APAS2016 CONFERENCE

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Proceedings of the

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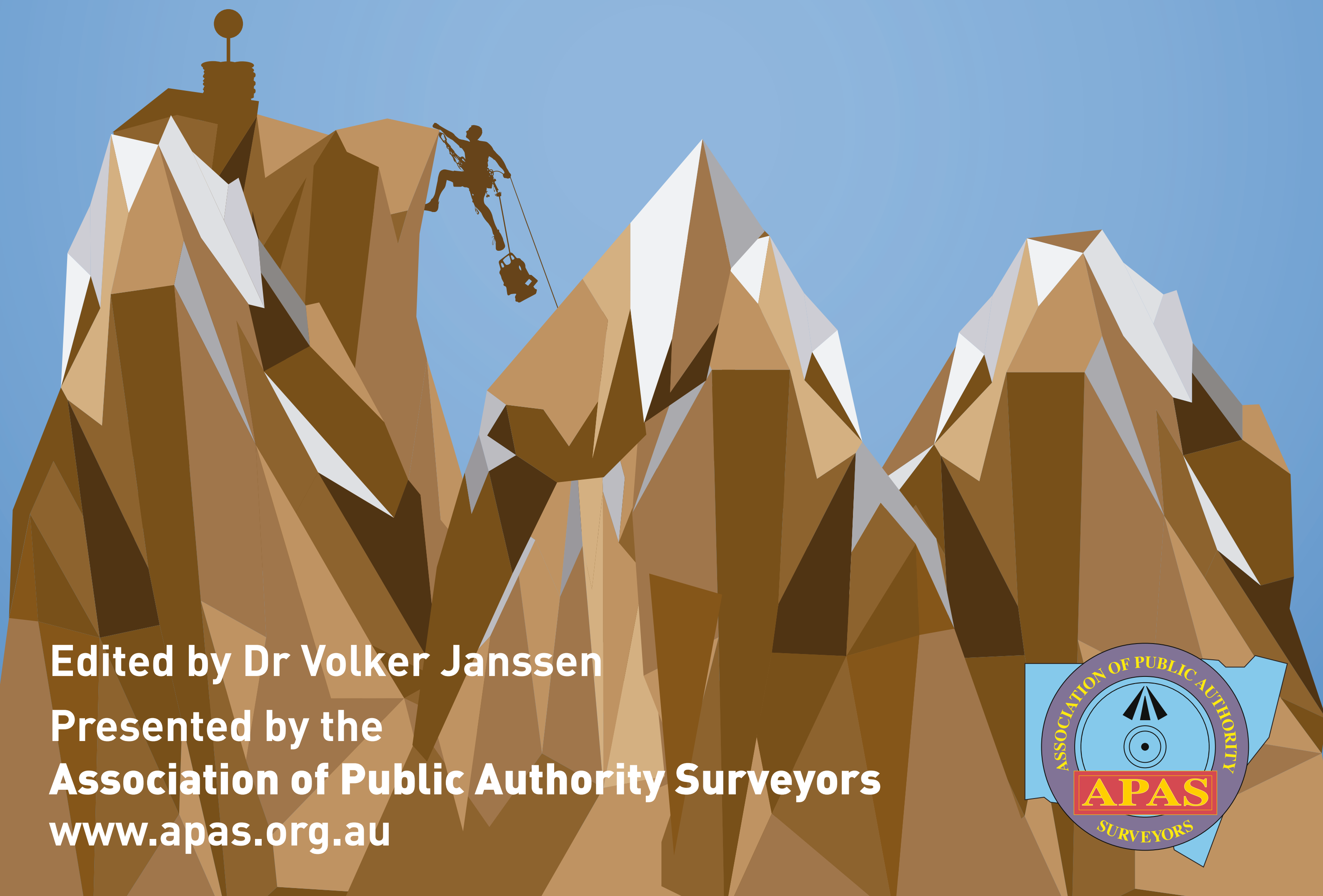

Edited by Dr Volker Janssen

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APAS

21th Annual Conference, Association of Public Authority Surveyors (NSW) Inc.

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Editorial

These proceedings contain the papers presented at the Association of Public Authority Surveyors Conference (APAS2016), held in Leura, NSW, Australia, on 4-6 April 2016. Papers were not peer-reviewed but have been subject to changes made by the Editor. The Editor would like to thank all authors for their contributions covering a wide range of topics relevant to the surveying and spatial information community, thus ensuring an exciting and informative conference.

Authors are welcome to make their paper, as it appears in these conference proceedings, available online on their personal and/or their institution's website, provided it is clearly stated that the paper was originally published in these proceedings. Papers should be referenced according to the following template:

Janssen V., Haasdyk J. and McElroy S. (2016) CORSnet-NSW: A success story, *Proceedings of Association of Public Authority Surveyors Conference (APAS2016)*, Leura, Australia, 4-6 April, 10-28.

NSW Land and Property Information (LPI) is gratefully acknowledged for providing the front cover artwork and producing these proceedings, and for sponsoring the conference in general. The APAS committee is thanked for their hard work in organising this conference.

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Aspiring Beyond UNSW: Connecting Students to Industry

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ABSTRACT

The recent BIS Schrapnel report commissioned by the Association of Consulting Surveyors highlighted the growing demand for graduate surveyors in New South Wales and across Australia. The former School of Surveying and Geospatial Engineering (SAGE) at the University of New South Wales (UNSW) was merged with the School of Civil and Environmental Engineering (CVEN) in 2013 and is now a group within the largest school at UNSW. The cohort of students studying surveying remains small, but the merger presents great opportunities for civil engineering students to be attracted into the surveying program. Because of the smaller class sizes, surveying students are exposed to many more hands-on exercises in the field and the lab as well as extracurricular activities in partnership with their own student society SurvSoc and the Institution of Surveyors NSW, Young Surveyors and Cumberland groups. All students are required to undertake at least 60 days of industrial training as part of their studies and some companies even suggest final year thesis projects to complete in partnership with academics at the School as a way of keeping bright students after graduation. UNSW was recently ranked 46th on the QS World University rankings with the School achieving a rank of 14 compared with other Civil schools globally. The ATAR score is the highest of any surveying program offered in Australia, which has the benefit of attracting the highest potential students into the programs. The school has recently purchased a suite of new GNSS receivers, a laser scanner, six UAVs, and an assortment of enabling software. All of these attributes provide fertile ground for a new generation of modern Surveying and Geospatial Engineering graduates. This paper details how these opportunities are being exploited and provides some examples of recent work conducted by our undergraduate students.

KEYWORDS: *UNSW, industry, students, industrial training, young surveyors*.

1 INTRODUCTION

Since its establishment in 1949 as the then University of Technology, the University of New South Wales (UNSW) has produced over 1,500 graduate surveyors (Loeffel, 2007). Many have gone on to become registered surveyors in NSW, directors of their own businesses, GIS professionals, leaders in government (local, state and federal) and influential academics. In recent times the landscape of higher education has evolved in Australia.

Universities are increasingly seeing the value in improving their international rankings to attract the best students (especially international students), the best staff and research funding. The QS rankings (QS, 2016) compare the world's top 800 universities using indicators such as academic and employer reputation, staff-student ratios, research citations and the proportion of international staff and students. As a university, UNSW ranks 46th in the world in the 2015-16 league table (up two places from last year). UNSW enjoys an enviable

employer reputation, ranking 22nd in the world, and 42nd for academic reputation. In the 'Engineering and Technology' category (where Surveying and Geospatial Engineering, SAGE, resides), UNSW Engineering has further strengthened its position to 21st (up 6 places) in the 2015/2016 QS World University Rankings.

These rankings bring prestige to the institution, but it should be noted that rankings are highly valued by international students deciding where to study. Domestic students will tend to study at their local university and not travel, however marketing at the Faculty of Engineering is increasingly trading on rankings for domestic students as well.

This change in landscape can be of great benefit to the surveying profession if members are willing to embrace this new paradigm. For surveying graduates from UNSW, their stocks are rising which could have extra value if working overseas, especially when dealing with international graduates from UNSW. Given this background, this paper seeks to offer suggestions on how the surveying profession can better engage with UNSW staff and students to exploit the combination of a high ranking institution, students with high potential and the many new geospatial technologies that can open new applications requiring SAGE expertise.

2 ENGAGING WITH STUDENTS

2.1 The School of CVEN

The merger of the former School of Surveying and Geospatial Engineering (SAGE) with the School of Civil and Environmental Engineering (CVEN) in 2013 presents many opportunities. CVEN is the largest school in the University, currently with over 2,500 students and staff. All year cohorts of the undergraduate Civil Engineering degree program comprise 300-400 students compared with around 15 undergraduate Surveying students per year.

Since joining the new school, the Bachelor of Engineering BE (Surveying) and BE (Geospatial) programs have been streamlined to better align with the BE (Civil) program. These new streamlined courses began in 2015 for both first and second year students. During this process, 12 core SAGE courses were identified as necessary to qualify graduates as potential candidates for registration in NSW as land or mining surveyors and/or to be well prepared as future geospatial engineers. Additionally some of the common CVEN core courses were chosen to support the registration requirements such as water engineering, transport and highway engineering and project management. The great advantage of this new streamlined course is that it enables CVEN students considering changing into SAGE an easier transition.

Further to this new streamlined BE (Surveying), a new dual award program in Civil and Surveying has been approved and will be offered in 2016. This will be a BE (Civil) / Bachelor of Surveying (CVEN, 2016a) and will require 5 years for completion. Graduates of this new program will be accredited as civil engineers by Engineers Australia and the Board of Surveying and Spatial Information (BOSSI) NSW for registration as land or mining surveyors in NSW.

This dual award program was prepared prior to the UNSW Courses and Careers Day, 5 September 2015, and considerable interest was generated by students on this day. Academics

and office staff are receiving numerous enquiries from students within the School wishing to change programs to either the new streamlined BE (Surveying) program or the dual degree.

2.2 Industrial Training

An opportunity for the profession to assist with marketing these new course offerings is through industrial training. All students studying engineering are required to undertake 60 days of industrial training. Surveying students have never had a problem acquiring this work experience. However, due to the large numbers of students enrolled in Civil Engineering programs, it is often difficult for Civil students to find appropriate experience with over 2/3 reporting that they do not get paid for their work experience obligations. This presents a terrific opportunity for the surveying profession. Often Civil students have little knowledge of the tasks of a surveyor as they are no longer *required* to take a first-year elective surveying course. Nevertheless, members of the profession could offer surveying work experience over the summer to Surveying or Civil Engineering undergraduate students as a way of introducing them to the discipline of surveying. If they enjoy the work, it will be much easier for them to change courses at UNSW into the new streamlined courses.

2.3 Final Year Thesis Projects

Final year students are required to undertake a thesis project (also called an honours thesis), which comprises a total of around 300 hours work (2 x 6 unit of credit courses ≈ 150 hrs each). Usually academics devise thesis projects in their existing research area or in a new research area of their interest and place on the school intranet for students to choose. These topic areas are organised on the school intranet site under the following categories which mirror the various groupings within the School:

- Engineering and Construction Management.
- Environmental Engineering.
- Geotechnical Engineering.
- Structural Engineering.
- Transport Engineering.
- Water Engineering.
- Surveying and Geospatial Engineering.

Sometimes students with a particular interest may devise their own thesis project but they must find an academic willing to supervise their work. Also with the new dual program about to commence in 2016, there is even more scope for thesis projects that straddle a few discipline areas.

Final year thesis projects offer a great opportunity for industry engagement with the School. Surveyors (government or private) with a particular interest in a topic could devise a project in partnership with academics in the School and hopefully attract a bright student to undertake research into this topic at no cost. Academics can assist with writing the project (only about half a page) and place on the School's intranet site. It is best when a supervisor from the government or private organisation agrees to assist with the supervision. Perhaps a new piece of equipment or software has been purchased, or perhaps the organisation is already undergoing a task and would like to investigate an aspect of this but simply does not have time. A thesis student will have the time to devote to a project and, with some guidance, may discover interesting aspects about the project risk-free and at no cost.

Industry-style thesis projects are often favoured by students and present a great opportunity for better industry engagement between the profession and the School and could potentially provide a graduate student to the organisation. It should be pointed out that SAGE academics also have access to Computer Science, Electrical Engineering and Mechanical Engineering students in case the topic of interest is outside of the discipline of Surveying or on the fringes of Geospatial Engineering. Members of the profession are encouraged to correspond with academics in SAGE regarding their project ideas.

An example of a new project description is given here:

> *Georeferencing in a Dynamic World*
>
> *How well is Google Earth georeferenced? Handheld GNSS gives about 5 m accuracy. The latest Google Earth (GE) images (using aerial photography) have a resolution of better than 10 cm for each pixel in the city. How well are these positions georeferenced on the ground? How does GE do it? Is it orthophoto standard? This project will investigate some areas within Sydney (and beyond where applicable) to determine the quality of georeferencing of the images. Further this project will have to contend with next-generation datums. GE uses WGS84. How are the images georeferenced at the epoch of capture? Australia moves NE at ~7 cm/yr. That is almost one pixel per year? What about other mapping applications on phones and other devices. How will they deal with next-generation datums if they can position in real time at the decimetre level?*

The outcome of this thesis project is not clear. The student will liaise with his/her supervisor as they learn more and the project will evolve. Often this is all that is required for a good thesis project description. A good idea with an achievable goal is all that is required for an interesting thesis project. However, not all projects are selected by students.

Some examples of recent student thesis projects include:

- Coordinated cadastre: Putting the puzzle back together.
- Performance testing of robotic total stations for real time tracking applications.
- Factors affecting quality of photogrammetric mapping with small unmanned air systems – *winner of EISSI University Student Prize 2015*.
- Computer vision-based traffic flow analysis.
- A modern multi-function map for Cataract Park.
- BeiDou performance within a multi-constellation continuously operating receiver system.

Since merging with the new School of CVEN, the SAGE group has been fortunate to purchase a range of new equipment including new Leica Viva GNSS now equipped to measure the Chinese BeiDou constellation, a Leica C5 laser scanner, a Trimble R1 sub-metre DGPS system and six UAVs across the School as well as a range of supporting and stand-alone software. All this equipment can be used for thesis projects and there is usually budget for minor purchases to support thesis research activities.

2.4 Awards

Student thesis projects are also eligible for the Excellence in Surveying and Spatial Information (EISSI) Awards, University Student Project prize category. If an organisation is associated with the award, they too receive some kudos (CVEN, 2016b). Alternatively, the thesis project could be rewritten as a conference paper such as Allerton et al. (2015), which won the best research paper award at the recent SSSI Locate'15 conference. Another example is Roberts and Boorer (2015), which has been published in the Journal of Spatial Science.

2.5 SurvSoc

The student society SurvSoc is a 'sandpit' for future leaders and contributors to the profession. SurvSoc has structure, with a committee comprising a president, vice president, treasurer, secretary, ARC delegate (on-campus societies), industry (ISNSW Cumberland group) and year representatives. They hold regular meetings with minutes and they organise events such as BBQs and sporting activities amongst themselves and with other student societies. Earlier this year, in association with ISNSW and especially the Young Surveyors group, SurvSoc held a small seminar with some invited speakers to learn about registration as a surveyor in NSW. All these activities are excellent training for their future professional careers and provide great opportunities for engagement with the wider industry. They must also negotiate a co-habitual arrangement with the larger Civil and Environmental Engineering society (CevSoc) within the same school (CVEN, 2016c).

3 WIDER INDUSTRY ENGAGEMENT

3.1 Research Partnerships

A further extension of a final year undergraduate student thesis project could be for a research partnership to commit funds and staff time towards a more ambitious research program. This is best done under the Australian Research Council (ARC). The ARC is an Australian Government Commonwealth entity. Its mission is to deliver policy and programmes that advance Australian research and innovation globally and benefit the community (ARC, 2016). The ARC offers a number of competitive grant schemes but perhaps the most appropriate is the ARC Linkage scheme. Linkage promotes national and international research partnerships between researchers and business, industry, community organisations and other publicly funded research agencies. Academics look for partnerships with such organisations and write an extensive research proposal detailing the intended research outcomes, budget and resources required. The best possible outcome could see a research partner receive $4 from the ARC for every $1 of cash they invest into the project. This money then funds either a scholarship for a PhD student (or several), or a post-doctoral researcher who will be dedicated to the project and some travel and equipment money to support the research. This is a major undertaking and there are no guarantees of receiving funding, however, in recent times UNSW has been one of the most successful institutions for ARC Linkage grant applications. Also it should be noted that unsuccessful but strong applications may receive internal university or faculty funding.

3.2 Industry Projects

Sometimes larger government organisations have ongoing projects which require manpower and do not necessarily have a definitive timeline. An example might be the Land and Property Information (LPI) update of survey control using AUSPOS or RTK updates of the Digital cadastral database (DCDB) in rural townships. With some creative thinking, perhaps there is scope for better partnerships between government and the university by devising a mutually beneficial student project that could undertake these ongoing tasks as part of an assessable course. Issues such as Work Health and Safety (WHS) and professional indemnity can be covered by the university. The quality of the data acquisition would have to be assured before it is used for public consumption.

3.3 Industry Partners Program

In order to assist with the funding of School based marketing activities, the Industry Partners Program (CVEN, 2016d) was set up to request sponsorship from civil engineering and now surveying companies. This money is used to support such activities as the annual 'bus tour' whereby 60 students from 60 different high schools come to the campus for a week of work experience at UNSW. This program was devised as companies complained that due to WHS, child protection and public liability regulations, it was very difficult for them to offer work experience to high school students. Academics from the School run activities in partnership with companies to offer work experience activities to students which doubles as marketing. Monies are also used to produce marketing material and a range of other activities run by the School.

For their support, industry partners receive access to the top students, preference for job listings, invitations to the elite student's breakfast, careers market, promotion of the company logo within the School, opportunities to attend industry/academic forums and sponsorship of the annual 4th year prize. Some companies who are industry partners can leverage this further to present guest lectures to students or even part-fund an academic position and receive academic advice on their own research and development strategies.

4 CONCLUDING REMARKS

There is some concern in the NSW Surveying profession that UNSW graduates are not 'job ready' and cannot lead field parties from 'day one', but this is not the purpose of a UNSW qualification. The high ATAR, combined with a daily exposure to an intensive research culture, means that the School continually challenges undergraduate students with higher level activities and problems. Consequently, graduates should have a better capacity to advance rapidly in their profession and to adapt readily to take up management positions, leading to company/organisational directorship and business ownership. The profession will never be led by those who are content to remain unchallenged and stagnant as 100% field operatives in either Surveying or GIS whilst technology and the nation's demands on the profession leaves them behind (Roberts, 2013).

The UNSW Graduate Capabilities include: "Leaders who are enterprising, innovative and creative; capable of initiating as well as embracing change. Professionals who are capable of independent, self-directed practice; capable of lifelong learning." This is the goal to which SAGE staff aspire (UNSW, 2016).

The best students coming into this program have high expectations and graduate with ambition and self-confidence. They have been exposed to world-leading research during their degree, hence know that advances in technology will not only lift productivity, but will also create new business opportunities. They are ready to embrace change, not fear the future. They are looking for a career that challenges them, offers opportunities, and fulfils them. These graduates will most likely become future leaders. Educators and the wider industry in general must appreciate this and nurture them (Roberts, 2013).

UNSW offers a high-quality undergraduate education with an appropriate balance of prescribed and elective technical subject matter, management courses and communications training, and project-oriented learning. There is clear evidence that UNSW graduates do go on

to be leaders in industry and the profession.

It is hoped that this article will help readers appreciate the pressures on and the principles reflected in UNSW programs, and will actively support us in our quest to attract more high-quality students to aspire beyond UNSW.

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CORSnet-NSW: A Success Story

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ABSTRACT

The introduction and expansion of Global Navigation Satellite System (GNSS) Continuously Operating Reference Station (CORS) networks across Australia and internationally has greatly improved access to positioning infrastructure for a wide range of GNSS applications and related research. Within only five years, CORSnet-NSW has matured into a world-class, state-wide, multi-function GNSS CORS network that balances public-good and commercial mandates. Now comprising 180 CORS, the network has revolutionised internal and external GNSS operations, not only supporting the surveying and spatial information profession but also making important contributions to national and regional geodesy. This paper outlines the success story of CORSnet-NSW, including its current status and the impact it has on providing first-class state infrastructure for GNSS users in New South Wales. The present difference between datum realisation via SCIMS and via CORSnet-NSW is explained, and efforts undertaken at LPI to rectify this situation by contributing to the modernisation of Australia's national datum are discussed. Finally, it is outlined how LPI supports the surveying profession and the wider spatial community in regards to GNSS. The State's CORS infrastructure has become crucial in catering for an increasing demand for accurate, reliable and easily accessible GNSS positioning information in today's society. In Australia, state jurisdictions provide the essential link between national initiatives and academia on the one hand and the profession on the other, e.g. via maintaining positioning infrastructure and conducting applied research that informs legislation and best practice guidelines.

KEYWORDS: *CORSnet-NSW, GNSS, CORS, positioning infrastructure, applied research.*

1 INTRODUCTION

Global Navigation Satellite System (GNSS) Continuously Operating Reference Station (CORS) networks have been introduced and recently expanded significantly across Australia and internationally to provide improved access to positioning infrastructure for a wide range of GNSS applications in areas such as surveying, mapping, asset management, precision agriculture, engineering and construction, airborne imaging and sensors, and utilities management. Real Time Kinematic (RTK) or Network RTK (NRTK) GNSS positioning

methods in particular, once initialised, provide high-precision coordinates and allow 'real-world digitising' with the ability to significantly enhance productivity. For example, CORS networks are well-suited to support improving cadastral infrastructure with RTK GNSS techniques (Janssen et al., 2011a), and NRTK produces superior coordinate results in regards to both precision and accuracy (e.g. Janssen, 2009c; Janssen and Haasdyk, 2011).

GNSS positioning technology is used around the globe, with 3.6 billion GNSS devices in use in 2014 – the surveying sector only accounts for a small portion of this number. By 2019, the number of GNSS devices is expected to increase to over 7 billion, i.e. an average of one device per person on the planet. The global core GNSS market is predicted to increase by 8.3% annually between 2013 and 2019 before slowing down to 4.6% towards 2023, i.e. the GNSS downstream market is expected to grow, on average, faster (7%) than the forecasted global Gross Domestic Product (GDP) during this period (6.6%) (GSA, 2015). The Location-Based Services (LBS) and road sectors dominate predicted cumulative GNSS revenues (with a combined total of more than 91%), driven by booming sales of smartphones, in-vehicle devices, location-aware applications and data services (Figure 1). This clearly illustrates the importance of GNSS positioning infrastructure, particularly in regards to rapidly growing mass-market applications.

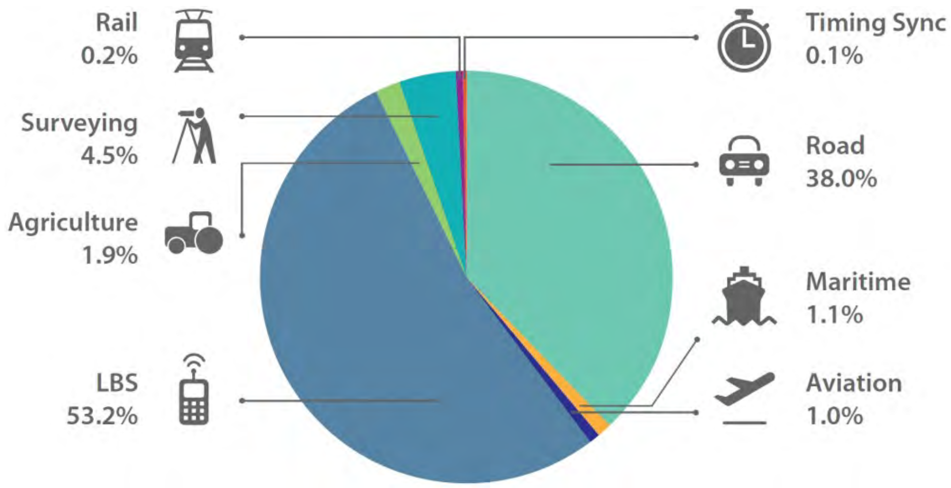

Figure 1: Predicted cumulative core GNSS revenue distribution by application 2013-2023 (GSA, 2015).

While the surveying sector is a very small and specialised GNSS market, it is a crucial one that underpins all others by providing the fundamental reference for GNSS positioning services. On behalf of the Surveyor General of New South Wales (NSW), Land and Property Information (LPI) has a legislative, regulative responsibility to maintain the geodetic control network in NSW. As such, LPI is the custodian of more than 250,000 marks in the NSW Survey Control Information Management System (SCIMS – see Kinlyside, 2013), which includes about 6,000 traditional 'passive' trigonometrical stations as well as at least 180 'active' GNSS CORS.

The Trigonometrical Survey of New South Wales, as the State's geodetic control network was then known, commenced in 1867 and continued with little interruption for almost 50 years until it was suspended for reasons of economy and war in 1916. By then, about one third of the State (mainly in the south-east) had been covered by a series of well-conditioned triangles of first and lower orders, observed as distances and angles between trigonometrical stations. The survey was resumed intermittently between the two World Wars with much of its progress attributable to the Royal Australian Survey Corps, particularly the connections to the

Victorian and Queensland networks, and along the NSW North Coast. In the 1950s and 1960s, the Division of National Mapping (now Geoscience Australia) extended the first-order networks into the western part of the State, and other networks were established by the NSW Department of Lands (now LPI). Together with the first-order traverses performed by the Royal Australian Survey Corps, the geodetic network had extended to approximately half of the State prior to the national adjustment of 1966 – this had taken 100 years (Rassaby, 1980).

In contrast, it took only five years to cover more than two thirds of NSW with 150 active GNSS CORS via CORSnet-NSW by July 2014 (Janssen, 2014), with more being added to the network today. While active survey control marks are more accurate and easier to maintain than passive control marks, both are required by the profession. Consequently, LPI continues to preserve, upgrade and maintain passive control marks using GNSS (Gowans et al., 2015) and other terrestrial methods.

This paper outlines the current status of CORSnet-NSW and the impact it has on providing first-class state infrastructure for GNSS users in NSW. The present difference between datum realisation via SCIMS and via CORSnet-NSW is explained, and efforts undertaken at LPI to rectify this situation through the upcoming national adjustment as part of the national Modernising Australia's Datum initiative (ICSM, 2015) are discussed. Finally, it is outlined how LPI supports the surveying profession and the wider spatial community in regards to GNSS infrastructure and applications.

2 CORSnet-NSW

CORSnet-NSW is Australia's largest state-owned and operated GNSS CORS network. It is built, owned and operated by LPI, a division of the NSW Department of Finance, Services and Innovation. Day-to-day operation is performed by the Survey Infrastructure and Geodesy (SI&G) section. LPI's first CORS was installed in 1992 in Bathurst, using in-house developed programming to support internal survey and aerial photography operations (Kinlyside and Yan, 2005). In 2004, a pilot-project network of seven CORS was installed in the Sydney metropolitan area and made available to the public one year later under the name SydNET (Roberts et al., 2007).

A renewed effort of expansion to extend the coverage of CORS throughout NSW commenced in 2009 as part of a 5-year, multimillion-dollar Survey Infrastructure Improvement Project (SIIP), which corresponded with the rebranding of the network as CORSnet-NSW (Janssen et al., 2010). In only five years, the network increased from 27 stations in November 2009 to 160 CORS in December 2014 (Figure 2) – an extraordinary achievement, considering the technical and resourcing challenges faced and time taken to get approval to build some sites (Janssen et al., 2011c, 2013). Today, the network continues to expand (Janssen et al., 2015). LPI aims to release its 200th CORS in conjunction with the modernised Australian datum and associated products (e.g. a new AUSGeoid) in early 2017 and be a major stakeholder in the evolving National Positioning Infrastructure (NPI) plan.

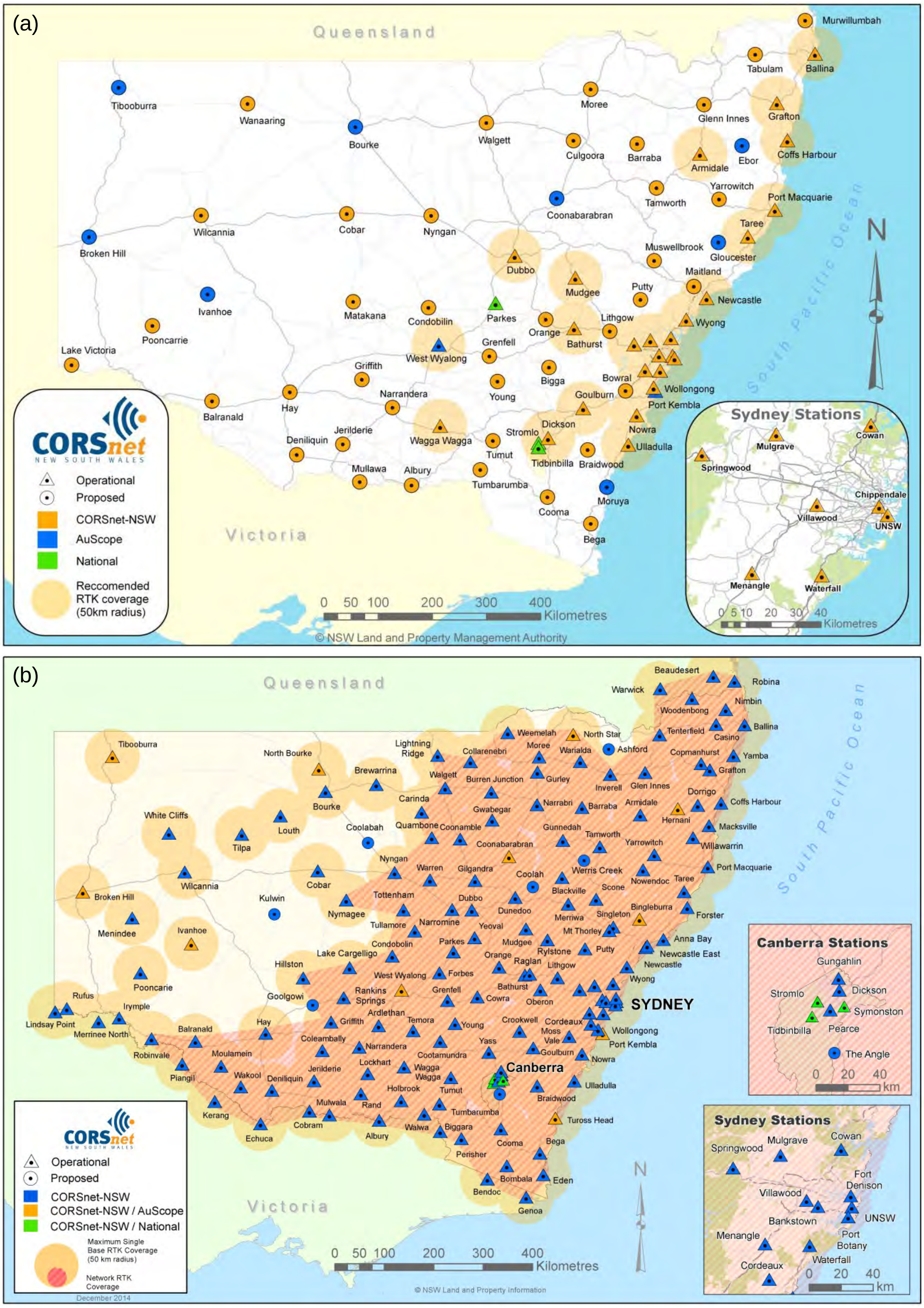

Figure 2: CORSnet-NSW network map as of (a) November 2009 and (b) December 2014.

2.1 Current Status

CORSnet-NSW is now a state-wide network of GNSS CORS providing fundamental positioning infrastructure for New South Wales (and the Australian Capital Territory) that is

accurate, reliable and easy to use (Janssen et al., 2011b, 2015; LPI, 2016). It supports the spatial community and provides stimulus for innovative spatial applications and research using satellite positioning technologies. As of March 2016, CORSnet-NSW consists of 180 active reference stations across the State.

The current coverage of CORSnet-NSW is illustrated in Figure 3, showing stations that are operational (indicated by small triangles) as well as planned stations (indicated by small circles) to be built in the coming months. A 50 km radius around active stations is shown to illustrate the maximum recommended coverage area for single-base RTK operation, while NRTK coverage at the 2-cm level (95% confidence level, horizontally) is shown as a striped, pink polygon in areas that have sufficient station density to support this technique.

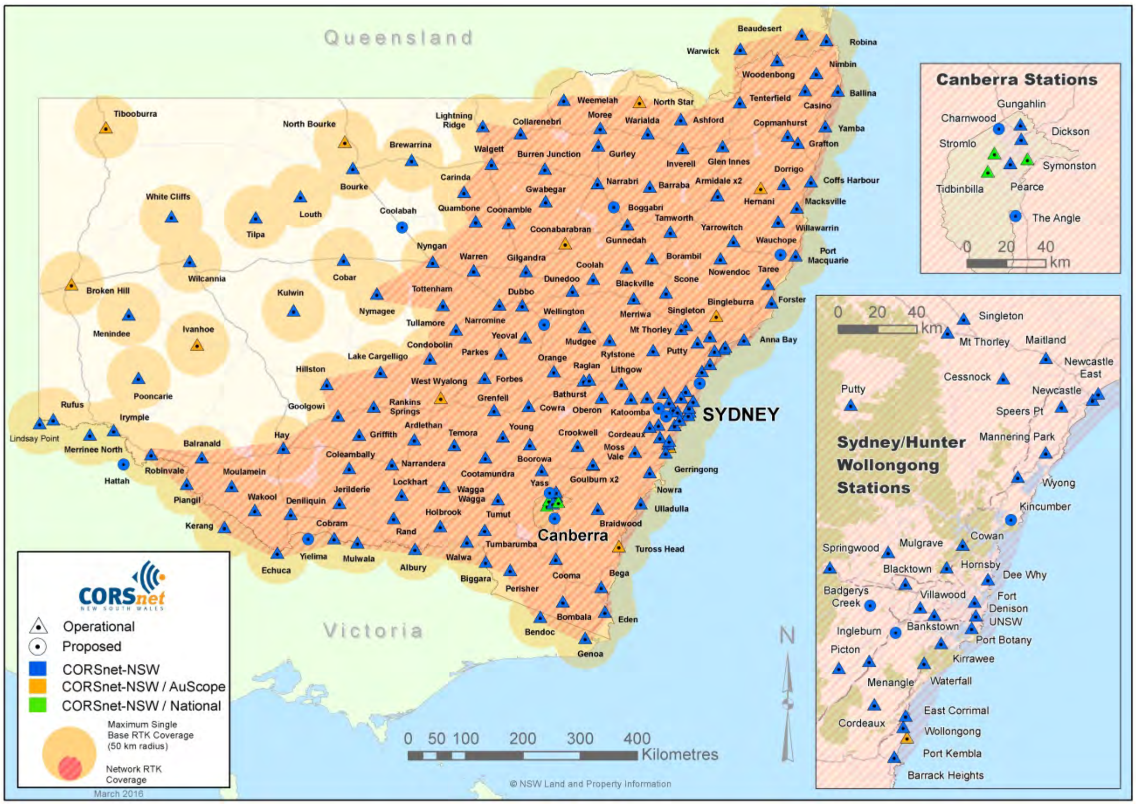

Figure 3: CORSnet-NSW network map as of March 2016 (LPI, 2016).

Currently, 75% of the area of NSW (and 99.8% of the population) is covered by the single-base RTK service, while NRTK is available to 56% of the area of NSW (and 98.6% of the population). More than 62% of the state's population is within 10 km of their nearest CORS. A sub-metre Differential GNSS (DGNSS) service is provided across the entire State. Other services include the provision of RINEX and Virtual RINEX data for post-processing applications (Janssen, 2013).

Figure 4 illustrates CORSnet-NSW station redundancy, i.e. the area concurrently covered by two or more CORS. In practice, this means that if the primary CORS should not be available for any reason, an alternative nearby CORS should ensure nearly the same user experience in regards to accuracy, time-to-fix, reliability of ambiguities, etc. Currently, such backup coverage is available to 39% of the State's area for RTK and 95% for DGNSS. Improving such redundancy to ensure the more effective and efficient delivery of services to our customers is of significant importance to LPI.

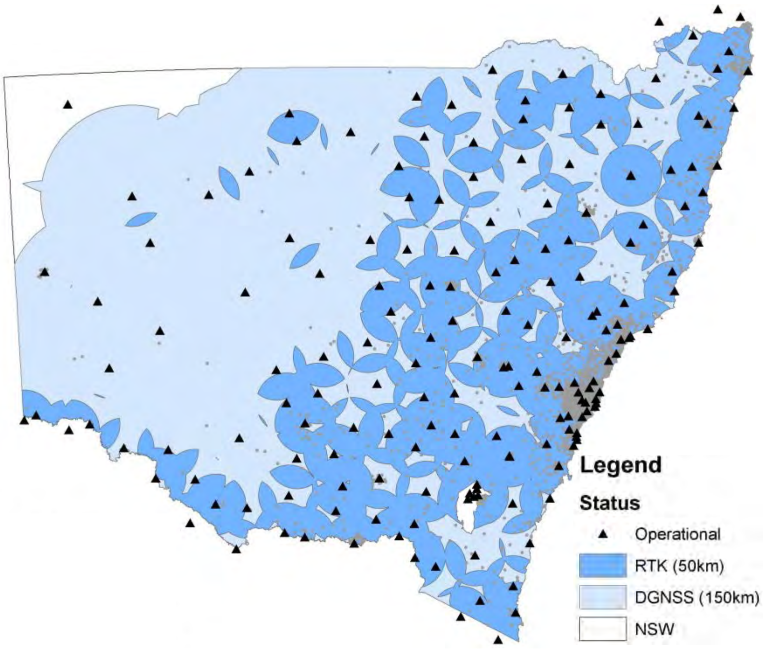

Figure 4: CORSnet-NSW backup redundancy map as of March 2016 (each dot indicates 2,000 residents per statistical local area).

All CORSnet-NSW stations are built to stringent LPI Tier 3 quality requirements in regards to technical design, installation, operation and maintenance (LPI, 2012a). Eleven CORSnet-NSW stations were built to (inter)national geodetic specifications with joint state/federal funding as part of the scientific, national (Tier 2) AuScope CORS network (Janssen, 2009a). Five CORS (Fort Denison, Port Botany, Newcastle East, Port Kembla and Eden) were built specifically to augment long-term tide gauges located along the NSW coast in order to support sea-level monitoring (Janssen et al., 2013). It should be noted that the tide gauge records available from Fort Denison, Sydney Harbour (since 1886) and the Pilot Station, Newcastle (since 1925) are two of the longest continuous records in the southern hemisphere.

Leveraging cross-border data-sharing arrangements, CORSnet-NSW also incorporates a number of interstate CORS in order to adequately cover areas in the Australian Capital Territory, along the Queensland and Victorian borders, and the external territory of Norfolk Island, in which the NSW Surveyor General executes certain responsibilities. Most stations in NSW are hosted by local councils (the equipment being owned by LPI), and two by private industry. In total, 90% of CORSnet-NSW stations are hosted by LPI's partners (currently 100+). Examples of typical CORSnet-NSW installations are given in Figure 5.

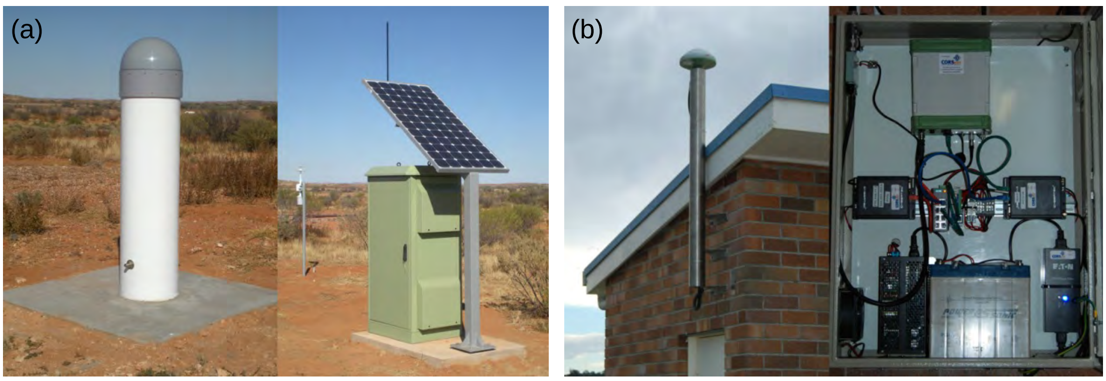

Figure 5: Typical CORSnet-NSW monumentation and auxiliaries at (a) Tier 2 and (b) Tier 3 sites.

In order to provide a legally traceable survey monument that allows the GNSS antenna to be oriented to True North without the need to introduce an antenna height, the CORSnet-NSW Adjustable Antenna Mount (CAAM, see Figure 6) was developed and patented by LPI specifically for use within CORSnet-NSW (Commins and Janssen, 2012). All Tier 3 CORSnet-NSW CORS installations since March 2011 use the CAAM, which has proven to be very effective and particularly invaluable when replacing or upgrading GNSS antennas because a zero antenna height is always maintained. This design is freely available to other CORS operators (LPI, 2012a).

Figure 6: Internal workings of the CAAM (Commins and Janssen, 2012).

CORSnet-NSW uses a mix of modern Leica and Trimble GNSS receivers, tracking both GPS and GLONASS satellites. LPI has specifically avoided the exclusive use of only one type of receiver to minimise risks and increase business/service continuity. Diversification has been limited to two brands in order to simplify fleet management. The network uses a mix of high-precision survey antennas (70%) and Dorne Margolin choke ring antennas (30%), generally with radomes installed. LPI intends to have future antennas individually calibrated by Geoscience Australia at its new test facility in Canberra (Riddell et al., 2015).

The NSW Foundation Spatial Data Framework (FSDF) 2020 Strategy (internal document) directs CORSnet-NSW to support new GNSS constellations and signals. More than half of all CORS are hardware-ready for (or at least capable of) tracking additional GNSS constellations such as Galileo and BeiDou in the future. This functionality will be activated by CORSnet-NSW only when each system officially reaches its Initial Operational Capability (IOC), system reliability has been proven and there is sufficient user demand. In the meantime, BeiDou satellites are currently tracked at six Tier 2 CORS (i.e. Bingleburra, Broken Hill, Coonabarabran, Hernani, North Bourke and North Star) and 67 Tier 3 CORS for research and evaluation purposes. This is particularly important given Australia's strategic geographic position on the globe, resulting in a multitude of satellite constellations being available in this region (Rizos, 2008). In this context, Figure 7 illustrates the number and distribution of GNSS satellites expected to be available by 2020, as well as the number of visible satellites for users anywhere on Earth. It is clearly evident that Australia is located in a GNSS positioning 'hotspot'.

The majority of all CORS feature dual communications (main and backup, e.g. ADSL and Next G) to ensure the highest possible standard in regards to data availability and data completeness. Installs are equipped with a variety of auxiliary devices such as industrial-strength modems, remote reboot relays, digital cameras with selective motion detection, door alarms, automatic cooling fans, solar power (on selected sites) and Uninterruptible Power Supply (UPS) units that last up to 30 days.

This is complemented by two mirror-image Network Control Centres (NCCs), located in Sydney and Bathurst, that utilise Commercial-Off-The-Shelf (COTS) CORS management software with full redundancy (Yan and Jap, 2011). ICT architecture allows for immediate failover between the two NCCs to ensure continuous data supply to users. The data centres employ server virtualisation technology to maximise hardware utilisation, flexibility and scalability while at the same time minimising power consumption, space requirements and carbon footprint. Network connectivity and availability is constantly monitored using external service providers. A third, ad-hoc development system is used for internal system testing. Services, system status, network information and applied research results are provided on the CORSnet-NSW website (LPI, 2016), which includes live information and other information.

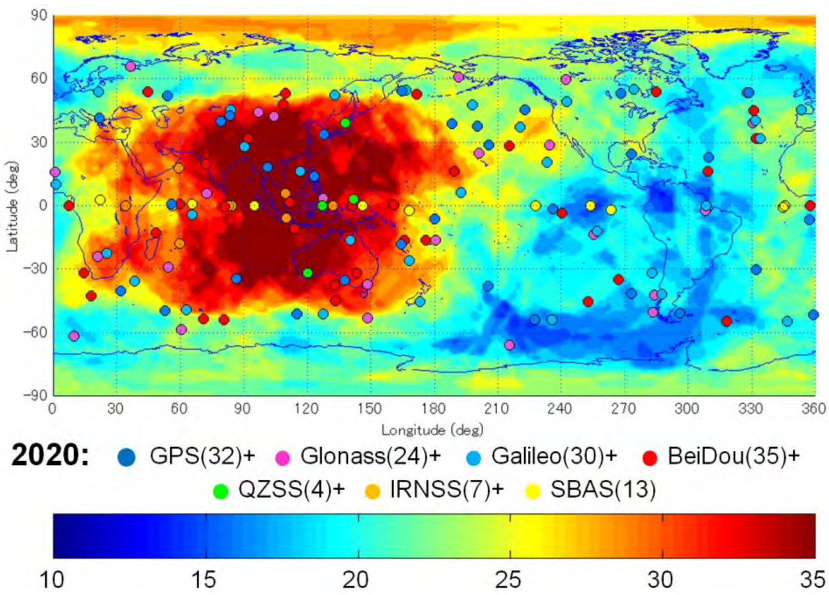

Figure 7: Number of visible GNSS satellites above 30º elevation expected in 2020 (courtesy Prof Chris Rizos).

The coordinates of each CORS are determined via the national Regulation 13 process (GA, 2016c), providing consistent positioning infrastructure that is compatible with other (public and private) CORS operators across the country and provides legal traceability. It should be noted that these 'Reg 13' coordinates are currently not compatible with SCIMS – therefore LPI also provides 'local' coordinates compatible with surrounding ground control marks in SCIMS (see section 3).

All CORSnet-NSW activities (builds, surveys, operations, maintenance and upgrades) are conducted in-house using SI&G staff. Contractors are only used for minor works (e.g. electrical or excavation work) during the build phase of some CORS. ICT support is provided internally through LPI. CORSnet-NSW operates 24/7, 365 days a year with front-line customer support services available during business hours (0830-1630 hrs). The CORSnet-NSW NCC is operated by three Full Time Equivalent (FTE) staff with strong ICT backgrounds that are embedded in SI&G (i.e. NCC Team Leader, NCC Operator, and NCC Support Officer). Site builds, maintenance and upgrades are conducted by one FTE staff (Senior Infrastructure Officer), while a variety of other SI&G staff (1.5 FTE) provide survey, research and management support (e.g. Bernese processing, local tie surveys, Regulation 13 certification, webpage updates).

Raw data is wholesaled to three premium resellers (SmartNetAus, AllDayRTK and Trimble VRS Now Australia), while CORSnet-NSW subscriptions are currently available through 16

authorised resellers servicing a wide range of applications. In addition, raw data from all LPI-owned CORSnet-NSW stations support national and local positioning applications via inclusion in the Asia-Pacific Reference Frame (APREF – see GA, 2016a) and Geoscience Australia's free online GPS processing service (AUSPOS – see GA, 2016b), resulting in better performance for users in and around NSW.

CORSnet-NSW infrastructure has recently been used in proven trials of Precise Point Positioning (PPP) solutions delivered by the Japanese Quasi-Zenith Satellite System (QZSS) via the LEX (L-band experiment) signal for precision agriculture applications in rural NSW (Harima et al., 2015). This was a small but significant first milestone in NSW's desire to introduce satellite-based delivery (through either premium resellers, NPI, international coordination or other mechanisms) to service new and emerging market sectors (NSW FSDF 2020 Strategy) and realise LPI's aspiration to improve service delivery through new technologies.

2.2 Quality Control

Quality control and integrity monitoring of CORS infrastructure is becoming increasingly important for legal traceability of data and measurements as well as for long-term stability studies of station coordinates. CORSnet-NSW operation and performance is monitored by LPI staff in real-time using Trimble's Pivot CORS network management software, which also has the ability to detect abrupt station movement in real-time. Long-term, multi-year station stability monitoring is performed in-house by determining high-precision daily coordinate solutions using the Bernese software (Dach et al., 2015) in an automated process (Haasdyk et al., 2010). Station coordinates are obtained in the International Terrestrial Reference Frame (ITRF – see Altamimi et al., 2011) and transformed into the Geocentric Datum of Australia 1994 (GDA94 – see ICSM, 2014) using the parameters given by Dawson and Woods (2010). For more information about coordinate systems, datums and associated transformations in the Australian context the reader is referred to, e.g., Janssen (2009b), Dawson and Woods (2010) and Haasdyk and Janssen (2011).

The ongoing analysis of the incoming data and computed coordinates can immediately reveal issues related to local ground deformation (or unauthorised interference with the CORS), thus contributing to the development of the National Distortion Model (ICSM, 2015). Site specific velocities of the network can be determined at higher densities than those provided by the global International GNSS Service (IGS) network, allowing comparisons with existing tectonic plate models and the development of a continuously updating National Plate-Motion Model (ICSM, 2015).

For each CORSnet-NSW site, the resulting coordinate time series showing the difference of the observed station coordinates from the official coordinates is made available on the CORSnet-NSW website (Figure 8). Results show that LPI station coordinates are calculated with millimetre-level precision and agree well with their Regulation 13 values, while velocities are obtained with 2-4 mm/yr precision and agree with the expected tectonic motion across NSW. System performance and station stability are also independently monitored by third parties, including premium resellers and the APREF analysis centres.

The stability of all Tier 2 CORSnet-NSW pillars is monitored by LPI at suitable intervals through high-precision Reference Mark (RM) surveys. These terrestrial surveys determine the horizontal position of the pillar relative to three surrounding reference marks with an accuracy

of better than 1 mm (95% confidence interval) and the vertical position of the pillar plate to within class L2A specifications (maximum misclose 2√d mm) (Janssen, 2009a).

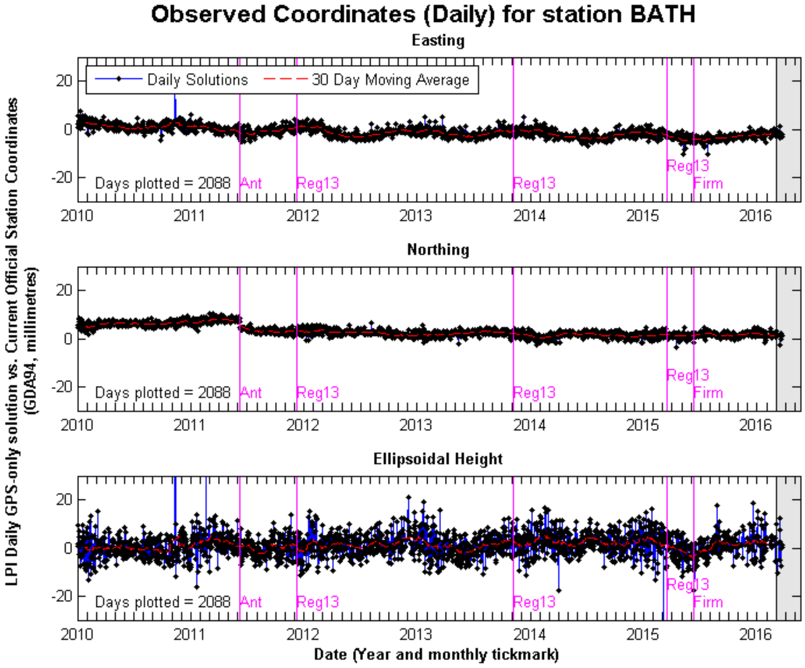

Figure 8: Observed position vs. official position of Bathurst CORS (LPI, 2016).

2.3 Future Plans

As indicated in Figure 3, CORSnet-NSW will continue to expand, with additional stations being built on a needs and opportunity basis. The LPI Statement of Business Intent clearly documents the authority's intention to expand the network to at least 200 CORS by the end of the 2016/17 financial year. Additional internal funding submissions aim to boost CORSnet-NSW to 220 stations by the end of the 2017/18 financial year. The network may grow even further subject to the outcomes of Geoscience Australia's AuScope II federal funding bid (AuScope, 2011). When CORSnet-NSW achieves its next major milestone, its 200th CORS, the majority of the State's users (i.e. urban users) will be within 10 km of their nearest CORS, thereby unlocking the potential of GNSS heighting. The network's continued expansion and ICT upgrades aim to provide users with even higher quality services, levels of reliability and backup, and to fully support the market's transition from experimentation to acceptance, to full or even sole reliance on CORS-based positioning.

CORSnet-NSW is providing the backbone of the ongoing efforts for Australian datum modernisation across NSW, which will result in significant improvements for the surveying and spatial information community in particular and the general GNSS user market in general (e.g. Haasdyk et al., 2014b; ICSM, 2015).

3 SCIMS VS. CORS COORDINATES

We are currently in a challenging transition period between traditional, passive ground control infrastructure and modern, active GNSS CORS infrastructure. Similarly, Australia is transiting to a modernised datum (ICSM, 2015). As such, CORS coordinates are currently provided in a variety of 'flavours' to suit different users. It is well known that systematic

distortions of up to 0.2 m horizontally and 0.3 m vertically exist in NSW between the legal coordinate datum as realised by SCIMS, known in NSW as GDA94(1997), and observations in the more homogenous realisation of the national datum as provided by CORSnet-NSW and Geoscience Australia's AUSPOS service, known in NSW as GDA94(2010) (e.g. Haasdyk et al., 2010; Janssen and McElroy, 2010; Gowans and Grinter, 2013). As an example, Figure 9 illustrates the regional nature of these distortions across the Central West, Sydney and Hunter regions of NSW.

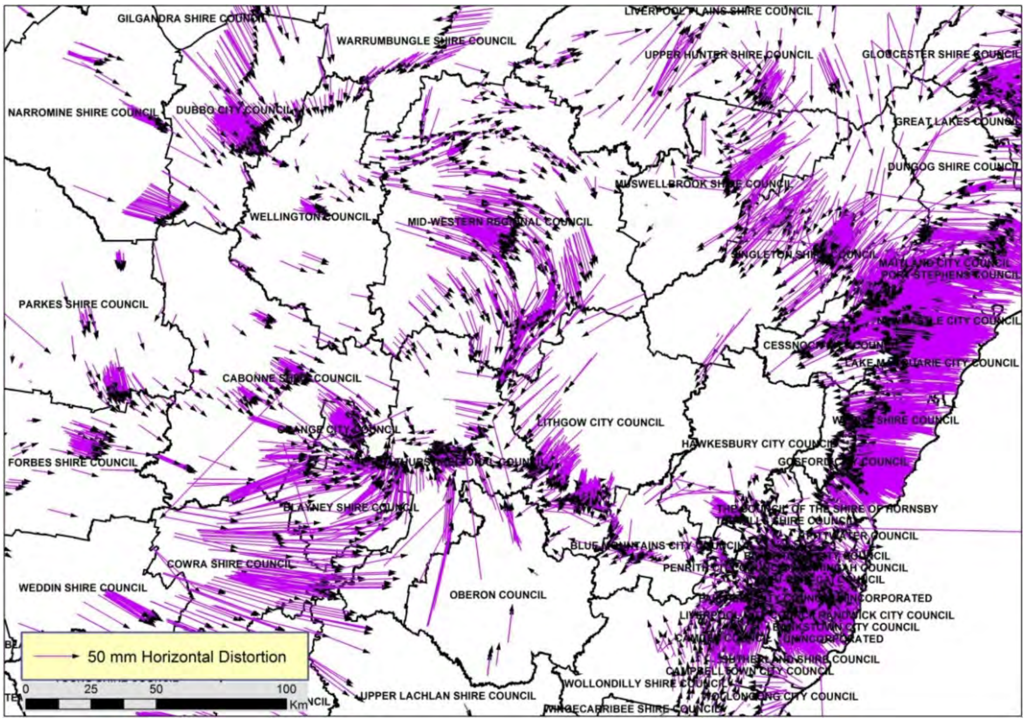

Figure 9: GDA94(1997) to GDA94(2010) horizontal distortion vectors at marks observed by GNSS, across the Central West, Sydney and Hunter regions of NSW.

Removing these distortions across NSW requires a re-adjustment of the entire NSW geodetic control network, without a hierarchy of fixed control. This will occur as part of the national adjustment to produce a modernised datum for Australia (Haasdyk et al., 2014a). In the interim, a site transformation is required to relate CORS-derived positions to the local (and legally accepted) ground control available in NSW via SCIMS (Haasdyk and Janssen, 2012). It should be noted that a site transformation is not required for (non-specialist) users interested only in relative accuracy and repeatability. Currently, efforts are underway to measure the existing distortions at a large number of trigonometrical stations and other strategic marks across the State and to obtain additional GNSS datasets for datum improvement (Gowans et al., 2015).

LPI carries out local tie surveys to connect each CORSnet-NSW station to the surrounding ground survey control, thereby bridging the gap between GDA94(1997) and GDA94(2010) (Gowans and Grinter, 2013). The immediate goal of each tie survey is to provide a best 'local-fit' position of the CORS that is consistent with surrounding ground control by intentionally propagating the local distortions in GDA94(1997) and the Australian Height Datum (AHD) to the CORSnet-NSW station. However, the ultimate goal is the opposite, i.e. propagating the Regulation 13 (or APREF-derived) CORSnet-NSW station coordinates outward to the ground survey network, via passive trigonometrical stations, as part of the national adjustment for the modernised Australian datum.

The growing use of CORS networks for GNSS-based height transfer has substantially increased the importance of accurate, absolute N values (or geoid undulations). Fortunately, the current AUSGeoid09 model has been shown to provide N values with unprecedented absolute accuracy across NSW and Australia (e.g. Janssen and Watson, 2010, 2011; Brown et al., 2011; Sussanna et al., 2014; Allerton et al., 2015; Sussanna et al., 2016). LPI continues to collect long-duration GNSS datasets on levelled benchmarks in order to improve future AUSGeoid products across the State.

4 BENEFITS OF USING GNSS CORS INFRASTRUCTURE

GNSS CORS infrastructure provides unparalleled access to positioning infrastructure that is accurate, reliable and easy to use for a wide range of GNSS applications and has become a critical foundation of today's society. This was formally recognised on 26 February 2015 with the United Nations adopting resolution 69/266 entitled "A Global Geodetic Reference Frame for Sustainable Development" (UN, 2015). This resolution outlines the importance of a globally coordinated approach to geodesy and recognises the need to invest proactively in the global geodetic reference frame (essentially the ITRF) and, by extension, our national connections into this frame. The resolution recognises the significant and ubiquitous role of geospatial information and calls for increased cooperation and investment into geodesy, including the open sharing of geospatial data, further capacity-building in developing countries and the creation of international standards and conventions. This is a mandate, from the highest source, to improve our geodetic framework and spatial information systems, and assist developing nations to do the same.

In Australia, for CORS operators and custodians of the national datum, benefits of modern GNSS CORS infrastructure include the ability for datum definition at unprecedented precision, rationalisation of infrastructure, establishment of multi-user systems, and the provision of positioning services that are similar and compatible across and between networks.

The many benefits for users of GNSS CORS networks include easy access to infrastructure that is maintained externally, facilitates a direct and consistent connection to datum, and provides some degree of legal traceability for satellite-based positioning. RTK and NRTK in particular allow instant 'real-world digitising' with the ability to significantly enhance productivity through increased precision, reliability, speed and ease of operation. The demand for high-quality spatial data is ever increasing, and the economic benefits offered by state-of-the-art GNSS-based positioning are immense. Improved productivity in the Australian surveying and land management sector alone was estimated to be 20-40% in 2012 and a further 20% by 2020, with billions of dollars in savings and productivity gains (ACIL Allen Consulting, 2008, 2013).

5 BENEFITS OF CORSnet-NSW

CORSnet-NSW has been designed, built and is operated on a 'build once, use many times' principle that serves the widest range of users (operational and scientific) and balances LPI's public-good and commercial responsibilities.

5.1 Supporting LPI

CORSnet-NSW was principally built with two main aims in mind, i.e. to support LPI's legislative and regulative responsibility to maintain the geodetic control network in NSW, and to support (and improve) internal LPI operations. Any commercial gain was seen as a welcome bonus that would help offset operational, maintenance and upgrade costs.

Internal LPI applications mainly revolve around the maintenance and improvement of the State's survey control network (SCIMS contains more than 250,000 survey marks across NSW). While the active GNSS CORS infrastructure is more accurate and easier to maintain than passive ground control marks, both are required by the profession. Consequently, LPI continues to preserve, upgrade and maintain passive control marks (Gowans et al., 2015). CORS-supported GNSS observations are crucial for this work, as well as for the ongoing efforts to update and upgrade the State's Digital Cadastral Database (DCDB). CORSnet-NSW has provided significant quality and productivity gains for airborne LiDAR and aerial imagery surveys (in regards to determining aircraft trajectories as well as providing ground control and test points for such surveys) and supported related research (e.g. Colombo et al., 2010a, 2010b, 2016).

5.2 Supporting National Positioning Infrastructure and the National Datum

LPI supports and sees itself as a major stakeholder in the National Positioning Infrastructure (NPI) policy and plans, which aim to provide reliable, compatible, homogeneous and sustainable positioning infrastructure across Australia to deliver access to fit-for-purpose position, navigation and timing (PNT) information in a multi-GNSS enabled information economy (Hausler and Collier, 2013).

Across NSW, the CORSnet-NSW infrastructure provides the backbone for the ongoing national efforts to produce a modern, next-generation datum for Australia (e.g. Donnelly et al., 2014; Haasdyk et al., 2014b; ICSM, 2015) by constraining the Regulation 13 certified (or APREF-coordinated) CORSnet-NSW stations. The GNSS baselines observed as part of the CORSnet-NSW local tie surveys (Gowans and Grinter, 2013) are crucial to propagate these coordinates outward into and through the existing survey ground control networks. This will provide a homogeneous national datum realisation across NSW and Australia, thereby significantly improving the State's geodetic infrastructure for years to come. In support of these efforts, LPI has performed extensive data-mining and cleaning of archived GNSS and terrestrial observations (e.g. Haasdyk and Watson, 2013; Haasdyk et al., 2014a), collected a large amount of new GNSS data across the State (Gowans et al., 2015) and made progress towards updating its SCIMS database in order to facilitate the modernised datum (e.g. Donnelly et al., 2013; Kinlyside, 2013).

In this context, it is important to remember that geodetic control underpins *all* spatial data, including water, boundaries, addresses, utilities, transport, elevation and imagery, but also that most revenue and GNSS data consumption will come in the near future from applications such as Location-Based Services and transport (GSA, 2015).

5.3 Supporting Governance and Best Practice

As a state jurisdiction, LPI is responsible for regulations, directions and guidelines, e.g. the Surveying and Spatial Information Regulation (NSW Legislation, 2015) and Surveyor

General's Directions. Of particular relevance to GNSS users in NSW are Surveyor General's Direction No. 9 (GNSS for Cadastral Surveys – LPI, 2014) and No. 12 (Control Surveys and SCIMS – LPI, 2012b). The former provides guidance in the use of GNSS technology for cadastral surveys, while the latter facilitates the continuing improvement of available survey control in collaboration with industry. Furthermore, LPI provides comprehensive guidelines for the establishment of GNSS CORS to ensure that all stations contributing to CORSnet-NSW, APREF and NPI are of the highest possible and consistent quality (LPI, 2012a).

GNSS validation networks, which include CORSnet-NSW sites, offer users in NSW the opportunity to test their equipment, processing, procedures and competency against a reliable external source in order to meet legal requirements (LPI, 2014).

