

A 3D Digital Cadastre for New Zealand by 2021: Leveraging the Current System and Modern Technology

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Key words: 3D Cadastral System, 3D Cadastre, Spatial Object, Rights Restrictions Responsibilities

SUMMARY

New Zealand's current digital cadastre is 2D with 3D situations handled via TIFF plan, section and elevation graphics and supporting textual information. The development of a 3D digital cadastre will enable the 3D spatial extents of property rights, restrictions and responsibilities to be captured, validated, lodged, integrated with existing data, visualised, and made available for use in other systems. Recent research has concluded that the most appropriate way for New Zealand to develop a 3D digital cadastre is to build upon its existing system. The 2D digital cadastre would continue to be the default layer with 3D situations displayed as and where necessary. To enable this requires a new approach to handling parcels defined in 3D (i.e., limited in their vertical extents). The representation of a parcel as a 'spatial object' is being considered to allow parcels limited in height to be integrated into the digital cadastre and subsequently maintained. A spatial object would represent the size and shape of the 3D parcel being defined – a polyhedron. It would need to be related to an underlying primary parcel through a defined relationship to either boundary points or permanent reference marks. The representation of the spatial object would be maintained in the digital cadastre through this relationship to its underlying primary parcel. In April this year Land Information New Zealand (LINZ) announced plans to replace its electronic survey and title system, known as Landonline, through a programme of work known as Advanced Survey and Title Services (ASaTS). The introduction of Landonline in the early 2000s took the New Zealand cadastral survey system on a significant step forward into the digital information age. It provides for the electronic capture, validation, lodgement, recording and supply of cadastral survey data in situations where the spatial extents of rights, restrictions and responsibilities are defined in the horizontal sense. However, analogue procedures (scanned imagery) were retained for handling surveys that defined these in the vertical sense. The ASaTS programme provides an excellent opportunity to consider the way in which cadastral survey data is handled. The Office of the Surveyor-General at LINZ has been exploring ideas to further develop the cadastral survey system with a particular focus being the development of a 3D digital cadastre. This paper will explain the work being undertaken by LINZ to transition New Zealand's 2D digital cadastre to 3D. The authors are especially keen to test ideas, such as the use of spatial objects, with the international community.

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1. INTRODUCTION

The authors of this paper have been actively promoting the development of a 3D digital cadastre for New Zealand since 2013. During this time: the status of 3D cadastral systems internationally has been examined; dialogue with likeminded international jurisdictions has taken place; attendance and participation at national and international conferences with a 3D cadastre flavour has occurred; and input from a practicing licensed cadastral surveyor has been sought and obtained. Outputs from these undertakings include a thesis, conference papers and presentations, a New Zealand survey publication article and several internal discussion documents. Many of these outputs are documented in the References and Bibliography sections of this paper.

A key finding of the research to-date is the need to develop a system that best accounts for New Zealand's situation, for which there are a number of unique characteristics. It is important to note that this paper is written from the perspective of a regulator. Accordingly the concepts described in this paper are tied to New Zealand's cadastral survey system. It is not the intention of the authors to offer a detailed design solution. Rather the purpose of this paper is to test theoretical concepts with the international research community and ultimately with the vendor assigned with the responsibility of building a new land administration system for New Zealand. As the title of this paper suggests, New Zealand is heading for a fully operational 3D digital cadastre by 2021. It will be the responsibility of the vendor to realise the vision for 3D with input of Land Information New Zealand (LINZ) and the surveying profession of New Zealand.

The following discussion commences with an overview of New Zealand's cadastral survey system. This is an important starting point as the system provides both the environment and platform on which to develop a 3D digital cadastre. With this context the next section presents an approach to achieve a 3D solution. This is followed by commentary to support why a 3D digital cadastre will be achieved by 2021. The paper ends with the discussion packaged into a conclusion.

2. THE CADASTRAL SURVEY SYSTEM IN NEW ZEALAND

The cadastral system in New Zealand is based primarily on boundaries defined by monuments in the ground. Surveyors measure between monuments and other survey marks, including geodetic control marks, and record those marks and measurements (bearings and distances) in a cadastral survey dataset (referred to in New Zealand as a CSD) – formerly a ‘survey plan’.

In New Zealand all cadastral surveys must be undertaken by licensed cadastral surveyors. Those surveys and the resulting cadastral survey datasets must comply with Rules (regulations) set by the Surveyor-General (currently the Rules for Cadastral Survey 2010) before they are lodged with LINZ. LINZ, the government agency responsible for the cadastral, geodetic and title systems, ensures each cadastral survey dataset complies with the Rules before approving it and then integrating it into the cadastre.

