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The Tomago to Stroud 132 kV Transmission Line: A Surveying Mixed Bag

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ABSTRACT

The 66 km Tomago to Stroud 132 kV transmission line project undertaken by TransGrid was a good opportunity for its survey group to showcase their spatial skills and knowledge and apply them to many facets of the project. Using numerous sources of survey and spatial data, the survey group delivered a homogenous, quality product that provided stakeholders with the information they needed whilst staying within critical time and cost constraints. The TransGrid survey group analysed and overlayed spatial data from many sources such as Airborne Laser Scanning (ALS), the Digital Cadastral Database (DCDB), aerial photography, SCIMS and field surveys to provide relevant accurate information to designers, land economists, land valuers and project managers. Based on this information a design was handed back, and the TransGrid survey group created route plans and set out the proposed structures, in effect 'testing' the design. This was an iterative process that refined the design to the 'for construction' stage. To protect this piece of infrastructure and to ensure the project progressed in a timely manner, easements had to be surveyed and created prior to construction. The survey of easements proved to be both interesting and testing from a boundary definition perspective with the new transmission line crossing through many old portions of limited title and definition. The TransGrid survey group took a 'whole of project' approach when tasked with the planning, investigation and delivery of spatial data services. In doing so, efficiencies in time and cost were achieved. Risks were mitigated through careful planning and understanding the internal clients' needs and requirements. The project was an excellent example of how diverse the surveying and spatial information profession is and highlighted the ever-evolving role of surveyors as the custodians of spatially accurate data and the increasing synergies with other professions reliant on this information. The TransGrid survey group exceeded client expectations by providing the expertise to deliver the project in a timely, cost-effective manner while improving survey infrastructure and cadastral definition in the project area.

KEYWORDS: *TransGrid, Airborne Laser Scanning, easements, infrastructure, boundary definition.*

1 INTRODUCTION

TransGrid has a long history in the power business (TransGrid, 2013). Since 1950, as part of the Electricity Commission, it has transmitted electricity throughout the State to give the people of New South Wales (NSW) a reliable, world-class power system. The Electricity Commission went on to become Pacific Power. Under Pacific Power, transmission and specialist engineering services were performed until 30 June 1994. On 1 July 1994, PacificGrid was formed as a wholly owned subsidiary of Pacific Power.

TransGrid, as we are now known, was formed as a Statutory Authority on 1 February 1995, under the Electricity Transmission Authority Act 1994. On 7 May 1996, under the Electricity Supply Act 1995, TransGrid developed and operated the State's electricity market and played a key role in facilitating the transition to the National Electricity Market (NEM). This role was handed over to the National Electricity Market Management Company (NEMMCO) when the National Electricity Market commenced on 12 December 1998. After further industry reform, TransGrid became a corporatised entity under the State Owned Corporations Act 1989 on 14 December 1998.

Demand for electricity on the NSW Mid North Coast has been steadily increasing for many years due to population growth and industry expansion. Analysis of the electricity transmission network has shown that, coupled with limitations in the capacity of the existing network (due to thermal overloads), the reliability and quality of electricity supply from TransGrid's network will be reduced as the demand continues to increase.

In order to maintain a reliable electricity supply to the Lower Mid North Coast, TransGrid, and electricity distributors AusGrid (formerly Energy Australia) and Essential Energy (formerly Country Energy), have proposed to increase the region's existing network capacity through a series of co-ordinated reinforcement projects.

2 PROJECT BRIEF

For TransGrid, the proposal involved the establishment of a 66 km long 132 kV transmission line between Tomago and Stroud (Figure 1). The new transmission line will run parallel to an existing 66 kV line where possible, with some deviations occurring where terrain and property constraints dictate. This project will serve to improve supply reliability across the Lower Mid North Coast network and provide support for other projects being completed by the distributors such as the Brandy Hill substation.

The need for the supply reinforcement, and the proposed network solution, underwent review and consultation within the National Electricity Market (through a 'Request For Proposals' process), to identify any feasible alternative and non-network solutions. No feasible alternative solutions have been proposed. The proposed transmission line reinforcement is considered the best long-term solution to meet the current and forecast supply demands on the Lower Mid North Coast.

