The New Technology of a Survey Data Model and Cadastral Fabric as the Foundation for a Future Land Administration System.

Ian HARPER, Australia

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SUMMARY

Accurate spatial definition and managing land objects or any other recognised usage, legal or social right affecting land is the foundation of an efficient Land Administration System. Creating those systems is the aim of developing countries and improving the efficiencies of existing systems is the aim of developed countries.

This presentation outlines how new survey data management technology builds a model of survey measurement geometry to represent the cadastre at a level of precision directly related to the source data.That survey measurement geometry model is then adjusted to fit a geodetic reference system to provide a spatially accurate, continuous 'cadastral fabric' model as the foundation for property and asset administration and governance.

Data sources can vary from migrating existing digitised databases as a starting fabric to utilising considerable rigour to check and validate survey data when appropriate for the highest levels of precision. Once the base cadastral fabric is built, upgrading is efficient and as more accurate field survey data is utilised in the up-grade, the spatial accuracy of the database is increased.

Importantly, all the original survey measurement data and historical cadastral parcels are stored in the geodatabase as part of the Land Administration System for titling history.

The process manages the transition from historical measurement based title systems created for the measurement technologies of the past to a position based title system to deliver the efficiencies provided by GPS and other technologies through to the coordinated cadastres of the future.

The technical outcomes of the process also underpin the vision that was outlined in the FIG CADASTRE 2014 Document for a future ISO Standard for land administration.

As the process manages measurement and spatial data it is applicable to any measurement or coordinated title jurisdiction.

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CONTENTS

1 THE NEW TECHNOLOGY COMPONENTS

1.1 The Survey Data Model

A model of survey and other measurement data is created and adjusted to fit a geodetic reference system to build a spatially accurate 'cadastral fabric' database as the foundation for property title and asset administration.

1.2 The Cadastral Fabric

The Cadastral Fabric is a continuous model of land objects (parcels) that provides an electronic representation of the legal cadastre.

The Survey Data Model and the adjustment process utilise the same survey rules that are applied by Registered Surveyors to define real world cadastral boundaries.

1.3 A Survey Accurate Cadastral Model

A 'survey accurate' cadastral model is one where all available (new and old) survey measurement data is utilised and considered in the adjustment on the basis of its spatial quality in line with recognised Torrens Title protocols.

It provides the most accurate model solution without physically going into the field to resurvey those boundaries and has no legal status.

2 THE CADASTRAL SURVEY DATA FABRIC MODEL

2.1 Features

2.1.1 The GeoCadastre/Cadastral Editor process is able to import and utilise all types of measurement data:

- Accurate field survey data
- Other survey data – tape measurements etc
- GPS
- Geodetic survey control coordinates
- Electronic survey co-ordinate geometry data
- Existing cadastral GIS databases
- Historical village or regional hard copy cadastral area maps
- Existing survey/title records

2.1.2 The accuracy of the model is dependent on the spatial quality of data imported

- The fabric accuracy is directly related to the precision of the survey data entered

- If modern survey data is entered, checked and managed in a rigorous process, the expected accuracy urban areas would be 20mm

2.1.3 The database retains original survey or title document records and details of historical parcels:

- Stored in the Geodatabase
- Important for legal background

2.1.4 The cadastral attributes can be identified and added at data entry stage or imported via 'intelligent' XML cadastral modelling data structure to be available for metadata or linked to Land Administration Models. This would include but not limited to:

- Unique parcel/plan identifiers
- Date of survey
- Surveyor's name
- Jurisdictional identifiers

2.1.5 Each stage of the GeoCadastre/ Cadastral Editor process is a rigorous process with various levels of data checking available.

2.1.6 The process includes the unique data feature of a line point which varies from a normal node point within a straight line. During the adjustment a node can introduce a small angle whilst the line point retains the straight line geometry either side of it.

2.1.7 The 'Parcel Joining' process:

- Can verify the precision of the geometry of a new survey if an existing accurate fabric model is available. (see 2.2.2 - NSW LPMA EPlan process)
- Forces the topology (spatial relationship) of the cadastre to eliminate gaps or overlaps between adjacent parcels.