For 2D surveys the cadastral survey dataset includes all the survey data in structured digital form (e.g., marks, measurements, boundaries, parcels) as well as a TIFF image (‘plan’) of the dataset. The system that is used for managing the cadastral survey (and title) information is called Landonline. Within that system, the dataset components are directly linked to the same components from previous surveys. For example, it is possible to see the measurements between two marks from many different surveys.

Integration includes recording all the data in the cadastral survey dataset as lodged by the surveyor, as well as generating 2D coordinates for all survey and boundary points in terms of the geodetic control network using least squares adjustments. The coordinates are assigned an accuracy ‘order’ based on their compliance with the Rules but they do not define the legal boundaries. Undisturbed marks in the ground and other physical evidence are the primary means of relocating boundaries. Integration also includes meeting topology requirements to ensure that there are no gaps or overlaps recorded in the network of ‘primary’ parcels. That primary parcel network covers all of New Zealand and consists of over 2.5 million parcels (Landonline interrogation).

Landonline also has a 2D network of ‘secondary’ parcels (e.g., for rights-of-way or other easements) which are generally related to the corresponding underlying primary parcels. In this secondary parcel network gaps and overlaps are permitted, although secondary parcels may not cross a primary parcel boundary.

2.1 The current New Zealand 3D cadastre

New Zealand has a well-established 3D ‘legal’ cadastre. The freehold title system under the Land Transfer Act 1952 supports rights, restrictions and responsibilities in property, regardless of whether they are restricted in height or not.

Unit titles (under the Unit Titles Act 2010 - previously the 1972 Act) are the most widely used form of multi-unit property ownership in New Zealand. At the time of writing this paper there are in the order of 14,000 residential and commercial unit title developments comprising around 140,000 unit titles (Landonline interrogation).

However unlike ‘2D’ cadastral survey datasets (i.e., those which do not contain height information), the detailed survey information (often both horizontal and vertical) is not spatially captured in the Landonline system. Rather it is drafted on a plan, with section and elevation graphics supported by textual descriptions. Height data (e.g., a reduced level) is included on the plan but is also not captured. These plans can be difficult to interpret, especially where the boundaries are not uniform. A unit plan is provided as an example in Appendix A.

2.2 Future goals for the New Zealand 3D cadastre

The aim is for New Zealand’s current 3D cadastre to become fully digital – however, there is no single, concise definition for what that means internationally (Gulliver, 2015). The following New Zealand definition for 3D digital cadastre was developed from a modified definition for cadastre in the Surveyor-General’s cadastral strategy, Cadastre 2034 (LINZ 2014):

the repository of digital cadastral survey datasets, including those with defined 3D data, and lodged with LINZ and integrated into its database.

(Gulliver, 2015, p. 63)

A 3D digital cadastre would permit data associated with the real world extents of property rights, restrictions and responsibilities to be digitally captured, automatically checked against requirements, combined with existing data (and subsequently maintained), and exported for re-use in other systems.

The primary goal is for the entire cadastral survey process (from ‘field to finish’) to move away from ‘plans’ and the associated pictorial representation of survey information, and instead rely on digital data. In this respect New Zealand is already well advanced in relation to 2D surveys (i.e., those that do not have height information) – but not for 3D.

Cadastral surveyors in New Zealand already utilise digital technologies when undertaking their surveys, calculations, and verification. They are also obtaining the digital models generated by architects and engineers for new buildings (e.g., through Building Information Modelling) and utilise them to define internal boundaries (with ground truthing). However, the current processes do not allow surveyors to submit that data to the cadastre, but instead require them to produce a plan image that cannot be interpreted by a computer and which require human interpretation.

Full digital representation of 3D survey data will maximise quality through digital verification techniques (e.g., clash detection for 3D boundaries). Visualisation tools offer the opportunity to significantly improve the quality and interpretation of 3D cadastral survey datasets and the digital models they contain. Functionality for zooming into a 3D model and changing the point of view is now readily available (e.g., 3D PDF viewers).

Availability of 3D digital cadastral data will enable it to be presented in various forms and utilised with other geospatial data for a multitude of purposes – this is routinely undertaken for 2D cadastral data, but can also be readily achieved for 3D datasets.

It is important to emphasise that while New Zealand currently records many parcels in 2D format, the associated rights are actually three dimensional – the boundaries extend down into the ground and up into the air (Figure 1). When creating new rights that are limited in height, the entire volume in the original right must be addressed and replaced as necessary. Our conceptual aim is, therefore, to fully integrate 3D ‘parcels’ with the ‘2D’ parcel records and enable visualisation of both, in 2D and in 3D.

