

Survey Accurate GIS Cadastre - County and Service Authority Case Studies

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ABSTRACT

Key words: GIS, numeric cadastre, survey accurate cadastral fabric

The case studies in this paper utilise the 'GeoCadastre' process. This paper outlines their needs, operations and benefits.

Gloucester is a rural County located in rugged terrain with areas of old survey Title plats with limited survey information. The County Office has created a digital Cadastral fabric for GIS operational purposes. Areas of poor survey integrity can now be easily upgraded as need and budgets allow.

Gosford is an urban County undergoing considerable growth. The pressure of development on the County has highlighted their need for a spatially accurate GIS database.

Hunter Water Corporation is a major infrastructure provider that must have spatial integrity in relation to their (underground) assets for maintenance, economic and legal requirements. Contractors must supply correctly formatted digital cadastre as a condition of works approval. Their expertise has allowed the development of a business subsidiary, maintaining survey accurate cadastral databases.

The issues discussed are universal and the skills of the cadastral surveyor must be a part of resolving some the problems, if it is to be done effectively. The opportunities must be recognised for the future of the profession.

SURVEY ACCURATE PARCEL NETWORKS AS THE BASE LAYER FOR ENHANCED GIS

Background and directions for the future with case studies of various levels of progressive Governments and Utilities in Australia

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GIS CADASTRE BACKGROUND

In its formative years, (10 years ago) the need for the survey accurate Cadastral layer in GIS systems was not critical as most information in the databases was spatially 'pictorial'. Data was added to the GIS using screen graphics and was spatially referenced to the existing database information. Any spatial integrity of new information was lost as it was positioned relative to features in the existing database. The closest thing to an adjustment was 'rubber sheeting'.

The core Limiting Factors have been the capacity of hardware and GIS systems to deal with geodetic coordinate systems. More powerful hardware and software has now expanded GIS capabilities. The spatial management of cadastral databases has been unable to keep pace with the improvement in spatial quality provided by GPS, photography and other data collection technologies.

Traditional methodologies of GIS systems involved the editing of **shapes** that would break the inherent topology and result in slivers or overlaps. Those systems also retained no historical data, which is relevant to survey boundary definition and legal issues affecting Titles. The new workflows in the Survey Analyst Cadastral Editor (GeoCadastre process) utilises a survey methodology where the geometry is defined by point and line attributes to produce a seamless fabric best describing the nature of a legal cadastre whilst also retaining all historical plats.

To overcome inaccurate cadastral base layers, different institutions who have overlapping areas of operations, have gone down their own internal paths. Each has looked to satisfy their own needs rather than identifying that each final product could also satisfy the needs for others. Unfortunately, the economic ramifications are considerable as each Survey/GIS department fights for funding to move towards a similar goal.

Also, as Institution staff are directed to follow 'Risk Management Assessment' protocols, poor quality GIS cadastres result in a hesitant approach to fully utilising a resource that management has invested considerable funds.

CREATION AND MAINTENANCE OF A SURVEY ACCURATE CADASTRAL BASE LAYER

CASE STUDIES

These case studies detail initiatives undertaken by a range of progressive Australian Government and Statutory Authorities:

- **Northern Territory (NT)** – A sparsely populated Territory looking towards Legal Parcel Coordinates
- **Hunter Water Corporation** - a major regional Service Authority with 20 years focus on cadastral integrity and now at the forefront of numeric cadastral fabric data management
- **Gosford City Council** – A historically rural Local Government Authority (LGA) undergoing significant urban growth.
- **Gloucester Shire Council**– a rural LGA embracing GIS technologies.

All of the above Institutions have had the same core issues with respect to the spatial quality of their GIS systems however they have recognised the value of this process and moved forward. Each was able to highlight some unique issues.

NORTHERN TERRITORY

The Northern Territory is building a coordinate based cadastre directly from survey data. This work is now well advanced, with the completed areas being built, installed and managed in an Oracle database. The objective is to utilise all of the “metes and bounds” data from existing cadastral survey plats to create a cadastral system which is appropriate for current and future surveying and data management technology.

As part of the software selection process, the NT Department of Planning and Infrastructure looked at boundary definition issues in great depth including field investigation of the practicality and effectiveness of the software solution. The software developed by Mimaka Pty Ltd (‘GeoCadastre’ process) is being utilised. The development team includes Michael Elfick who is a registered surveyor with wide ranging field experience.

The NT has enacted legislation to “legalise” the derived coordinates. As areas reach a required standard of accuracy they will be “proclaimed” and the coordinates will then become the primary evidence as to the location of parcel corners.

