS data processing is based on geocentric reference frames (the default is WGS84) because the geocentre is the origin of the GPS satellite orbits. Results can be transformed to non-geocentric datums after processing but a number of different methods are used to carry out this transformation and there are many opportunities for ambiguity or error.
International Terrestrial Reference System (ITRS)	A coordinate reference system maintained by the International Earth Rotation Service (IERS) in order to meet the requirements of international geodesy and astronomy. This is a civilian reference system which is easily accessed for precise positioning.
International Terrestrial Reference Frame (ITRF)	The ITRS is realised in a practical form periodically by an International Terrestrial Reference Frame. The IERS uses a mixture of geodetic measuring systems (GPS, SLR, VLBI, DORIS, etc.) to provide coordinates and velocities of key stations around the world. Transformations (including time variations) between different ITRFs and other key international frames are provided. Details of the mathematical models used to define ITRFs are available for review by the international geodetic community.

New Zealand Geodetic Datum 1949 (NZGD49)	New Zealand's current and only geodetic datum. The datum is effectively defined by the coordinates of 1st Order stations as determined in 1949. Relative motions of up to 2.5 metres between these stations since 1949, and the advent of efficient new survey technology have affected the ability of this datum to support modern requirements.
Orthometric Height	Height above a level surface that approximates mean sea level. Orthometric height is influenced by the earth's gravitational field. It may be indirectly derived from ellipsoidal height but current accuracy of this process in New Zealand is a few metres.
Remote Sensing	This is a wide field which covers the use of measuring instruments - usually optical (photographic) or radio (radar) - to sense the physical environment from a distance. The measurement systems are fixed to mobile platforms such as a satellite or aircraft. Satellite-based systems naturally use geocentric reference frames because the geocentre is at the focus of the satellite orbit. Other systems generally use GPS or similar technology to coordinate the position of the mobile platform and are thus also based on geocentric systems. Remote sensing systems are being developed which can achieve decimetre or even centimetre positional accuracy. Remote sensing generates relatively cheap datasets and will increasingly be combined with other spatial data. Alignment of diverse reference frames and datums can cause significant difficulty, ambiguity, or error.
World Geodetic System 1984 (WGS84)	A global geocentric reference system, defined and maintained by the US Department of Defense, which is used by the Global Positioning System. WGS84 was recently upgraded to be more consistent (within a decimetre or two) with the International Terrestrial Reference System. Positioning in terms of WGS84 is relatively easy at the accuracy level of a few metres. At higher accuracy levels this is difficult to achieve without access to US military equipment and sites.

Annex C

Consultation

1 Stakeholders

Since 1995, the Department of Survey & Land Information and Land Information New Zealand have taken a number of opportunities to present ideas on the possibility of a new geodetic datum and seek feedback. Much of this has been informal discussions with surveyors and other spatial data users. Some of the more formal presentations of ideas are listed below.

1.1 *Cadastre 2000 Conference 1995*

D.B. Grant presented a paper entitled “A Dynamic Datum for a Dynamic Cadastre” to an audience of experts in cadastral systems - principally from New Zealand and Australia. The paper was generally well received with Australian participants acknowledging the special circumstances in New Zealand due to earth deformation.

1.2 *NZIS Annual Conference 1995*

D.B. Grant presented a paper entitled “Accommodating Change: Development of a Dynamic Geodetic Datum for New Zealand” to the annual conference of the NZ Institute of Surveyors. The paper received an award for best conference paper.

1.3 *GMS User Requirements*

As part of the Survey & Title Automation Programme, the Geodetic Management System (GMS) User Requirements project team interviewed a number of key geodetic system users and some overseas agencies that co-operate with LINZ on geodetic issues in Antarctica and in the Australasian region. The questions asked were not limited to the proposed GMS application but also user requirements of the entire geodetic system. Agencies interviewed were:

- LINZ Geodetic business
- LINZ Topographic/Hydrographic business
- LINZ cadastral survey automation
- NZ Institute of Surveyors
- NZ Survey Board
- NZ Defence Force
- NZ Civil Aviation Authority

- Airways Corporation of NZ
- NZ Antarctic Institute
- Institute of Geological & Nuclear Sciences
- Geology Department, Victoria University
- Telecom NZ
- Terralink NZ
- Australian Survey & Land Information Group
- US National Science Foundation
- US Geological Survey

Some of the requirements identified by users which relate to the datum were:

- the need for consistency of the national datum with technology such as GPS
- a single geodetic datum to cover LINZ area of responsibility,
- maintenance of coordinate accuracy in the presence of earth deformation
- compliance with international and regional geodetic standards
- ITRF compatible datum.

1.4 *Geodesy 2000 Conference*

This conference in 1997 attracted interest from a mixture of geodetic users and geodetic experts. Contributors were invited to present provocative ideas including criticisms of the department's ideas on datum development. D.B Grant and G.H Blick presented papers entitled "Geodetic Cadastral Coordinates - Should they be Carved in Stone Tablets?" and "Do we all Need to Develop Dynamic Datums?" at the conference. A GIS user highlighted difficulties to GIS users if a fully dynamic model were to be introduced. Resistance from users in Australia towards the implementation of the Geocentric Datum of Australia 1994 (GDA94) was discussed.

2 Geodetic peers

Ideas on managing the dynamics of a datum in a country affected, as New Zealand is, by earth deformation, have been tested by presentation to geodetic experts around the world. These are listed below.

2.1 *UNSW Research Seminars 1994*

D.B. Grant presented a paper entitled "A Dynamic National Geodetic Datum for New Zealand?" to the Annual Research Seminars at the University of NSW in Sydney. These seminars attract a wide range of geodetic, survey and other spatial data users and experts throughout Australia. The paper attracted interest and general support. There was some scepticism from one geodesist on the practicality of implementing the dynamic modelling in the short term.

2.2 *IAG General Assembly 1995*

D.B. Grant presented a paper entitled "Proposal for a Dynamic National Geodetic Datum for New Zealand" to an international audience of geodetic experts at the International Association of Geodesy General Assembly. The only critical comment was in the use of the word "dynamic" rather than "kinematic". Several participants requested copies of the paper and commented favourably on it.

2.3 *IAG Meeting 1997*

G.H. Blick presented a paper entitled "Possibility of a Dynamic Cadastre for a Dynamic Nation" to an international audience of geodetic experts at the International Association of Geodesy meeting in 1997. Discussions with conference participants identified similar developments in South America. The NZ proposal to link geodetic and cadastral data management was well received.

2.4 *Geodesy 2000 Conference*

See 1.4 above.

2.5 *Independent Research (Dr Ian Reilly)*

Research was commissioned in 1995 from retired mathematician and geodesist Ian Reilly into practical issues relating to the implementation of a dynamic datum.

2.6 *PhD Research (Dr Merrin Pearse)*

The PhD thesis, "A Modern Geodetic Reference System for New Zealand" and the work leading up to it, have been subject to examination and review within the University of Canberra, the University of New South Wales and by other respected geodetic experts in New Zealand, Australia and South Africa.

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