Developing a Three-Dimensional Digital Cadastral System for New Zealand

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3D Cadastral System, 3D Cadastre, Rights Restrictions Responsibilities.

SUMMARY

In the early 2000s Land Information New Zealand (LINZ) introduced an integrated automated survey and title system, known as Landonline, which enabled the electronic capture, lodgement, recording, and supply of cadastral survey data. A highlight of Landonline's success is that advancements in technology and changing expectations of society were embraced whilst ensuring that New Zealand's accurate, authoritative and assured land-based property system was preserved. Despite these achievements, it is apparent that the current cadastral system will not be optimal going forward. This observation is recognised in a strategy for developing the cadastral system published in 2014. A significant component of the strategy is to make provision for three-dimensional (3D) cadastral capabilities.

The present system caters for the third dimension through two-dimensional plan and elevation graphics supported by textual descriptions. This portrayal is no longer meeting current and emerging expectations of government, land professionals and the public and is inhibiting the efficient collection and presentation of 3D cadastral data offered by modern technologies.

The objective of the work being undertaken by LINZ is to progress from research to actual development and eventual implementation of a fully automated 3D cadastral system. This system will allow the capture, submission, validation, visualisation and recording of rights, restrictions and responsibilities in 3D. The government has recently given approval for LINZ to develop a business case to advance New Zealand's cadastral system to the next level, including early development of these 3D capabilities.

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1. INTRODUCTION

Land Information New Zealand (LINZ) is a government agency responsible for land tenure, geodetic and cadastral systems, topographical and hydrographic information, managing Crown property and a variety of other functions.

The existing cadastral and land tenure systems in New Zealand provide for the recording of rights, restrictions and responsibilities in land in three-dimensions (3D). The foundation of these systems is a two-dimensional (2D) digital cadastre with geometric and descriptive information based on 2D land parcels even if real property is defined in 3D. Stoter (2004) and van Oosterom (2013) contend that while such systems have been adequate for dealing with simple, low-density parcels with single ownership they have deficiencies in more complex ownership arrangements.

A primary driver for a truly 3D cadastre is the intensification of land use particularly in major urban centres. As a result building constructions and infrastructure are increasingly being positioned under and above each other and this "puts the practicality of the currently used concept of 2D cadastral parcels to the limit" (Stoter & Salzmann, 2003, p. 396). Cadastre 2034 (LINZ, 2014) identifies other drivers including rapid changes to society and in technology. An effective, fully digital 3D cadastral system should help enable better understanding and management of all rights, restrictions and responsibilities in land and real property.

2. PRESENT SITUATION IN NEW ZEALAND

2.1 The Current Cadastral System

The cadastral system in New Zealand is a core component in the national property rights system managed by LINZ that promotes efficiency and confidence in transacting property rights. LINZ (2014) describes the core features of a property rights system as being able to define:

- ***what*** rights, restrictions and responsibilities are in law
- ***who*** (or which organisation) holds rights, restrictions and responsibilities or are subject to them
- ***when*** rights, restrictions and responsibilities come into effect or when they cease to apply
- ***where*** the land or real property is that rights, restrictions and responsibilities apply to, including their spatial extent.

The primary purpose of the cadastral system is to define the 'where' in the property rights system – the last point above. The other core features above are primarily managed by various land tenure systems. In addition to being a repository of information about the current and historical extents of rights, the cadastral system includes boundary and survey marks, regulations, rules and standards, required competencies and professional regulation (LINZ, 2014). In summary, the system enables the extents of the rights in property to be confidently established and understood in the real world.

2.2 The Cadastre

Closely associated with cadastral system is the term 'cadastre'. The strategic document, Cadastre 2034 (LINZ, 2014, p. 8) refines the term through the identification of specific contents. Firstly, the term 'fundamental cadastre' is used to describe "…the repository of cadastral survey datasets lodged with LINZ and integrated into its database [i.e., Landonline], and which are regulated by the Cadastral Survey Act 2002…".