5.4 Supporting Applied Research

LPI continues to be active in conducting applied research that contributes to national initiatives, educates the profession, informs legislation and best practice guidelines, and enhances internal operations and decision making. SI&G, in particular, is mandated through the NSW FSDF 2020 Strategy to "adapt to new positioning services through applied research and innovation" (internal document). These efforts have produced 80 papers over the last 7 years (2009-15), communicating research findings to both the scientific community and the profession (i.e. technical vs. more general), and feedback has been very positive. Some specific GNSS-related examples of contributing to best practice guidelines via conducting applied research include:

- Demonstrating that CORSnet-NSW users achieve the biggest benefit from NRTK by using 1-2 minute observation windows separated by at least 10-30 minutes and being aware of overly optimistic coordinate quality indicators provided by the GNSS rover equipment (e.g. Janssen and Haasdyk, 2011).
- Showing that a site transformation consisting of a block shift is sufficient to relate CORSnet-NSW-derived RTK/NRTK observations to SCIMS ground control for surveys requiring centimetre-level accuracy, provided AUSGeoid09 is applied (e.g. Haasdyk and Janssen, 2012).
- Quantifying AUSGeoid09 performance across NSW and showing that resulting GNSS-derived heights generally agree with AHD at the ±0.05 m level (1 sigma) (e.g. Janssen and Watson, 2010; Sussanna et al., 2014; Allerton et al., 2015; Sussanna et al., 2016).
- Showing that positioning results using Virtual RINEX data are comparable (at the few-mm to few-cm level) to those based on observed data, thus allowing GNSS users to benefit from network-based corrections for post-processing applications (e.g. Janssen, 2013).
- Educating GNSS users about the effect of the ionosphere on positioning quality (e.g. Janssen, 2012; Colombo et al., 2016).
- Informing GNSS users about the capabilities of Precise Point Positioning (e.g. Grinter and Janssen, 2012; Rizos et al., 2012; Grinter and Roberts, 2013; Harima et al., 2014).
- Explaining the intricacies of control surveys and the impact of utilising satellite positioning technology for such surveys (e.g. Dickson, 2012).
- Providing guidance for CORS network operators and designing the patented CORSnet-NSW Adjustable Antenna Mount (CAAM) to ensure that CORSnet-NSW installations are of the highest quality (e.g. Janssen et al., 2011c; Commins and Janssen, 2012).

This shows that the CORSnet-NSW network is utilised (directly and indirectly) in many ways, some of which may not be obvious at first glance.

6 CONCLUDING REMARKS

On behalf of the NSW Surveyor General, LPI has a legislative, regulative responsibility to maintain the geodetic control network in NSW. GNSS CORS infrastructure has become crucial to cater for the increased demand for accurate, reliable and easily accessible positioning in today's society. State jurisdictions provide the essential link between national initiatives and academia on the one hand and the profession on the other, e.g. via maintaining geodetic infrastructure and conducting applied research that informs legislation and best practice guidelines.

This paper has outlined the current status of CORSnet-NSW and the efforts undertaken at LPI to further improve the State's geodetic control network on the basis of the GNSS CORS infrastructure through the upcoming national adjustment as part of the modernised Australian datum. It has also discussed how LPI supports the surveying profession and the wider spatial community in regards to GNSS infrastructure, demonstrating the enormous contribution that CORSnet-NSW makes to the geodetic fabric across NSW and Australia.

By reaching its 150 CORS milestone in July 2014, CORSnet-NSW has matured within only five years into a world-class, state-wide, multi-function GNSS CORS network that balances public-good and commercial mandates. Currently comprising 180 CORS, the network is expected to grow to 220 CORS by 2018. CORSnet-NSW has revolutionised internal and external GNSS operations, not only supporting the surveying and spatial information profession but also making important contributions to national and regional geodesy.

CORSnet-NSW's evolution, operation and continued development is testimony of LPI's vision to be a world leader in spatial information and its mission to develop and maintain products and services to empower commercial and government organisations, tertiary organisations, the public and the community of NSW. SI&G's applied research achievements demonstrate its commitment to promoting LPI as the NSW Government's centre of excellence in spatial information.

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Datum Modernisation for Australia

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ABSTRACT

Increasingly accessible geospatial technologies that generate large amounts of spatially accurate data have highlighted deficiencies in Australia's current national datum, the Geocentric Datum of Australia 1994 (GDA94). The economic and technological drivers to achieve greater productivity have created an unavoidable need for datum modernisation, so that a spatially empowered Australian community can reach their required accuracies, now and into the future. The Australian landmass also sits on the fastest moving continental tectonic plate on Earth. This creates a situation where coordinates produced by unaugmented Global Navigation Satellite Systems (GNSS) quickly become biased in time with respect to plate-fixed coordinates. Coordinates measured relative to GDA94 are now over 1.5 metres offset to the positions provided inherently by GNSS. The ability to then confidently integrate disparate spatial datasets, captured at different times, is creating a growing level of frustration among both professional and inexperienced users of spatial data. Systems that will be commonly available on familiar platforms such as smartphones will make accurate position even more accessible to the spatially illiterate population. The ability to deliver real-time accuracies better than the definition of GDA94 will likely be upon us within the next decade. These issues clearly indicate that leading surveying and spatial sciences professionals must ensure that the required level of accuracy needed by the community is attainable. This presentation describes the process of modernising the nation's coordinate system, the move to update GDA94 and a future time-dependant datum.

KEYWORDS: *Datum, geodesy, coordinates, ellipsoid.*

Cadastre NSW: A Single Land Cadastre

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ABSTRACT

The NSW cadastre does not belong to any one agency or organisation. While Land and Property Information (LPI) is its custodian in NSW, the cadastre transcends organisations and industry groups as the link between all interests, restrictions and affectations of land. It is a fundamental building block that enhances the State's location intelligence and supports the NSW share of the $5.4 trillion of real property held across Australia. NSW, however, does not have a 'single' digital representation of the cadastre used ubiquitously across government and industry. Instead, many organisations maintain separate cadastral datasets, which represent the same core information but vary in their spatial positioning, attribution and the type of features displayed. Consequently, NSW is hindered through duplication of effort and misalignment when spatial information from multiple sources is combined. The Cadastre NSW Working Group has been formed to identify and address issues related to the creation of a single land cadastre for NSW. The group is planning a digital transformation to improve the way that cadastral information is sourced, managed and delivered to implement their vision for a next-generation cadastre for NSW. This paper discusses the actions taken to date to prepare for the development of a collaborative business case for Cadastre NSW. It also discusses the policy and social drivers for change such as the NSW Government's digital transformation agenda and public expectation for access to information instantly, anywhere and on any device. To initiate the development of Cadastre NSW, LPI has commenced work on a number of projects including stakeholder needs analysis and engagement, and implementation of ePlan and LandXML processes to enable electronic submission and management of survey plans.

KEYWORDS: *Cadastre, digital transformation, location intelligence.*

1 INTRODUCTION

Cadastral information is used across government and industry to manage land, plan and assess development, build and manage infrastructure, protect the environment and deliver vital services. It underpins the NSW share of $5.4 trillion of real property held across Australia and is a core component of many systems and processes that drive our economy. However, due to duplication of effort and lack of coordination, the cadastre is still not being used to its full potential.

This paper discusses the actions taken to date to prepare for the development of a collaborative business case for Cadastre NSW. It also discusses the policy and social drivers for change such as the NSW Government's digital transformation agenda and public expectation for access to information instantly, anywhere and on any device. To initiate the development of Cadastre NSW, LPI has commenced work on a number of projects including stakeholder needs analysis and engagement, and implementation of ePlan and LandXML processes to enable electronic submission and management of survey plans.

2 BACKGROUND

Since the 1980s, LPI has maintained a Digital Cadastral Database (DCDB) to provide a spatial representation of land parcels current within its titles register. The DCDB is consumed by individuals and organisations across government and industry for a vast array of purposes including planning and development of Local Environment Plans (LEP), disaster management, evaluation of Development Applications (DA), asset design, surveying and customer management and billing.

While LPI is the custodian of NSW's state-wide DCDB, many local councils and utilities also maintain digital cadastral datasets to meet their organisational needs. These needs often relate to ensuring early or proposed information is captured during the development process. The current time lag for information reaching LPI is problematic as plan lodgement and registration occurs right at the end of the development process. The accuracy or type of features included in LPI's cadastre may also not be sufficient for an organisation's business needs.

It is estimated that there are around 140 cadastral datasets being maintained on a day-to-day basis across NSW. Some organisations have developed their own DCDB from scratch, while others have adopted LPI's DCDB at a point in time but updated it independently since. While all stakeholders recognise the benefits of greater coordination, there is significant complexity and risk in adjusting existing business processes to an externally managed dataset.

Many organisations who maintain a DCDB regularly update their dataset to make it more spatially accurate. However, changes to the position of features in the DCDB cause a ripple effect for the hundreds, if not thousands, of layers that need to be aligned to it. This can either be a coincident alignment (common for planning layers) or relative relationship (common for asset information). While it was accepted that upgrades need to happen from time to time, most of the organisations needed to be in control of when changes to the DCDB occur to ensure they have the resources and time available to update all the other related datasets.

The fact that various versions of the DCDB exist also means that combining DCDBs or any related dataset from different sources will result in misalignments. This problem has increased complexity for the Department of Planning and Environment's new ePlanning viewer, which brings together planning layers produced by councils across NSW and overlays them with LPI's DCDB. For NSW the implications include significant duplication of effort, a higher regulatory burden on industry, poor decision making and unnecessary barriers to digital government services.

To address these issues, a single land cadastre workshop was held on 1 July 2015 with the aim of agreeing on an approach to the design, development and implementation of a single land

cadastre for NSW. The workshop consisted of 35 representatives from across industry and government and achieved a broad consensus in rebranding the single land cadastre initiative as 'Cadastre NSW' and producing a vision and strategic roadmap to achieve that vision.

The vision comprises 'a cadastre as a service', a single source of truth that is underpinned by agreed management rules and governance, is technology agnostic and of known currency, accuracy and completeness to support the legality of location-based decisions. The roadmap endorsed communication of the benefits to stakeholders, formal analysis of the current state, establishing pilots and business models, and ultimately development of a business case for the initiative.

3 CADASTRE NSW

Around the world, government providers are trying to keep pace with technological change and community demand for accessible, accurate and temporal information. The Cadastre NSW vision is to utilise technology to enable users to access what they need, at any time, on any device. As such the initiative also supports a number of the strategic goals and state priorities of the NSW Government such as digital government (NSW Office of Finance and Services, 2014), faster housing approvals, improving government services and increasing digital transactions to 70% by 2019 (NSW Government, 2016).

3.1 Cadastre NSW Working Group

Following the workshop on 1 July 2015, the Cadastre NSW Working Group (CNWG) was formed to provide leadership and strategic direction of the Cadastre NSW initiative. The working group is a mix of industry and government representatives, which reflects the broad scope of business and government stakeholders whose core business transactions rely on cadastral information. Membership of the CNWG includes:

- Surveyor General of NSW.
- Land and Property Information (LPI).
- Local Government professionals.
- Department of Planning & Environment.
- Urban Development Institute of Australia (UDIA).
- Australian Property Institute (API-NSW).
- Australian Consulting Surveyors (ACS) / Country Surveyors NSW.
- Institute of Surveyors (IS) NSW.
- Sydney Water.
- Hunter Water.
- Water Directorate.
- Energy Networks Association (ENA).
- Department of Industry.

3.2 Stakeholder Review: Problems, Opportunities and Benefits

In December 2015, the CNWG supervised the production of a stakeholder review with the aim of gathering information to inform the development of a business case for Cadastre NSW. The stakeholder review included a total of four stakeholder workshops, which identified three common priorities or problem and opportunity areas within current cadastral management arrangements.

The problems and opportunities chosen by stakeholders represent the areas within cadastral management that have maximum potential for reform or where reform will create maximum impact. The three problems and opportunities identified are (Figure 1):

- *Proposed plan data is not consistently distributed* – The lack of a coordinated dissemination of proposed plan data has led to delays in connecting new homes to utilities, higher cost regulatory processes for housing development and reduced planning capacity for utilities. The review found that the opportunity to address this problem is high in the short term (~2 years) as changes in processes and existing systems will remediate problems in this area.
- *Users are uncertain about the cadastre's accuracy* – The absence of definitive information on the accuracy of cadastral data means that there is uncertainty around the location of underground assets, reduced ability of authorities to enforce regulation for the benefit of the public and adds to the cost of infrastructure and property development. Given the greater complexity of this problem, the review found that it would take around 3 to 5 years to address this problem.
- *Lack of a coordinated minimum NSW cadastre* – The lack of a coordinated minimum cadastre means that there are a number of hindrances for NSW. These include the issue of unnecessary duplication of effort across government and industry, barriers to open data and digital government services, reduced accuracy of land valuations and delays in processing the sale of Crown land. Implementation of a minimum cadastre will require targeted and progressive change in existing systems and processes projected to be achievable in around 5 years.

The five broad benefits to NSW that can be realised from addressing the problems identified are:

- Improving the efficiency of local council operations.
- Improving the efficiency, reliability and safety of building infrastructure.
- Reducing land and property development costs.
- Accelerating online government service delivery and private sector opportunities.
- Strengthening strategic planning, decision making, compliance, enforcement and prosecution.

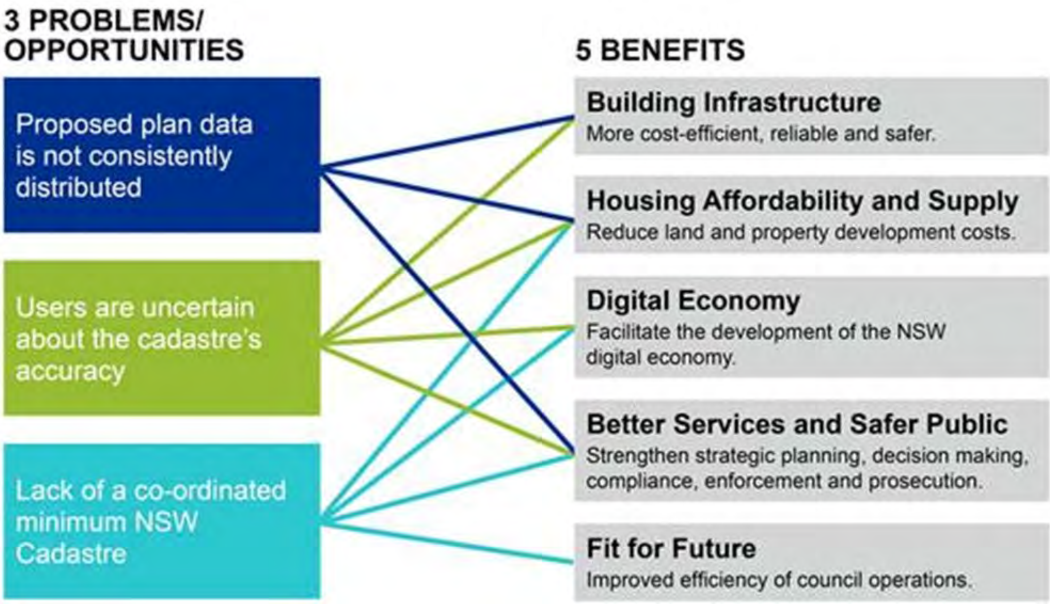

Figure 1: Problem/opportunities and the benefits for NSW in addressing the issues.

Many of the benefits are also complimentary to larger reform initiatives such as improving Australia's digital economy through digital transformation and the NSW Government's 'Fit for the Future' Local Government reforms in addition to other NSW strategic goals, as illustrated in Figure 1.

3.3 Next Step: Business Case

The next step is to develop a business case to seek capital funding from NSW Treasury for the project. The business case will set out costs, benefits, document the need for the service, analyse the risks and demonstrate the lead agencies' capability to implement the project.

4 IMPLEMENTATION: DPXML

The foundation for any cadastre in NSW is the catalogue of registered survey plans held by LPI. New plans being registered are able to be submitted (lodged), or captured post-lodgement, in the digital LandXML format. This allows for examination, registration, storage and use of plan data in a seamless ePlan environment and avoids many of the shortcomings of a manual plan registration system.

Pre-existing survey plans are currently stored as digital TIFF images that were captured from hardcopy originals or from microfilm copies. These plan image files are easily accessible but are essentially a 'dumb' image, requiring interpretation and data entry for any digital spatial environment or system of cadastral data management.

ePlan and LandXML provide a standardised format for generating, lodging, storing and accessing survey data for individual plans. LPI is undertaking a project to capture existing Deposited Plans (DPs) into LandXML for use by Cadastre NSW stakeholders and to help develop the single land cadastre. The project will run for approximately 4 years and capture some 800,000 DPs.

4.1 Guideline Development: New Format / Old Plans

The international schema for LandXML has been ratified by the Intergovernmental Committee on Surveying and Mapping (ICSM) for use in representing surveying information in Australia (see https://icsm.govspace.gov.au/files/2012/11/LandXML-1.2.xsd for an example). The LandXML schema forms part of the ICSM ePlan protocol, which has been implemented by LPI as the NSW LandXML recipe (LPI, 2016).

The Deposited Plan LandXML (DPXML) project is now underway to capture existing, previously registered DPs into the LandXML format based on the NSW recipe. Converting the old plans into a new digital format presents a significant challenge. LandXML is designed to facilitate the interoperability of data, based on standardisation of information in an XML format, while the plans themselves represent an evolution of survey information and regulatory requirements that have continually changed during more than 100 years of practice.

The NSW recipe has been developed for new plans which conform to current Acts and Regulations. Any DPs more than about 25 years old tend to be quite variable in their content and format. Changes in standards over time as well as individual surveyor's drafting methods result in older plans being more difficult to interpret and convert to LandXML.

Some common issues that arise in capturing older plans include:

- Plans with missing or inaccurate SCIMS reference table (including pre-SCIMS and MM plans).
- Plans without (or with limited) connection to Permanent Marks.
- Missing or inaccurate observations.
- Inadequate irregular boundary definition.
- Missing or inaccurate administrative information.
- Misclose and other errors that have not been corrected during lodgement and examination.

In order to ensure consistency of data across all plans being captured during the DPXML project, a register of unique plan issues has been established. This records non-standard scenarios that occur in the wide variety of plans and may be a result of original field observations, plan drafting or limitations in data capture.

4.2 Quality Assurance

The unique nature of each survey project and subsequent plan, as well as the many complexities contained in compiled plans, highlight the importance of good quality controls during the plan capture process. Data capture of plans is being outsourced and the quality control processes during capture are managed by the service provider, with final quality assurance undertaken by LPI. It is important to note that while all efforts are made to ensure that the LandXML file is an accurate representation of the original plan, it is the plan TIFF image which remains the legal point of truth for each registered DP.

Quality control during data capture includes check observations, validation of all marks and connections, validation of area and misclose, double data entry of tables and administrative information, visual checks of the geo-referenced TIFF plan, automated mathematical and logical checks, the LPI ePlan validation service report, and LPI python scripts.

Quality assurance of LandXML data supplied to LPI is undertaken by a project team of six staff who run a series of automated and manual checks against the plan files. This includes logical, accuracy and attribute checks for coordinates, marks, reduced observations and parcels. The LandXML is also rendered into a shapefile for scrutinising coordinate, geometry and connection information. DPXML plans which fail quality assurance are returned to the service provider for correction.

Despite all efforts being made during the data capture and quality assurance steps, there is going to be a significant number of errors and anomalies in this data. Many of these will be minor and have little impact of the fit-for-purpose quality of the LandXML representation of the original plan. However, an essential requirement for release of LandXML for broader use is the communication of quality information, which highlights the limitations, possible errors and quality checks that have been undertaken for each plan.

4.3 Applications

4.3.1 Pilot(s)

In 2015, a pilot project was undertaken to test the proposed capture methodology for DPXML. The first trial area was completed using approximately 1,500 DPs from The Hills Local Government Area (LGA). The initial pilot results were very encouraging. During the

first part of the pilot activity, many areas for improving capture processes were identified and subsequently incorporated into the workflows. With pilot work proving very successful, a decision was made to extend the trial area with some supplementary and more complex plan scenarios and fully test the end-to-end capture process, also over The Hills.

A final pilot stage will comprise a 3-part limited production run, through to the end of June 2016. The intention of this stage is to increase throughputs and stress test all production processes, as well as identify areas for ongoing quality improvements. The plans for this stage were sourced from the southwest and northwest Sydney growth areas, as well as Gosford LGA. The limited production stage 1 pilot has been a success, confirming requirements for moving ahead with stages 2 and 3. Full project production should start in July 2016 and will continue to ramp up through the calendar year, reaching peak throughputs in December 2016.

4.3.2 Plan Test

One of the benefits of DPXML is the time that will be saved during the electronic plan lodgement (ePlan) and examination process (plan test). During plan examination for newly lodged plans, a thorough analysis of existing survey information is undertaken for the subject plan and adjoining reference plans. Where existing plans are available in LandXML, as a result of DPXML capture, it will mean that plan data will not need to be manually entered, a significant resource saving for LPI and time saving for lodging parties. The plan test process can proceed much more efficiently for newly lodged plans.

4.3.3 DCDB, Valnet, SCIMS and Addressing

There are several other important areas of LPI activity which will benefit from the availability of LandXML data. The DCDB is updated using new survey plans and also upgraded (improvements in spatial accuracy) from existing plan data and other source information. DCDB maintenance will benefit greatly from ready-to-use plan data. Valnet will be able to use area information derived from LandXML file data to verify property details, and LPI's addressing database will access standard and complex address details. These changes represent a significant improvement to workflows and reduction in manual data entry for LPI.

4.3.4 RMS Cadastral Models

Roads and Maritime Services (RMS) have a very significant Forward Work Program 2020, which encompasses major projects for the next 4 years. RMS has indicated that any assistance from LPI in enabling the use of LandXML in cadastral models for its surveying and construction activities would be helpful. Given the scale and importance of these infrastructure projects, LPI will be collaborating with RMS on some test areas and, if possible, schedule DPXML capture on a priority basis.

4.3.5 Survey Industry

The availability of DPs in LandXML means that surveyors will have access to ready-to-use data from already registered plans in the area of interest at the start of each survey job. Observations, marks, coordinates, connections, parcels, roads, areas, arcs, administrative information and all other plan data can be used without the overhead of data entry. Planning and preparation for cadastral survey work should become more streamlined and plan preparation and drafting can become more efficient with survey project software and drafting packages ingesting the LandXML data as well as outputting LandXML for lodgement.

4.3.6 Other Applications

Inefficient access to data and long lead-in times for planning and development approvals are a significant overhead for urban planning, design and development feasibility analysis. While hard to measure, the time savings and data improvements made possible through readily available digital plan data will be significant.

5 CONCLUDING REMARKS

The NSW DCDB is a key information asset for NSW which supports the delivery of new homes, infrastructure and government services. The current level of duplication and lack of coordination for managing cadastral and associated information is a barrier to the NSW Government achieving its strategic outcomes, such as improving housing affordability and providing online digital services.

Through LPI's current data capture agenda, as well as a whole of government approach through the Cadastre NSW Working Group, the time is right to reform the way cadastral information is sourced, managed and delivered in NSW. The next major step will be the development of a business case for Cadastre NSW to secure the funding and resources necessary to achieve a single land cadastre for NSW. It should be noted that the information given in this paper is correct at the time of writing and may be subject to change.

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Towards a Single Cadastre in NSW: The Why and How

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ABSTRACT

Availability of cheap and effective Geographic Information Systems (GIS) has resulted in a wide range of government and non-government organisations utilising these systems. The range of spatial datasets held by these organisations has increased dramatically as has the desire to access this data by an increasing array of consumers. The cadastre is the basis of a wide variety of spatial datasets without which they become almost meaningless. In New South Wales the cadastral base for these systems has been purloined from its original centralised origin and is now managed separately by a range of authorities and organisations. Additionally the quality of the cadastre has been found to be lacking, leading to individual GIS managers within these bodies implementing uncoordinated changes to the original. The end result is a plethora of detached cadastral databases that respond to individual needs and cannot be utilised to provide a single point of reference in order to allow access to spatial data beyond the bounds of the specific cadastres to which they relate. The benefit of a single cadastre to which the full range of spatial datasets relate is difficult to estimate, not because it is limited but rather it is limitless. A system that integrates all functioning cadastres into an apparent single entity needs to be agreed on and implemented. This paper outlines the aspirational goal for a single state-wide spatial information system that will provide an increasing array of 'aligned' spatial data viewable by a range of customers at no cost through multiple entry points. It explains in lay terms what such a system would look like and how it would be an improvement on the current situation. It also provides examples demonstrating the value of such a system and explores a range of initiatives that might be implemented to develop it.

KEYWORDS: *Cadastre, spatial information, GIS, standardisation*.

1 INTRODUCTION

This paper provides a 'plain English' discussion relating to the need for an agreed state-wide common electronic cadastre. Its purpose is to stimulate discussion and challenge those organisations currently using individualised cadastres to accept the obvious benefit that a common dynamic (constantly updated) cadastre would provide. This paper discusses the how's and why's and outlines the considerable benefits and opportunities that would flow from the availability of an up-to-date, common, state-wide cadastre for all levels of users. It examines commercial opportunity and 'opening the door' to private enterprise to use the common cadastre as a base layer for commercial application.

While not providing all the answers and certainly being likely to raise differences of opinion, its primary aim is to open up the topic for discussion and promote action. This paper does not enter into the technological processes needed to achieve a common cadastre, which (while complex) are certainly available, because so often such discussion becomes incomprehensible

to non-technocrats and mitigates against action.

2 THE CADASTRE

2.1 Who Owns the Cadastre?

Answer: Surveyors? This is a simplistic answer, but worth examining. All cadastral boundaries in NSW have been created or defined by surveyors, both government and private. Although many have left this earth, many remain, or at least the companies they established or worked for remain. In city areas, almost all boundaries have been defined by private surveyors.

If and when any commercial value is placed on cadastral information obtainable through Geographic Information Systems (GIS), should the surveyors who invested their intellectual property into providing this information receive a return? This is a particularly interesting question for those talking about a survey accurate cadastre, as one presumes this accuracy will (at least in part) be established from coordinate data and measurements included on Deposited Plans produced by surveyors for other purposes.

2.2 Who Should Manage the Cadastre?

Surveyors are the people who understand the complexity of the cadastre and have the ability to manage it as a state-wide dataset, particularly if it is to become a dynamic dataset, rather than a static representation of property boundaries at a point in time (more on this later). Certainly the profession to manage the cadastre is the surveying profession. Have you ever tried to explain 'projections' to other professions?

2.3 The Cadastre is Dynamic

This fact is the nub of the problem, many users and administrators in various government authorities do not realise or acknowledge that an accurate representation of the cadastre is dynamic and changes virtually minute by minute.

Spatial changes to the cadastre stem from:

- Boundary changes, e.g. subdivision, consolidation and boundary amendment (daily changes).
- Local adjustments to improve accuracy (the timing of changes can be managed).
- Overall adjustments, e.g. projection and geodetic driven changes (the timing of changes can be managed).

Informational changes relating to land parcels that are part of the cadastre change even more frequently:

- Ownership.
- Encumbrance on title.
- Valuation information.

Static cadastres are therefore a potential disaster as they provide out-of-date data, causing confusion and potentially financial loss. For example, a recent visit to the cadastre-based planning information system available through a major NSW government department

revealed incorrect out-of-date property and planning information resulting from a recent subdivision not being recognised. As councils with GIS that is based on the cadastre and used to provide property and planning information know, the cadastral information and related data must be maintained or there is a real risk of legal action.

2.4 Who Uses the Cadastre?

Users of the cadastre fall into two basic categories, information generators and information users.

Information generators are those who use the cadastre to present spatial information, including councils (e.g. zoning maps), government authorities (e.g. Rural Fire Service, bushfire-prone land maps), instrumentalities (e.g. telecommunication companies, service location diagrams) and private enterprise (likely to increase).

Information users are those who examine information sources based on the cadastre to find out land related information, e.g. builders, planners, public enquiry, valuers, surveyors, engineers, marketing people and just about everybody else.

2.5 What Type of Information is Defined by the Cadastre?

Just about every set of spatial data is defined, or is locatable, by reference to cadastral boundaries. In addition to the spatial definition of information, textural attributes relating to land parcels form part of the cadastre.

2.6 How Accurate Does the Cadastre Have to Be?

The current cadastres in use have widely varying accuracies, and in many areas are not fit for purpose. Country towns with 10- to 20-metre shifts are not uncommon, and rural area boundaries that vary widely from on-ground boundaries are the norm (as can be seen from virtually any overlay of cadastres onto now fairly accurate pixel-adjusted air photography). Within city areas accuracy varies but is mostly fit for purpose at the 1-metre level.

While survey accuracy is desirable and actually achieved in some local cadastres (e.g. Sutherland Shire), it is a long way off on a state or city wide basis and an impractical goal in the short and medium term. It would be nice to achieve sub-metre accuracy across the state but even this is a big ask in the short to medium term. However, it is certain that delaying a common cadastre to wait for acceptable accuracy attainment is unrealistic. Instead, the 90% rule should be applied, i.e. introduce and utilise the available cadastre and improve it over time.

If an agreed dynamic common cadastre is achieved, accuracy improvements can be introduced as information becomes available. This will allow improvement in accuracy on a local ‘as needed’ basis as well as facilitating programs for overall or more widespread improvement. A program to achieve optimal accuracy, perhaps on a variable basis (e.g. 0.1 m in cities, 0.5 m in suburbs and towns, 2 m in closely settled rural areas, and 5 m in remote areas), could be easily developed.

2.7 Spatial vs. Textural

One of the most significant changes in information management stemming from the GIS

revolution was the ability to store and manage information spatially rather than in textural databases. Management and quality control of large textural data bases is (was) certainly a nightmare in local government where up to 100 and sometimes more attributes had to be recorded against land parcels in order to meet statutory obligations (planning and rating information). Imagine checking 25,000 land parcels in a textural database to see if they were bushfire-affected or not (i.e. comparing a field of numbers on a screen with a paper map). Obviously, errors are (were) frequent.

Compare this with simply asking which land parcels in the cadastral layer of the GIS system are intersected by the bushfire-affected land polygon. Or simply asking that question on a land parcel by land parcel basis as an enquiry is made. Better still, allow the user to view the 'map layers' directly and obtain an enquiry report.

Additionally, textural information relating to the land parcel can be 'attached' to the relevant polygon and delivered by enquiry through the GIS (e.g. owner and address information). While textural databases with land-related information continue to exist, this seems to be a legacy of textural information databases woven into organisational operating systems. The fact is maintenance and quality control of land parcel relevant textural information is now achievable through the GIS.

The current duplication of information (both spatial and textural) in GIS and textural databases is inefficient and leads to increased data management costs and errors. Where information can be spatially represented or directly attached to a land parcel in a GIS, this GIS information should be used as the single source.

3 A SINGLE DYNAMIC CADASTRE

3.1 Why Have a Single Cadastre?

The need for a single cadastre is obvious, recognising that the cadastre is dynamic and it is therefore essential to update the spatial information and textural data as it changes. Many of the cadastres in use are fairly static and differentially updated (if at all). Multiple cadastres prevent single-source access to *all* available information. Many cadastres and their respective information datasets are not directly available to users.

A single agreed cadastre, available to all *information generators*, that is current in terms of its graphic representation of land parcels would form a consistent base for all spatial information datasets. It will reduce duplication and maintenance, resulting in overall cost savings.

3.2 What Information Systems Utilise the Single Cadastre?

This list of information systems utilising a single cadastre is endless. Some examples are given below.

Systems providing access to cadastral data:
- Lot and DP details.
- Location of property boundaries.
- Dimensions, size and shape of properties.

Systems providing access to subsidiary spatial datasets:
- Zoning.
- Hazards.
- Planning information.
- Vegetation mapping.
- Soil mapping.
- Land form (e.g. LiDAR and contours).
- Transport systems.

Interactive systems allow interrogation of spatial and related textural systems relating to land parcels. These are already in use by a range of authorities but can be better managed and provide better service through a common cadastre based system. Current examples include ePlanning systems, issuing planning certificates online, SCIMS (Kinlyside, 2013) and service location.

A significant single feature of a state-wide cadastral database linking planning, hazard, service and environmental information (all of which is currently available in disparate systems) would be the ability to spatially integrate layers of information on a state-wide (or regional) basis. A simple planning example would be to find the number of properties with an area greater than 800 m^2 within land zones R2 (low density residential) not affected by flooding or bushfire hazard with a slope of less than 15%.

Currently queries such as this just cannot be dealt with at the state or regional level, significantly limiting planning at that level. Future users (both public and private) should be able to access the common cadastre to provide interactive systems in accordance with agreed (and where appropriate contracted) protocols. Fee for service is an obvious factor.

3.3 What Should a Common Dynamic Cadastre Allow Users to Do?

Information generators should be provided with access to an up-to-date state-wide NSW (and aspirationally Australian) dynamic cadastre (or the section of the cadastre to which their use relates) as well as an agreed procedure and mechanism for adjusting cadastre-related information as changes occur. This protocol and mechanism is the essential management element if a single cadastre is to be developed and implemented.

Information users should have multiple entry points available, but no matter where you enter a spatial information system based on the common cadastre, you should reach all available datasets:

- All data available once you enter a system.
- Seamless access (you do not know where the cadastre comes from; you just know it is up to date and can determine the accuracy metadata).
- No passwords required.

3.4 How to Build and Maintain a Single Dynamic Cadastre?

Take the best available sections of the cadastre and ‘stitch it together’ from the individual sources to form a composite cadastre. Each source body should be responsible for maintenance (which they do now anyway). Currently it seems that the only authorities using and maintaining a cadastre are a number of local councils. These would act as sources for

sections of the dynamic cadastre.

The State would be the de-facto manager of the single dynamic cadastre, supporting it where other authorities do not have the capacity to do so. Maintenance would be carried out on an agreed basis and the updated sections projected into the composite cadastre. Initially this update could be on a weekly basis, but as systems evolve it would head towards real time.

3.5 How Can Subsidiary Layers Be Maintained?

As previously stated, many information layers ‘hang off’ the cadastre, i.e. spatial information is defined by polygons that are based on the boundary locations within the cadastre. This means that any change in location of boundaries in an agreed common cadastre need to be reflected in the subsidiary layers of spatial information. This is why many authorities (mainly councils) have been loath to change the base cadastre other than updating for individual lot creation and consolidations. Councils with a comprehensive GIS based on the cadastre already maintain these subsidiary information layers and related textural information as changes to their respective cadastres occur. This process is not cheap but is essentially the same or less than previous manual systems of information recovery and leads to huge performance improvement, e.g. planning certificates available online in real time, ePlanning systems and improved land management (rating) systems.

The cost to maintain these datasets is approximately $5-10 per parcel per annum for councils using comprehensive GIS with multiple subsidiary layers. Some authorities/bodies can manage their respective subsidiary layer information, others cannot (opportunity for service provision at cost for a central government authority or private enterprise). What is certain is that there should be only one ‘layer’ of like subsidiary information available and its maintenance should be in accordance with an agreed protocol.

Classic examples of multiple layers of essentially the same information are land zoning maps in NSW, some maintained and some not. A single dynamic cadastre and agreed management and maintenance protocols between information providers would eliminate duplication (save costs) and provide users with updated and correct information. Where this information is statutorily based (e.g. zoning maps and bushfire-prone land maps), legislative changes will be required.

3.6 Legislation Required

Legislative change is needed on several fronts. Legislation is required to allow formal reliance on computer (GIS) generated spatial data. The classic examples are zoning maps and bushfire-prone land maps. Both are primarily used in their GIS form but statutorily required in hard paper (or like) format. Legislation should also require statutory information that can be expressed spatially to be so expressed rather than as a written specification. In the planning sphere alone this would cut red tape dramatically, e.g.

- A single map layer showing where complying development is permissible rather than a bundle of written restrictions most of which can be spatially expressed.
- State Environmental Planning policies being expressed spatially (as a map layer).

3.7 When?

A 10-year timeframe has been talked about. However, in the author’s opinion, 10 years is 8

years to long. Project times greater than 2 years are simply unrealistic politically, financially and technologically. Delivery of outcomes must commence within 2 years or ‘it’s a dead duck’. Initial delivery might be limited to a number of significant datasets and services (i.e. low-hanging fruit) with a clear program to deliver increasing functionality and accuracy over time. The target should be one year to plan and one year to commence delivery.

3.8 How?

A project plan needs to be developed. The following tasks might be included but not necessarily in this order:

- Identify information providers that manage their own cadastres.
- Identify information providers that rely on others to maintain the cadastre.
- Identify information providers that rely on an unmaintained cadastre.
- Develop a protocol for a dynamic composite cadastre.
- Develop a protocol for maintaining the composite cadastre.
- Develop a protocol for maintaining subsidiary layers.
- Specify the procedure and requirements to produce and maintain a composite dynamic cadastre.
- Specify the procedure and requirements to maintain subsidiary layers relating to the composite dynamic cadastre.
- Prepare a stakeholder agreement.
- Get buy-in from users.
- Identify required legislative changes.
- Prepare a cost-benefit analysis.
- Prepare an implementation plan.
- Establish a timetable.

This needs to be followed by implementing the plan.

4 COMMERCIAL OPPORTUNITY

Commercial opportunity abounds on several fronts. Certainly if action is not forthcoming and immediate private enterprise is likely to recognise the opportunity and enter the market place on a selective customer-focused basis, i.e. setting up systems serving high-use areas and ignoring areas where costs outweigh income (rural NSW).

Where authorities do not have the capacity to manage and maintain a section of the dynamic cadastre or subsidiary layers, a de-facto manager should be established. Given current roles and skill sets, the only public authority with capacity is LPI. However, it should be recognised that private enterprise is looking over the shoulder.

Given the considerable benefits such a system will realise in reduced duplication and improved service levels, this service must be funded either directly from those obtaining the service (in lots of cases this will be ‘poor’ country councils) or State Government (at least initially until other commercial opportunities can be developed and exploited). Public sector and private enterprise interactive systems based on the common cadastre will provide a range of commercial opportunities.

4.1 Layer-Related Advertising

Every time a layer is accessed, opportunity is available for related services to be advertised on a spatial basis. For example, the zoning layer is viewed in in a specific Local Government Area (LGA). This enables a 'pop up' advertisement *Find a Planner,* and when the user clicks (at their discretion), ads for town planners servicing this area are provided. The planners pay for this service. Similarly, this would work for bushfire consultants, engineers, builders, certifiers. More sophisticated systems can obviously be developed relating to associated textural information.

4.2 Sale of Information

Sale of information can include:

- Sale of title and land-related documents (e.g. Deposited Plans, Certificates of Title, dealings).
- Planning certificates.
- Service diagrams.

4.3 Applications with Associated Fees and Charges

These applications can include:

- Application lodgement facilities (including private enterprise).
- Obtaining quotations for services.

5 CONCLUDING REMARKS

The cadastre is a valuable item, however ownership is unclear. A common dynamic cadastre is the logical next step. It would provide the base layer for a range of spatial and related information systems that will improve productivity and reduce costs. Commercial opportunities utilising the cadastre abound. The technology is available. Legislation is needed. Gesta non verba (deeds, not words).

This will involve the following:

- Establish ownership of the cadastre.
- Achieve agreement between stakeholders as to the need for a common cadastre and define roles and responsibilities.
- Develop a staged plan to make it available.
- Develop systems and procedures to ensure subsidiary information layers are consistent with the cadastre.
- Identify and develop commercial opportunities.

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Examples of Legal Aspects of Boundary Surveying as Apply for Crown Lands in NSW

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ABSTRACT

It is well recognised that surveyors are included among those professions with an ageing workforce and need to look towards systems to capture knowledge of peers before it is lost. The Department of Primary Industries (DPI) – Lands (Crown Lands) is also experiencing the loss of knowledge due to staff retirements and restructuring for both surveyors and allied staff. As I look to my own retirement, I have determined to prepare a reference document that is a collation of knowledge collected over many years by personal experience and from my peers who hold specialised knowledge in many areas of Crown Lands operations. The title of this paper is a deliberate play on words from Hallmann's well respected tome. For this or any conference, a paper of this nature would be almost certain to send even the most interested audience to sleep. As such and with constraints of time, a number of examples have been compiled to outline issues with some detail of knowledge sources, precedents and opinion. Land law includes opinions and advice that may be regarded as valid until tested in court. The examples provided include matters involving tidal and non-tidal waters, possession adverse to the Crown, closer settlement, land ownership and roads.

KEYWORDS: *Crown lands, land law, closer settlement, adverse possession, roads.*

1 INTRODUCTION

The role of Crown Lands surveyors includes the provision of professional survey advice and support services for Crown land and lands adjoining Crown land as well as project managing land management projects to achieve government priorities in the management of Crown land. The team provides expert support to all of the Department of Primary Industries – Lands / Land and Natural Resources business programs.

Over the years many different issues and requests for advice both by internal and external clients have required resolution. With the aid of available resources including written material particularly Hallmann (2007), Willis (1982), Registrar General's Directions (LPI, 2015a), the Office Practice Guidelines – Crown Lands Management (DPI-Lands, 2013) and publications dealing with water as a boundary (Lands, 1989) as well as experienced co-workers, surveyors and non-surveyors, solutions have been determined and advice provided. It should be noted that the Office Practice Guidelines have not been updated for many years and have moved from a hard-copy, loose-leaf resource available in Crown Lands offices to online form and have recently been severely restricted in access. While current policy and procedure may not be reflected in the guidelines, they do contain valuable historical concepts that are among the 'lost' or now unavailable knowledge resources.

This paper provides information and examples for some issues as a prelude to an anticipated more detailed information document or resource that will provide future surveyors with reference material that will go some way to filling the void in the knowledge database of past colleagues who are no longer available.

The examples that are presented in this paper include some matters that have been resolved from written material and the advice given is sound and unlikely to be challenged. Other examples include matters that have no precedents and the advice is based on learned opinion and may well be challenged sometime in the future. It is equally possible that some opinions may change – we all learn as we go ahead in life. A different set of eyes on a subject or a lapse in time can be rewarding in that there may be further advancements in our collective knowledge pool. The author encourages ongoing peer review and sharing of matters learned particularly in specialised areas.

2 CROWN LAND AND TENURES

2.1 Grants

European settlement following the colonisation of Australia brought with it many laws and statutes from England, among them the declaration that all of the land including the beds of all waters was Crown land. Grants of land were the means for alienation or transfer of land from the Crown to individuals. Initially grants were made to members of the militia and other persons in public office in recognition of service or of respected members of English society. Later grants were provided to the wider community, both in the colony and in England to encourage further settlement.

The Crown grants each form a record of the initial land dealing and provide details including the location and description of the land and applicable reservations and conditions. Land law (Butt, 2010) distinguishes between exceptions from the grant and reservations (see chapters 20.81.1 and 23.10.1). Under an exception, no part of the excepted land passes with the grant. As an example, the 30.48 m (100 foot) reservations of land above the Mean High Water Mark (MHWM) are exceptions. Reservations are placed over the granted lands with the Crown retaining a right to take back the specified land or property if and when required. It is not uncommon for reservations to have been wrongly used as exceptions. Titles deriving from the original grant show as a second schedule notification the continuation of reservations and conditions of the grant. Prior to any survey or dealing with land, it is essential that the grant is obtained and all details applicable to the land are understood.

In the not too distant past, unless it was possible to attend the Land and Property Information (LPI) office in Sydney, it was frequently an awkward and timely process to obtain copies of grants for lands to be surveyed or examined. In recent times, LPI has continued to make land and title records available online via the Spatial Information eXchange platform (SIX – see LPI, 2015b).

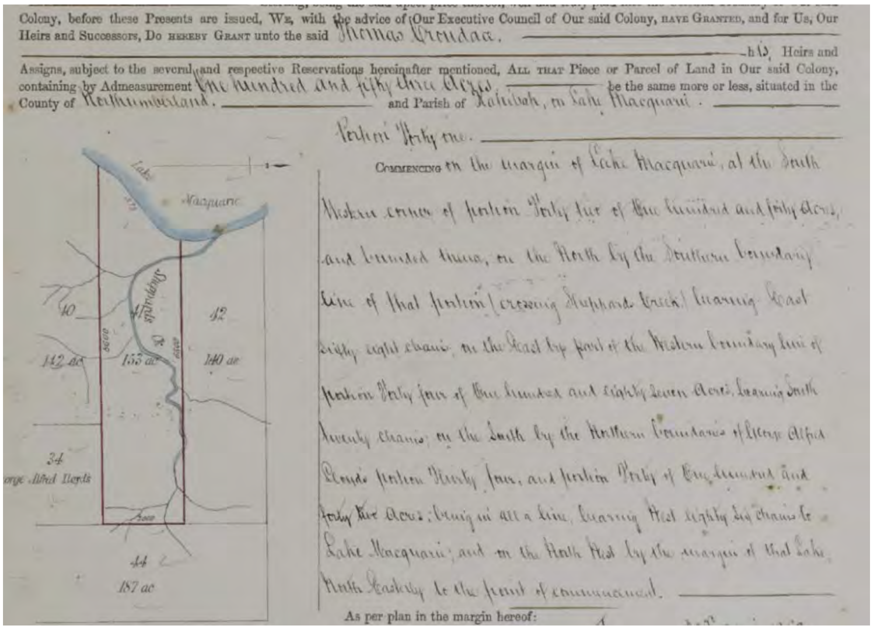
2.1.1 Sheppards Creek

Sheppards Creek flows into Lake Macquarie near Valentine about 20 km south of Newcastle. The original grants of land through which the creek flows were constructed with no mention of the creek, and the associated Crown plans similarly were devoid of defining the creek more

than by way of a line on the face of the plans. Crown Lands received a request for an authoritative determination of the ownership of and management responsibility for the bed of Sheppards Creek between the margin of Lake Macquarie and the bridge at Macquarie Drive (Figure 1).

Figure 1: Sheppards Creek, Valentine.

The issue of ownership of Sheppards Creek has been raised on a number of occasions previously by different sections within Lake Macquarie City Council (LMCC). Early responses provided had mostly stated that title records indicate that the creek was included in the lands granted to Thomas Croudace in June 1869 following sale of portions 41A and 42A in the Parish of Kahibah and County of Northumberland. An extract from the grant of Portion 41A is shown in Figure 2.



Colony, before these Presents are issued, We, with the advice of Our Executive Council of Our said Colony, have Granted, and for Us, Our Heirs and Successors, Do hereby Grant unto the said Thomas Croudace, his Heirs and Assigns, subject to the several and respective Reservations hereinafter mentioned, All that Piece or Parcel of Land in Our said Colony, containing by Admeasurement One hundred and fifty three acres, be the same more or less, situated in the County of Northumberland, and Parish of Kahibah, on Lake Macquarie.

Portion Forty one.

Commencing on the margin of Lake Macquarie, at the South Western corner of portion Forty two of One hundred and forty acres, and bounded thence, on the North by the Southern boundary line of that portion (crossing Sheppards Creek) bearing East eighty eight chains; on the East by part of the Western boundary line of portion Forty four of One hundred and eighty seven acres, bearing South twenty chains; on the South by the Northern boundaries of George Alfred Lloyds portion Thirty four, and portion Forty of One hundred and forty two acres; being in all a line, bearing West eighty six chains to Lake Macquarie; and on the North West by the margin of that Lake North Easterly to the point of commencement.

As per plan in the margin hereof:

Figure 2: Extract of part of grant.

Unfortunately, misunderstanding of officers not qualified in the matter of land ownership has created doubt for various management authorities, and that doubt persists even to the time of this latest request. The confusion stems from the fact that Sheppards Creek is a significantly tidal watercourse that is navigable for a distance and has been populated by berthing and mooring facilities for private vessels.

Figure 3 shows a timeline of significant land dealings for both portions 41A and 42A. Where the land affected by the dealings includes the physical creek (i.e. the creek is within or is adjacent to the land), the timeline is shaded by blue colour.

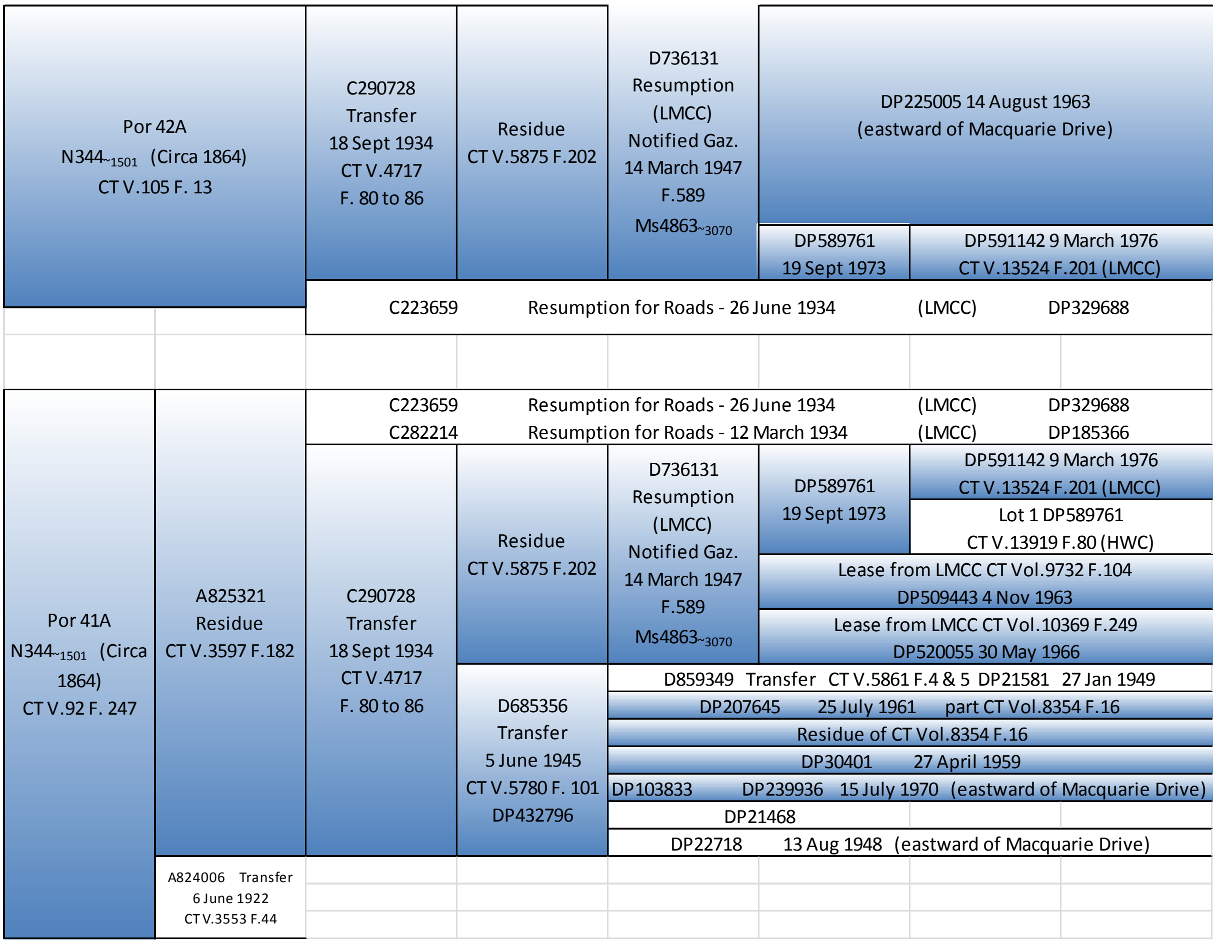


Figure 3: Timeline for dealings.

Following the completion of a thorough investigation of the plan and title records of portions 41A and 42A and derivatives there from, it is apparent that Sheppards Creek was an apparently non-tidal waterway that was not excluded from the land granted to Thomas Croudace in 1869. Crown plan N344~1501 (Figure 4) was completed in the early 1860s.

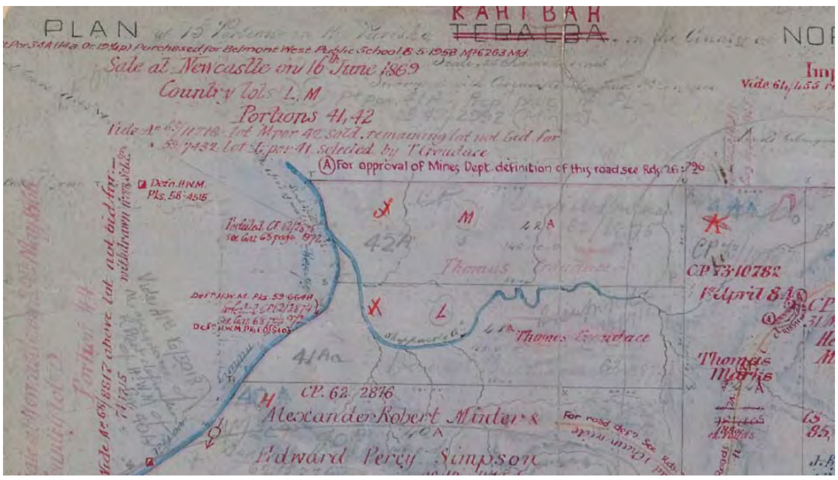


Figure 4: Part of Crown plan 344.

It should be noted that there was also doubt as to the tidality of Lake Macquarie beyond the entrance channel at Swansea, even to the 1980s. A comprehensive study was undertaken by the then NSW Department of Public Works with the result that tidal variations do occur to the margins of the lake and upstream in most of the creeks and rivers that flow into the lake. The ownership of and responsibility for the bed of Sheppards Creek is therefore with the grantee or heirs and assigns thereafter. While the creek or part of the creek may now exhibit tidal variations, from a land boundary perspective it retains the original non-tidal status as determined by historical records. In 1947 much of the land including the northern part of portion 41A and all of portion 42A was resumed by LMCC for improvement and embellishment of the area. Gazette 14 March 1947 folio 589 and Crown Plan (CP) Ms4863$_{\sim 3070}$ refers. DP589716 is a 1973 survey of part of the land resumed by Council in March 1947 west of Macquarie Drive. Land including lot 2 in DP589716 was later surveyed as DP591142. For the part of the creek shown by DP591142 as separating the two parts of lot 200, Lake Macquarie City Council is considered to be the owner and responsible party as a consequence of the resumption.

It should also be noted that DP591142 incorrectly shows Sheppards Creek as a tidal waterway, this is clearly not the case despite the apparent approval of the plan by the Under Secretary of Lands. At the time of the investigation, Permissive Occupancy 12350 was held by Council over a part of Sheppards Creek for the purpose of a swimming pool. Action to terminate this account with effect from 2 April 2012 was recommended.

For the part of the creek that is in the southern section of portion 41A and not being part of the land resumed by Council in March 1947, CT Vol. 5780 Fol. 101 refers. Ownership is individually or severally held by owners of adjacent lands unless retained, reserved or otherwise transferred by a prior landholder:

- The land in CT Vol. 5861 Folios 4 & 5 was transferred as depicted by DP21581 with the individual parcels abutting the creek with title extending only to the creek. The title to the bed of the creek remains with the residue land.
- Part of the residue of the preceding title is CT Vol. 6287 Fol. 134 – this title clearly retained the bed of the creek. As such it is verified that the owners of lots within DP21581 where they abut Sheppards Creek do not own part of the bed of the creek.
- DPs 30401 and 207645 are subdivisions of part of the land in CT Vol. 6438 Fol. 177; these plans again show the lots abutting the creek as being limited by the bank of the creek.
- Transfers of parts of the title with no creek effect included the lands shown by DP21468 and DP22718.
- CT Vol. 8354 Fol. 16 includes the remaining land prior to DP207645 and part of the land east of the Macquarie Drive.

Ownership of this part of the bed of Sheppards Creek is recorded as being part of the residue of CT Vol. 8354 Fol. 16; as such this section of the bed of the creek is owned privately. This title is recorded as a cancelled title.

Figure 5 is a plan of the area showing the creek with part owned by LMCC and part privately owned. That part shown by vertical hatching (i.e. southern part) is privately owned. Where the proprietor of land is unknown and possibly lost in the processes of subdivision and transfer, it may be possible on the basis that there may be a public benefit, to recommence the title process through resumption by Council and creation of a new folio of the register under section 31A of the Real Property Act 1900. It was suggested that Council pursue its own legal

advice concerning the cancelled title and the ownership of the residue of that title.

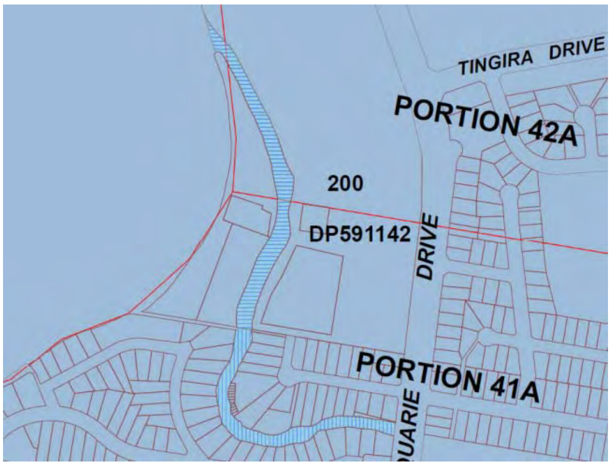


Figure 5: Ownership of Sheppards Creek.

2.1.2 Macleay River

The Macleay River is one of the big coastal rivers of New South Wales; it flows from the watershed beyond Kempsey to the coast near South West Rocks. It is a tidal river with the tidal limit established as being near Kempsey some 30 km from the sea (Figure 6a). Figure 6b shows Spencer Creek as a deviation to the main river channel.

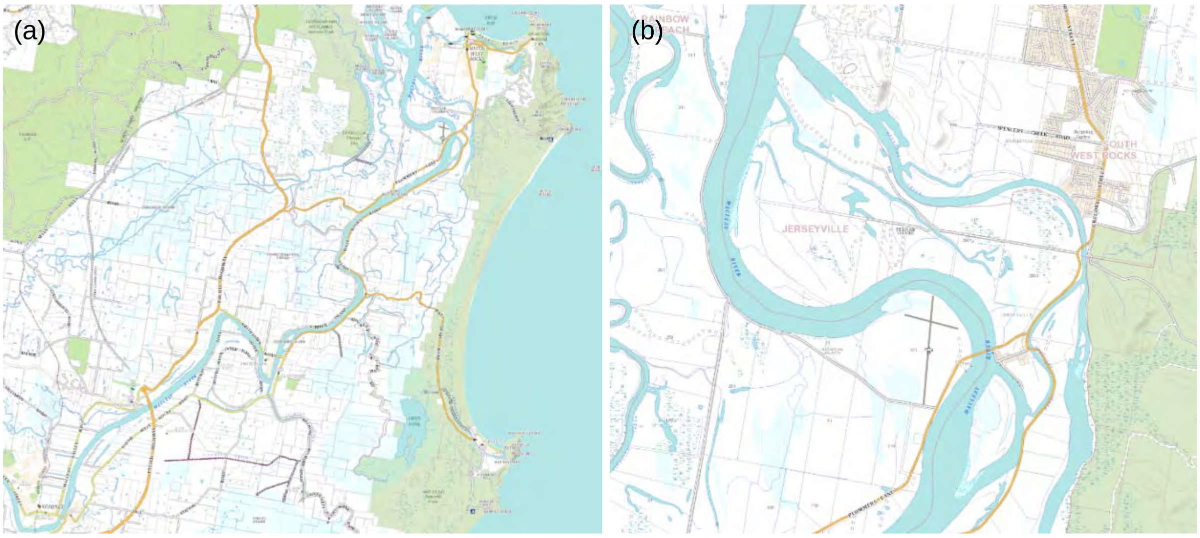


Figure 6: (a) Macleay River to Kempsey and (b) Macleay River and Spencers Creek.

The parish maps are one of the few records that show the tidal limits; the Crown Lands offices also hold an electronic file ‘Tidal limits of watercourses in NSW’. The tidal limits for NSW waters were recorded at varying times mostly since the early 1900s. Table 1 is an extract from the above resource showing for the Macleay River a description of the location of the tidal limit and the file reference for the determination. There are no apparent records for earlier determinations. Parish maps prior to the dates of the corresponding reports either did not show the tidal limits for tidal waters or they were subsequently added as a notification on the face of the then current edition of the map.

Table 1: Tidal limit of Macleay River.

Mangrove Creek	P: Ashby C: Clarence	Tidal to the northern boundary of portion 100	Pks.34-229
Macleay River	P: Yarravel & Kalateenee C: Dudley	Tidal influence extends to Belgrave Falls on southern boundary of portion 1 Parish of Yarravel and on northern boundary of portion 17 Parish of Kalateenee	Pks.34-229
Matenga Creek	P: Scope	Is tidal for about 500m from its junction with Bookram Creek	Pks.34-229

Figure 7 shows the location of the tidal limit at Belgrave Falls, about 5 km upstream from the town of Kempsey, as depicted on the map of the Parish of Yarravel, County of Dudley. This is the 9th edition, printed in 1975 and placed in use in 1978, showing the tidal limit as printed information. The 5th edition dated July 1920 shows the tidal limit as a hand-written notation on the face of the map.

Figure 7: Tidal limit at Belgrave Falls.

It is worth mentioning at this point that another publication exists that records recent tidal limits from 1996 to 2005 (MHL, 2006). This can be a source of confusion to people who do not realise the legality of the historic location of the tidal limits.

The following question has been asked: “How can we know and prove the tidality of a river or section of river prior to the reports being completed?” Why is this question important? It can be very difficult to prove the tidality of a river and if tidal where the limit of tidal influence is and was at prior times during the period of settlement. While in many cases it may not be possible to prove these attributes of waterways, it is necessary to collate as much information from all reference sources to be able to put a case to make a judgement call.

Firstly, the tidality of a river is important as the applicable rights that assign to lands abutting waterways differ and then those rights apply according to the tidal nature when the land was granted. Consequently, if a waterway changed its tidal regime at some time after the land was granted, the type of boundary and the applicable rights remain as at the time of the grant.

Secondly, while the English ‘land laws’ were passed into the legislative and statutory processes of the colony, in particular New South Wales, the construction of early grants and associated Crown plans may be less than conclusive with regard to the extent of lands with boundaries comprising waterways other than on the sea coast. It has been found that for many, if not all grants and plans prior to 1886, there was no distinguishing between tidal and non-tidal waters. It appears from a review of old surveying instructions and regulations that prior to the release of the 1886 surveying regulations there was no mention of High Water Mark

(HWM). The 1886 regulations were apparently the first instructions for surveyors to actually identify and measure the HWM and adopt it as a boundary.

Some grants do not show internal waters and the accompanying plans are similarly devoid of measured lines to enable these features to be excluded from the title. This remains so even if the waters are tidal and the grant is subsequent to the general reservations of the beds of rivers and creeks. Grants and the relevant Crown plan surveys abutting waterways prior to 1886 were devoid of any distinguishing characteristics for tidal waters; they appear exactly the same as those applying to lands abutting non-tidal waters.

An application was received for an easement for underground powerlines over part of the bed of the Macleay River and a small creek deviation of the main river channel. Both of these waters are at the present time tidal waters. As the beds of tidal waters are Crown land, easements across tidal waters must be acquired. Figure 8 shows the proposed easement in red colour where it crosses both waterways.

Figure 8: Proposed easements across Macleay River and Spencers Creek.

The case officer investigated the application and based on available records including current titles and recent survey plans that indicate the waters to be tidal, advised the applicant that the required easements were to be acquired. CP $608_{\sim 666}$ is a plan dated March 1869 that shows 22 portions as measured for sale by auction. Apart from notations later added to the plan, there is little to indicate the tidal status of the waterways. Figure 9 is an overlay of this plan and the proposed easement on recent aerial imagery.

The applicants sought legal advice and, based on the advice received, claimed that the Crown did not own the beds of the waters as the grants and original Crown surveys for the abutting lands show the waters to be non-tidal. It is the author’s opinion that the legal advice was made without appreciating the lack of survey instructions, directions and regulations regarding tidal waters prior to 1886. The Macleay River would certainly have been tidal for a considerable distance past the site of the required easements since at least European settlement. On this premise it is considered that the applicable original grants were in error and the waters were tidal at the time of alienation and titles to the lands abutting excluded any presumptive ownership of the bed of the river or creek. If this opinion was to be challenged in the courts, it would require the services of well-briefed legal team to challenge the concept that the grant is infallible and indefeasible. It is noteworthy that quite a number of recent plans and titles in the area of investigation are recorded as showing the river as tidal and abutting a tidal river.