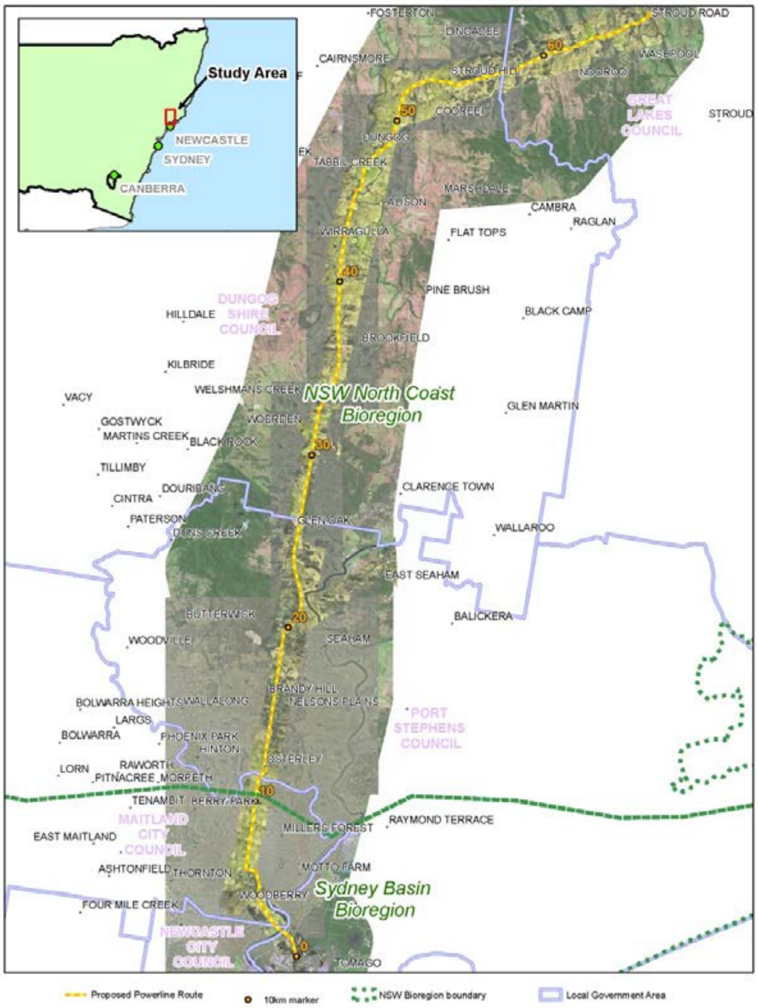

Figure 1: Project area.

3 SURVEY ELEMENTS

The TransGrid survey group were asked to provide the project team with the spatial products and services necessary to progress the project from the feasibility stage to completion. Many facets of the surveying and spatial information profession were utilised to deliver accurate data in a timely and cost-efficient manner. These products and services included:

- Airborne Laser Scanning (ALS)
- Aerial imagery
- GPS control survey
- Cadastral surveying
- Constraint mapping
- Route selection
- Production of route plans
- Manipulation of spatial data
- Converting between different data formats
- Structure setout
- Internal consultation
- Public consultation

3.1 Airborne Laser Scanning and Aerial Photography

Based on the results of the Environmental Assessment and community consultation, a final corridor was chosen as the preferred option. In order to aid centreline location, concept design and final design, a survey accurate 3D model was required. The model was to contain sufficient data to aid identification of ground constraints such as buildings, creeks, roads and railways as well as non-ground constraints such as vegetation and existing powerlines. Due to the length of the project and its time constraints, it was not feasible to create a 3D model by traditional survey methods. Based on past project experiences, it was decided that Aerial Laser Scanning (ALS) was the best-suited technology and method for the acquisition of the ground and non-ground data along with aerial photography.

TransGrid developed comprehensive ALS and aerial photography specifications to ensure that the data received by contractors was of a quality and format that would satisfy the end users' requirements as well as ensure consistency with previously acquired data. A shape file was provided to Terranean Mapping Technologies showing the proposed corridor as well as a buffer where data was to be captured but not processed. This was contingency planning for deviations that invariably happen in these types of projects. Terranean provided a thinned point cloud, which was classified into ground and non-ground ALS layers using specific filtering routines and delivered in a format suitable for import into PLS-CADD transmission line design software.

The ground data was triangulated to create a Digital Terrain Model (DTM). This model was verified by ground survey of well-defined points such as edges of roads and fencing. The 3D data was further verified by checking the ground model against actual ground heights obtained during the setout stage of the project. Figure 2 shows a frequency histogram of the differences in height measured between the ALS model and those obtained by the GPS survey during setout. It is expected that the 'bell-shaped curve' be centred about zero, however in this case it is centred about +0.19 m. Some argue that the pegs were not 'flush' and sticking out of the ground by 0.19 m, but the offset is actually due to the difference between locally derived Australian Height Datum (AHD71, see Roelse et al., 1971) values and those used by the ALS flight.