2.1.8 The Least Squares Adjustment (LSA) process:

- benefits from as much survey measurement data as possible. This provides redundancies which increases the level of rigour in the outcome.
- is an iterative process
- will report on the increment of the adjustment
- will identify problems in existing survey information – i.e. Drafting errors, data entry errors.
- allows control points to be not held fixed, which allows the model to generate new coordinates to check against the true coordinates. This provides independent validation of the spatial precision of the survey geometry model.

2.1.8 The adjustment is optimal for less than 5000 parcels:

- The adjustment is managed 'in-house'.
- The boundary of a 'packet' of parcels is held fixed, the packet extracted, new data joined, the packet adjusted and returned to the fabric in the geodatabase.

- The affect on the database of a cadastral survey is usually localised, thus it is beneficial that the adjustment is able to manage that localised area easily.
- This allows the opportunity for regional agencies to locally manage the cadastral fabric with data they know and understand and provide a clean, accurate database back to provincial or national agencies.

2.2 Outcomes

2.2.1 GIS Databases and Land Administration Systems

- Efficiency in cadastral database management.
- Once the cadastral fabric is created, the database is easily updated and spatially improved.
- The survey rigour in the process provides the highest level of accuracy from the survey data available with many checks to validate the data.
- The process provides a tool to manage other data sets spatially dependent on the cadastral layer. If you alter the cadastral layer, you then can alter all the dependant layers to retain the original spatial relationship.

2.2.2 Surveyors

- An accurate survey data model becomes a legitimate tool for surveyors particularly as survey measurement data is used to populate the database.
- The cadastral fabric is used by surveyors in the field – in difficult areas, as survey marks are found, accurate control data is added to the model and the adjustment run in the field to provide an upgraded model to assist in locating other marks.
- The survey data model does not replace the surveyor for field boundary definition unless it is legislated that the survey database will be the prima facia evidence to locate a boundary (e.g. Northern Territory).

2.2.3 A Spatial Tool.

- The NSW Land and Property Management Authority (LPMA) EPlan project has implemented the electronic lodgement of survey plans in a LandXML file format. As part of this strategy the LPMA is building a survey database model using the GC/CE process which will facilitate the checking of the accuracy of survey plans lodged as one of the many automatic checks undertaken as part of the EPlan lodgement process - this will provide considerable cost savings and other efficiencies. (See Sec 5.2 for the business outcomes achieved)

3 FIG CADASTRE 2014 DATA MODEL VISION

The **'ArcGIS Cadastre 2014 Data Model Vision' (Kaufmann)** document was released in 2004 and comments on the major components of the Cadastre 2014 document and the outcomes expected.

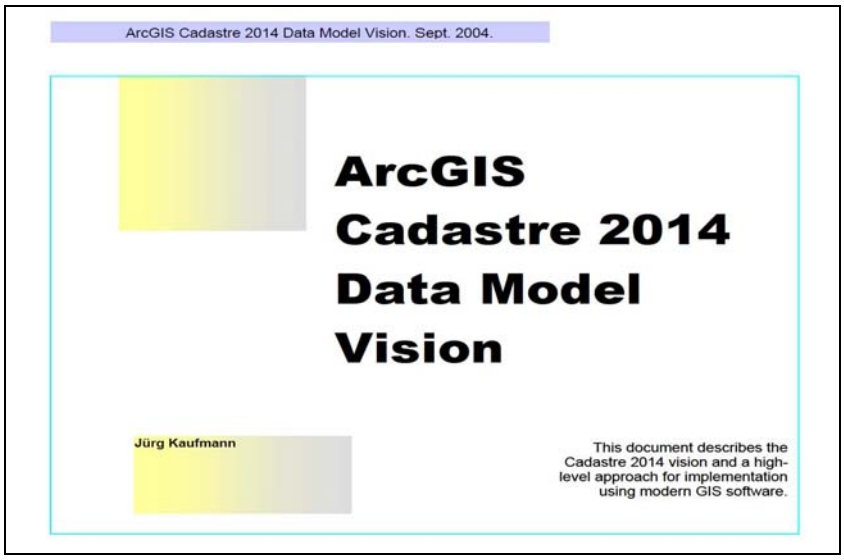

Diagram 1 – A report on the vision of Cadastre 2014 from 2004

Remarkably, the vision that was identified is now close to reality.