Secondly, the term 'broader cadastre' is used to describe other rights, restrictions and responsibilities in land which are "…created and managed in terms of other legislation or rules of law and which are not clearly part of the fundamental cadastre…". Examples of other rights, restrictions and responsibilities that can be associated with the broader cadastre include licenses, such as for mining, and responsibilities to maintain public drains on private property.

The above definition of cadastre provided by LINZ (2014), and also that by Dowson & Sheppard (1952) and FIG (1995), commonly relate to 'land'. The Cadastral Survey Act 2002 defines 'land' to include "subsoil, airspace, and water and marine areas". These definitions of land are recognition that property rights are 3D in reality. Despite the 3D nature of actual property rights, New Zealand's current cadastre is technically 2D in a digital sense.

2.3 The 2D/3D Nature of the Current Cadastral System

In the early 2000s LINZ introduced an integrated automated survey and title system, known as Landonline, which enabled the electronic capture, lodgement, recording, and supply of cadastral survey data. A process model outlining the substantial role of Landonline in cadastral surveys is included as Appendix A.

Landonline is an application and database that can be considered as being the core component of a 2D digital cadastral system where the vertical extents of a land parcel are not digitally defined. The accuracy of this horizontal cadastre is maintained within Landonline through the adjustment of survey observations which are connected to cadastral and geodetic control marks already integrated into the cadastre. Vertical observations are currently not digitally captured in the cadastral survey datasets that are submitted into Landonline and, therefore, not included in the adjustment and integration processes.

Where the vertical extents of rights are defined by survey, details (often both horizontal and vertical) are captured through scanned plan and elevation graphics supported by textual descriptions.

Cadastral surveyors, licensed under the Cadastral Survey Act 2002, must comply with standards when undertaking cadastral surveys and lodging resultant cadastral survey datasets with LINZ. These standards, referred to as the Rules for Cadastral Survey 2010 (amended 2012), require the vertical extent of a parcel, where the vertical extent is limited, to be defined by either a 'stratum boundary' or a 'permanent structure boundary'.

A stratum boundary is defined as a surface that is mathematically described and related to a reduced level or is either the surface or bed of a water body. A permanent structure boundary is related directly or mathematically to a building or recognisable structure that is likely to remain undisturbed for fifty years or more (LINZ, 2012).

In situations where vertical extents are defined by reduced levels, the survey must be in terms of an official vertical datum control mark (where one exists within a specified distance from the survey). New Zealand has fourteen official vertical datums (LINZ, 2010). Of these, thirteen are regional and one, the New Zealand Vertical Datum 2009 (NZVD 2009), is national. The importance of a national vertical datum to a 3D digital cadastral system is considered later in this paper.

3. DRIVERS FOR A 3D DIGITAL CADASTRAL SYSTEM

3.1 Evolving Society

New Zealand is experiencing an increase in multi-level multi-occupancy developments. Unit titles, which are governed by the Unit Titles Act 2010 (and previously the Unit Titles Act 1972), are the most widely used form of multi-unit property ownership in New Zealand. There are over 18,000 residential and commercial unit title developments comprising more than 90,000 units (Ministry of Business Innovation & Employment, 2012). A simple Unit Title plan is provided as an example in Appendix B.

The changes to the way in which people live and work are accompanied by rapid changes to the expectations of government, land professionals and the general public. LINZ (2014) identifies that society is increasingly demanding ready access to cadastral information. The general public increasingly expect to be well-informed of their rights and this is placing pressure on the cadastral system which is currently incapable of representing fully all rights, restrictions and responsibilities in land.

3.2 Advancements in Technology

Today's surveyors use equipment and methods which allow efficient collection and processing of 3D data. This information is used by surveyors, engineers, urban designers and architects for design and planning purposes which often precede cadastral work. The 'intelligent' information is then 'watered-down' in the course of capturing it into Landonline. A 3D digital cadastral system would promote the retention of all relevant location data determined by survey and align with current practice by land professionals.