Figure 9: CP608, overlaid on aerial imagery.

2.2 Reservation by Exclusion of Land

Grants are issued with conditions and reservations. In the early 1800s our forefathers recognised the importance of maintaining access to waters ‘as a public need’. Consequently, some early grants, and later all grants where the land adjoined tidal waters, excluded from the grant by reservation to the Crown all of the land above and along the Mean High Water Mark (MHWM) boundary to a width of 30.48 metres or 100 feet. There have been errors in so much as these reservations have been included in grants where the adjoining waters were non-tidal and thereby invalidating the reservation.

The position of these reservations is defined as at the date of the grant. That means that the landward boundary remains fixed at a distance of 30.48 m landward of the MHWM at the date of the grant. The MHWM boundary of the reservations is subject to accretion and/or erosion where the doctrine of ‘accretion’ is satisfied in that the processes of change are natural, gradual and imperceptible. Consequently, subsequent to the grant the reservation may alter in width as the MHWM boundary ambulates.

The quality of surveys at the time of old grants is frequently poor or possibly more often not even on public record. The practice that has been encouraged is to adopt as a pseudo ‘grant’ survey, the first available survey that is often the survey accompanying a primary application.

2.2.1 Hunter River at Raymond Terrace

Some years ago a landowner had made a purchase of a rural parcel of land with a frontage to the Williams River, a tidal river near the confluence of the Hunter River. Figure 10 shows the property partly surrounded by water boundaries.

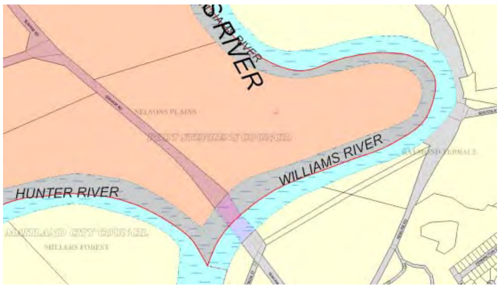
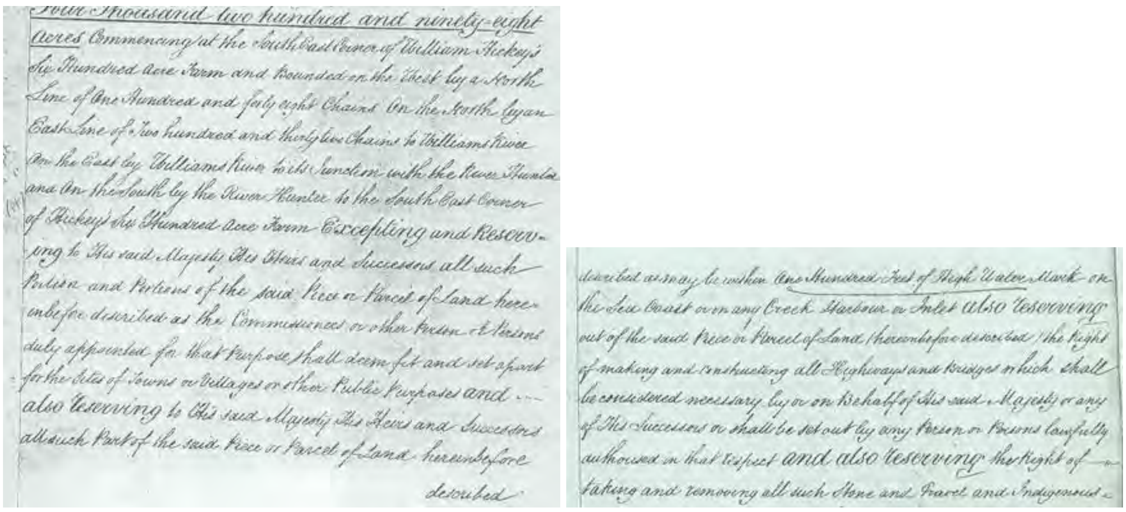


Figure 10: Lot 1 DP136263.

This landowner had engaged the services of a solicitor to negotiate the many hurdles that may be revealed during the conveyancing process. Prior to the purchase, a Crown Lands account search was obtained. Unfortunately, this search is only for advice of any Crown authorisations or tenures that are applicable to the land and does not include advice as to titular matters. The land was purchased and the owner then proceeded to develop the land, until it was revealed that the development would include part of the land excluded from the grant by way of reservation to the Crown.

The solicitor was subsequently found to have been unaware of the 30.48 m wide reservation of land along the MHWM boundary. The solicitor had relied upon old conveyances that did not include the reservation and did not recognise the importance of the second schedule notification of the latest title in that it includes conditions and reservations of the Crown grant. Figure 11 is part of the grant showing the description of the land bound by the Williams and Hunter Rivers. The second part shows the reservation of all land within 100 feet of the HWM on the sea coast or on any creek, harbour and inlet.


Four Thousand two hundred and ninety-eight acres Commencing at the South East Corner of William Hickey's Six Hundred Acre Farm and Bounded on the West by a North Line of One Hundred and forty eight Chains On the North by an East Line of Two hundred and thirty two Chains to Williams River On the East by Williams River to its Junction with the River Hunter and On the South by the River Hunter to the South East Corner of Hickey's Six Hundred Acre Farm Excepting and Reserving to His said Majesty His Heirs and Successors all such Portion and Portions of the said Piece or Parcel of Land hereinbefore described as the Commissioner or other Person or Persons duly appointed for that Purpose shall deem fit and set apart for the Sites of Towns or Villages or other Public Purposes and also reserving to His said Majesty His Heirs and Successors all such Part of the said Piece or Parcel of Land hereinbefore described

described as may be within One Hundred Feet of High Water Mark on the Sea Coast or on any Creek Harbour or Inlet also reserving out of the said Piece or Parcel of Land (hereinbefore described) the Right of making and constructing all Highways and Bridges which shall be considered necessary by or on Behalf of His said Majesty or any of His Successors or shall be set out by any Person or Persons lawfully authorised in that respect and also reserving the Right of taking and removing all such Stone and Gravel and Indigenous

Figure 11: Extract from Crown grant.

2.2.2 Black Neds Bay, Swansea

The original grant of land to John Herring Broughton was for 2000 acres, being portion 45 in

the Parish of Wallarah and County of Northumberland, excluded land within 30.48 m of the MHWM of Black Neds Bay even though the grant included the waters of Black Neds Bay. Figure 12 is an extract of the grant showing the description of the land including a salt water basin and the gut connecting it with the entrance to Lake Macquarie. Without a diagram it is very difficult to interpret the extent of the grant. The grant continues with the reservations including the land within 100 feet of the HWM.

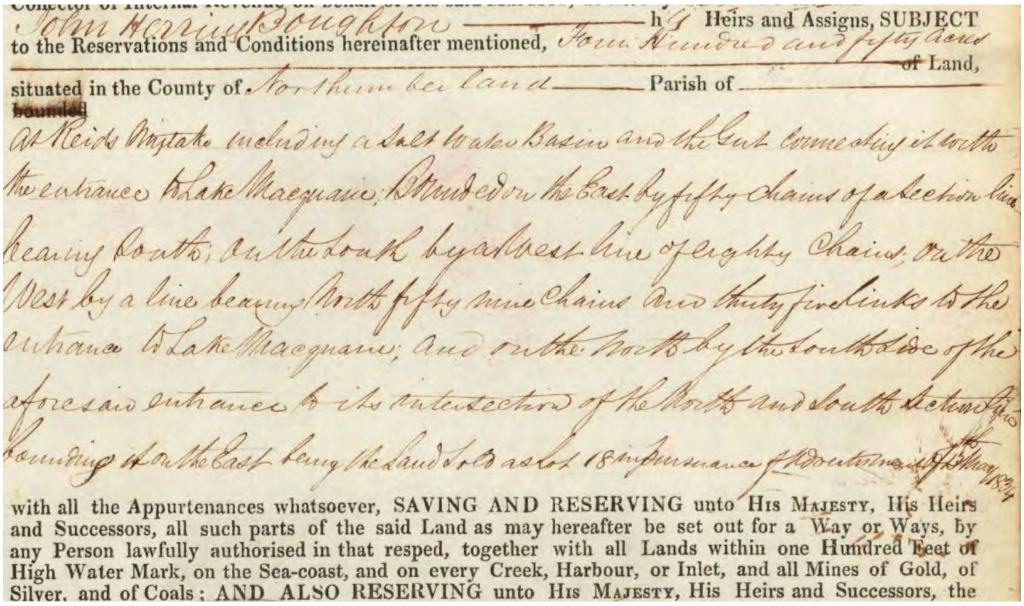

John Herring Boughton his Heirs and Assigns, SUBJECT to the Reservations and Conditions hereinafter mentioned, Four Hundred and fifty Acres of Land, situated in the County of Northumberland Parish of
bounded
At Reids Mistake including a Salt Water Basin and the Gut connecting it with the entrance to Lake Macquarie; Bounded on the East by fifty chains of a section line bearing South; on the South by a West line of eighty Chains; on the West by a line bearing North fifty nine Chains and thirty five links to the entrance to Lake Macquarie; and on the North by the South side of the aforesaid entrance to its intersection of the North and South Section forming its East boundary being the Land sold as lot 18 in pursuance of ... May 1834
with all the Appurtenances whatsoever, SAVING AND RESERVING unto His Majesty, His Heirs and Successors, all such parts of the said Land as may hereafter be set out for a Way or Ways, by any Person lawfully authorised in that resped, together with all Lands within one Hundred Feet of High Water Mark, on the Sea-coast, and on every Creek, Harbour, or Inlet, and all Mines of Gold, of Silver, and of Coals; AND ALSO RESERVING unto His Majesty, His Heirs and Successors, the

Figure 12: Extract from Crown grant.

Figure 13a is provided to assist with the location of the grant, particularly in relation to CP $H96_{\sim663}$, i.e. the plan of portion 45 (Figure 13b).

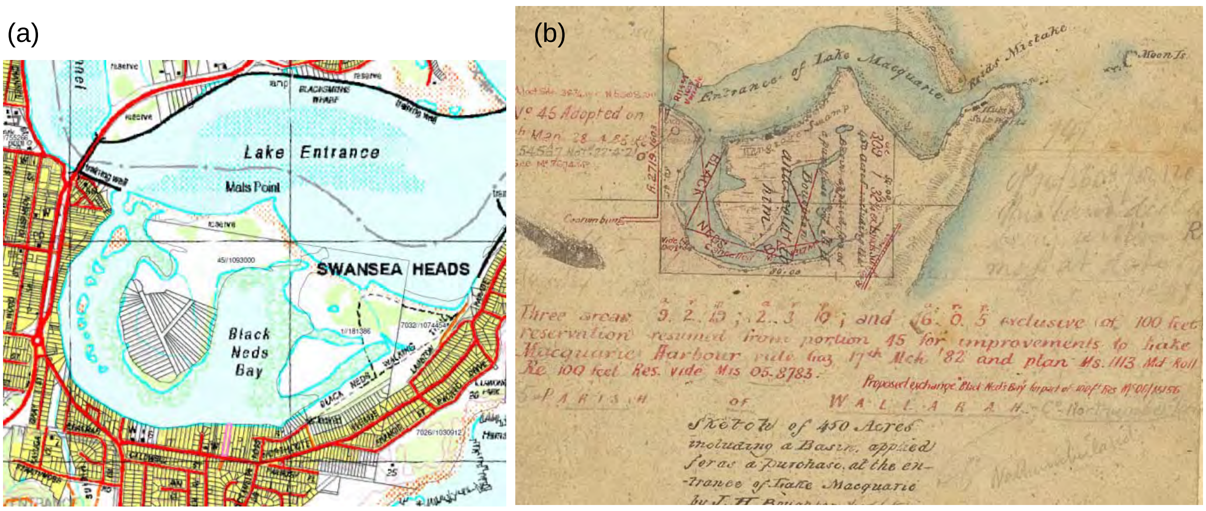


Figure 13: (a) Map of Black Neds Bay and (b) part of Crown plan H96.

Figure 14 is a notification added to the Crown plan that is very explicit in relation to the land 3 feet wide below the HWM. The notation refers also to CP $Ms1317Md_{\sim3070}$ and indicates that some land has been surrendered to the Crown in accordance with Ms1317. The cadastral integrity for some properties abutting Black Neds Bay has been questioned due to the uncertainty of the ownership status and title of a strip of land 3 feet wide below the MHWM that may have been excised from the Crown estate.

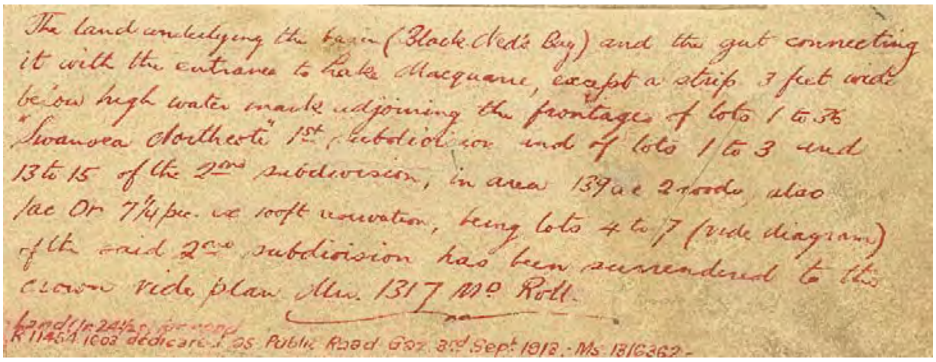

The land underlying the basin (Black Ned's Bay) and the gut connecting it with the entrance to Lake Macquarie, except a strip 3 feet wide below high water mark adjoining the frontages of lots 1 to 35 Swansea Northcote 1st subdivision and of lots 1 to 3 and 13 to 15 of the 2nd subdivision, in area 139ac 2roods, also 1ac 0r 7¼ per. ie 100ft reservation, being lots 4 to 7 (vide diagram) of the said 2nd subdivision has been surrendered to the Crown vide plan Ms. 1317 Mo Roll.
R 11464.1603 dedicated as Public Road Gaz. 3rd Sept 1918. Ms 1816362

Figure 14: Notation on Crown plan H96.

The investigations found:

- Ms1317 represents an investigation and MHWM redefinition survey and is considered to form the basis for survey definitions and extent of titles for the area.
- A strip of land 3 feet wide as shown on Ms1317 affects some properties.
- Crown ownership of the bed of Black Neds Bay, excepting a strip 3 feet wide below the MHWM by Ms1317.
- A right existed for certain adjoining landowners to reclaim beyond the MHWM to a line 3 feet easterly of the MHWM as defined by Ms1317.

The following outcomes resulted from deliberations between Crown Lands and LPI:

1. Those properties where the right to reclaim has been exercised with longstanding effect are to be considered for title purposes, to be bound by right line(s) being the easterly limit of the 3-foot strip as shown by Ms1317 or occupied part thereof.
2. Those properties where the right to reclaim was not put into effect or was effected in relatively recent time are to be considered for title purposes to be bound by the MHWM as shown by Ms1317.
3. The right to reclaim has expired due to the passage of time.
4. Where the right to reclaim has expired including any part of the 3-foot strip not utilised for reclamation, the land being part of the bed of Black Neds Bay is Crown land.

The Australian Joint Stock Bank sought to develop parts of the grant and negotiated to exchange the 30.48 m reservation with the bed of Black Neds Bay. Following the land exchange of the tidal waters of Black Neds Bay for the 100-foot reserve (gazette 19 January 1910), titles were issued over the land containing the 100-foot reserve so that properties fronting Bowman Street could be extended to the bay. Those titles were issued to the MHW and dimensions mentioned in titles correspond to those found on Ms1317. The outcome was that the 30.48 m reservation was added to the alienated land and the bed of Back Neds Bay (excluding a 3-foot strip of land below MHWM fronting part of Black Neds Bay) was returned to the Crown. Prior to the survey for Ms1317 conveyances between the Australian Joint Stock Bank and the adjacent land owners included grants to those owners of a right to reclaim out to the eastern limit of the 3-foot strip. After considerable investigation and consideration together with senior survey, legal and title staff of LPI, it was determined that the strip of land was a right to claim land that was occupied at that time. Where the land was not occupied, the Crown owned the bed of the bay to the MHWM.

Figure 15 is part of Ms1317 and shows the survey for the 3-foot strip along the north-western part of Black Neds Bay. Diagram A as shown in the plan provides much needed clarification of the survey detail. As evident, this plan is in a very poor state of repair and the standard

monochrome image view is less than adequate. The plan heading as shown in Figure 16 also provides details of the actions proposed and completed with respect to affected lands.

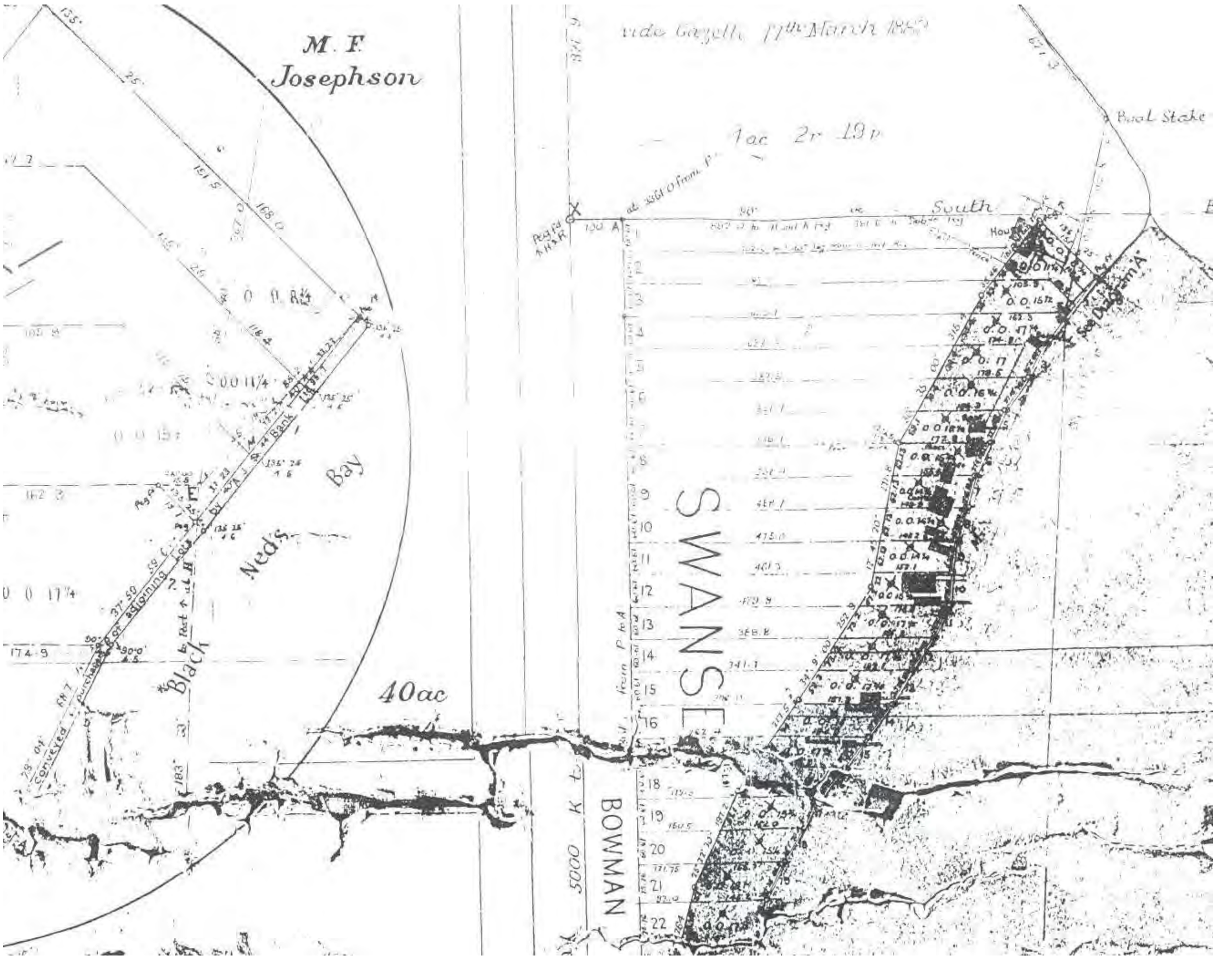


Figure 15: Part of Crown plan Ms1317.

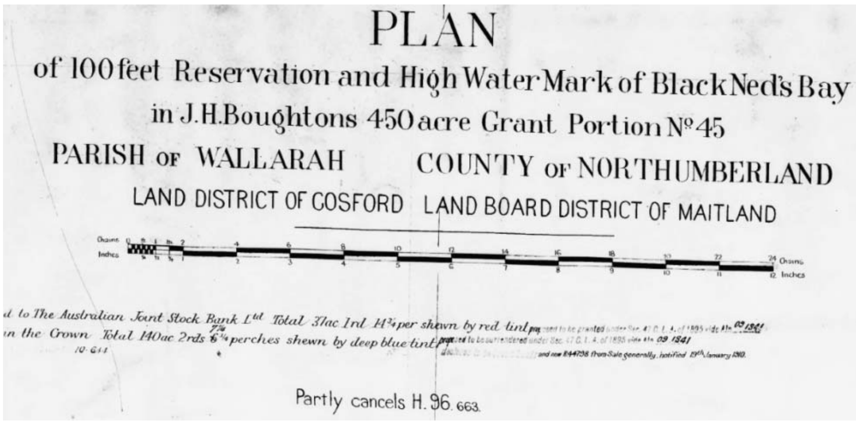


Figure 16: Plan Heading of Ms1317.

The land underlying Black Ned's Bay except a strip '3 feet' wide below the MHWM adjoining lots 1 to 36 in Northcote's First Subdivision and some lots of the second subdivision were surrendered to the Crown vide plan Ms1317. This plan of survey was completed in 1908, showing the 100-foot reservation and the HWM of Black Ned's Bay in portion 45.

Despite the land in the original grant being old system title, the exchanged land comprising the 100-foot reservation and 3-foot strip are Torrens title by virtue of the survey of 1908. Based on the information available, the author is of the opinion that the position of the MHWM as shown by CP Ms1317 MdR supersedes that indicated by DP977409. This plan is thought to be a sale or proposed subdivision plan that preceded Ms1317.

Due to the physical changes such as seawalls that are now constructed along the foreshore of the bay and a lack of photographic or other information depicting the processes of change, the boundary is considered to be in the position as shown by Ms1317 Md. This assertion may be complicated by the fact that the 3-foot strip below the MHWM was also conveyed to the adjoining land owner(s) where the right to purchase was satisfied. Legal opinion at LPI is that the requirement to satisfy the right was the construction of seawalls on this land within a defined period of time. Where the right was not satisfied, the land reverted to Crown ownership as part of the bed of Black Neds Bay. The ‘seaward’ position of the strip would have been fixed at the date of ‘transfer’ just as the landward strip of a reserve is fixed at the date of grant of land including such reservation.

Are the lands that include the 3-foot strip bound by a right line boundary in a position 3 feet below the MHWM? As a consequence of the right applying to the construction of a structure, the author believes this is the case and as such the land is not affected by accretion or erosion. This boundary by virtue of how it is defined is a right line boundary, thus the ambulatory MHWM cannot move beyond it.

2.3 Adverse Possession Against Crown

At a first look, section 170 of the Crown Lands Act 1989 (NSW Legislation, 2015) appears to preclude adverse possession against the Crown:

Section 170: Limitation on acquisition of title by possession against the Crown

(1) Title to any land of the Crown which has been:

(a) set out as a road under an Act or in connection with the alienation of land of the Crown,

(b) left between Crown grants for use as a road or driftway,

(c) dedicated under the Crown Lands Acts or any other Act for a public purpose, or

(d) reserved in a Crown grant or recorded in a folio of the Register as being reserved to the Crown, may not, on the basis of adverse possession, be asserted or established against the Crown or any persons holding the land in trust for a public purpose.

(2) Title to any land of the Crown reserved under the Crown Lands Acts or any other Act for a public purpose (not being land referred to in subsection (1)) may not, on the basis of adverse possession, be asserted or established against the Crown or any persons holding the land in trust for that public purpose.

(3) Title to any other Crown land may not, on the basis of adverse possession, be asserted or established against the Crown.

(4) This section does not affect the operation of section 46B of the Real Property Act 1900.

(5) This section does not affect the title to any land:

(a) which has, in any proceedings to which the Crown has been a party, been held not to be land of the Crown:

(i) before the date of assent to the Crown Lands (Amendment) Act 1931 in the case of land referred to in subsection (1),

(ii) before the date of assent to the Crown Lands (Amendment) Act 1977 in the case of land referred to in subsection (2), or

(iii) before the date of commencement of Schedule 4 (11) to the Crown Lands (Miscellaneous Provisions) Amendment Act 1982 in the case of land referred to in subsection (3), or

(b) which the Crown was debarred from recovering by the operation of the Crown Suits Act 1769 or the Limitation Act 1969:

(i) at the date of assent to the Crown Lands (Amendment) Act 1931 in the case of land referred to in subsection (1),

(ii) at the date of assent to the Crown Lands (Amendment) Act 1977 in the case of land referred to in subsection (2), or

(iii) at the date of commencement of Schedule 4 (11) to the Crown Lands (Miscellaneous Provisions) Amendment Act 1982 in the case of land referred to in subsection (3).

A full reading of this section shows that adverse possession against the Crown is possible, and Hallmann (2007) gives a very good presentation on this legislation with section 170(5) in particular being clarified (chapter 9.46):

Section 170 of the Crown Lands Act 1989 (formerly section 235B of the Crown Lands Consolidation Act 1913) provides that title cannot be established by adverse possession in respect of:

(1) land of the Crown which has been set out as a road, or left between Crown grants for use as a road or driftway (i.e. a travelling stock route or similar way), or dedicated under any Act for a public purpose, or reserved to the Crown in a grant or in a folio of the Register;

(2) land of the Crown reserved under the Crown Lands Act or any other Act for a public purpose (not being land mentioned in (1));

(3) any other Crown land.

The abovementioned provisions do not apply, however, to defeat a claim where the adverse possession of:

- *land referred to in (1) had matured before 2 October 1931,*
- *land referred to in (2) had matured before 31 October 1977,*
- *land referred to in (3) had matured before 19 July 1982.*

Chapter 9.47 continues to complete the picture regarding need for action to occur before the elapse of time:

Prior to 1971, a person out of possession and entitled to recover possession of freehold land, who failed to take action, was barred from recovery after the lapse of 20 years from the time when the right of action first began. The limitation provisions were adopted from a contemporary English Act and took effect from 1 August 1837. Since the commencement of the Limitation Act 1969, the period of 20 years has been reduced to 12 years for the benefit of possessory titles running from 1 January 1971.

The limitation period begins to run when a person goes into adverse possession of land and conversely, at the same time, a right accrues to the true owner to bring an action for recovery of the land.

2.3.1 30.48 m (100 ft) Reservation

With respect to a 100-foot reservation used as part of a grazing property for over 60 years maturing prior to October 1931, advice received from legal services is that possession adverse to the title landowner has to be a barrier to re-occupation. As such the land must be fenced or otherwise used to bar access to the land, grazing itself is not sufficient and where there is no fencing along the waterway, the land may be re-accessed.

2.3.2 Survey of Crown Land at Sedgefield

The survey represented by the Plan of Subdivision of part lot 7300 DP1127501 – Possession adverse to the Crown is required for the purposes of the transfer of title for land granted under section 36 of the Aboriginal Land Rights Act 1983 (ALRA). Figure 17 shows lot 7300 as unidentified land in that the title is a limited folio of the Torrens register. The survey requires lot 7300 to be subdivided to provide for the transfer of the land granted under the ALRA and that the title is delimited.

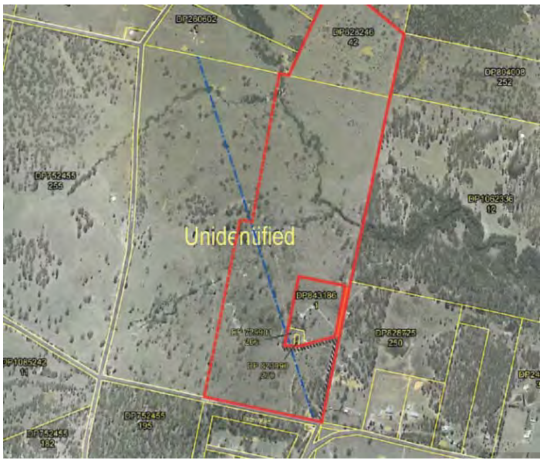


Figure 17: Unsurveyed Crown land.

In the process of survey it was found that existing fencing along the northern boundary common to lots 1 and 4 in DP260602 is located within the subject lot 7300. The very old fence is on the line of the remains of a very much older post and rail fence and commences in the east close to the boundary and diverges westward such that it is about 1.5 m south at the intersection of lots 1 and 4 and then continues to the western extent of lot 1 where it is about 3.7 m south of the boundary. CP(road) R6115$_{\sim1603}$ dated 1898 (Figure 18) shows the line of an old post and rail fence in a similar position to that now found remaining. The plan was of a road opened under the Crown Lands Act of 1884, the road was through portion 219 Parish of Darlington, County of Durham that was reserved (Commonage) Crown land as depicted in CP247$_{\sim1557}$ dated about 1863. This plan was not used for titling purposes.

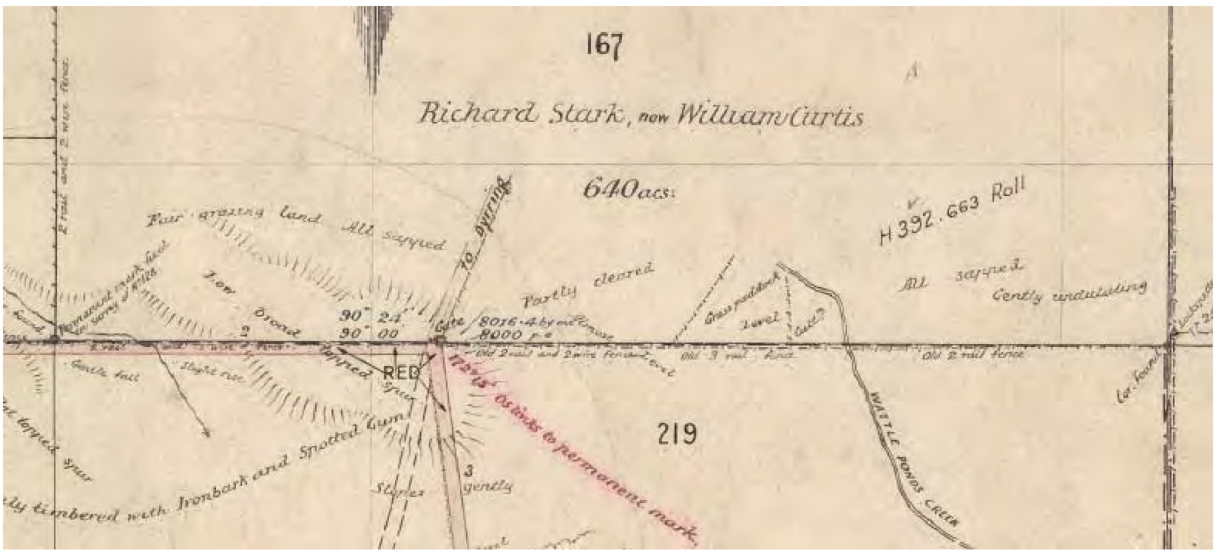


Figure 18: Part of Crown plan R6115.

The evidence of occupation for more than 117 years upon part of the subject land is considered to limit the extent of land available to lot 7300. Section 170 of the Crown Lands Act 1989 refers to limits on acquisition of title by possession against the Crown. On the basis of this and prior legislation and with reference to the highly respected texts of Butt (2010) and Hallmann (2007), the author is of the opinion that the Crown is barred from re-asserting any ownership over land that was adversely possessed where that possession matured prior to that date set down by the Statute of Limitations.

The subject land is Crown reserve and is captured by Sec. 170 (2) and (5)(b)(ii), the date of assent being 31 October 1977. As such the occupation adverse to the Crown must have commenced prior to October 1917. If the occupation can be shown to have been uninterrupted for 60 years, then the Crown's title will have been extinguished for that part of the land.

Section 170 (1) (d) is not applicable in so much as while lot 7300 DP1127501 has since May 2008 been recorded in a folio of the Register as land reserved to the Crown, the land was not part of a folio at the time of dispossession on or prior to 31 October 1977. Folio identifier 7300/1127501 as a limited title is subject to existing rights of occupation as may define the extent of the title.

The boundaries that have been surveyed are to the limit of the Crown's title being the old occupation along the northern boundary of the land. The unsurveyed land north of the occupation has not been surveyed. It should be noted that the landowner for lot 42 in DP628246 is the Local Aboriginal Land Council (LALC) and they will be the owners of the eastern part of the subject land (lot 732), as such there will remain a strip of land between lot 42 and lot 732 that is no longer Crown land. This land may be added to LALC's holdings following a successful possessory application at some future date.

2.4 Closer Settlement

The Closer Settlement legislation was implemented to assist soldiers returning from the World Wars to purchase holdings for farming purposes. In short, alienated lands were resumed by the Crown and set aside for new grants of lands for closer settlement holdings.

2.4.1 Hunter and Goulburn Rivers near Denman

This case was brought to the author's attention in the early 1990s with the aim to resolve a situation where applications were pending for sand extraction within part of the river beds. The problem relates to the apparent overlap of titles to parcels of land abutting the confluence of the Goulburn and Hunter Rivers near Denman.

Figure 19 shows the cadastre by Digital Cadastral Database (DCDB) with respect to recent aerial imagery. When the lands were originally granted in the 1800s, some grants abutted non-tidal rivers and included presumptive title ad medium filum aquae. This presumption is due to the lands having been alienated prior to the general reservation (R52788) of the beds of all rivers and streams in the eastern and central divisions on 3 May 1918.

Figure 19: Aerial image showing cadastre by DCDB.

Under the Closer Settlement Acts, the Crown was able to resume private lands for the purpose of using the land as settlement farms or other settlement tenures. Where the lands were subsequently re-granted, they were subject to a new survey. Additionally, for lands that abutted non-tidal rivers and creeks where the grant was prior to the notification of R52788 the title continued to include the presumptive title rights, however where R52788 had been notified then the Crown retained ownership of the part of the river bed.

In order to achieve a resolution for the problem, it was necessary to compile the records of plans and titles and collate that information with the physical land attributes. Both Crown Lands and LPI were required to investigate the matter. Figures 20-22 are extracts from parish maps showing the portions in relation to the rivers. Field survey work was completed to prepare a sketch plan showing the parcels of land in the positions of the river banks at differing periods of time. Figure 23 is part of the survey showing the bank positions by plan records using field survey to connect the old surveys.

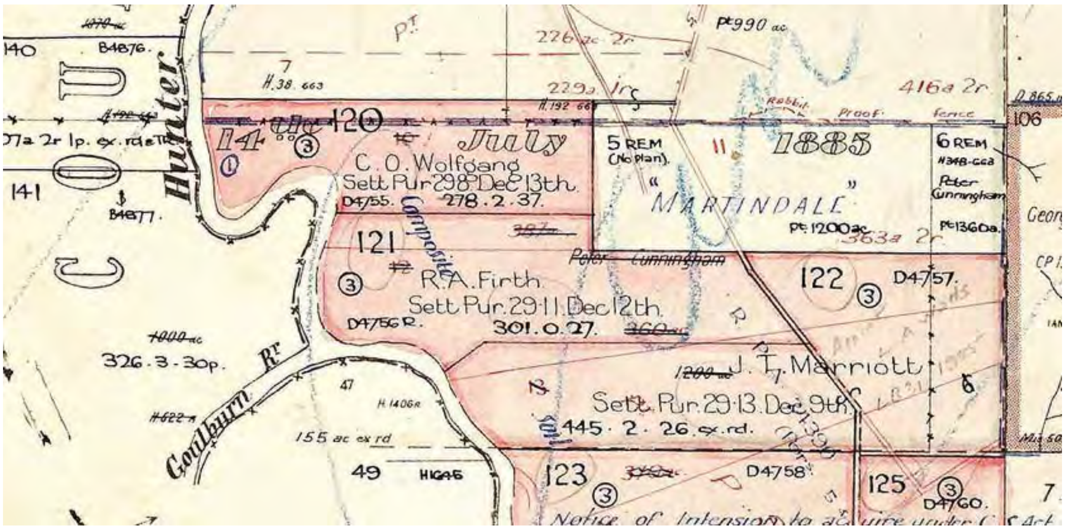


Figure 20: Extract from Parish Map of Althorpe 1921.

Figure 21: Extract from Parish map of Bureen 1938.

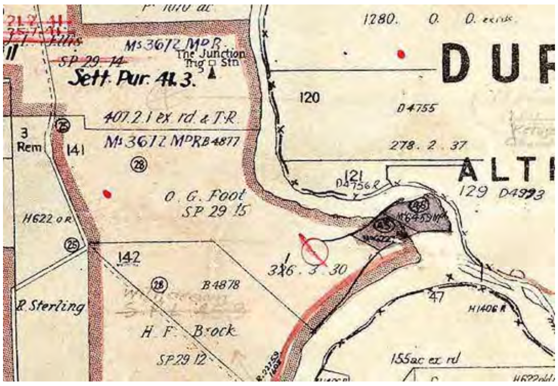


Figure 22: Extract from Parish map of Denman 1937.

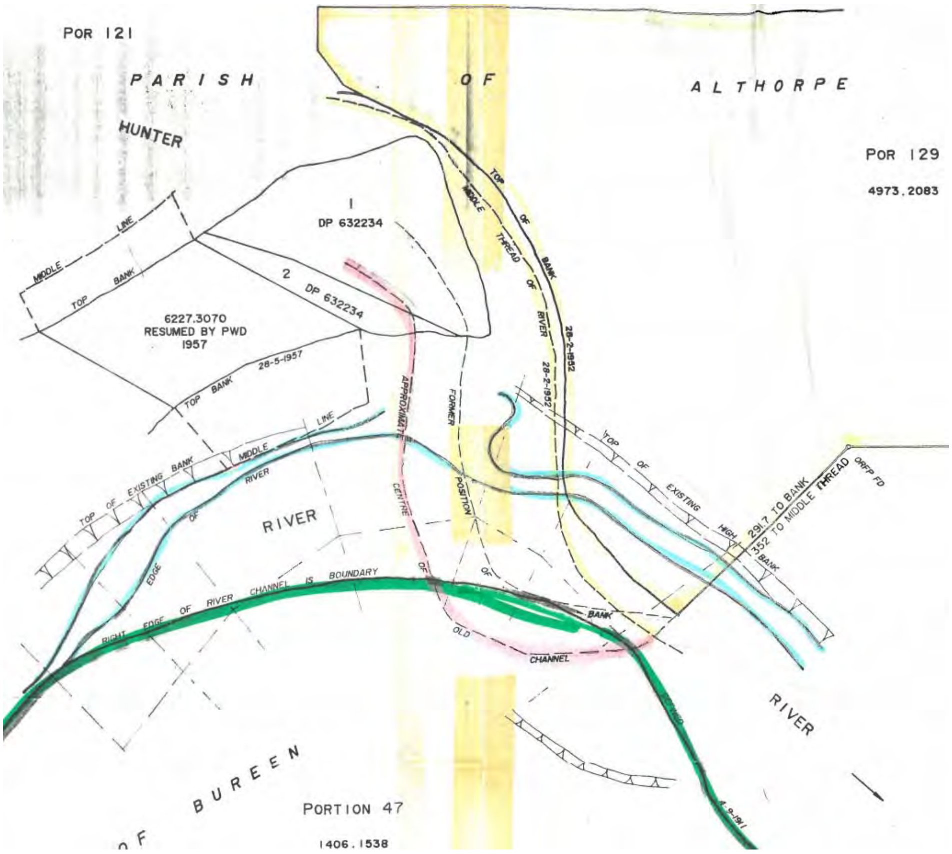


Figure 23: Plan showing river bank positions.

Investigations revealed that portion 121 in the Parish of Althorpe, County of Durham, was part of an area of land that was included in the 'Martindale' settlement purchase area that was notified on 15 November 1929. Under the Closer Settlement Act 1907, land granted was considered perpetual leasehold, i.e. it was effectively freehold land. Portions 121 and 122 were initially surveyed in July 1929 as CPs D4756$_{\sim 2083}$ and D4757$_{\sim 2083}$, then portion 121 was resurveyed 1952 as CP D4973$_{\sim 2083}$ to create a portion 129 with residue part being the remains of portion 121.

Portion 47 in the Parish of Bureen, County of Hunter was a water reserve prior to 1911. Portion 47 was initially surveyed in 1911 as CP H1406$_{\sim 1533}$. Portions 140 and 141 in the Parish of Denman, County of Brisbane were also surveyed in July 1929 as CP B4877$_{\sim 2096}$ and 4878$_{\sim 2096}$. A Closer Settlement farm grant was issued over portion 47 in May 1912. Title to the new grant of portion 47 included the presumption of lands ad medium filum as it was prior to R52788.

In 1929 when the other parcels in the Parish of Althorpe (portion 121, 122 and 129) and Denman (portions 140 and 141) were surveyed for closer settlement purposes, the general reservation of 1923 was in place. As such, the grant of these lands after 1923 excluded any title ad medium filum. In 1929, when those portions were surveyed, the positions of the banks of the Goulburn and Hunter Rivers had been significantly affected by floods. Substantial changes in the positions in the river banks had been recorded by both survey plans and aerial photography. The surveys of the portions failed to recognise the historical flood effects on the positions of the river banks and, furthermore, failed to recognise the existing title to portion 47.

With the aid of historical aerial photographs and plans of early surveys, the processes of title issue and river movement were given some understanding. It was determined that the title surveys for most properties were reliable and in positions that could not be disputed. However, with regard to parts of portions 121 and 129 at least, it was considered that the position of the river adopted as defining its bank may require amendment.

With the advent of modern survey equipment and office systems including Geographic Information Systems (GIS), it is not difficult to correlate surveys with those on record and consequently existing land titles. Of course it goes without saying that the DCDB should not be used for anything more than a rough guide to the cadastral layout. Back in the early 1900s, when these surveys were being prepared, the processes to correlate surveys were to do more field measurement including lands on both sides of the river. It is apparent that mistakes were made both by the field surveyors and by the government agencies responsible for the surveys and titles.

The first survey of portion 47 in 1912 had a virtual 'greenfield' site as the river was within the settlement area and as such any prior boundary the river may have formed was nullified. The surveyor was able to measure the land to the bank as defined by the regulations in place at the time of the survey. The subsequent surveys were on the opposite side of the river. The surveyor may possibly have believed that the river formed an ambulatory boundary and the bank at that time represented the boundary with portion 47 limited by the changed position of the opposite bank. Alternatively, the surveyor may have just surveyed to the bank in the same manner as was done for portion 47 in 1912. As the river position has changed significantly by the processes of floods, LPI had advised that the rivers were considered to be volatile and the doctrine of accretion did not apply. While the river had changed its position, the boundary

remained as it was prior to the changes subsequent to 1912. Accordingly, the titles by surveys as depicted overlap.

It was believed that both Crown Lands and LPI have responsibility for the review even though the lands are now freehold. The reasons being that the Closer Settlement Act was administered by the Department of Lands and then Crown Lands even though the surveys of the parcels were undertaken by private surveyors. LPI, in its operation, is required to issue indefeasible titles. The situation of overlapping titles should not have occurred.

3 WATER BOUNDARIES

3.1 Tidal or Non-Tidal Waters

As already mentioned, the nature of the water boundary fronting land is always the same as it was at the time the land was granted.

3.1.1 Williams River at Clarence Town

The Williams River is a tidal river to a location just upstream of Clarence Town. The Seaham Weir was constructed to dam the waters upstream of the weir to supplement the water storage for the Lower Hunter. As a consequence of this construction, the water level behind the weir rose and tidal influence past the weir ceased. The boundaries of lands along the river from the weir to the prior tidal limit were fixed in their positions immediately preceding the completion of the weir.

3.1.2 Etymalong Creek

Investigations have been undertaken since the 1970s to determine the status of the bed of Ettalong Creek (formerly known as Etymalong Creek). Parish maps show the creek as flowing from Etymalong Swamp.

Figure 24 shows portion 52 in the Parish of Patonga, County of Northumberland and Gosford Local Government Area (LGA); it is shown to be bound on part of the west, north and east by the creek. This portion so created, was alienated by way of sale on 7 February 1873, the grant is recorded as Certificate of Title Vol. 215 Fol. 167. The date of alienation was prior to the notification for the general reservation (R56146) from sale or lease of all beds of rivers and their tributaries within the eastern and central divisions of the state on 11 May 1923. It was also prior to the earlier general reservation (R52788) of 3 May 1918 that did not include the beds of lakes, estuaries and lagoons.

Etymalong Creek is depicted by CP N33$_{\sim 2111}$ that was completed in August 1872 (Figure 25). This plan clearly shows sand as a probable bar to surface water flow to the ocean. Despite the name indicating a creek, it was most likely closed from the sea and as such a lagoon. This is also the same by CP 3434$_{\sim 2111}$ being the survey for the Crown reserve east of portion 52. Old files report that the creek had been deemed non-tidal and that the adjoining landholders enjoy presumptive title to the middle thread of the creek.

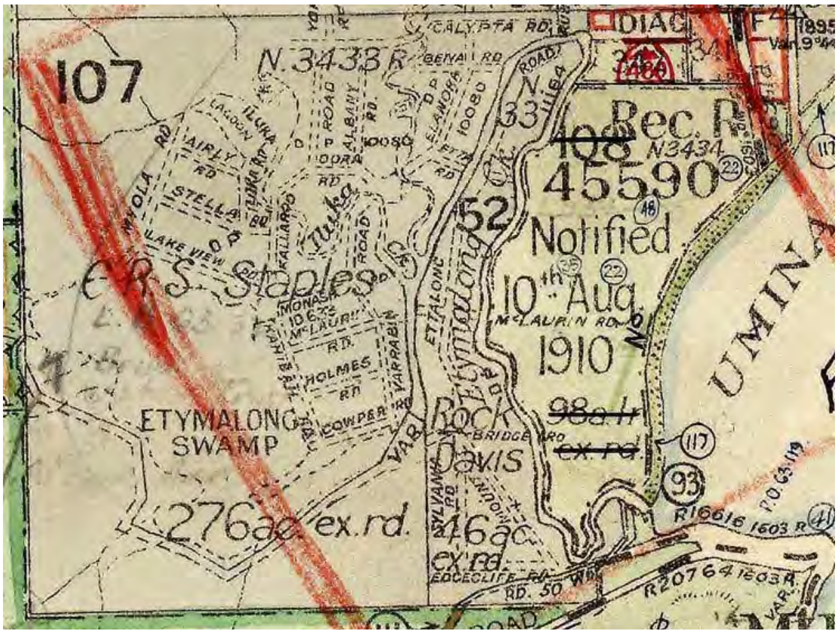


Figure 24: Extract from Parish Map of Patonga, edition 12, 1953.

Figure 25: Part of Crown plan N33.

An application was received for the approval the water boundary as shown on a plan of redefinition of land being a lot within a subdivision of part of portion 52. The proposal was that the title extends to the centreline of the creek. This is contrary to the notation on the current title plan dated January 1991, which stated that the boundary is the MHWM. An earlier subdivision as DP11184 dated August 1919 (Figure 26) has no such notation and shows the creek as the boundary together with an arrow to indicate the direction of flow towards the ocean, this being the convention for non-tidal streams.

With the aid of historic photographs, it is apparent that there is an obvious difference between the position of the present creek and that defined by prior survey. There is no doubt that the creek has moved north and west by considerable amounts. Any change eastward is not as easy to assess due to the sandy beach between the subject property and Broken Bay.

The Doctrine of Accretion and Erosion holds the same for non-tidal streams as it does for the seashore and tidal inlets. At the time of the investigation the main issue was whether the change has been slow, imperceptible and by natural means. Now, however, some 15 years later, the main issue would appear to be whether the creek was in fact a lagoon and as such the extent of all adjoining titles is the bank and no part of the bed attached to those lands.

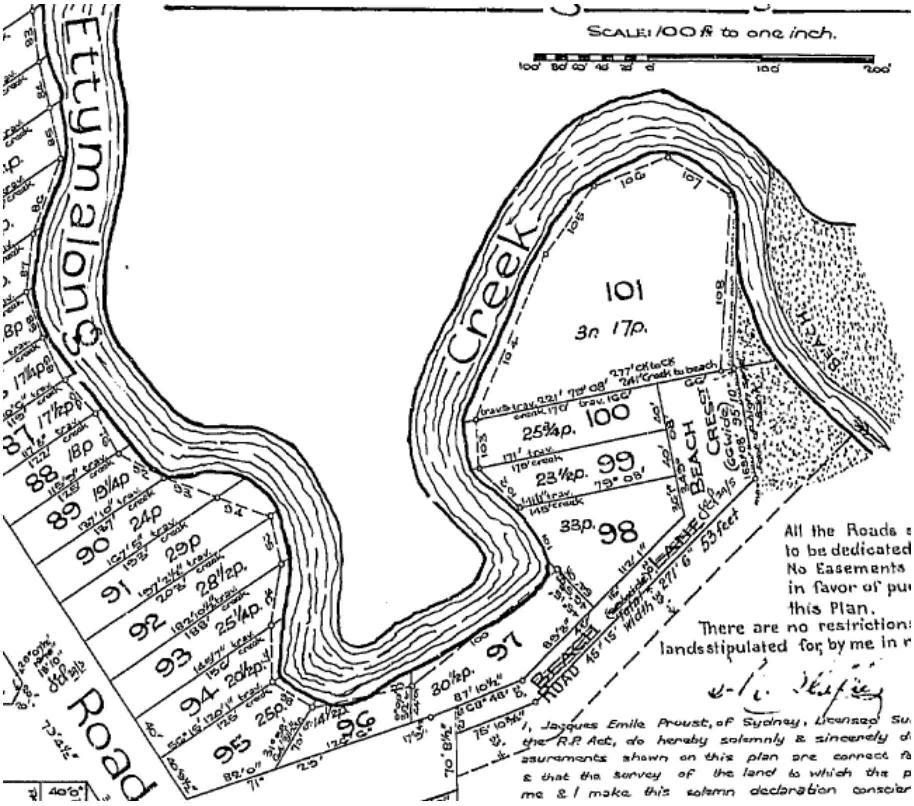


Figure 26: Part of DP11184.

3.2 Gazetted Reservation of Beds of Waters

3.2.1 Reservations of Crown Land

Crown reserves are areas of land set aside for the community for a wide range of public purposes including environmental and heritage protection, recreation, open space, community, business and other purposes. Under the provisions of the various Crown Lands legislations Crown land has been and can be reserved for public purposes. Specifically in relation to the reservation of the beds of waters, including both tidal and non-tidal, a number of general reservations have been notified by publication in the NSW government gazette.

The first of these was the General Reservation of 17 April 1862. In pursuance of the provisions of the Crown Lands Alienation Act 1861, the land specified in the schedule until surveyed was reserved for the preservation of water supply or other purpose. The schedule was in two parts, the first part listing land in a number of localities and the second, headed General, being "*All Islands within the Colony of New South Wales, with the exception of Palmer's, Micalo, and Woodford Islands, in the Clarence River; Rawdon Island, in the Hastings River; and Oxley, Mitchell, Mamboo, Cabbagetree, and Jones' Islands in the Manning River*."

By the General Reservation on 3 May 1918, Reserve (R52788) from Sale or Lease generally made in pursuance of the provisions of the Crown Lands Consolidation Act 1913, the application of the *ad medium filum aquae* rule in New South Wales was considerably restricted (Lands, 1989). The notification is: "*All the beds of rivers and their tributaries in the Eastern and Central Divisions of the State, inclusive of all shingle, gravel, and sand beds and alluvium thereon; and inclusive of all Crown lands between the banks of such rivers or their*

tributaries, together with all Crown lands between such river banks and alienated or granted land bordering thereon."

Similarly on 11 May 1923, Reserve (R56146) from Sale or Lease generally extended the reservation by R52788 as: "*All the beds of rivers, their tributaries and ana-branches in the Eastern and Central Divisions of the State, inclusive of all shingle, gravel, sand-bed, and alluvium thereon or adjacent thereto, and inclusive of all Crown Land between the banks of such rivers or their tributaries or ana-branches, together with all Crown Lands between such banks and alienated or granted land bordering thereon; also embracing all beds of lakes, estuaries, and lagoons; 100 feet reservation, wherever situated not reserved from sale for a public purpose or held under special lease; also inclusive of all islands or parts of islands in the Divisions referred to, and those situate in harbours, inlets, bays, ports, estuaries, or off the sea coast within territorial limits not alienated, held under special lease, or reserved from sale for a public purpose other than under the reservation from sale under general notice of 17th April, 1862, revoked this day.*"

Lastly, following the commencement of Commonwealth legislation Coastal Waters (State Powers) Act and Coastal Waters (State Titles) Act in 1980 where the coastal waters to the 3 nautical mile limit were vested in the states, on 3 February 2006 under the provisions of the Crown Lands Act 1989, Reserve (R1011268) for the purpose of future public requirements was notified. The notification was: "*All of the land covered by R56146 from sale or lease generally, notified 11 May 1923, together with all foreshore land below the mean high water mark of New South Wales extending to the territorial limit of 3 nautical miles from the low water mark of the coast." Neither R56146 nor any existing reserve for a public purpose that is affected by this notification is revoked by this notification.*" This notification was required to cover the coastal water from the HWM to the territorial limit.

On the basis that the government does not as a rule make retrospective legislation, it has been considered by practitioners of land law that the above reservations did not apply to land that had previously been alienated, i.e. the government has no right to take without lawful resumption land that has already been granted. As such the comment that the *ad medium filum* rule was severely restricted (Lands, 1989) is correct, and the alternative that the rule ceased to exist and all lands previously claimed as presumptive title reverted to the Crown would make no sense. Unfortunately, there is a perception among some that the general notifications do actually mean *all* and not just the unalienated lands (beds) that remain at the time. In the last year or two, a notice was received from a client, a leading international law firm, that the Crown Solicitor's Office (CSO) is now of the view that the wording for these reservations is that the Crown has ownership of all creeks, rivers etc., not just those remaining after the general reservation(s). Unfortunately, the CSO has similarly suffered a knowledge loss due to expert staff not being replaced with staff with similar knowledge but rather staff who can apply their skills more generally.

A specific reserve was notified on 19 April 1880 for Reserve R75 from Sale for Public Purposes. The notification was published as: "*County of Northumberland, Parishes of Wallarah, Morisset, Coorumbung, Awaba and Kahibah, area about 180 acres. The Crown Lands within 100 feet above high water mark along the shores of Lake Macquarie.*" Despite this, the parish maps were noted for lands including those that were no longer Crown land. This fact, when recognised, lead to parts of this reserve being invalid and titles to those lands where the invalid reservation had been added were amended.

4 ROADS

Roads in legal terms imply a right of passage along a specified route regardless of whether it is in a defined position, is distinguishable from surrounding land and is actually capable of being traversed. It is the public right to use the land as a way rather than its physical nature that makes the land a road (Ibbotson, 1982). Until the commencement of the Roads Act 1993 there were many different Acts, some with overlaps in application to public roads. The Roads Act was intended to clarify the status of all public roads in the state.

The main issue regarding roads prior to the Roads Act 1993 is the knowledge of ownership or 'road status' and to do this it is necessary to investigate the parish or town map, plan and title records for details to establish whether the land has actually been created as road and if so, the type of road so created. There may also be events subsequent to the creation of a road that have extinguished the road or varied the status from that when created. In addition to the primary sources of Hallmann (2007) and Willis (2010), there are other documents that are highly regarded for the collation of road knowledge: Le Gay Brereton (1933), Ibbotson (1982), Searle (1989), Searle (1996) and Marshall (2006).

In essence, there are two main classes of roads: public and private. These include Crown, Council and private subdivision roads. The following outlines some road types together with a very general description. The abovementioned references provide the complete picture up to the respective date of each publication.

4.1 Reserved Crown Roads

In the conduct of surveying portions it was the practice to leave strips of land between adjoining portions for the purpose of access. The strips were usually shown on the plans as Crown Road and were termed 'Boundary Roads'; they were frequently impractical in the sense that they had no regard to the land and actual, practical access along these roads. These Crown roads have frequently been seen as unnecessary and have formed part of the road closure program.

Early Crown grants contained a reservation that as much land as was required for public ways could be excluded. Later following the expansion of the colony when tracks began to be used to access lands further from Sydney, surveys were prepared to define by measurement the road to be excluded from the relevant grants. Similarly, the grants were constructed to specify the road so excluded.

Roads on Crown land were legally classified as being either 'public' or 'non-public roads'. 'Public roads' were created over Crown land, but 'dedicated' as 'public roads'. The dedication was then gazetted. Since 1 July 1920, once the dedication was gazetted, ownership in the land upon which the 'public road' was created would vest in the relevant local government entity by virtue of the Local Government Act 1919.

'Non-public roads' were also created over Crown land, but these roads were not dedicated. These roads remained in the ownership of the Crown until an application to close the particular road was received and approved by the Minister administering the relevant road legislation (or his/her delegate). 'Non-public roads' were generally known in the land administration and surveying community as 'Crown roads'. Surveyors would use the term 'reserved roads' to depict non-public roads on plans of survey. Thus, prior to 1993, the terms

'non-public roads', 'Crown roads' and 'reserved roads' referred to the same thing, and these terms were used interchangeably by members of the land administration and surveying community.

Generally, survey plans show non-public roads as 'reserved roads'. After the passage of the Roads Act 1993, the term 'Crown road' was defined by this Act and non-public roads became known as 'Crown public roads'. The roads previously known as 'public roads' now became known in the surveying and land administration community as 'Council public roads' (a term which reflected the fact that these roads were owned by local government entities).

4.2 Designed Roads

When a (Crown) grant excluded (reserved) part of the land for road or public way, then that 'public' right of passage exists even though the location of the road may not have been surveyed. These non-surveyed roads are referred to as 'designed' roads and are depicted on parish maps and plans by parallel broken lines separated by the width of the road. This representation can be misleading as the symbol is the same as used for private subdivision roads. Figure 27 is an example of a 'designed' road as shown on a parish map. Figure 28 is an extract from a grant where a road is excluded from the granted land and has no survey information.

Figure 27: Example of symbol for designed road.

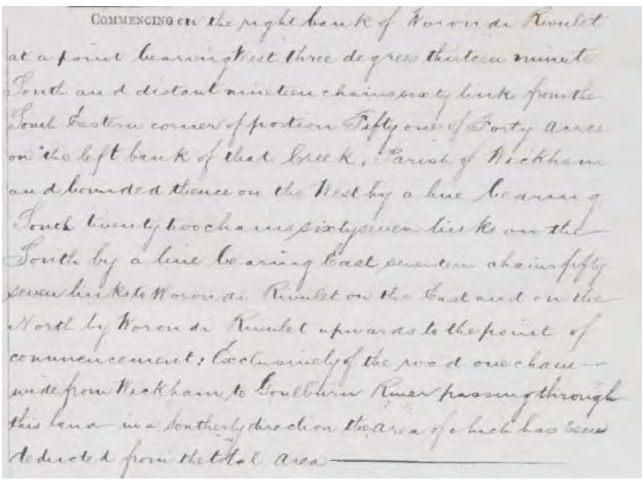

COMMENCING on the right bank of Woron di Rivulet
at a point bearing West three degrees thirteen minutes
South and distant nineteen chains sixty links from the
South Eastern corner of portion Fifty one of Forty acres
on the left bank of that Creek, Parish of Wickham
and bounded thence on the West by a line bearing
South twenty two chains sixty seven links on the
South by a line bearing East seventeen chains fifty
seven links to Woron di Rivulet on the East and on the
North by Woron di Rivulet upwards to the point of
commencement; Exclusively of the road one chain
wide from Wickham to Goulburn River passing through
this land in a Southerly direction the area of which has been
deducted from the total area

Figure 28: Extract of grant with an unsurveyed road.

4.3 Act 4 William IV or Confirmed Roads

The first Act to authorise the government to make, alter and improve the roads through private lands in the colony was the Act 4 William IV No. 11, which commenced in August 1833. A 3-step process was required to dedicate such a road as a public road:

1. (Preliminary notification on): Notification of intention to open a line of road.
2. (Confirmation on): After consideration of any objections lodged, notification confirming or altering, the line was gazetted. Construction was then carried out and, if required, compensation was paid.
3. (Proclaimed on): Proclamation that the road was open for public use.

The plan of survey was noted to show each step completed together with reference to the gazette notification for each. These roads were also known as confirmed roads. Where the three steps were not completed, the road was not legal. With the exception of certain arterial roads denoted under the Act as ‘public roads’ that were maintained at public expense, public ways were called ‘parish roads’ and were maintained from rates levied on the adjoining owners.

With the further development of the colony, private lands were subdivided and the road network was amplified as required. Private subdivision roads are rarely shown on parish maps and if they are the symbol is parallel broken (dashed) lines separated by the width of the road. From the commencement of the Local Government Act 1919 on 1 January 1920, the common law position regarding the ownership of the land comprising a road changed for public roads excluding Crown roads in that it then vested in the ownership of the council for the area. Private subdivision roads created before this date would then become council public roads; however there are circumstances where debate concerning the transfer to council continues between interested parties. The debate generally relates to the evidence of expenditure of public money for the road.

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Riparian Cadastral Boundaries: A Step Toward Reform

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ABSTRACT

The subject of riparian cadastral boundaries would, on initial examinations, appear to be well understood by surveyors in New South Wales. Surveyors have been undertaking such boundary definition for hundreds of years so you would think they have it down pat by now. But look a little closer and you will soon discover the truth is far different, as in some instances practice and subsequent determination do not comply with the definition for the boundary. Within just the proceedings of the last 20 years of APAS conferences there have been a number of papers presented that bring into question not only the methodologies used by surveyors to determine a riparian cadastral boundary but also the very definitions that form the basis of those boundaries. Through the avenue of the conference papers, reforms, or at the least review, have been called for. To date there appears to have been little movement toward undertaking those reforms. Now is the time to put something forward on which to make a basis for reform. From previous papers the misinterpretations of both tidal and non-tidal riparian cadastral boundaries have been brought forward into this one place. Alternatives are then offered that could form the basis of reform. Even the doctrine of accretion and erosion is dealt with. No conclusions are drawn as that is not the purpose of this paper. This is just the basis upon which to formulate future dialogue.

KEYWORDS: *Cadastral surveying, riparian cadastral boundaries, reform.*

1 INTRODUCTION

The definitions for the various riparian cadastral boundaries have been handed down to surveyors to interpret from legal deliberations, interpretations and precedence, some from more than 100 years ago. The definitions are complex, difficult to understand, and in some instances without adequate explanation to positively identify all necessary components. Over time, surveyors have applied their own interpretations and practices that do not necessarily comply with the strict wording of the definitions. Some riparian boundary practices that have evolved are not compliant with the legislated requirements. The fault for non-compliance does not necessarily lay solely with the surveyor. The legal representatives that tried to define a complicated natural phenomenon did not necessarily fully comprehend the complexities of what they were undertaking. Their interpretational choices sometimes result in ambiguous and contradictory results that do not satisfy what they envisaged (Blume, 1995; Songberg, 2015).

Investigations within the literature listed have shown that there are disparities between the happenstance of the riparian boundaries, the legal interpretation and definitions intended to define the natural phenomenon that creates the riparian boundaries, and the practical methodologies of surveyors to undertake the physical determination of the boundaries. Today there is a greater understanding of the natural phenomenon that creates these boundaries than was available during the first attempts at definition by legal professionals. The reason why the

disparities exist today is that we are still trying to use, inappropriately, those inadequate definitions. The only way in which the situation can be rectified is for something to change. The easiest way forward is to change the legislation by changing the definitions so that they better represent the riparian boundary and make it clear and practical as to what is required. Such a change is only likely to be effected if the legal precedence is abandoned and a more physical practical approach taken.

