Shaping the Cadastral Infrastructure for a Digital Future

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ABSTRACT

Australia's cadastral network, represented by the Digital Cadastral Database (DCDB), plays a fundamental role in Australia's Spatial Data Infrastructure (SDI), supporting decision making across all levels of government. The accuracy and integrity of the DCDB is essential to ensure critical decisions are made based on current and correct land information. With the introduction of e-Conveyancing and e-Plan digital lodgement, land information from a variety of external sources will rapidly populate the SDI with Global Navigation Satellite System (GNSS)-based information. The integration of this highly accurate information will compound the inherent historical inaccuracies within the DCDB, causing considerable impact on service and information delivery. In order to ensure responsive service delivery in a digital land administration of the future, cadastral fabric technology is transitioning the decades-old static DCDB to a dynamic survey title-based Numerical Cadastral Database (NCDB) that accurately models the nation's cadastral network. This paper provides government professionals with a comprehensive overview of how improved rigour and accuracy of the DCDB will provide powerful spatial infrastructure to generate technical and legal certainty for all stakeholders. It outlines the Tasmanian Numerical Cadastral Database Project and discusses the vision, the challenges and the benefits a project of this nature can deliver.

KEYWORDS: *DCDB, cadastral fabric, spatial data infrastructure.*

1 INTRODUCTION

For over 150 years in Australia, surveyors have been establishing the geodetic framework and establishing or re-establishing boundaries; the two most important themes in a spatial information infrastructure. The role of the surveyor in these functions is still critical – the only difference between the surveyors of the past and our current surveyors are the tools of the trade. They still continue to capture the evidence, make informed decisions and manage information.

Since the establishment of Australian colonies, surveyors have been establishing and maintaining the most important information system in Australia's economy – the cadastral framework. Initially, this was a piece meal approach but over the last 30 years, it has been recognised that a national approach is required for this framework. In the early stages of creating this framework, each state produced their version of a Digital Cadastral Database (DCDB) from survey plans. In New South Wales (NSW) for example, the DCDB started with a cadastral fabric created by the utilities authorities in the Sydney area. The land agency now known as Land and Property Information (LPI) progressed the DCDB out to the state's borders. Over time, the DCDB has become the adopted representation of the cadastre and has been used as the basis for most Geographic Information Systems (GIS).

As with all tools and technology, progress has been rapid and this has never been more true than in the last few years. This increase in computing power – in surveying technology and the ability to use remotely sensed satellite systems such as Global Navigation Satellite Systems (GNSS) – has dramatically changed the way information is captured and managed. The DCDB is just one of the information management systems that have been positively impacted by the change in technology advancement.

This paper looks at the benefits of the technology advancements in managing the information in the current DCDB cadastre frameworks. In order to demonstrate these benefits, this paper investigates a case study from Tasmania. The Tasmanian government has invested in a project to upgrade their DCDB to a Numerical Cadastral Database (NCDB). The NCDB is designed to upgrade the spatial accuracy of the cadastral fabric. This paper will also investigate what the future holds for the nation's cadastral infrastructure, with Tasmania and other jurisdictions either actively progressing or considering moving towards spatially improving the accuracy of their state's cadastral fabrics. Finally, the paper will discuss the impacts of changes in spatial systems to the management of cadastral fabrics and the potential benefits to the spatial industry, the government and the community.

2 THE HISTORY OF DIGITAL CADASTRAL DATABASES

A DCDB consists of tables and layers, representing different aspects of land and property boundaries. These different aspects include but are not limited to (LPI, 2013):

- Government boundaries, including Local Government Areas, state and federal electoral boundaries and other administrative areas.
- Property boundaries, lots within Deposited Plans and Strata Plans.
- Suburbs.
- Proclaimed boundaries of state forests, National Parks & Wildlife reserves and Livestock Health and Pest Authority districts.
- Road corridors and centrelines.
- Boundaries of bodies of water.

In 1992, Australia's Surveyors-General gathered to discuss the importance of national datasets, including a digital cadastral databases. The important aspects of the discussion included:

1. The reasons for building the DCDBs.
2. The methods used to compile the DCDBs.
3. The computing capability required to store and maintain DCDBs.