Technology has produced the tools that deliver the technical outcomes identified in the vision. The underlying component is accurate and efficient definition of objects to represent all the spatial components of a Land Administration System with an asset management system an integral part. This basic spatial component applies, irrespective of existing or current political, social or religious edicts.

Those technical outcomes also facilitate the future governance issues identified in the vision.

CADASTRE 2014 is a standard that is built on spatially defining real world property objects and then defining the many types of relationships between those objects and people.

3.1 Statement 1 – "Cadastre 2014 will show the complete legal situation of land."

- All public and private rights must be defined to avoid conflict – accuracy in the model is beneficial

"Consequences – A new thematic model is necessary. Surveyors must take into consideration public law."

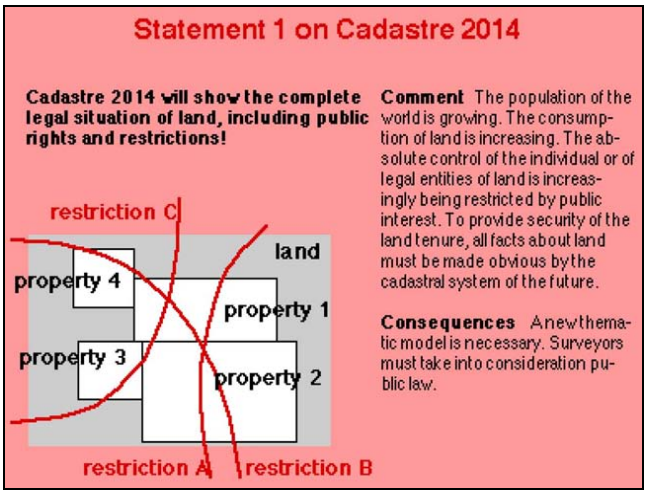

Diagram 2 – Documentation of the legal situation of land

3.2 Statement 2 – "The separation between 'maps' and 'registers' will be abolished."

- Electronic technology will change existing workflows between spatial representations and registers of interests."

"Consequences - The division of responsibilities between surveyor and solicitor in the domain of cadastre will be seriously changed."

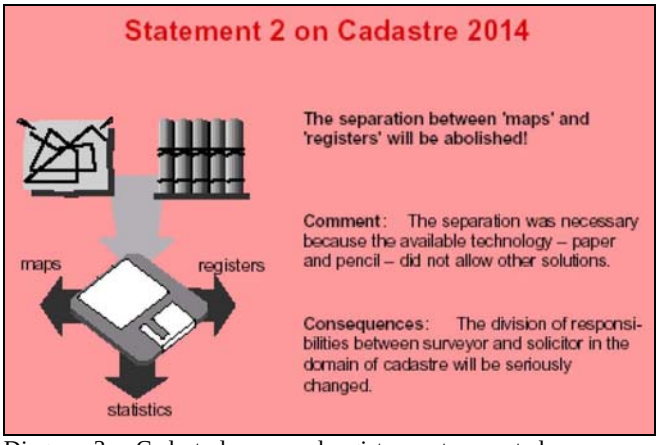

Diagram 3 – Cadastral maps and registers not separated

3.3 Statement 3 – The Cadastral mapping will be dead! Long live modelling

- In CADASTRE 2014 Cadastral Modelling will be the basic tool defining spatial objects.

"Consequences – In 2014 there will be no draftsman and cartographers in the domain of cadastre."

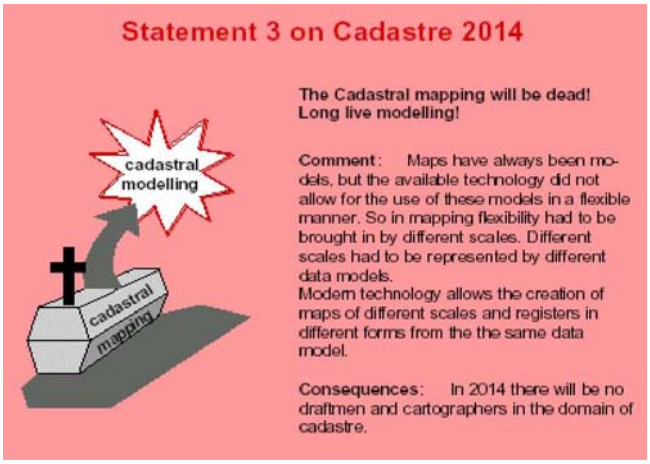

Diagram 4 – Cadastral modelling is most important

3.4 Statement 4 – 'Paper and pencil' – cadastre will have gone

- In CADASTRE 2014 all object and subject data will be stored electronically.