2 TIDAL BOUNDARIES: MEAN HIGH WATER MARK

The definition of the Mean High Water Mark (MHWM) boundary requires the determination of the tidal plane Mean High Water (MHW). The current definition, contained in the Surveying and Spatial Information Regulation 2012 (NSW Legislation, 2016a), is "*Mean High-Water Mark means the line of mean high tide between the ordinary high-water spring and ordinary high-water neap tides*." The original definition, with no reference to ordinary, was handed down from an 1854 court case in England, *Attorney General v. Chambers.* It was later modified in 1907 by another court case *Tracey Elliot v. Morley (Earl)* which added in the ordinary, resulting in a definition that may be impossible to comply with. Unfortunately neither party fully comprehended the complexity of the tidal regime and their attempts at definition result in highly fluctuating determinations of MHW (Songberg, 2015).

The definition itself is lacking in both meaning and reliable direction for surveyors to positively establish the tidal land boundary. Figure 1 shows that the MHWM is actually the line along the foreshore that the MHW surface traces across the land. When comparing Figure 1 to the definition, the shortcomings of the definition wording become clear. The definition does not define the line along the foreshore, which is the MHWM, as there is no reference to the foreshore or to the land. The definition instead is an attempt to define the MHW surface. The two parts of the definition do not equate.

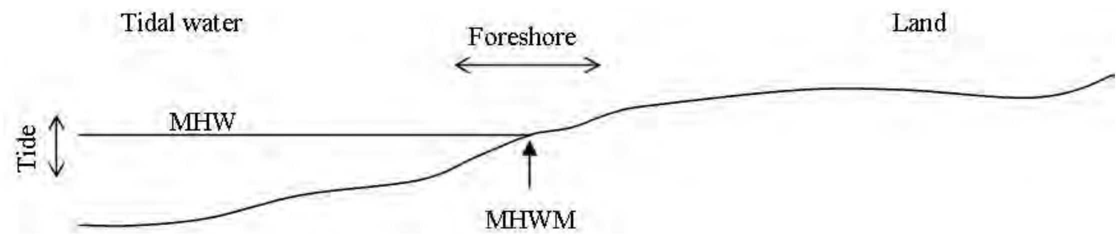

Figure 1: MHW and MHWM.

The shortcomings of the definition are further compounded by the lack of positive identification of both spring and neap tides. There is no clear or exacting definition of either (Songberg, 2015). About all that can be determined is the spring tides occur around the time the earth, sun and moon align and the neap tides occur around the time when the moon is perpendicular to the sun-earth alignment. The interval in time between these two events is approximately 7 days. Add to this the uncertainty of ordinary and the surveyor is left with no guidance at all.

Adding to the uncertainty was the Manual of the NSW Integrated Survey Grid (ISG) (Lands, 1976) in which an alternate definition was given that was in contravention to the legislated definition: "*Mean High Water … is the mean of all high tides (including both spring and neap tides) taken over a long period*." At least in this definition both parts equate in that the definition is for MHW. Although the MHWM is the subject of this part of the publication, and

often mentioned, there is no definition of it in the manual. The manual goes through a number of processes of defining the MHW surface (and sometimes confuses MHWM with MHW) but does not give any direction that the intersection of that surface with the land is the MHWM. It is left to the surveyor's interpolation to arrive at that conclusion.

Recognised survey practice methods to determine MHW have evolved as a consequence of the ISG manual publication. Even so the surveying practices that have evolved do not comply with the strict wording of either the manual or the regulation definition. Both definitions require an observation to be undertaken of high tides between the neap and spring. No surveyor does such. Most determinations undertaken over the last few decades use the published tidal plane analysis of MHW that is a result of mathematical modelling, which is not compliant with the legislation definition. As a consequence, every boundary determination undertaken using such data does not comply with the Surveying and Spatial Information Regulations of the time, potentially making all invalid (Songberg, 2015). Further investigations into the practices postulated in the ISG manual have also shown that they produce inconsistently accurate results so that considerably different answers will result from the different methods. Even using the same method over time produces similar fluctuating results (Songberg, 2005). Should an attempt be made to fully comply with the regulation definition, the 7-day observation period required will produce widely fluctuating results (Figure 2). That is, if it is even possible to comply as positively identifying the end points which measurements need to be taken between is virtually impossible (Songberg, 2015). If surveyors produced MHWM determinations based on these MHW surface levels, it is likely that litigation occurrences would escalate.

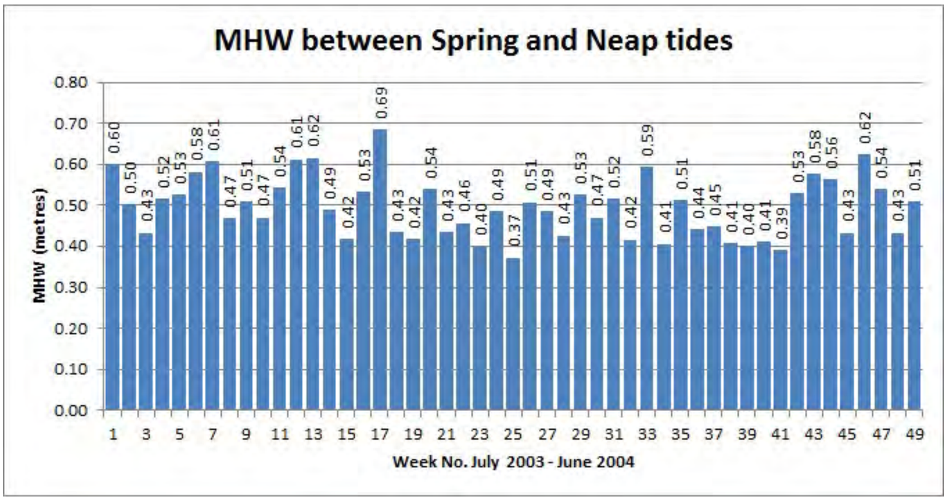

Figure 2: MHW observation using 7-day period neap-spring tides.

Neither the Surveying and Spatial Information Regulation, the ISG manual definitions or current determination practice recognise changes in sea level. Within present climatic changes there is a sea level rise, around NSW of about 3 mm per annum. The Surveying and Spatial Information Regulation definition cannot deal with the phenomenon due to its limited (7-day) observation period, which the definition wording requires. The ISG manual definition, despite requiring the observation to be taken over a long period, also cannot deal with sea level rise because the phenomenon limits the period in which a mean can be determined. The study of 20-year datasets for MHW, from the Public Works Manly Hydraulics Laboratory publication OEH NSW tidal planes analysis 1990-2010 harmonic analysis (Couriel et al., 2012), shows sea level change is detectible within that period (Figure 3). The MHW values used today (2016) are mostly a product of the mean for the 1990-2010 period. As a consequence, they are

already out of date and, when compared with the overall trend in sea level change, will result in determinations of MHW being made too low. Further study is required to determine the time limit for which a MHW value can be held constant and not significantly differ from the trend before a definitive answer can be given. The limited study over the 20-year datasets produced some mixed results which require further investigation (Songberg, 2015).

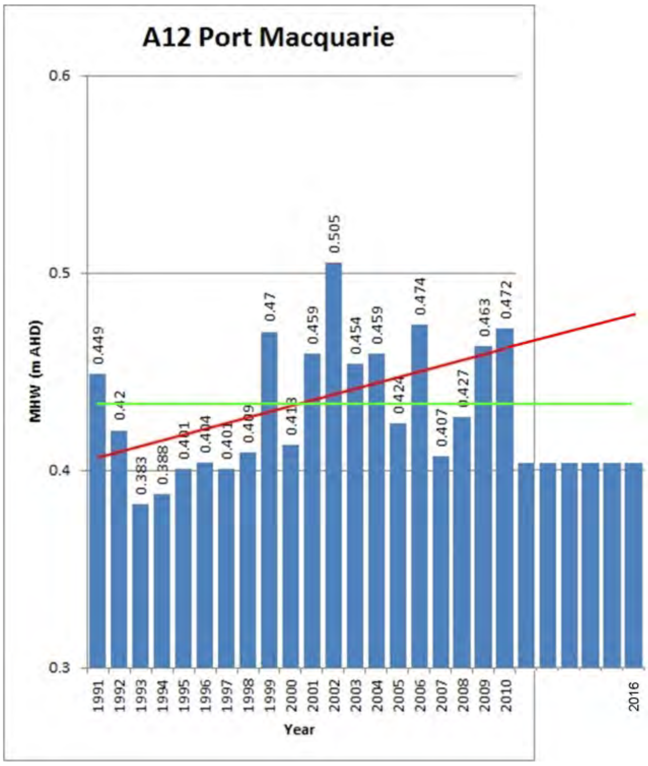

Figure 3: Mean high water trend v. mean from 20-year dataset extrapolated to present day, illustrating the consequence of not considering sea level rise.

Community expectations require the MHWM boundary to be determined with reasonable accuracy and consistency over time. The community, including land titling, has yet to come to terms with sea level rise, although it is detectable and measurable. Highly fluctuating determinations from week to week as required by the regulations (Figure 2), month to month or year to year from tidal analysis (Figure 3) would not be acceptable nor would they be tolerated. There would be considerable litigation if one surveyor determined the MHWM boundary tens of metres different to the neighbour or changed the location significantly from a previous but recent definition as a consequence of the variability in determination methods.

Assuming the MHWM is to be retained as a tidal boundary, it of course does not have to be, the definition must consider sea level rise and produce reasonably consistent results over time. Of the methods of determination available to surveyors, only the use of long-term tide gauge data and tidal planes combined with the trend in change over time due to sea level rise is able to provide some uniformity and consistency in results.

2.1 MHWM: A New Definition

There is a fundamental difference between MHW and MHWM. The Mean High Water *Mark* is just that, the mark that the *plane* of mean high water makes against the shore. This fundamental difference is often misused or simply not considered and sometimes incorrectly interposed. The Surveying and Spatial Information Regulation 2012 is the most classic case of

misuse. There is no mention of the shore so the definition actually refers to MHW and not MHWM. The definition of MHWM should be *the line which the plane of mean high water makes against the shore*. There should be a separate but companion definition of MHW.

2.2 MHW: A New Definition

The definition in the Surveying and Spatial Information Regulation could simply have the header changed to mean high water and leave out the mark. The issue with that is the inconsistencies and uncertainties within that definition make it impossible to use. In order to allow current determination practice to comply, the new definition should be related to the established tide gauges. There is also a need to recognise sea level change to a new definition by the application of the trend in values calculated by harmonic analysis over the entire record length of the gauge and extrapolated to a maximum of 2 (or other appropriate period) years after the last published value. Such a definition for MHW could be *the trend value of MHW determined from year to year by harmonic analysis of an established tide gauge (for the full length of record) as determined for the date of survey extrapolated a maximum of 2 years after the last yearly determination of MHW*.

Alternative methods must also be available for use in areas where the tide gauge network does not extend. Such methods could be environmentally based, and range-ratio methods might also be applicable. Simple immediate on-site estimation is most likely in the more remote areas. Experience has shown that the tide gauge method will be applied in areas of greater population where more accurate results are expected and other methods used in more rural and sparser populated areas. The adoption of such a definition will first require the complete revision of all tidal data as well as the review of all tide gauges.

2.3 MHWM: Definition Limits

The current upstream limit to which MHWM determinations extend is the tidal limit, the location of which is usually recorded on the parish maps. That limit, however, is mostly based on the maximum reach of the tide. The difference between MHW and the highest tide, which determines the tidal limit, could be more than 0.5 m. There could be a significant difference in the distance upstream, which MHW will reach compared to the current tidal limit. A lot will depend on the nature of the individual stream profile. Any differences are not currently determinable. However, there could be an impact on what titles have tidal or non-tidal boundaries, especially around the changeover point.

2.4 An Alternative Tidal Boundary

The use of MHW to define the tidal boundary is entrenched in history. The tidal boundary does not have to be limited so. The recognised tidal limits are not based on MHW so that some MHWM boundaries near the tidal limits, under a MHW regime, may not actually be such. An alternative tidal boundary is to adopt the full reach of the tide as the indicator of the boundary. Such is already likely to occur in areas where tide gauge readings are not used and the boundary is determined by the surveyor’s instantaneous observation of the environment. MHW is somewhere within the tidal environment, and use of MHW does result in some of that tidal environment being held within the land-based title. Use of environmental indicators coupled with a fuller tide than MHW to indicate the boundary would separate tidal and land-based environments. For example, the location of the MHWM in Figure 4 is uncertain and would depend on the method used. The division between land and tidal environments is clear,

located between the mangroves and oak trees to the right of the picture. To place the boundary at this point has some merit. Such a boundary would simply be labelled as the *tidal boundary*.

Figure 4: Tidal flats.

3 NON-TIDAL BOUNDARIES: THE BANK

It is unknown where the definition of the bank of a non-tidal stream originates or whether it has changed, but it comes to us in the present from section 172 of the Crown Lands Act 1989 (NSW Legislation, 2016b). The definition is, however, convoluted and also includes the definition of a lake. The application of the same definition to both lake and stream is not necessarily compatible.

The definition states "*bank means the limit of the bed of a lake or river*". At first, this sounds simple but the definition depends on firstly defining the bed and therein lay the complications that cause grief to surveyors and are the cause of varied results.

It is stated that "*bed means the whole of the soil of a lake or river including that portion*:

(a) *which is alternately covered and left bare with an increase or diminution in the supply of water, and*
(b) *which is adequate to contain the lake or river at its average or mean stage without reference to extraordinary freshets in time of flood or to extreme droughts*."

3.1 Stream Banks

Surveyors historically have had difficulties coming to grips with exactly what constitutes the bed of a stream and therefore the bank. Some will go to the water's edge as it existed during the time of survey, while others will extend to the low bank often found located beside the water or channel, while others extended their interpretation to the major bank at the far extremity of the river gravel beds. Some have even interpreted the definition to be the usual stage rather than the average or mean stage. The usual stage is closer to the low flow than the average and is contained in a smaller channel within the bed and does not extend to the banks (Songberg, 2012). As a consequence of the varying interpretations, the position of the bank as defined can vary considerably and still not equate to the definition as worded. The main issue that clouds the definition process is the qualitative nature of the surveyor's interpretation. Different people will view the same stretch of stream and choose differing locations as to what they consider the bank. Factors, other than stream flow, such as vegetation, soil structure

and the existence or lack of water influence the determining process. The definition, however, makes no mention of these other factors but relies solely on stream flow and an analysis of which quantum of stream flow is required to determine the average stage. Somewhere in Figure 5 is the cadastral bank. It is not likely to be at the edge of the water or at the high bank to the rear of the river flats. Only through stream flow analysis and cross section data can a reasonably reliable assessment of the mean flow, and thus the cadastral bank, be made.

Figure 5: A non-tidal stream.

Mathematical analysis of stream flow data from long-term stream gauges has found that it is possible to remove the qualitative nature of bank determinations and replace it with a purely quantitative mathematical determination (Songberg, 2012). The mathematics indicate that the mean stage, without reference to extraordinary freshets in time of flood or to extreme droughts, is little different, if any, to the simpler, mean of all stages (Figure 6). The usual flow is closer to the mean annual low flow than the cadastral or total mean.

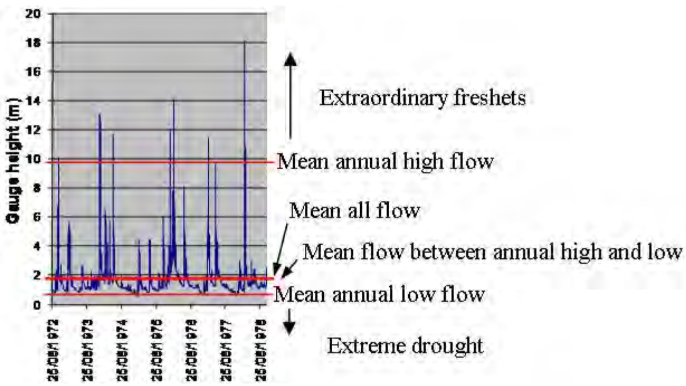

Figure 6: Flow relationships in a typical river regime.

What the mathematics also found was that the resultant cadastral bank is approximately the rear of the lower level gravel beds that sometimes lay close to the low flow water channel. Also the mean flow is only around 0.5% to 3% of the stream's maximum capacity. As a consequence, the cadastral extent of the bed will only be a small percentage of the entire riverine geological structure. The resulting bank is also considerably lower than the geological bank, which is often associated with the term bank full discharge. As a consequence, there will be a disparity between the cadastral land title bank and the geological bank.

From time to time reference to the high bank also forms part of the land title. Surveyors have also found that upon remeasure of the land the chosen bank by the early surveyors was indeed the high bank. It may be that the early choice of the bank was given as the dividing line between the riverine environment and that which the farmer could fully utilise. This high bank is also likely to be synonymous with the geological bank. Such a choice in some ways may be the wiser choice as it becomes clear which is land and which is river. Having the cadastral boundary somewhere down in the gravel flats causes considerable confusion and without reliable stream flow data any assessment is purely qualitative, open to a variety of interpolations with none likely to be correct.

3.2 Stream Bank: A New Definition

With the variety of banks available within and about the riverine environment, there are any number of choices which could substitute the existing definition. Maintaining the status quo as much as possible, the existing definition could be simplified to *the bank of a non-tidal stream is the outer extent of the bed sufficient to contain the stream at its average or mean stage*. It is then left to the surveyor to determine the likely average or mean stage with reference to the whole extent of the river dynamics, something which would be extremely difficult without stream flow data. Another possibility is to entirely separate the riverine environment from the land environment. In Figure 7, the extent of the river environment becomes a little clearer when compared to Figure 5. From this aerial vantage point, it would be a valid consideration that the river extended to the high bank which was seen in Figure 5. This aerial view and other landform characteristics are likely to be factors in locating the stream extent, as is a reference to the geological bank. The surveyor, using such factors, would be tasked with locating the bank by separating the stream and land components.

Figure 7: Aerial view of a non-tidal stream bank consideration.

What should be stressed is that the water's edge does not form the limit of the stream and never has. It is a common misconception that is even used by some surveyors. The water's edge is usually the much diminished low flow and is found in a much smaller channel within the confines of the much larger riverine structure. As with tidal boundaries, the non-tidal could also be defined by environmetnal considerations. Whether the high bank or the geological bank defines the limit of the stream is yet to be determined. Some non-tidal stream titles already exist that are defined as "the high bank" and even "the extreme margin of the

river", so extending the extent of the bed to include the wider river structure could be acceptable. Describing such a boundary may not necessarily be the called bank but could simply be called the "river (or creek or stream) boundary".

3.3 Lake Banks

The bank, through the definition from the Crown Lands Act, also provides the limit of a lake. Lakes, however, are not subject to the same influence as streams. Many lakes, especially inland, are either dry or full. Coastal lakes are periodically tidal whenever the seaward sand barrier is breached, naturally or artificially. Determining the shoreline on the basis of the average stage does not reflect the extent of the lake environment. Inland the average stage might be a considerable distance out from the edge of what is environmentally, obvious to all, the edge of the lake.

The use of the average stage as part of the definition, however, does not extend to an artificial lake as such a lake is expressly excluded from the definition of a lake in the Crown Lands Act. It has been left up to a court case in 1895, *Yeomans v. Peter*, to determine that the top water level of an artificial lake, usually the top water level of a dam, forms the bounds of the lake, something that is not mentioned in the Regulation. As a consequence of this, different lakes have different methods of how their boundaries are determined. Some inland lakes are partially natural and partially artificial as a consequence of irrigation schemes. Whether natural or artificial, lakes tend to produce a naturally occurring division between the lake environment and the land. This natural environmental division will likely to be in contradiction to the result of the average stage being determined. In Figure 8, both a low water level and a high water level (the line across the face of the reeds) can be seen, but what is the bank of the lake? Is it the middle line in between or is it near the edge of the trees? Without long-term lake height data any assessment is purely guess work with each surveyor offering a different choice with potentially none being correct. Such is the failing of trying to find the average or mean stage by purely visual assessment. The environmental extent of the lake, however, is more easily identified. The average or mean stage and the environmental extent of this lake are also not likely to be the same.

Figure 8: Consideration of a lake boundary.

3.4 Lake Bank: A New Definition

The determination of the extent of a lake needs to be made consistent with all types of lakes. A reference to a bank determined by an average or mean stage does not do that. The extent of a lake must include the whole of the lake, not just part. An environmental style assessment as to what is lake and what is land is more likely to provide a meaningful interpretation of the

limit of a lake. Thus any definition should reflect such a scenario. In part, the determination of the extent of an artificial lake meets such criteria. Similar to the determination for a stream, "lake boundary" would be the alternative description.

4 THE DOCTRINE OF ACCRETION AND EROSION

Quite simply, the doctrine should be abandoned. It should be replaced with the premise that if nature moves the physical boundary of the stream, lake or shoreline, then so too does the boundary of the land move. Artificial right line boundaries should not be a barrier to this premise. Nature does not recognise such boundaries. Conversely, if man moves the physical boundary, then the title boundaries associated do not move. In Figure 9, the physical river and the river defined by old cadastral boundaries, centred on the blue line, are for the most part separate entities. Land occupation and land tenure may also be two differing entities. The changes have not been by gradual means and the river is likely to change again at the next major stream flow event.

Figure 9: River changes.

The doctrine was formulated in a bygone era in environments that differ considerably to Australia. Environmental conditions in Australia that physically control the position of the riparian bounds are more known for their extremes than their consistency. It is those extremes, which occur in a random series of events entirely dependent on the vagaries of the weather, that shape the banks of streams and our shoreline (Songberg, 2002; 2004). The doctrine does not help the land owners in Figure 9 in determining the extent of their land. The river does, however, determine the extent of land which is occupied.

The normal day-to-day flow of a non-tidal stream is the low flow which does not have sufficient capacity in both force and volume to touch the banks let alone erode or add to them. It takes a flow event that statistically is only likely to occur every 1 or 2 years to even reach the bank. In the case of *Boyle Concessions Ltd v. Yukon Gold Co 1917* (unfortunately not an Australian case but it shows how the legal mind works), a yearly monsoon induced flow was not considered as one that would cause gradual change. What then does that mean for Australia where statistically such bank-reaching and potentially change-causing flows only

occur once every year but in reality happen randomly? Such an event could occur 2 or 3 times in a single year or not occur for 10 years (Songberg, 2002; 2004; 2012). What does that mean for gradual change?

In tidal streams, islands tend to migrate downstream and bank bars or spits habitually point downstream (Figure 10). If the ebb and flow of the tide were the contributing factor in shaping the streams then these two phenomenon would not occur. In contrast, down around the estuary mouth sand is constantly being draw into the estuary from off the coast suggesting that it is the inflowing tide that has the greater strength despite extra water being theoretically available to the outgoing tide. If the outflow tide were the greater then materials would constantly be pushed out to sea rather than there be continual calls for dredging from the community. Unless there is physical intervention, it is the major flow events that push materials back out to sea and at times unplug the bar that sometimes builds up preventing any ingress or egress of water.

Figure 10: Downstream pointing bars and migrating islands in tidal estuary.

The doctrine does not work in Australia and never has. Trying to comply with it results in uncertainty and disappearing rivers in a titling sense, not physically. As a consequence, we can lose the integrity of the river and have it subject to individual manipulation to the detriment of the wider community. The title extent of the land either side of the river in Figure 9 is a mess. It would be even worse if the changes had been gradual. If there are instances where gradual change does take place, more extreme forces tend to come along randomly and completely remove or significantly alter those smaller changes, negating all that was done. There are many instances along the coast where storm events erode the beaches, taking away the sand that was gradually built up, pushing the beaches inland and threatening property.

Although it has been happening since the last ice age, the new awareness of climate change and the accompanying sea level rise must also be incorporated in a new doctrine. It should be noted that these two phenomena are fact, something that has so far been ignored in formulating tidal boundaries. The influence that man's actions have on these events is, however, still subject to debate and does not form part of this discussion. If the land is to make way for the sea, and only the erection of a dyke, being continually raised higher, around the country will prevent this happening, then so too must the land title make way for the commonly held title of the sea, irrespective of whether the boundary is right line or ambulatory. Inland the land must also make way for the movement of a river. Physically the

two environments cannot coexist. Title should reflect the physical state and not overlap the boundaries between the two entities. There is, however, nothing stopping title being issued in either entity. There will, however, need to be different criteria in how such title would operate in the riverine or marine environment. The present doctrine of accretion and erosion cannot cope with such a fundamental change in approach in dealing with riparian cadastral boundaries.

5 CONCLUDING REMARKS

At this point, there is no conclusion to what has been put forward in this step to reform of riparian boundaries. As the title implies this is just a step toward an unknown conclusion. The issues that have been raised in the preceding papers and the options expressed here might not even move forward. What should be, according to legislation, and what is, according to survey practice, are at times two different things. That needs to change. Changing survey practice to conform to current legislation is likely to create uncertainty in land title which is unacceptable due to the inadequacies of the legislation. Changing legislation to more align with survey practice would create greater certainty and consistency. But in saying such, there also needs to be some change in survey practice as well. Survey practice is not always consistent as surveyors, like everyone else, have differing perspectives to the same scene. Changing both legislation and survey practice to align with the natural environment also makes a world of sense. What will happen in the future is unknown. It is possible that nothing will happen but it is hoped that this will not be the case.

ACKNOWLEDGEMENTS

I would like to thank, or maybe not, Peter Blume for presenting his paper at the first APAS conference in 1995. It was possibly his questioning of mean high water more than anything else that set me on the course of 20 years studying, rather closely at times, the intricacies of riparian boundaries. Much of the opinions expressed in this and previous papers come from direct observations and through many case investigations. This paper is perhaps the evolution of all those that precede it.

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Discussion Forum: GDA2020 – Are You Ready to Make the Move?

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ABSTRACT

In nine short months at the start of 2017, GDA2020 − the modernised Australian datum − will be released to the public for implementation testing. Ultimately, it is expected that this new static datum will be adopted for wide-spread use in Australia by January 2020. Following that date, additional tools and methods will be made available to allow users to accurately account for deformation, whether predictable or spontaneous, and whether small or large-scale. By 2023 it is expected that all users will be able to seamlessly integrate data and observations gathered at different times by making appropriate use of time-stamp metadata and deformation models in their spatial processes. Datum modernisation will allow for greater productivity and innovation in the spatial industry, while still supporting those who desire a static datum for their conventional daily work. The increasing accuracy of spatial information now available to, and required by, both professional and inexperienced users is well known, but so too are the disastrous results that come from not properly understanding the datum which underpins that spatial information. It is imperative that spatial professionals now learn, understand and prepare for this upcoming datum modernisation and become aware of the differences between common datums in operation in Australia, including WGS84, ITRF2008, GDA94 and GDA2020. In particular, GDA2020 will be built on a new and more rigorous national adjustment with a modernised reference epoch. These changes will result in a more homogenous datum with known distortions removed and allow contemporary observations to better match fundamental datasets, but will also introduce an apparent coordinate shift of approximately 1.8 m in all spatial data. This forum is intended to promote discussion of questions or concerns related to datum change, and how we as a community can minimise any disruption as well as take advantage of the opportunities presented by the upcoming Australian Datum Modernisation.

KEYWORDS: *Next generation datum, infrastructure, GDA94, GDA2020, Australia.*

Hologram Room: New Technology to View Scan Data

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ABSTRACT

The hologram room is an ‘Australian made’ tool for viewing Mobile Laser Scanning (MLS) files. It brings high-density point cloud data to life in a 3D ‘virtual world’. The viewer is provided ‘Superman’ like powers, as they can fly through the cloud, walk through walls, view features from all angles, hover above points of interest and zoom in to inspect any feature in more detail. The hologram room is a very powerful tool for project visualisation and data inspection. It is developed by a company whose core technology is for managing large sets of point cloud data. The hologram room creates a real life ‘virtual world’ using the point cloud data. The scan data is projected onto the walls and floor and fully immerses the user into the point cloud. The viewer wears ‘tracked’ glasses, which enables them to inspect the data in the room in true ‘3D’. The hologram room provides a very powerful way to inspect equipment and structures – and provides engineering accuracies to enable design work to be carried out. This paper describes the hologram room, its evolution and some things learned from being involved with the evolution of what will one day be part of everyday life.

KEYWORDS: *Hologram room, 3D data, point cloud, laser scanning, holoverse.*

1 INTRODUCTION

The concept of a hologram room is not new and many visions and implementations of the mythical room have been put together over the last few decades. While across the board technology to implement such a room advances every year, the rapid advancement in laser scanners and their capability to capture the real world has been exceptional. In 2001, the HDS2500 terrestrial scanner produced 1,000 points per second and was considered state of the art. In 2012, the HDS7000 produced 1,000,000 points per second. This is an increase of 3 orders of magnitude in 12 years. The introduction of Mobile Laser Scanning (MLS) has meant that even larger quantities of data can be collected – measured in 100s of gigabytes of data per day. The sheer quantity of data being collected makes it challenging to store, view and manipulate these datasets. Large computer servers are required to store the data, and data handling is often slow. Initially, software visualisation tools were limited.

A key algorithm advancement made by a small Australian company early in the 21st century to address this problem has proven to be much more dramatic in terms of change than first anticipated. Amongst many other events, this advancement has led to the development of a

new incarnation of a hologram room. In this paper, to distinguish it from other incarnations, it will be referred to as the holoverse.

Over the past 18 months the authors have been fortunate to be able to have one of the first holoverses developed for commercial use. We have been able to work with the company who developed the technology, have provided feedback on the use of the room and have watched as they have developed the room from an R&D concept to its current capabilities. We are very excited about the future of the holoverse and believe it will have a major impact on many aspects of our future. While 20 years ago it would not have been easy to predict some of the advancements of today (i.e. social media and the iPad), once you have been in the holoverse it is not hard to imagine it as a standard household item similar to a modern-day theatre room. While there has been a lot of overhype and disappointment with 3D movies and 3D televisions, we believe the holoverse is different. As the holoverse provides users in different industries with some real value, it is envisaged that its uptake will be rapid once hardware becomes mass produced and appropriate content is available.

This paper introduces some of the background of this technology. It explores, through our experiences with the holoverse, what the technology is capable of today. Finally, we look at where this exciting technology may lead.

2 THE HOLOVERSE

In simple terms, our implementation of the holoverse is just a rectangular room with a relatively high ceiling painted black (Figures 1 & 2). On the ceiling and walls are six fairly standard 3D projectors. Four projectors project onto the walls and two project onto the floor areas. In addition, there are sensors that track the movement of the headset worn by the user in the room. The headset contains a set of active 3D glasses. These glasses alternate blocking one eye and then the other so rapidly that it cannot be detected by the human eye. The 3D projectors transmit two alternating images in synchronisation with the glasses – each one showing the view that would be obtained by the matching eye in the virtual world. This provides a very realistic 3D effect.

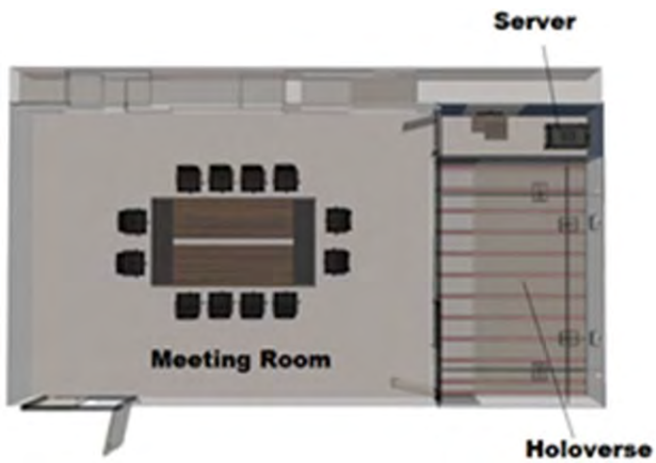

Figure 1: The holoverse is shown on the right hand side. The room has a server room adjacent to the holoverse that contains the PC running the holoverse software and a meeting room with a large screen outside for viewing.

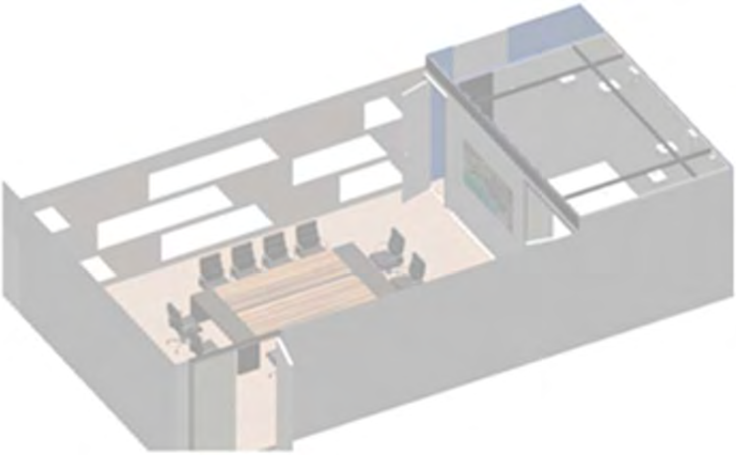

Figure 2: A 3D view of the holoverse facility.

However, being immersed in a room and surrounded by 3D projections synchronised with each other and with your headset is not enough to make a holoverse. Another core component of the holoverse is the ability to track exactly where the user's head and eyes are within the virtual world. As the user's head moves, the viewpoint in the virtual world changes. In order for the scene to remain realistic, the data projected onto the world must be updated in real time (Figure 3). If this is done smoothly and accurately, then the user immediately feels the power of virtual reality. If it is implemented poorly, the user can feel disorientated and maybe nauseous. Therefore, the software engine driving the holoverse is critical.

Figure 3: The holoverse with no dataset loaded.

The software that runs the holoverse uses a proprietary point viewing engine. While the end product looks similar to standard video games, the method of projecting the points on the screen evolves from a radically different process. While video game technology has evolved steadily since the 1980s with the advance in software and video display hardware, the new method of displaying point clouds may as well have been developed on a different planet.

Looking to solve some gaming issues and using a completely different way of thinking, the inventor indirectly created a new point cloud viewing engine. This led to the founding of a company to exploit this technology. While many inventors would be happy simply inventing a revolutionary technology and then selling out and retiring, in this case the inventor has been able to bootstrap this success and find numerous areas where the technology can be applied.

The holoverse was one of the first of these (Figure 4). It was developed in response to challenges arising from laser scanning technology:

- What is the point of having a method to display millions of 3D points incredibly quickly if you are limited by the resolution of a standard PC monitor? The holoverse solves this problem.
- What if laser scanning cannot provide the resolution that the point cloud engine can support? The answer to this problem was another product called Solidscan that merges photographs and point clouds to create photo-realistic 3D models. The best place to show these Solidscan images was again in the holoverse.

Figure 4: An example of a user selecting from 3D menu in holoverse.

In this way, the holoverse is part of an ever-growing family of products built around the core ‘point cloud viewer’ engine development. The holoverse approach to 3D viewing differs significantly from traditional approaches by directly importing the point clouds of scanned objects. Traditional approaches typically transform the 3D point cloud into vector data (i.e. a set of polygons) in order for it to be displayed quickly enough by the computer graphics hardware. This translation from point cloud to vectors is a very time-consuming and expensive process.

The holoverse is unique in that it works directly with point clouds without any modelling required. In fact it is quite a paradox, in that the standard industry requires point clouds to be modelled and transformed into polygons and vectors in order to display them. The holoverse not only displays points directly, but it does the complete opposite and converts any traditional Computer-Aided Drafting (CAD) models from textured polygons into points before displaying them.

3 THE VIRTUAL WORLD

Why would someone want to immerse themselves in a virtual world such as a holoverse? One of the many answers to this question is that we have more power in the virtual world than the real one. For instance, in the real world we can navigate by walking around our model and using our feet and eyes to move closer to objects. We can look at them in detail or move away to view a larger scene. We can turn our head left and right to view objects in what, to us, is a very intuitive interface – it should be because we have been using it since birth.

However, the real world is limiting. In the virtual world we can use exactly the same interface as the real world. We can turn our head left or right to choose what we see. We can also walk

around the room to inspect objects more closely (Figure 5). The holoverse allows us to scale our movement, so that one small step in the holoverse can allow us to move 3 steps in the virtual world. However, in the virtual world there are extra things that we can do that we simply cannot do in the real world (without super powers). Some of these things are outlined in this section.

Figure 5: Looking over a rail and down a stair well in the virtual world.

3.1 Fly

By pointing our controller and pushing a button we can take off into the air exactly like Superman. We can watch as the ground below us gets smaller. We can increase our speed and pick a point for our eventual landing. Flying is fun, but it is also a very useful way to get somewhere quickly and to navigate to a spot. Wherever you look is the direction that you fly and you can control speed by movement of the wand. It takes a bit of practice but in a very short time you can perfect a landing. If you want to do a visual inspection of power lines, you can fly along the pixelated power lines as if you were a bird (Figure 6).

Figure 6: Flying in the holoverse.

3.2 Jump into Hyperspace Through Space

If you want to change countries (say, go to Paris) in the real world, you need to drive to the airport and spend time and money before you are standing in front of the Arc de Triomphe. In the holoverse, with one swipe of the wand a menu appears, you load your next model and there you are (Figure 7).

Figure 7: Swiping to bring up a menu of bookmarks to change model.

3.3 Jump into Hyperspace Through Time

As well as changing to different models, in the virtual world you can be looking at a scanned model of a particular area and change to the exact same view of an older model scanned at an earlier time period. Once accurate models have been collected and archived it will be great to watch and measure buildings and other objects change over time. This adds a valuable historical perspective to data scanning. Imagine being able to walk around the Coliseum as it was when in its peak in Rome. If only the Romans had laser scanners.

3.4 Move Through Walls

In the real world, there are strict protocols and rules of physics, e.g. to get from upstairs to downstairs you must use the stairs or the lift. In the holoverse, you can also do it this way, but if you want to take a short cut and see what is below the floor, above the ceiling or on the other side of a wall, all you need to do is put your head through the wall and see if the model is complete. This is the beauty of the holoverse in that the wall is only a visual limit. In fact for certain ‘user’ experiences the holoverse developers are looking at ways to enforce the real world rules and stopping users passing through surfaces.

3.5 Change Scale

In the real world, our scale changes only slowly as we grow from child to adult. In the virtual world, you can be standing next to a tree and then with the selection of a menu item shrink down to the size of a mouse and look at the smaller part of the model from this viewpoint (Figure 8). Naturally, the model we are viewing requires sufficient density to provide views at the smaller scale. This can be a very powerful feature for viewing something in more detail.

Figure 8: Viewing the point cloud as a 3D map to pick a point to zoom into.

3.6 Measurements

In the virtual world, you can use the equivalent of a laser pointer to point at an object. By holding down a button and dragging the pointer away, a line can be seen in the air with the distance superimposed (Figure 9). It is this easy to take measurements in the virtual world without the need for a tape measure.

Figure 9: Taking a measurement in the holoverse.

4 GEOSPATIAL APPLICATIONS TODAY

4.1 Point Cloud Quality

If you are in the business of collecting point cloud data, there is no better tool for appreciating the quality of the data you are collecting than by immersing yourself in the dataset. Most point clouds look good from a distance. Terrestrial scans in particular look great when viewed from the viewpoint of the scan station. From this location, there is good point density of any objects near the scanner. The point density for distant objects (which are less important) is lower. From another viewpoint, however, it is clear that the point density is uneven and inconsistent.

When traversing through your data in the holoverse, these varying point densities are clearly seen and any laminations, poles not aligning or holes in the data become apparent very quickly. The holoverse is an excellent tool to visually inspect the accuracy, density and general quality of any point cloud data. Currently, many end-users prefer that vector data is extracted from point clouds so that it can be loaded into traditional CAD packages for design. The holoverse can be used to validate the quality of the extraction of these strings against the raw point cloud (Figure 10).

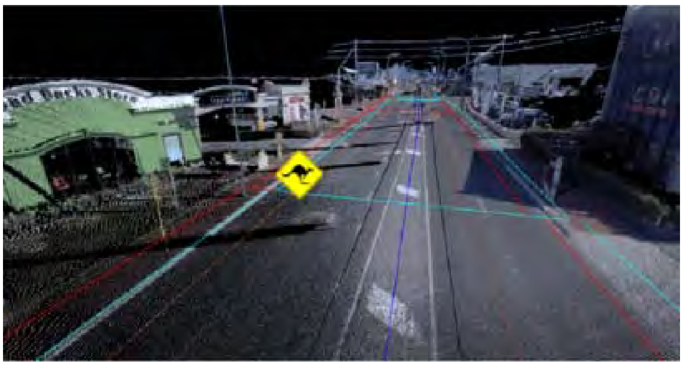

Figure 10: Example of line work being superimposed on the point cloud for validation.

4.2 Planning

An ideal application for the holoverse is visualisation and planning. The first real application for the holoverse was in a proposed development on the coast in Perth, Western Australia. The developers were interested in building a multi-story building along the coast and were naturally concerned with the opinions of the neighbouring residents. They were looking for a way to alleviate some of the unnecessary fears of the residents. They also wanted to provide an accurate view of the final structure to the councils, to enable them to make an informed decision that will be as fair as possible for all the stakeholders and the future of the area.

To facilitate this, the suburb was scanned from the air at a low density and also from the ground along the main streets to provide a very accurate point cloud of the area. The advantage of the low density aerial scan data was that it provided a good model of the views in the distance of the sand dunes, marina and distant houses. The high density mobile scan data provided the houses and balconies of the local residents. This enabled operators to view the impact of the proposed structure from the balconies of every resident in the area.

The proposed development was brought into the point cloud as a 3D model. The view could then be inspected with the model included and the model removed to fully evaluate the effect on each resident in the most realistic way possible (Figure 11). In this situation, the holoverse provided and ideal tool for both the council and the residents to view and analyse the visual impact of the proposed structure. These decisions are never easy, but using the holoverse provided everyone the best information available for the decision making process.

Figure 11: Super-imposing a building into a point cloud model.

4.3 Small Scale Planning

While large scale projects are obvious candidates for scanning and viewing in the holoverse, there are many small scale projects where the same benefit is obtained. A very common case is the development of a single resident property and concerns of the neighbour of shadowing, loss of views and the deterioration of the quality of life for the initial resident. Using scanned data in the holoverse, both the residents and council decision makers can not only see maps and plans of wall heights and roof lines but they can get the feel of walking in the final development. It is not hard to imagine that in the future every council responsible for such decisions will have a holoverse and the capability to collect data for such decisions. The aim is to ensure that at the very least decisions are made on real rather than perceived concerns (Figure 12).

Figure 12: Inspecting a bus stop.

5 THE USER EXPERIENCE

During the first 18 months of its use, the holoverse has changed significantly and we have had to learn and adapt our approach. Over this time, we have encountered some technical issues (e.g. poor tracking of the headset and projector replacement) but the system is slowly evolving into a more robust 'consumer-level' product.

From the first use of the holoverse, the most notable thing has been the 'realness' of the experience. When looking over the side of a 6-story building, one user accidently pushed the laser button knocking him off the edge of the building. Momentarily forgetting he could fly, the user gave out a small squeal. It is surprising that even though there are enough clues that the situation is not real (i.e. you can see the side walls) the brain is happy to accept what it is seeing as reality. During the last year, we have had a few hundred people visit the room. Approximately 95% come away excited from the experience. There is a small percentage that for some reason does not feel well or did not see 3D properly. It is easy to tell from the body language when someone really believes what they are seeing.

Many features of the holoverse have evolved over time. One of the challenges is moving the viewer around within the model – controlling both velocity and acceleration. Similar to the evolution of standard controls used to drive a car, a standard way of navigating a holoverse will evolve to allow anyone to easily navigate the virtual world. The first incarnation for speed control used a button and a fixed velocity that was set in a menu. However, it was soon discovered that some control over acceleration was required to fly and land like Superman. A recent mode added called 'rocket mode' enables high-speed flight where the ground tilts as the user banks to turn a corner. While at first it is confronting, with some use it seems powerfully natural. The system incorporates both bookmarks (to quickly remember and jump to different scenes) and also the ability to record and playback a route.

One current limitation is that the holoverse only supports one person at a time. This is a natural limitation due to the images shown on the walls being customised for the perspective of the one user's location. However, development is underway to be able to connect multiple rooms so that two people in different rooms can be connected and traverse the same virtual world – similar to multi-player gaming. Connecting more than one person will be essential for gaming and training applications. A similar feature being considered is the ability to display the user experience on a screen outside the room. This allows external groups to share the

user's experience (both visual and audio), making using the room a much more collaborative experience.

6 OTHER TECHNOLOGIES

The holoverse is not the only virtual reality product being developed by the wider community. There are many others. 3D glasses and helmets have been evolving for over 20 years and always seem to be on the cusp of a breakthrough. A myriad of devices have been on the market, and games developed for people interested in 3D gaming are always improving. There have been major acquisitions of companies with technology for headsets, indicating that the market considers the big breakthrough of this technology into the mainstream market is imminent.

It should be noted that the makers of headset systems are battling a different problem to that of the holoverse. With a headset, there is a small computer screen directly in front of each eye. The aim is to update these screens in such a way that the brain believes it is seeing the same view as if the user was really moving around in the virtual world. Similar to the holoverse, the device must also take into account the head and possibly eye movements of the user. However, with the headset, the screen must be updated immediately when the wearer moves their head at a suitable rate so as to convince the brain that the scene is real. Any lags in the update of the screen (even if only a few milliseconds) will only convince the wearer that they do not feel well.

The geometry of the holoverse is more forgiving in that the virtual world is being drawn on a wall several metres from the operator. If the wearer moves their head, the new view will need to adjust but the tolerances for error are considerably less. For both technologies, the mass market will not adopt them unless the average person can find the experience comfortable and believable. Headsets have many advantages in portability and cost over a holoverse and they will one day reach their objective. However, it should be noted that headset development may take longer as it is simply a more difficult problem that is being tackled and obscure issues with names like 'vergence-accommodation conflict' may take some time to resolve.

The other technology for virtual worlds is the standard 3D computer screen, again with some form of head tracking equipment. In some ways this is very similar to a holoverse and there are some very good products in both the geospatial and gaming worlds built around this technology already.

At present, the main difference between the holoverse technologies and these products is whether the software is using standard video card technology and showing textured polygon models or raw point cloud points. There is an extremely large and profitable industry built around the current technology. Grand Theft Auto is a good example of a video game built around a complete virtual world (Figure 13). There is already lots of activity in turning these types of virtual worlds into 3D games based on existing technologies that are well suited to the task. Naturally, both technologies will evolve, and time and market forces will eventually determine which technology will become the winner.

Figure 13: Screen shot from Grand Theft Auto video game.

7 THE FUTURE

Similar to the Global Positioning System (GPS) in the 1990s, surveyors were the first to use this new technology as they had one of the first applications that could justify the cost. While in the early days few outside of surveying and the geosciences knew or cared about this exciting satellite-based technology, few would have appreciated that 20 years later Global Navigation Satellite System (GNSS) technology would be built into every person's mobile phone along with a camera. Even fewer would have predicted the number of applications developed that required location devices or that there would be a trend called 'big data' where masses of information would be uploaded automatically from these devices for processing.

Today, the geospatial industry is the early mass user of point clouds and we are privileged to be the first to see and use this new holoverse technology. However, it is not too hard to see that over time geospatial users will become a smaller part of the pie chart. The gaming industry will clearly be a big user of this type of technology and it may even bring back the return of the gaming arcade that was lost to the home computer market of X boxes and play stations more than a decade ago. The new arcades would be full of holoverses and possibly rule for a time until the home holoverse eventually becomes the standard for modern living.

Why would you want a holoverse in your home? Shopping is one option. Imagine if rather than a webpage on your computer screen you could visit stores in the virtual world. You could walk around the show room and look at a car or boat in full 3D just as if you were there. Shopping, whether for clothes, appliances or even food, can all be better in 3D. Imagine floating down a virtual supermarket isle selecting items with your wand to fill up your virtual shopping basket. Home shopping is there now but the holoverse would provide a more natural interface.

Selling real estate is clearly a big market and well suited for virtual computer tours. Would it not be a better experience to go to a 'state-of-the-art' holoverse and without travelling view properties from all around your suburb, state, country or the world, and experience them as if you are actually there?

Just as nearly all industries have benefited from computers, industries such as medicine, architecture, real estate and construction will also benefit from the advent of the virtual world and holoverses. Each industry will naturally evolve their own custom applications to meet their needs.

One of the first industries that will benefit almost immediately will be in training and health and safety, particularly in mining and on oil and gas platform situations. There are many places that are difficult to experience and train for without being there. Imagine the power of being able to simulate these environments in minute detail so the user is fully aware of the environment, dangers and safety features before ever arriving on site. However, in reality, it is unlikely that we will know the full extent of how this technology will be used in the future. All we can say for sure is that it will be in 3D.

8 CONCLUDING REMARKS

The version of the holoverse discussed in this paper was implemented in March 2014 and has been evolving slowly with improvements in software and hardware ever since. Using the holoverse has been a great tool in evaluating the quality of point cloud data and also in communicating development and planning decisions today. While we are continuing to improve our point cloud collection and processing methods, the holoverse is currently a valuable tool in this process. The full list of applications for the holoverse in the future and the direction this technology will take are both unknown and limitless.

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Capturing, Representing and Visualising the 3D World

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ABSTRACT

Combined use of laser scanning and CAD modelling techniques to accurately capture, represent and visualise the 'real' 3D world, with all of its intricacies, is one that Cardno have proficiently mastered and remained at the forefront of technology. Although the aforementioned application remains a difficult challenge for many firms to accomplish, this presentation demonstrates the proven methods, techniques and achievements that Cardno have established in order to bring clarity, understanding and satisfaction to clients, even for the most complex projects. From simple trees to expansive railway stations, suspended bridges and major shopping centres, one objective is to highlight key projects that detail critical start-to-finish workflows for successful project completion. The use and effectiveness of static terrestrial laser scanning while comparing CAD modelling packages such as Rhino and Revit is illustrated, and how they can be combined effectively to produce interactive deliverables such as 3D pdf's and TruView photography. The power of simulated fly-throughs, walk-throughs and fly-overs is also illustrated. In summary, the approach to the 3D world is not one-size-fits-all and every job is unique in its requirements and complexity. The 3D world is always moving forward and technological advancements are constantly being introduced. Adaptation and successful implementation of these technologies is crucial for being up-to-date, whether in the hardware, software or personnel, in order to remain competitive. However, when all elements are successfully performed the results can be quite spectacular.

KEYWORDS: *Laser scanning, BIM/CAD modelling, 3D visualisation.*

The Z Factor: Creating a New Digital Surface and Elevation Model for NSW

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ABSTRACT

Geographic information throughout history has been an important aspect of mankind's development, mapping the world we live in, from prehistoric cave wall drawings to the traditional paper map and digital spatial data of more recent history. Today, developments in technology provide rapidly advancing ways in which Geographic Information Systems (GIS) visualise and analyse spatially enabled data in digital environments. Previously limited to 2D, spatial modelling is today able to visualise and analyse objects in 3D digital environments, changing how we plan, design, construct and mitigate risk. The growing interest in Government, business and communities for identifying our world in 3D is driving widespread development of digital surface and elevation models in innovative ways. Land and Property Information (LPI), through the NSW Surface Model Enhancement Project (SMEP), is the first agency in Australia to embark on the ambitious goal of developing high-resolution, information rich, state-wide digital surface and elevation models. This data will meet the strategic goals of the NSW Foundation Spatial Data Framework (FSDF) and NSW Location Intelligence, delivering elevation data that will provide the capability to attribute existing datasets and lead to the development of new datasets for the future. These models will allow the agency and its stakeholders and customers to realise true 3D spatial data environments that will:

- *enhance our ability to visualise and analyse spatial data,*
- *reduce overall NSW Government ad-hoc spending on surface model procurement,*
- *improve the NSW Governments' capacity to effectively plan, respond to and mitigate against the risks and impacts of climate change and natural disasters,*
- *better support hydraulic and hydrologic modelling, mitigation and planning,*
- *provide stakeholder organisational efficiencies, and*
- *continue supporting LPI's systems and services provided to stakeholders.*

This presentation will outline some of the key benefits and challenges of the Surface Model Enhancement Project before looking at the data and a range of innovative workflow enhancements that have delivered tangible results. From there it will explore the ability for feature extraction and attributing opportunities that the soon-to-commence 3-Dimensional Feature Extraction (3DFEx) project will focus on.

KEYWORDS: *LiDAR, point clouds, surface models, feature extraction.*

Land Administration Reform

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ABSTRACT

This paper highlights the importance of improved land administration services and the impact that the lack of a good land administration system has on the socio-economic development of many countries. Drawing on extensive experience in implementing land administration reform in many countries, the paper considers the issues that can and do impact on the provision of good land administration services (particularly deficiencies in policy and legislation), the large gap that typically appears between policy/legislation and what actually happens on the ground, and the implications of attempting to implement policy/legislation without adequate funding and resources. The environment for land administration reform projects is also changing. There is increased emphasis on pro-poor policy, better land governance and the adoption of procedures and technology that are fit-for-purpose. The paper concludes with the observation that land is fundamental in any society and that the surveyor has a key role in the provision of good land administration services. The focus on improved governance and fit-for-purpose procedures and technology is as relevant to surveyors in New South Wales as it is for surveyors in the developing world.

KEYWORDS: *Land administration, land policy, land governance, institutional reform, capacity building.*

1 INTRODUCTION

In most countries, land and immovable property attached to it ('land') accounts for between half and three-quarters of national wealth. Land is a fundamental input for agriculture and is directly linked to food security. It is also a primary source of collateral in obtaining credit from formal and informal providers of finance. Fees and taxes on land are often a significant source of government revenue, particularly for local governments. Land has cultural and religious significance in many cultures, and the formal recognition of rights is often vital in ensuring that indigenous and other vulnerable groups have access to land.

Land Equity International (LEI) has been privileged to work in many countries in land administration reform and capacity building, and this paper sets out some information on some recent projects. Four surveyors (including two former Surveyor-Generals) formed LEI in 2001. The Wollongong-based consultancy specialises in land sector projects in the developing world. LEI's founders had been working on international projects since the early 1980s, initially as part of BHP Engineering and from 1999 as part of Hatch Associates. LEI focuses on the land sector, however, this covers a very wide scope. Early projects were major land titling projects, mainly in South-East Asia, where a significant part of the activity was to develop and scale up mass programs to formally recognise land rights and issue land titles or certificates. However, land sector projects now cover many different areas, including land policy and legislation development, land governance and safeguarding the interests of the

poor and vulnerable. The skills needed to work on land projects are also very broad (much broader than just surveying and mapping) and include law, IT and records management, institutional development (e.g. organisation, strategy, budgeting and planning), human resources development and management, capacity building, gender and public awareness. In implementing land projects, LEI has drawn on specialists from the private sector, government and academia.

Although this conference focuses on domestic topics of relevance to public sector and private surveyors, there is value in reviewing recent international experience and some new considerations, such as an increased emphasis on good governance, the Food and Agriculture Organizaton of the United Nations (FAO) Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (VGGTs), and recent work by the World Bank and FIG on fit-for-purpose land administration. Surveying is a very conservative profession, particularly cadastral surveying. You only need look at the way survey directions cover technology such as Global Navigation Satellite Systems (GNSS) and photogrammetry to understand this. Too often we take things for granted, and it is only when you need to explain *why* we do things the way we do, that you start to appreciate the opportunities that ever-improving technology offers. The increasing pressure by policy makers in many countries to come up with low-cost solutions that produce results in the short term adds incentive to explore options.

2 PERSPECTIVE OF THE PROBLEM

2.1 The Problem

It is very difficult to estimate how many land parcels there are in the world. However, a generally-accepted estimate is that there are about six billion land parcels (globally), of which only 1.5 billion are registered in a land administration system that accurately and reliably records the extent and location of the land parcels, as well as the rights held over the land parcels (McLaren, 2011). The land administration system in Australia, like most Organisation for Economic Co-operation and Development (OECD) countries, works so well that we take it for granted.

It is worthwhile revisiting the benefits of a good land administration system. Williamson et al. (2010) list the traditional benefits of having a good land administration system in place. These include:

- Support for governance and the rule of law.
- Poverty alleviation.
- Tenure security.
- Support for formal land markets.
- Credit security.
- Support for land and property taxation.
- State lands protection.
- Land dispute management.
- Land planning improvements.
- Infrastructure development.
- Resources and environmental management.
- Information and statistical data management.

Many of these benefit society as a whole. Others, such as poverty alleviation, tenure security and credit security, benefit individual land owners. The importance of extending the system for the formal recognition of property rights to all sectors in society in the developing world, rather than just the elite privileged few, was highlighted by de Soto (2000) – a lesson that the West learned two centuries ago. It can be difficult to appreciate the nature of these benefits.

In 1997, the author was Team Leader on the design and preparation of the World Bank-funded Peru Urban Property Rights Project (PUPRP). In the decades leading up to the end of the 20th century, Peru experienced a massive shift in population from the rural areas in the mountains to the urban areas on the coast. In 1997 (largely due to a very complicated process for urbanisation that had been and was being poorly enforced and implemented), a large proportion of urban dwellers in the major cities of Peru were classed as 'informal settlers' living in residences lacking formal approval on land lacking formal registration. By June 2004, the PUPRP had registered more than 1.2 million properties and issued about 920,000 titles. The project directly benefited 4.6 million Peruvians (a significant proportion of the total population at the time, which was around 27.2 million – see https://www.inei.gob.pe/media/MenuRecursivo/Cap03001.xls), mobilised about US$400 million in formal credit for marginalised communities, and increased the value of formalised property by around US$523 million (World Bank, 2004). However, by strengthening tenure, there was reduced need to protect rights by occupation, and socio-economic studies have since demonstrated that titling has resulted in a substantial increase in labour hours, a shift in labour supply (from work at home to work in the outside market), and substitution of adult for child labour (Field, 2007).

If the benefits of having a sound land administration system are so clear, why are countries with a good land administration system the exception, rather than the rule? There is great variety in the situations and contexts of countries seeking improved land administration systems.

In Africa, most countries are faced with a weak central government that often has limited authority outside the capital city. This dual tenure regime is a legacy of colonial administration – with a western model operating in areas of economic activity, various forms of customary tenure applying elsewhere, limited finances and technical resources, a general lack of reliable information, limited access to existing information, poor enforcement, and a general lack of transparency in systems and procedures.

Latin America also has a strong colonial legacy that has resulted in large inequities in the distribution of land. Significant past land reform in the region, while largely unsuccessful in addressing the inequity, has created new tenures and institutions. There is large informality in the region in both urban and rural areas.

In response to the collapse of communism, Eastern European and Central Asian countries all implemented significant changes to land administration systems. These countries frequently faced institutional issues with (typically) different agencies having responsibility for the cadastre, building registration and the recording of rights. However, most countries had basic information and skilled staff. It is perhaps not surprising that seven of the 10 countries ranked in 2015 by the World Bank Doing Business assessment as the 'easiest' to register property in are from these regions (Lithuania is ranked 2, Georgia 3, Estonia 4, Slovak Republic 5, Kyrgyz Republic 6, Belarus 7 and Russian Federation 8, while Australia is ranked 48 – see World Bank, 2016).

Key issues impacting on many efforts to improve land administration systems include a lack of clear land policy and ineffective legislation to put this policy into effect. The author was fortunate, in 1984, to start work on major international land projects in Thailand. Readily appreciating the quality of life available in Thailand (with a strong culture, friendly people and good food) and, as the photomapping adviser, he soon became immersed in the task of helping the Department of Lands scale up a major 20-year land titling program. What was not appreciated at the time was that the program was built on a very strong foundation. The Department of Lands had (at the time) about 14,000 staff and large headquarters in Bangkok with nearly 1,000 province, branch and district land offices throughout the country. The Department had a very strong *esprit de corps* and was (within the Ministry of Interior) the most powerful ministry. The land administration system was maintained by the Department and was (and still is) largely a manual system; but it was one of the most efficient systems in the world. By regulation, a registration had to be made on the day of application unless there was a legal requirement for further evidence, such as a cadastral survey. The Land Code of 1954 provided a very clear legal basis for a major land titling program – at least as far as the 47% of the country that was classified as non-forest. The Department had a very pragmatic approach to survey and map standards and the technical staff did as they were instructed by the land administrators. It was only when the author started to work in Indonesia and the Philippines that he started to appreciate the strong base in Thailand.

In Indonesia, the National Land Agency had only been formed in 1988 and operated as a loose coalition of previously separate organisations. It had taken 12 years to prepare the Basic Agrarian Law of 1960, and this law lacked major implementing regulations and had not been fully implemented. The Land Administration Project started in 1994 and it took three years to update the implementing Presidential Decree to facilitate systematic registration. The project was able to produce 1.87 million certificates, but this program was not scaled up as planned, and little was achieved in building capacity to maintain the land administration system and provide improved services.

In the Philippines, the institutional and legal framework was even weaker than in Indonesia. There were at least five different ways to obtain a title, two agencies that approved survey plans and the land registration system was a judicial Torrens Title system that was implemented in 1901 in the Philippines and based on the 1894 legislation in the US State of Massachusetts. Virtually all the land administration legislation in the Philippines was put in place under American colonial administration and there were many inconsistencies.

In this context it is useful to note that the 'rule of law' is defined by the World Justice Project as a system where the following four universal principles are upheld (World Justice Project, 2016):

1. The government and its officials and agents as well as individuals and private entities are accountable under the law.
2. The laws are clear, publicised, stable, and just; are applied evenly; and protect fundamental rights, including the security of persons and property.
3. The process by which the laws are enacted, administered, and enforced is accessible, fair, and efficient.
4. Justice is delivered timely by competent, ethical, and independent representatives and neutrals who are of sufficient number, have adequate resources, and reflect the makeup of the communities they serve.

Many developing countries, particularly countries where the rule of law does not apply and/or the legislative process does not work well, have developed a comprehensive statement of land policy that has been developed (typically) with broad stakeholder consultation and has been adopted in some formal manner. Countries that have developed a comprehensive land policy include Tanzania (in 1995 – see United Republic of Tanzania, 1997), Ghana (in 1999 – see Government of Ghana, 1999) and Uganda (in 2013 – see Republic of Uganda, 2013).

While important, these documents tend to focus on problems and issues with limited attention paid to key actions to address the problems and issues. Even where there is a comprehensive land policy, there can be a gap between the policy and legislation. The National Land Policy (NLP) in Tanzania was put into effect by the Land Act No.4 of 1999, the Village Land Act No. 5 of 1999 and the Courts (Land Dispute Settlement) Act No. 2 of 2002. Although the NLP highlighted issues with all rural sectors, including agriculturalist and pastoralists, the Village Land Act (specifying the rights for village land, which covers about 70 percent of mainland Tanzania), largely focuses on the interests of agriculturalists. There can also be a big gap between policy/legislation and implementation. In 2005, the European Union (EU) funded the preparation in Tanzania of the Strategic Plan for the Implementation of the Land Laws that was costed at about US$300 million. This plan set out an ambitious scope of work that has largely not been implemented. A major reason for this was the lack of funding.

2.2 Some Country Examples

The following summaries of issues faced by governments in improving land administration systems for Romania, Tanzania and Vanuatu (i.e. three countries that LEI has recent or ongoing experience in) provide an insight into the wide variety of issues that need to be addressed.

2.2.1 Romania

Background: Romania is a republic located in South-Eastern Europe, bordering the Black Sea, between Bulgaria and Ukraine. It also borders Hungary, Serbia and Moldova. The country lies between latitudes 43° and 49° N, and longitudes 20° and 30° E. The terrain is distributed roughly equally between mountains, hills and plains. Romania has one of the largest areas of undisturbed forest in Europe, covering almost 27% of the territory. Romania has a total area of about 238,400 km^2 and a population of about 21.1 million. There are 42 counties and 3,181 territorial administrative units (UATs) in Romania. Of the 3,181 UATs in Romania, 320 are cities and municipalities and 2,861 are communes in rural areas (rural UATs). There are an estimated 40 million properties in Romania, 8 million in urban UATs and 32 million in rural UATs.