In the fourteen years since the introduction of Landonline there have been major advances in technology and also expertise in developing property rights applications. There have also been significant advances in the information technology readily available to the general public. Smartphones and tablets can provide immediate access to location information and enable visualisation of objects in 3D (LINZ, 2014). These advances are leading to increased public expectation that data will be readily accessible in this form.

4. SUPPORT FOR A 3D DIGITAL CADASTRAL SYSTEM

There are a series of interrelated initiatives underway at LINZ. Each initiative has involved and/or is continuing to involve consultation with government, land professionals and the general public. The ability to fully reflect all rights, restrictions and responsibilities is a common theme to the initiatives, which are briefly outlined below.

4.1 Better Property Services

Those wanting property information or property services currently need to interact with a number of central and local government agencies. Property service information tends to be fragmented, and the information provided is often not easily integrated with information from other agencies or the private sector. This causes delays and costs for users.

LINZ is working with other government agencies to explore how to make it easier to find and use property information and services. A report assessing the economic value of a Better Property Services future promotes the concept of interoperability and concludes that there would be significant benefits from such enhancements (LINZ, 2013a).

4.2 LINZ 10-year View – The Power of Where

LINZ has developed a view of its future direction for the next decade (LINZ, 2014a). The 10-year View identifies areas where LINZ can best apply focus, funding and people to the greatest benefit for New Zealand. Location information is identified as central to LINZ's strategic direction with a key component being the concept of a "location system". The location system will enable diverse location-based datasets to be merged to gain new knowledge, provoke better decisions and inspire innovation.

Grant *et al.* (2013 p.4) identifies that New Zealand's property rights system will be a significant part of this location system "…by enabling New Zealanders to relate the intangible legal spaces (boundaries within which rights, restrictions and responsibilities apply) with the tangible 3-dimensional and dynamic world in which people make important decisions related to the use of land and real property."

4.3 Advanced Survey and Title Services

LINZ is developing a business case to advance the current Landonline application. A key focus of this initiative, known as Advanced Survey and Title Services (ASaTS) is to make provision for 3D cadastral capabilities while providing for greater interoperability with other property and location information systems.

LINZ’s ASaTS programme has been prioritised by the Minister for Land Information and will help realise strategic goals outlined in Better Property Services and also the LINZ 10-year View.

4.4 Canterbury Spatial Data Infrastructure Programme – 3D Enabled Cities

The Canterbury Spatial Data Infrastructure (SDI) Programme is an initiative consisting of eight projects designed to:

- accelerate the earthquake recovery in Canterbury by increasing the ability of Canterbury organisations to share and use location-based information to improve planning and to coordinate critical recovery and rebuild activities
- contribute to the development of a regional and national SDI.

One of these projects, 3D Enabled Cities, aims to develop a system to allow government agencies, private sector companies and the general public to view and edit 3D models of greater Christchurch.

4.5 Cadastre 2034

Cadastre 2034 (LINZ, 2014) is a comprehensive strategy for the development of the New Zealand cadastral system over the next 10 to 20 years (FIG Congress 2014 paper, A New Zealand Strategy for Cadastre 2034 (Grant *et al.* 2013)). A primary objective of the strategy is to enable New Zealanders to understand where their rights in land are.

The strategy proposes a number of substantial changes to the cadastre. These include broadening the scope of the cadastral system to cover the boundaries and extents of all rights restrictions and responsibilities in land and real property. A significant component of the strategy is to make provision for 3D cadastral capabilities.

4.6 New Zealand Positioning Strategy

In February 2014 the National Geodetic Office at LINZ released a draft New Zealand Positioning Strategy for consultation (LINZ, 2014b). This document defines the strategic direction for the development of the geodetic system for the next ten years. The strategy includes a goal to “enable the efficient definition of three-dimensional property rights through an accessible geodetic system” (LINZ, 2014b, p. 6). The Strategy proposes the establishment of a network of control marks with heights determined in terms of the official national vertical datum.