The NT has some unique problems because of its size and the types of survey data. Adjustments could include boundaries ranging from representing a step on a building wall in a town to a rural parcel boundary of 80 kilometres (50 miles) in length.

During the project, there has been close cooperation with local surveyors and the Department of Planning and Infrastructure and this has resulted in a practical, cost effective approach with strong emphasis on quality assurance for the final product. The logic and design of this overall system has now been incorporated by ESRI in the Survey Analyst Cadastral Fabric editor extension.

HUNTER WATER CORPORATION

Background

Hunter Water Corporation (HWC) is the water and wastewater service provider to the Lower Hunter region on the Central Coast of NSW. The area covers about 5,400 km² (2000 Square miles) and comprises 5 local government areas. Hunter Water Corporation serves a population of approximately 496,000 people on 209,000 properties. Their pipe network comprises 4,300 kilometres (2,700 miles) of water-main and 4,400 kilometres (2,750 miles) of sewer-main.

Hunter Water Australia Pty Limited (HWA) is a subsidiary company, wholly owned by HWC, which provides services in the fields of water, wastewater, storm-water and catchment management, environmental issues and spatial management, all of which rely heavily on asset mapping.

Historical

HWA has a long history of survey accurate cadastral mapping. In the 1970s and 1980s plastic film base sheets were prepared using data derived from field connections between the NSW Trigonometric network and cadastral marks shown on Survey Plats. Coordinates for each land parcel on a plan were generated using hand calculators and coordinates were then plotted in ink on the film base sheets.

The location of pipe nodes (manholes, stop valves, hydrants etc) were gathered by field survey methods and satisfactory agreement between the pipe network and the land cadastre was achieved. With the advent of computers and CAD in the mid 1980s hand drafting was largely superseded. The methods used for mapping in this period were essentially an adaptation of earlier techniques: bearings and distances were shown on survey plats and subsequently keyed into a coordinate geometry software package.

This approach had a major shortcoming: once the coordinates for parcel corners had been calculated, the underlying bearing and distance information, as well as the thought processes which led to particular choices for adjusting misfits between adjoining parcels, was lost.

In the early 1990s, the NSW Lands Department used Hunter Water's hardcopy film base sheets, the coordinate data held on computer and other hardcopy map sheets held by the Lands Department to create the Digital Cadastral Database (DCDB) for the Hunter Region. At this time Hunter Water commenced implementation of a GIS to record all of its underground pipe assets. The position of most of the pipe work was digitised from hard copy sheets and more recent digital field data was added to the dataset. The digital land cadastre generated and supplied by the NSW Lands Department revealed poor spatial accuracy between the pipe network and digitised parcel boundaries. Consequently, Hunter Water commenced its own program to accurately map the cadastre with the requirement to achieve a spatially accurate digital cadastre defined to "**the width of a backhoe bucket**" ~ **0.6m (2 ft)**.

In 1994, following earlier trials, Hunter Water adopted the **GeoCadastre** process for cadastral database mapping. The most important criterion driving Hunter Water's adoption of the software proved to be its superior survey based mathematical rigour, compared with alternative approaches such as spine traversing or infilling with coordinate geometry (COGO). The software weights survey plat information according to age and adjusts large parcel networks by least squares and coordinate variation methods to generate seamless parcel networks in accurate association with the pipe work infrastructure.

A further compelling reason for adopting this workflow was that it preserves the integrity of the original field survey locating the pipe network. As new accurate survey data is added to the original parcel information, the parcel fabric is regenerated and updated coordinates for the pipe assets are produced. This became critical in areas where land parcel mapping was poor, due to the age of the original survey plans, but could be incrementally improved as older lots were resurveyed as part of a subdivision or new, accurate parcel corner control point coordinates were generated using GPS field surveying techniques.

Once their cadastral database was a dynamic entity, HWA ensured upgrading was maintained as data became available. HWC imposed a condition that, when new water & sewer construction work is completed, **a spatially accurate electronic dataset of the asset and the cadastre is lodged with HWA by a Registered Surveyor**. The data is supplied in a specified format to ensure the cadastral fabric is updated quickly.

Hunter Water has now used this approach for over a decade. Each day Hunter Water adds data from approximately five new survey plans to the DCDB, equivalent to 3,500 new parcels per year. Maintenance and updating of the DCDB is achieved with a resource of 0.75 staff.