Overview of Land Tenure Arrangements: The land tenure arrangements in Romania have the following historical background:

- Records of transcriptions and inscriptions, regulated by the Civil Code and the Code of Civil Procedure based on rules implemented under the Ottoman administration, have existed in the former provinces Wallachia, Moldavia, Oltenia and Dobrogea, which constitutes about half of Romania.
- Land books were introduced in the second half of the 19th century under Austro-Hungarian laws in Transylvania, Banat, Crişana, Satu Mare, Maramureş and South Bucovina, which covers about half of Romania.

- During the communist period (1945-1989), most Romanian agricultural land was nationalised, and large collective and state farms were formed. Out of a total number of 3,181 UATs in Romania, 2,478 UATs are in cooperative areas, 442 UATs are in non-cooperativised areas, and in 261 UATs there is a mixture of villages that have been cooperativised and land that has not been cooperativised.
- After the revolution, an early decision was made to restitute land under a variety of laws that have evolved over time from 1991. Restitution of land started before the necessary legal basis for registration was in place. The restitution process of the agricultural and forestry land belonging to the private domain is almost complete (about 93%). A law was passed in 2013, which has the objective of completing restitution in kind or equivalent.

Key Land Sector Issues: After the revolution in 1989, Romania initiated efforts to create a national system for recording property rights. The legal framework of this new system was created by Law No. 7/1996, the Law on Cadastre and Land Registration. The implementation of the law throughout the country began in July 1999. The registration system (based on the old land books and on transcription-inscription records) is still in place in many areas in Romania, but will be replaced over time with new land books. The process of implementing Law No. 7/1996 is ongoing and has been difficult due to a lack of human and material resources and difficulty in harmonising the various related legal rules.

The National Agency for Cadastre and Land Registration (ANCPI) was formed in 2004 through the merger of the cadastre under the Ministry of Administration and Interior and the land book registers under the Ministry of Justice. At the time, ANCPI underwent substantial organisational reform, bringing the two entities together physically. In 2009, the originally autonomous and self-financing ANCPI reverted to central budget financing and government payroll restrictions, which has held back progress in implementing organisational and strategic reforms. This reversion was not easy and led to a large turnover of key staff members. Consequently, while ANCPI has managed to conduct daily operations and maintain registration relatively well, the reform agenda stalled, and training and capacity building activities were severely underfunded. Under the latest changes to Law No. 7/1996, and since the approval of Government Decision for the National Program for the Cadastre and Land Book (NPCLB) 294/2015, ANCPI has regained the ability to retain revenue and public funding for salaries and investments.

Over 8.3 million properties have been registered and entered into the new land book system, which is administered in the eTerra ICT application maintained by ANCPI. About 3.9 million of these registered properties are in urban areas and 4.4 million properties are in rural areas.

Current Initiatives to Improve Land Administration: Law No. 7/1996 on Cadastre and Land Registration, as amended by Law No. 150/2015, sets out the purpose of "registration of immovable property without charge within the integrated system of cadastre and land book, issuing the cadastral plan of immovables and opening of land books in all administrative territorial units". Existing entries in the cadastre and land book system have largely been made on the basis of sporadic requests by individual landowners to have their land registered. This has been effective in urban areas where nearly 50% of properties have been registered, but has been a lot less effective in rural areas where only 13.7% of the estimated properties are registered.

To implement the law, ANCPI has adopted a policy of undertaking systematic registration in rural UATs in Romania. Systematic registration has commenced in 51 rural UATs and been

completed in seven UATs. This means that there are 2,810 rural UATs where systematic registration has not commenced.

A draft National Strategy for Systematic and Sporadic Registration was finalised in August 2014 by ANCPI with support from specialists from the World Bank, and a draft NPCLB was completed by ANCPI in January 2015 – again with assistance from the World Bank. The budget for the NPCLB from projected retained ANCPI revenue over the next 10 years is tight and ANCPI has only been able to plan to complete registration under the NPCLB in 320 urban UATs and in 2,017 rural UATs. ANCPI proposes to complete systematic registration in the remaining 793 rural UATs under the EU-financed project in the programmatic period 2014-2020. The NPCLB and the EU project (as planned) will complete the registration of all UATs in Romania.

2.2.2 Tanzania

Background: Tanzania, officially the United Republic of Tanzania, is bordered by Kenya and Uganda to the north; Rwanda, Burundi and the Democratic Republic of the Congo to the west; Zambia, Malawi and Mozambique to the south; and the Indian Ocean to the east. European colonialism began in mainland Tanzania during the late 19th century when Germany formed German East Africa, which gave way to British rule following World War I. The mainland was governed as Tanganyika, with the Zanzibar Archipelago remaining a separate colonial jurisdiction. Following their respective independence in 1961 and 1963, the two entities merged in April 1964 to form the United Republic of Tanzania. There is a separate land policy and legislative framework for mainland Tanzania and Zanzibar. Mainland Tanzania has an area of 947,303 km^2 and had a population of about 44.9 million (in 2012).

Overview of Land Tenure Arrangements: The land tenure practice in Tanganyika was that indigenous lands were treated as ‘not owned’ and titles in these lands were vested in the state, except for land alienated to settlers under documentary titles. The procedures applying under colonial administration were largely left in place for the first 35 years of independence. In 1963, freehold titles were converted to government leaseholds and, in 1969, to rights of occupancy. The Villages and Ujamaa Villages Act of 1975 changed the fundamental nature of rural tenure, where households were removed, sometimes forcibly, from individual remote homesteads to designated settlements with the objective of providing better services, including health and education. By 1979, there were about 15 million people living in 8,300 registered Ujamaa Villages.

With the land policy and legislation largely left unchanged from colonial times, the post-independence policy of villagisation leading to increasing social tension, and a growing population with increased urbanisation putting added pressure on available land, the government prepared a NLP that set out 15 fundamental principles and was passed by parliament in 1995. The NLP was put into effect by the Land Act No.4 of 1999, the Village Land Act No. 5 of 1999 and the Courts (Land Dispute Settlement) Act No. 2 of 2002. There are then three categories of land under these laws:

1. General land (about 2% of the country), which is classed as land that is neither village nor reserve land.
2. Village land (about 70% of the country), which is land within the boundaries of a registered village that is occupied by its inhabitants and falls under the jurisdiction of its respective village council to whom the Commissioner of Lands has issued a certificate of village land.

3. Reserve land (about 28% of the country), which is land reserved and governed for purposes set out in nine listed laws. The purposes include environmental protection, national parks, forest and wildlife reserves, marine parks and areas set aside for spatial planning and infrastructure development.

All land in Tanzania is public land under the trusteeship of the President. The Granted Right of Occupancy (GRO) is the main form of land holding in mainland Tanzania and is granted by the President for a period of up to 99 years over general and (in some cases) reserve land. The GRO may be traded as any other personal property through sale, lease, mortgage, etc. Village land is administered under the Village Land Act, with procedures specified to demarcate and survey village boundaries, issue certificates of village land, prepare village land use plans and to issue Certificates of Customary Right of Occupancy (CCROs). Although the Commissioner of Lands has oversight of this process, a large portion of the authority is assigned to institutions established in the villages.

Key Land Sector Issues: In recent years, the number of rural land use conflicts has increased, particularly between traditional pastoralists and traditional agriculturalists as they have expanded the scope of their activities. Urban areas have also experienced an increase in the number of disputes over land, as the urban population has expanded from 686,000 in 1967 to over 10 million in 2013. Urban land has expanded into rural land with little control and government procedures for providing urban housing. 'Land delivery' has failed to meet the demand. In Dar es Salaam, the major city, the number of informal residences has increased from an estimated 50,000 in 1974 to over 500,000 (or 80% of the total residences in the city) in 2013.

Both a rapidly increasing population and rapid urbanisation will place strong pressures on existing land. In 1967 the population of mainland Tanzania was 12.7 million and this grew to 44.9 million by 2012 (Burns et al., 2013). There are predictions that the population will grow to 62 million in 2020, 108 million in 2040, 137 million in 2050 and 299 million by 2100 (UN Department of Economic and Social Affairs, 2015). There has also been a rapid increase in the percentage of the population living in the urban sector. This has risen from 5.7% of the population in 1967 to 29.1% in 2012. Given the scale of the increases in population, there will be increasing pressure on land in both the urban and rural sectors.

Current Initiatives to Improve Land Administration: In April 2014, a land laboratory was added to the 'Big Results Now!' initiative (United Republic of Tanzania, 2015). This laboratory set out some ambitious targets. Two objectives set out in the plan included the issuance of 10 million CCROs by the end of 2016, and the survey and titling of five cities, and Dodoma, by the end of 2016. In March 2013, only 139,721 CCROs had been issued.

There are a number of development partners preparing or implementing projects to assist the government improve land administration systems:

- DFID, Sida and Danida are supporting the Land Tenure Support Program.
- USAID is funding the Feed the Future Tanzania Land Tenure Assistance activity.
- The World Bank is supporting the Private Sector Competitiveness Project, which has a land reform component and is also supporting work in the urban sector.

2.2.3 Vanuatu

Background: The Republic of Vanuatu is a South Pacific island nation lying between 13º and 21º S and 166º and 170º E, placing the archipelago 1,750 km to the east of northern Australia (Queensland), 500 km north-east of New Caledonia, south-east of the Solomon Islands and west of Fiji. It has a total land area of 12,190 km² and a population of just over 270,000.

Overview of Land Tenure Arrangements: Land tenure arrangements are governed by the Constitution 1980 (as amended in 2013), supported by a number of land-related laws. The Constitution states that "all land in the Republic of Vanuatu belongs to the indigenous custom owners and their descendants" (Article 73). Land held by customary owners and referred to as 'customary land' currently makes up over 95% of the total land area in Vanuatu. For those wishing to 'acquire' land for business, investment and other purposes, the Land Leases Act 1983 facilitates the creation, registration and management of leasehold titles, enabling a lessee to obtain a leasehold interest for a term not exceeding 75 years.

Key Land Sector Issues: Despite the existence of a seemingly sound constitutional and legislative framework post-independence, Vanuatu has continued to struggle with a range of land sector issues including:

- A lack of adherence to the spirit of the constitution, with successive governments failing to ensure that leasing arrangements are not prejudicial to Vanuatu and its citizens. Currently, approximately 10% of Vanuatu is under lease with 60% of coastal Efate leased.
- A dysfunctional leasing process, with successive Ministers abusing their powers and signing off leases on behalf of custom owners.
- Legislative failings that have given rise to confusion as to what falls under the jurisdiction of the formal legal system and what can/should be dealt with under the customary system.
- Institutional and administrative failings arising from poorly-resourced organisations, outdated practices and procedures, limited use of new technology, poorly maintained records and limited human resource capacity.
- A general lack of awareness among the citizens of Vanuatu about their rights and responsibilities regarding land matters.

Current Initiatives to Improve Land Administration: The Vanuatu Land Program (the Program) was a 5-year initiative funded by the Australian and New Zealand Governments and designed to address these issues. The Program supported a range of activities that focused on both the formal and customary land sectors, and was designed to strengthen institutions, build capacity, improve governance and improve service delivery.

In respect of customary land, the Program supported a major land reform initiative that included constitutional amendments, legislative change (including the limiting of Ministerial powers), the introduction of a more open, transparent and participatory leasing process and outreach, and public awareness workshops.

In the formal sector, efforts focused on improving the core land administration functional areas of surveying, registration and valuation, and included organisational reviews, capacity building through training and education programs, process re-engineering, digitisation of records and IT systems development and implementation.

3 CHANGING ENVIRONMENT FOR LAND PROJECTS

When designing a major land project, there is often a tension between a focus on private rights and a focus on public land. There is also often a tension in deciding whether the focus is on the urban or the rural sector. Projects in the urban sector typically have objectives focused on economic development, markets and employment, while projects in the rural sector (often concerned with agricultural production and markets) are typically concerned with aspects such as food security, environmental sustainability, forest management and customary tenure.

There is also tension between a focus on the formal and informal sectors. In many cities in the developing world there are pockets of informal settlements that have been occupied for generations. In rural areas, the formal rights systems, which often include economic land concessions, are bumping up against the rights of indigenous peoples and those traditionally reliant on access to forests, rivers and foreshores. Furthermore, there is tension between a focus on projects to formally recognise existing rights and projects that seek to redistribute land rights. The Global Land Tool Network (GLTN) has developed the concept of the ‘continuum of land rights’ (Figure 1), which has gained general acceptance (GLTN, 2015). About 30 years ago, when the author started working in Thailand, there was a focus on land titling – the scaling up of a participatory process to systematically register existing rights in land. Today, projects are encouraged to recognise rights along the continuum of land rights and/or seek to change the rules to broaden the scope of the tenures recognised by the formal system.

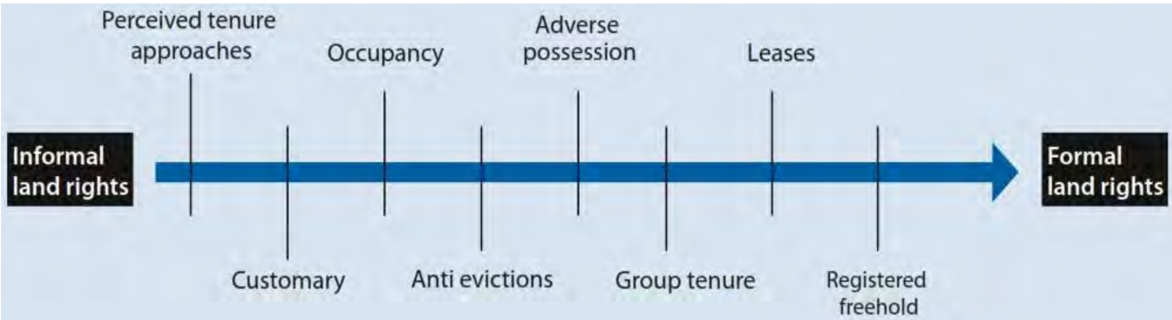

Figure 1: Continuum of land rights (UN-HABITAT, 2008).

A number of other recent developments shape how projects to improve land administration systems are designed. These developments include global development goals, an increased focus on land governance, particularly the VGGTs and the concept of fit-for-purpose land administration. These developments are briefly discussed below.

3.1 Global Development Goals

The Sustainable Development Goals (SDGs) replace the Millennium Development Goals that expired in 2015 (UN, 2016a, 2016b). The SDGs were adopted in a meeting of the Heads of State and Government and High Representatives at the United Nations Headquarters in New York in September 2015. There are 17 SDGs with 169 associated targets. The new goals and targets have come into effect on 1 January 2016 and will guide development decisions over the subsequent 15 years. The SDGs have been designed to be implemented at the country, regional and global levels.

A comprehensive range of 241 indicators has been developed to monitor progress in realising the SDGs. Six of the suggested global monitoring indicators and two of the suggested complementary national indicators have a significant focus on land (Table 1).

Table 1: Sustainable development goals with a substantial land component.

Indicator		Goal/Target	
#	**Description**	**Goal**	**Target**
1.4.2	Proportion of total adult population with secure tenure rights to land, with legally recognised documentation and who perceive their rights to land as secure, by sex and type of tenure.	1. End poverty in all its forms everywhere.	1.4 By 2030 ensure that all men and women, in particular the poor and vulnerable, have equal rights to economic resources, as well as access to basic services, ownership, and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services including microfinance.
5.a.1	(a) Proportion of total agricultural population with ownership or secure rights over agricultural land, by sex; and (b) share of women among owners or rights-bearers of agricultural land, by type of tenure.	5. Achieve gender equality and empower all women and girls.	5.a Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws.
5.a.2	Proportion of countries where the legal framework (including customary law) guarantees women's equal rights to land ownership and/or control.		
11.1.1	Proportion of urban population living in slums, informal settlements or inadequate housing.	11. Make cities and human settlements inclusive, safe, resilient and sustainable.	11.1 By 2030 ensure access for all to adequate, safe and affordable housing and basic services, and upgrade slums.
16.5.1	Proportion of persons who had at least one contact with a public official and who paid a bribe to a public official, or were asked for a bribe by these public officials, during the previous 12 months.	16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.	16.5 Substantially reduce corruption and bribery in all its forms.
16.5.2	Proportion of businesses who had at least one contact with a public official and who paid a bribe to a public official, or were asked for a bribe by these public officials, during the previous 12 months.		

In summary, these six indicators include:

- An indicator that seeks to ensure that the adult population has secure rights to land with legally recognized documentation and perceives their rights as secure, by sex and type of tenure.
- An indicator or indicators to assess the proportion of the total agricultural population with secure tenure, by sex, and share of women amongst owners or rights-bearers of agricultural land, by type of tenure.
- An indicator to assess the proportion of countries where the legal framework (including customary law) guarantees women's equal rights to land ownership and/or control
- An indicator on the percentage of the urban population living in slums or informal settlements.

- Two indicators on bribery and corruption, something that is relevant as the land sector has been highlighted as prone to corruption in many of the surveys by Transparency International.

3.2 Emphasis on Governance

The actions of government are increasingly being more open to oversight and commentary by the domestic and international community. There is increased focus on good land governance. One example of this is the Land Governance Assessment Framework (LGAF) that the author helped develop with the World Bank (Deininger et al., 2012). LGAF is a tool that cuts across the traditional institutional silos in the land sector. Using local experts, LGAF (over 3-6 months) reviews:

1. How property rights to land (for groups or individuals) are defined, enforced, can be exchanged and transformed.
2. The way land is managed, land use plans and regulations are prepared and implemented, and how land is taxed.
3. What is state land, how it is managed, acquired and disposed of.
4. The nature and quality of property ownership information available to the public and the ease with which it can be accessed or modified.
5. The way in which disputes are resolved and conflict is managed.

The LGAF assessment and report is presented in a form that provides the basis for decisions by policy makers and development partners. LGAF has been undertaken in about 40 countries and is being implemented at the sub-national level (LGAF, 2016).

To support the focus on land governance, a range of indicators have been developed. Some of these focus on land markets, such as the Global Real Estate Transparency Index covering 102 global land markets (JLL, 2016). The International Property Rights Index focuses on property rights and how well governments recognise and protect them (Property Rights Alliance, 2015). The World Bank's Doing Business indicator assesses a range of indicators on how government fosters business activity and one of these indicators is registering property (World Bank, 2016).

3.3 Voluntary Guidelines

The FAO VGGTs were officially endorsed by the UN Committee on World Food Security on 11 May 2012 (FAO, 2016). The VGGTs, which were developed by FAO through a broad global partnership of international, regional and national organisations of different types are voluntary and are not legally binding on governments. They do not replace existing laws. The guidelines outline principles and practices that governments can refer to in making laws and administering land, fishery and forest rights.

3.4 Fit-for-Purpose Land Administration

Another concept that guides the design of land projects is the concept of fit-for-purpose land administration. This concept was published by the International Federation of Surveyors (FIG) and the World Bank at the World Bank Land Conference in 2014 (Enemark et al., 2014).

In many countries, the land administration system is often inherited from colonial administrators and is controlled by special interest groups, such as lawyers and surveyors. The insistence on high standards has a serious impact on the cost of land administration services (both to government and the public) and is a factor in the lack of investment in land administration in many countries. Fit-for-purpose land administration has the following elements:

- There is flexibility in the approach to data capture.
- It is inclusive in the tenure covered.
- It is participatory in its approach to data capture.
- It is affordable for governments to establish and operate and for society to use.
- The information provided by the system is reliable.
- It can be attained in a short timeframe within available resources.
- It can be upgraded over time.

The key principles to establish a spatial framework for a fit-for-purpose land administration system are:

- Visible (physical) boundaries, rather than fixed boundaries.
- Aerial/satellite imagery, rather than field surveys.
- Accuracy relates to purpose, rather than technical standards.
- Demands for updating and opportunities for upgrading and ongoing improvement.

A Guide for Fit-For-Purpose Land Administration is being finalised by GLTN. This guide has been prepared using a pragmatic approach for land administration reform in developing countries that aims to provide security of tenure for all within a generation. This approach is a bold change from the traditional approach, which is based on building capacity to scale up existing systems and practices.

4 PROJECTS TO IMPROVE LAND ADMINISTRATION SYSTEMS

4.1 General Nature of Land Administration Projects

In considering land interventions, it is important to realise that there is a wide range of rationales for undertaking projects. These rationales include land reform, land administration reform, systematic registration, public land management, tax mapping and property tax collection, and natural resource management. In comparing different projects, it is important that these different rationales are considered. There has also been a different view in the development community of the scope of land intervention and this has changed over time.

Based on his experience in the land sector, Prof John McLaughlin of the University of New Brunswick, Canada has described four waves of land projects, which the author has found to be very useful. McLaughlin considered the first wave to be the successful introduction of western institutions and structures in Japan, Taiwan and South Korea after World War II. The second wave was implemented by USAID and others in the 1970s with a focus on land reform. Land reform was implemented with varying degrees of success in South America, Vietnam and the Philippines. The third wave (implemented from the 1980-90s) focused on land titling and was implemented in Thailand, Peru, Mexico and in Europe and Central Asia (ECA) countries as they moved from socialist to market economies. The fourth wave is the current wave, which is driven by globalisation and built around a more flexible approach to cadastres and tenures, and embodied with the principles of good governance, service delivery

and clear indicators.

There are many land interventions being implemented throughout the world as shown on the Land Governance Programme portal (http://landgov.donorplatform.org) that was established by development partners (DPs). As at 12 December 2015, there were 678 projects listed across 129 countries (and they were only the projects listed by major DPs). About 20 years ago, land projects were funded by the World Bank and a limited number of bilateral DPs. Now, land projects are funded by governments, multilateral and bilateral development partners, philanthropic organisations (e.g. the Ford and Gates Foundations, and the Omidyar Network), civil society organisations (CSOs), private companies and combinations of the above.

4.2 Some LEI Land Administration Projects

Summarised in this section are some of the recent and current experiences of LEI on designing and implementing land projects, focusing attention on some of the environmental factors discussed above.

4.2.1 Land Policy in Palestine

The National Land Policy Framework (NLPF) for Palestine was prepared by LEI under a World Bank contract. The work started in January 2007 and was completed in March 2008. The work involved eight individual studies on land registration, land markets, land disputes, State and municipal land, land valuation, land related fees and finance, legal and institutions, and an education needs assessment. These studies were largely completed by mid-2007 and laid the foundation for the preparation of the NLPF and draft laws. All the studies and the preparation of the NLPF were undertaken with significant stakeholder consultation. The schematic set out in Figure 2 was developed to support the formulation of the NLPF.

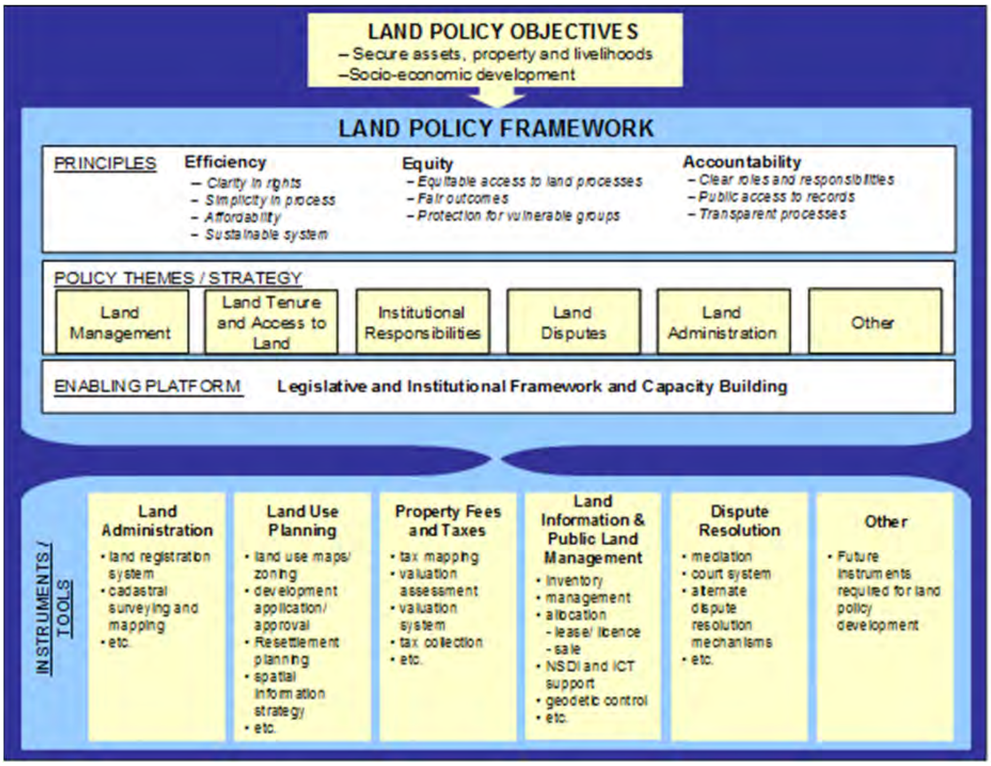

Figure 2: Land policy schematic.

The draft NLPF document was presented to key stakeholders and policy makers at workshops held in August 2007. The NLPF presents a comprehensive set of 32 policy statements covering the key aspects of land policy in Palestine:

- Land management.
- Land tenure and access to land.
- Institutional responsibilities.
- Land disputes.
- Land administration.

The policy statements were presented in a series of meetings to a council of Ministers and the text was agreed. The policy statements provided clear guidance in drafting new legislation. The NLPF was agreed by government, but has never been implemented. Late in the assignment there was a dispute between the Minister of Planning (who LEI was working for) and the Prime Minister/Minster of Finance (who administered the Palestinian Land Authority, PLA). The dispute was largely driven by the fact that the newly appointed Chairman of the PLA was unhappy with some of the provisions for more transparency in the way land was administered in Palestine. The Minister of Planning stepped back and the NLPF was never implemented.

The key lesson here is that success in implementing land administration reform requires *political will* and the clear desire of policy makers to support those seeking to implement reform.

4.2.2 Pilots for Regularisation and Formalisation in Tanzania

Tanzania has one of the highest levels of urban informality worldwide. Currently, there is a gap of at least 2.6 million urban properties that are not registered. In recent years, about 20,000 new Certificates of Right of Occupancy (CROs) have been issued annually. At this rate, it will take 65 years to register the estimated 2.6 million urban properties that are not registered. However, in practice, it will take much longer to register all urban properties in mainland Tanzania. The 2012 census reported an average annual growth of the urban population of 2.7% between 2002 and 2012. If this average continues for the next 65 years, in 2080 there will be an additional 14 million urban properties needing to be registered – purely as a result of growth in the urban population. Another important concern, other than the time required to complete registration in urban areas, is the cost of doing so. The unit cost of issuing CROs in Mwanza in western Tanzania under a recent World Bank project was about TZS 400,000 (about US$ 250 in 2010). The cost to register 2.6 million properties at this unit cost would be about TZS 1,040 billion (about US$ 650 million).

It also needs to be recognised that many of the existing urban properties that are not registered cannot be registered under the current process, either because the residents cannot afford the time and cost necessary for registration, or because their property would not be eligible for registration under the current procedures. There are only about 188 registered surveyors in Tanzania. Without a fundamental re-engineering of the process to ensure scalability, drawing on lower-cost fit-for-purpose approaches, realising the ambitious targets set by the government in 2014 will be virtually impossible.

A manual has been prepared to pilot a new approach to regularisation and formalisation (Figure 3) in three urban areas: Tabora, Mbalizi and Morogoro.

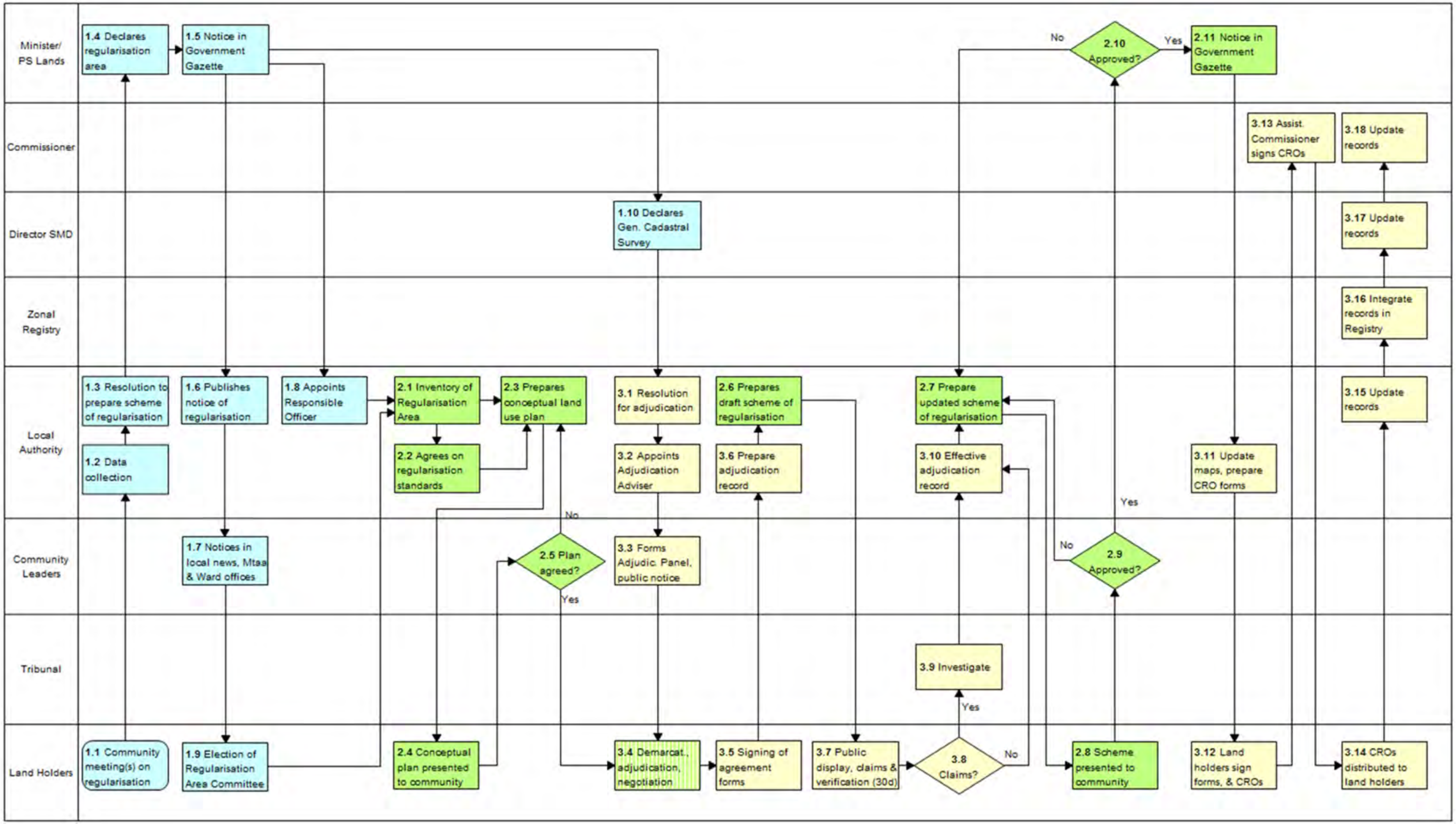

Figure 3: Process for regularisation and formalisation in Tanzania.

The process to be piloted has been developed to accord with current legislation (in consultation with key stakeholders) and seeks to pilot, test and refine a process that can in a very participatory approach prepare and approve a regularisation scheme and an adjudication record that will issue CROs at less than US$ 10 per CRO. At the same time, a comprehensive socio-economic evaluation of the impact of regularisation and formalisation will be undertaken. The lessons from the pilots and the socio-economic evaluation will be used to identify regulatory changes and prepare a roll-out plan that can be implemented by government with support from DPs.

A key constraint in getting the new process approved has been getting the consent of the key professions of surveying and planning on the adoption of new, simplified approaches. The Land Survey Act (chapter. 324) was enacted in 1959 under colonial administration (see http://www.ardhi.go.tz/index.php?option=com_phocadownload&view=category&download=71:The%20Survey%20Act.%20Cap%20324&id=16:Survey%20and%20Mapping&Itemid=336). Despite the fact that the Act provides a good deal of flexibility in the survey methodology that might be applied, the profession is very conservative in its approach to cadastral surveying. Considerable effort was required to get the survey profession to consider the use of high-resolution satellite imagery as the map base and to adopt a practice of encouraging land holders in emplacing reference marks instead of the traditional requirement of insisting on concrete beacons.

The Town and Country (Town Planning Space Standards) Regulations of 1997 specify a minimum plot size of 400 m^2 and a minimum right-of-way width of 6 m. The average plot size in many informal settlements in Tanzania is less than 100 m^2 and the gaps between plots are frequently too narrow for vehicles. A key step in the regularisation process is the formal adoption of regularisation standards, particularly for plot size and right-of-way width. Too high a standard will lead to large-scale resettlement for which there is no funding.
The pilots were planned to commence early in 2015, but they have been delayed for a range of reasons, including the national election which was held in October 2015. However, a main factor in the delay has been the continued reluctance of surveyors to adopt a streamlined process. As the pilots have not commenced, we have not reached the stage where planners need to demonstrate flexibility in adopting flexible regularisation standards.

The key lesson here is that the professions and professional standards can be a serious impediment to the search for simplified procedures and systems.

4.2.3 Protecting Small-Holder Farmers in the Mekong

The Mekong Region Land Governance (MRLG) project aims to contribute to the design of appropriate land policies and practices in Cambodia, Lao PDR, Myanmar and Vietnam, responding to national priorities (in terms of reducing poverty, improving nutrition and increasing economic development), and supporting family farmers so that they can be secure and make good decisions on land use and land management (MRLG, 2016). The first four years of the planned 8-year project commenced in early 2014, funded by the governments of Switzerland and Germany. It is being implemented by LEI in association with Gret (Professionals for Fair Development, France).

The MRLG project is a multi-stakeholder-driven project that is very different sort of project for LEI. The project does not directly interface with government and build government capacity. It has been a challenge to negotiate standard memorandums of understanding

(MOUs) with government agencies – the traditional basis for implementing development projects. The project focuses on 'reform actors' (or those from civil society, government, academia and the private sector) with an interest in the land tenure security and livelihoods of traditional small-holder families, and building the capacity of reform actors to work with government to develop improved policies and legislation. The project recognises land policy is an inexorable element of nation sovereignty and identity. However, decades of international and national economic reform favouring the flow of capital across national borders, alongside recent economic crises, have resulted in new threats to land access security of smallholders.

The MRLG project has two key objectives (Figure 4):
1. To strengthen the effectiveness of reform actors.
2. To assist the development and process of more favourable policies, institutions and practices.

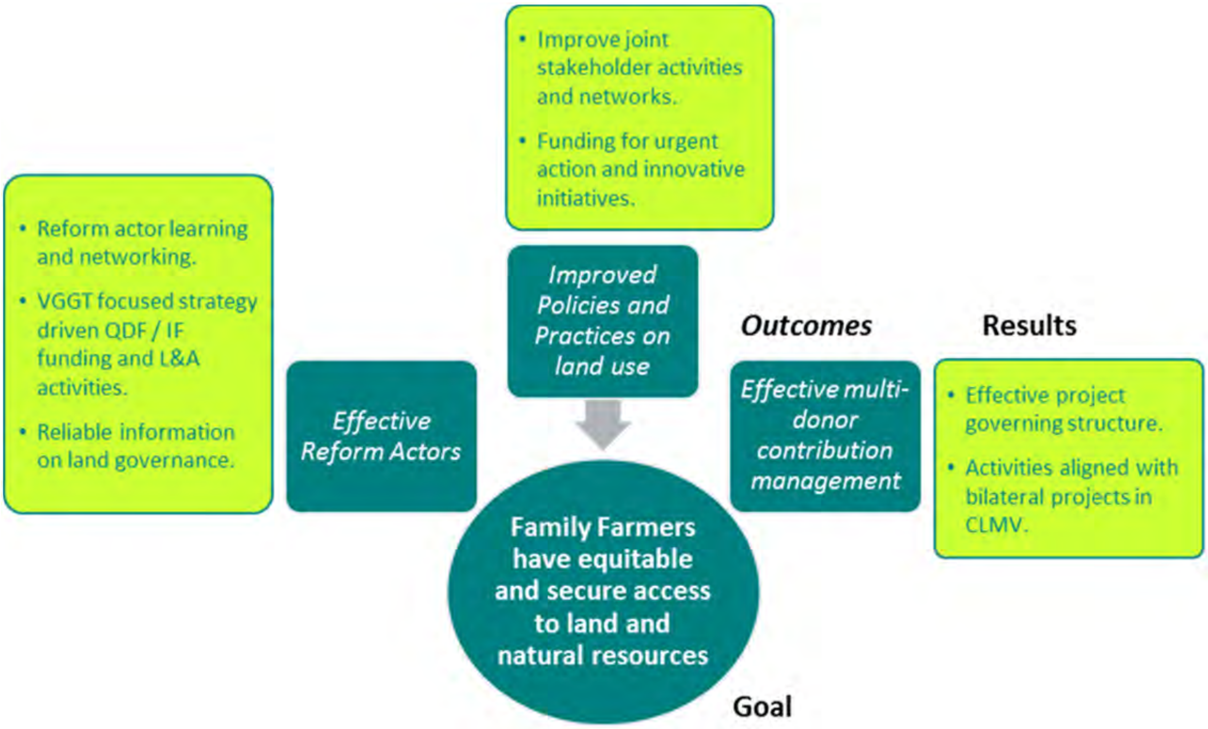

Figure 4: Objectives for the Mekong Region Land Governance (MRLG) project.

The project is funding a learning and alliance building program that supports information collection, analysis, dissemination, horizontal learning and structured learning visits, coaching and pairing, training and organisational strengthening at the national and regional levels. The project also has a grants facility that funds short-term activities contributing to improved land governance and medium-term (one to two years) pilot activities to develop and test innovative practices that might be scaled up.

Land is increasingly being recognised as a fundamental cross-cutting issue. The key lesson from this project is that governments are increasingly being encouraged to adopt policies that protect all in society and develop and implement more transparent systems and procedures.

5 CONCLUDING REMARKS

This paper has highlighted the importance of improved land administration services and the impact that the lack of a good land administration system has on the socio-economic development of many countries. There are real lessons for surveyors, particularly those working in the public sector, from what is happening in regards to land administration internationally.

First, land is increasingly being recognised as an important cross-cutting issue that needs to be managed in a more comprehensive and sustainable manner as the world faces increasing population pressure and other environmental pressures, such as climate change. Australia, like most OECD countries, does not have a land policy. We have a strong rule of law and our legislative framework is consistent and coherent. We also have the complication of being a federation with land management and administration being traditionally a state responsibility. With the recent Paris accord and increasing focus on issues such as climate change, the author believes that Australia will have a land policy in the not too distant future.

Second, the surveyor has a central role to play in land management and administration. Advances in technology are making the job of the surveyor easier, but they are also making surveying and mapping technology more readily available to a wider audience. The surveying profession can embrace this change or lose relevance. There are encouraging signs, but things could go either way.

Finally, there is much relevance in some of the topics that are prominent in international land projects. The focus on improved land governance is just as relevant in Australia as it is overseas and surveyors have an important role in land governance. The concept of fit-for-purpose land administration is also very relevant. Surveyors have, traditionally, been taught to measure things as accurately as possible and to take check measurements to ensure that their field book has all the information necessary to produce authoritative plans and titles. Too often, improving technology has only pushed the desire for improved accuracy. Often, there is a necessary balance in assessing the social and economic case for accuracy, i.e. in deciding on standards and procedures considering the purpose, rather than the technical capacity for accuracy.

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Filling the Void: Silver City Highway

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ABSTRACT

'Filling the Void' was a collaborative LandTeam Australia Pty Ltd / Roads and Maritime Services (RMS) submission into the 2015 Excellence in Surveying and Spatial Information Awards. Having been born off the land in the southwest of New South Wales and having been fortunate enough in the 1970s to travel as a surveyor to remote areas of Australia with BHP, to say that the author has developed an affinity with the outback is an understatement – I simply love it! This passion for the arid zone has been fuelled over the years with regular non-surveying trips to inland Australia and its bewildering environs. So, when an opportunity arose in June 2014 to perform the control and detail surveys for an RMS upgrade of a remote 14 km section of the Silver City Highway some 230 km north of Broken Hill, the excitement was difficult to contain – the opportunity to spend perhaps 2 weeks getting to know intimately a 'micro section' of the outback whilst working is a rarity. The purpose of the survey brief was to procure a detail engineering survey with network control suitable for input into detail road design and network control for the HW22 Shannons Creek Initial Sealing Project and designed to allow the Royal Flying Doctor Service to land on the highway to deal with emergency medical matters within the wide environs of the locality. This presentation outlines that this was no ordinary RMS infrastructure survey.

KEYWORDS: *Broken Hill, survey, logistics, RMS, Royal Flying Doctor Service.*

Cox's Road Dreaming: The Development of an Innovative Thematic Tourism Package

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ABSTRACT

Greening Bathurst's contribution to Bathurst's bicentennial celebrations in 2015 was the production of a thematic tourism guide, "Cox's Road Dreaming Guide Book: A Natural History of Cox's 1814/15 Road – Australia's First Inland European Road". The guide consists of a 100-page coloured booklet and 8 accompanying maps. The booklet describes 116 sites along the line of Cox's Road or in the immediate surrounds, between the Flag Staff at Bathurst (the location where Governor Macquarie proclaimed Bathurst on the banks of the Macquarie River on 7 May 1815) and Prospect Hill on the Cumberland Plains, east of Emu Crossing (where the building of Cox's Road commenced on the Nepean River on 18 July 1814). The objectives of the project were to (1) enable contemporary Australians to better understand the iconic nature of William Cox's Road both as a road building exercise that opened up inland Australia to European exploration and settlement, as well as to understand the adverse outcomes for indigenous people that eventually resulted in them becoming fringe-dwellers in their own land, (2) facilitate tourists being able to experience 'history with their boots on' by visiting a range of carefully chosen sites that illustrate the difficulties and technologies used in colonial road building, the natural history of Cox's Road, the geography of the road, and the complex factors necessitating Governor Macquarie to order its construction in 1814, (3) enable tourists to better understand the subsequent plethora of roads that gradually replaced the original line of Cox's Road from 1815, (4) appreciate pre-1814 European explorations and Indigenous knowledge that made it possible for Cox's Road to be constructed, and (5) enable tourists to experience aspects of early colonial history and Aboriginal culture through the telling of European and Indigenous stories of people who ventured over the mountains via Cox's Road or subsequent roads. The criteria used to select sites along Cox's Road are described, as are the factors determining which stories should be told, and how a balance was eventually achieved between the many disciplines that have been drawn on to tell this Dreaming story.

KEYWORDS: *Cox's Road, natural history, road construction, surveying, thematic tourism.*

1 INTRODUCTION

Cox's Road Dreaming Guide Book: A Natural History of Cox's 1814/15 Road (Goldney, 2015) is a thematic tourism guide, jointly developed by Greening Bathurst (GB) and NSW Land and Property Information (LPI). It was produced and printed in 2015 as Greening Bathurst's and LPI's contribution to the bicentenary celebrations of Bathurst as Australia's oldest inland European settlement. To access the newly discovered Bathurst Plains named by George Evans in 1813 during his inland expedition, Governor Macquarie ordered a 'road' (in reality little more than a bush track) be built between Emu Plains on the Nepean River and the

Bathurst Plains on the Macquarie (Wambool) River. Lieutenant William Cox was commissioned by Macquarie to build the road (about 163 km in length), remarkably completing it in 6 months on 21 January 1815. Cox deployed a continuously changing team of soldiers, volunteer free men, unchained convicts working for their freedom and two Darug men (Figure 1). The guide consists of a 100-page coloured booklet and 8 accompanying maps. It describes 116 sites along the line of Cox's Road or in the immediate surrounds, between the Flag Staff at Bathurst (the location where Governor Macquarie proclaimed Bathurst on the banks of the Macquarie River on 7 May 1815) and Prospect Hill on the Cumberland Plains, east of Emu Ford crossing. The building of Cox's Road commenced on the Nepean River on 18 July 1814.

Since much of the route of Cox's Road between Emu Ford and Mount York now lies buried beneath the Great Western Highway, with some sections having been incorporated into minor Blue Mountains domestic roads and others located under housing estates, it should not be surprising that only 42 sites (36%) are on the route of Cox's Road or at locations where John Lewin, the colonial artist who travelled with Macquarie's entourage in 1815, sketched his paintings mostly along the line of Cox's Road. The remaining 74 sites are at locations that provide complementary information that help us to better understand the human and environmental aspects of Cox's Road including Aboriginal culture and history. Parts of the road remain within the Crown roads estate but cannot be accessed since they are enclosed within private land. This is the case for the 17 km section from the junction of the Mid Hartley Road and the Great Western Highway, and the Rydal Hampton Road tracking along the ridge of the Great Dividing Range. The 8 coloured maps include a slightly exaggerated side elevation of the route of Cox's Road from Bathurst to the Nepean River (Figure 2), a plan view, two maps identifying the geology and vegetation communities along a 2 km wide transect of the route (Figure 3), and 4 maps identifying the location of each site in relation to Cox's Road, matched by written directions and a description for each of the 116 sites.

2 NATURAL HISTORY AS THE PROJECT'S PRIMARY DRIVER

The major thrust of the project was to describe the natural history of Cox's Road. There have been a number of publications that provide a range of insights in to the history of Cox's Road, including William Cox's diary written whilst building the road in 1814/15 and the various experiences of those who travelled the road (Mackaness, 1950), at least one biography of William Cox (Cox, 2012), a robust bicentennial souvenir (Cox-Whittaker, 2014), one significant historical-archaeological study of Cox's Road with significant input from surveyors of the Lands Office in Orange (Karskens, 1988) and a recent historical analysis of the history of the building of Cox's Road (Karskens, 2014).

The project described in this paper would have been more difficult to implement without the availability of a reliable route of Cox's Road at an appropriate scale (1:25,000). Fortunately, the route of Cox's Road had been meticulously reworked by Allan Carey and other Department of Lands surveyors in the 1980s and recently brought to light again and updated by Kevin Boole (LPI) and Patsy Moppett, as members of the National Trust Cox's Road Project Committee. However, there remain some uncertainties regarding parts of the Carey model, particularly in the section from the O'Connell Road through to Bathurst.

Figure 1: Surveyor General John Oxley's 1815 map of the road to Bathurst that very soon was known as Cox's Road (Oxley, 1815) – see references for further information about the discovery of this important map.

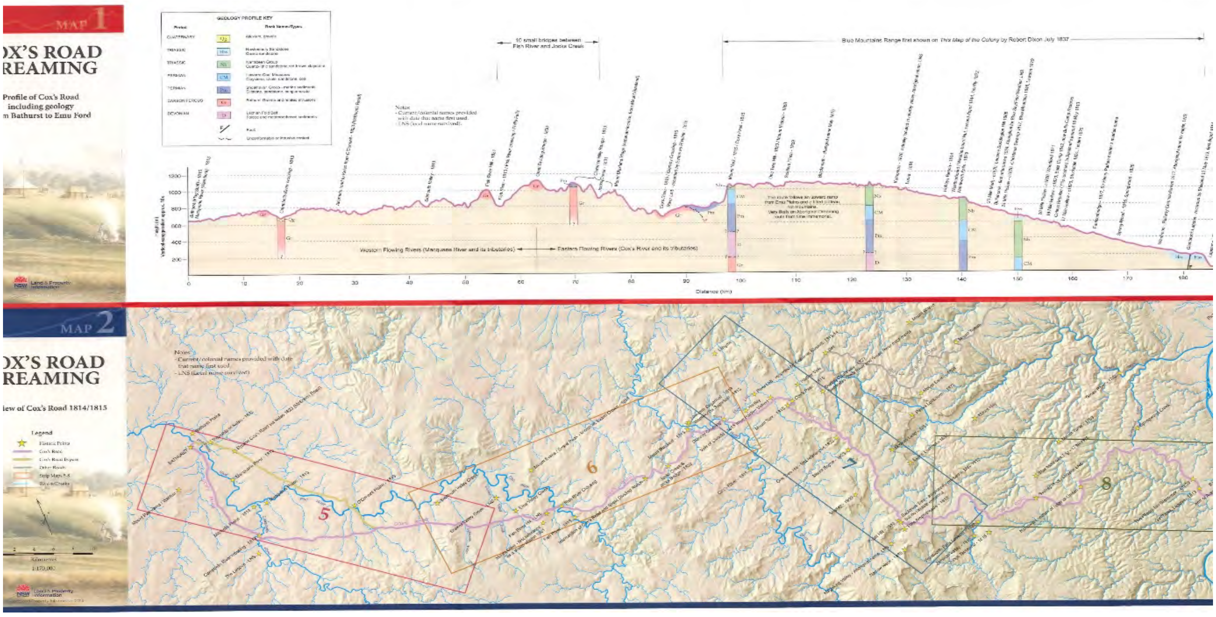

Figure 2: Maps 1 and 2 from Cox's Road Dreaming illustrate the geography and route of Cox's Road.

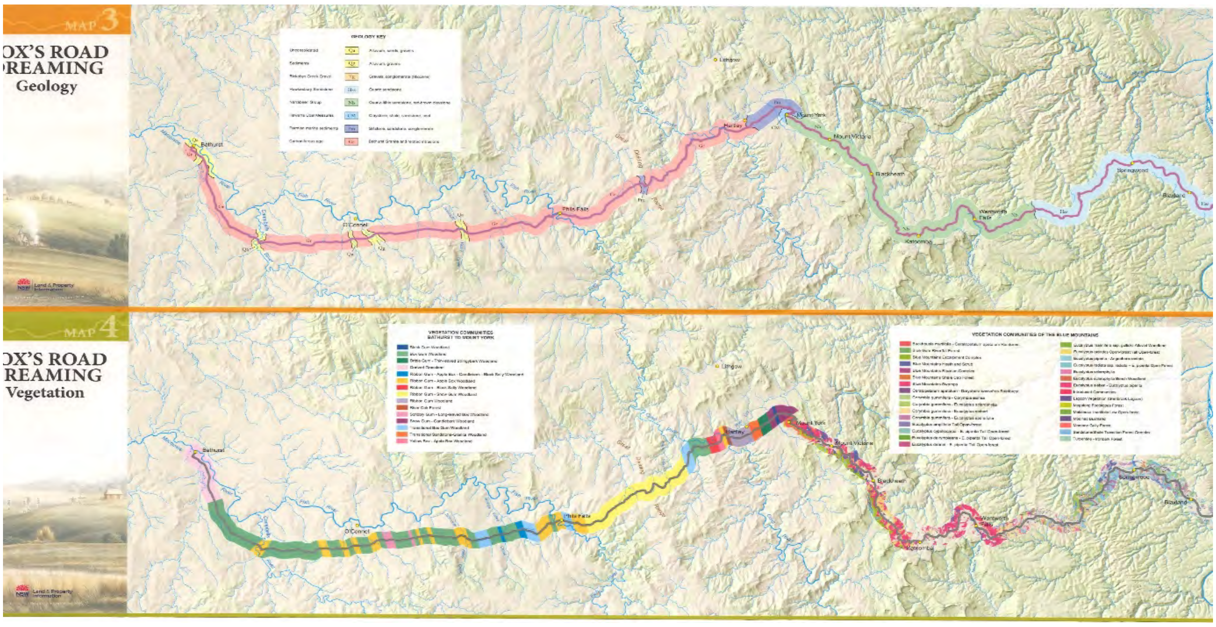

Figure 3: Maps 3 and 4 from Cox's Road Dreaming illustrate the geology (upper map) and the vegetation communities (lower map) along the route of Cox's Road.

No one has previously attempted to examine Cox's Road in relation to its rich natural history. Natural history (from the Latin *historia naturalis*) is the study of organisms in their environment. It was widely practiced in the 19th and early 20th centuries as a very fashionable pseudo-scientific hobby, often in a form little different from stamp collecting. Nevertheless it has an honourable history stretching back to the ancient Greeks. When approached from a more scientific perspective, natural history focused on life cycles of living organisms and their systematic collection to help facilitate the classification of living organisms into similar groups using the binomial system (a 2-part name for every organism). This naming system was devised by Linnaeus in 1753 and is still in place today. In the 19th century, natural history incorporated the study of geography, geology, biology, biological and physical processes, and the developing applied sciences. It also embraced the study of Indigenous culture, often in a

very paternalistic and demeaning manner, including the theft of Aboriginal artefacts, excavation of burial grounds and the removal of body parts including severed heads that were sent back to Europe to a range of museums and wealthy collectors. At its best the study of natural history was undertaken to improve the understanding of nature and at its worst as a means of making easy money. However, European colonial and Aboriginal history is the glue that holds these natural history stories together. The discipline of natural history is now absorbed into the contemporary science of ecology that seeks to understand the numerous patterns in nature rather than concentrating on gathering numerous unrelated facts or objects.

3 COX'S ROAD DREAMING

The use of the term 'Dreaming' often has quite different meanings for Aboriginal and non-Aboriginal people. This Dreaming story (or rather 116 individual 'stories') is not seeking to emulate Aboriginal Dreaming and song lines, although inspiration is drawn from Aboriginal culture (see Appendix). In the Cox's Road Dreaming story-telling we sought a nuanced reappraisal of this period of colonial history, particularly that relating to Aboriginal people, the debunking of some myths without necessarily robbing them of their continuing importance, and identifying the outcomes for Aboriginal people that led to their dispossession, the precipitous decline in their numbers, and their new reality as colonial fringe-dwellers in their own country. At many sites stories about Aboriginal people and their cultures are told without in any way claiming that these represent other than snapshots of Aboriginal history. The guide does attempt to communicate the Aboriginal understanding of *dreaming* and *song lines*, since these concepts are generally poorly understood by non-Aboriginal people. The guide recommends visiting McMahons Point (site 85). Parts of the description of this site are reproduced in the Appendix, retelling the majestic Gundungurra Dreaming/Creation story of Mirrigan, the giant quoll, and Gurangatch, a giant fish, in their epic predator-prey chase.

4 OBJECTIVES OF THE PROJECT

The objectives of the project were to:
1) Enable contemporary Australians to better understand the iconic nature of William Cox's Road both as a road building exercise that opened up inland Australia to European exploration and settlement, as well as to understand the adverse outcomes for Indigenous people that eventually resulted in them becoming fringe-dwellers in their own land.
2) Facilitate tourists being able to experience 'history with their boots on' (Ward, 1970) by visiting a range of carefully chosen sites that illustrate the difficulties and technologies used in colonial road building, the natural history of Cox's Road, the geography of the road, and the complex factors necessitating Governor Macquarie to order its construction in 1814.
3) Enable tourists to better understand the subsequent plethora of roads that gradually replaced the original line of Cox's Road from 1815.
4) Appreciate pre-1814 European explorations and Indigenous knowledge that made it possible for Cox's Road to be constructed.
5) Enable tourists to experience aspects of early colonial history and Aboriginal culture through the telling of European and Indigenous stories of people who ventured over the mountains via Cox's Road or subsequent roads.

5 IMPLEMENTATION STRATEGIES

Developing a complex project such as Cox's Road Dreaming within a defined budget and the need to meet a strict deadline (the dual launches in August and September 2015) revolved around the following: (1) Background research, (2) project management, (3) access to an appropriate budget and fund raising, (4) careful and appropriate selection of sites to be utilised, (5) the design of 8 maps and the guide book, (6) developing a project website, and (7) developing a sales network. Only topics 4-7 will be briefly addressed in this paper.

5.1 Site Selection and Criteria Used to Select Sites

Approximately 200 sites were initially selected over a 2-year period (2012-2014), each site being visited by the author. These were whittled down to the current 116 sites by May 2014, when the author began the task of preparing site descriptions. Sites were selected based on the following criteria:

- Enabled a reasonably even distribution of proposed sites along the line of Cox's Road. 24 sites were located on Map 5 between Bathurst and Lowes Mount Road. 13 of these sites were clumped in or around Bathurst or in the immediate surrounds. 19 sites were located on Map 6 between Lowes Mount Road and Glenroy crossing, along with three roads built after 1815. 42 sites were located between Glenroy Crossing and Wentworth Falls, along with the location of three roads built after 1815. 33 sites were located between Wentworth Falls and Emu Crossing, with three sites located east of the Nepean River. Two of these sites were also roads built post 1815.
- Sites were to be accessible by car and/or a short walk, or would enable access to a track head from where a track could be readily walked. 74 sites can be directly accessed by driving to and parking nearby (e.g. Bathurst Flag Staff), 21 sites can be accessed from a car park and then by walking 1-3 km to reach a particular site (e.g. Evans Crown view over the Bathurst Plains), 5 sites can be accessed using a parking bay at a track head and then undertaking a 2-6 km walk (e.g. Darwin's Walk at Wentworth Falls), and 8 'sites' were alternative roads built post 1815 that can still be driven along either their complete length or in part (e.g. parts of Lockyer's Road, but not Lockyers Pass, the latter being only a walking track).
- Enough information existed either from existing sources or by undertaking relevant research to facilitate its interpretation in relation to its natural history features and/or its European and/or Aboriginal history and culture, enabling the writing of a short and interesting story.
- Site selection sought to ensure there was a balance between the various discipline categories and avoid an overemphasis on technical matters (in-depth treatment of particular topics could be accessed via the project web resources by those wishing further information).
- The story developed for a site was deemed to be analogous to a piece of an historic jigsaw puzzle, and the pieces (when put together) would, over time, provide a comprehensive understanding (picture) of the history and natural history of Cox's Road.

5.2 Design of the Maps and Guide Book

The 8 maps and 116 site descriptions with images and/or illustrations were designed to facilitate a high level of integration between different ways of presenting information about Cox's Road:

- A close examination of Maps 1 and 2 at a scale of 1:170,000 is the recommended entry point for those engaging for the first time with Cox's Road Dreaming. These maps are designed to communicate basic geographical concepts about Cox's Road in a readily understood graphic form. Map 1 is a profile/side elevation of Cox's Road with a vertical exaggeration to emphasise changes in elevation. The basic information that can be gleaned from this map includes the names and dates of features named by Europeans in the colonial period, notes on the map highlighting particular features (e.g. catchment boundaries, locations where Cox built bridges, and the tilted and ramp-like nature of Cox's Road over the Blue Mountains), the numerous 'hollows' that both enabled valley and hanging swamps to form (thereby providing water for stock and people as well as providing a welcome respite from the constant climb from Emu Ford to One Tree Hill [Mount Victoria]), the location of the three major river valleys that are crossed by Cox's Road (the Cox's, Fish and Campbells river valleys), geological columns at six locations together with an interpretative legend, the Lapstone Fault and the monocline creating Lapstone Hill (the first major obstacle to the road builders, eventually solved by constructing a zigzag based on the principle of the inclined plane).
- Map 2, at more or less the same scale as Map 1, enables a direct comparison to be made between the two maps. It demonstrates the snaking of Cox's Road as it wends its way from west to east (the Macquarie River, the Fish and Campbells Rivers, Cox's River and the River Lett), north of Cox's Road in the Blue Mountains the Grose River and its numerous tributaries including Springwood Creek, the Grose River draining into the northwards flowing Nepean River. Historic European names are provided and significant changes in elevation demonstrated through subtle shading. The locations and width of strip maps 5-8 are also demonstrated on this map.
- Maps 3 and 4 identify a 2 km wide transect along the length of Cox's Road, Map 3 demonstrating changes in the geology along Cox's Road, mainly granite west of Mount York and Narrabeen and Hawkesbury sandstone east of Mount York. The Quaternary, recent alluviums and gravels associated with the five main rivers and creeks crossed at right angles by Cox's Road west of Mount York stand out (but not alluviums at the Fish River Crossing at Phills Falls) as Cox's Road approaches Emu Ford in the east.
- Map 4 illustrates the vegetation communities that Cox and his road building team encountered in their trek from east to west. 15 mainly open woodlands were encountered west of Mount York. The numerous swampy meadow formations are not illustrated because of their small scale distribution. East of Mount York the very complex vegetation of the Blue Mountains along the transect is well illustrated (31 vegetation communities in all). These communities range from forests to woodlands with the intermittent swamps (valley and hanging) of the mid Blue Mountains also included. By directly comparing the geology transects with the vegetation transects, it is possible to discern that in some cases vegetation communities appear to change in response to geology as well as elevation.
- Maps 5-8 illustrate the locations of individual sites in relation to both Cox's Road and cotemporary major roads. The route of the suite of historic routes that mushroomed post 1815 are also illustrated.
- The Guide Book is designed to provide the following information about each site: Site name and number (the sites are numbered from 1-116 moving from west to east), usually an image or map, a brief description as to how the site can be accessed, the position (altitude, latitude and longitude), the estimated time that is required to visit the site, the relevance to furthering participants' understanding of the natural history and history of Cox's Road, a site description including some words/phrases highlighted that are defined in the glossary located on the project website, and a key question to reflect on for most sites. References for each site are only provided on the website (see section 5.3). The

opening sections of the Guide Book provide a brief overview of the building and history of Cox's Road as well as suggestions as to how best to organise and optimise explorations of Cox's Road.

5.3 The Project Website

The project website is located at http://coxsroaddreaming.org.au/. It complements and enriches the Cox's Road Dreaming experience by enabling the following:

- Access to additional material for each site including more detailed maps and/or satellite imagery to help locate each site.
- Access to a klm file of Cox's Road, which can be 'dropped' into Google Earth or NSW Globe via the LPI website portal, enabling viewers to see Cox's Road overlaid on the latest available aerial photography. This enables a user to simultaneously read the relevant Guide Book description and also to view its location on a laptop or iPhone at any scale.
- Access to the project glossary that defines words or phrases that are in bold in the Guide Book and to biographical information for some colonial identities held online via the Australian Biographical Dictionary (e.g. William Cox and Lachlan Macquarie).
- Access to hundreds of historical references used as the basis for the preparation of site descriptions.
- Access supporting material such as in-depth descriptions of the geology and vegetation of Cox's Road in commissioned papers by experts in their field.
- Access to reviews of Cox's Road Dreaming.
- Access to a pdf file of Cox's Road overlaid on the relevant LPI topographic maps for those wanting to travel with hardcopy 1:25,000 maps in hand.
- Suggestions as to how best to organise expeditions to sites along the road based on areas of interest.

6 INFORMATION PROVIDED IN COX'S ROAD DREAMING GUIDE

An excerpt of a site description is provided in the Appendix. The description provided integrates geology and landform, aspects of the history of Lake Burragorang, information on the D'harawal and Gundungurra people, a brief description of vegetation along the Kings Tableland Road, engages with the classic Gundungurra Dreaming story of Mirrigan and Gurangatch, and reflects on the importance of Dreaming and song lines to Aboriginal people. Other sites might have a narrower focus, say on geology, vegetation or European history, but most are multi-faceted, providing a wealth of information.

The information provided for each site description is based on one or more of the following discipline/subject areas:

- Natural History (e.g. geography, flora and fauna, swamps [swampy meadows, valley and hanging swamps], geology, geomorphology, hydrology, floods and droughts, climate, road and bridge building including land bridges, navigation and surveying techniques).
- European and Aboriginal history and culture specifically relating to the Darug, Gundungurra and Wiradyuri people.
- Dreamtime stories and their meaning.
- Aboriginal explorers.
- Historic wells and precincts.

- Landscape paintings along the route including John Lewin's paintings created as a member of Governor Macquarie's entourage that came over the road in April-May 1815 to the Bathurst Plains, and intriguing mysteries regarding the locations of some of Lewin's Cox's Road paintings.
- Descriptions of travelling over Cox's Road by laypeople and naturalists who used Cox's Road or roads that were subsequently built.
- Colonial houses and other infrastructure along the road or subsequent roads.
- Early explorations that pre-dated the building of Cox's Road.
- Agricultural pursuits.
- Transport used by colonial travellers and difficulties in travelling along these early roads.
- Early signs of land degradation.
- Pioneer settlements.
- Building techniques and sawpits.
- Colonial maps of the period.
- Roads that were built post 1815 to enable more efficient travel across the Blue Mountains to Bathurst and Mudgee.
- Panoramic views.
- Colonial cemeteries.
- Colonial poetry.
- Archaeological sites.
- Infectious diseases.
- Stock routes and traffic using Cox's Road.
- World views and preconceived notions held by settlers and explorers.
- Myths associated with Cox's Road and pre Cox's Road explorations.

