e-Cadastre – Automation of the New Zealand Survey System

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ABSTRACT

Land Information New Zealand is in the midst of automating the nation's survey system. Features of the automated system include:

- Establishment of a new geocentric datum;
- Digital integration of the cadastre with the new geodetic network;
- Integration with the title system;
- Conversion of existing survey data to establish a Survey-accurate Digital Cadastre;
- Digital submission of new surveys by private surveyors;
- Automated validation and processing of surveys.

A key to the integration of the geodetic, survey, and title data is the data model and its implementation through mainstream information technology.

Survey data is observation based and is adjusted through least squares to produce accurate coordinates as required. The survey data for approximately 70% of the parcels in the country is being captured to improve the quality of the existing Digital Cadastral Database (DCDB) derived data. Where the data meets the accuracy standards required in the regulations, the nodes are assigned Survey-accurate Digital Cadastre (SDC) status.

Surveyors will be able to undertake virtually all aspects of their surveys electronically. They can extract digital survey data from the system while a new survey will be able to be submitted on-line from a surveyor's office. The survey dataset is subject to a high degree of automated validation and processing against the existing record.
The format for the transfer of the submitted data sets (LandXML) is being developed in conjunction with international organisations and survey software vendors.

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1. INTRODUCTION

Almost all aspects of our daily lives have been touched by digital technology. Electronic information flows lie at the core of most businesses. However while digital technologies have dramatically affected the field and office components of cadastral surveying, the final result is still a paper plan that requires manual interpretation and processing before being added to the authoritative survey system.

New Zealand has embarked on a programme that aims to make the cadastre electronic and deliver the benefits that arise from so doing.

2. CONCEPTS

In 1996 the government instructed Land Information New Zealand (LINZ) to develop a proposal to automate the nation's survey and title system. LINZ is the government department responsible for these systems. The aims of the automation were to integrate all survey and title processes, to provide them in digital form, to reduce the costs of both provision and compliance, to utilise technological development, and to meet the growing community demand for improved quality and delivery (Bevin, 1999).

A Strategy was developed that identified the business drivers, a vision, its key components, and its justification (cost/benefit).

2.1.1 The Vision

The three key components at the core of the vision were:

- **Intelligent Record.** In contrast to the paper records and plans, information would be held as intelligent digital data to enable process redesign and automation opportunities with potential for significant efficiency gains.
- **Business Rules.** Institutional knowledge and expertise would be transformed into business rules managed by automated information systems, including their use in transaction validation by surveyors.
- **Automated Transaction Processing.** Information systems that automate the processes and integrate the intelligent record and business rules.

2.1.2 Vision Building Blocks

A number of building blocks were identified that would be used to progress the vision. These included:

- Design and Build of the Integrated System.
- Implementation of the Survey-accurate Digital Cadastre
- Conversion of the Paper Records (to intelligent data)
- Imaging of Survey Plans
- Introduction of a Modern Geodetic Framework

2.1.3 Making the Case

Government required LINZ to develop a business case to support the programme. The key benefits were:

- Lower LINZ costs through reduced staff and closure of several offices
- Simplifying surveyor processes and reducing requisitions
- Reducing transaction times, leading to savings for land developers
- Enabling the use of modern technology
- Improving access to land information
- Improving the integrity of LINZ records
- Standardising processes on a national basis

The information system that resulted from this programme is called Land*online.*

2.2 Digital Surveying / Submission / Validation by Surveyors

The vision components combined to allow cadastral survey information to be transferred electronically through all processes, and allow information systems and surveyor's software to manipulate and validate the data. The high level process is depicted in Figure 1.

1. The surveyor logs into Land*online* and spatially searches the area of interest. Copies of relevant old survey plans are obtained and data is extracted into a file.

2. This file is imported into the surveying software and digitally overlayed with other site information.

3. The survey points are downloaded into an electronic field book, GPS, or similar. The coordinates are used to accurately locate any old marks in the field. The survey is undertaken, new marks placed, etc. in relation to existing boundaries. Parcels are defined and areas calculated.