5. DEVELOPING THE 3D DIGITAL CADASTRAL SYSTEM

As indicated earlier, New Zealand already has a system for defining 3D property rights, with support of current legislation and rules, through a combination of digital spatial and aspatial processes. The focus, therefore, will be on the technical ability to implement a fully digital 3D cadastral system.

5.1 3D Digital Cadastral Processes

The specific requirements of a 3D digital cadastral system will be the subject of significant research and design. At the current and early stage in this process it is intended to review the overall processes involved in the survey, capture, validation, reporting, visualisation and analysis of rights, restrictions and responsibilities in 3D. Some of these processes are undertaken by the surveyor utilising various field and office technologies while others are part of the current cadastral system application, Landonline. The following discussion considers the current cadastral survey workflow in terms of 3D requirements.

5.1.1 Undertake the Survey and Prepare Cadastral Survey Dataset

The cadastral survey starts with a spatial search in Landonline to identify the information about the existing underlying boundaries, the geometry of affected land parcels, relevant geodetic and cadastral survey marks, underlying and historic survey plans and associated supporting documents, including title information.

The extraction and uploading of 3D information from the system for use in external software applications and survey equipment will be a fundamental requirement and promote both correctness and efficiency of the cadastral survey and lodgement of the resultant dataset. LandXML is the file format currently used to transfer cadastral survey data between the software used by surveyors and Landonline. The interchange of 3D data will require LandXML to be updated or replaced by an alternative solution.

Surveyors typically refer to the architectural designs when establishing the boundaries of units. There is likely to be a continued need for surveyors to verify design dimensions with as-constructed measurements and ensure the correct relationship between units and underlying land parcel boundaries. The potential role of a process such as Building Information Modelling (often referred to as 'BIM') in assisting surveyors to digitally determine and describe new 3D cadastral boundaries, particularly those associated with units, appears worthy of further consideration.

5.1.2 Data Capture

Currently 2D parcels are captured and integrated into the cadastre through bearing and distance observations and calculations which are connected to cadastral and geodetic survey marks. These may be captured either directly in Landonline or through external software with data subsequently uploaded into Landonline using a LandXML file. A 3D object-oriented approach will need to be developed to allow property objects to be captured whilst maintaining survey accuracy. The extent to which these processes are undertaken within survey software or the new system will be based on assessments of the overall efficiency and effectiveness.

5.1.3 Plan Generation and Visualisation

Under the current regime, for 2D surveys that are captured spatially, plans detailing survey and title information are generated in Landonline through a combination of automated and user-controlled processes. The system generates an overall plan diagram (based on input bearings, distances, marks, boundaries, and parcels) and the user then identifies areas where additional diagrams and annotations need to be generated for clarity.

For 3D surveys, such as multi-storey unit title developments, plans including cross-section and elevation views are drafted using external software and then uploaded into Landonline as a graphic image. The data collected by the surveyor is not captured spatially in Landonline. Unit details are linked to the underlying land parcel but are not portrayed digitally in Landonline's spatial view.

The ability to visualise and analyse 3D property objects could be the most tangible result of a 3D digital cadastral system. The role of and approach to plan generation poses interesting questions and challenges in terms of visualisation of digital 3D information. A primary requirement will be to ensure that the extents of rights, restrictions and responsibilities are unambiguously described for legal and title purposes. An ability to generate on-the-fly plan and elevation views, in addition to cross-section views discussed by Shojaei *et al.* (2013), is likely to facilitate understanding of information, particularly in complex situations.

5.1.4 Validation

Automated business rules will need to be developed to check the validity of new 3D data. Of particular importance will be to ensure that each volume is fully closed and that there are no illegitimate gaps or overlaps of abutting 3D property objects. While similar tests are a feature of the current 2D system, the development of automated business rules for 3D data presents a significant increase in complexity.