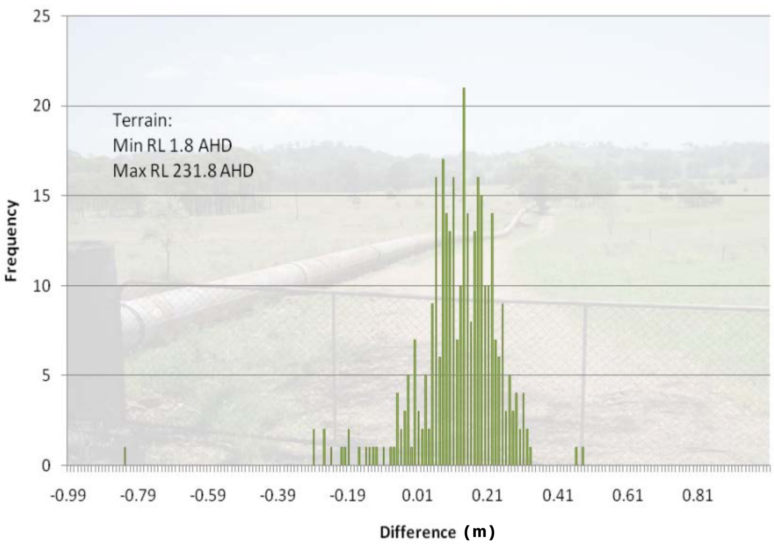

Figure 2: Frequency histogram of differences between reduced levels (RLs) from the GPS survey and ALS.

The aerial photography was captured at the same time as the ALS. The images were ortho-rectified and geo-referenced to enable the digitalisation and mapping of features such as roads, railways, buildings and watercourses. The aerial photography was then imported as an image overlay ECW in PLS-CADD along with the mapping delivered as a 3D DXF file. This allowed the generation of a photo-realistic 3D model as a base layer for the transmission line design (Figure 3). It also had the added benefit of providing instant conceptualisation of the proposed design for relevant stakeholders.

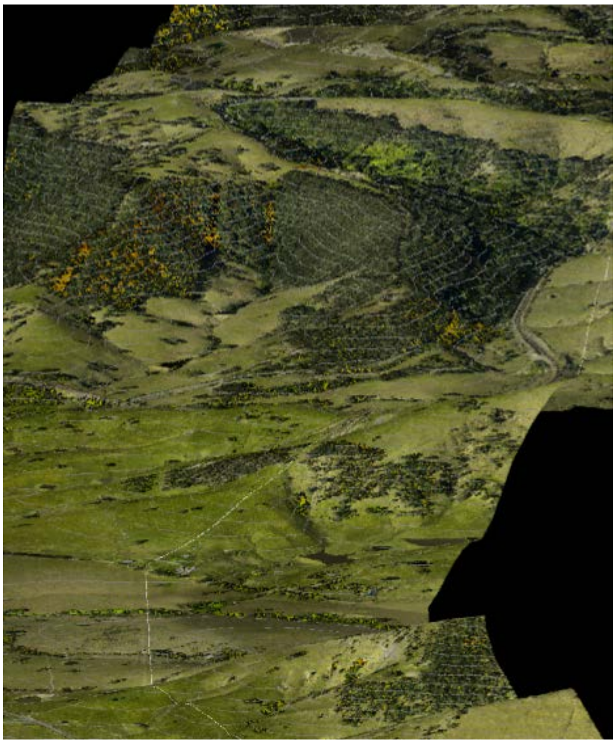

Figure 3: 3D view within PLS-CADD.

3.2 Control Survey

Once the transmission line corridor was locked in, it was time to plan how the surveys to follow would be controlled. A review of SCIMS (LPI, 2013a) revealed that sufficient control for Real Time Kinematic (RTK) based survey tasks (e.g. easement and setout surveys) was not available throughout the length of the proposed line. At that point in time (January 2010), CORSnet-NSW (Janssen et al., 2011) did not cover the area of interest and as such was not an option. In fact, the implementation of the CORSnet-NSW network seemed to follow us around the state, usually with a CORS being installed about four weeks after we had finished a project! It was decided that the fastest and most relatively accurate method of establishing a control network over the 66 km project area would be a static GPS control survey (Figure 4). The control survey tied non-established marks to geodetic stations of higher class and order as well as tied into newly placed permanent marks at locations suitable for RTK base stations (Figure 5).

The control survey was undertaken using the principles of the ICSM guidelines set out in the Standards and Practices for Control Surveys (SP1) document (ICSM, 2007). The method of survey was rapid static, post-processed GPS observations using four simultaneous units. This meant that each session was a geometrically braced quad. Over a period of two weeks of fieldwork, 36 marks were surveyed, including seven new marks that were placed during the survey in accordance with Surveyor General's Direction No. 1 (LPI, 2009).

Figure 4: Big sky country – the Tomago-Stroud project had an abundance of 'sky', making GPS extremely effective.