4. The survey dataset is exported to file.

5. The surveyor logs into Land*online*, initialises a new survey, imports the file, and uses the Capture tool to complete the survey dataset. The dataset is run against a set of business rules to test, amongst other things, internal consistency and the topological and geometrical fit with existing data. Conflicts are resolved, reworked etc. A plan image (TIFF file) is generated semi-automatically from the digital data. The removal of the need to generate a traditional survey plan is seem as a significant cost saving.

Where required, the survey is submitted to local government for planning approval (can be given on-line).

6. The surveyor "signs" the dataset using their digital certificate and presses the "Lodge" button.

7. The survey appears in the in-tray of a LINZ Survey Analyst who revalidates the survey using the automated business rules, applying any manual interpretation where required. Requisitions may be issued to the surveyor to correct the survey or undertake additional work. On completion the survey appears in an Approving Surveyor's in-tray. The Approving Surveyor undertakes a high-level overview for good survey practice and, if satisfactory, presses the Approve button and the data is automatically added to the current record, new parcels are created, and underlying parcels made historic. LINZ then adjusts the newly approved survey data to generate new coordinates in terms of the surrounding cadastral and geodetic framework.

This digital process is expected to provide significant savings through increased data quality (the digital transfer avoids manual errors), faster processing, and reduced effort for both the surveyor and LINZ.

2.2.1 Transfer Format - LandXML

The success of the electronic survey processes is dependent on the high quality transfer of the survey data between Land*online* and the surveyor's software. This data has to include not only the observations (typically bearings and distances), but also the topology, parcels, and coordinate system information. Although coordinate information may be included, Land*online* generates new values utilising coordinates for existing points and the new observations.

As all the data that is transferred is textual, spatial transfer formats (eg. DXF) are not appropriate. LINZ has been collaborating with international survey software vendors and other interested agencies to extend the LandXML schema to enable "submission" of completed surveys. Development of this XML format is expected to overcome the problems that have commonly occurred with the transfer of survey data and should lead to acceptance by survey software vendors at the international level.

2.3 Survey-Accurate Digital Cadastre

To be able to support an automated cadastral system, an accurate positional record of the cadastre is imperative. The existing DCDB, which covers the entire country, was not designed for this purpose. Coordinates in the DCDB were obtained by digitising cadastral record maps and contain varying, unpredictable, and unquantified errors. Uncertainties of 1-2m are typical, but errors of 20m or more are common in rural areas.

New Zealand has a working cadastre that has been providing high integrity survey data for over 120 years. Land*online*, which now holds the survey data provided by the surveyor and approved by LINZ, must also hold coordinates whose quality is known by the system in terms of their compliance with the relative and absolute accuracy requirements specified in the Survey Regulations 1998. Points that meet the requirements are given “SDC” status. This quality label assures surveyors of the accuracy of the position, simplifies the proof of boundary definition, and enables enhanced geometrical validation of new surveys over these points.

Wider users of the cadastre, such as local government, utility companies, emergency services, and other users of GIS who currently use data from the DCDB will also benefit from the survey-accurate boundaries.

2.4 Observation Based

The automated system has been designed so that all points can be co-ordinated by least squares adjustment of survey observations (typically bearings and distances or GPS vectors). To this extent the Survey-accurate Digital Cadastre is consistent with its historical roots in being an observation-based cadastre – it is not a coordinate *based* cadastre. However the role of coordinates is more important than has been the case historically. They can be used to locate marks (typically within centimetres in terms of the control framework), as well as to validate that observations on new surveys are correct (by least squares check against fixed points – see ref. to “SDC” status in section 2.3).

2.5 Geodetic Framework

A high integrity geodetic control framework is a fundamental requirement for the automated system. The framework is used to reliably coordinate cadastral marks on a national basis and allow surveyors to locate and connect marks with confidence. Figure 2 shows how the geodetic network provides the spatial framework for a number of systems. The systems in the dark boxes (geodetic, cadastral, title, electoral) are currently included in Land*online*.