HWA Operations

The process for recording asset locations is simplified when the location data is collected by conventional survey or GPS measurements related to the Map Grid of Australia (MGA) rather than needing to be associated by survey to a boundary corner. The assets fit within easements and road and property boundaries, which also assists field repair crews needing to excavate pipelines.

HWA internally developed the GIS system known as SWIMS (Sewer & Water Information Management System) for their mapping needs. SWIMS comprises: a server with an Oracle database; PC workstations and Intergraph FRAMME software for maintaining and adding spatial data and attributes; Intergraph Projection Manager for maintaining the cadastral base; and Intergraph Web Map to allow intranet viewing and printing of the mapping data by all staff. The system is being maintained by a staff of four with surveying backgrounds.

The GIS has seven major layers of text attributed graphical information stored within the Oracle database. Those layers are:

- a cadastral layer which is a composite of Hunter Water survey accurate cadastral data, NSW DCDB, and Hunter Water digitised cadastral data;
- a watermain layer
- a sewermain layer
- a stormwater channel layer
- a contour layer
- a customer service point layer

- a layer of ortho-rectified imagery. Some areas also contain project based data such as wetland boundaries, soil maps and flood inundation boundaries.

Maintenance crews with field laptops, can view and print the current GIS data set, to quickly locate pipes or valves in an emergency. The GIS dataset on the laptops is upgraded weekly.

Outcomes

Considerable economies in operations include minimising database maintenance costs and field operations where the excavation of a 1 metre² (9 square feet) hole is required, compared to a 10 metre² (90 square feet) search hole which may necessitate road closures or other significant safety procedures. Hunter Water now provides:

- 'Dial Before You Dig' and other requests for location based data via an automated email and facsimile system linked to the GIS.
- Property water & sewer connection point plans, needed for due diligence for the transfer of land ownership, are sent electronically to solicitors.

Hunter Water's survey accurate cadastre is also now shared by Energy Australia (Australia's largest energy distributor).

The staff and management of HWA have developed considerable expertise in cadastral management over the last 20 years. Those skills are now used as part of a business unit consulting to other Councils and Authorities to create and manage survey accurate cadastral and other mapping datasets. Cadastral projects have included mapping and spatial upgrade projects in the Hunter Valley NSW, Townsville Queensland, Great Lakes NSW, Gloucester NSW, Coliban Water Victoria and Northern Midlands Council Tasmania.

GOSFORD CITY COUNCIL

Background

The Gosford LGA is generally a rural area undergoing significant urban, commercial and infrastructure growth as a bedroom suburb to the Sydney urban sprawl. The LGA population is approx 163,000 with approx 70,000 land parcels of which around 40,000 are urban and the remaining rural and the system is maintained by 2-4 corporate GIS staff. The existing DCDB was found to be out by 1-5 metres (3 -1 5 feet) in urban areas and up to 20 metres (60 feet) out in rural zones. In 2005, high resolution Aerial Photography was acquired and this highlighted the poor DCDB accuracy. Specifically, the waterfront boundary definition of the DCDB was visually and legally unacceptable for Council when dealing with planning issues relevant to multi-million dollar waterfront development.

Objectives

Council have sought to build up a survey accurate parcel fabric and improve data accuracy and integrity over time. This would reduce the current risk to Council in providing incorrect information based on data retained relative to the existing DCBD. It will also ensure GPS data collection in the field will marry with database Land Parcel boundaries

The Process

First stage of the program was to focus on critically important Coastal strip suburbs. Work was also done in conjunction with the NSW Lands Department who provided extra Survey control in Areas where it was lacking or of poor quality. Presently 4,500 parcels have been captured and adjusted with future capture subject to needs & funding

Benefits

In the completed areas Council have accurately aligned cadastre & photography. Engineering design layout (rotaries or roundabouts etc) is being completed in the office. Survey information collected by Council surveyors is now being added to the GIS. Previously, they saw no point in populating the GIS with 'work as executed' data due to the poor alignment with the cadastre.

GLOUCESTER LOCAL GOVERNMENT AREA

Background

The Gloucester LGA is a rural Council generally located in hilly/mountainous terrain, which includes part of the Barrington Tops World Heritage Rainforest and Wilderness areas. The total LGA population is over 4,900 with Gloucester Township containing over half (2600).

The Council has limited professional resources with a total of 20 administration staff, including 1 GIS operator and corresponding budget limitations. Council was aware of the poor quality of the existing DCDB and its detrimental effect on an operational GIS and there was no indication of improvement of that situation in the near future.