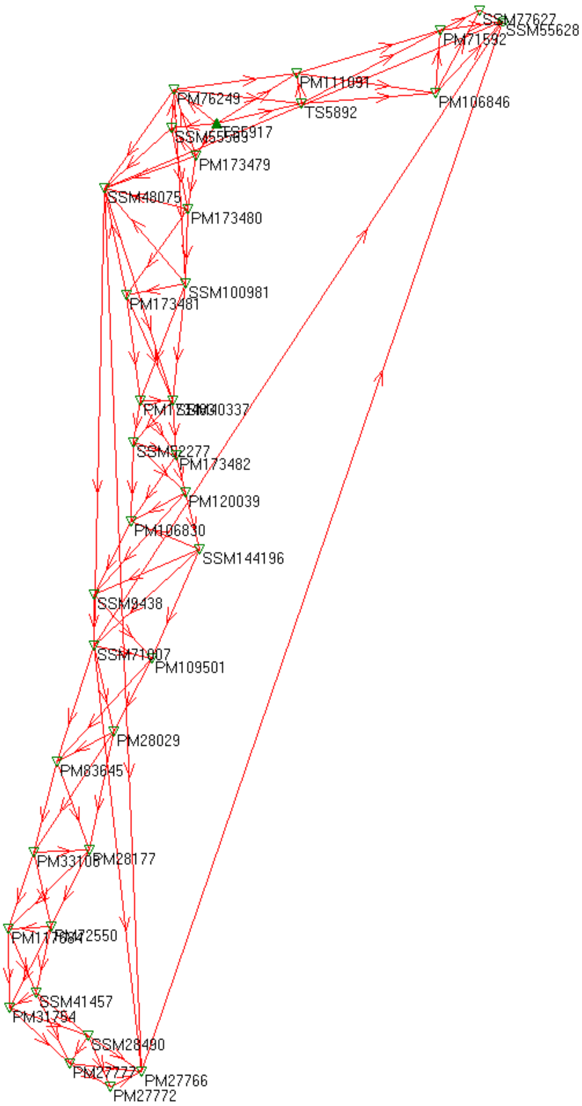

Figure 5: Static GPS control network comprising a system of braced quadrilaterals from Tomago to Stroud Road.

In addition to TransGrid's processing, the baseline data was also sent to Land and Property Information (LPI) for processing, adjustment and upload to SCIMS for public use in accordance with Surveyor General's Direction No. 12 (LPI, 2012). The marks previously not established were updated to Class B Order 2, providing the area with a much more robust level of horizontal and vertical control.

3.3 Centreline Alignment Selection

With the control network adjusted and entered into SCIMS, and an approximate location of the centreline known, it was time to lock in the angle locations. Approximate locations were derived using aerial photography and ALS data. These were then staked in the field with RTK to see how it fitted with current occupations and land uses (Figure 6). This gave landowners an opportunity to visualise the proposed location and make comments. In most cases, the angles were tweaked and re-measured in a seemingly ongoing iterative process.

Figure 6: Needle in the haystack – a proposed angle location.

At this stage, it was important to start considering impacts on the cadastre. In some instances the boundaries dictated where the centreline was to be located due to various reasons such as landowner requests or avoiding certain holdings altogether (e.g. national parks, state forest or disgruntled locals). Once the angles were agreed on, the coordinates were entered into PLS-CADD to define the design centreline.

3.4 Cadastral Survey

In the past, TransGrid acquired easements for transmission lines after the line was constructed. This enabled us to use the existing line of poles or towers to define the centreline and a set easement width was taken according to the design voltage (Figure 7). This process had the advantage that if there were any design changes, it had no adverse impacts on the easement.

The current procedure is to aim to acquire the easement before the construction commences. This negates the need for access agreements for construction and ensures all landowners are compensated before their land is affected. It is a far more transparent approach that gets all of the issues onto the table before the project advances to a final stage.