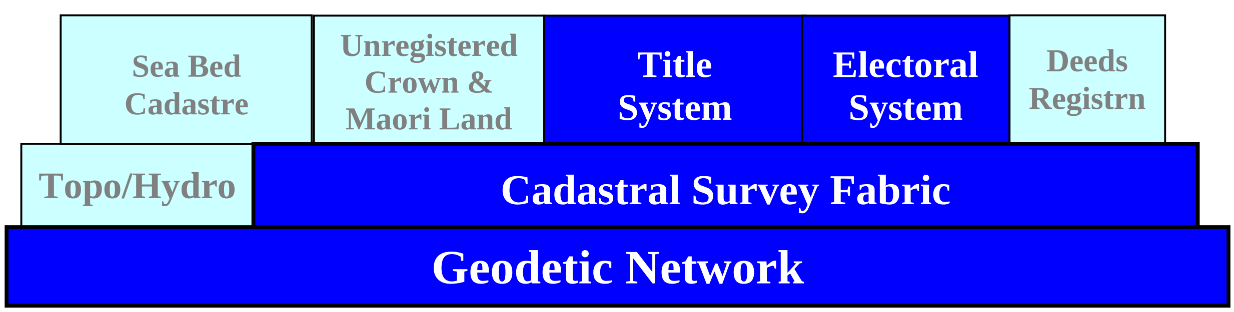

Figure 2 - Integrated Systems

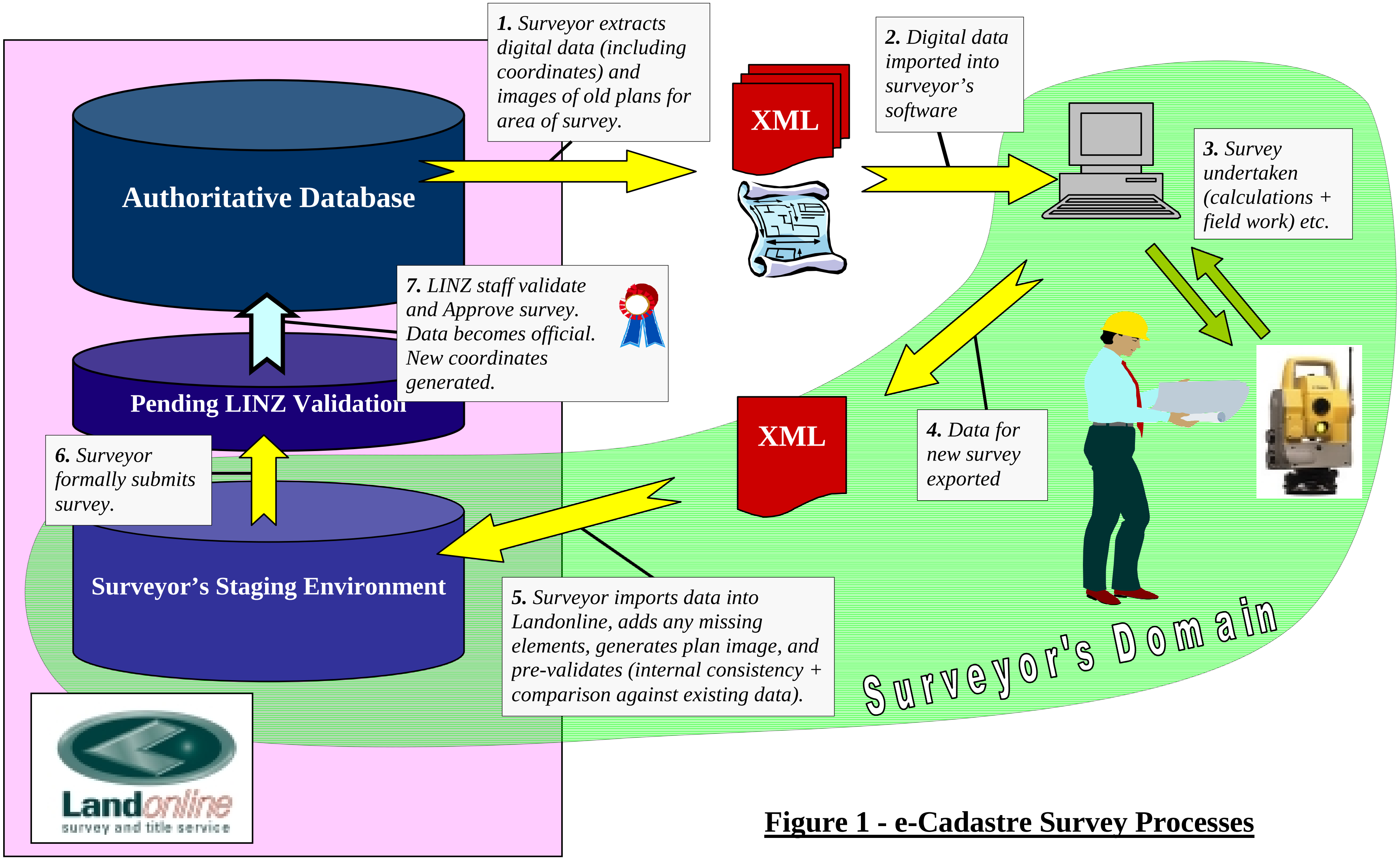

Figure 1 - e-Cadastre Survey Processes

2.5.1 A New Datum

New Zealand's previous geodetic datum (NZGD49) was established in 1949, well before the advent of satellite surveying techniques such as GPS. Fifty years later, it was clear that tectonic movement of several metres together with systematic errors in the original triangulation had caused significant and continuing degradation of the positional accuracy of NZGD49. While coordinates might be consistent locally, they were no longer coherent nationally, with distortions of up to 5m now detected. Additionally, as it was based on a local Earth model it is not compatible with the direct use of GPS.

A new datum, NZGD2000, that is both geocentric and dynamic has been implemented to overcome the deficiencies in NZGD49 (Grant and Blick 1998). This new datum lies at the core of Land*online*, which coordinates all points in terms of it.

The NZGD2000 control network that forms the physical basis of the cadastre is described in Section 4.

2.6 Survey and Title Integration

The paper-based survey system and title system have historically been managed separately, and only recently been managed within the one government agency. However under Land*online*, all survey and title data is managed within the one information system. In terms of process flows, the survey system creates and locates the parcels while the titles system issues the titles for those parcels, etc. The extent of the integration of the two historical (manual) records has been dependent on ability to match (through their appellation) a surveyed parcel with the parcels defined on a title.

2.7 Professional Responsibility and Legislation

In New Zealand all cadastral surveys are undertaken by the private sector. Historically, the government survey department was heavily involved in confirming the quality of the lodged surveys before they were added to the official record. To realise the full benefits of the automated systems, surveyors will need to rely less on manual checking of survey plans by the government department and take more responsibility for the quality of their own work. Under a fully automated system many surveys would be able to be automatically validated against the existing record and require little additional validation by LINZ staff.

In 1998 LINZ introduced a system of Accreditation and Audit of surveyors, to recognise surveyors whose work is of a consistently high standard. These surveyors are rewarded with lower fees and faster processing times. The government is currently developing legislation that will create a system of licensing of cadastral surveyors (Bevin and Haanen, 2002), that will effectively take the Accreditation system to the next step, where the retention of a licence to practice surveying is contingent on continuing to meet the required standards. These significant business changes are an important contribution to the success of the e-cadastre.

The legislation under development will also provide a legal basis for the use of the digital survey and title records (rather than the paper or plans) as the official records.