"**Consequences – The modern cadastre has to provide the basic data model. Surveyors all over the world must be able to think in models and to apply modern technology to handle such models.**"

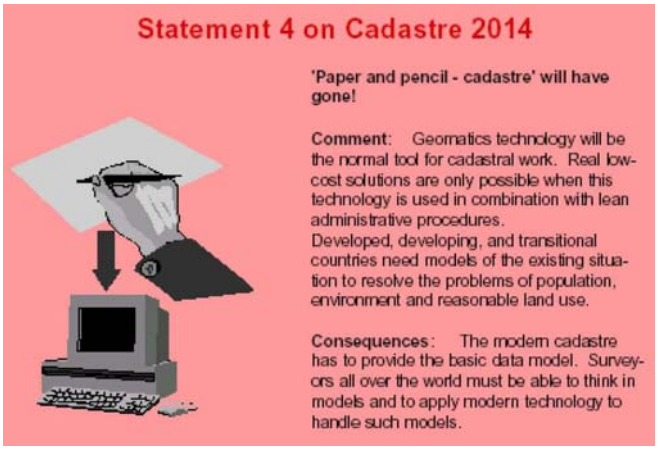

Diagram 5 – "Paper and Pencil" cadastre will have gone

3.5 Statement 5 – "Cadastre 2014 will be highly privatised! Public and private sector are working closely together!"

"Consequences – The private sector will gain in importance. The public sector will concentrate on supervision and control."

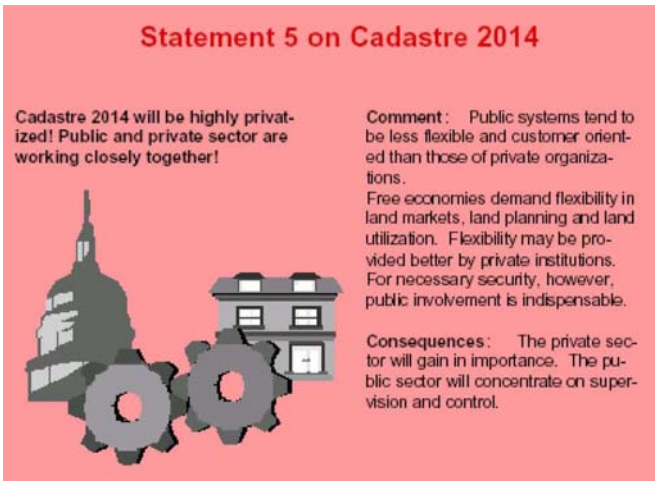

Diagram 6 – Public and private sector working closely together

3.6 Statement 6 – "Cadastre 2014 will be cost recovering!"

-The CADASTRE 2014 model must be economically sustainable.

"Consequences – Cost benefit analysis will be a very important aspect of cadastre reform and implementation. Surveyors will have to deal more with economic questions in future."

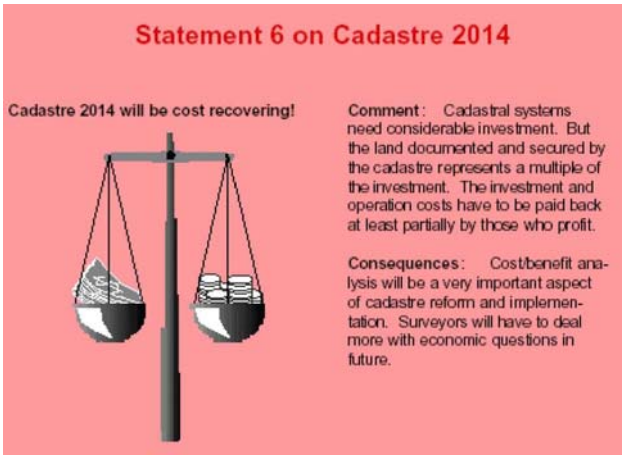

Diagram 7 – Cadastre 2014 will be cost recovering

The conclusion of the vision document notes that "**The important work in CADASTRE 2014 is to identify legal land objects".**

The CADASTRE 2014 Land Administration Model provides a universal framework applicable to any jurisdiction, but just as important to the model is the supporting infrastructure.