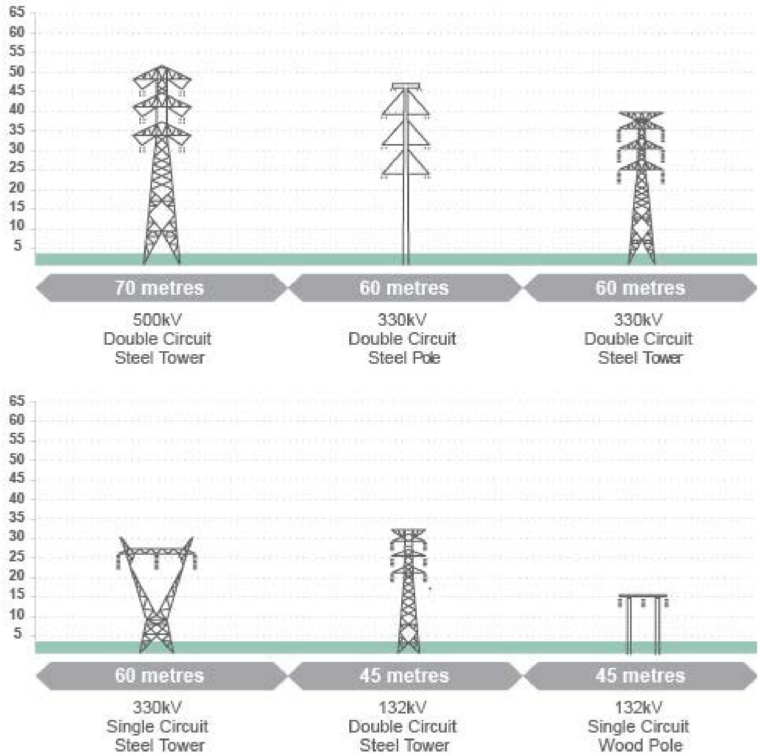

Figure 7: Easement widths as a function of operating voltage.

Easement surveys for TransGrid assets are undertaken using the Registrar General's Directions for Deposited Plans – Easements for electricity supply purposes over an existing line of poles or underground cables (LPI, 2013b).

The Registrar General's Directions state: "*An easement intended to be created for the purpose of the supply of electricity from an electricity supply authority by means of overhead or underground power lines affecting rural or suburban land can be identified by centreline traverse. The centreline should be defined by survey, however, a compiled plan will be accepted provided it complies with the requirements set out below.*

The easement may be created by:
- *A dealing registered under the Real Property Act 1900 based on either:*
  - *a plan of survey or compilation registered as a deposited plan, or*
  - *a compiled plan annexed to the dealing.*
- *A section 88B instrument lodged for registration with a new deposited plan, or*
- *A deed registered in the General Registry of Deeds (Old System) based on either:*
  - *a plan of survey or compilation registered as a deposited plan, or*
  - *a compiled plan annexed to the deed.*"

For this project, full plans of survey were needed covering the entire proposed line. Preparing easement plans by centreline traverse negates the marking of the edges of the easement as well as showing bearings and distances on the plan around the easement site. Cuts are shown along intersecting boundaries to the centreline and conversely along the centreline to cutting boundaries (Figures 8 & 9). This approach has the great advantage of increasing plan readability without adverse effects on cadastral or easement definition.