Currently the majority of validation checks are embedded within the Landonline application and are applied by the surveyor before certifying the dataset. Once the dataset is lodged, LINZ also applies the validation checks as part of its statutory role in approving the dataset. There is a requirement to perform a series of manual checks in addition to those performed through the automated business rules. These manual checks are a reflection of particular limitations of the current system and also the complex nature of surveying, for which automated checks to cater for every scenario is not practicable.

In a 3D cadastral system, it may be possible to offer the validation checks as web services that can be accessed by both the survey software used by surveyors and by the Landonline application used by LINZ. Such a validation service may also be able to be applied to other datasets outside the fundamental cadastre that are not intended to be lodged with LINZ but are part of the broader cadastre.

5.1.5 Integration into the Cadastre

The surveyor's role is complete once the cadastral survey dataset is 'approved as to survey' by LINZ. Following approval there is a final and important step, to integrate the survey into the cadastre. This includes LINZ staff fitting the new parcels into the integrated parcel and survey network, and applying a least squares adjustment to the area to update the coordinates of the marks and assign an 'order' based on the accuracy of those coordinates.

In a 3D cadastral system, new 3D objects will have to be integrated into a 3D network. This will require a vertical datum that covers the whole country to avoid the historical problems caused by boundaries that are defined on different regional datums.

5.2 A National Vertical Datum

New Zealand's existing vertical datum, NZVD2009, allows the separate regional levelling datums to be linked and enables Global Navigation Satellite Systems (often referred to as 'GNSS') to be used to determine heights. However, NZVD2009 was established using historical gravity data that was not collected with the intent of being used for height system definition (LINZ, 2012a). This has resulted in a number of problems including levels of accuracy, uncertainty of how datum accuracies have been maintained and an inability to provide heights reliable enough to meet cadastral requirements.

6. UTILISATION OF 3D DIGITAL CADASTRAL DATA

Cadastral data is no longer the sole domain of the property rights system. It is used extensively by government and private sectors for the provision of non-cadastral services. LINZ (2014, p. 13) states that the cadastre is a "…mechanism that supports the delivery of social, economic, and cultural benefits, and which relies on and contributes to the overall spatial data infrastructure and property rights system." Councils use cadastral information to underpin land valuation, rating, administration, planning, electoral and resource management roles. Private sector businesses and individuals use cadastral data when developing applications such as route optimisation and research and analysis for social, cultural, economic and environmental purposes.

The 3D cadastral data in the new system will need to be made readily available through interoperability frameworks that enable it to be used for the existing applications indicated above and for future applications. Organisations will then be able to integrate the cadastral data with other data, both spatial and aspatial, in real time and provide services customised for particular purposes.

7. PROGRESS IN DEVELOPING A 3D DIGITAL CADASTRAL SYSTEM

7.1 Improving the National Vertical Datum

In 2012 LINZ commenced a project to acquire a national airborne gravity dataset. This will allow a more accurate definition of the NZVD2009 reference geoid shape and, in turn, support more accurate height measurements across the country. The completion of this project will help achieve the primary goal of the New Zealand Positioning Strategy, to "enable the efficient definition of three-dimensional property rights through an accessible geodetic system" (LINZ, 2014b, p. 6).

7.2 Advanced Survey and Title Services (ASaTS)

The ASaTS programme to improve the cadastral processes and upgrade Landonline will provide the primary mechanism to progress the initial development of a 3D digital cadastral system. The programme has entered into the detailed business case phase with an intention to take it through the government approval process later in 2014.

Subject to final government consent to the detailed business case, LINZ is expecting to begin the design and build phase from late 2015.

7.3 Supplementary Research

In support of the ASaTS programme research is being undertaken by one of the authors, Trent Gulliver, on developing a 3D cadastral system for New Zealand with a particular focus on issues and opportunities, solutions and strategies. This research, which is scheduled to be completed in 2015, will benefit enormously from the substantial international research and collaboration on the topic of 3D cadastres.