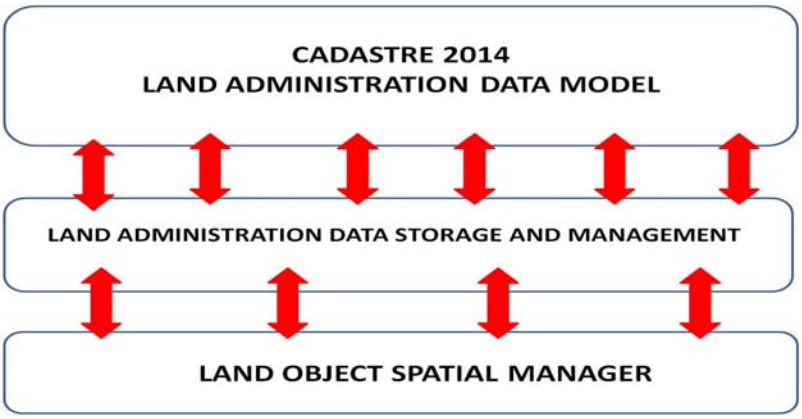

Diagram 8 – The supporting structure for Cadastre 2014

For the greatest efficiencies the database structure must incorporate a Land Object Spatial Manager that provides the highest precision for administration and operational purposes.

4 APPLICATION OF THE PROCESS - VIETNAM

4.1 Existing land administration issues

There are many levels of governance and other issues to consider in the creation of the Land Administration Model for Vietnam. They include but are not limited to:

- General Department for Land Administration
- Ministry of Construction
- State-owned land
- State-owned enterprise
- -1998 Land Law
- People Committees
- Land transfers
- -State land management
- Un-allotted State land,
- Socialist Economic Theory
- Land Brokers
- Urban & Rural land valuation
- Land Title Certification
- Foreign ownership rights
- Occupancy rights
- Usage rights
- commercial leases
- Tenure period

Most importantly, the spatial component of those issues must be defined as effectively as possible.

4.2 Spatial Land Administration Data Model Workflow.

The workflow Stages of spatial and cadastral data include:

4.2.1 Data Collection

- Digitised area maps
  Whilst these area maps may be spatially poor, the cadastral relationships are recognizable by all parties. Even an illiterate land user would recognise their parcel shape by the relationship to adjoining owners or physical features. These maps would contain the required cadastral intelligence and would be valuable to allow a functioning Land Administration System to operate immediately.
- Field survey data
  -Tape measurements
  -Total Station
  -GPS

4.2.2 Survey data interpretation, computations, parcel creation and fabric creation.

Survey data can be collected in various forms, however it must be presented in a database format, so that the spatial component, which is the focus of the surveyor can be combined with the cadastral intelligence required for a Land Administration System.

However cadastral data is represented, the essential elements are some form of spatial definition of a parcel shape (coordinates or measurements) and a unique parcel identifier. Those essential elements combined with a date or knowledge of the data accuracy is all that is required to begin working in a cadastral fabric environment in the geodatabase. Whatever other cadastral intelligence is available - plan number, areas, State, location, surveyor's name, date of survey etc, etc, can also be added for a more powerful database.

Some survey coordinate geometry software is capable of producing these intelligent database outcomes, otherwise the connection of spatial data and cadastral intelligence must be done through several software processes, which affects productivity.

4.2.3 Data Management and Storage

The Cadastral Editor process simplifies the electronic updating of large cadastral databases. It would be possible that a database for a locality or region can be updated and adjusted by the local operators. This has some advantage of allowing the people who collect and know the data to have input into the adjustment process to more easily recognise and overcome problems with the data. Once a section of the database is updated it can be forwarded as 'clean' data to the regional or national database register for efficient implementation.