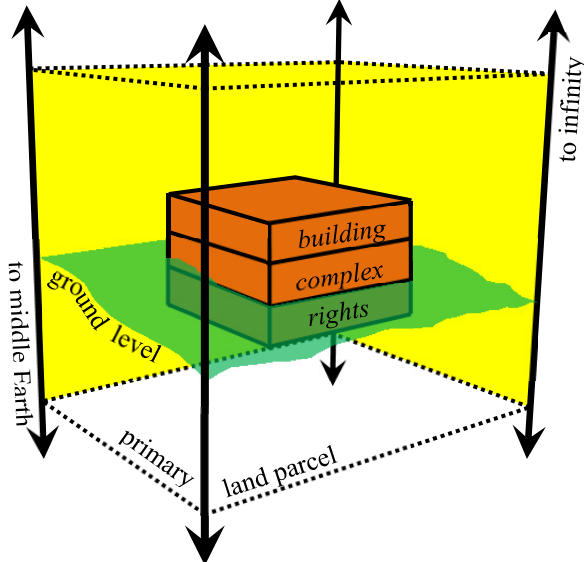


Figure 1. Extents of property rights (Gulliver, 2015, p. 63)

3. APPROACH TO ACHIEVING 3D

3.1 Developing a solution

Solutions need to consider how the extents of 3D property rights, restrictions and responsibilities are legally defined in a digital environment and also how the related digital data is incorporated into and managed within the system. New Zealand’s legislative framework already supports the definition of property rights, restrictions and responsibilities in 3D and does not inhibit the development of the cadastral survey system to cater for 3D digital data.

3.1.1 Requirements

Technical and operational changes are required for the cadastre to handle 3D information digitally. The specific requirements are identified and defined in Table 1.

Table 1. Requirements of a 3D digital cadastre (adapted Gulliver, 2015)

Requirement	Description
Search	Users will need to be able to visualise, interrogate and extract digital 3D property rights related information.
Capture/Lodgement	Cadastral surveyors will need the ability to digitally capture/lodge 3D cadastral survey datasets.
Validation	Automated business rules will be necessary to check the validity of incoming data.
Integration	3D data will need to be integrated into the cadastre.
Maintenance	The spatial accuracy of the cadastre will require horizontal and vertical network maintenance.

3.1.2 Establishing an approach

Gulliver (2015) considered Netherland-centric research by Stoter (2004) where three fundamental interpretations of 3D cadastre are presented: full 3D cadastre, hybrid solution and 3D tags. The option promoted here for New Zealand is based on a variation on the concept of ‘hybrid cadastre’. Under this approach 3D property rights, restrictions and responsibilities can be integrated into the digital cadastre and subsequently maintained. In situations where the upper and lower height limits of property rights, restrictions and responsibilities are defined, a full 3D spatial depiction would be used. Otherwise ‘2D’ parcels would be maintained as a default.

The development of a 3D digital cadastre using a variation of Stoter’s hybrid approach is deemed to be the most appropriate solution to enhance New Zealand’s cadastral survey system. This approach builds on the existing robust 2D digital cadastre by allowing 3D data to be digitally captured, validated, maintained and made available for reuse on an as and where necessary basis. Importantly the approach also allows New Zealand’s monument and observation based cadastre (refer to s. 2) to be preserved as the foundation of the digital cadastre.

3.2 The concept of 3D spatial objects

The concept of a ‘spatial object’ is being considered as an approach to allow parcels defined in 3D to be submitted and integrated into the digital cadastre and subsequently maintained.

Spatial object modelling is a seasoned tool for use in GIS applications (Molenaar, 1998). In the context of this paper, a spatial object describes (within specified accuracy standards) the size, shape and extent of property rights, restrictions and responsibilities - as a 3D polyhedron. In a GIS context, the spatial object is a coordinated 3D shape – defined in terms of x, y and z. Modern spatial technologies, including GIS, have functionality for creating, manipulating, viewing, and managing such spatial objects.

Figure 1 (below) is a perspective view of a 3D spatial object representing a secondary right that is restricted in upper and lower heights located in relation to its underlying primary parcel.