3. CADASTRAL INFORMATION SYSTEM - Land*online*

The computerised system that realises the concepts is Land*online*. It utilises mainstream information technology, and is spatially enabled rather than spatially driven. This means, for instance, that virtually all authoritative data, including coordinates, are held and manipulated aspatially (i.e. as numeric or textual data in database tables rather than as spatial objects). When new coordinates are generated for a point (eg. by least squares adjustment), a spatial representation (object) is generated and added to the database. This in turn is used to generate spatial representation of connected data such as observations, parcels, boundary lines, etc. This approach has enabled Land*online* to be more easily integrated into related IT strategies and systems.

3.1 Geodetic and Cadastral Data Integration

Early in the system design, it was decided to fully integrate the cadastral survey and geodetic functionality within Land*online*, as the cadastral system is technically dependent on the geodetic system. Geodetic control marks are assigned orders from 0 to 5, while cadastral survey marks are assigned orders 6 or 7. Points for which Land*online* holds no genuine survey information (eg. converted from DCDB), or which are not rigorously connected to the geodetic network through survey observations, are assigned orders from 8 to 10. Query and editing functionality are used for all points. Coordinates for all points, whether cadastral or geodetic, are generated by least squares adjustments also using common functionality.

3.2 System Functionality

In order to meet all the conceptual requirements, Land*online* includes (among other things) the following functionality:

- Search for geodetic control, marks, parcels, surveys, titles, etc. View and/or extract the structured, image, or spatial records as appropriate.
- Capture new surveys in digital form, initially in paper form and in the future via LandXML data file.
- Validate new surveys (both automatic and manual check items) including using automatic least squares adjustments and automatically update the database layers following Approval, etc.
- Manage coordinate systems (datums and projections).
- Coordinate all geodetic and cadastral points by least squares adjustments, test against geodetic standards or cadastral Survey Regulations (respectively) and assign SDC status where appropriate. This also includes points that do not have survey observations, by the adjustment of “pseudo” observations.

- Automatically workflow tasks, calculate lodgement fees, edit data, manage users, administration, etc.
- Processes for Titles (not further discussed in this paper), including the transfer of land, registration of other interests in land and issuing of new title for the parcels created by survey.

4. GEODETIC CONTROL NETWORK

A high order network of geodetic control was surveyed over the majority of the country to provide the physical realisation of the geodetic framework. Marks were placed at densities appropriate to the expected amount of use with specific focus on areas that were to be subject to Survey Conversion (see section 5.4). The mark densities were designed so that the vast majority of boundary marks would be no more that 200m from a control point in urban areas, 600m in peri-urban areas, and 2km in rural areas.

Both existing and new marks were coordinated by a combination of re-adjustment of existing data (including historical control traverses) and new GPS surveys. Some 60,000 marks have been added to the NZGD2000 network through this programme.

5. DATA CONVERSION

The realisation of the electronic cadastre requires the conversion of the existing, mainly paper-based, records into digital form. Titles conversion involved the imaging of title documents and the subsequent data capture of information on those images (not discussed further here). On the survey side there were several key projects:

5.1 Survey Plan Imaging

Virtually all (1.2 million) existing survey plans were scanned from either microfilm or original plans and loaded into Land*online*. The images were linked to the plan references spatially located on the converted DCDB so that they could be readily accessed spatially. This conversion meant that the original plans could be more safely preserved, held in storage rather than behind a public counter, and that the images could be accessed online from anywhere in the country.

5.2 Geodetic Database Conversion

The marks in the existing geodetic database were loaded into Land*online*. Marks that were coordinated only in terms of NZGD49 were assigned additional coordinates in terms of NZGD2000, generated by transformation. New NZGD2000 control marks or coordinates were subsequently added using Land*online* functionality.

5.3 DCDB Conversion

The existing DCDBs for each of the twelve Land Districts were converted into the new format and loaded into Land*online.* This process included generating "pseudo" observations and associated accuracies for each boundary line so that all boundary points could be coordinated by least squares adjustment as new survey data was added. This conversion created the spatial map of all the parcels in the country in Land*online*.