The Geodatabase is the main storage component of the system. The benefits of Cadastral Editor operating inside the GEODATABASE include:

1. It holds the complete cadastral fabric database ranging from a small project to a State or Federal government database.
2. Allows only specified users access to amend the cadastral fabric.
3. Allows one person at a time to amend a specific 'packet' of cadastral data

4.2.4 Data usage in Land Administration Model

The effectiveness of the Land Administration Data Model relies on its ability to access and utilise the stored data and the linkages between that data.

The Vietnam Cadastral Database Spatial Workflow diagram.

The workflows must consider a variety of data sources and also a variety of software options to generate the cadastral fabric in the geodatabase. Once that data and its cadastral intelligence is prepared, it is stored in the Geodatabase. (See Diagram 9)

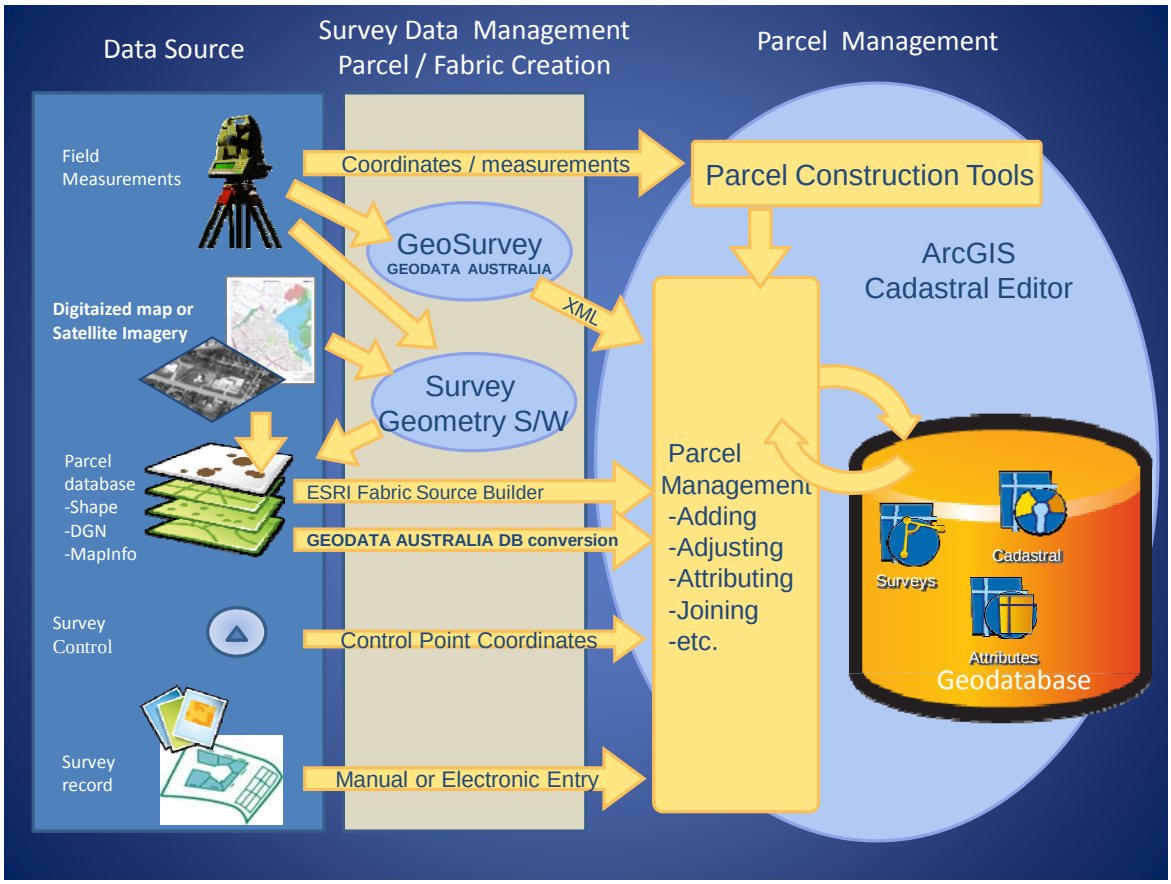

Diagram 9 – The Cadastral database workflows

The Geodatabase then becomes the working data silo for the Land Administration System (LAS)