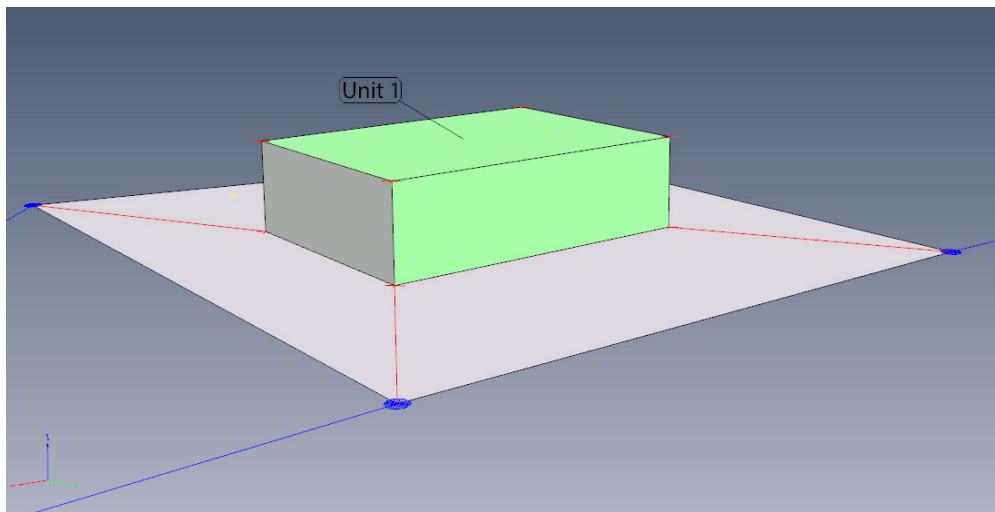


Figure 1. '3D spatial object' representing a secondary right within a primary parcel

Each spatial object would have a defined relationship to its underlying primary parcel, and that parcel would have previously been captured and integrated into the 2D digital parcel fabric.

The approach takes advantage of the fact New Zealand has a mature digital '2D' cadastral survey system. The use of spatial objects builds on the current system by allowing property rights, restrictions and responsibilities that are defined in 3D to be digitally incorporated into the cadastre.

3.3 Creation of spatial object

A spatial object would be based on data collected and verified as correct by the surveyor responsible for certifying and lodging the cadastral survey dataset. These data may be obtained through a variety of sources, including architectural and engineering designs, Building Information Models, and via direct survey measurements made in the field. It is expected that the latter would also be used to ground-truth each of the preceding scenarios.

As discussed in the previous section, every 3D spatial object is by definition coordinated in terms of x, y, and z coordinates. In order to have a defined relationship between a spatial object and its underlying primary parcel, there would be a need to link the spatial object to the underlying parcel or nearby permanent reference marks (refer to Figure 3).

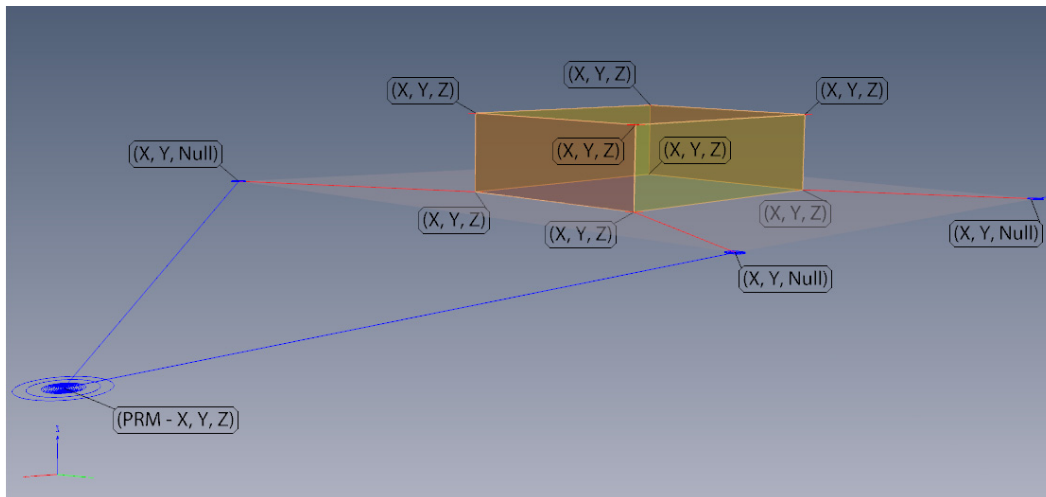


Figure 2. XYZ definitions of '3D spatial object'

The following subsections consider the definition of spatial objects for the types of parcel boundary permitted by the Rules.

3.3.1 3D spatial object for 3D parcel represented by right line, arc, water or irregular boundaries

From a survey definition perspective, the 3D parcel (a parcel with defined height limits) must be defined in relation to its underlying primary parcel. This ensures that the boundaries of the 3D parcel could be relocated by firstly relocating boundary points on the underlying primary parcel which will have been fully defined by monuments.