These three aspects are discussed in the following sections.

2.1 Reasons for Building DCDBs

There are a range of reasons that DCDBs were required to be built. A statement made by Effenberg and Williamson (1997) is an excellent summary: "*The processes for updating and upgrading DCDBs are gaining considerable attention world-wide as GIS users recognise the importance of the currency, quality and content of the DCDB that underpins their GIS application.*"

The uses of DCDBs were gaining momentum in the late 1990s as one of the most critical datasets required as base layers in GIS. With the cadastre viewed by many as the basis of most economic systems globally, it is logical that it forms the basis of most information systems that are based on land.

Some of the uses for a DCDB include:
- Local government asset management.
- Environmental monitoring and mapping.
- Mining and exploration.
- Defence and security.
- Forestry.
- Asset management for utilities.
- Management of roads.
- Statistical analysis.
- Mapping of a whole range of items of interest.

2.2 Methods Used to Compile DCDBs

The first land agencies in Australia used similar methods for the creation of the first DCDBs. They all selected a nominated starting point and used the latest survey plans available to build the DCDB by digitising the latest survey plans – entering the dimensions of the boundaries or importing sections of the DCDB created by local government authorities or utilities organisations. The database was compiled and progressed until all the boundaries within the jurisdiction were added. This was a significant task for the jurisdictions. However, in a period of about 10 years they were able to produce DCDBs for all of Australia, which included over 15 million parcels.

Over the next 10 years, the role of the state jurisdictions was to maintain and improve the DCDBs based on the changes that constantly occur with the trading, subdividing and amalgamating of parcels within the cadastral fabric. The issue with the upgrade and maintenance of the DCDB was that any changes needed to be 'rubber sheeted' into the existing structure of the DCDB. The ability to spatially upgrade the DCDB was limited to fitting any new data into the DCDB. This resulted in more accurate surveys being degraded to fit the accuracy of the DCDB. This produced a dataset that was pictorially representative of the cadastral fabric but was not spatially accurate.

2.2 Computing Capability Required to Store and Maintain DCDBs

The 1990s saw the beginning of the computer revolution, and the internet started to become mainstream. The storage capability of computers began to grow exponentially, but at the same time, the beginning of computer miniaturisation ensured that storage devices could handle larger capacity – but in hardware that was about the size of a large personal computer. The hand-size mobile phones started to become common in the 1990s.

Prior to the 1990s, the ability of computers to store massive vector datasets was confined to large mainframe servers. These were generally only available to government departments and universities. As such, the use of GIS was largely confined to organisations with the ability to host these large computers. During the 1990s, the computing power of personal computers grew by over 100 times and made it possible for GIS to be used on these types of computers. During this period Esri released ArcView 1.0 – this product was the beginning of the development that led to ArcGIS Desktop as it is known today. This was the first Esri GIS product that allowed non-traditional GIS users to view and query maps. These capabilities began to drive the demand for mapping applications. As this demand grew, so did the demand for the base data, including the cadastre.

3 CHALLENGES AND ACCURACY OF THE EARLY DCDB

The accuracy of the DCDB was always an issue from its inception. The methods of data capture, the mix of old and new data, and the methods for combining these data all but guaranteed the accuracy of the DCDB would be compromised. Initially, this was not a major issue. Users would match the DCDB to other datasets, e.g. aerial photographs, topography or other data they may have captured. It was realised the DCDB was a visual representation and as such the accuracy issues were not of concern.

However, accuracy was a key priority to managers of high-value assets such as utilities, mines, power stations and other similar facilities. These users required high degrees of accuracy between their assets and features that defined boundaries. The reason for this was that utilities were located in the footpaths and on the roads, generally about 600 mm from the property boundaries. Mines and power stations needed to ensure the assets they assisted in building were within the boundaries of the leases or parcels. With any inaccuracies in the DCDB, maps displaying these types of assets could easily show the assets in the wrong property, or in some cases totally misplaced. During surveying experiences in South Australia, NSW and north-western Queensland, the author often found errors of up to 500 m between the coordinates derived from the DCBD and sub-metre GPS positioning.