Objectives

Council aimed to capture and convert all historical and current parcels within the Gloucester LGA using GeoCadastral software. This created a complete seamless parcel fabric for the Gloucester LGA so that Council will have a framework to build a correct and survey accurate GIS. They also needed to determine the extent of discrepancies between the DCDB and the numeric cadastral database

The Process

The LGA was broken into 17 subregions and parcels and survey control entered into a subregion. Areas requiring extra Survey Control were highlighted by the software & GPS field work undertaken to add some extra control points to the fabric. The subregions were then adjusted and joined.

Project Issues

Many old Title plats (from late 1800's) were illegible in standard issue format. There were considerable cost implications to retrieve legible original documents from State Government archives. Also plats with limited or no survey information were encountered. Diagram 1.0 shows a sale plan with no survey information that was the only record of the subdivision and was subsequently nominated as the Title plat.

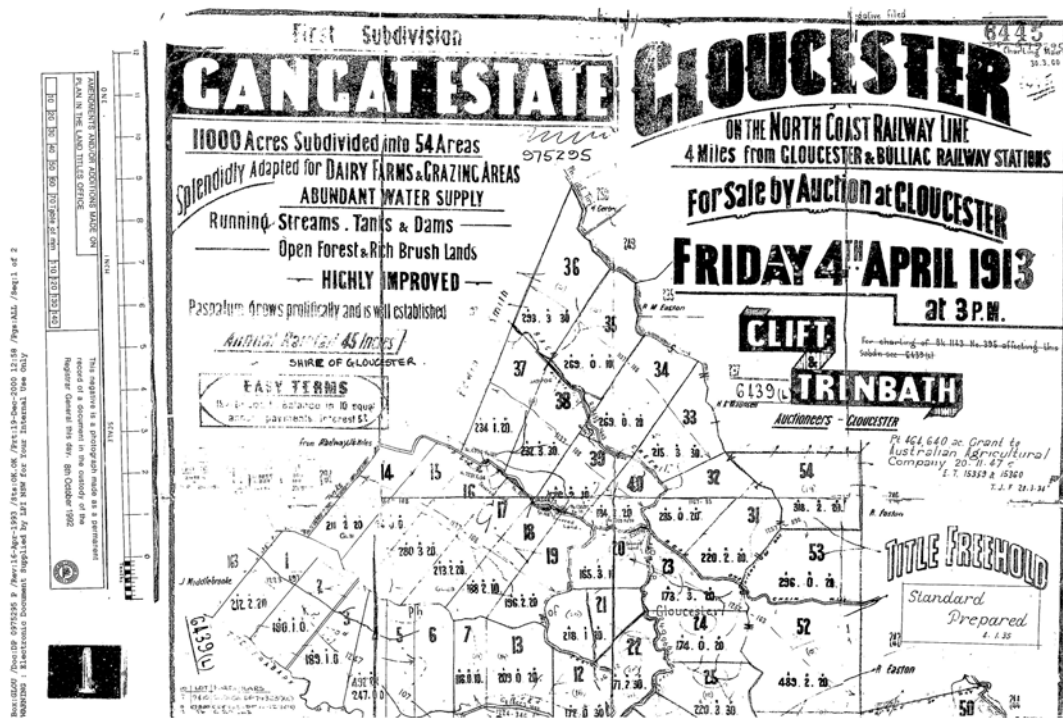


Diagram 1.0

The corners of these parcels were digitised and boundary dimensions created to provide a starting numeric cadastre. Also, in many plats, the boundaries along creeks were never surveyed, so the approximate lines of the creeks were digitised from the plat to provide a numeric approximation of boundary to complete the fabric.

Project Outcomes

A cadastre consisting of 4,264 historical & current parcels were captured and converted into a seamless parcel fabric for the Gloucester LGA. Attributes identified in the Cadastral dataset were:

- Lot number
- Associated Deposited Plan (DP) Number
- Date of survey for the associated DP
- Function of the lot (eg road, easement)
- Plan Area and Calculated Area for each Lot
- Misclose of each Lot
- Accuracy of each Lot
- Status-historical lot, compiled plan etc

Discrepancies of up to 50 metres (150 ft) were found between the DCDB and the numeric cadastre created and areas of poor survey integrity were identified and able to be upgraded as the need and budgets allow. Plans of any development work (Subdivisions, Building or infrastructure) now undertaken in the LGA are lodged with Council and are required to be spatially accurate (endorsed by Registered Surveyor) to ensure an efficient transition to the GIS.