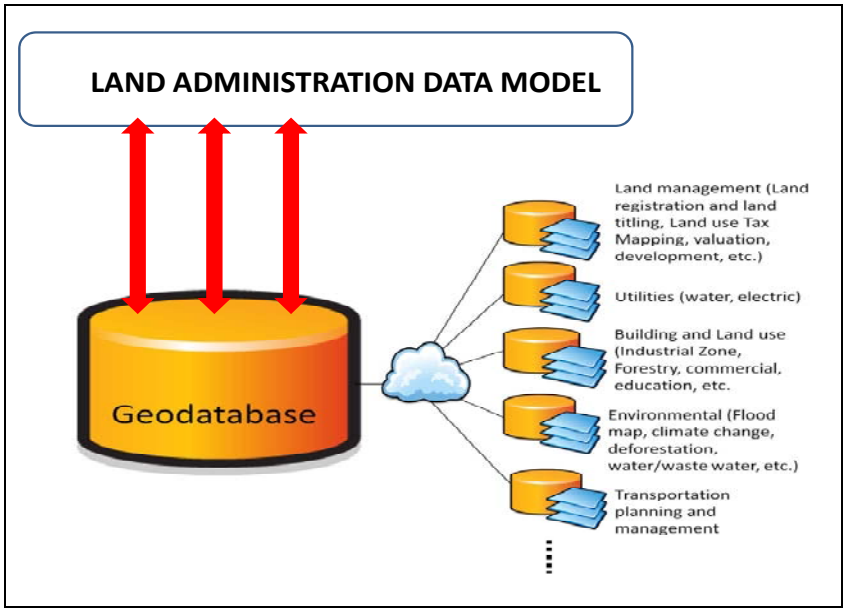

Diagram 10 – The Geodatabase supporting The Land Administration Model

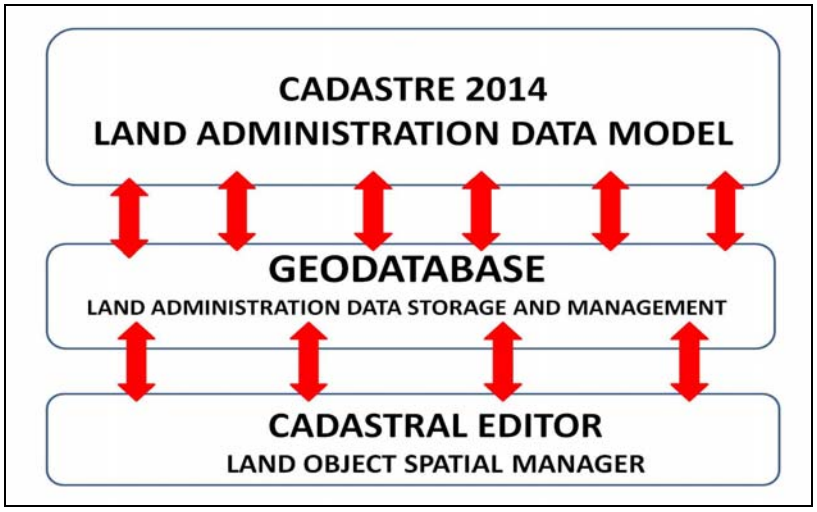

Diagram 11 – Cadastral Editor and the Geodatabase supporting The Land Administration Model

Very few jurisdictions have implemented a complete LAS, but most countries are planning and implementing their Land Administration Data Storage and Management and Land Object Spatial Manager. With the level of interoperability available, the tools are now available to build these components for future integration into the LAS.

An underlying key to efficiency and spatial interoperability is accuracy which begins at the cadastre.

5 THE BUSINESS CASE FOR A SURVEY ACCURATE CADASTRE

The value of accuracy in a cadastral database is not easily quantified. Some measure can be defined by comparing the operations and efficiency levels of spatially poor cadastres with accurate cadastres.