Similarly, in the cadastral survey dataset, the relationship between the 3D spatial object (representing a 3D parcel) and its underlying primary parcel needs to be explicitly defined. This can be achieved by including in the dataset, horizontal coordinates that correspond to boundary points previously defined on its underlying primary parcel. Wherever the boundaries of the 3D parcel and the underlying parcel are coincident, the horizontal coordinates of both ends of the underlying boundary would also need to be included in the dataset. The accuracy between those coordinated points on the underlying parcel and the vertices of the spatial object would have to meet the relevant standard in the Rules. These requirements would also ensure that the spatial object for the 3D parcel could be maintained in alignment with the primary parcel network.

The vertical position of the 3D parcel needs to be capable of being re-established in the future, and also reflected spatially in the digital cadastre. Therefore, the 'z' vertices inherent in the 3D spatial object would need to be related to 'z' coordinates on existing boundary corners of the underlying primary parcel and/or permanent reference marks, all in terms of the official vertical datum.

3.3.2 3D spatial object for 3D parcel represented by permanent structure boundaries

The Rules allow certain types of secondary parcels to be defined by permanent structure boundaries. These boundaries are described in relation to a physical feature (e.g., the outer

face of a wall, or an offset to the feature). The licensed cadastral surveyor who certifies the cadastral survey dataset is responsible for defining the position and accuracy of the permanent structure boundary in relation to the permanent structure.

Two options have been identified for recording this relationship:

1. Spatial object representation of the permanent structure boundary only. The parcel and its boundaries would be defined by a 3D spatial object, along with a description of the physical structure to which it is related and the relationship (e.g., 'boundary through centre of wall' or 'boundary follows centre of concrete floor'). The description of the relationship between the permanent structure boundaries and the permanent structure is of great importance as it defines the legal position of the boundary.
2. Spatial object representation of the permanent structure boundary and the permanent structure. The parcel and its boundaries would be defined by a spatial object, as would the permanent structure itself. The relationship between the two would not necessarily be required as this would be able to be determined from the spatial objects using a measurement tool in spatial software. A level of supporting description may still be required (e.g., 'internal wall' or 'concrete floor').

Common property, being land or building that is for the use of all the property owners, would not be defined by a spatial object. That common property will be that part of the total volume remaining after the 3D spatial objects have been excluded.

The relationship between the 3D spatial object and its underlying primary parcel would also need to be defined. This could be determined by applying the same principles used for right line, arc, water or irregular boundaries (as discussed under s. 3.3.1). However, as indicated earlier, this definition cannot be authoritative as it is the permanent structure boundary that provides the legal definition of the boundary. Therefore, the spatial position of a 3D spatial object for a permanent structure boundary would be indicative only in the digital cadastre.

3.4 Validation of spatial object

Data being submitted into the cadastre needs to be validated. The primary purpose of validation is to ensure that the data complies with the Rules and that it is able to be integrated into the digital cadastre. Some validation rules that may be required are:

- Spatial object is a correctly formed shape and meets the definition of a spatial object
- 3D spatial object secondary parcel is contained within its primary parcel (this would require the ability to extrude the horizontal boundaries of the underlying 2D parcel fabric vertically)
- Cadastral survey dataset contains XYZ coordinates for a sufficient number of underlying primary boundary points and/or permanent reference marks
- Spatial object to be checked for collisions with other spatial objects (e.g., parcels for units).

3D clash detection routines found in current surveying, engineering and GIS software indicate that validation of 3D spatial objects ought to be readily achieved. Despite any validation

procedures, the responsibility for correctness of certified data will continue to be the obligation of the surveyor responsible for the cadastral survey dataset.

3.5 Integration of spatial object into digital cadastre

The vision is for a digital cadastre where 3D property rights, restrictions and responsibilities are represented digitally in 2D or 3D as appropriate in a single integrated and seamless system.

Once a cadastral survey dataset is approved, it would be adjusted into the digital parcel network and the representation of the spatial object would be repositioned relative to its underlying parcel or the permanent reference marks in terms of the official coordinate datum and projection.

Currently primary and secondary parcels defined by nodes and lines are fully integrated into the boundary network. This means they are managed topologically and coordinates are generated through least-squares adjustment of the vector (bearing and distance) data. However, under this proposal the spatial objects would be managed through a different process. Topology would not be directly managed, and alignment would be maintained by applying a transformation to the spatial objects, using the connection points to the cadastral network as the ‘control’ (i.e., either the boundary points on the underlying parcel or the permanent reference marks, as recorded in the cadastral survey dataset).

LINZ needs to be able to maintain and update the spatial location of the secondary parcels in the network over time. Any movement of geodetic marks (such as that caused by tectonic movements) that affect cadastral marks may have an effect on the underlying parcels which in turn has an effect on the spatial object. The processes for adjusting the primary parcel network will need to be extended to also adjust any secondary parcel to keep them in the correct relationship. The requirement for connections that meet the accuracy standards in the Rules is intended to ensure that the transformation would result in negligible distortion of the spatial object during future alignment processes.