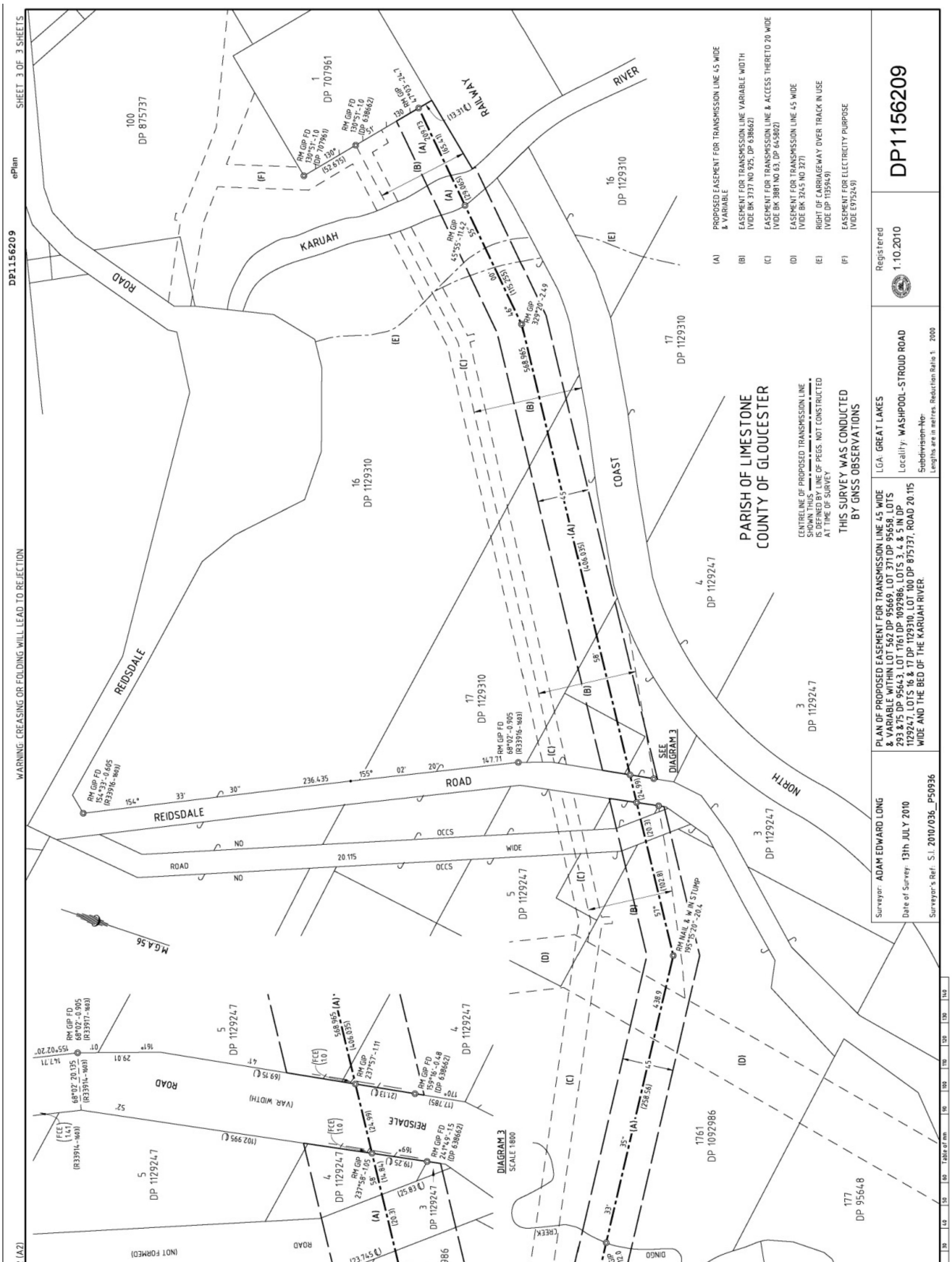

Figure 8: Example of an Easement Plan of Survey.