In order to ensure accuracy, these users would create their own localised DCDB from the original survey plans and accurately locate their assets to features such as kerb lines, existing defined property boundaries and other easily definable features. Once the assets were defined in relation to these boundaries, the utility companies would use the assets as a point of reference and move the boundaries in relation to the asset if new information was obtained. During this period of time these companies typically had an entire branch of surveyors and supporting staff working continuously on locating their assets and performing boundary reinstatement to locate these assets to the boundaries. These companies would use their assets as the basis for their GIS, and the cadastre was used as a context layer that could be moved if accuracy issues were identified. Other GIS users also used the DCDB as a context layer, but generally accepted the errors or made manual adjustments to ensure the DCDB and other layers were representative of the relationship between the layers without any accuracy consideration.

Other challenges faced by GIS users were also presented during the early DCDBs. If attributes were linked to the boundaries of the DCDB, with each new version of the DCDB the attributes would have to be unlinked, with the new DCDB data loaded and the linkages recreated. A similar process was required each time a boundary was manually moved. This made the process of upgrading the DCDB extremely time-consuming and expensive. As such, users would delay the upgrade process until it was absolutely necessary.

3.1 What Changed?

In 1957, U.S. scientists discovered that they could track the orbit of a satellite in space by listening to the changes in radio frequency – now known as the Doppler effect. This led to the creation of the U.S. Navy's TRANSIT Navigation System in the 1960s. A series of six satellites were initially launched with the purpose of tracking submarines. The full constellation for this system was 10 satellites, but users would have to wait up to several hours to pick up a signal. During this time, engineers Ivan Getting and Bradford Parkinson were the project leaders of a U.S. Department of Defense project, designed to provide continuous navigation information. The project was initially called NAVSTAR Global Positioning System (GPS) and was launched in 1973 during the Cold War. The first of the GPS satellites was launched in 1978 and the constellation of 24 satellites was completed in 1995 (Bellis, 2013).

The GPS and consequent Differential GPS (DGPS) techniques enabled users to accurately position assets and features to an accuracy of between one and 20 metres consistently. This new capability offered a new accurate data capture method to GIS users without the slow and labour-intensive survey techniques previously used by surveyors to coordinate features. This new capability enabled GIS users to capture large quantities of accurate data to put into their GIS. However, a new source of error was discovered – the datum. The Australian Geodetic Datum (AGD) and the World Geodetic System 1984 (WGS84) used by the GPS differed by approximately 200 metres. In order to solve this issue, the Intergovernmental Committee on Surveying and Mapping (ICSM) created a new Geocentric Datum of Australia 1994 (GDA94) and the consequent Map Grid of Australia (MGA94) to support the increasing use of GPS/GNSS. The use of GPS has been a driver for improving the accuracy of spatial systems such as the DCDB. New equipment and techniques now mean that features, survey marks and corners can be located within a few centimetres with GNSS.

Additional to the advances in the professional tools for positioning, the ever-progressing mobile hardware is now capable of positioning within two to five metres on a regular basis with the appropriate satellite constellation and access to an open skyview. As technology capability increases, the demand for information and data that reflects the accuracy of the technology is expected by users.

4 IMPACTS OF NEW MEASUREMENT SYSTEMS ON THE DCDB

Since the inception of the modern GIS in the 1960s, the work of surveyors and GIS users has been predominantly separate. GIS users have relied on data captured by surveyors, but there was no direct linkage. This has changed, with the GIS becoming the repository for survey measurements, boundary dimensions and the associated attributes. The cadastral fabric of today is providing more than a pictorial representation of the cadastre. It is based on the geodetic framework and is the basis for all information relating to the land parcels. In this paper, these new DCDBs will be referred to as NCDBs. The term NCDB has its origins in the work currently being undertaken in Tasmania (see section 5).

The modern GIS has the ability to create linkages called associations between features and aspatial attributes (i.e. attributes with no spatial components such as a property owner's name), called topologies. While this linking ability in itself is not new, the NCDB provides the additional capability to change, upgrade, add or delete boundaries within the GIS and at the same time retain the topological relationships between the original features and the aspatial attributes. The NCDB also makes it possible to alter the aspatial attributes without impacting the parcel boundaries.