8. CONCLUSION

Fourteen years have passed since the introduction of New Zealand's automated survey and title system, Landonline. During that period there have been significant advancements in technology and on-going changes to the expectations of society as well as those of land professionals.

Work is now underway to progress from research to actual development and eventual implementation of a fully digital 3D cadastral system that will allow the capture, submission, validation, visualisation and recording of rights, restrictions and responsibilities in 3D. This new 3D cadastral system will deliver cadastral information through interoperability frameworks that will enable it to be reused and integrated with other spatially-related information. The expectations of society will continue to be embraced whilst ensuring that New Zealand's accurate, authoritative and assured land-based property system is preserved.

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BIOGRAPHICAL NOTES

Trent Gulliver is a Senior Cadastral Survey Advisor with the Office of the Surveyor-General at Land Information New Zealand. He graduated from the University of Otago's School of Surveying with a Bachelor of Surveying with Honours in 2005 and became a Licensed Cadastral Surveyor in 2009. He is currently undertaking a Master of Geographic Information Science part-time through the University of Canterbury.

Anselm Haanen is the New Zealand Deputy Surveyor-General. He holds a Master of Surveying degree from the University of Otago, obtained registration in 1983 and is a Licensed Cadastral Surveyor. He has provided advice on Land Information Systems and spent 2 years in Fiji as Advisor to the Fiji Land Information System. He was also technical leader in the build of the Landonline survey-accurate cadastral database.

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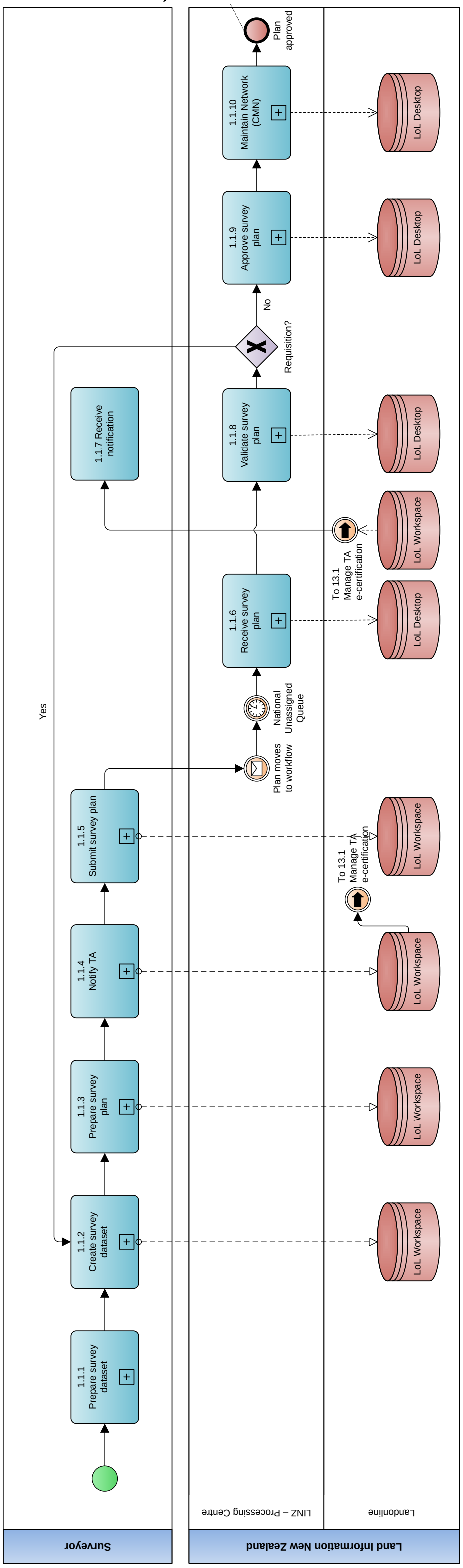
APPENDIX A

Cadastral Survey Process: *commencement – integration*
(source: ASaTS business case documentation)



APPENDIX B

Example of a Unit Plan depicting 3D rights aspatially (source: LINZ).