Possibility of a Dynamic Cadastre for a Dynamic Nation

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ABSTRACT

New Zealand, lying across the Pacific/Australian plate boundary, is subject to ground movements within the country of approximately 5 cm/yr. The existing geodetic control network and datum, New Zealand Geodetic Datum (NZGD) 1949, has been distorted by the effect of this ground movement. Because of these distortions, cadastral boundary coordinates, if held fixed in a coordinate cadastre, would eventually conflict with the position of slowly moving ground marks. However, the use of new technology such as GPS is ideally suited to the development of a coordinate cadastre. A dynamic coordinate cadastre is a possible outcome of recently started projects. A programme is underway to develop a modern control network and new datum (referred to as NZGD 2000) to replace the existing network. This could include up to 30 GPS permanent tracking stations which would monitor the integrity of the new datum and determine rates of ground deformation. A four dimensional (dynamic) datum with coordinates assigned velocities and changing to reflect ground movements is an option. As a separate project, the Department is considering the automation of the survey and land title systems. The automation of the survey system would see the digital capture of land parcel dimensions. Through connection to the geodetic network, geodetic coordinates would be assigned to parcel boundary points resulting in a coordinate cadastre. As the geodetic network moves to reflect ground movements, adjustment for this could be applied to boundary points forming a dynamic coordinate cadastre. In this manner, coordinates of boundary points would encapsulate available evidence of their true ground positions. This would not be a legal coordinate cadastre, but in the absence of other evidence the coordinate could be accepted as evidence to define parcels. To take the model further, it is conceivable that the cadastral surveyor in performing surveys would contribute to the geodetic network and dynamic datum. This possible model is debated.

INTRODUCTION

New technology such as the Global Positioning System (GPS) is ideally suited to take advantage of a coordinate cadastre because of its ability to survey and coordinate points directly in terms of geodetic control. In the near future, it may be possible to routinely obtain centimetre level accuracy real time positioning over wide areas using Wide Area Differential GPS (WADGPS) networks and satellite communication techniques. This, and the possible adoption and integration of other technologies such as inertial systems, is expected to result in the ability to routinely coordinate cadastral boundary points to required accuracy relative to a reference network. Such a system could result in large savings to government in maintenance of the spatial infrastructure and savings to surveyors and their clients in undertaking cadastral surveys. It is conceivable that a highly accurate GPS reference network and the survey methods described above, may enable the number of geodetic survey control points in New Zealand, (over 30,000 in the geodetic database) to be reduced dramatically to a few thousands or hundreds. The future may also see well defined physical features in the environment (eg houses or manhole covers) being used to densify geodetic control for cadastral surveys.

In a dynamic (kinematic) environment such as New Zealand's, several challenges must be addressed and overcome before the development of dynamic coordinate cadastre can be contemplated.

THE CHALLENGES

New Zealand is a Dynamic (Kinematic) Nation

New Zealand is a dynamic (kinematic) nation, lying as it does across the Australian/Pacific tectonic plate boundary. It is subject to ground movements across the country of approximately 5 cm/yr, disregarding the effects of large earthquakes [*Walcott* 1984]. This amounts to approximately 2.5m in the 50 years since the current New Zealand Geodetic Datum 1949 (NZGD49) was observed and established. Added to this are the catastrophic effects of large earthquakes and the more localised effects of volcanic activity, ground creep, and subsidence due to, for example, geothermal extraction.

The earth movements have led to distortions in, and a deterioration in the accuracy of, the current datum. The distortions increase with time causing the coordinates of the trig stations defining NZGD49 to become increasingly incompatible with new survey observations. Bevin and Hall [1995] provide a review of the current datum and distortions within it. These movements also result in movement of cadastral boundary marks, so that boundary coordinates, if they were fixed in a coordinate cadastre, would eventually conflict with the position of the slowly moving ground marks [*Grant* 1995].

Development of a dynamic coordinate cadastre (*a cadastre where coordinates of boundary marks change to reflect their true positions*) will necessitate modelling of earth movements.