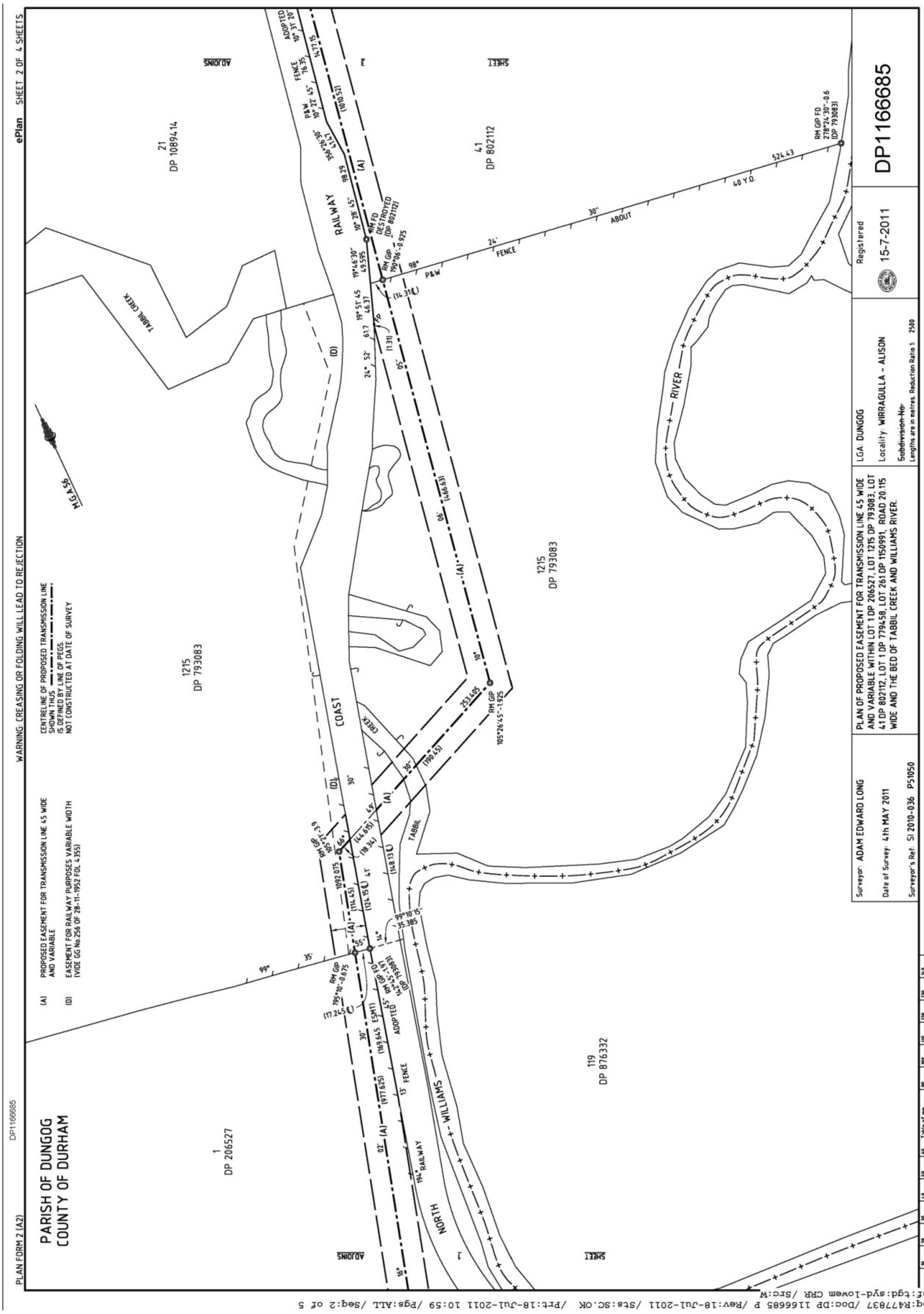

Figure 9: Example of an Easement Plan of Survey abutting railway land.

A total of 20 Deposited Plans were surveyed by TransGrid surveyors, covering 51 km of transmission line easement. In addition, one plan covering some 15 km was prepared by Rennie Golledge Pty Ltd.

The survey of easements proved to be both interesting and testing at times from a boundary definition perspective with the new transmission line crossing through many old portions of limited title and definition. Most sections crossed through land that had previously been surveyed in the 1960s, most notably by Andrew Clark whose plans were a pleasure to work with. However, some sections, such as around Duckenfield, had very little cadastral information. At one stage, boundary definition was relying on information in DP197 created in 1838. In this situation, the location of cadastral boundaries was aligned with existing occupations such as old fencing or walls (Figure 10).

Figure 10: A lot of boundary definition relied on occupations such as this.

Parts of the Hunter Water pipeline (Figure 11), which the centreline criss-crossed, had very little reliable survey information to work with as most of the plans were compiled. The centreline also crossed at very acute angles making the showing of ‘cuts’ very difficult at times. There were also railway boundaries, original Crown grants, farm plans and Australian Agricultural Company lease issues to deal with – a real ‘mixed bag’ of cadastral challenges.

There is now 70 km worth of cadastral survey on MGA94 orientation, which should make future boundary surveys in the project area a little easier. The easement plans progressed from south to north, each plan covering about 6 km over four sheets. As boundaries continued to be defined by survey, the cadastral layer for the whole project was adjusted and updated for inclusion on the Route Plans.

Figure 11: The Hunter Water pipeline weaves its way under the proposed line on its way to Chichester Dam.

3.5 Route Plans

Route plans combine all of the collected spatial data to form a homogenous plan of the project (Figure 12). The rout plant is an information-rich product generated by the survey group to aid many different end users. It includes the following information:

- Aerial imagery
- Cadastral boundaries from DCDB 'tweaked by survey'
- Local government area, parish and county boundaries
- Landowner and title details
- Roads, railways and pipelines
- Access tracks
- Edges of vegetation
- Creeks, rivers, streams and dams
- Control marks
- Low voltage crossings
- Proposed centreline, structures and span distances

The route plan is used at many stages of the project, e.g. to help analyse impact on land holdings and/or environmental impact, initiate discussions with landowners, complement design profile drawings as a plan view attachment, and determine access strategies for construction and maintenance.

Figure 12: Example of a route plan.

3.6 Structure Marking

The design was completed by Brisbane based company PLD Consulting using the PLS-CADD model created from ALS. The aerial imagery was used to map constraints that told PLS-CADD where structures could not be placed, i.e. in areas near dams, roads, railways and watercourses. Using certain design criteria inputs such as design voltage, pole types, statutory clearances and maximum span distances, PLS-CADD created the design in a fairly automated process (Figure 13). For this reason, it is crucial that the design be setout in the field to confirm that the design can work and that all constraints have been considered.