THE DELIVERY OF A DYNAMIC SURVEY ACCURATE CADASTRAL SOLUTION TO GIS

The process of integrating the 'GeoCadastré' software into the ESRI suite of programs is part of a much wider initiative to bring together GIS & surveying worlds.

Historic Differences

GIS

- Coordinates are Integers
- Point defined by coordinates
- Topology important for object matching

Survey Calculation Software

- Coordinates are floating point numbers (higher accuracy)
- A point is an object with an ID or point number
- A coordinate is just one attribute of a point
- Points, lines and polygons are defined by point ID's

THE TECHNICAL CHALLENGES CONQUERED BY THE ESRI & GEODATA DEVELOPMENT ALLIANCE

It has been 2 years coming to this point. The reason for this was the need, for the first time ever, to design and deliver an architecture which created or migrated a parcel network fabric into the GIS database and then allowed an automatic adjustment and update of both survey points and GIS features without sacrificing the quality of the source data.

GeoData developed the fundamental computation engine, as currently used by the GeoCadastré software, into a core engine component that the ESRI development team now uses in the Survey Analyst – Cadastral Editor software. GeoData provided a solution and core concepts presented through the elegant workflow demonstrated in the GeoCadastré software that inspired the ESRI development team to emulate the same

principles in the new solution for the geodatabase.

Geodata and ESRI jointly defined a new XML transfer format, based on the GeoCadastral file format that allows a seamless communication of parcel data between the geodatabase and the computation engine. The development process has resulted in a new data model for parcels built within a geodatabase, that defines the primitives of a land information system, that many clients can expand on to incorporate their own specific needs, be they in Australia, Canada, the USA, and elsewhere.

ESRI developed a system that is completely integrated into the GeoDatabase, and developed the Cadastral Editor following the tried and tested ESRI user interface fundamentals that have proven enormously successful. ESRI developed the concepts and technology for leveraging the improvements in spatial accuracy of the parcel fabric into the other GIS layers that use the cadastral fabric as a base map. ESRI used a practical approach to using the multi-user geodatabase versioning environment for managing the GIS layer adjustment as well as the least squares adjustment of the cadastral fabric. All this was achieved despite the communication barriers imposed by different time zones, accents, and sporting interests.

THE FUTURE

Local Government Authorities and local Utilities are best placed to control the domain of creating and maintaining their own asset databases and directly appreciate the role that the GIS database plays in their operations.

Greater demands are being placed on GIS as its capabilities are recognised by people within & outside the hosting organisations.

Initially only surveyors and experienced GIS operators recognised the risks presented by an inaccurate cadastral layer. Information from the GIS is given, sent or downloaded to users who see a professionally presented plan and use it for a purpose it was not intended.

People at all levels of Institutions then become involved when a pipe, cable or building was constructed on the incorrect side of the boundary. The **real** economics of this type of scenario is rarely included in the business cases put forward.

Also the true economics of creating a survey accurate GIS cadastre relative to the ongoing costs in maintaining an existing poor quality should be recognised.

THE CHALLENGES TO STATE GOVERNMENT.

- Facilitate the creation of one quality Numeric Cadastral Database with uniform formats.
- Larger States should look to Local Government or other sources to manage the core cadastral data collection and provide upgrades to be incorporated in a timely manner.
- Support Local Governments with that creation – (Queensland provides councils with all survey documentation and information free of charge and assists with extra survey control)
- Ensure the source data (Title plats & survey control) is:
 - readily available (preferably by Web access)
 - legible
 - cost friendly
 - current

THE OPPORTUNITIES TO LOCAL GOVERNMENT.

- Provide the direction and infrastructure for the public and private sectors to contribute to the Cadastral Fabric by providing cost return or other incentives for sharing of information.
- Ability to facilitate and impose dataset collection as part of the Development process
- Understand the true cost benefits and efficiencies of a spatially accurate GIS at higher management

- levels within their organisation
- Look to work with other overlapping Institutions such that resources are not 'doubling up'

THE RELEVANCE TO THE SURVEY PROFESSION.

- Recognise the changing circumstances which require a shift of focus in individual and corporate practices with respect to CAD & GIS databases.
- Business opportunities supplying skills to database creation & maintenance
- Supply of 'local knowledge' and 'private' survey control and databases for a greater good
- Be prepared to provide electronic survey and cadastral data which has the ability to be easily integrated into existing numeric databases

The work of the Survey Profession creates the fundamental blocks for the foundations of GIS systems and they must recognise that the opportunity exists to control that foundation and to maintain their rightful future role of custodians of the Cadastre and its integrity.

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