Similarly over time, the height values of spatial objects represented in the 3D parcel network will need to be able to be adjusted as the height values of geodetic control marks change over time.

3.6 Extracting the data for the spatial object

Exports of the spatial objects for use in other software would be dependant on the user’s requirement of the data. Two different options for extracting the spatial object would be available:

1. as transformed to fit the digital cadastre at the time, recognising that positions change over time due to improved data and geodetic shifts; or
2. as it was lodged, certified and approved in the cadastral survey dataset, as that is the authoritative record of the legal position of the boundary.

In this latter case the surveyor could then transform that data to fit marks found on the new survey to accurately determine the location on the ground at that time.

Spatial objects would be able to be easily integrated into any GIS or other spatial information system and overlaid with other datasets. Being coordinated in terms of the official geodetic datum would enable the boundaries of the primary and secondary parcel (position of the spatial object) to be readily determined on the ground, especially through the use of positioning technologies.

3.7 Visualisation of the digital cadastre

It will be important for users to have the ability to become informed of the location and spatial extents of all property rights, restrictions and responsibilities through visual interrogation and analysis of the 3D digital cadastre.

3D spatial objects need to be suitably displayed in spatial views in terms of the underlying primary parcel fabric. In addition to 3D perspective views, 2D plan views could provide for quick assessment of the ‘footprint’ of all property rights, restrictions and responsibilities in relation to underlying primary parcels. The user would be alerted to situations where a ‘footprint’ represents a right defined in 3D. 3D views would then be explored if further understanding was required by the user.

Earlier it was mentioned that there would be a need to vertically extrude the horizontal boundaries of underlying primary parcels for validation purposes. The ability to extrude such boundaries would also benefit visualisation. In addition, the draping of the digital cadastre over a Digital Terrain Model would enable 3D spatial objects to be visualised in the context of their surrounds (albeit indicatively only).

The ability to visualise a 3D digital cadastre by anyone could be readily achieved, based on functionality of current surveying, engineering and GIS software, and also 3D PDF viewers.

4. 3D DIGITAL CADASTRE 2021

New Zealand already has a mature 2D digital cadastre that enables the digital lodgement of 2D cadastral survey datasets, and their integration into survey and parcel networks. The proposals highlighted here are intended to extend this to 3D, but what other contributing elements exist that make 2021 an achievable target?

4.1 National property rights system

The first element in support is that New Zealand has a national property rights system with LINZ having sole jurisdiction. Appreciation that this is a contributing aspect is evinced by the observation made by Karki (2013) that where countries have multiple jurisdictions, each with their own legislation, systems and practices, this can be seen as an impediment to the implementation of a national 3D cadastre. Having the one national system also makes it less problematical to facilitate change, particularly with regard to mandating certain requirements, if or when they may be considered necessary.

This single jurisdiction model does mean LINZ has the responsibility to continue to enhance the property rights experience for all users, hence the desire to advance the 3D cadastre. One

of the drivers to keep enhancing the system, particularly with respect to digital 3D data, relates to what other 3D data is being collected and what other applications it is being used for, by providers other than LINZ. If LINZ is slow to respond to the changing needs and expectations of society, it is possible that non-authoritative 3D systems may be established to fill the void, thus creating a competing system to undermine New Zealand's current property rights system (Gulliver, 2015).

4.2 Accommodating legislation

As highlighted earlier, New Zealand's legal cadastre already accommodates 3D property rights, restrictions and responsibilities. In fact, New Zealand has had a 3D legal cadastre since the inception of the survey and title systems during the 1800s. The key legislation relating to New Zealand's survey and title systems are the Cadastral Survey Act 2002 and Land Transfer Act 1952 respectively. These acts also do not preclude the development of a 3D digital cadastre to better reflect the legal situation.

4.3 New national vertical datum

A 3D digital cadastre requires national horizontal and vertical datums suitable for cadastral survey purposes. New Zealand's current horizontal datum, New Zealand Geodetic Datum 2000 (NZGD2000), covers the country and is sufficient in its current form.

Currently heights recorded in cadastral survey datasets are defined in terms of 13 different local vertical datums. As of June 2016, New Zealand also has a suitable national vertical datum, New Zealand Vertical Datum 2016 (NZVD2016). NZVD2016 is the culmination of a project commenced by LINZ in 2012 to acquire a national airborne gravity dataset. This allowed a more accurate definition of a reference geoid shape to support survey accurate elevation determinations across the whole country. NZVD2016 represents a step towards achieving the primary goal of the New Zealand Positioning Strategy, to "enable the efficient definition of three-dimensional property rights through an accessible geodetic system" (Land Information New Zealand, 2014a, p. 6).