Current Spatial Definition of the Cadastre is Provided by Survey Observations

The spatial definition of the New Zealand cadastral system is currently based on physical marks in the ground and survey observations (bearings and distances) between those marks, rather than coordinates. Witness marks placed close to the boundary are used to validate the location of boundary marks or to reinstate missing boundary marks. Because the distance between witness or survey mark and boundary mark is small (tens of meters) the current system has proved to be very robust. It accommodates distortions in the datum and the effects of earth movement because the distortions over small areas are generally insignificant. In the case of catastrophic events, movements cannot be ignored and resurveys are required. In the current system, high relative spatial definition is maintained over short distances. Absolute positional accuracy may be only of decimetre or metre accuracy but the definition of the cadastre is not adversely affected by this.

Such a system may have limitations as we move to new technologies such as GPS with the capability to deliver sufficient accuracy for cadastral survey over much longer distances and the desire to achieve survey economy by operating over these greater distances, eg, WADGPS networks. Distortions in the networks and cadastre then become significant and new ways of accommodating these distortions must be found. Otherwise, new precise observations will need to be distorted to fit the lower accuracy survey network.

CURRENT PROJECTS TO OVERCOME THE CHALLENGES AND HELP DEVELOP THE CONCEPT OF A DYNAMIC COORDINATE CADASTRE

Development of Datum 2000

The New Zealand geodetic control network is the culmination of developments over the past century [*Lee* 1978] . Geodetic triangulation was commenced in 1909 and completed in 1949, forming the 1st Order triangulation of New Zealand. The coordinates of the 1st Order trig stations were held fixed and used to define NZGD49 which is based on the International Spheroid. The current geodetic control network has served the cadastral system well but it now suffers from a number of limitations [*Blick and Rowe* 1997].

Recognising the limitations of the current datum, a programme was commenced by the Department in 1995 to re-observe the 1st order triangulation network (293 stations) which define NZGD49. In addition, a new network was established and surveyed to form the basis for a new datum, tentatively referred to as New Zealand Geodetic Datum 2000 (NZGD 2000). The requirements of the new datum are described by Blick and Linnell [1997].

It is proposed that the new datum will be geocentric and tied to the IERS International Terrestrial Reference System. Three options are being considered, a 'fixed' datum, a 'dynamic' datum [*Grant and Pearse* 1995] or a semi-dynamic datum. As with the current NZGD49 datum, a new 'fixed' datum is not considered appropriate as it too will degrade through time due to the effects of ground deformation and changing user requirements.

Automation of the Survey and Titles Systems

Land Information New Zealand has been charged with the development of a strategy for integrated automation of the survey and title systems in New Zealand [*Grant et al* 1997]. Under this strategy survey and title transactions could be combined into a single generic land transaction with survey and/or title components. This will enable surveyors and solicitors to develop new relationships for creating and submitting transactions in land.

In such an automated system, it is envisaged that cadastral survey data would be submitted in a digital format. The fundamental building block for the survey component of an automated system is a survey accurate coordinate cadastre based on the geodetic network that would allow efficient electronic validation of this new survey data. There will be a requirement for a spatial reference system to underpin the integration of all cadastral survey data into a digital database. The development of a survey accurate coordinate cadastre would see the capture and adjustment of parcel dimensions in terms of the new geodetic datum 2000 network. This would enable all boundary points to be assigned geodetic coordinates.

Development of a GPS Permanent Tracking Network

Under the development of a new geodetic datum (discussed above) is the development of a new geodetic network to support that datum [*Blick and Linnell* 1997]. This new network will include a number of GPS permanent tracking stations to monitor the integrity of the geodetic network. Currently four such stations are operating.

A plan by the New Zealand Institute of Geological and Nuclear Sciences (IGNS) proposes that a number of organisations in New Zealand combine resources to develop a network of approximately 40 geophysical monitoring sites, half of these sites including permanent GPS tracking stations. Partners in such a project may include those with scientific interests, Land Information New Zealand for monitoring the integrity of the new datum 2000, and commercial organisations who may enhance and sell the data. Under such a system the very network that controls the dynamics of the datum may also be used by survey practitioners to define the cadastre (eg by development of a WADGPS network).

IMPLEMENTATION OF A DYNAMIC COORDINATE CADASTRE

Development of a New Datum

In a dynamic country such as New Zealand, any new datum will need to account for the effects of ground movements. Several options can be considered for the implementation of such a datum.