4.1 Benefits to GIS Users

The benefits for GIS users begin with the ability to make the upgrade of the NCDB a simpler process. The new updates to the NCDB versions of cadastral data are able to be added without impacting topology or data that do not require change. As systems improve for surveyors to provide data transfer files in place of survey plans, a more efficient process can be created for updating the GIS with new data and making these data available to the public. The benefit to the GIS user is an authoritative and reliable base data 'layer' that can be provided through web services and kept up to date almost in real time. The need for GIS users to store large base datasets is also no longer necessary as information services, such as the cadastre, topography and water networks, are delivered as information services that can be mashed up to create the required 'map' at the time of use.

4.2 Benefits to Surveyors

Surveyors will still be the primary source of cadastral information in the NCDB but will need to grasp the concepts of GIS. The reason is that data will be provided to them from the GIS, in a format such as LandXML. The surveyor will need to provide it back to the land agency in the same format. The information contained in LandXML is more extensive than a normal AutoCAD file provides. The ability to take a dataset supplied by a GIS, add or amend it and provide it back is a more substantive process than drafting a plan in AutoCAD. This will enable surveyors to employ staff skilled in using GIS and therefore these skills are another capability the company is able to offer to their clients.

The plan searching process will be more digitised and streamlined as a result of NCDBs. With the survey measurements able to be stored in the cadastral fabric, the surveyor will just require the information service for the area of the new survey. Additionally, the surveyor should be able to obtain the cadastre representation line work as the basis for the survey submission. The requirement to submit a 'survey plan' will also no longer be required. The descriptors will simply be attributes to the survey data. The use of the original survey information service will ensure the location of the survey is known and the submission will just be a revised version of the previous download. The LandXML transfer file is the first step in this direction. It is, however, a way to transfer the data contained on the current survey plan and has limitations. Over time, the LandXML format should be modified to make it more useful for the transfer of information, instead of replicating a survey plan digitally. Over time, this transfer method will be refined as the legislative requirements are changed to reflect the capability of the technology such as the Esri Parcel Editor.

The creation of standards relating to transfer of data between surveyors and the land agencies will lead to more consistent national survey standards of practice. In the past, the differences in regulations between the jurisdictions were often associated with the production of the survey plan. As the plan is replaced by the transfer of information, an opportunity exists to make this transfer nationally consistent.

5 THE TASMANIAN EXAMPLE

In 2008, Tasmania created the Tasmanian Spatial Information Council (TASSIC). The Honourable Gary Nairn was appointed the Chair, with the new council consisting of delegates from state government, local government, industry and academia (TASSIC, 2012). TASSIC was formed to maximise opportunities for government, industry and the community through the efficient and effective development, maintenance and use of the Tasmanian Spatial Data Infrastructure (TSDI). TASSIC was awarded project funding, and the Department of Primary Industries, Parks, Water and Environment (DPIPWE) was given the responsibility for the management of the Spatial Information Foundations (SIF).

SIF is a 2-year project to develop a contemporary platform for the management and distribution of spatial information across all tiers of government and the private sector and facilitate the improved use of spatial information for key priorities of the Tasmanian government. There are seven SIF projects in total, with five of these projects being well underway, and scheduled for delivery before 30 June 2013. Some of the projects are under review and their future is uncertain at this stage. The SIF program will improve the quality and timeliness of services and decision-making, especially in the areas of planning, economic development, policy development and emergency management. The SIF project is part of the Tasmanian government's ICT Strategy, and it supports the Economic Development Plan, strategies for planning reform and the SenseT (Sensing Tasmania) program.

This investment enhances the technological framework of the Land Information System Tasmania (LIST), which was developed in the 1990s (Tasmanian Government, 2009). Key anticipated outcomes of the project include:

- A new web interface for the LIST – for improved access to a wider range of spatial information.
- A web-based spatial data and services directory – providing improved discoverability of spatial data and services for use, analysis and reuse by more users.
- High speed image servers – with rapid delivery of remotely sensed imagery through LISTmap and web services.
- A data management and delivery system for planning data – providing new web-based capabilities for the visualisation and spatial integration of planning information.
- An address validation service – for automatic verification and more efficient management of address information within government agencies.
- A web-based spatial data delivery service – providing new capabilities for downloading and delivering spatial data.
- A web-based, emergency services Common Operating Picture (COP) for Tasmania – providing emergency management organisations with an authoritative, shared view of critical emergency and incident information.
- A new Tasmanian land parcel and property boundary database (numeric cadastre) – an enhanced cadastral dataset that is able to maintain boundary alignment with core administrative data, e.g. planning zones.
- A sustainable strategy for the ongoing acquisition and delivery of remotely sensed imagery for Tasmania – allowing the detection of changes in natural and built assets over time.