4.4 Advanced survey and title services

The most significant development towards New Zealand realising a 3D digital cadastre is the scheduled replacement of the current survey and title system, Landonline, through a programme of works known as Advanced Survey and Title Services (ASaTS). In the context of this discussion, ASaTS provides a pathway to realising a 3D digital cadastre. Importantly, ASaTS is supported by the New Zealand government.

Landonline is built on technology that was considered to be leading edge in the 1990s. There have since been substantial advancements in technology, knowledge and expertise in developing land administration systems. There are also changing expectations by an increasingly diverse range of customers and consumers that include land professionals, such as surveyors and conveyancers, along with experts and non-experts in spatial science, systems and information. These expectations relate to the functionality and performance of the system and the applications for which its data can be used. In particular there is increasing demand from the spatial community, and indeed the general public, for 3D property information in a digital and readily consumable format.

A primary objective of ASaTS is to modernise New Zealand's electronic survey and title system and provide all users of the system and its data the experience of a better service. It aims to improve and extend the functionality already offered by Landonline while being a more interactive, portable and flexible system. The current system uses monolithic IT architecture which means making changes can be slow and costly to implement. ASaTS will counter this shortcoming through a modularised IT architecture solution.

LINZ is taking an 'as a service' approach to developing ASaTS. Rather than owning the system, as Landonline currently is, LINZ will select a provider that can deliver a suitable system that LINZ will pay to use. This concept, which can be likened to renting, is being used successfully by land administration jurisdictions in Australia and Canada. It is important to note that while the new system will be owned by another party, LINZ will retain control of the data and its use. LINZ and its staff will also continue to process and assure the quality of survey and title transactions.

In April 2016 LINZ released an Expression of Interest document inviting prospective vendors to register their desire to work with LINZ to deliver the ASaTS solution. LINZ is currently working with a number of potential vendors and is expecting the successful vendor to be in place in 2017. Following this, the development of and transition to ASaTS is likely to occur over a five-year period, with LINZ envisaging the new system to be completely in place by 2021.

5. CONCLUSION

New Zealand is well-placed to design, build and implement a national 3D digital cadastre. A mature property rights system that already accounts for 3D situations combines with a robust 2D digital cadastre to provide a sound platform on which to realise this objective.

The approach presented by the authors is founded on the belief that the core components of a 3D digital cadastre can be achieved by applying currently available technologies to New Zealand's existing system. This approach, which is from the regulatory perspective of the authors, will need to be tested and refined as necessary. Feedback from the international research community and the vendor assigned with the task of building the 3D digital cadastre will be vital in this regard.

Ultimately, New Zealand has the desire, support and means to achieve a 3D digital cadastre by 2021.