5.4 Survey Conversion – Generating the Initial Survey-accurate Digital Cadastre

While the DCDB conversion created a digital cadastre in Land*online*, the accuracy of the points was far from "survey accurate". The Survey Conversion project aims to provide this quality by capturing data from existing survey plans for selected areas.

The boundary bearings and distances are being captured for about 70%, mainly urban, of all parcels. Parcels defined on very old plans may not be captured, as their data are unlikely to meet modern standards. Additional "traverse" bearings and distances are captured to join blocks together (e.g. across roads) and to connect the parcel fabric to the NZGD2000 control, which provides the fixed framework. The aim of including this data is to maximise the geometric strength of the network for adjustment by least squares and the generation of coordinates. The success of this approach in any area is dependent on the fact that individual surveys have been done to a reasonable and consistent accuracy, and that there are good interconnections between surveys.

Least squares adjustments are used to assess compliance with the accuracy requirements contained in the 1998 Survey Regulations (typically a few centimetres in urban areas). The test includes both relative and absolute accuracy tests, treating the geodetic control points as "origin" marks. Each node (mark) is tested, and assigned SDC status if it passes. Nodes that are either poorly connected to the control network or which are fixed by lesser quality (older) observations are unlikely to achieve SDC status. This back-capture of historical data can at best only achieve the standards of those surveys – the survey-accurate cadastre will only be as accurate as the surveys that comprise it.

5.4.1 Selection of Survey Conversion Areas

Analysis indicated that in the large rural tracts of New Zealand surveys have tended to be mathematically inconsistent and geometrically weak and conversion would not result in precisions compatible with SDC standards. In addition, the high cost of converting these areas, which are surveyed very infrequently, would far exceed the benefits derived. As the majority of the benefits are derived from more efficient survey processing, the areas in which surveys were likely to occur drove the selection criteria. Priority was therefore given to urban, high-density peri-urban, and rural areas containing intensive pattern of parcels or development. Further areas where there had been a large amount of recent survey activity were added.

A total of some 1.35 million (of the country's 2 million) parcels will be converted. Most rural and romote areas that comprise some 90% of the country's total area will not be converted. Further details of this large project, which has a staff of 130 and will take several years to complete, can be found in Spaziani (2002, at FIG XXII).

6. REVIEW

The development of the electronic cadastre in New Zealand has been an ambitious and probably unique, undertaking, integrating a series of large projects within an overall business driven strategy. The programme is still in progress, and will require further enhancement, but is already operational.

The e-cadastre is based on the tried and true principles of cadastral surveying, yet facilitates the use of modern and future technology to derive the benefits that the electronic age brings.

The Survey-accurate Digital Cadastre provides a vision and path for an improved and more efficient cadastre, and is repositioning the spatial cadastre to meet emerging and expanding needs for spatial and attribute data in digital form.

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BIOGRAPHICAL NOTES

Tony Bevin has worked in various field, administrative and regulatory capacities in the New Zealand government's survey offices for 40 years. He was deputy Surveyor General in the Department of Survey and Land Information from 1989 to 1996, and is currently Surveyor General in Land Information New Zealand. He is also the chair of the New Zealand Survey Board and currently chair of the Council of Reciprocating Surveyors Boards of Australia and New Zealand. He is a registered surveyor and a fellow of the New Zealand Institute of Surveyors, and was a vice-president of the Institute from 1987 to 1989. He has had published a number of papers on geodetic surveying, electromagnetic distance measurement, automation and cadastral survey reforms.

Anselm Haanen has worked in various capacities in government's cadastral offices for 20 years. He was Advisor to the Fiji Land Information System for 2 years and since 1996 has been the Survey Database Advisor to the Surveyor General. He was recently seconded to the Survey Conversion Project as the LINZ Survey Business Expert. He holds a Master of Surveying degree from Otago University.

Neil Sutherland worked as a cadastral and geodetic surveyor for the government's survey department for 15 years. For the past 12 years he has worked at the University of Otago where he lectures in surveying and GIS. He has also worked on the Land*online* project at various times over the past 4 years.