At the heart of the SIF is the NCDB project, which is a fundamental component to all the other projects within the SIF. The aim of the NCDB project is to create a framework for the spatial improvement of the Tasmanian cadastre. The Tasmanian government released a Request For Tender (RFT) in May 2012 and a consortium of Esri Australia, Geodata Australia and Applied Land Systems was the successful tenderer.

Since August 2012, the Esri Australia NCDB team has been working to create the framework for the NCDB using the capability of the Parcel Editor technology within the ArcGIS for

Desktop product suite. This capability has its origins in Australia and was created by Geodata Australia. In 2008, Esri acquired the capability and in 2010 it was embedded with the core ArcGIS product suite.

The Esri Parcel Editor technology is designed to import the survey measurements from the latest survey plan for a parcel or an area into a cadastral database, called the Parcel Fabric. The 'lines' of the parcels are linked to form the fabric. The fabric must be located accurately in location and the geodetic network of survey marks and the connection between the parcel corners and these marks are added to the fabric. The technology – through its adjustment engine – provides residuals for the differences between the location of the parcel corners from the fabric and the location of the same corner from the survey mark connection. It allows gross errors to be detected and removed and an adjustment is performed to create a new set of coordinates for each parcel corner. The important aspect of this adjustment is that the survey measurements are not changed but retained.

Throughout the import process, the attributes are associated with the appropriate parcels. The adjustment does not impact these associations and the attributes do not need to be reassociated with their parcel. The parcel fabric is able to be exported for GIS users to use as their base layer. The difference is that the parcel fabric is now aligned to real coordinates and can be adjusted as changes to the fabric are made.

The Esri Australia NCDB project team has been undertaking the following activities as part of phase 1 of the project:

- Modification of the Cadastral Data Model to fit the Parcel Editor Data Model.
- Loading the pilot area data into a database.
- Resolving topology issues, e.g. overlapping polygons.
- Loading of natural boundaries and ensuring they align appropriately with surveyed boundaries.
- Loading of easement and other encumbrances on the parcels.
- Ensuring administrative boundaries are aligned with the parcel boundaries.
- Ensuring attribute data are loaded and linked to the appropriate parcel boundaries.

Phase 1 is focused on a pilot area located at Launceston, with a total number of approximately 40,000 parcels. At the time of writing, the project team are about to visit Tasmania to conduct a week of User Acceptance Testing (UAT) on the work completed in the pilot area.

6 THE FUTURE

Currently, South Australia, NSW and the Northern Territory are moving closer towards working within the framework of the NCDB, and are all using some variation or version of the original Geodata Australia product called GeoCadastre or the Esri Parcel Editor technology. Victoria has produced a business case for consideration by the Victorian government to move in this direction. Queensland is about to begin writing a business case to seek funding to start a spatial improvement of their DCDB. Western Australia is keeping a watching brief on the other projects in progress around the country. They will consider their options in approximately two years.

One of the big changes to the Australian positioning environment that will impact these projects is the move towards a dynamic datum of Australia. This will have significant benefit to the users of the system as it will future-proof the cadastral fabric for the best part of the next decade. With the speed of change in technology, this is a significant achievement.

7 CONCLUDING REMARKS

The cadastral fabric remains one of the most important spatial information services our profession produces for the benefit of the community and the Australian economy. As technology changes, the methods used for maintaining, updating and upgrading this vital information service also need to change. The community is hungry for information that is accurate, current, and available in real time and from a range of devices. The information age is gaining momentum and our profession is expected to keep up. Advances in technology offers land administration agencies within Australia and around the globe the ability to produce an information service that will be relevant not only today, but well into the future.

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