Dynamic Geodetic Datum: A dynamic geodetic datum is one where the actual motion of trig stations is accounted for in some manner. For example, all trig stations could have defined velocities (centimetres per year) which allow their future and past coordinates to be easily calculated. In other words, the datum definition includes a *velocity model.* Such a datum carries within its definition, mechanisms for change. Earth deformation and the increasing accuracy needs of the nation can be accommodated. Changes in coordinates are smooth and reasonably predictable rather than being jerky and unpredictable as with a series of static datums. Such a datum may see coordinates of control points in an automated system changing regularly (weekly, monthly or yearly).

Semi-dynamic Geodetic Datum: It is possible to have a hybrid static / dynamic datum. We can "freeze" the coordinates of a datum at a specified reference epoch just as NZGD49 coordinates were frozen in 1949. However we can develop and maintain a non-zero velocity model to be used with this datum. Therefore, this could be called a "frozen" dynamic datum which is accessed and maintained using dynamic transformations. We can define a new datum with a reference epoch of 1 January 2000 and define a velocity model based on actual observations of earth deformation. If we have observations made in 2005 we can convert the 2000 coordinates of existing stations to 2005, adjust the new observations at that date and convert the coordinates of all new stations back to 2000. By relating the observations to station coordinates at a common epoch, we can ensure that the effects of earth deformation are accounted for. This does not stop the physical network being distorted but it does stop the datum being distorted. We are able to monitor and maintain the changing relationship between the physical network of ground marks and the datum coordinates which are used in calculations.

It is probable that initially a semi-dynamic datum will be developed with a possible future move to a fully dynamic model after the proposed automation of the survey system. A velocity model for New Zealand is being developed by IGNS. This will enable survey observations and coordinates of surveys marks to be managed in a way that reflects the ground motions using either a dynamic or semi-dynamic datum.

Development of a Dynamic Coordinate Cadastre

Connection of the geodetic network to the cadastral system as proposed in the Land Information New Zealand automation project would allow geodetic coordinates to be assigned to all parcel boundaries. It is proposed that this not be a legal coordinate cadastre but that in the absence of other evidence, such as an undisturbed boundary mark, that the coordinate will provide another layer of evidence.

As coordinates of a dynamic control network are allowed to change due to ground deformation, so these movements could be propagated into the coordinate cadastre. The coordinates of boundary points would also move to encapsulate the best available evidence of their true position and accommodate the effects of ground deformation. This would see the development of the dynamic coordinate cadastre.

Keeping Track of the Dynamics

A GPS permanent tracking network could control the datum at the large scale. Other control points will be required to provide origin for surveys to ensure that un-modelled distortions have not crept into the network. While a surveyor may make GPS observations relative to a base station many tens of kilometres from the site of their survey, they could be required to connect to control in the vicinity of the survey to ensure that the modelled coordinates in that area reflect the true position of the ground marks.

Taking this concept further, as surveyors make cadastral surveys and submit data in digital format to the Department under the proposed automated system, the observations used to establish and prove the survey origin (the geodetic component of the survey in a dynamic coordinate cadastre model) could be used to enhance and update the datum. In future well defined physical features in the environment (eg houses) could possibly be used to densify the control network. In this manner, the effects of crustal deformation over small areas could be monitored and used to improve the velocity model. Where large changes were recorded, eg due to the effects of an earthquake, a resurvey of the area might be required to re-definite the datum in the affected area.

Beyond GPS Permanent Tracking Stations and Survey Control Marks

Future survey technology (eg, remote sensing) may soon give the ability to map crustal deformation in detail utilising a few survey marks for calibration and control. The use of Interferometric Synthetic Aperture Radar (InSAR) to interpolate earthquake deformation is an example of what is possible. Utilising such detailed deformation maps along with the ability to easily and precisely fix well defined physical features in the environment could result in reduced need for geodetic control points. Hardware in the environment would take over the current function of dense, lower order control. Each house corner may essentially become a control point. The potential of this, combined with high resolution remote sensing, could provide a built cadastre showing both legal and physical aspects of land ownership.

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