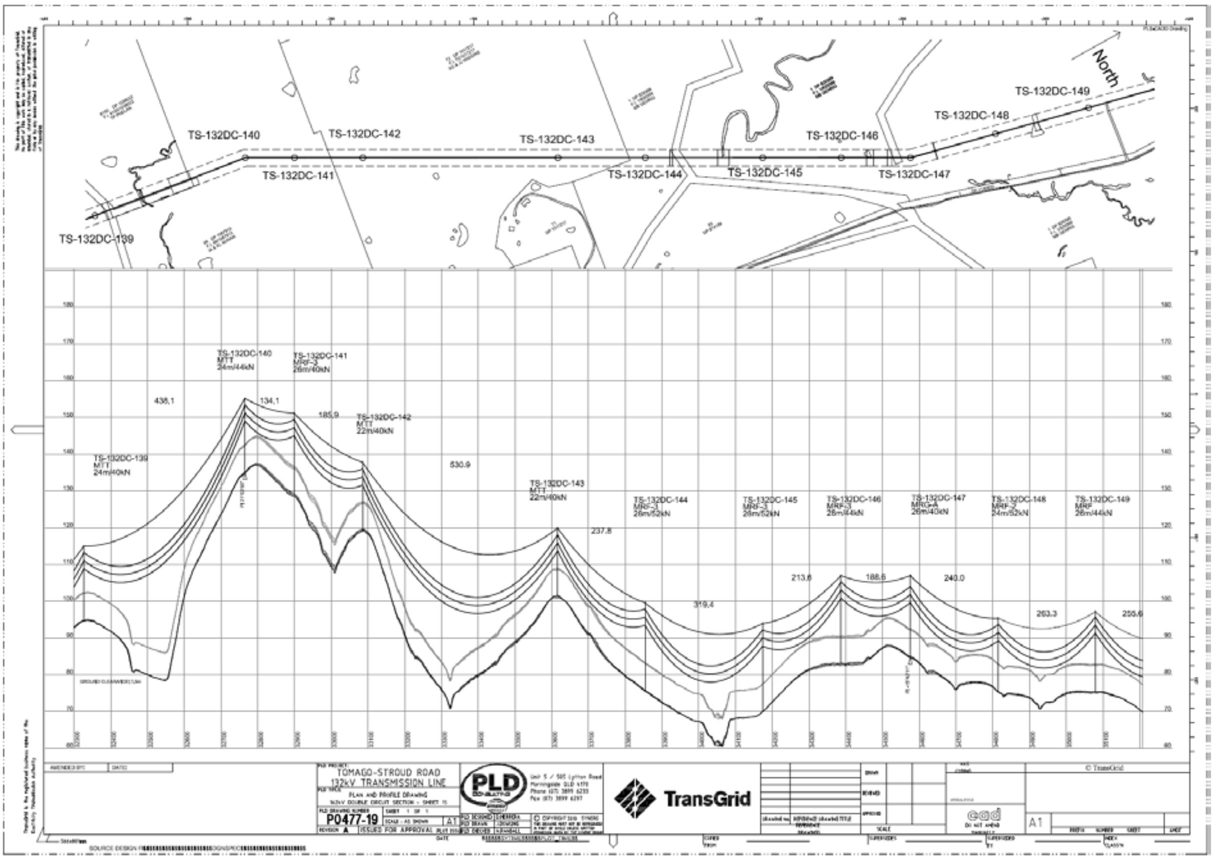

Figure 13: Example of a design profile.

PLS-CADD outputs each structure and guy location as Easting and Northing on MGA94 and AHD 71 heights suitable for setout by RTK GPS survey using either CORSnet-NSW or local base stations (Figure 14). As each structure is setout, the surveyor checks that the proposed structure location does not affect visible services, access ways or watercourses. As problems are found, structures can be moved on the ground to a more suitable location and input back into the design. This process is very iterative with a lot of communication required between ground staff and designers.

Figure 14: TS Dungog and TS Coorei – the use of RTK GPS had great benefits throughout the project.

4 CONSTRUCTION

Construction on the project began in May 2012. So far, 85% of access tracks have been completed and more than 5 km of the new transmission line, including 70 of the planned 300 concrete pole structures, have been installed (Figure 15). Recently the southern section of the transmission line at Brandy Hill had been connected to Ausgrid's new Brandy Hill substation, reinforcing electricity supply to communities in this expanding region of the Hunter Valley. Work is now progressing with the stringing of the new transmission line north of Brandy Hill to the Martins Creek Tee. Construction is due to be completed by the end of 2013.

Figure 15: Section of newly constructed line heading towards Brandy Hill and example of power pole type.

5 CONCLUDING REMARKS

The Tomago to Stroud 132 kV transmission line project certainly put TransGrid's surveying capability to the test. Throughout the design phase of the project, quality spatial products and services were delivered that provided stakeholders with the information they needed whilst staying within critical time and cost constraints. Overall, this project was an excellent example of surveyors proving that they are the experts when it comes to analysing and manipulating spatial data, and providing survey accurate plans, drawings and 3D models.

It was evident that technical skills alone are not sufficient in this type of environment. The project highlighted that exemplary communication skills with all stakeholders were essential for progressing the project from feasibility to 'for construction'. The project confirmed that TransGrid's survey group has the experience, skills and drive to deliver on large-scale infrastructure projects for the benefit of the state of NSW.

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