The major focus of each of the 116 site descriptions, based on 11 categories, is shown in Table 1. However, as previously indicated, most descriptions draw on many discipline areas, seeking to integrate multiple information threads into pertinent and interesting accounts. Not surprisingly, natural history topics dominate site descriptions as the major focal point on 33 occasions, 43 if Lewin's paintings are also included in this category.

Table 1: Major focus of each site based on 11 categories.

Category	Number of Sites	Percent of Sites in Category
Natural history	33	28.5
Colonial buildings & infrastructure	16	13.9
Aboriginal history & culture	15	12.9
Road building	15	12.9
Analysis of John Lewin paintings	10	8.6
Post 1815 roads	8	6.9
Personal accounts of people using roads	5	4.4
Colonial transport	4	3.4
Colonial explorers	4	3.4
European history & culture	4	3.4
Cemeteries	2	1.7
Total: 11 categories	**116 sites**	**100%**

7 SITE DESCRIPTION CASE HISTORIES BASED ON LEWN'S 1815 PAINTNGS

John Lewin was an outstanding colonial painter as well as an excellent naturalist. He is widely regarded as the first colonial artist who was able to capture the Australian landscape including its flora and fauna, not only in a creative manner but also imbued with the true colours of the bush, whilst retaining an aura of naturalness. Lewin came over Cox's Road with Governor Macquarie's entourage in 1815 as the expedition's artist. He teamed up with Major Henry Antill, agreeing that he would paint a number of scenes during the journey with Antill recording the crossing expedition in his journal (Mackaness, 1950). In Cox's Road Dreaming, 18 of Lewin's 20 Cox's Road paintings are reproduced at the 13 sites where they are relevant (including two of the Bathurst Plains and three in different locations descending Cox's Pass). These are an invaluable historical record of the landscape in 1815 through which Cox's Road traversed. In this section, a selection of these paintings is reproduced to illustrate how each painting helped to contribute to the richness of each site description.

Figure 4 shows Lewin's depiction of the Bathurst Plains with Macquarie's expensive Bengal tent positioned on the left bank of the Macquarie River between two lesser tents. Lewin's initial sketch was from the opposite bank of the river (the right bank). In the background is a row of two wheeled carts, each laden during the crossing expedition with goods and chattels, each pulled by one ox or horse. The flag pole is located in front of the Bengal tent, the Union Jack waving in the morning breeze flaps in a south-easterly direction. The camp site is located on the first river terrace, a quaternary relic of the Macquarie (Wambool) River as it cut down through the river valley. The tops of River She-oak lining the edges of the Macquarie Rive are just visible, with a group of regenerating River She-oaks located to the left of the painting. The rising smoke from the camp fire appears to be drifting ever so slightly in a south-easterly direction in response to a very light breeze from the north-west. The flag pole represents the location where Governor Macquarie proclaimed Bathurst as a settlement on 7 May 1815. It is now the location of the Flag Staff monument commemorating Bathurst's bicentennial. The undulating treeless Bathurst Plains are there for all to see with a corridor of the now endangered Yellow Box Woodland gracing the ridge west of the camp site on the foot slopes of Mount Panorama (Wahluu). There appear to be no shrubs on the grassy plains. This painting so admirably depicts the classic-style parkland that so appealed to settlers and explores alike, part of the magic of the 160 km^2 area that constituted the Bathurst Plains.

Figure 4: Lewin's painting of the Bathurst Plains with Macquarie's expensive Bengal tent in the centre.

This was a landscape that reminded them of the great estates in Britain, which were also creations of the human imagination created by gifted landscape gardeners. Macquarie and his fellow colonialists viewed these lands as virgin, desirable, well-watered land, nevertheless

'waste' land ripe for the development of civilised agriculture and immediately useful as grazing land. Through the eyes of a 21st century ecologist, this same view demonstrates a cultural landscape intentionally created by Wiradyuri people to optimise their lifestyle and cultural expression through the use of a range of land management strategies very likely including the periodic use of fire. Such were the differences in world views of the colonial explorers and settlers and the Wiradjuri, it was not possible for Governor Macquarie or fellow colonialists to entertain the possibility that Aboriginal people too were also 'gifted landscape gardeners'. Without this and other Lewin paintings of the Bathurst Plains, it is doubtful that our imaginations alone, even with the aid of the many thoughtful colonial descriptions, could in their own right conjure up appropriate images of the Bathurst Plains. Lewin's paintings illustrate the saying that one picture is worth a thousand words.

Figure 5 shows Lewin's instructive painting of the Campbells River crossing south of Bathurst. It appears to have been sketched on the right bank while he was facing directly west. Again his eye for detail is seen in the colour of the foliage, tree canopy shapes and other tree habit characteristics. These observations enabled an experienced botanist (Bower, 2015) to identify this treed scene as Ribbon Gum-Apple Box woodland. Many other features can be inferred such as tree height and diameter, the nature of the simple wooden bridge that was constructed over the river, the spacing between trees, the absence of understorey shrubs and felled timber as well as the grassy understorey free of dense woodland floor litter. There is much more to be discerned in this painting. Faithfully portrayed is the park-like landscape, again very likely a cultural landscape created by Wiradyuri people. Figure 5 as did Figure 4 greatly enriches our understanding of the Bathurst landscape in ways that words alone could not convey.

Figure 5: Lewin's painting of the Campbells River crossing south of Bathurst.

Figure 6 shows Lewin's painting entitled *Sidmouth Valley Showing the Macquarie River*. It is included in the guide but is not a site that can be visited since there is significant uncertainty about its location. The author's description in the guide (p. 28) provides compelling reasons as to why this cannot depict the Macquarie River. One knowledgeable regional botanist argues that it is possibly a painting of a location on the Cumberland Plains (R. Medd, pers. comm., 2015). The location of two other Lewin paintings is also in dispute, although not reproduced here. These include *Pitts Amphitheatre*, a view over a mountain valley near Katoomba that is very likely a location from a nearby valley (Site 72), and the well-known painting labelled *Emu Ford Crossing* (Site 112). The morphology depicted in that painting does not match the present-day landscape, and whilst undoubtedly a painting of the Nepean River, it is very likely from much further upstream. While Lewin's paintings are very helpful in enabling contemporary viewers to better understand the landscape of the colonial era, a

healthy scepticism needs to be in play when considering historical data.

Figure 6: Lewin's painting *Sidmouth Valley Showing the Macquarie River*.

Lewin's painting *Jamison Valley* (Figure 7) is reproduced here not only because it too sheds light on the environmental conditions encountered by the expeditionary party, but because it provides the only clue in regards to one of the building techniques that must have been regularly used by the Cox's Road building team. Illustrated in the painting is a completed wooden hut. In the foreground is a 3 m section of a tree trunk around 0.2 m in diameter, propped up at one end by two pieces of timber. Half a dozen men are standing nearby, one slightly bending within the doorway frame work. Cox regularly describes in his diary the search for suitable timber needed to build bridges over rivers and two rocky sections of the road, fences, and in this case the building of a basic hut. Nowhere in his diary does he explain the preparation of timber after it had been felled, dragged by an oxen team to the preparation site, prior to a trunk being sawn into planks or structural beams. The technology of the day generally used at a permanent site required a sawpit to be dug. A log was then placed in position over the pit and two sawyers, one in the pit and one on top of the log were able to rip the log with a long two handled saw. Digging a saw pit was not an option for a team in a hurry, more so in sandstone and granite country. Rather, Cox's team must have jury rigged a range of above ground sawpits, each design likely very dependent on the terrain in which they were working. Here at Jamison/Jamieson Valley near Wentworth Falls, the raw timber is likely being readied for sawing into planks using a very rudimentary pair of timber props. Lewin's informative painting in this case appears to partly fill an information gap about the team's use of basic everyday technology. From Cox's point of view, this was not really worth a mention in his diary.

Figure 7: Lewin's painting *Jamison Valley*.

Figure 8 shows Lewin's painting *Springwood*. Lewin depicts a towering forest with trees up to 65 m tall. The forest is dominated by Mountain Blue Gum (*Eucalyptus deanei*). The luxurious tall forest grows well on Wianamatta Shale soils overlying the less fertile soils derived from Hawkesbury sandstone. The forest floor has minimal litter, few to no ground logs, and self-evidently was readily accessed by Cox's men in their carts and drays. The height of a dray wheel roughly equates to the height of a man, enabling an approximate estimate of tree diameters, height and spacing. Site 97 encourages participants to visit Deanei Reserve to experience a similar but growing forest in a younger state of development. The forest floor is messy – logs and shrubby understorey are present in stark contrast to the open and clean floor visible in the Lewin painting. Neither a 4WD nor a horse-drawn cart could drive through one of the contemporary forests without a significant amount of clearing. From these observations we can deduce that Lewin is depicting a cultural landscape imagined and created by Aboriginal people (either Darug or Gundungurra).

Figure 8: Lewin's painting *Springwood*.

8 CONCLUDING REMARKS

It is unlikely that many people will have the time or the inclination to visit all 116 sites along the length of Cox's Road. The website does suggest ways in which groups of sites can be visited around a particular theme, e.g. geology, botany or Aboriginal culture. Some have substituted the practical approach 'history with your boots on' in favour of armchair reading and appeared to have enjoyed the experience, as well as significantly increasing their understanding of this period of colonial history. The author has escorted people in bus and car trips along much of the route, many warming to the presence of a knowledgeable guide who can easily find each site. Clearly some find greater enjoyment in listening to a riveting story rather than reading about a site. Disciplined travellers can drive to most sites, but not walk the trails, in a whistle-and-stop 2-day tour. In the author's view it is the interdisciplinary nature of this thematic tour of perhaps Australia's most iconic trail that is its most enduring quality. There is something very fascinating about the intertwining natural histories along the trail responding to quite different time scales, ranging from days through to hundreds of years and indeed back to the beginning of time. However, Cox's Road Dreaming is still waiting to be discovered by most of the populace.

At the time of writing (February 2016), about 600 of a print run of 2,000 copies had been sold using the limited distribution network between Penrith and Bathurst. A further 100 copies were given as gifts to the many people who facilitated the production of Cox's Road

Dreaming or who were financial sponsors of the project. The website was completed on 28 February 2016. The feedback to Greening Bathurst has been overwhelmingly positive. A number of very supportive independent reviews have been written and are available on the website.

ACKNOWLEDGEMENTS

Permission to use the digital images of the Lewin paintings reproduced in this paper was provided by the State Library of NSW. Permission to use the digital image of John Oxley's 1815 map of the Road to Bathurst was provided by The National Archives, UK. This is the earliest known map of the route of Cox's Road. This map was 'discovered' by Bathurst Historian Dr Robin McLachlan in 2014, just in time for it to be widely used and acknowledged during Bathurst's bicentenary year.

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Oxley J. (1815) Map of the country to the westward of the Nepean River showing Cox's Road, NSW Surveyor General's Office.

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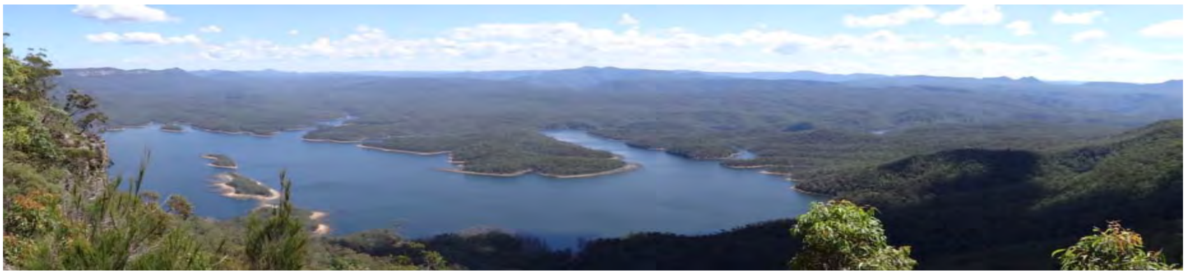
APPENDIX

Site 85: McMahons Lookout– Kings Tableland (A section from Cox's Road Dreaming p. 73):



Relevance of this site to Cox's Road: Provides: (1) a geographical perspective to colonial explorations pre and post the construction of Cox's Road; (2) an experience of the changing vegetation communities from Cox's Road to McMahons Point; (3) a better understanding of the geology of the Blue Mountains; and (4) most importantly to become acquainted with Gundungurra Country and the Dreaming/Creation story of Mirragan and Gurangatch.

The Burragorang Valley is part of the ancient lands of the D'harawal and Gundungurra people. They were rapidly dispossessed of their land soon after Robert Hoddle surveyed an access road into the valley in 1824. The Cox's Road Dreaming Guide includes a number of Aboriginal sites. At best these are brief encounters to demonstrate some aspects of Aboriginality in relation to Cox's Road – an attempt to rebalance well known European historical stories where Aboriginal people have so often been excluded or written out of the cast. Our Dreaming story is not an Aboriginal history. But here at McMahons Lookout, overlooking where the Cox's River once ran freely, we will briefly engage with the Gundungurra Dreaming story of Mirragan (a giant quoll and a great hunter) and Gurangatch (a giant fish, possibly a Murray Cod). The story commences at a large waterhole at the junction of the Wollondilly and Wingecaribbee rivers and describes Gurangatch being chased by Mirragan after unsuccessfully trying first to spear him and then to poison him with hickory bark, again unsuccessfully. Seeking safety in a predator-prey epic chase, Gurangatch begins to tear up the Wollondilly Valley, born along by the disturbed waters, followed in hot pursuit by Mirragan, along the rivers and tributaries of the southern Blue Mountains and up over the Great Dividing Range. The unrequited chase ends at Jooljundoo, a waterhole just west of the Great Divide, likely in the upper Duckmaloi River, possibly at the waterhole that was used to establish the Duckmaloi offtake weir. The weir is part of the Fish River scheme, ironically bringing western flowing water to the eastern catchment to guarantee supply to Blue Mountains towns. There Gurangatch dives into the depths to recover from the fatiguing chase and to rest his wounded body. Mirragan, with the help of some friendly water birds, is able to wrench off a piece of flesh from Gurangatch. The legend ends curiously with the prey safe but wounded, and the predator's hunger satisfied. The co-creators of this landscape continue to live on in their respective domains, as 'Burringilling', heroic personages, animals with human attributes. Martin Thomas and Jim Smith draw important understandings from this extraordinary myth. This is not just a good ripping yarn but a Gundungurra Creation Story. It is more than a story, since the chase represents a cultural map, not a topographical map familiar to most Europeans that nevertheless includes the naming and descriptions of particular geographical features such as limestone caves, bends, hills and rock formations. The ethno-musicologist Catherine Ellis first called the adventures of these Dreaming characters' song lines. Others have called them story strings or story lines, but most commonly the Dreaming. Thomas writes about the pre-European landscape being full of geographical markers of an ancestral journey, such as has been briefly described here – so much so that he writes 'the Australian landscape was mythically invested.' These Dreaming stories – song lines, story strings – interconnect throughout the Australian landscape, brilliantly conceptualised by David Mowaljarlai's 1993 map of trade routes and storylines linking Aboriginal Nations across Australia. Storylines on David's map even reach out into the continental shelf, suggesting storylines that exist in cultural memory back to the period when sea levels were much lower. These song lines served multiple purposes: they encouraged engagement with Country; helped to demarcate territory; fused mind maps and storytelling together; invited participants to read the landscape; facilitated navigation through familiar and unfamiliar landscape (if one knew the story or could sing the story); and, most importantly, probably helped renew an individual's or groups' relationship with the ancestral creation beings thereby facilitating the ongoing well-being of Country.

Forensic Fencing... The Dark Art of Re-Defining an Old DP (or the Problem with Using Just the Street to Fix the Street)

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ABSTRACT

Local councils own the land which contains our streets. In the City of Ryde many of the first streets were created well before 1921 and were not marked with anything other than pegs. After 1921 any survey which created a new street was required to place sound and solid reference marks in order to define the street boundary. Obviously, the surveying fraternity rejoiced, in the knowledge that survey reference marks would lead the way in the future definition of these streets. So much have the survey reference marks in Grand Avenue, West Ryde, influenced the current definition of Grand Avenue, that the street is now, with Land and Property Information (LPI) insistence, variable width, contains several dramatic bends and bears little resemblance to the Grand Avenue as created in 1905, which was 66 feet (20.115 m) wide and straight for its entire length of about 1,450 feet (442 m). This paper investigates whether the fencing occupations, by themselves, can deliver a fix of original DP 4516 (1905), which is in closer agreement than using any of the found reference marks.

KEYWORDS: *Fencing, deduction, defining, fixing.*

1 INTRODUCTION

In the City of Ryde the original rural properties began to be subdivided for residential usage in the 1880s. By the early 1900s, subdivision had developed apace. New streets were created and the current subdivision patterns were established.

The Grand Avenue (now called Grand Avenue) (Figure 1), was surveyed and created by DP 4516 in 1905 as 66 feet wide (20.115 m) and straight for its entire length of about 1,450 feet (442 m). Since 1924, there has been a regular registration of plans (26 in total) with 12 by compilation and 14 by survey. These 14 plans of survey (see Appendix) have been made by 13 different surveyors! Grand Avenue has not been aligned.

The most recent plan of survey, DP 1210616 (2015), was a plan for the redefinition of a single lot, midway along Grand Avenue (Figure 2). This current fix of Grand Avenue shows various bends and 'variable width'. How does this occur? Are the reference marks moving? Are the different surveyors relying on different bits of evidence and information?

This paper firstly investigates what happened to the fix of Grand Avenue since 1949, when plans of survey re-commenced 45 years after the first subdivision plan. Secondly, it investigates how Grand Avenue could be re-fixed if all the reference marks were gone. Can current fencing occupations, by themselves, deliver a fix of Grand Avenue that is in closer

agreement to the original DP 4516 than the fix achieved by using the available survey reference marks?

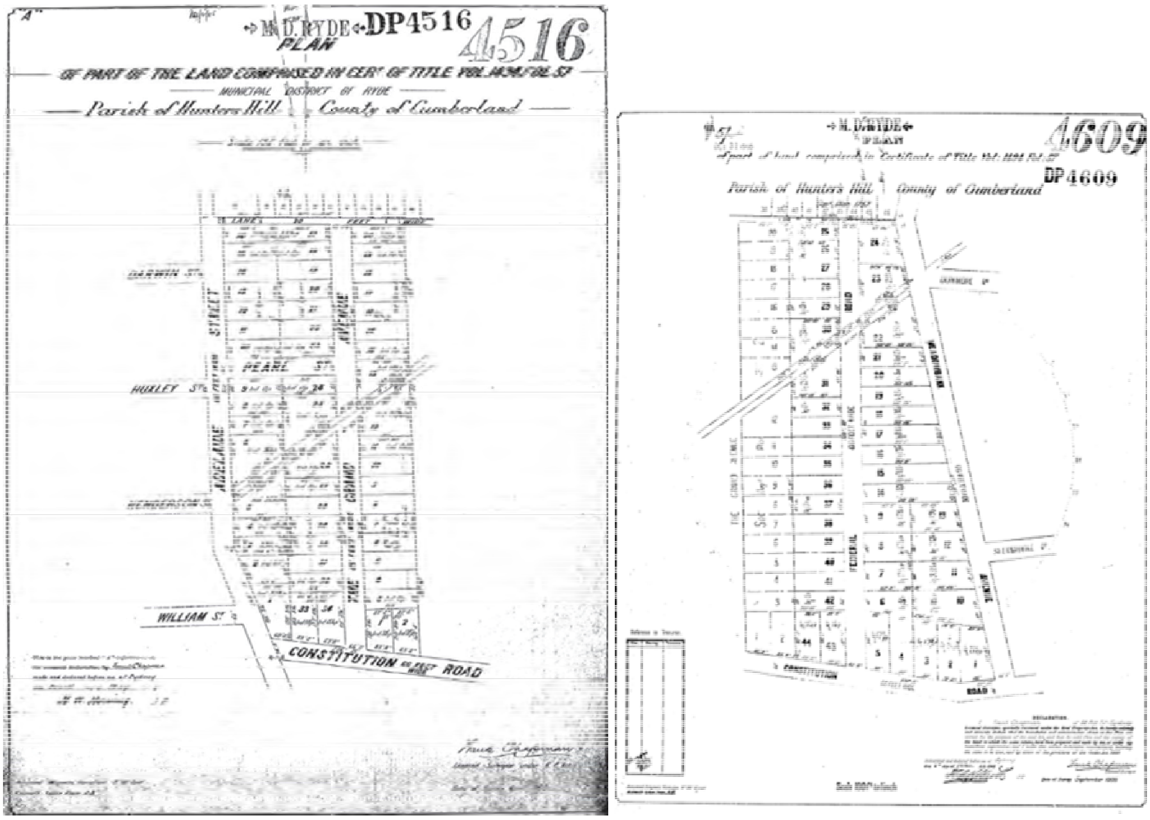

Figure 1: Two adjacent subdivisions done by the same surveyor in April and September 1905.

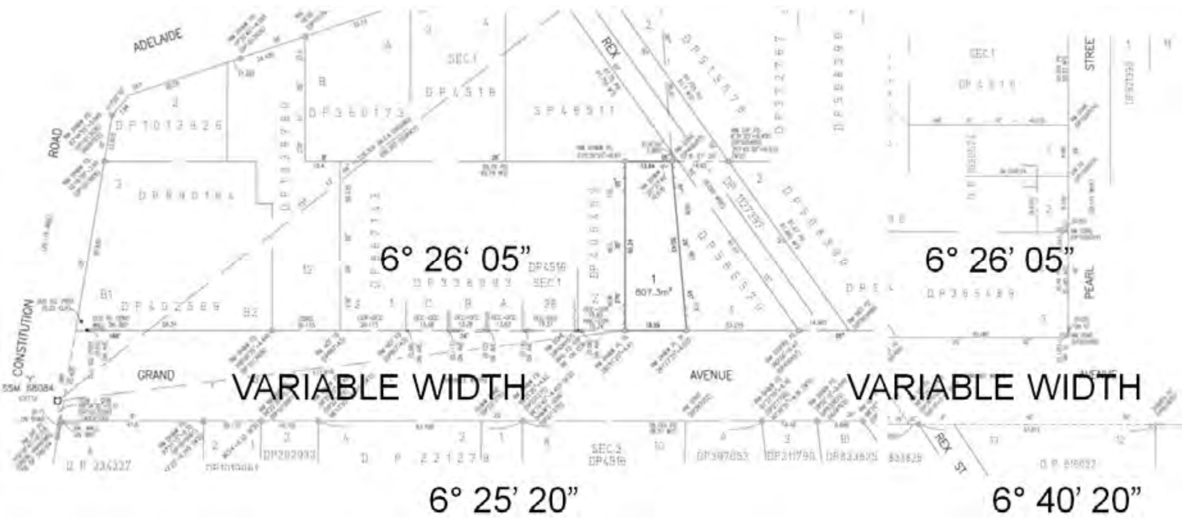

Figure 2: DP 1210616 (2015) showing the current fix of part of Grand Avenue.

2 HOW DID THE STREET REFERENCE MARKS FIX THE STREET?

In 1949, DP 365489 was the first re-subdivision survey plan in Grand Avenue and the first to place survey reference marks. Since that time 26 survey reference marks have been placed in Grand Avenue, of which 17 still exist. Some of these have been shown ‘gone’ on several plans. DP 365489 found and adopted two rock marks in the middle section of Grand Avenue

(Figure 3). These two rock marks are at original distance apart, and although not stated on the plan, the inference is that the rock marks were placed by the original 1905 survey.

In 1956, DP 397052 adopted one reference mark (GI Pipe placed by DP 365489 in 1949) together with occupations at the southern end of Grand Avenue. In 1957, the next surveyor adopted the same fix for Grand Avenue.

In 1959, DP 410618 adopted occupations at either end of Grand Avenue, showed one of the rock marks 'found' and re-referenced another mark (the GI Pipe placed by DP 365489 in 1949).

In 1962, 1963 and 1977, the surveyors adopted one reference mark (DH&W in face of kerb placed by DP 397052 in 1956) together with occupations at the southern end of Grand Avenue. The 1963 surveyor had also undertaken the 1956 survey.

In 1966 and 2013, the surveyors adopted a corner mark (DH&W on wall as placed by DP 410618 in 1959) together with an occupation at the northern end of Grand Avenue.

In 1993, DP 833825 adopted occupations at the southern end of Grand Avenue together with one reference mark (GI pipe placed by DP 211790 in 1962). It should be noted that this plan of survey also connected to the street fix of 1966 and showed two bends in Grand Avenue heading north.

In 1997, 1999 and 2000, the surveyors adopted occupations at the southern end of Grand Avenue together with one corner mark (DH&W placed by DP 221279 in 1963).

Finally, in 2015, DP 1210616 adopted a street fix from all the previous survey plans with the result that Grand Avenue is now shown, at Land and Property Information (LPI) insistence, as 'variable width' with bends!

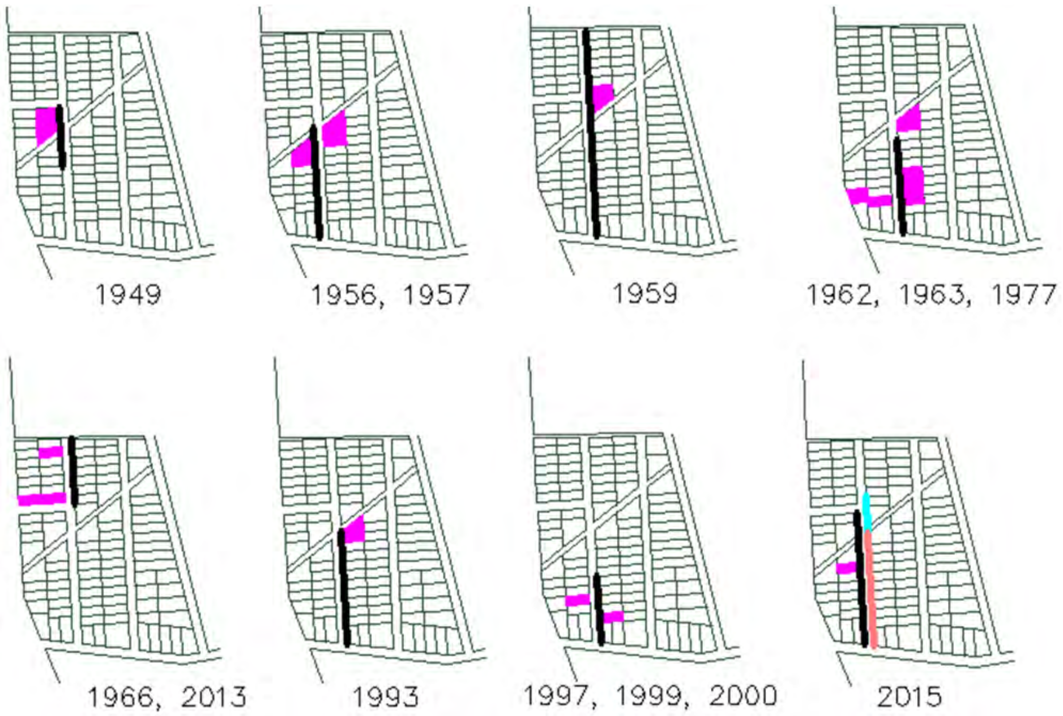

Figure 3: Survey azimuth lines for the fixing of Grand Avenue.

3 WHAT IS A REFERENCE MARK?

A reference mark is placed at the time of survey and provides a snapshot of the cadastral evidence at the time of survey, tempered by:

- The surveyor's experience.
- The field party's diligence.
- Availability of close-by reference marks.
- Cost of the LPI search.
- Expediency and time factor.

Who is going to pass up two beautiful reference marks, either side of the job (Figure 4), or investigate the definition on which they were placed, or determine whether they were even placed correctly? Registered plans from the LPI are gospel, right?

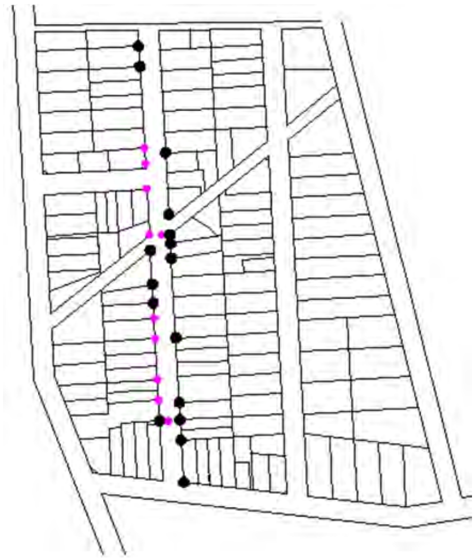

Figure 4: Survey reference marks in Grand Avenue, as placed (dots) and as found (black dots).

4 WHAT IS A FENCING OCCUPATION?

A fencing occupation separates and demarcates two adjoining properties or lots and forms a physical barrier. Adjoining land owners are generally adamant where their side boundary is. Land owners are fiercely protective of their side boundaries and insist that any new re-placement fence is erected exactly in the same location as the previous, older fence. Any fencer with integrity will only replace a side fence in the same location, or rely on visible survey marks.

In the Grand Avenue example and other subdivisions from that era, it would be fair to say that, at the time of erection of the first fences, pegs would be marking the corners of the lots and therefore the side boundaries. Given the age of the original subdivision is 110 years, there is little likelihood that any of the first fences remain. Figure 5 does show a very old timber fence, but it is more probable that the current side fences are all into their second or third re-incarnation, given that the life of a paling fence is around 40 years.

Figure 5: Old and disintegrating timber fence with palings retained and preserved by wire ties.

Why concentrate on side fencing occupations? Because street occupations seem to be more random. For a start, the Council is the adjacent owner of the street land but is rarely involved in the front fence location – relying instead on the private land owner doing the right thing.

When it comes to building a front fence, the land owner (or his fencer) simply joins between existing fences, lines up with existing fencing down the street by extrapolation, or guesses, taking such reliable guidance as the edge of a Council concrete footpath. On the other hand, side boundary occupations are almost always erected with the knowledge, consent and agreement between neighbours. Therefore, the side fence is retained in the same position and is more likely to be close to the originally marked boundary.

Which point best defines or represents the fenced line? Is it the centreline of a fence, the face of a fence, or some other feature of the fence structure? A fence obviously has a thickness, depending on whether it is made of timber (Figure 6a), brick and masonry (Figure 6b), metal tray (Figure 6c), or any other material.

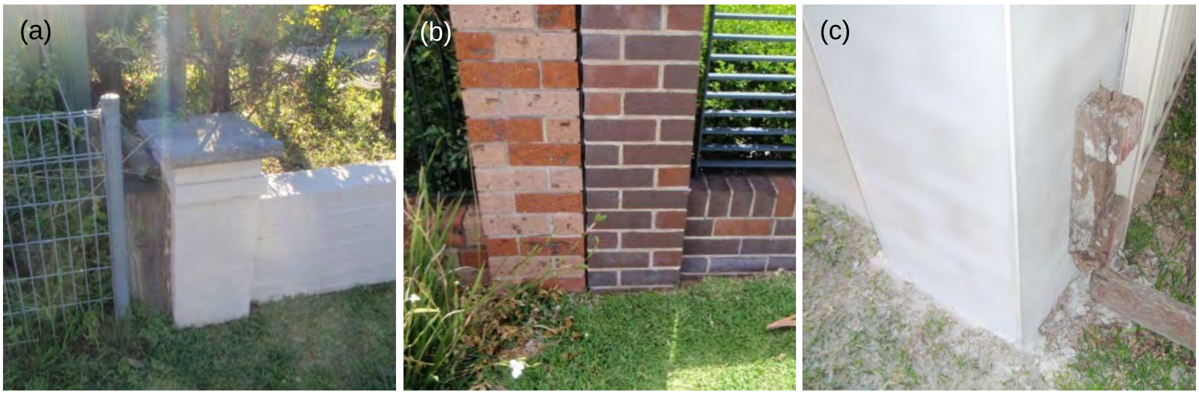

Figure 6: (a) Timber fence with brick pier abutting, (b) brick piers abutting at a side boundary, and (c) old post retained as new front and side fences are erected.

Careful and close inspection of the terminal of a side fence, where it meets the street, can reveal much forensic detail, such as:

- New fencing ending at a very old post (Figure 6c).
- Evidence of a former post by such clues as paint silhouetting (Figure 7a).
- Fence rail slots in the back of brick piers.
- Edge of poured concrete (Figure 7b – note evidence of a previous brick pier, a previous fence post, a previous line of paling fence and the cut-off base of a metal post at ground level).

Figure 7: (a) Silhouette of removed timber post outlined on the brick pier by old paint, and (b) evidence of several previous fence structures.

5 HOW DOES THE FENCING OCCUPATION HELP FIX AN OLD DP?

Knock-downs and re-builds remove evidence of original house walls that were generally built parallel to, and at a set distance from, side boundaries. These days, with free access to lots being often very difficult or time consuming, few surveyors rely on these old buildings' walls. With buildings gone, can we look to the side fences as providing boundary evidence?

In the old DP 4516 from 1905, 54 lots were created. There are now 77 lots, as a result of subsequent subdivisions. However, throughout all this subdivision activity, 44 side boundaries have remained unchanged from that original DP (Figure 8a). When DP 4609 adjoined, it created lots in similar configuration to DP 4516, resulting in a further 14 complementary side boundaries that remain unchanged from 1905 (Figure 8b).

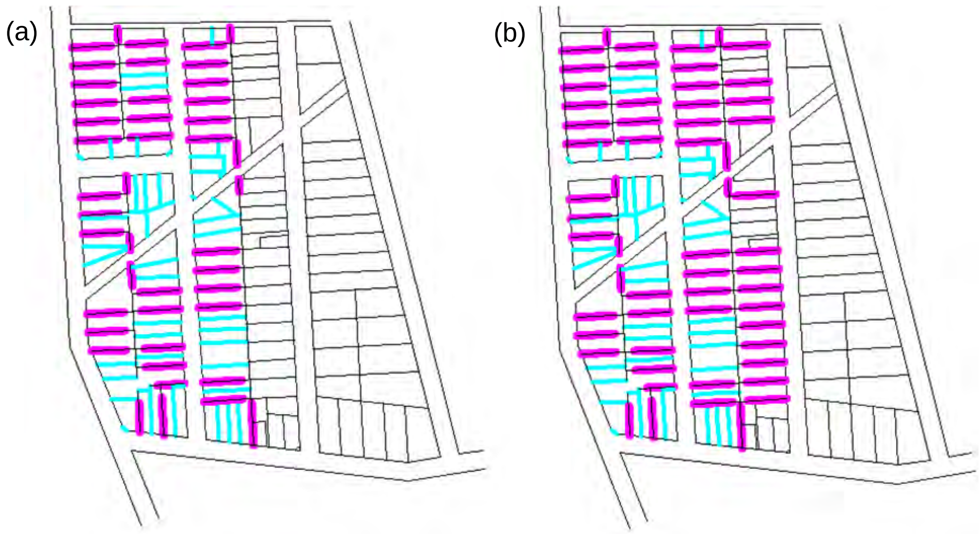

Figure 8: Side boundaries (shown in pink) that are unchanged from (a) DP 4516 and (b) DP 4609 (1905).

So there are 58 side fences that together could confirm the location of the original DP 4516. Notice, from the original subdivision pattern and the remaining side boundaries, that there are six boundary points (indicated by arrows in Figure 9) showing three key straight lines which traverse the whole of DP 4516. Also of note are the two boundary lines immediately south of the key east/west line, as they too extend the whole way across the DP.

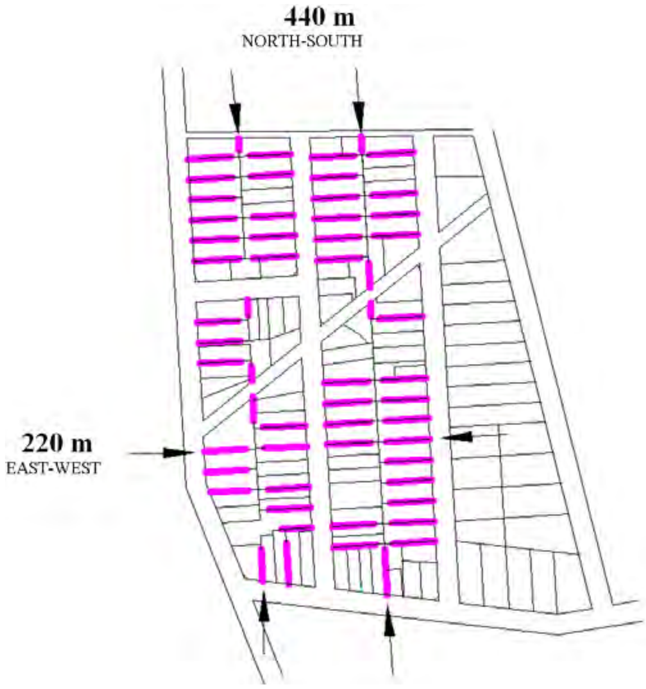

Figure 9: Shows six boundary points on three key lines.

The overall extent of DP 4516 is 440 m north/south and 220 m east/west. These are substantial distances, over which any large shift amounts to only a small effect in bearing. For example, a 60 mm shift over 200 m creates a swing of 1’ of angle. A 120 mm shift over 400 m also creates a swing of 1’ of angle.

A full field survey, controlled by closed traverse and connection to available SCIMS marks, was undertaken to locate the centrelines of the side fences at the key points together with the centrelines of the other 52 relevant side fencing occupations. It should be stressed that only the terminal of a centreline, where it met the street, was surveyed. There was no intention to survey the rear ends of the side fences. Even though all the survey reference marks were included in the field survey, none of them was used to help define a street or side boundary in this investigation using side fences.

A best fit was obtained in two iterations by overlaying the boundary pattern onto the surveyed side fence positions (Figure 10). Firstly, an orientation and east/west shift was achieved by using all of the occupations along the two key north/south lines, with validation by considering the angular effect on the key east/west lines. Secondly, a north/south shift was introduced after considering all the remaining side occupations.

Figure 10 also contains images of the actual fencing on each of the key lines. It would appear that none are original, although a couple of the brick piers seem to mirror the age of its relevant house, being built of the same matching material.

The final result (Figure 11a), after overlaying the boundary pattern onto the fencing occupation survey, culminated in 36 of the 58 side boundary lines (62%) being within 50 mm of fencing (Figure 11b), 9 of the side boundary lines being between 50 mm and 100 mm from fencing, and 12 of the side boundaries being further away than 100 mm (with 5 of those closer than 150 mm). An even distribution of very close fencing, over the whole area of DP 4516, confirms that a fix by side fencing is possible and has been achieved in this case.

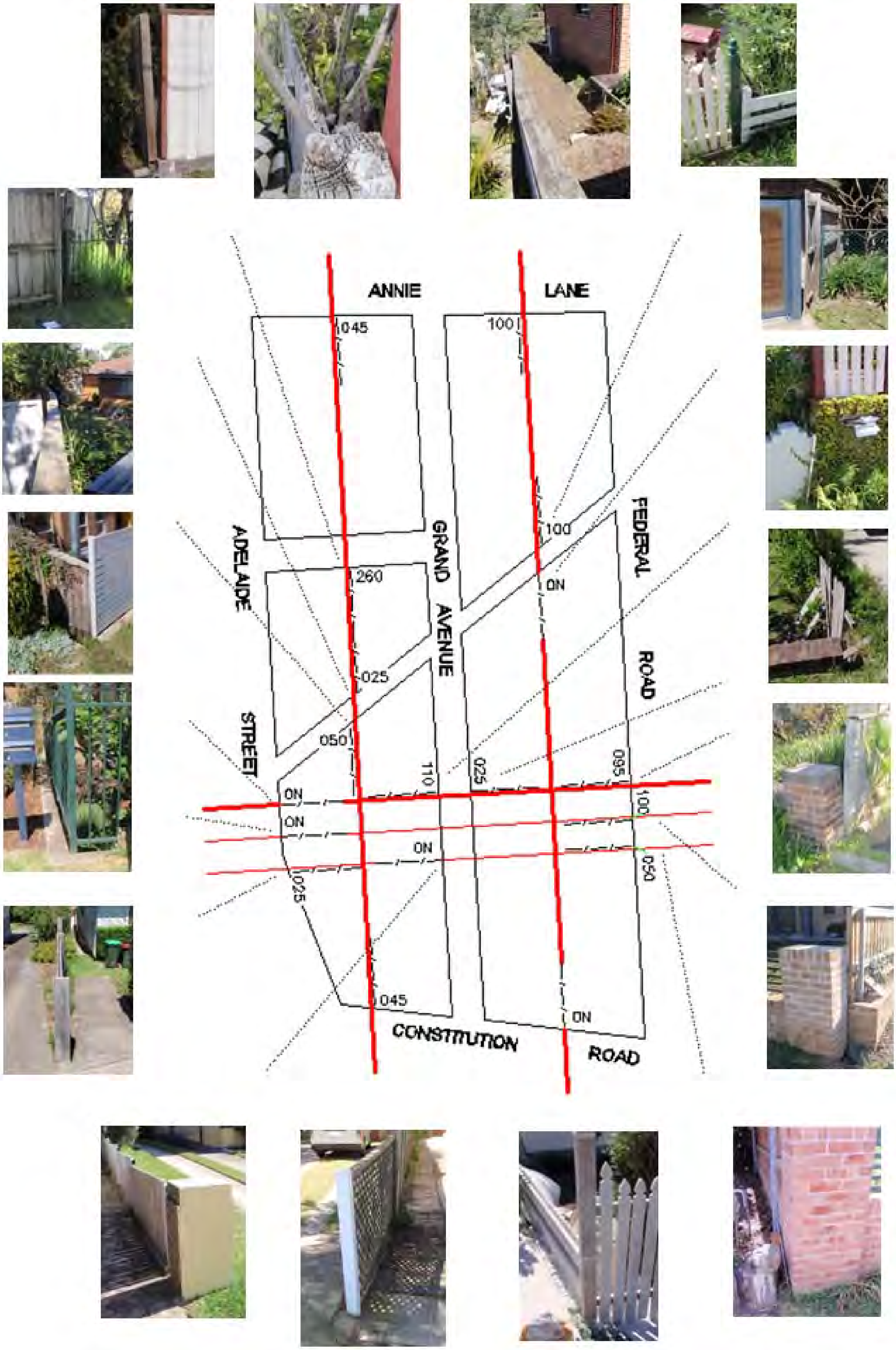

Figure 10: Relationship (in mm) of five key boundary lines in DP 4516 to fencing occupations.

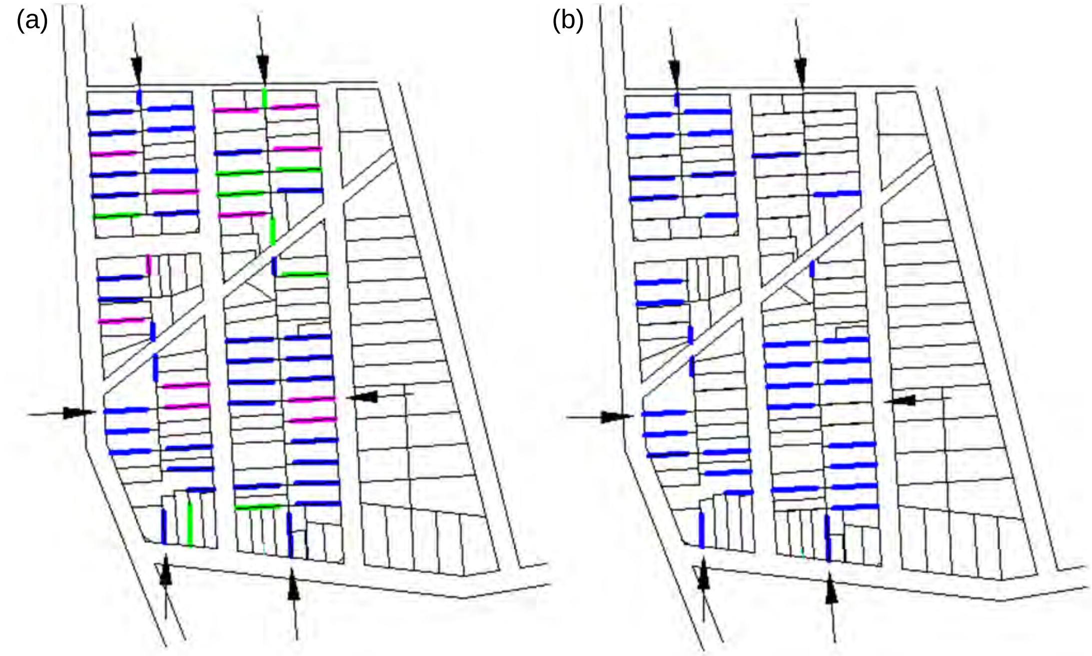

Figure 11: (a) Relationship of side boundaries in DP 4516 to fencing occupations (blue indicates <50 mm, green indicates 50-100 mm, red indicates >100 mm), and (b) distribution of side fencing that fits within 50 mm of side boundaries in DP 4516.

6 COMPARISONS

Confirmation that a reliable boundary fix of the old DP 4516 (1905) had been achieved was apparent when the occupations at bends and intersections in surrounding streets were compared (Figure 12).

Figure 12: Additional occupations and fencing (within 50 mm) at street corners and bends.

In Adelaide Street and Annie Lane, occupations stand within 50 mm of the street boundaries. Of particular note is that the 'face of very old brick shop' is only 10 mm off line. This face of the shop has been adopted by surveyors for decades as defining the boundary of Adelaide Street! The resultant bearing for Grand Avenue, after investigating the relevant side fencing occupations, is 6º27'55". This compares to 6º26'05" in DP 1210616 (2015).

A comparison between the street fix by side fencing and the street fix by reference mark is shown in Figure 13. The differences show where the reference mark street fix is in relation to the re-defined old DP boundary.

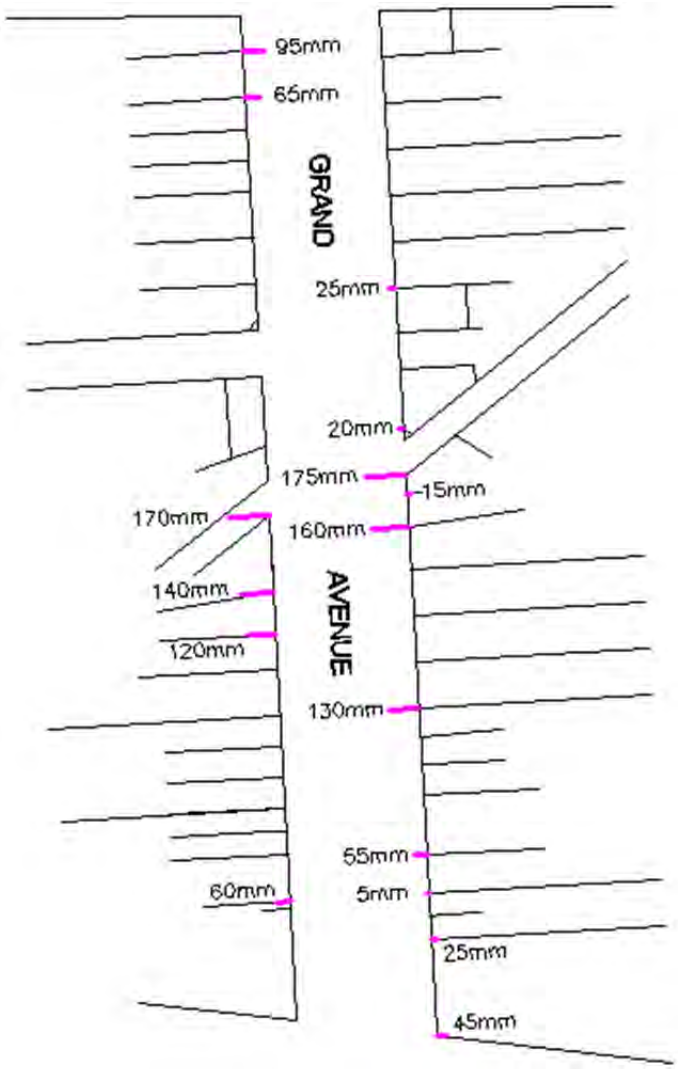

Figure 13: Street boundary fix by reference marks (pink) compared to street boundary using only side fencing.

7 PRE-CONCLUSION

Ryde Council's efforts to preserve survey reference marks in recent years may be contributing to future anomalies in street definition. If a reference mark is available it can influence the street boundary. If a reference mark is gone, then definition reverts to other means such as evidence by fencing or other long-standing occupations. The registered surveyor is then compelled to look further back (behind the current DP) and perhaps even look at the old original subdivision DP. It should be remembered that survey plans after 1885 are accurate. If

the surveys created a street as one straight line, then most likely the street was marked as one straight line. With a loss of reference marks, surveyors tend to try to emulate the original intention of an old DP. But in long streets such as Grand Avenue it is rare (see Figure 3) for surveyors to make that effort and survey a street from end to end. The surveyor in DP 410618 (1959) did survey it end to end, and his plan is in closest agreement to the investigation.

8 CONCLUDING REMARKS

This investigation was successful in that the solution obtained in re-defining an old DP did not upset the surrounding cadastre. Was its success due to the high percentage (70%) of original side boundaries within the old DP being still existent? If just the side boundary points along the key lines were used (25% of the original side boundaries), the final result would not change. Of course, the result may have differed if the rear of all the side fences were analysed as well. However, the object of the exercise was to attain a solution using only the side fence occupations at their junction with the street, i.e. where they are readily accessible. One of the problems of an old DP is its sheer size. In this example the survey needed to cover an area 440 m by 220 m.

Analysis of the current street fix of Grand Avenue, using the available survey reference marks, shows that if surveys over the years had been carried out from end to end of Grand Avenue, then they would show a result closer to that of this investigation.

Streets shown ‘variable width’ could be a clue for LPI that the street fix is meandering away from the original intention. Is it correctable? There are ramifications for future surveyors setting out side boundaries when using a changing street boundary fix, especially when side boundaries are related to the street by an angular relationship.

Finally, there is a predilection for surveyors to adopt street occupations at bends and intersections, so should Council, as the adjoining land owner, be more involved when private land owners intend to construct a front fence, especially at bends and street intersections?

ACKNOWLEDGEMENTS

The author wishes to acknowledge the most valuable contribution made by Dennis Liu and Albert Li (future registered surveyors) for undertaking the field survey work that gathered all the information used in the boundary investigation.

APPENDIX

TIMELINE FOR A GRAND STREET FIX

						REFERENCE MARKS	
DATE	PLAN	TYPE	STREET	LOTS	SUBDIVISION OF	PLACED	FOUND
1903	DP 926032	SURVEY	ADELAIDE AND MONS EXIST		SYDNEY WATER	0	
1905	DP 4516	SURVEY	ANNIE, PEARL , GRAND, REX	54	FIRST SUBDIVISION	0	
1924	DP 310086	COMP	THE GRAND	3	LOTS 19 -20 OF SECTION 1 IN DP 4516	0	
1926	DP315090	COMP	CONSTITUTION	2	LOT 34 OF SECTION 1 IN DP 4516	0	
1928	DP185439	COMP	CONSTITUTION	2	LOT 33 OF SECTION 1 IN DP 4516	0	
1936	DP 334327	COMP	CONSTITUTION	3	LOTS 1 & 2 OF SECTION 2 IN DP 4516	0	
1938	DP338993	COMP	THE GRAND	3	LOTS 29 & 30 OF SECTION 1 IN DP 4516	0	
1949	DP 365489	SURVEY	THE GRAND	4	LOTS 24-25 OF SECTIOIN 1 IN DP 4516	2	1
1956	DP 397052	SURVEY	GRAND	3	LOTS 11-12 OF SECTION 1 IN DP 4516	2	0
1957	DP406457	SURVEY	THE GRAND	3	LOTS 26-27 OF SECTION 1 IN DP 4516	2	1
1957	DP 402569	COMP	THE GRAND	2	LOT B IN B389497	0	
1959	DP 410618	SURVEY	THE GRAND	4	LOTS 13-14 OF SECTION 1 IN DP 4516	2	2
1961	DP 20933	COMP	GRAND	2	LOTS 4-5 OF SECTION 1 IN DP 4516	0	
1962	DP 211790	SURVEY	GRAND	2	LOTS B-C IN DP 397052	2	2
1963	DP 221279	SURVEY	GRAND	4	LOTS 6-7 OF SECTION 2 IN DP 4516 AND LOT 1 IN DP 202933	2	2
1966	DP 521390	SURVEY	PEARL	3	LOTS 10 & 23 OF SECTION 1 IN DP 4516	2	0
1973	DP 565570	COMP	THE GRAND	2	LOTS X-Y IN DP 406457	0	
1977	DP 590164	SURVEY	GRAND	3	LOT 32 OF SEC 1DP 4516, LOT 11-DP 531772 , LOT A-DP 185439	2	1
1979	DP 616037	COMP	GRAND	2	LOTS 2-3 IN DP 410618	0	
1992	DP 1182367	COMP	GRAND	2	LOT 20 OF SECTION 2 IN DP 4516	0	
1993	DP 833825	SURVEY	REX	2	LOT 1 IN DP 211790	1	1
1997	DP 867143	SURVEY	GRAND	2	LOT 31 OF SECTION 1 IN DP 4516	2	0
1999	DP 1019061	SURVEY	GRAND	2	LOT 3 OF SECTION 2 IN DP 4516	2	2
2000	DP 1013926	SURVEY	ADELAIDE	2	LOT 1 IN DP 590164, LOT 12 IN DP 531772	1	1
2001	DP 1029780	COMP	GRAND	1	CONSOLIDATION OF LOT 1-DP 1013926 & LOT 2-DP 590164	0	
2008	DP 1127397	COMP	REX	1	LOT 3 IN DP 926032	0	
2013	DP 1180371	SURVEY	GRAND	1	REDEFINITION OF LOT 18 OF SECTION 1 IN DP 4516	2	2
2015	DP 1210616	SURVEY	GRAND	1	REDEFINITION OF LOT 3 IN DP 565570	2	2
112 YEARS		28 PLANS		54 ORIGINAL LOTS		26	17
		16 SURVEYS		77 LOTS NOW		PLACED	STILL
		12 COMPS		[23 STILL ORIGINAL PLUS		IN	EXIST
				14 COMP FROM DP 4516]		GRAND	

Note: The names of the surveyors responsible for each DP have been omitted from this table on purpose. Suffice to say that the 26 plans since 1924 have been prepared by 24 different surveyors (the 14 plans of survey prepared by 13 different surveyors).

Precise GNSS Positioning: Past, Present & Future

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ABSTRACT

We are witnessing the launch of a surge of new navigation satellite systems, with a significant increase in satellites and signals. This heralds the transition from a GPS-dominated era – that has served the geodesy and precise positioning community for over 30 years – to a multi-constellation Global Navigation Satellite System (GNSS) world. The first civilian applications of GPS were for geodetic surveying and geodetic science. From those first precise positioning applications of GPS have evolved today's techniques based on carrier phase tracking and relative positioning, in which receivers were deployed on reference stations to provide the datum and to facilitate the mitigation of spatially-correlated measurement biases. The evolution of precise differential positioning techniques during the 1980s and 1990s also led to the establishment of geodetic services. Several technological developments led to the mainstreaming of precise positioning techniques such as Real-Time Kinematic (RTK), that are now used for almost all engineering, construction, surveying and machine guidance applications. Recently Precise Point Positioning (PPP) has become a viable alternative technique, and several commercial services have been launched. On the other hand, there is increased interest in the role that Space Based Augmentation Systems (SBAS) can play for non-aviation applications. These disparate developments are occurring just as precise positioning is poised to become mainstream, and the influence of the surveying, geodetic mapping and precise navigation communities will grow as new classes of users embrace the new GNSS technology and confront issues such as datums, reference station infrastructure, integrity, and others. This presentation examines the implications of techniques such as PPP for traditional positioning and navigation applications using multi-constellation GNSS, but also speculates on what type of GNSS techniques – PPP or SBAS – and what type of commercial or scientific services, will be used for future positioning applications of driverless cars and other advanced Intelligent Transport System (ITS) applications.

KEYWORDS: *GNSS, SBAS, ITS, IGS, RTK.*

AMSA's Differential Global Positioning System (DGPS) Network and the Quest for Resilient PNT Services

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ABSTRACT

The Australian Maritime Safety Authority (AMSA) operates a Differential Global Positioning System (DGPS) network, which consists of 16 stations. They are located strategically around Australia's coastline, based on the volume of shipping traffic and degree of risk. Areas covered include major ports and their approaches, the Great Barrier Reef, Torres Strait and Bass Strait. The network aims to improve the accuracy and integrity of the mariner's GPS data. This paper describes how the system meets international maritime performance requirements. The United States is proposing to decommission 62 of their DGPS sites, leaving 22 operational sites available for maritime users. The decision to reduce the number of DGPS sites is based on a number of factors including increased use of the Wide Area Augmentation System (WAAS), the removal of GPS Selective Availability, no mandatory carriage requirement for DGPS receivers, increasing availability of other Global Navigation Satellite Systems (GNSS) and the continued modernisation of GPS. This paper discusses these factors in the Australian context. AMSA's future plans for its DGPS infrastructure are outlined, as are the results of a recent user survey of AMSA's DGPS network. This paper also discusses the importance the International Maritime Organization-led concept of e-Navigation attaches to resilient Positioning, Navigation and Timing (PNT), and the emergence of alternative technologies and innovative solutions (e.g. DGPS in the R mode) in the quest for resilient PNT.

KEYWORDS: *AMSA, DGPS, GNSS, PNT.*

1 INTRODUCTION

This paper discusses the Australian Maritime Safety Authority's (AMSA's) network of Differential Global Positioning System (DGPS) radio beacons, which provides mariners with increased GPS positional accuracy and signal integrity data. While DGPS is intended for the maritime industry, other sectors also enjoy the benefits provided from these signal augmentations.

This paper also outlines the reasons for the United States Coast Guard's (USCG) proposed decommissioning of 62 of their Nationwide Differential GPS (NDGPS) sites. Finally, this paper discusses the International Maritime Organization's concept of e-Navigation and its quest for resilient Positioning, Navigation and Timing (PNT) services for mariners.

2 AUSTRALIAN MARITIME SAFETY AUTHORITY

AMSA is responsible for ship and seafarer safety, provision of marine and aviation search and rescue services, and the protection of the marine environment. AMSA is a self-funded Commonwealth authority that generates its revenue through the application of levies on commercial shipping.

The principal functions of AMSA are to promote maritime safety and protect the marine environment, prevent and combat ship-sourced pollution, provide a national search and rescue service and provide infrastructure to support safe navigation within Australian waters. A part of AMSA's role in supporting safe navigation and providing adequate navigational infrastructure is the provision of the Australian DGPS network.

3 AMSA'S DGPS NETWORK

AMSA's DGPS network provides increased positional accuracy and signal integrity data to vessels navigating off Australia's coastline. 16 broadcast stations are located around the coast of Australia, based on the volume of traffic and degree of navigational risk (Figure 1). DGPS signal coverage includes the Great Barrier Reef, Torres Strait and Bass Strait. Each broadcast station provides signal augmentation coverage out to approximately 150 nautical miles (277 km) from the coast.

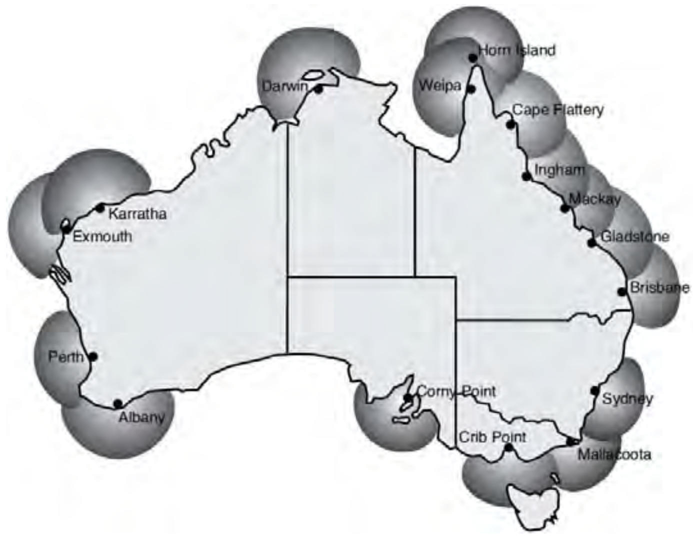

Figure 1: AMSA's DGPS network.

A DGPS transmitter is located with a reference station and integrity monitor, whose location is known precisely. The station compares its known position with the position it derives using pseudo ranges calculated from GPS satellite signals and corrected for atmospheric errors. Corrections to the pseudo ranges are determined and transmitted as 'differential' corrections to vessels fitted with DGPS receivers. DGPS also provides integrity monitoring of the constellation by analysing GPS signals for data that falls outside of specification and notifies users to disregard that satellite's information.

For the maritime environment, typical results achieved by DGPS are a horizontal accuracy of better than 10 metres and a 10 second time to alarm for a failure in the system and its presentation on the bridge of a ship. These accuracies and alarm limits meet the International

Maritime Organization (IMO) requirements for ocean, coastal, port approach and inland waterways transit (IMO, 2001).

4 UNITED STATES COAST GUARD'S NDGPS SERVICE

The United States Coast Guard (USCG) has operated a National DGPS (NDGPS) service since 1999 (Figure 2). This nationwide network has allowed GPS corrections to be broadcast from 84 sites around the continental United States, Alaska, Hawaii and Puerto Rico (USCG, 2016). The USCG NDGPS service provides increased positional accuracy and GPS integrity monitoring to allow for the navigation of vessels undertaking the Harbour and Harbour Approach (HHA) phase of their voyage (IMO, 2001). The USCG assessed that there had been a decline in the use of the NDGPS service, necessitating a review to identify end users and service aims.

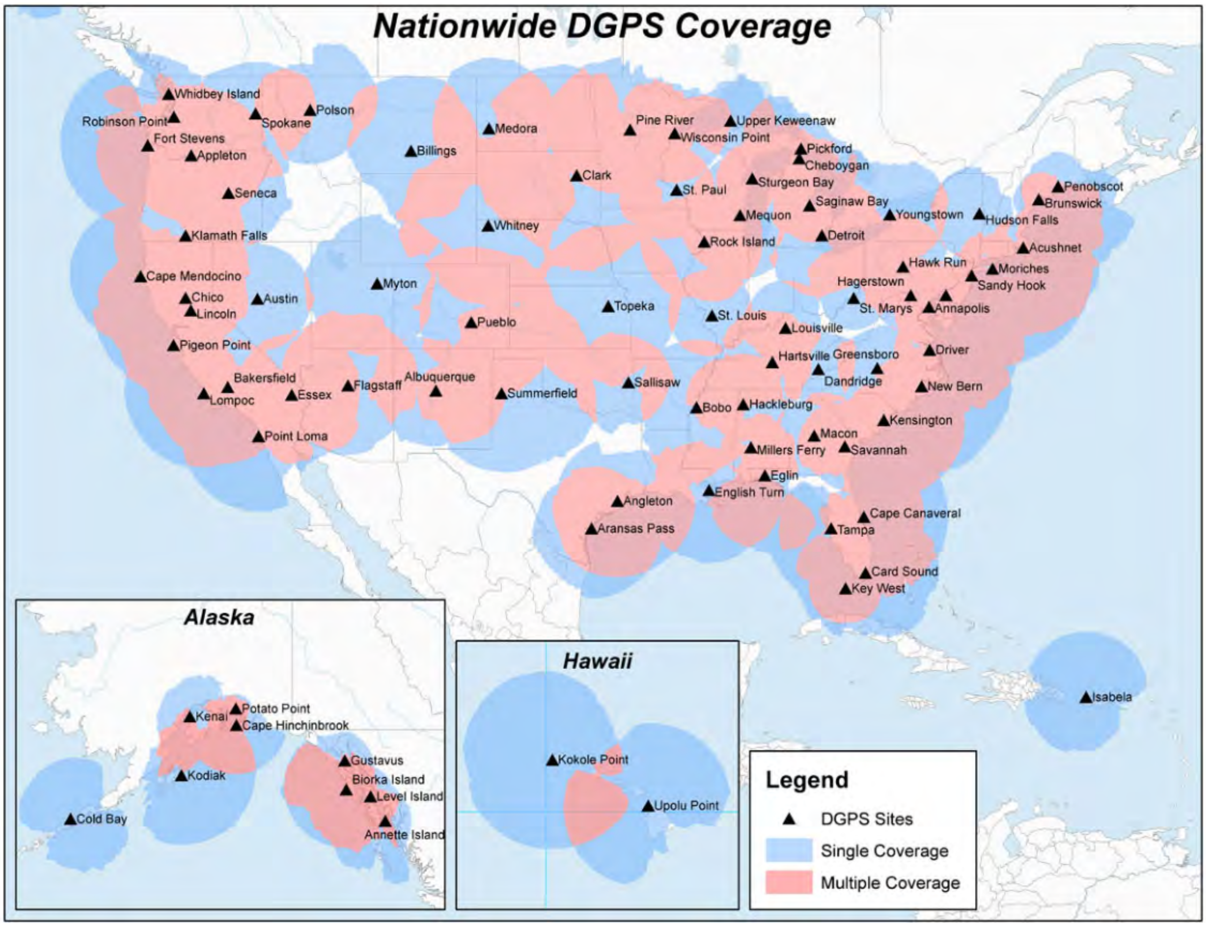

Figure 2: Current NDGPS coverage (USCG, 2016).