5.1 The Economics of a Spatially Poor Cadastral Database

- **Duplication of resources at various levels of government and utilities.**
  Where existing databases are not of reasonable spatial quality, many users commit resources to creating and maintaining other in-house cadastral databases to meet their needs.
- **Project Cadastral Databases**
  Accurate databases are being compiled for small and large infrastructure projects without the opportunity to contribute that quality work to a greater database
- **Interoperability**
  A large part of the current maintenance processes in a GIS is in the cleaning up the polygons and realigning all the layers each time that a change is made to the base layer. There may be connectivity between data sets in different organisations, but from a GIS point of view, the benefit is limited if the different data sets do not line up.
- **Other Data Sets Spatially Dependent on the Cadastral Layer**
  In a GIS, matching is done by position, and a typical local government system may have fifty or so data sets which are dependent on the cadastral base. Services may have been located in the field with respect to boundary fence lines and these in turn will be stored in the GIS with respect to the DCDB boundaries. If you alter the base layer, you have to alter all the dependant layers as well so that they match the positional changes for polygons and boundaries in the base layer.

5.2 The economics of an accurate Cadastral Database

- **Efficiency in:**
  - Database Management
    - No duplication of resources in database creation
    - Interoperability
    - Data export
    - Managing spatially dependent layers – generally not an issue with a survey accurate cadastre
  - Operations – spatial precision will allow reduction in the areas of influence of maintenance etc and accordingly disruptions to external issues (traffic etc) and times to complete works.

- **A Spatial Tool**
  A cadastre of high spatial quality allows comparisons of data for assessment and better decision making.

The NSW LPMA EPlan digital lodgement and checking process will introduce considerable efficiencies and departmental cost reductions including:

- On-line self checking by surveyors prior to lodgement will considerably reduce errors in plans and time taken for plan registration appraisal.
- Automation of manual plan checking will assist staff and reduce time and costs
- Reduction in plan checking staff resource needs
- Less experienced plan checking staff can take on greater workloads and assist in throughput as the process quickly identifies complying plans.
- Reduction in processing times for projects at a critical time when maximum funding has been expended
- Immediate population of all cadastral intelligence into Land Administration databases

- **Risk Management Benefits**
  - Accuracy in the cadastre allows certainty in spatial definition resulting in refinement of safety factors
  - Critical infrastructure (optic fibre etc) can be defined with certainty and assist the provider considerably with resolution of liability issues when problems arise
- **Higher Levels of Governance**
  - Accuracy in the cadastre allows certainty in spatial definition of all levels of governance boundaries (eg. planning & environmental zones)

5.3 Conclusion

Whilst the highest returning business case is the building of cadastral databases from all the original measurement data, technology exists to create a cadastral fabric database by migrating cadastres from existing databases. This retains the existing level of spatial quality but provides a high level of efficiency to work towards increasing cadastral accuracy. It does not provide a complete or truly effective database for reasons including:

- the true title dimensions are not stored as attributes
- historical parcels are not available
- initial spatial uncertainty
- does not contain all survey cadastral intelligence

Governments will immediately benefit from a "survey accurate" cadastre, rather than working towards one and benefiting in the future. The Continuously Operating Reference Station (CORS) network provides much easier access to cm accuracy and provides the strongest case for the most accurate cadastral database.

The more accurate a cadastral model is, the more effective it becomes, eventually providing title definition. Thus, a complete and accurate cadastre based on survey records should be the desired outcome for all jurisdictions. It should be maintained by the Titles office and can contribute to the checking and charting process for new plans and be a reliable foundation for all aspects of governance in a Land Administration System.

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Gail SWAN - Program Development Manager, EPlan, NSW Land and Property Management Authority

BIOGRAPHICAL NOTES

Ian HARPER – Bachelor of Surveying UNSW (1977)

- 25 years experience as a managing cadastral surveyor in a private consulting company
- 5 years consulting in survey and cadastral database management

CONTACTS

Ian HARPER
GEODATA AUSTRALIA
PO Box 2285
East Maitland NSW 2323
AUSTRALIA
Tel. +61 (0) 412453170
Email: harper@ geodata.com.au
Web site: www.geodata.com.au