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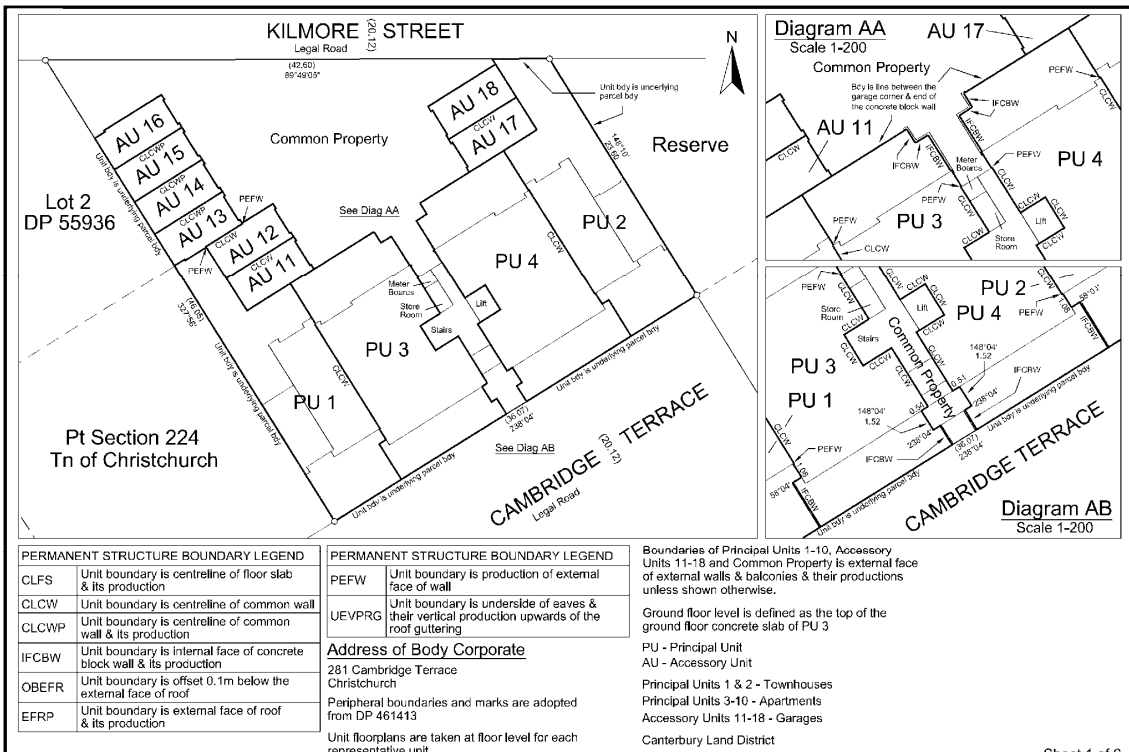
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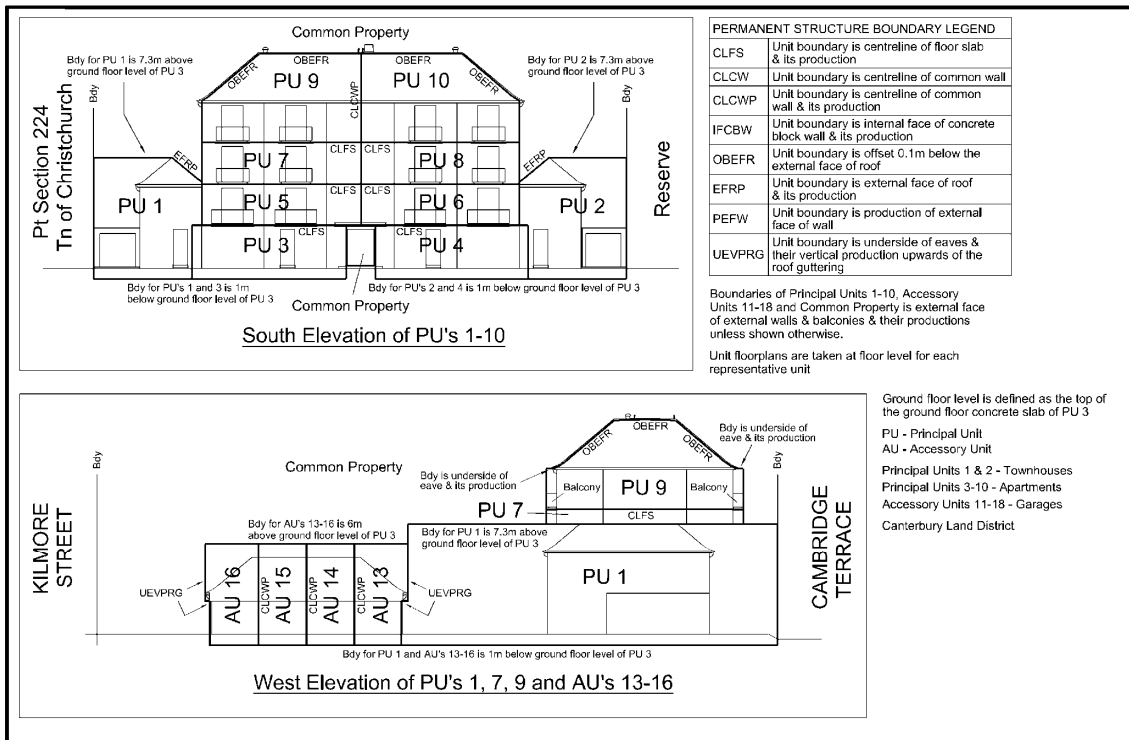
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Appendix A. Part unit cadastral survey dataset



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BIOGRAPHICAL NOTES

Trent Gulliver is currently a Senior Survey Advisor with the Office of the Surveyor-General at Land Information New Zealand. He graduated from the University of Otago School of Surveying with a Bachelor of Surveying with Honours in 2005 and became a Licensed Cadastral Surveyor in 2009. In 2016 he graduated with a Master of Geographic Information Science with Honours, from the University of Canterbury. His thesis, entitled Developing a 3D Digital Cadastral Survey System for New Zealand, has provided a basis from which to inform the development of a 3D digital cadastre.

Anselm Haanen is currently 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.

Mark Goodin is currently a Senior Landonline Application Specialist at Land Information New Zealand. He has spent the majority of his career in the Private Sector operating as a Licensed Cadastral Surveyor for a multi-disciplinary engineering consultancy. He has extensive practical experience in 3D digital data capture with specific expertise in carrying out cadastral surveys involving the definition of 3D property rights, restrictions and responsibilities.

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