4.1 The declining Use of NDGPS

In 2013, the U.S. Department of Homeland Security and the USCG requested public comment on the discontinuation of the NDGPS service. A separate evaluation of the U.S. Government use of and need for NDGPS was also being undertaken. The public request for comment received limited feedback with the majority of responses coming from the maritime sector, primarily marine pilots.

Marine pilots indicated their use of the service for precision ship-handling. Based on this feedback, it was assessed that there were insufficient users to justify the broadcast of corrections inland. As well as the limited response, the Department of Homeland Security and Coast Guard identified a variety of other factors that have contributed to the declining use of the NDGPS service (van Dyke, 2013).

4.2 Lack of USCG Requirements

The USCG amended its internal policy to allow aids to navigation (AtoN) to have their location determined with a GPS unit fitted with and using Receiver Autonomous Integrity Monitoring (RAIM), instead of ordinary GPS receivers augmented by NDGPS signals. RAIM is a method of monitoring the integrity of GPS, which is able to detect failures of individual satellites. RAIM software is incorporated into commercial GPS receivers and compares the time and position data from six or more satellites to determine incorrect information and exclude such data from the positional solution (CASA, 2006).

AMSA, as the provider of AtoN for levy-paying commercial shipping in Australian waters, has not adopted a similar policy to use RAIM as the primary method to measure the location of navigational buoys. The current cost of RAIM receivers makes the adoption of this technology prohibitively expensive.

4.3 Increased Use of WAAS

The introduction of the Federal Aviation Administration's (FAA's) Wide Area Augmentation System (WAAS) has led to a decline in users of NDGPS. WAAS is a Space Based Augmentation System (SBAS) that was developed as an aid to navigation for commercial aircraft operating within the United States' national airspace (FAA, 2016).

WAAS works by receiving and analysing signals from the GPS constellation at numerous land-based reference stations. These reference stations are precisely surveyed and errors in position and time obtained from the satellites can be measured. The information is forwarded to the WAAS master station that generates augmentation messages and provides this data to the geostationary WAAS satellites via an uplink. Finally, the corrections are broadcast from the WAAS satellites on a similar frequency used for the GPS L1 signal (Department of Transportation and FAA, 2008). This process is illustrated in Figure 3.

While WAAS was primarily designed and implemented for the aviation industry, it is now used by other sectors including surveying, construction and major utility companies. WAAS is assessed to be the most widely used GPS augmentation system in non-aviation sectors within the U.S. Indeed, it is now difficult to find new GPS devices that are not WAAS enabled (Gakstatter, 2015).

The Australian / New Zealand region is the only region that does not currently have an SBAS such as WAAS. The Japan Aerospace Exploration Agency has begun launching satellites as part of its Quasi-Zenith Satellite System (QZSS). The final constellation will comprise seven satellites (by 2023) that will be compatible with GPS signals (Office of National Space Policy, 2016). As the constellation continues to grow, the intended orbit design may allow for countries such as Australia to potentially benefit from the use of this new SBAS (Figure 4).

Figure 3: WAAS architecture and operational environment (Department of Transportation and FAA, 2008).

Figure 4: QZSS orbit (Office of National Space Policy, 2016).

4.4 Carriage Requirements and Availability of Receivers

The United States has no legislation that makes the carriage of DGPS receivers mandatory for vessels operating in their waters. There is also no IMO requirement that stipulates the mandatory carriage of a DGPS receiver on board ships. Similarly, Australia has no legislation that makes the carriage of DGPS receivers compulsory on board ships operating within Australian waters. AMSA conducted a DGPS survey in 2014, with results indicating that over 70% of vessels who submitted responses carried two or more DGPS receivers.

4.5 Discontinuation of GPS SA

In May 2000, then U.S. President Bill Clinton announced that the United States would stop the intentional degradation, known as Selective Availability (SA), of civilian GPS signals. The decision to discontinue SA was part of the United States' intent to eliminate a source of global uncertainty of GPS's potential performance (Clinton, 2000). The discontinuation of SA increased the unaugmented positional accuracy from about 100 m to better than 20 m. Multiple sectors and industries derived new benefits from this increase in positional and timing accuracy (Department of Commerce, 2000). As of 2008, the GPS performance standard now states an unaided GPS standard positioning service accuracy of better than 13 m (Department of Defense, 2008).

The NDGPS was designed to correct the intentionally degraded GPS signal to provide better accuracy and integrity data to civilian users. At the time of removal of SA, the United States retained the right to degrade GPS, if required by the National Command Authorities. New satellites that are being procured and launched to replace the existing constellation have had the capability to invoke SA removed. This change will affect the future GPS Block III satellites and is part of the United States' commitment to users that this global activity can be counted on to support peaceful civil activities (The White House, 2007).

4.6 GPS Modernisation

The removal of SA was the first step in the GPS modernisation program. Future steps include the upgrade of the space and control segments and the introduction of new signals for both civilian and military use. The GPS constellation will be modernised with the launch of new satellites from 2017 onwards. These new satellites will deliver four new civilian signals to improve accuracy and signal strength, meet safety-of-life requirements for aviation and improve signal reception in cities and other areas considered to be a challenging reception environment. The availability of these signals across the entire GPS constellation is expected to occur by the late 2020s (National Coordination Office for Space-Based Positioning, Navigation and Timing, 2016).

4.7 Positive Train Control

Positive Train Control (PTC) is an integrated system for the command and control of communications with, and information on, train movements. The system is designed to increase safety, security and efficiency and is being implemented across the U.S. with the passing of the Rail Safety Improvement Act. The system aims to prevent train collisions and prevent derailments through the use of physical rail sensors and a complex UHF radio network to determine a train's position and speed. To implement PTC the Department of Transportation determined that NDGPS was not a requirement for the system (FRA, 2016).

Australia is developing a similar system, i.e. the Advanced Train Management System (ATMS). The aim of ATMS is to increase freight capacity, train safety and reliability across the national rail network. The system will use GPS for location determination rather than a dedicated UHF radio network. The benefits in the use of GPS are that it reduces the initial and ongoing costs of sustaining trackside infrastructure. It is currently unknown if DGPS, when within range, will be used to augment the location determination of the system (Department of Infrastructure and Regional Development, 2015).

4.8 Proposed DGPS Site Decommissioning

Comments called for in the U.S. Federal Register, the daily journal of the United States Government, advised that the Coast Guard proposed to shut down 62 DGPS sites, leaving only 22 sites still operational within the network. Comments on the proposed NDGPS decommissioning closed in November 2015. The Department of Homeland Security and the Coast Guard are now assessing the responses to their proposal. The intended date of decommissioning of sites is 15 January 2016. The remaining sites represent the assessed regions that are critical for the provision of augmentations and will service predominantly coastal waterways where marine pilots operate, commercial shipping is the heaviest, and the need for a more precise position is the greatest (USCG, 2015).

Australia's DGPS network was, and still is, operated for the primary benefit of levy-paying commercial ships. The difference between the current United States' network and Australia's is that a large proportion of the U.S. service is devoted to the provision of coverage to inland areas. With the NDGPS review and potential decommissioning, the sites that are proposed to remain in the United States are similar to Australia's, as they provide improved accuracy and integrity monitoring in critical areas of the nation's coastline (Figure 5).

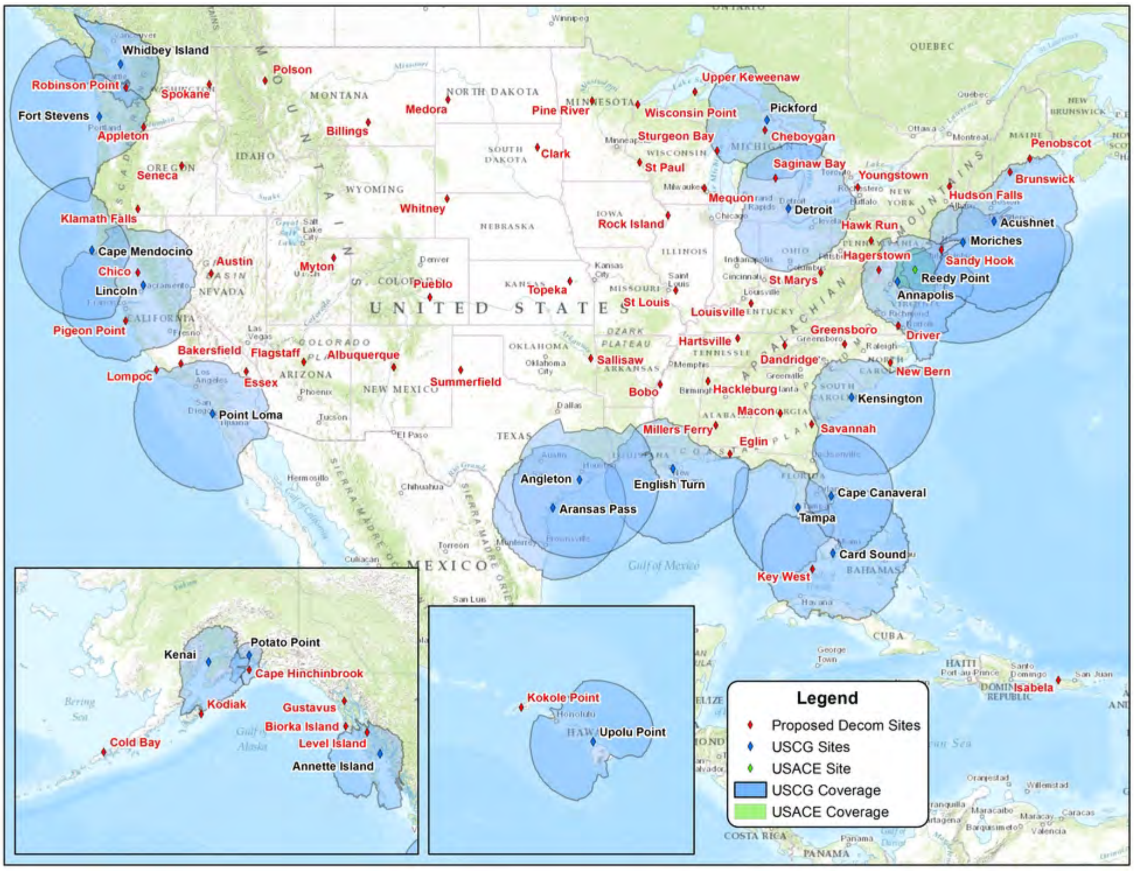

Figure 5: NDGPS Network – Post site decommissioning (USCG, 2015).

4.9 DGPS Site Status

The U.S. Federal Register completed the comment period in November 2015. Over 160 comments were received from various sectors including federal and state government departments, marine and land surveyors, marine pilots and commercial business operators. Most comments highlighted the importance of NDGPS for real-time augmentations as well as

the contribution that the sites make to the U.S. CORS network. No formal announcement has been made about the future of the NDGPS network. However, in January 2016 the USCG commenced decommissioning NDGPS sites, with notices issued through the DGPS advisory section of their Navigation Centre webpage. As of the end of January 2016, 15 sites have been decommissioned with users provided less than two weeks' notice (Figure 6).

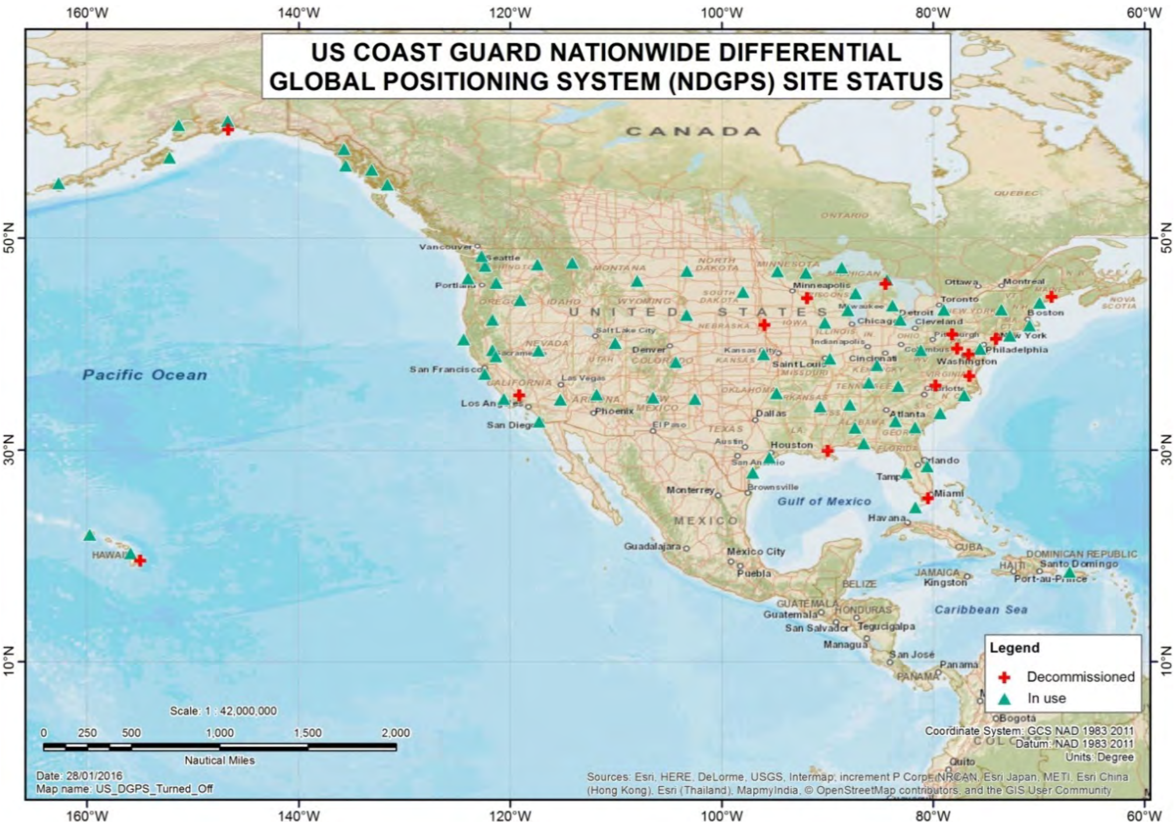

Figure 6: NDGPS Network – January 2016.

5 USER REVIEW OF AMSA'S DGPS NETWORK

In 2014, AMSA conducted a user survey to gauge the uptake and usefulness of its DGPS service. A total of 134 responses were received with distribution of surveys undertaken via peak bodies and AMSA's marine surveyors conducting Port State Control inspections. Respondents identified the primary use of DGPS for general navigation, pilotage in ports and complex waterways and monitoring of anchorage positions. Other identified uses of the DGPS service included commercial fishing, hydrographic and geotechnical surveying, maritime enforcement, research and work involving aids to navigation.

The majority of vessels surveyed, over 70%, carried two or more DGPS receivers. Maritime users also identified a wide variety of navigational aids that DGPS fed into including radar, electronic charting systems, a vessel's Automatic Identification System (AIS) and communications systems. 98.5% of respondents said that they found AMSA's DGPS service to be useful. As maritime organisations continue with the development of e-Navigation, one of its five prioritised solutions is improved reliability, resilience and integrity of bridge equipment and navigation information. To achieve this e-Navigation solution, other independent (yet complementary) forms of PNT will need to be developed (IMO, 2014).

6 E-NAVIGATION

The International Maritime Organization (IMO) is a specialised agency of the United Nations that is responsible for the safety of shipping and the prevention of pollution of the marine environment. AMSA represents Australia at IMO for the development of standards for ship safety, safety of navigation, search and rescue, maritime communications and the prevention of marine pollution.

E-Navigation is an IMO-led concept that was initiated in the mid-2000s and is driven by user needs, based on the harmonisation of navigation systems and supporting services. E-Navigation is defined as "*the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment*" (IMO, 2007).

Two core objectives of e-Navigation are to facilitate the safe and secure navigation of vessels having regard to hydrographic, meteorological and navigational information and risks and demonstrate defined levels of accuracy, integrity and continuity appropriate to a safety-critical system (such as an electronic charting system). To complete these objectives and to achieve the e-Navigation solution, nations must consider the need for resilient PNT infrastructure whose components operate independently, yet are complementary to each other (IMO, 2008).

7 RESILIENT POSITIONING, NAVIGATION AND TIMING

In the maritime sphere, resilient PNT has to meet IMO requirements for accuracy, integrity, availability and continuity. The provision of resilient PNT for maritime users is vital, due to heavy reliance on GNSS. Use includes being a key input to Electronic Chart Display and Information Systems (ECDIS), in positioning of aids to navigation, input into Global Maritime Distress and Safety Systems (GMDSS), obtaining a ship's position for transmission through Automatic Identification System (AIS) and for the coordination of Vessel Traffic Services (VTS). Due to the altitude of GNSS satellites and the weak received signal strength of GNSS, the signals can be easily blocked or interfered with.

Jamming devices can be used to intentionally block or disrupt signals by transmitting their own signal on GNSS frequencies. They cause excess noise that prevents a unit from receiving useful PNT data. Spoofing is where false PNT data is transmitted and where it is indistinguishable from authentic GNSS signals, allowing continuation of activity without users suspecting there is a position error. This was proven in 2013 when a research team from the University of Texas at Austin spoofed the navigation system of a superyacht. The team were able to alter the course of the yacht by several degrees without any alarms being triggered. The ability to spoof a vessel's navigation system without warning could have potentially serious consequences for the safety of navigation (The University of Texas at Austin, 2013).

Examples such as this demonstrate the need to develop resilient PNT services that are independent and dissimilar of existing services, but are able to complement current services. Possible PNT options for the maritime environment include eLoran and DGPS beacons fitted with R mode.

7.1 eLoran

Enhanced Loran (eLoran) is the modern day successor to the old Loran-C navigation system. Loran-C provided PNT services across much of the northern hemisphere with an accuracy of 0.25 nautical miles (460 m). With the development of GPS and the resultant increase in PNT accuracy, The United States' Loran-C was no longer seen as a viable option for transportation or military use and the program was terminated in 2010 (USCG, 2012). China still operates a Loran-C chain, as does Russia with their CHAYKA chain. Both chains are mainly used by the country's military as a redundancy to the United States owned and operated GPS service.

eLoran emits timed radio pulses at 100 kHz from terrestrial base stations. These stations form part of a chain with the master station initiating pulse transmission, followed by successive transmissions from secondary stations. The PNT outputs provided by eLoran are similar to GNSS but benefit from being a completely separate network that requires no data input from satellites to provide information to end users. The low frequency and high power transmissions make eLoran signals difficult to jam or spoof and are complementary to the GNSS low-power, high-frequency signals. Ranges achieved by eLoran depend upon the local terrain near the transmitter and the transmitted power. However, current infrastructure in Western Europe typically achieves 540 nautical miles (1,000 km).

Trinity House (the English General Lighthouse Authority) announced in December 2015 that the transmission of eLoran would discontinue with effect from 31 December. Signals from other Western Europe transmitters in Norway and France will also cease at this time (Trinity House, 2015). As Western Europe ceases transmissions, the U.S. is considering the implementation of eLoran. The National Executive Committee for Space-Based Positioning, Navigation and Timing (PNT ExCom) has recommended the use of eLoran as a near-term alternative to GPS for essential timing data while they consider what capabilities are required for a complete GPS backup. PNT ExCom is responsible for co-ordinating GPS related matters across different federal agencies to ensure the system is able to fulfil national and military requirements (Divis, 2015).

For the maritime user, eLoran seems to be a viable alternative to GNSS for PNT services due to transmission ranges, signal strength, signal frequency and eLoran's ability to operate without input from GNSS constellations. The service may also meet IMO requirements of availability and accuracy for a radionavigation system. However, with mixed messages coming from the UK and the U.S. the future of e-Loran is far from certain.

7.2 DGPS R Mode

Trial transmission of R mode (or Ranging) from existing DGPS infrastructure was conducted as part of the Accessibility for Shipping, Efficiency Advantages and Sustainability (ACCSEAS) project being conducted in the North Sea region. ACCSEAS was able to use the existing DGPS radio beacon infrastructure and were able to transmit both R mode and DGPS signals within a single channel. The R mode receiver measures the pseudo range from the transmitter and decodes signals and messages sent by the transmitter, allowing a ship receiver to determine range from the transmitting beacon – this is quite similar to eLoran.

The benefits of DGPS with R mode are that much of the infrastructure is already in place and would only require modifications to the transmitter. What is required to bring this technology to fruition is the development of commercially available receivers that can receive the pseudo

ranges and decode the signals. For the conduct of the testbed, ACCSEAS developed their own receiver to process R mode data. The usable range for the R mode test was assessed to be to 54 nautical miles (100 km). Analysis at the completion of the testbed indicated a measured range error of better than 10 m (Williams et al., 2015).

8 CONCLUDING REMARKS

The United States Coast Guard's decommissioning of NDGPS sites will reduce the availability of corrections to inland users of the service. The Coast Guard's mission is to protect those at sea and the recent review of the need to maintain their extensive NDGPS network can be seen as a method to ensure that they focus their finite resources on those they primarily aim to serve (USCG, 2014).

AMSA's DGPS network services cover the main shipping arteries and navigationally complex areas of Australia's coastline. For the short to medium term, and in the absence of updated guidance from the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), AMSA has no intention of discontinuing its DGPS service.

Resilient PNT is critical to facilitate the safe and secure navigation of vessels and to demonstrate defined levels of accuracy, integrity and continuity in associated safety critical systems. AMSA's DGPS service is a key component of our commitment to facilitate safe navigation. As e-Navigation continues to evolve, the quest for resilient PNT will be a core component requiring further studies, testing and implementation to achieve the program's outcomes and to provide both the maritime and non-maritime community with alternative PNT services that are independent of, yet complementary to, GNSS.

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GPS in Schools: Agencies Partnering for Industry

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ABSTRACT

The 'GPS in Schools' project as it relates to NSW and ACT is a showcase example of commonwealth, state and territory agencies collaborating together to facilitate a program that will provide enduring benefits to our industry. The surveying teams from NSW Public Works and the ACT Office of the Surveyor-General partnered with Geoscience Australia to successfully roll out this important industry and educational program as part of the AuScope Geophysical Education Observatory project. Our teams were successful in identifying suitable high school sites for the installation of seven (five in NSW, two in ACT) Tier 3 Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS). These receivers have not only provided further densification and redundancy to the CORSnet-NSW network but have provided a focal point for education and industry promotion to the up and coming surveyors of tomorrow. This paper discusses the experiences of both the NSW Public Works and the ACT Government survey teams who liaised and coordinated with individual schools and teachers, suppliers, contractors and fabricators to get the job done. With more than a little help from NSW Land and Property Information (LPI) in the site assessment, fabricating and installation phases of the project, our teams were able to deliver the projects on time and on budget. This program has established a link between Geoscience Australia and each of the seven schools through CORSnet-NSW, the distribution of educational material and various GNSS receivers. This relationship will drive further educational advancements for students in the fields of geoscience, surveying and spatial reference systems. Furthermore, the most positive outcome has been the direct interaction between industry and students that has enabled school students in both jurisdictions to engage with real-life surveyors and spatial professionals, which may never have happened under typical circumstances.

KEYWORDS: *GNSS, educational, Geoscience Australia, NSW Public Works, ACT government, NSW LPI, CORSnet-NSW, industry promotion.*

1 INTRODUCTION

In 2013-15, Geoscience Australia (GA), with funding through the AuScope Australian Geophysical Observing System (AGOS) program (AuScope, 2016), rolled out the 'GPS in Schools' program Australia-wide through collaboration agreements with State and Territory geoscience agencies. Jurisdictions were offered funding and Global Navigation Satellite System (GNSS) hardware to establish Continuously Operating Reference Stations (CORS) in a number of their schools.

As stated in the collaboration agreement between GA (Commonwealth) and the States (NSW Government), the main objectives of the program are to:

1. Maintain and enhance the understanding of crustal deformation in Australia for applications in fundamental geospatial infrastructure and emerging geophysical energy issues.
2. Encourage the integration of scientific research and education by engaging students, teachers and the public in GNSS observing through a program called 'GPS in Schools'.

Additionally, both the NSW and ACT project teams saw that benefits could be yielded from the program to foster interest and broaden the knowledge of high school students in the area of surveying and spatial information with a particular focus on GNSS mapping technology. This program has already been successfully rolled out in other states across Australia.

Following installation of the CORS (i.e. GNSS antenna, receiver, mount and auxiliary equipment) in each of the five NSW high schools, the equipment will be owned, operated and maintained by the NSW Government through Land and Property Information (LPI) who is the custodian of CORSnet-NSW, its state-wide network of GNSS CORS (e.g. Janssen et al., 2015, 2016). The ACT Government through the Office of the Surveyor-General owns and maintains the CORS installations in the ACT. All seven CORS built under this project form part of the CORSnet-NSW network (LPI, 2016).

This paper has been adapted from the NSW Public Works submission to the 2015 Excellence in Surveying & Spatial Information (EISSI) Awards to include the experience of our ACT Government colleagues for the purposes of this paper.

2 PROJECT DETAIL

The objectives of the 'GPS in Schools' program were briefly explained in the previous section, along with the program's drivers, and the associated expectations of the key stakeholders. Prior to discussion of the project management principals, this paper will summarise the overall project outcomes in order to help with the contextual understanding of the discussion to follow.

In terms of project scope outcomes, the teams have clearly exceeded all expectations. Seven Tier 3 CORSnet-NSW GNSS CORS have been successfully installed in high schools across the two jurisdictions, meeting stringent quality requirements (LPI, 2012). Our teams have also assisted with establishing a link between Geoscience Australia and each school through the distribution of educational material, and education and guidance in the use of Garmin handheld GNSS receivers. This relationship will drive further educational advancements for students in the field of earth geosciences, surveying and spatial reference systems. Furthermore, the most positive outcome has been the direct interaction between industry representatives and students. This has enabled many school students to engage with real-life surveyors, which may never have happened under typical circumstances. The following sections demonstrate how each team reached these project outcomes.

2.1 Summary of Roles

Table 1 provides a breakdown of how the project tasks were allocated amongst the NSW Public Works project team.

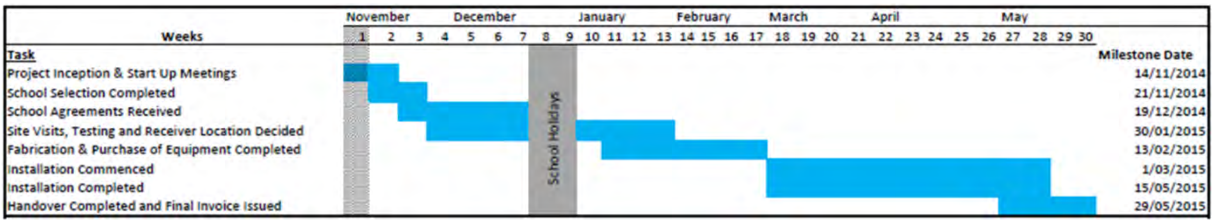
Table 1: Task allocation.

Project Director	Project Manager	Project Surveyor
- Approval of decision-making and risk assessment - Decision to take project on despite considerable risks - Overall strategic direction - Primary contact with GA and LPI management - Seek background information from ACT colleagues - Contract negotiations with GA and LPI - Documentation review, edit, and approval - Industry publicity of GPS in Schools program through presentations at SMIC and Consulting Surveyors Surveying Taskforce - CORS subscription negotiations - Payment of hardware orders - Chair regular project meetings - Organise freight of equipment to Bathurst for pre-assembly - Assist with material for schools start-up tutorial including presentations on surveying careers - Prepare EISSI Awards submission	- Control and monitoring of project budget - Preparation of monthly status report to GA including progress, budget, issues arising - Ordering of hardware and electrical components under instruction from LPI - Preparation of monthly invoicing - Report and contribute to regular project meetings - Cold-calling of schools to explain program and seek interested parties - Maintain and update communications register with schools - Engagement with school senior representative, e.g. Principal - Drafting of documentation and schools correspondence - Mail in / mail out of schools correspondence - Logistics liaison with LPI operations representative - Initial desktop site review - Engagement of electrical contractor, seek quotes - Payment of hardware orders - Peer review EISSI Awards submission	- Drafting of schools documentation including information package, installation agreement - Logistics liaison with LPI CORS installer - Initial desktop site review - Cold-calling of schools to explain program and seek interested parties - Report and contribute to regular project meetings - Site suitability inspections - Engagement with school representative, e.g. Maths or Geography teacher, regarding installation - Liaison with electrical contractor - Develop Project Safety Plan - Supervise field deployment for site installations - Installation logistics - Lead schools start-up tutorial including use of Garmin handheld devices, CORS explanation and drafting of supporting documentation - Peer review EISSI Awards submission

2.2 Program of Works

Table 2 details the NSW Public Works planned schedule with milestones. Four of the five installations were completed early, with the final installation delayed at the request of the school and in consultation with GA and LPI. In addition to this installation program, our team also conducted a start-up tutorial at each school.

Table 2: Planned program.



3 PROJECT MANAGEMENT

3.1 Managing Expectations (Perceived or Real)

The NSW project team identified in the early stages that bias towards certain schools or regions may have been perceived by some stakeholders. With only five permanent GNSS receivers to be installed over the whole of NSW, there was potential for some stakeholders to question why they had missed out. Furthermore, there may also be perceptions around independent vs. public vs. systemic schools, well-resourced vs. under-resourced schools, and Sydney metropolitan vs. regional and rural schools.

This situation raised the question of how the team was going to evenly and equitably distribute the GNSS receivers and what criteria were going to be applied to ensure that sound, evidence-based decisions were being made about which schools were to receive the infrastructure and which were not. All decision-making was captured within MS Excel spreadsheets including a communications log and desktop site assessment log.

As highlighted earlier, the schools were clearly a key stakeholder, but so too was LPI. After all, it was LPI who was going to be the eventual asset owner, so it made sense to base our decision-making around their needs and CORSnet-NSW objectives. It was deemed important by the project team that not only were the schools to benefit, but the overall CORSnet-NSW network should be consolidated and improved upon as a result of these installations. We were mindful of not simply agreeing to install the receivers in the first schools that showed some interest in the program. We judged that the schools' location should be geographically well-suited in terms of its value to the overall CORSnet-NSW network.

Accordingly, LPI was consulted and asked to identify the short-to-medium term objectives in terms of locations for upcoming GNSS CORS infrastructure. LPI was able to provide the team with some high-level objectives as well as some more detailed preferences for sites. The objectives LPI put forward included:

- Densification of the existing network: In the Sydney metropolitan area this meant locating reference stations in the 'middle ring' of Sydney. Currently, there are a number of CORS in the outer suburbs and many in the inner suburbs. For example, between Port Botany CORS and Waterfall CORS there is a straight-line distance of nearly 40 km. Between Fort Denison CORS and Cowan CORS there is nearly 45 km. Based on this information, suburbs such as Sutherland and Hornsby were therefore identified as examples of preferred locations for new sites. In regional areas, between CORS at Wollongong and Nowra was a distance of nearly 80 km. It followed that the southern Illawarra region was identified as a preferred geographic location for a new CORS.
- CORS black spots: These locations were identified but were typically quite remote or were not well-serviced by mobile phone coverage.
- Back-up stations: These typically were identified in larger regional centres. To ensure redundancy and to minimise risk to the ongoing use of the network, LPI identified that back-up receivers in some areas would be a prudent and desirable objective to work towards. From this analysis, two of the eventual new sites selected, Armidale and Goulburn, fitted well with this LPI objective. Many other regions were also identified but were either found to be not suitable from a site analysis perspective or schools in the region did not demonstrate a strong interest in the program when contacted.

GA was keen to roll out the program by providing funding, educational material and equipment, but site selection turned out to be influenced by LPI and the CORS site criteria. In terms of the NSW Public Works project team and its influence on site selection, clearly, if we could identify a majority of sites that were not overly remote from our offices, then managing the budget by keeping travel and accommodation costs to a minimum would be a good outcome.

The initial site in the ACT was selected through happenstance. The science laboratory at Melrose High School, in the suburb of Pearce, already participates in the 'Australian Seismometers in Schools' program (AuSIS, 2016), and the school approached the ACT Office of the Surveyor-General with a view of joining the 'GPS in Schools' program. The location of Melrose High School (Pearce CORS) provided a suitable enhancement of CORSnet-NSW by increasing network density, and hence the redundancy of the existing Canberra stations (Figure 1).

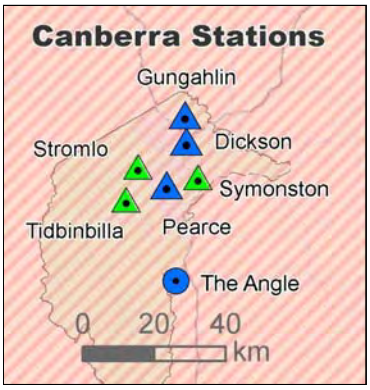


Figure 1: CORSnet-NSW stations in the ACT (LPI, 2016).

Gungahlin College (years 11 and 12), located in the northern suburbs of Canberra, was chosen as the second ACT site to improving network geometry and redundancy. Furthermore, the Canberra Institute of Technology (CIT), which provides Certificate and Diploma courses in surveying and spatial science, has a campus co-located at Gungahlin College. In addition to providing education and industry exposure to the college students, the linkages between CIT and the Office of the Surveyor-General have now been enhanced.

3.2 Managing Time and Cost

Contractually, the deadline stipulated by GA was for the CORS to be installed by mid-May 2015. Both ACT sites were built and operational by September 2014. However, given that the NSW contract was only signed off in October 2014, and that the school summer holidays (typically of 6-8 weeks duration) fell in between those milestone dates, the NSW delivery program was identified as critical. The NSW team set about planning and completing as many tasks as possible prior to the end of the 2014 school year. With schools closed, contact with principals and teachers was not going to be feasible during these times. In addition, our own staff would be taking recreational leave over summer, so clearly the project was going to be stalled during this period.

In reality though, GA wanted to be assured that although the actual installation may not be completed at each school by the deadline of mid-May 2015, their expectation was that the final five schools must be identified, that agreements were in place with the schools, and arrangements for installation were well progressed by that time. The risk being that if the

project had not progressed to the satisfaction of GA, NSW Public Works may not have been paid, yet contractually we would be obliged to complete the project. In terms of the final progress outcome, GA was very pleased that our team had achieved four out of five installations by the mid-May deadline. The final deployment was planned and an approximate installation date agreed upon with the school (The Armidale School).

To manage the time commitment of each NSW team member, project meetings were held where clear tasks and an expected hours budget for each task was allocated. The team were very organised and in the early stages of the project only undertook tasks that had to be done. There was a danger of over-committing resources to this project with potentially scores of schools needing to be inspected and teaching staff consulted and educated about the program. A conscious decision was made to limit the number of resources on this project to the three key members to lessen the chances of extra staff doing more than was necessary, particularly early on in the project. During our early discussions with LPI, our team was introduced to Russell Commins from LPI. Russell is LPI's key CORS infrastructure officer and both the NSW Public Works and ACT Office of the Surveyor-General project teams would like to acknowledge the vital role he has played in ensuring the success of this project.

With Russell's advice and proactive approach the procurement of the necessary hardware and electrical components was made easy and efficient. His involvement saved the project time and money through expert advice and assistance on key elements of the installation preparations. Through Russell, LPI was able to assist with the following:

- Advice on site suitability criteria.
- Reviewing information documentation to be forwarded to schools.
- Attending site inspections and helping to identify suitable buildings for the CORS antenna, secure rooms for the receiver cabinet and routes for cabling conduits.
- Fabrication and design of the stainless steel CORS monument, which included the CORSnet-NSW Adjustable Antenna Mount (CAAM), providing a legally traceable survey monument that allows the GNSS antenna to be oriented to True North without the need to introduce an antenna height (Commins and Janssen, 2012).
- Providing a list of components and hardware to purchase for each installation.
- Providing lists of preferred suppliers for the above.
- Pre-assembly of components and hardware at LPI in Bathurst prior to installation.
- Transport of pre-assembled units to the schools.
- Installation and CORS unit commissioning.

Not only did Russell's involvement with the project ensure a quality installation was achieved at each site, we believe that it was hugely beneficial in saving the project valuable time and costs through his experience and proactive approach to helping our team reach our objectives. Costs on the project were also minimised through the use of our in-house staff for some of the more minor or simpler tasks.

3.3 Managing Quality

It was vital that the experts in CORS infrastructure were involved to ensure that the quality of the final installations was as high as possible and met CORSnet-NSW specifications (LPI, 2012). Again, through Russell's involvement, the quality and the efficiency with which the installations progressed was very high (Figure 2). With all components pre-assembled and tested off-site, any quality problems were able to be identified and resolved prior to the installation team and contractor arriving on site.

Figure 2: Installation of cabinet for Barrack Heights CORS, Warilla High School.

With the installation process being well-organised and efficient, this reflected well on the project teams and the stakeholders such as LPI and GA. The schools had been provided with succinct and timely information about the installation process and they were widely impressed with the quality of the work and the assistance provided by the team.

Of the four fundamental principles of project management (i.e. time, cost, quality and scope), the quality component of the installations was regarded as the easiest element to manage and that was comfortably handled through Russell's involvement.

This project was, however, about far more than just the CORS installations and there was a tangible opportunity to enhance the experience for the schools and for the project outcomes to reflect well on the project team and the industry as a whole. This opportunity was through the documentation and correspondence provided to the schools. The NSW project team identified that if we initially supplied simple and succinct documentation, then the quality of the experience could be enhanced, which could result in more than enough schools showing interest and ultimately signing up to host one of the CORS.

It was agreed that after the initial phone contact with the school, a follow-up information pack would be forwarded to the main school contact. This document would explain the program and its benefits to students. It was identified that the document must be presented in clear, simple terms and language, with helpful pictures and a clear explanation of the process involved. With schools often being solicited to participate in various programs, it was important that our submission did not end up being dismissed by the schools. It was evident that we had to effectively manage the communication stream to the school and get the schools on board by highlighting three key benefits of the program:

1. The CORS infrastructure and educational material would be provided to the school at essentially no cost.
2. There would be a tangible benefit to both the teachers and students in terms of geospatial and science education.
3. The program would not require a substantial input of a teacher's time, i.e. the program would not be a drain on the school's teaching resources.

If we could demonstrate these three key advantages, then it was far more likely that the principal of each school would endorse the program and would allow the teachers and students to actively participate in the 'GPS in Schools' program.

The appendix contains a copy of an information pack sent to the schools. This document signified the first formal correspondence with the school. In terms of managing quality, this document was instrumental in setting the standard for the overall implementation of the program. The document sets out to briefly explain the program, the drivers, the benefits, the responsibilities of the parties involved, and how to go about getting involved. We also included references to supporting reference material and links to helpful websites.

Testament to the quality of this document and the associated phone and email contact, 15 information packs were sent out to NSW schools, from which 7 positive responses were received. Only one school indicated they were not interested.

3.4 Managing Scope

The scope as defined in the terms of the Collaboration Agreement contract signed by GA and NSW Public Works was quite clear: "*GA will provide 5 GNSS antennas and receivers to the Collaborator (NSW Public Works) and funding for deployment in five NSW educational facilities. The Collaborator will install the 5 GNSS receivers and antennas and perform all project management associated with the installations*."

On face value, this presented as a reasonably straightforward project management exercise. However, the complexity of dealing with multiple stakeholders and their differing priorities would dictate that the project team had to gain a clear understanding of each stakeholder's perceived expectations to enable a clear vision of the actual scope of the project. To that end it was important to do what was reasonable in terms of satisfying the stakeholder expectations, yet have a clear understanding of any cost implications that may be associated with these expectations. We needed to communicate clearly to the stakeholders that we would do what could be done within the confines of the approved budget.

Once each site had been inspected and the specific location for the antenna, cabling and cabinet had been decided, an installation agreement was drafted for each site. Each school was asked to review the agreement and sign off that what was being proposed was officially agreed to. More discussion about the installation agreement follows below, but it was this document that played an important role in limiting scope and managing expectations.

Once the project had progressed to a stage where the team was comfortable with the budget, we then were able to consider implementing those initiatives that were clearly beyond the scope nominated within the Collaboration Agreement with GA, such as providing guidance, instruction and advice to the teachers and students post-installation. Both project teams felt an obligation to extend our scope beyond just the installation, and to provide an initial start-up tutorial to each school. This extra effort would reflect well on the project teams and the industry as a whole. This thinking also fitted well with the overall program objectives of encouraging students to take up surveying as a career. This additional effort added significant value to the program, was outside the scope, but was done within the constraints of the approved budget.

3.5 Managing Risk Factors

3.5.1 Exposure to Financial Loss

To ensure all risk factors are considered prior to taking on any project, NSW Public Works undertakes a process of due diligence through the 'go / no go' process. This process considers the type of projects, the available resources, the likelihood of success, likely risks and their mitigation measures before a decision is taken to proceed with a fee proposal. Unlike most projects, the 'GPS in Schools' program was offered to us directly through LPI and GA. Our in-house experience with schools and managing projects including procurement of contractors led our team to the conclusion that we could take this project and make it successful. The ACT Office of the Surveyor-General had previous experience in the establishment of Dickson CORS (build with help from LPI), and was confident, again with LPI technical assistance, that another two CORS builds would be successful.

3.5.2 Unclear or Poor Communications

As described earlier, one of the biggest risk factors to the take-up and implementation of the program was being able to generate sufficient interest in enough schools at the outset. The NSW team identified that with five hosts ultimately required, we would need perhaps three times as many schools initially showing interest. This would then give the team a pool of potentially 15-20 possible sites from which to selectively choose from. Each school would need to meet certain site criteria to progress to the next stage of the selection process. If we could only generate a small pool of interested schools, there was a high likelihood that those sites would be deemed to be unsuitable, therefore leaving the project exposed.

The information pack (see Appendix) was a key document for the reasons explained in section 3.3. This document delivered the first formal clear communications to the school stakeholders and was crucial in mitigating the risk associated with the take-up of the project.

3.5.3 Schools Slow to Respond

With a tight deadline for implementation of the project, if the schools were slow to respond to our initial contact, again, the pressure to identify enough schools to select from would rise. To help progress the initial responses from the schools, the NSW team would follow up each information pack mail-out with a phone call to the school to make sure that it was received and if any help was needed. Clearly, with the schools having other priorities, personal follow-up by phone calls was an effective project management tool and helped to extract responses from schools in a timely manner.

3.5.4 Lack of Interest by Schools

It was unknown at the commencement of the project whether or not 'GPS in Schools' was a program that schools would be interested in. Somewhat surprisingly, but with credit to the team members who personally contacted individual school principals and explained the offering, the initial feedback from the schools was one of high interest and enthusiasm. With many students and teachers exposed to satellite positioning technology on a daily basis through smart phone technology, using street maps, in-car navigation and other applications, the appetite to take that basic education several steps further was appealing.

3.5.5 Information Management

With multiple stakeholders, a variety of information had to be captured, including site information, school contact person, LPI site preferences, schools that had previous contact with GA, and names of suppliers and contractors. It was important that this information was captured and recorded succinctly to avoid duplications and information gaps. Through the use of simple spreadsheets to record and capture events, a valuable information log developed and contributed to efficiency gains. For the site selections, we also logged the decision-making process through the spreadsheets, so that if any questions arose about why certain schools were selected or not, then we had documented steps and reasoning behind each decision.

3.5.6 Cost of Identifying Suitable Sites

For the NSW Public Works team to successfully manage the budget, doing long road trips to visit multiple sites all over the state just to complete an initial cull was judged to be not feasible. Armed with the CORSnet-NSW site criteria (LPI, 2012), the LPI preferences and GA's list of schools that they had previously dealt with, a very effective, desktop-only, site suitability assessment was undertaken using essentially free online street maps and aerial imagery, including Google Maps and Street View. These tools allowed our team to develop a picture of the terrain surrounding the school, the nature of the main buildings and a feel for the vegetation coverage of the site. Those schools that did not make it through the desktop cull were not contacted at all, thus saving valuable time. Our team only focussed on schools that passed this initial desktop cull, and from there the schools were contacted, and if an interest was shown, then we would make arrangements to visit the school.

3.5.7 Work Health and Safety

Just as project risks discussed previously were important factors to consider, work safety risks were assessed and control measures put in place to ensure the safety of all personnel involved. Common hazards at each site included working at heights, potential asbestos contamination, use of power tools and electrical hazards. Additionally, the need to keep inquisitive students and other people clear of the installation site, particularly when the installation team were working from an elevated work platform, was paramount (Figure 3).

Figure 3: Installation of a GNSS antenna monument, demonstrating a number of work safety measures in action.

Both the NSW and ACT teams took overall responsibility for work safety at each site and developed the Project Safety Plan accordingly. All those involved in the installation, including our teams, electrical contractors and LPI staff, were asked to sign on to our over-

arching Project Safety Plan. No work safety incidents were reported as at the completion of the two ACT and five NSW installations. One consideration in selecting the actual site for the CORS installation was whether the building could be accessed easily and safely.

3.5.8 Potential Lack of Expert Support

It was also unknown at the commencement of the projects if both NSW Public Works and the ACT Office of the Surveyor-General would be able to call on LPI for support in the installations. Discussions were held and LPI kindly provided that support through Russell Commins to work on installing the GNSS infrastructure (Figures 4 & 5). Without that support, the outcome of the project may have been very different. As NSW Public Works were not keen to be the eventual owners of the infrastructure, LPI gratefully stepped in and arranged for the infrastructure to be incorporated into CORSnet-NSW and to take ownership of these assets. However, in the ACT the ownership and responsibility of Pearce CORS and Gungahlin CORS remains with the ACT Office of the Surveyor-General.

Figure 4: East Corrimal CORS antenna at Corrimal High School.

Figure 5: Pearce CORS cabinet, Melrose High School.

4 ADDING VALUE

Not only were the schools to host the CORS infrastructure, the GA program included an educational package developed by the University of Tasmania and a number of Garmin handheld GNSS devices. By the time the project had progressed to the stage where installation costs were known and could be forecast, the project team had a good idea of what

funding would be available to provide some added value to the project at the back end. Both teams felt that we could compliment the GA offering through engaging directly with students and teachers at each of the seven schools. The teams undertook to invest some time in providing the schools with a start-up tutorial that included a brief description of the CORS network, satellite positioning technology, use of the Garmin handheld devices, careers options and study pathways into surveying and mapping careers. From this, additional documentation and presentations were developed. Following the CORS installation, the teams arranged for a follow-up visit to the schools where the students were presented with the Garmin GNSS devices, the educational material and the tutorial presentation.

Our team also felt it was important that from the perspective of industry promotion, publicising the program, our teams' efforts and the contributions of LPI and GA was an important value-add to the overall program. The first author delivered presentations to the Surveying and Mapping Industry Council (SMIC) and to a meeting of the Surveying Taskforce hosted by Consulting Surveyors NSW. Publication of those presentations also followed in industry newsletters.

In the ACT, the 'GPS in Schools' project was the catalyst for the SSSI (ACT Region) 'Let's Locate' educational program, which aims to increase the spatial literacy of school students through exposure to surveying and spatial technologies (G. Ledwidge, pers. comm., 2015).

5 CONCLUDING REMARKS

The GPS in Schools project has provided numerous tangible benefits to the surveying and spatial information industry through the collaborative efforts of several stakeholders. The project has brought together contributors from throughout the industry including federal and state government agencies, surveying professionals, schools and teaching professionals, technicians, students, and surveying industry groups. Both the NSW and ACT teams are proud to have been involved in the CORS installations, industry promotion and educational activities. We feel we have contributed to the improvement of the CORS network as well as educating high school students on aspects of surveying and spatial information. Hopefully, this exposure may encourage some students to pursue a career in the spatial sciences.

The project presented each team with challenges. However, this paper demonstrates that by taking a project management approach to this engagement, our teams were able to focus on time, cost, quality and project scope to achieve the desired outcomes for all stakeholders whilst managing project risks and expectations successfully.

This paper also demonstrates what can be achieved through government agencies partnering and collaborating together for positive industry outcomes. The model implemented to manage this project should be promoted and used to provide further benefits to our important industry.

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- The Schools (NSW: Warilla High School, Corrimal High School, The Armidale School, Goulburn High School, and Kirrawee High School, ACT: Melrose High School, Gungahlin College and Canberra Institute of Technology) – enthusiastic engagement with the project, assistance from the principals and teachers in providing access and approval to host the GNSS CORS infrastructure.
- Surveying Taskforce, Consulting Surveyors NSW – provider of surveying careers promotional material to be presented to the schools during the start-up tutorials and for publicising the positive outcomes of the program (Veronica Bondarew, CEO).
- Surveying and Mapping Industry Council (SMIC) – inviting our team to present this topic at SMIC meetings and for publicising the positive outcomes of the program (Narelle Underwood, Chair).

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APPENDIX: Schools Information Pack

NSW | Public Works

GPS in Schools

INFORMATION PACK

27TH November 2014

DOCUMENT CONTROL

Version	Author	Reviewer	Approved for issue	
			Name	Date
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What is the GPS in Schools Project?

The GPS (Global Navigation Satellite System) in Schools project is funded by Geoscience Australia (Commonwealth Government) and is an initiative with essentially three objectives:

- Encourage the engagement of students in geoscience through the integration of research and education.
- The strengthening of the CORSnet-NSW network of permanent Global Navigation Satellite System reference stations.
- Encourage students to consider surveying and related geospatial sciences as a potential career.

Under the agreement between the NSW Government and Geoscience Australia, NSW Public Works has been allocated five GNSS receivers to install within suitable high schools in NSW and your school has been identified as a potentially suitable site to host one of these receivers. This project has already been successfully rolled out in other states across Australia.

What Equipment will be Installed?

It is proposed to install five Tier 3 CORSnet-NSW reference stations in high schools throughout NSW as part of this program. The tier relates to the physical standards of the installation. Higher order installations, including Tier 1 and 2 require concrete pillars and stable rock foundations. A typical Tier 3 installation is far less substantial and typically consists of:

- A stainless steel mast, attached to a masonry building, where the mast (with GNSS antenna attached would extend above the eave line of the building (see image below).
- A GNSS receiver, data communication hardware, power supply and other ancillary electronic devices in a small secure cabinet within the building to which the mast is attached (see image below).
- Cabling for power and data, and associated conduits, brackets and hardware.


Antenna Mast


Receiver Cabinet

Photos: Tier 3 CORSnet Reference Station as installed at Gungahlin ACT

What are the Benefits?

Schools participating in the GPS in Schools Project will receive the following:

- a CORSnet-NSW Tier 3 GNSS antenna and receiver installed on-site
  - a focal point for education relating to surveying, satellite technology and the geospatial sciences
- a full CORSnet-NSW licence which will enable on-line access to GNSS signals from the entire CORSnet-NSW reference station network
  - Licence will enable users equipped with RTK (Real Time Kinematic) capable GNSS equipment to obtain survey-accurate real time positioning data. NB: *Provision of this RTK capable equipment is not part of GPS in Schools Project.*
- an educational package developed by the University of Tasmania relating to the capture and use of GNSS positional data
- phone and email support from Geoscience Australia to help schools make use of GNSS data and educational material in class exercises.

Other Benefits

- installation, operation and maintenance are essentially at no cost to the school. The equipment is owned by NSW Government. All ongoing communication costs associated with the reference station will be paid for by NSW Government.
- assistance from Geoscience Australia to facilitate school visits to the Geoscience Australia Educational Centre in Canberra.
- an opportunity for students to engage with NSW Public Works Surveyors during the site assessment and installation phase.
- assisting the NSW Government and Geoscience Australia achieve their educational and scientific goals by hosting a CORS station that is an integral part of the state-based positional reference framework.
- an increased awareness of geography, physics and the spatial sciences for students and teachers alike, and developing awareness of career options.

What are the Schools Responsibilities?

The schools participating in the GPS in Schools Project do have some responsibilities including:

- Initially, NSW Public Works Surveyors will require access to the school to provide an introduction to the project and the personnel involved, and to undertake an initial site suitability assessment. Additional visits to the site are likely during the assessment and installation phases.
- Allowing schools-compliant contractors to access the site and undertake the installation works, this will include access to power for installation and ongoing operation of the equipment (NB: ongoing power costs are considered minimal)
- Nominating a school representative to be the contact person on site. Ideally, we are targeting geography and physics teachers to take up this opportunity. The contact person will also need to be able to accompany NSW Public Works Surveyors on the site suitability assessment.
- Once installed, the antenna will require unobstructed access via a ladder or cherry-picker, depending on the site. The school will need to keep the area in the immediate vicinity of the antenna reasonably clear of vegetation or other physical obstructions to allow for occasional maintenance (NB: It is expected that the equipment may need to be accessed once or twice per year).
- The school must sign a ***Memorandum of Understanding (MoU)*** which sets out the agreement between the school and NSW Government. If the site is found to be suitable the MoU will negotiated prior to installation proceeding.
- Provide NSW Public Works with an up to date Asbestos Register.

For a site to be deemed suitable, there are some criteria that need to be met. These will be investigated at the site suitability assessment, namely:

- The antenna requires a clear view of sky down to 10° above the horizon, with no short-medium term prospect of being built or grown out.
- Both the antenna and cabinet need to be securely located – ensures tamper free operation of reference station.
- Potential risks introduced by the installation of any component of the reference station, including aesthetics are to be acceptable or resolved to the satisfaction of the school and NSW Government.

What is CORSnet-NSW?

CORSnet-NSW is a network of Global Navigational Satellite System (GNSS) Continuously Operating Reference Stations (CORS) located around New South Wales with data links to NSW Land and Property Information (LPI NSW).

Currently CORSnet-NSW has 157 stations spread across the State with that number growing to a planned density of towards 200 stations over the coming years. Where possible, CORSnet-NSW equipment is housed in LPI NSW own regional offices. Where this has not been feasible, LPI NSW has worked in partnership with other government departments, local councils and the private sector to accommodate the equipment. Of the 157 operational stations, 7 are located in Rail Corp facilities, 96 are located in local council buildings and 18 more under agreement in NSW State Government offices (further information on rollout and partnerships is available at http://www.lpi.nsw.gov.au/surveying/corsnet-nsw/network_information

CORSnet-NSW enables suitably equipped users operating in the coverage area to receive data from the GNSS base stations and offer survey-accurate positioning in real time as well as providing access to stored data for higher order post-processing applications.

CORS technology is now being used worldwide with applications developing in many fields including scientific research, precision navigation, engineering and precision agriculture. In NSW, state government agencies and corporate industry involved in infrastructure development (road, rail, ports) and utilities (power, water, telecommunications) find CORSnet-NSW an efficient system for their precise positioning tasks such as asset capture, planning work and as-built surveys.

For LPI NSW, CORSnet-NSW is an efficient resource for densifying cadastral (title boundaries) control to improve the spatial accuracy of the Digital Cadastral DataBase (DCDB). In addition it is fast becoming an invaluable resource for the operation of aerial photography and LIDAR

programs. It is expected that over time, CORSnet-NSW will replace the need to maintain a significant portion of the existing physical survey control network in the region including current trig stations.

Each CORS typically consists of the following equipment:

- **Stable monument**. The monument is used to mount the antenna and may range in type and size from a small pole mounted on a rooftop to a free-standing pillar concreted into the ground.

- **High precision GNSS receiver**. All receivers in service are able to use signals from both the American GPS and Russian GLONASS satellites. New installations will utilise receivers which are also able to take advantage of signals from other GNSS satellites such as the European Galileo, Japanese QZSS and Chinese Compass systems as well.

- **Antenna**. CORSnet-NSW uses precision antennae which are passive (receiving only) and relatively small (less than 40cm in diameter). Each antenna is connected to the receiver using low loss coaxial cable with a lightning arrestor installed.

- **Power Management**. Dependent upon the type of installation, each setup will use either a UPS or other form of battery backup. The UPS is a 240/12 volt battery backup unit which powers the receiver. Its dual function is to both control power surges to the receiver and offer extra operating time for the system in the event of a power failure. The alternative is a direct battery configuration that will provide additional up time in the event of a mains power failure.

To Get Started

The school needs to:

- Read and review the covering letter and information document.
- Nominate a school representative as the preferred contact.
- Complete the quick questionnaire indicating your interest and supply other information requested in the questionnaire.
- Return the signed questionnaire to the NSW Public Works contact in a timely manner.
- If your school indicates interest in the project, NSW Public Works will contact the nominated school contact person to arrange an initial site suitability assessment in the coming weeks.
- The school DOES NOT need to sign the sample MoU yet. The MoU will be discussed and agreed upon prior to the installation proceeding.

Questionnaire

If your school is interested in participating in the Geoscience Australia GPS in Schools Project please complete and return the following questionnaire.

- **Our school is interested in participating in this project ______ YES / NO**
- **Schools nominated contact for all future correspondence with NSW Public Works:**

  Name: ____________________
  School: ____________________
  Position: ____________________
  Phone: ____________________
  Email: ____________________

- **Can the school provide an up to date Asbestos Register prior to the site suitability assessment if required? ______ YES / NO**

I / the School understand that completing this questionnaire does not guarantee a CORSnet-NSW reference station will be installed at the school. It merely indicates an interest in proceeding to the next stage of the selection process. I / the School understand that the final selection of schools to receive CORSnet-NSW reference stations will be dependent upon, but not limited to factors such as:

- **The location of the school with respect to existing CORSnet-NSW reference stations.**
- **The physical suitability of the site for install and maintenance.**
- **GNSS signal quality at site and data communication rates from the site to LPI.**

Name: ____________ Title: ____________
Signed: ____________ **Date:** ____________

Please scan and email response within 2 weeks of receiving this information pack to:

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NSW Public Works
Adam.Veersema@finance.nsw.gov.au

Helpful Links and Websites

- **Geoscience Australia**

  More information on global positioning systems and CORS, including information on educational programs.

  http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/gnss-networks
  http://www.ga.gov.au/education/visit-our-education-centre

- **Land and Property Information (LPI NSW)**

  More information, details and usefuls links related to the CORSnet-NSW system.

  http://www.lpi.nsw.gov.au/surveying/corsnet-nsw

- **NSW Public Works – Surveying and Spatial Information Services**

  More information on the Surveying and Spatial Information Services team of NSW Public Works.

  http://www.publicworks.nsw.gov.au/infrastructure-engineering/surveying-spatial-information

Railway Underbridge Renewal at Granville

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ABSTRACT

Over the Christmas – New Year period 2014-15, Sydney Trains Engineering staff were called on to renew a major railway underbridge at Granville. The Granville underbridge spans Parramatta Road, carries four busy rail tracks and spans four very busy lanes of road traffic. This paper outlines the role played by surveyors in the project, viz:

- *Detail surveys of the existing bridges – key structural components and surrounding topographical detail.*
- *Pre-fabrication of girders and track panels – setting out and checking of sizes and dimensions.*
- *Measuring deformation in a 'dummy' set-out situation.*
- *Abutment alterations, headstock and bearing pads installation.*
- *Installation of new bridge components.*
- *Track restoration.*

There was a short period of time available for bridge installation, and (like other field staff) the surveyors had to work to challenging deadlines, using total stations and digital levels under difficult conditions. The works were successfully completed and trains running to timetable at the planned times – due in no small part to the critical work done by the survey teams.

KEYWORDS: *Railway surveys, underbridge, deadlines, role of surveyors.*

1 INTRODUCTION

The project was to upgrade an underbridge on the Main Western Line at Granville. The existing bridge consisted of four separate structures, each continuous over two spans with a length of about 33 m. The plan was to replace the two inner superstructures, built in the 1920s, with new steel girders and retain the outer steel girders. The existing timber transoms would be replaced with pre-cast deck units, which would also be on the new girders. Complete replacement of the bearings would also be carried out. Various other works also formed part of the scope, e.g. installation of hand rails, signalling and electrical works, abutment and pier strengthening.

Conventional methodology for bridge removal and install (i.e. lift sections out and in by crane) would not work in this location as there was insufficient time to remove and replace the overhead wiring, so a new methodology was adopted: The new girders would be jacked up from underneath using hydraulic jacks that run along rails positioned on the road below (Figure 1). For this to work, the existing eastern girder had to be removed and replaced after the centre girders had been positioned.

Figure 1: The jack on its rails on Parramatta Road.

The work was carried out on 26-31 December 2014, and surveyors were required to provide 24-hour support and guidance throughout the installation process as well as prior surveys to ensure the construction process was smooth and successful. Project Surveyor was Robert Thyer under the supervision of Senior Surveyor Michael Athorn. Other key survey staff included David Lang, Matt Friend and a large team of volunteers and draftees who assisted during the closedown works.

2 DETAIL SURVEY

The design process is a long one, and the initial detail surveys were done 5-6 years prior to works being carried out. Existing plans of the bridge were typical of the time (Figure 2), and current practice required a full detail of the existing girders, abutments and piers, ballast walls, tracks, overhead wiring and overhead wiring stanchions, bearings and holding-down bolts to create a model that could be used by all affected designers.

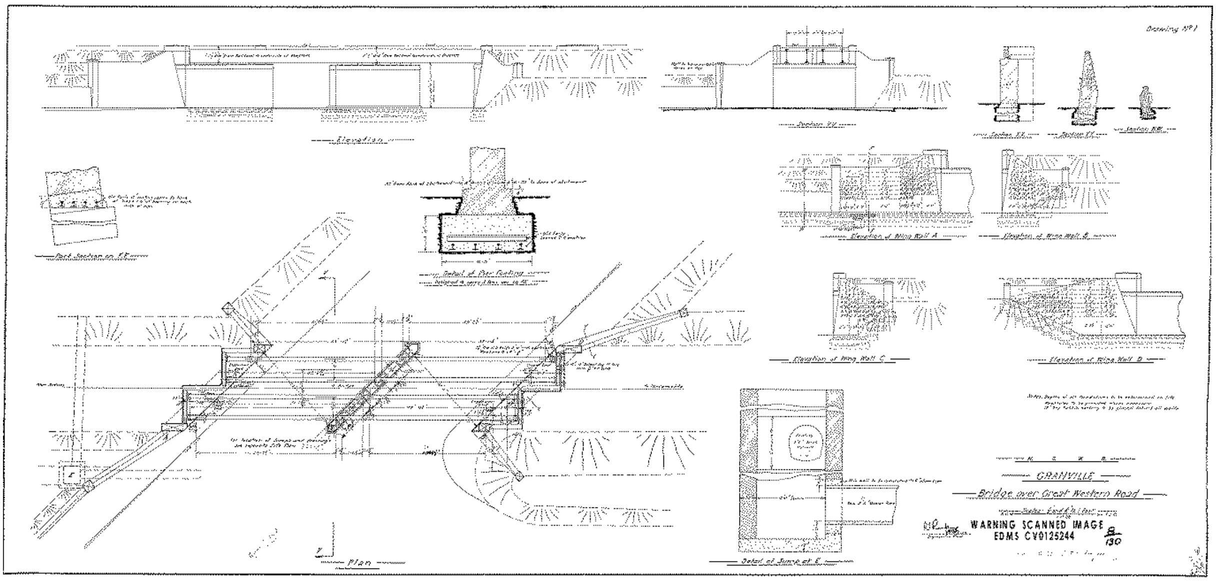

Figure 2: Old design drawing.

Track access in that area is limited, so a number of weekend possessions were needed. Parramatta Road access is even more limited, so night closures of Parramatta Road in March/April 2014 were used to get additional detail requested by the designers and to update the original survey. Current alignments in that area are related to ISG/MGA, so that was the coordinate system adopted.

3 PRE-CLOSEDOWN WORKS

As the closedown time was limited, it was necessary to complete as much of the work as possible prior to Christmas. Tasks that were completed included signal troughing lowering, OHW adjustments, erecting scaffolding and, importantly from the surveyors' point of view, strengthening of the piers and abutments. The strengthening work involved coring 36 mm by 4 m vertical penetrations into the piers and abutments and these penetrations had to be set out by the surveyors during road and rail night possessions in October/November 2014.

The bridge was actually pre-assembled, off site, prior to Christmas. The girders were positioned correctly relative to each other and the pre-cast concrete slabs installed to make sure everything fitted together. Correct positioning of the rails depended on correct positioning of the slabs and attached sleeper plates, so spending the time to get the sleeper plates correct was critical. All the girders and slabs were marked at this time to make the 'lining up' easy when installation occurred. The surveyors would be required to get the base of the girders correct for line and height and, in theory (and in practice), the slabs and track would be 'on design'.

Bridge deformation and deflection was also an issue to be addressed – not the deformation of the bridge that occurs when a train travels across it, but possible deformation (either permanent or temporary) that might occur when the girders were moved along the rails and jacked into position. The worry was that any deflection might affect the bridge ends and they may not fit into the pre-cored holes. The surveyors worked closely with the jacking contractor to simulate the proposed movement of girders (using smaller jacks) and to measure any deformation – fortunately there were no significant problems.

The surveyors also needed to set out the rails for the jacking system – the setting up of the jacking system in a timely manner was critical to the whole project. Line marks and recovery marks were placed on Parramatta Road early one Sunday morning a few weeks prior to Christmas.

4 CLOSEDOWN WORKS

The construction of the rails for the jacking mechanism started in the early hours of Boxing Day, and the survey teams successfully worked closely with the contractors to ensure the jacking mechanism was positioned to the required tolerances (Figure 3). After the existing girders were stripped down and removed and the abutments exposed (Figure 4), the surveyors were involved in marking out bearer plate locations, core holes and the beam locations in both the horizontal and vertical dimension, ready for the new girders to be brought in.

Figure 3: Mark that!

Figure 4: Removing the old girders.

Prior to the girders being introduced into position via the jacks, the pre-cast concrete segments had to be lined in and bolted down under the instruction of the surveyors – making use of the centreline marks placed on the segments during the 'dummy' build. When the girders were finally moved into position, the surveyors again were front and centre making sure the girders were positioned correctly. After the placement of each girder, the sleeper plates (about 100 on each girder) had to be levelled, packed and re-checked to ensure that the final rail level would be correct.

As each girder was installed and rails placed, it was time for the tampers to pull/lift the track to its new design. The surveyors assisted in this work by placing recovery marks using RoadRunnerRail. This work would normally be carried out prior to the closedown, but in this case the restricted access and the sheer amount of construction work going on made placing of recovery marks too early a waste of time.

Many of these tasks were happening concurrently, often in the dark and certainly always with people and machinery obstructing and complicating the process.

5 CONCLUDING REMARKS

Sydney Trains surveyors were an integral part of the whole design and construction process. Instruments used were Leica TS30 total stations and Leica DNA03 digital levels.

On the construction site, challenges that had to be overcome included:

- Providing two survey parties 24 hours a day, 5 days a week during the holiday season.
- Finding places to put control marks that were safe, secure and useable.
- Working amongst up to 100 construction staff and their associated machinery and equipment.
- Working to the project's tight timescale.

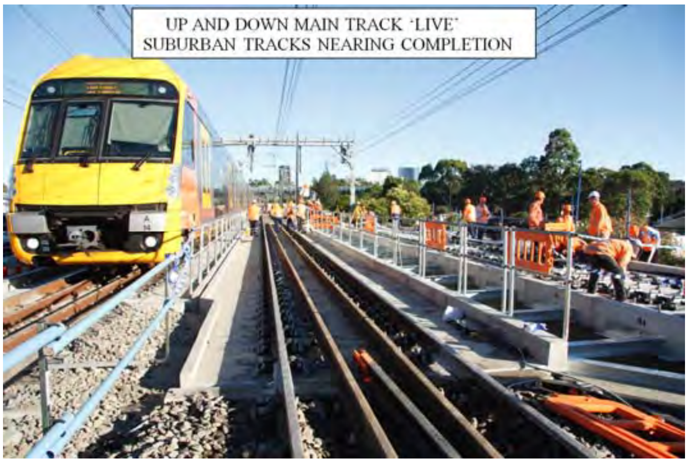

Figure 5: Work nearly finished.

ACKNOWLEDGEMENTS

Thanks to Project Surveyor Robert Thyer, Project Manager Hassan Boussi and Principal Design Engineer, Bridges Joe Muscat, all from Sydney Trains, for their assistance.

The Development of GEOSCAPE: A National Database of Building Outlines

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ABSTRACT

This paper focuses on the development of a new product called GEOSCAPE, which is a national representation of building outlines together with additional building information. The paper looks at the development of the product from concept through to the reality of a consistent national product, integrating contributions from a wide range of data sources to produce a product that has an extensive range of uses. Projects like these are more than a technical challenge, so the paper also outlines the process of developing the product along with the depth and breadth of skills and disciplines required. It also presents some of the interesting spatial challenges and learnings gained along the way that may be of interest to professions working in the spatial industry as well as users of these products.

KEYWORDS: *Spatial data, database, product development.*

1 INTRODUCTION

PSMA Australia offers a national asset of quality spatial information derived from authoritative data sources. These national location datasets underpin an ever-expanding range of business solutions and government services. Our flagship product, G-NAF, is Australia's only authoritative, geocoded physical address file. G-NAF is complemented by datasets of roads, cadastre parcels, administrative boundaries, features of interest and more. Used together, or separately, PSMA datasets provide the geographic context that enables effective decision-making and innovation based on quality location data.

PSMA Australia and its clients have been exploring the possibility of expanding its product range to include a national representation of building outlines to supplement the existing products. This product is to provide a new nationally consistent window into the built environment and a mechanism for more readily integrating the existing products and other information through different lenses.

Opportunities to develop products from a blank canvas are few and far between, so the strategy and approach adopted needed to be flexible and iterative. The development of requirements is constantly being tested against the hard reality of what is achievable in a reasonable timeframe and budget.

Over the last two years, PSMA has been developing the concept and exploring ways the product can be developed over Australia either through our existing spatial data channels or through other sources available in Australia. In parallel, a similar exercise has been underway identifying the key applications and client requirements as well as exploring the technologies

and approaches which could be used to develop the product. PSMA was also aware that others here in Australia and overseas were looking at developing similar products and services although from different lenses and perspectives about the built environment.

2 GEOSCAPE THE PRODUCT

From the outset it was understood that GEOSCAPE must integrate with existing products developed by PSMA and help provide an interface into the built environment. Roof and Oleru (2008) defined the built environment as the human-made space in which people live, work and recreate on a day-to-day basis, encompassing places and spaces created or modified by people including buildings, parks and transportation systems. The existing PSMA products and services currently reflect parts of characteristics articulated and expected by users interested in the built environment (Table 1). The structure of GEOSCAPE is simple and incorporates a number of components that can be expanded into the future (Table 2).

Table 1: Existing PSMA products and their characteristics.

Product	**Characteristic**
CadLite	More than 14 million cadastral polygons representing over 10 million cadastral and property features.
G-NAF	More than 13 million geocoded addresses generated from over 30 million addresses from 10 contributors.
Transport and Topography	More than 2.7 million km of road centreline plus railways, airports, greenspace and hydro.
Features of Interest	More than 8 million point and polygon features.
PSMA Cloud Service	Daily refreshed databases providing address verification and spatial capabilities across key government and commercial services.

Table 2: Selected GEOSCAPE components.

Building outlines: • 2D roof polygon. • Roof area. • Roof pitch/complexity. • Ground level coordinates for roof vertices. • Number of roof vertices. • Ground level building centroid. • Maximum roof height. • Swimming pool indicator. • Roof material. • Solar panel indicator. • Residential land use indicator.	
Landcover: • Impervious surfaces: o Built up areas. o Road and path. o Bare earth. o Buildings. • Vegetation: o Tree coverage. o Grass coverage. • Water.	

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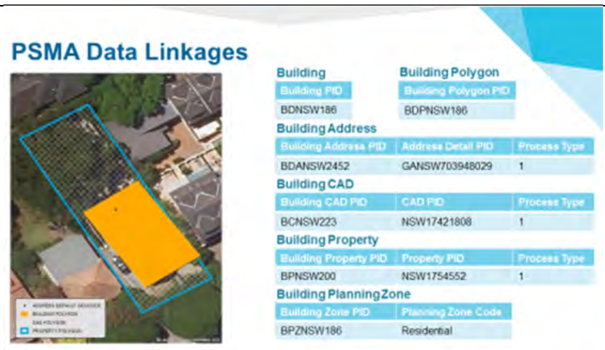
<td>
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2.1 GEOSCAPE Indicative Uses

Initial concepts envisaged GEOSCAPE being used across a range of industries and sectors including utilities, finance, agriculture and emergency services. The uses that have been identified to date far exceed these initial expectations and the list is not complete. The visualisation of the GEOSCAPE concepts has not been fully explored, however a couple of concepts were developed from the 2.5D products which we are sure will be developed more professionally by the PSMA VAR network or direct clients. Figure 1 shows some very basic outputs developed from the first pilot study over the Chatswood region in Sydney. They give an indication of what can be produced from the data. This incorporates building outlines displayed as 3D features using feature attributes along with shading based on roof complexity and roof type characteristics in addition to 3D trees/vegetation representations.

Figure 1: Examples of GEOSCAPE products.

Based on what we can see, the benefits of the data go beyond the simplistic 3D representations as illustrated in these images. We understand from some clients the data is likely to generate operational efficiencies without further modelling, with many further benefits that could be realised through modelling.

3 THE DEVELOPMENT APPROACH

The development of the product has been very iterative, involving both business partners and technology providers in an attempt to develop the most flexible product:

1. *Product concept* – initial development of the product concepts were explored through high-level consultation with the potential end users, data custodians, a range of experts, industry colleagues and the PSMA Board. From the outset the project looked technically achievable, however gauging the maturity of the market and balancing expectations against realistic targets, budgets and timeframes was the initial challenge.
2. *Desktop research* – was undertaken to review research and pilot approaches from within Australia and around the world. This also included further consultations with subject experts to provide advice and guide on feasibility around production techniques and strategies. This drove home the additional challenge that such a project has not previously been undertaken nationally at this level of detail. It also identified the diversity of data that exists within Australia at the government and private company levels. Again, the challenge has been around understanding the data and its suitability for inclusion in this type of product and project.
3. *Pilot projects* – Three pilot sites (about 16 km^2 in size each) in Sydney and Brisbane were chosen to test the technologies and prototype product models in the Australian context. From a technology perspective, the pilots tested satellite technologies marketed by Digital Globe and Airbus, as well as aerial approaches utilising LiDAR and traditional photogrammetric techniques provided by local companies. The pilot areas were chosen to test a range of complex structures (residential, commercial, industrial and high-rise buildings), terrains and vegetation forms.
4. *Product and production specifications* – Following further market testing of the pilot products, the full national production and testing specifications were developed for both the 'urban' and 'rural balance' areas. This was the most resource-intensive phase involving both the preferred contractor (Digital Globe) and key client groups. As with all PSMA production processes, documenting and understanding process flow is critical, particularly given the production can be done across different technology platforms, companies and a need to fit in with other PSMA product delivery schedules.
5. *First production area* – As the first stage in the production implementation, an area of approximately 16,000 km^2 surrounding Adelaide has been initiated. This will test the full production methodology and provide an opportunity for a final review of the specifications. This will be completed by early April 2016.
6. *Full production* – The full national coverage is planned to take a further 15 months from the completion of the Adelaide site.
7. *Maintenance* – A rolling maintenance schedule will be implemented to coincide with PSMA's existing quarterly maintenance schedules as well as specific client requirements.

4 PROJECT COMPLEXITIES

There are a number of issues and interesting points that arise from a project like GEOSCAPE. Some are not new to PSMA but take on a different perspective with this product. Some, which are more relevant to the surveying and spatial information community, are outlined in this section.

4.1 Diversity of Skills

Diversity of expertise and skills is essential in scoping such a project, and certainly the consultations and planning phases to date have involved the usual GIS, surveying and associated technical skills, but also a healthy mix of IT, databasing, business, project management, financial and crowd-sourcing skills.

The area where this has been more challenging has been around generating a common base level of understanding about the product across all the participants who carry their own specialised lenses into the product and its production. This has been made more complex as the product concepts have evolved and a deeper understanding is gained about each of the components required. This is hard enough when everyone is in the same organisation but certainly more complex when you are dealing with different experts and organisations around the globe. Regular structured communications through teleconferences, webinars and internet-based project and document management tools have contributed a lot in managing everyone's understanding.

4.2 Product Categorisation of Australia

One of the business drivers has been to develop the product based on some of the priorities as identified by the key clients. These priorities generally reflected population densities but this was not necessarily uniform across Australia. A critical part of the product research identified there were different product characteristics across Australia. However, the method of classifying these differences was not consistent and a uniform approach could not be easily developed. Some of the characteristics required varied with topography, population density, standard administrative boundaries as well as different proximity criteria.

An initial assessment of existing data sources indicated there is a general lack of reliable information nationally about infrastructure and the built environment. Obviously, for this type of project the location and density of infrastructure is critical along with an understanding of the business drivers for end user applications. An initial assessment and categorisation of areas was undertaken using a combination of population based on the ABS Australian population grid (ABS, 2014) and an understanding of some risks that could be related to other geometries. This was sufficient to broadly classify Australia and to determine the approximate size of each category and distribution around Australia. Figure 2 illustrates that over 90% of Australia's population lives in less than 1% of the Australian landmass, which also largely reflects the majority of the infrastructure that is being targeted in this product.

Statistics based on the ABS data suggest that of the approximately 30,000 km^2 where 90% of the population exist, one third of the areas are communities greater than 1 million, the middle third cover populations from 4,000 to 1 million people, and the remaining third covers populations less than 4,000 people. Populations over 1,000 are classified as 'urban' under this initial capture program developed by PSMA.

While it is important to understand where 90% of the population are located, it is a slightly more complex approach to identify where the remaining infrastructure is located. The ABS population grid focuses on people and residential characteristics of that population. It is less reliable when this is extrapolated to identifying the existence of infrastructure. The population grid does not reflect the location of low population and rural infrastructure well. Likewise, the population grid is based on the 2011 census and in some areas (primarily fringe urban) there has been substantial change in the last 5 years.

While PSMA initially used a number of criteria to develop five categories over Australia, this has been condensed to two categories being 'urban' and 'rural balance'. This change evolved as a greater understanding was gained about specific use cases and the accuracy levels expected by the users in each of the categories. Simplistically, within urban areas there is an expectation that the location of building and the depiction of building will be higher than

those in more rural locations. This is an entirely reasonable expectation given the linkages that will be developed to other PSMA products.

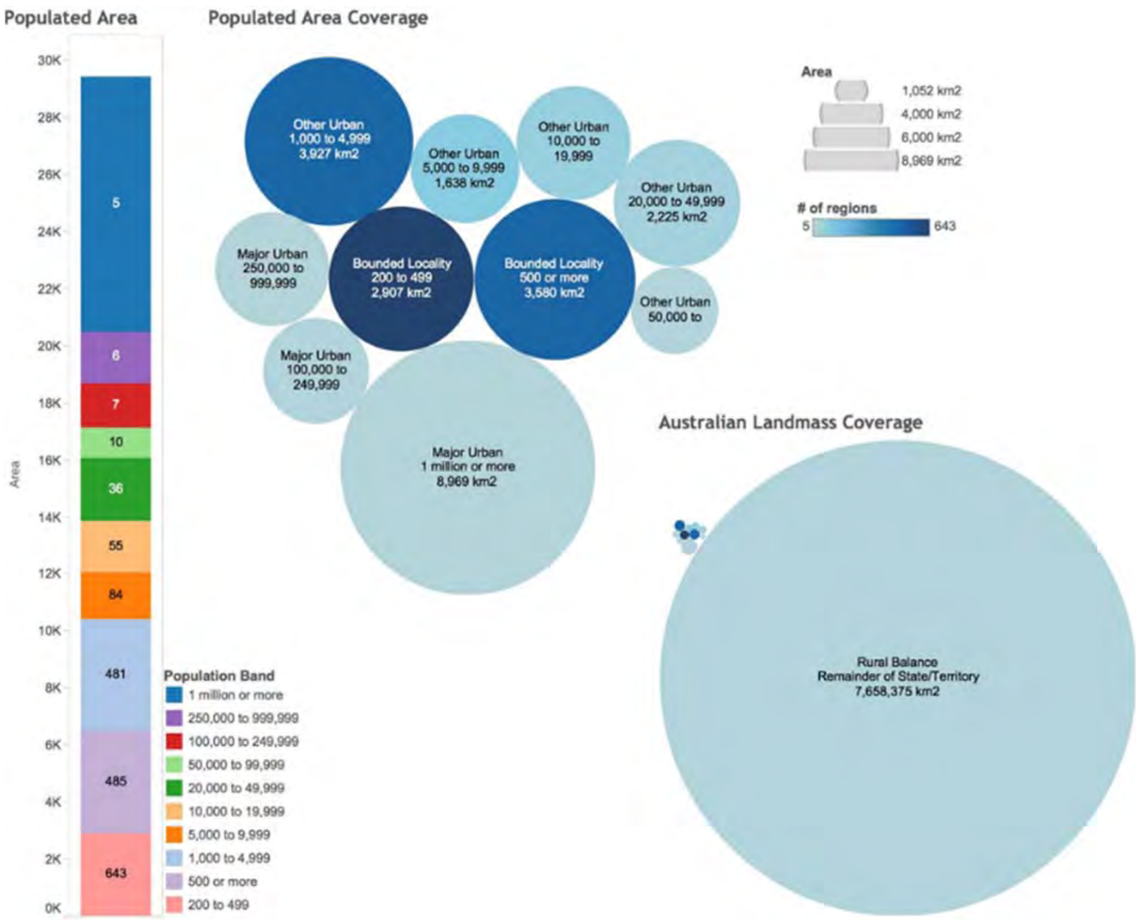

Figure 2: Analysis of population density across Australia, derived from the ABS Population Grid 2011.

Based on a greater level of understanding about the end user requirements, it has been necessary to undertake a further review of the categorisation of the country to ensure that significant populations and associated infrastructure has been classified within the urban areas (Figure 3). The analysis has been undertaken with limited additional reliable information other than data PSMA has access to from other sources. The process used was neither scientific nor repeatable and included both visual interpretation of the most current imagery available as well as other derived data where we could derive associations from our other contributions. It is estimated the second iteration may have increased the percentage of structures in the urban classification by approximately 1.5% over the previous attempt, and it has generally created more uniform coverage over the main metropolitan areas and condensed the area covered around individual smaller communities (generally by removing areas where infrastructure was not present). Figure 4 illustrates the urban classification over Sydney.

In total, it is estimated there are in the order of 25 million buildings represented nationally in this product and that the maintenance schemes used can be better targeted once we understand the current infrastructure. While it is generally understood that Australian urban areas are growing, we do not necessarily understand where the growth areas are outside the main metropolitan areas. Certainly the mining boom has generated a lot of growth in Western Australia and Queensland over the last decade. In some cases, in these states, complete communities have been constructed in less than 5 years.

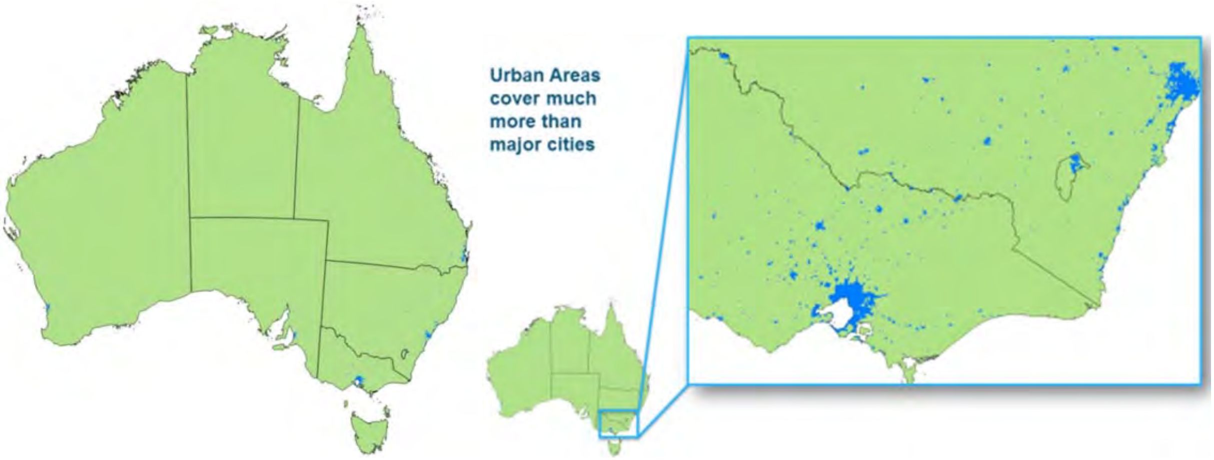

Figure 3: Distribution of urban centres in Australia.

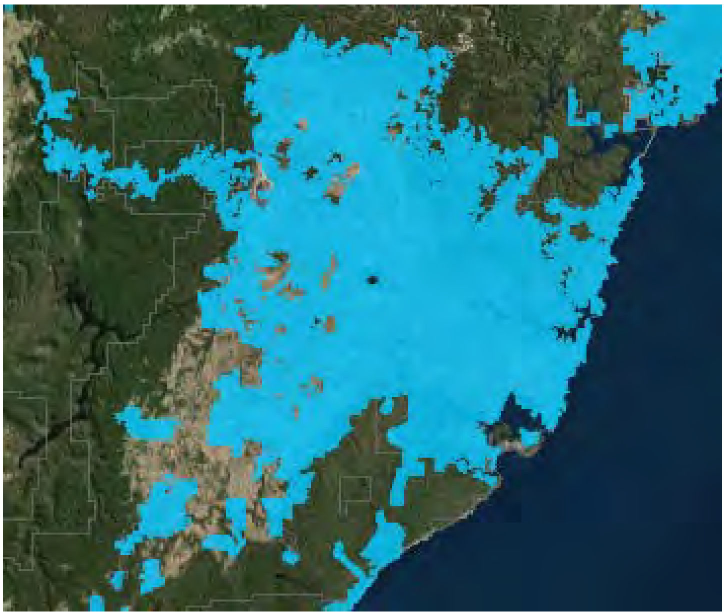

Figure 4: Urban classification across Sydney.

4.3 Quality of Building Representations

As part of the preliminary investigations, the difference between satellite imagery, LiDAR and traditional photogrammetric extraction techniques using 3- and 4-band imagery were tested to determine the differences and qualities of each approach. Differences were identified in the resulting representations, but they were not considered significant. Hence the decision was made use high-resolution satellite imagery provided by Digital Globe. This solution is likely to provide greater opportunity to develop a nationally consistent product, which is not possible with the other approaches tested. Figure 4 demonstrates the satellite solution utilising high-resolution imagery over the urban areas (yellow shaded areas) and mid-range imagery for the rural balance (unshaded areas).

While the product will initially only utilise satellite data, there is no reason to limit the range of alternative input sources into the future. Certainly the initial review of the outputs from LiDAR (captured at 1 point per m^2) suggests this is not dense enough to provide consistent building outlines. Unfortunately, the majority of LiDAR captured across Australia at present is at this lower end of the point density spectrum. It will be interesting to look at the outputs

from the ACT LiDAR capture program to see what can be achieved with a much higher point density.

Likewise, the techniques used to develop products from aerial photography showed considerable variation across study areas, possibly due to a combination of factors which may have proven difficult to control in a large project. Certainly to use these techniques would require extensive use of existing data archives as well as new imagery where each project would carry different characteristics and qualities reflecting its original purposes. This carries the risk of a higher range of output qualities, which may impact the application of the end products. This can also be an advantage, however in the initial stages of developing a national product it was seen as a large challenge to manage nationally.

The local companies who assisted with this assessment certainly demonstrated a high level of expertise, knowledge and honesty. It is hoped that PSMA can find ways to utilise their services into the future.

4.4 Product Maintenance

Whilst the initial data capture is a relatively straight forward process, the process of product maintenance is not and presents a number of challenges. There are two key variables that need to be captured and managed:

1. Urban expansion, which is likely to occur on the fringes of the existing urban areas, and a combination of change as a result of urban infill and renewal.
2. Changes in land use, which could result in changes to infrastructure in both urban and rural areas.

Some of the informal testing of the level and location of change suggests that some can be more easily predicted while others are generally more difficult to determine. In the latter cases, they may be near-spontaneous or may not materialise for several years. PSMA already has to deal with these apparent contradictions in the existing products, so GEOSCAPE is likely to assist users in rationalising some of the differences.

The refresh frequency required to map the changes will largely be reflected by the end users. However, there is a commitment to maintain the data on different frequencies, ranging from annually to once every 4 years. Again, this will depend on users, uses and geographic location. No one technique will identify all forms of change and the subsequent need for maintenance satisfying all users. PSMA is looking at a range of techniques utilising grids to synthesise areas of change and user requirements to help form the maintenance program. Some examples of different approaches are illustrated in Figure 5.

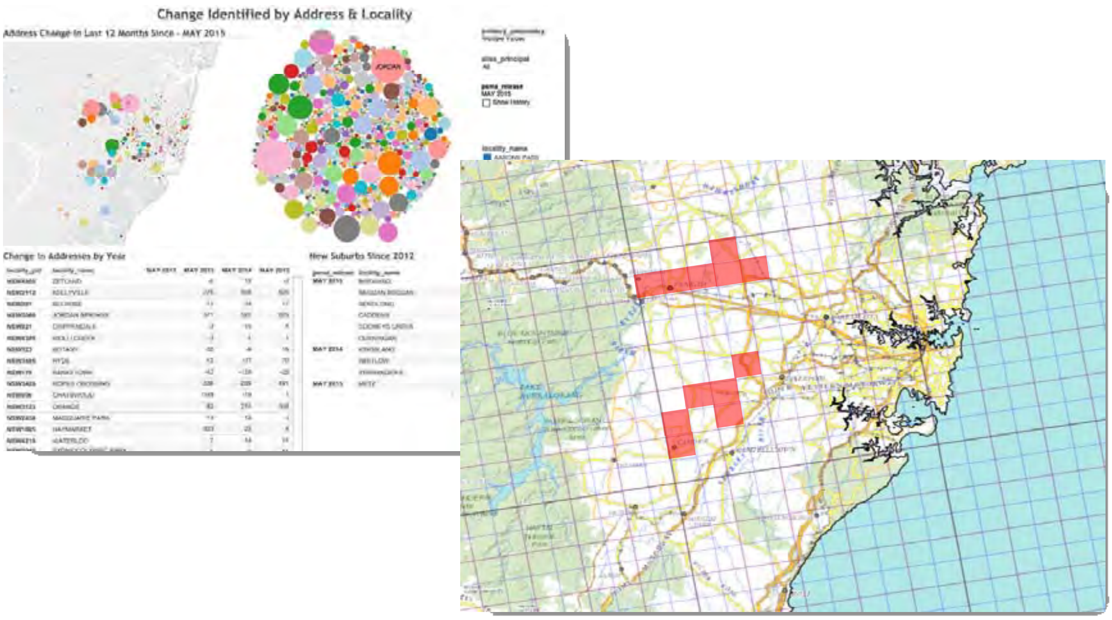

Figure 5: Change detection by locality and maintenance by geographic grid.

4.5 The Cadastral Challenge

One of the challenges facing PSMA is how to rationalise the differences within and between the cadastres across Australia. We know there can be significant spatial inaccuracies in different locations across all the cadastres. In the past, most users have understood they exist, and users have developed work-arounds to overcome the differences. Most GIS operators have seen the differences between road networks and the cadastre, but these differences can often be ignored in applications. In GEOSCAPE, these spatial differences will be evident as there will be a consistent spatial accuracy across Australia that will not be present in the cadastres.

The other challenges with each of the cadastres and property representations will be differentiating ownership from other rights, and accommodating vertical interests. In terms of ownership and rights, most of the cadastres treat these differently, and there is a general assumption that GEOSCAPE will assist is identifying relationships between ownership and some rights to the physical structures present on a site. GEOSCAPE will show some relationships between property and buildings.

In some States and Territories there is very good differentiation between vertical interests, such as differentiating various ownerships in a high-rise development. Unfortunately not all cadastres have this level of sophistication. In other situations the cadastre may only represent one feature being the ground level base parcel with little or no reference to vertical developments and ownerships. Some of these differences have already been addressed in PSMA's existing products whose integration with building outlines appears to be consistent and legitimate from existing testing.

The differences also extend under the ground with some cadastres representing interests such as carbon sequestration interests. These are very legitimate uses for a cadastre, and PSMA fully supports their inclusion as long as they can be easily identified and differentiated from other forms of ownership, rights or interests.

Other challenges arise where rights are used to handle developments such as large infrastructure projects either owned/licensed privately or controlled by the State/Territory, e.g. railway traversing across other forms of right or ownership. In some cases, these may not be represented in the cadastres or may not be easily differentiated within the cadastre. Some of these may be historical artefacts such as multiple occupations on a single Crown entity. In some cases, these Crown lands units/entities may not be titled or treated as a rateable entity and may or may not be addressed. In the Sydney pilots, the largest number of structures that could not be associated with an address were structures controlled by local councils (sporting and other facilities), churches, and complex facilities such as hospitals and universities.

The GEOSCAPE pilot studies have also helped to identify a very small number of inconsistencies in the cadastres and associated addresses. In these particular cases, these have been fed back into the respective State and Local Government agencies for clarification and or correction. These are all opportunities and challenges which are likely to be encountered through the development of GEOSCAPE.

4.6 Utilising the Crowd

One technique which has not been previously used by PSMA is crowd sourcing. GEOSCAPE will utilise crowd sourced information in the production processes. There are different ways to utilise the ‘crowd’, and in recent years crowd sourcing has proven very successful in providing quick responses to humanitarian disasters around the world. A lot has been learnt from these campaigns in both what can be collected and how to present information to the crowd to maximise the chance of them being able to provide a valid judgement. In many ways crowd sourcing is similar to consumer market researching, where it is important to ask the right questions in the right setting to solicit measurable and meaningful responses.

The pilot studies utilised crowd sourcing for solar panels and swimming pools, and the results were promising. Crowd sourcing works well where there is a visual interpretation required, and the use of imagery can be very powerful for a lot of applications. Given the size, shape and form of both swimming pools and solar installations, crowd sourcing was seen to be well placed to identify and differentiate these types of structures.

Depending on the type of interpretation required, there may be different characteristics required to be present in the imagery. In the case of swimming pools and solar panels, it is possibly best to use mid-summer imagery where there is little impact from shadowing of the feature. For the pilot area, winter imagery was used, which unfortunately meant pools could be empty, obscured by pool covers or could be shadowed by nearby vegetation. This made it more difficult for the crowd to differentiate between features in the imagery. The crowd was also presented with representations from more than one dataset. In a few instances where there were slight misalignments between the representations, the crowd was not able to consistently determine/rationalise what they were being asked to assess.

This all illustrated the need to be very careful about what information is used in crowd sourcing and that structuring a campaign well requires a well thought-out plan taking into account the perspective of the crowd. The benefits of crowd sourcing are that the crowd is multicultural, global, works 24 hours a day, is passionate and very good at this type of activity. While the pilot area was limited in size, the information collected from the crowd was very useful and has provided valuable learning for the real production process.

5 PRODUCTION TIMEFRAMES

Originally, this was seen as a project that could be completed relatively quickly and the business case would only take 4 months. In reality, the business case has taken over 12 months to prepare in parallel with other activities. Currently, PSMA is working with Digital Globe on the production of the next milestone being the development of the Adelaide Production Area. At this point, the first production stage has commenced over the Adelaide region and this should be completed in April 2016.

Following the Adelaide region, the next milestones are:

1. Two more major capital cities (urban areas) by June 2016.
2. The remaining capital city urban areas by September 2016.
3. The remaining urban areas (nationally) by March 2017.
4. The rural balance by June 2017.
5. Maintenance program commences in September 2017, using target grid cells and an annual national land cover refresh for all urban areas.

6 NEXT STEP: ADELAIDE

The Adelaide production area extends north to Port Wakefield, east to near the River Murray and south to just east of the River Murray mouth. This area is seen as a test of the entire production process as it will include both the main metropolitan area as well as the surrounding smaller urban centres. In total, this production area is some 16,000 km^2. Figure 6 illustrates the Adelaide production area (red) urban classified areas (blue) and the Digital Globe World View 3 image footprints (blue). The image capture was not fully completed in this image.

Figure 6: The Adelaide Production Area.

CONCLUDING REMARKS

GEOSCAPE has been an opportunity for PSMA to plan a product from a blank canvas using the knowledge that has been accumulated over the past decade from its other national products. It is utilising new sources of data and developing production techniques that will help integrate and complement the existing product suite. GEOSCAPE is one lens into the built environment with very specific initial objectives, however it has been developed in such a way as to maximise its flexibility and to enable the product to evolve and provide a scalable platform into the future.

The development methodology has been rigorous, iterative and involved all stakeholders and clients throughout the initial phases. This has extended the time to develop the product prototypes and full specification and production methodologies, however the full production phases and future developments should all benefit from the rigorous approach adopted.

While Australia has an urbanised population, the built environment is not as urbanised and is not currently well understood or represented nationally. This product is designed to provide a more nationally consistent representation of building outlines to help raise the understanding of this part of the built environment. Initial indications are that it will achieve its objectives and provide a wider range of benefits to industry and the wider community than initially anticipated.

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NorthConnex: Subsurface Stratum Acquisition

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ABSTRACT

NorthConnex is a proposed 9 km tunnel motorway designed to link the M1 Pacific Motorway in Wahroonga to the Hills M2 Motorway in Pennant Hills. The tunnel is part of the NSW Government's State Infrastructure Strategy forming an essential link in the Sydney Orbital Network and expected to cost $3 billion. In January 2015, NorthConnex received official project approval by the NSW Government. The earliest access date required for tunnel construction was July 2015. The NorthConnex project team engaged the Roads and Maritime Services (RMS) Cadastral Survey Unit for the stratum acquisition of approximately 900 lots. The acquisition was predominantly subsurface, but also included surface land, strata title, and community title acquisition. Between the project approval date and the tunnel access requirements, we had a timeframe of two months to acquire the first 80 lots in the initial stage. This paper outlines how the RMS Cadastral Survey Unit was able to respond, using a plan production and lodgement strategy unique to previous motorways. With Land and Property Information (LPI), we developed the Subsurface Stratum Definition Strategy to allow for the compilation of boundaries for subsurface acquisition plans. Once the strategy was in place, the extent of acquisition was determined from analysis of spatial data and the tunnel model. Compiled plan production, and occasionally field surveys, could then take place to complete the acquisition process. The strategy and spatial analysis were fundamental to a plan production program that will consist of at least 100 compiled and surveyed Deposited Plans used to acquire the tunnel stratum. With the help of the NorthConnex project team, and LPI, we have delivered six of the seven stages of acquisition, all within the key project timeframes.

KEYWORDS: *Stratum, subsurface, NorthConnex, acquisition.*

1 INTRODUCTION

NorthConnex is a proposed 9 km tunnel motorway designed to link the M1 Pacific Motorway in Wahroonga to the Hills M2 Motorway in Pennant Hills. The tunnel is part of the NSW Government's State Infrastructure Strategy forming an essential link in the Sydney Orbital Network. The project is expected to cost $3 billion. Of that, $2.65 billion is allocated to construction costs with the remainder set aside for land acquisition and project delivery (NorthConnex, 2016).

In January 2015, NorthConnex received official project approval by the NSW Government. In February 2015, the construction contract with the Lend Lease Bouygues (LLB) Joint Venture was finalised. The earliest access required for tunnel construction was July 2015.

The NorthConnex project team engaged the Roads and Maritime Services (RMS) Cadastral Survey Unit for the acquisition of subsurface stratum affecting approximately 900 lots. The

acquisition process also included surface acquisition, Strata Title acquisition and Community Title acquisition. Between the project approval date and the tunnel access requirements, the RMS Cadastral Survey Unit only had a timeframe of two months to acquire the first 80 lots in the initial stage. Further property acquisition was required in stages governed by a series of key access dates required by the LLB Joint Venture.

The objective of this paper is to describe the process of the NorthConnex subsurface acquisition. Firstly, the paper outlines the basic concepts of subsurface acquisition, as well as the challenges and complexities inherent to the NorthConnex project. Secondly, the methodology of the acquisition process is explained. This is followed by short case studies of particular surveys that challenged the acquisition process. The paper concludes with a summary of the project progress and the effect of this project leading into the development of future motorways and tunnels.

2 PROJECT CONCEPTS AND COMPLEXITIES

2.1 The Nature of Subsurface Stratum Acquisitions

In the past, RMS developed a general configuration for subsurface stratum acquisitions for tunnels. Usually, RMS will acquire a lot that extends infinitely in height, and down to the centre of the Earth. Imagining a vertical slice of the land that has been acquired for a tunnel, the components of the acquisition comprise three lots (Figure 1):

- Surface lot.
- Tunnel stratum lot.
- Support lot.

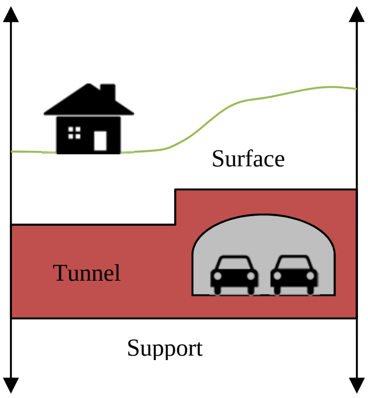

Figure 1: Stratum acquisition section.

The surface lot extends infinitely in height to a depth limited in stratum to a chosen Reduced Level (RL). The surface lot remains in the ownership of the current title holder (i.e. the owner in the title's first schedule). The limitation of the surface lot in depth is governed by the RL of the top of the tunnel stratum.

The tunnel stratum lot is a subsurface lot limited in depth and height by levels governed by the design of the tunnel. The stratum lot is also limited horizontally, with the horizontal configuration depending on the complexity of the tunnel structure as well as supporting structures. For instance, the tunnel stratum lot must contain not only the tunnel, but also any rock anchors, shafts, tunnel utilities and ramps. The tunnel stratum lot is initially acquired by

RMS, but will usually be leased to a tollway management company at a later stage once the tunnel is operational. Care must be taken to ensure that the tunnel stratum is deep enough below the surface. This is to provide enough space for the owner of the surface lot to use the land.

The support lot is limited in height to the bottom of the tunnel stratum lot, but extends infinitely to the centre of the Earth. This lot is acquired and owned by RMS. The intention is to limit the ownership of land under the tunnel stratum. This also allows for acquisition flexibility should the tunnel require upgrades, or if a future infrastructure project requires the space.

2.2 Project Scope

The 9 km NorthConnex tunnel spans across approximately 900 existing lot parcels, from Pennant Hills to Wahroonga. The types of lots affected include private subdivisions, publicly owned lots, strata schemes, community schemes, motorways and public road lots. The aim was to acquire land for the purposes of constructing the NorthConnex tunnel.

In order to enable the acquisition of land, the following tasks had to be performed for each affected lot:

- Determine the level of the ground surface.
- Determine the upper level of the tunnel stratum.
- Calculate the depth from the ground surface to the top of the stratum.
- Calculate the position of the boundaries (horizontally and vertically).
- Survey or compile the boundaries for plan production.
- Produce a Deposited Plan for acquisition, and lodge with Land and Property Information (LPI).

2.3 Timing

The general property acquisition process for NorthConnex is as follows:

1. Determination of subsurface stratum location.
2. Preparation and lodgement of Deposited Plans.
3. Proposed Acquisition Notices distributed to property owners.
4. Approval by the Minister for Gazettal and construction access.

Project approval for NorthConnex was granted in January 2015. The deadline for property acquisition was July 2015. This meant that by July the tunnelling joint venture (LLB) should have unrestricted access to the land for construction. Considering the timeframes for ministerial approval and Proposed Acquisition Notices, this left the RMS Cadastral Surveying Unit with two months for the production of Deposited Plans for lodgement (a deadline of February 2015). Fortunately, the acquisition programme could be separated into stages that reflected the tunnelling access requirements. Even then, the workload was still extremely demanding, as shown in Table 1.

Table 1: NorthConnex subsurface stratum acquisition schedule.

Stage	Plan Lodgement Date	Proposed Tunnelling Access	No. Deposited Plans
1	6 February 2015	July 2015	14
2	8 March 2015	August 2015	24
3	24 April 2015	October 2015	13
4	30 July 2015	November 2015	16
5*	30 September 2015	January 2016	20
6	8 February 2016	May 2016	8
TOTAL[1]	--	--	95

[1] Final count of plans may depend on additional plans in reaction to amendments and/or design changes.
* Stage 5 also included additional plans to amend or change acquisitions in previous stages.

2.4 Technical Constraints

As mentioned in the previous section, the first step in the acquisition process was to determine the location and extent of the subsurface acquisition. To do this, the spatial extent of the tunnel had to be determined.

The LLB Joint Venture provided the design constraints for the tunnel, accounting for road design and geotechnical investigation. The stratum envelope to contain the tunnel has to conform to the following rules:

- Horizontally, the subsurface stratum must be offset 12 m from the sides of the main tunnels, or offset 20 m in locations that are shallow, of geotechnical risk or near shafts and dive structures.
- Vertically, the upper surface of the tunnel stratum is 20 m about the control line of the tunnel (Figure 2). However, it must not be less than 3 m below the ground surface. The lower surface is undefined for the location of the RMS support lot below (generally 20 m below the control line of the tunnel).

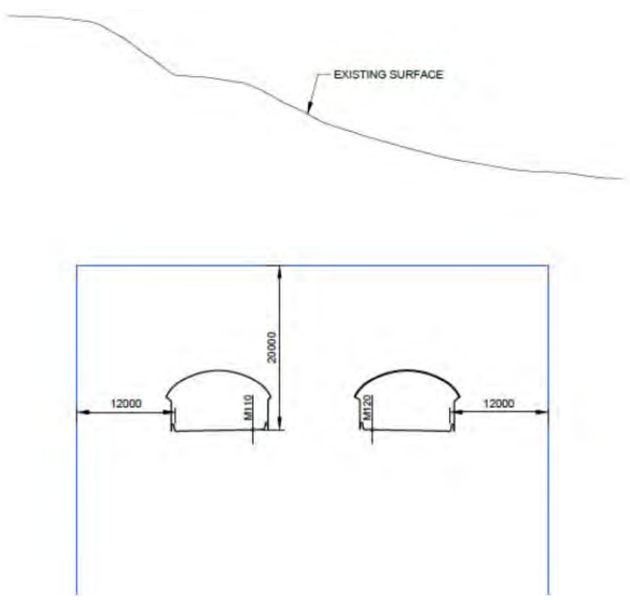

Figure 2: Typical cross section schematic of the tunnel stratum (courtesy LLB and Aurecon-SMEC).

There are also technical constraints related to survey and plan production. To produce plans based on traditional survey for the entire length of the project would not be feasible within

project timeframes. The geometry of the tunnel stratum dictates the need for plans of survey. The tunnel stratum contains level changes that reflect the vertical and horizontal curves of the tunnel structure. Ramps that incline or decline also complicate the situation.

Compiled plans would simplify the acquisition process greatly. However, in most cases, compiled boundaries are only accepted by the Registrar General in cases where the boundary determination is very simple (straight line boundaries, no more than four lots, etc.). In order to progress, RMS needed to resolve this issue (see section 3).

Lastly, there are technical constraints inherent to the NorthConnex project and its location. While the intention was to compile most of the acquisition, it was necessary to identify areas where plans of survey were absolutely required. Over the length of the project, there were some areas that required special attention:

- Where surface acquisition is required, particularly near ramps, shafts, and where NorthConnex merges with existing roads. In this case, surface acquisitions refer to the acquisition of land extending from the centre of the Earth to infinity.
- Where the entry ramps to the tunnel descend below the surface. The tunnel geometry was likely to be exceedingly complex to be suitable for acquisition by compiled plan.
- Where acquisition is required over Strata Lots (not just Common Property). RMS has never before acquired a Strata Lot by survey.
- Where acquisition is required over lots in a Community Title scheme (not just the Community/Neighbourhood Lot). RMS has never before acquired a Community Scheme Lot by survey.
- Where any other stratum boundaries have been identified, particularly the North West Rail Link.

The methodology behind the acquisition process had to take into account these technical constraints in order to provide Deposited Plans for acquisition that were suitable for the construction of the tunnel and lodged with LPI within the key deadlines. The methodology for plan production is explained in greater detail in the next section.

3 METHODOLOGY

The RMS Cadastral Survey Unit was able to develop a solution to facilitate the acquisition of land for the NorthConnex tunnel. This approach can be broken down into the following components:

1. Developing the Subsurface Stratum Definition Strategy.
2. Analysis of spatial data using a Geographic Information System (GIS).
3. Surveys and compiled boundary calculations.
4. Deposited Plan preparation.

3.1 Subsurface Stratum Definition Strategy

The development of the strategy was crucial to the success of the project. The Subsurface Stratum Definition Strategy is an agreed set of conditions used to facilitate compulsory subsurface stratum acquisitions and the eventual registration of a tollway lease for NorthConnex. The first Strategy meeting between RMS Survey and LPI occurred on 15 September 2014. This was in expectation of the incoming wave of stratum acquisitions for NorthConnex (initially predicted to be around 1,000 lots and 150 plans). A conclusive

meeting was held on 9 February 2015, with the strategy finally developed and signed by all parties on 4 March 2015.

The key benefit of the strategy was that it allowed for compiled plans to be used for the acquisition of NorthConnex. This will reduce the timeframe for complete acquisition of the NorthConnex tollway from 10-15 years to 1-2 years. The strategy was also given the exemption number ‘2015M7100(119)RMS’ for use on NorthConnex compiled acquisition plans.

For the Strategy to work, RMS and LPI had to agree on a number of important conditions, as summarised below (RMS and LPI, 2015):

1. The plans will be compiled Deposited Plans only (not surveyed).
2. All stratum planes shown on the compiled plans must be horizontal planes.
3. Two established control marks must be shown on the plan, as a guide to relative depth to the stratum.
4. The notation “Compulsory Acquisition purposes only and will be subject to final survey” is not a requirement for the compiled Deposited Plans.
5. Traditional cadastral survey is required where the motorway structure is close to the surface, where inclined planes or benches are required within properties, or where critical properties are affected.
6. RMS Survey will undertake control or cadastral mark recovery to establish the network prior to any construction work.
7. Where minimal effect (<50%) acquisition is determined and/or a large parent parcel is partially affected, a vertical stratum boundary will be calculated. The new boundaries will be calculated between existing corners or designated rounded offsets (nearest metre) along existing property boundaries.
8. Definition will include subsurface lots across all affected public roads. These acquisitions can be calculated and depicted on the acquisition Deposited Plans that affect private lots. The public road area above the tunnel stratum will also be defined by calculated lots and remain as public road in Council ownership.
9. No Certificates of Title will be created or issued on any of the acquisition plans at registration. Titles will be created (but not issued) following gazettal action and lodgement of 31A(3) (Real Property Act 1990) applications.
10. Consolidate all subsurface lands once acquired, then create and issue titles. These consolidation plans will be compiled.

With the strategy in place, it was possible to proceed with the preparation and lodgement of acquisition plans.

3.2 Analysis of Spatial Data

While the strategy outlined in section 3.1 was being finalised, the RMS Cadastral Unit also had to develop a solution to facilitate the creation of dozens of plans within the timeframes set for each acquisition stage. The basic process can be seen in Figure 3.

Before determination of the acquisition extent can begin, models had to be created in order to organise and illustrate the existing information that was available, and make it easier to analyse. The models created had to show RLs of the upper and lower surface of the tunnel stratum, lot and Deposited Plan details, and additional tunnel stratum geometry for any complex tunnel locations.

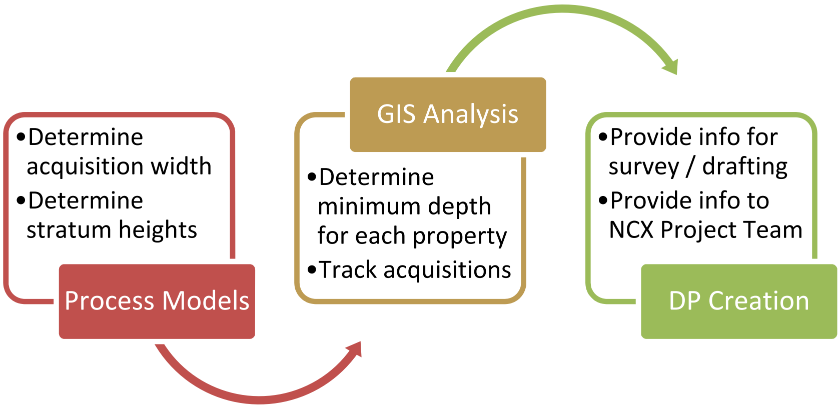

Figure 3: The basic process for subsurface stratum acquisition.

3.2.1 Initial Input

At this stage, the structural design of the NorthConnex tunnel was also in its infancy. The only design input available, at the time, consisted of:

- 2D model showing the horizontal tunnel widths and Master Control Lines (generally the centre line of each carriageway).
- Plan showing the approximate horizontal location of the tunnel stratum (based on the 12-20 m offsets mentioned in section 2.4)
- Plan of longitudinal sections along the Master Control Lines.

With the NorthConnex project approval (the official start date) approaching, and the acquisition deadline following soon after, determination of the tunnel stratum location had to be based on the information available.

3.2.2 Processing the Model – Horizontal

By combining the input data, a 3D model was created to be suitable for approximating the position of the tunnel stratum (Figure 4). The MXROAD software platform was used to create the model in this instance. Horizontally, the originally neat 12-20 m buffer around the tunnel had to be reworked to a ‘sawtooth’ configuration to meet the conditions of the Strategy, i.e. minimally affected lots (<50%) remain as partial acquisition and greatly affected lots (>50%) are acquired in stratum to the full horizontal extent of the lot. Wherever allowable by design, some minimally affected lots could be ignored altogether (no stratum acquisition).

3.2.3 Processing the Model – Vertical

Once the horizontal dimension of the stratum was determined, the level of the horizontal stratum footprint was ‘draped’ to follow the levels of the Master Control Lines. This created a base 3D surface at the level of the tunnel control. By copying and offsetting this initial surface 20 m higher and lower, the first approximation of the upper and lower surfaces of the tunnel stratum was made.

By combining the model with topography (and later, LiDAR contours), the tunnel stratum could be compared to the ground surface. Some locations required ‘massaging’ of the upper stratum surface to correspond to the 3 m minimum depth requirement below the surface (see section 2.4).

Using MXROAD, the depth from the ground surface to the upper tunnel stratum surface was determined using volume contours (Figure 5). The volume contour model could be transferred GIS analysis software (ArcGIS) for further analysis with the cadastre.

Figure 4: Model showing the Master Control Lines (red), tunnel design, and ‘sawtooth’ boundary (blue).

Figure 5: Screenshot showing volumetric contours.

3.2.4 GIS Analysis

Using ArcGIS, the volume contours (indicating depth) were overlaid on top of the cadastre. To meet another requirement of the Subsurface Stratum Definition Strategy, it was required to determine only one upper surface stratum level for each acquisition lot. As a quick way to determine this for 900 lots, the 'spatial join' tool for ArcGIS was used. Using this tool, two datasets (depth values and lot boundaries) were combined by calculating the smallest depth value inside each lot parcel. This provides the shallowest depth for each lot, highlighting any locations where the tunnel stratum comes close to the ground surface.

Extending this further, the highest RL for each lot parcel (using the shallowest depth in the previous combined dataset) was determined. The result of this was the creation of a map of the entire NorthConnex tunnel showing the affected lots and the upper (and lower) RLs for each lot, as shown in Figure 6.

The depths and levels can be cross-checked against updated information and cross sections as provided by the tunnel designers. In addition, the levels are also checked prior to plan lodgement. With the GIS analysis above, and combined with the search for DPs, titles and survey control sourced from the Survey Control Information Management System (SCIMS – see Kinlyside, 2013), the creation of acquisition plans could begin.

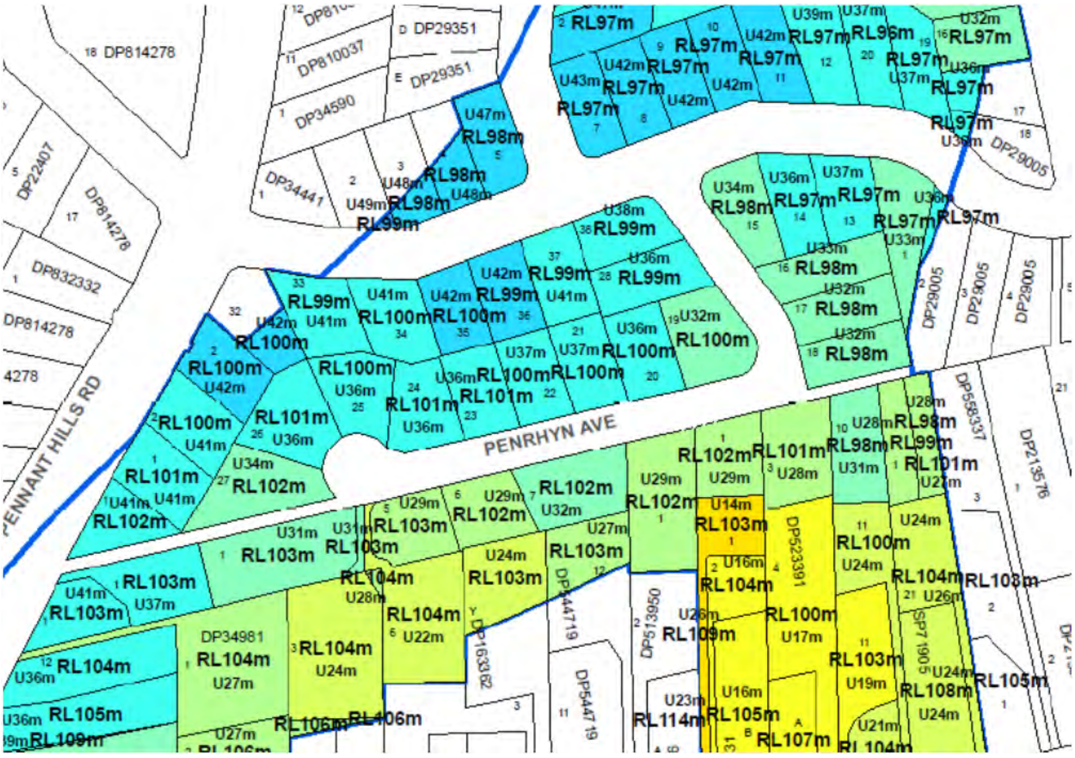

Figure 6: Map of affected lots showing depth to the upper surface of the tunnel stratum and its RL.

3.3 Plan Preparation

The preparation of the subsurface stratum acquisition plans began with calculations to locate the existing boundary. Most of the boundary calculations were straightforward at this stage. The calculations were put together based on logical relationships between the lots, e.g. lots using the same base Deposited Plan or plans that can be rotated onto a more encompassing parent plan. Some of the Deposited Plans prepared were more complex or contravened the

strategy for compiled boundaries and, as such, were treated as special cases. These cases will be discussed in further detail in section 4. Once the boundaries had been calculated, they were sent to the cadastral draftsperson with the other relevant search information.

The distinctive features of the acquisition plans are listed as follows:

- Three plan views: ground level view, upper stratum level view, and a lower stratum level view.
- Cross section diagrams spanning as many lots across the plan as possible.
- Stratum statements for every lot, describing their relative position above/below other lots, and their absolute position above/below stratum RLs.
- Partial acquisition boundaries below the surface – shown as a dashed line on the ground level plan view, but a thick solid line in the stratum views.
- Acquisition lot and Certificate of Title schedule (RMS standard for all acquisition plans).
- Motorway access restrictions along only the exterior of the NorthConnex stratum corridor (some plans show boundaries exterior and interior to the tunnel corridor).
- Any existing stratum boundaries (e.g. North West Rail Link).

Once the initial draft is completed, it is checked by the Senior Cadastral Information Officer. It is then checked by a Senior Surveyor for signature, and then forwarded to the Principal Surveyor for final approval as a plan for acquisition. The plan is then lodged by the Senior Cadastral Information Officer by electronic plan lodgement (known as ‘ePlan’ by LPI). This triggers the release of Proposed Acquisition Notices to the property owners, upon receipt of the Deposited Plan number.

4 CHALLENGING CASES

This Section highlights some of the interesting components of the NorthConnex acquisition project.

4.1 Grace Avenue and the North West Rail Link

Deposited Plan: DP1208231

This Deposited Plan was one of the most complicated compiled acquisition plans created by RMS. The plan contains a total of 98 lots with a combination of total (horizontal) subsurface stratum and partial subsurface stratum acquisition. In addition, the North West Rail Link (NWRL) subsurface stratum corridor crosses the NorthConnex subsurface stratum corridor at a higher elevation. A conscious decision was made to abut the upper stratum surface of NorthConnex to the bottom of the NWRL stratum, in order to avoid any hiatus between the two corridors (which, given time, would be lost forever).

4.2 Pennant Hills Golf Course Survey

Deposited Plan: DP1207275

The Pennant Hills Golf Course acquisition was completed using a plan of survey by RMS surveyor, David Burke. In this case, 6.4 ha of NorthConnex stratum were contained within 39 ha of the single golf course lot. Due to the size of the acquisition lot, the acquisition had to be accomplished by traditional means. Furthermore, this lot is adjacent to the M2 interchange,

and therefore the tunnel structure in this area consists of two separate declining carriageways of differing elevations.

The final subsurface stratum containing these carriageways is comprised of hinge joints connected by inclined planes, elevation benches between the two carriageways (as seen in the cross sections), and horizontal curves to accommodate for the tunnel/ramp geometry. The boundary definition involved the survey of the entire golf course block, fixation of Pennant Hills Road, as well as the location of survey marks inside the golf course proper. The plan also created a separate stratum limited easement for rock anchors over the golf course near Pennant Hills Road.

4.3 Kingsley Close Community Scheme

Deposited Plan: DP1208012 and DP1209861

The stratum acquisition for the Kingsley Close Community Scheme consists of two plans. The acquisition was separated into two plans because in the first instance subsurface stratum was for the majority of the lots, and in the second instance NorthConnex required the surface acquisition of the Neighbourhood Property (which is the Kingsley Close road and park area).

The first case was a compiled plan that neatly acquired the tunnel stratum underneath the lots in the Community Scheme whilst avoiding the Neighbourhood Property lot. This allowed for Proposed Acquisition Notices to be issued to the private owners within the timeframe demanded by the project. It also prioritised the acquisition, buying time for the second plan.

The second case was a traditional plan of survey by RMS surveyor, Michael Waud. The survey affected only the Neighbourhood Property lot, being the road Kingsley Close. On one end of Kingsley Close the lot was to be acquired purely in subsurface stratum. On the other end of the road, closest to the M1/F3 interchange, was full surface acquisition of the Neighbourhood Property lot. Once the Certificate of Title is created for the acquired surface lot, this triggers an action to add additional sheets to the Community Plan showing the changes.

5 CONCLUDING REMARKS

The request for the NorthConnex subsurface stratum acquisition was demanding on the RMS Cadastral Survey Unit. It required the acquisition of land for 9 km of tunnel, in a timeframe that would be considered impossible in the past. Acquisition for shorter tunnels such as the Cross City Tunnel and Lane Cove Tunnel took years to complete (and was finalised post-construction).

Five of the six stages of NorthConnex acquisition have now been completed (at the lodgement stage). At the time of writing, this equates to 96 Deposited Plans lodged in 12 months. During this time, RMS had initially exceeded its $100,000 lodgement fee cap with LPI. Lodgement fees at the time of writing currently stand at $460,000. The final stage of acquisition will be completed two months ahead of schedule, with the final plan to be lodged before Christmas 2015 (but is due February 2016).

The continuing success of the NorthConnex subsurface acquisition contributes to the delivery of an important link to the Sydney Orbital Network strategy – by providing the cadastral envelope that encompasses the construction, tunnel structure and supporting structures. The most significant effect of this project comes from the agreement to the Subsurface Stratum Definition Strategy, between RMS and LPI. The intention of the strategy was not only to develop a flexible solution for the compulsory acquisition for NorthConnex, but to provide the blueprint for future subsurface stratum projects. The strategy will be reviewed on a project-by-project basis, which will provide opportunities for improvement. As RMS and LPI work with the strategy, it can evolve into a set of conditions that provides for rapid, efficient, and responsible subsurface stratum acquisition.

From a boundary surveying perspective, stratum boundary definition will be increasingly important. As our cities continue to develop vertically, there is a need to look for alternative engineering and planning solutions to build infrastructure in challenging environments. The NorthConnex subsurface stratum showcases a number of different subsurface stratum situations. The RMS Cadastral Survey Unit has been contacted to apply this expertise to a number of new purposes, such as the enclosure of bridge structures, advertising signage and the disposal of land with high vertical development potential (e.g. RMS-owned land within Sydney CBD).

Due to the success of NorthConnex, the RMS Cadastral Survey Unit has been engaged by the WestConnex Delivery Authority to assist with the subsurface acquisition for the WestConnex motorway. The principles and lessons from NorthConnex will be carried into future projects. This has been recognised by project managers from other departments and alliances. Surveyors in RMS are working hard to develop efficient and flexible solutions using the resources available. An acquisition strategy combined with the assistance of cadastral surveyors industry-wide will help meet the infrastructure demands of NSW. Projects like NorthConnex and WestConnex bring to light the necessity of surveyors to any infrastructure project, particularly cadastral surveying and the role they play in the acquisition process.

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Maintaining the Integrity of the Cadastre and State Survey Infrastructure

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ABSTRACT

The preservation of survey infrastructure is a significant issue that the surveying and spatial information profession of NSW needs to address because cadastral reference and permanent survey marks are fundamental in underpinning the integrity of the cadastre and state control network. With evidence of significant loss of survey infrastructure associated with major road projects, the Surveyor General set Roads and Maritime Services (RMS) the task of addressing and managing the destruction of survey marks on RMS sites. This presentation focuses on the strategy and processes undertaken by the RMS Surveying Section to ensure the state survey control network is protected and preserved and cadastral integrity is maintained throughout the duration of projects. It will also include an overview of how the Engineering Services Surveying Section can assist project managers and contractors address the requirements of RMS specifications G73 and G71.

KEYWORDS: *Survey infrastructure, preservation, cadastre, integrity, collaboration.*

WHS Issues with Working Near Roads and the New National Standards

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ABSTRACT

This presentation provides a health check for surveyors working near roads, including traffic control issues. It discusses the national Work Health and Safety (WHS) standards and the approach taken by Roads and Maritime Services in order to ensure a safe working environment for all parties involved.

KEYWORDS: *WHS, standard, working near roads*.