Coordinate Systems used in Railways in NSW and their Effects on Cadastral Surveying, Engineering and Mapping

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ABSTRACT

This paper describes the common coordinate systems used in the railways in NSW. The range of coordinate systems includes the Map Grid of Australia (MGA), Integrated Survey Grid (ISG), Railway Integrated Grid (RIG), local plane systems and also a Cassini-Soldner grid used in Sydney. A brief description of each of these coordinate systems is given as well as some of the peculiarities of some of these systems. Examples of each of these systems are presented together with a number of the variations that can be found. The effects of coordinate systems on the process of the definition of railway boundaries are discussed with examples from recent works. The cadastral and environmental footprints of proposed works are some of the early issues raised in a number of projects and if not addressed can cause problems at a later date. Cadastral and environmental processes often have long lead times and are therefore often on the critical path for a project. Other effects of coordinate systems in use include the long-term maintenance of engineering infrastructure, including the more obvious rail tracks and the less seen underground services that are essential for the safe and efficient operation of a railway. The products produced on a typical project include local mapping products to support a wide variety of operational, maintenance and construction works, showing above ground and underground infrastructure and the associated formation works required to support this infrastructure. Some observations from a number of recent projects are discussed and a number of recommendations are presented.

KEYWORDS: *Coordinate systems, mapping, railway, cadastre, NSW.*

1 INTRODUCTION

There are many coordinate systems that have been used over time throughout the railways in NSW. These systems have each been implemented to solve problems and provide a framework for current and future works using the information and tools available at the time and taking into account the uses of the information. Some of these systems are not what they seem, so understanding the details of the particular system can make the difference between straight forward survey work and many hours of hair pulling and concern as designs not fit together.

No discussion about railway coordinate systems would be complete without at least mention of the most used and common system of “line”, “chainage” and “offset”. This is the system that most railway information is collected and disseminated in, and is understood throughout the industry. Although not the subject of this paper, this system is none-the-less significant due to its widespread use and the ease that staff have in measuring and applying the information. This paper, however, examines the Cartesian coordinate systems more familiar to surveyors, describing some of their properties, and implications to those using the information.

2 EARLY SURVEYS AND DESIGNS

The early surveys for the construction and maintenance of the railway, track, formation, structures and cadastre, were based on traditional traverse and closure calculations. These surveys typically traversed the centreline directly, reducing the amount of calculations. The process often dealt with secant and tangent lines for curves. The boundary was often parallel to the track centreline. Details of boundary definition based on the original railway plans are available in Webber (1983).

Vast lengths of railway were surveyed using this method, with calculations often undertaken in tents at night using tables, and later the mechanical calculators for basic mathematical calculations. Evidence of this is sometimes found in longer curves where the curves were broken into multiple compounding curves of the same radius each with its own intersection point. This was done for the purpose of marking, to ensure that the curve was not too far from the tangent line between the intersection points. These alignments were later monumented (a process of permanent marking), and the intersection points and other critical points in the framework were marked together with recovery points near the critical points on the centreline as well as regular intervals along the centreline. It will be noted that in all the records found for this work, coordinates do not seem to have been considered.

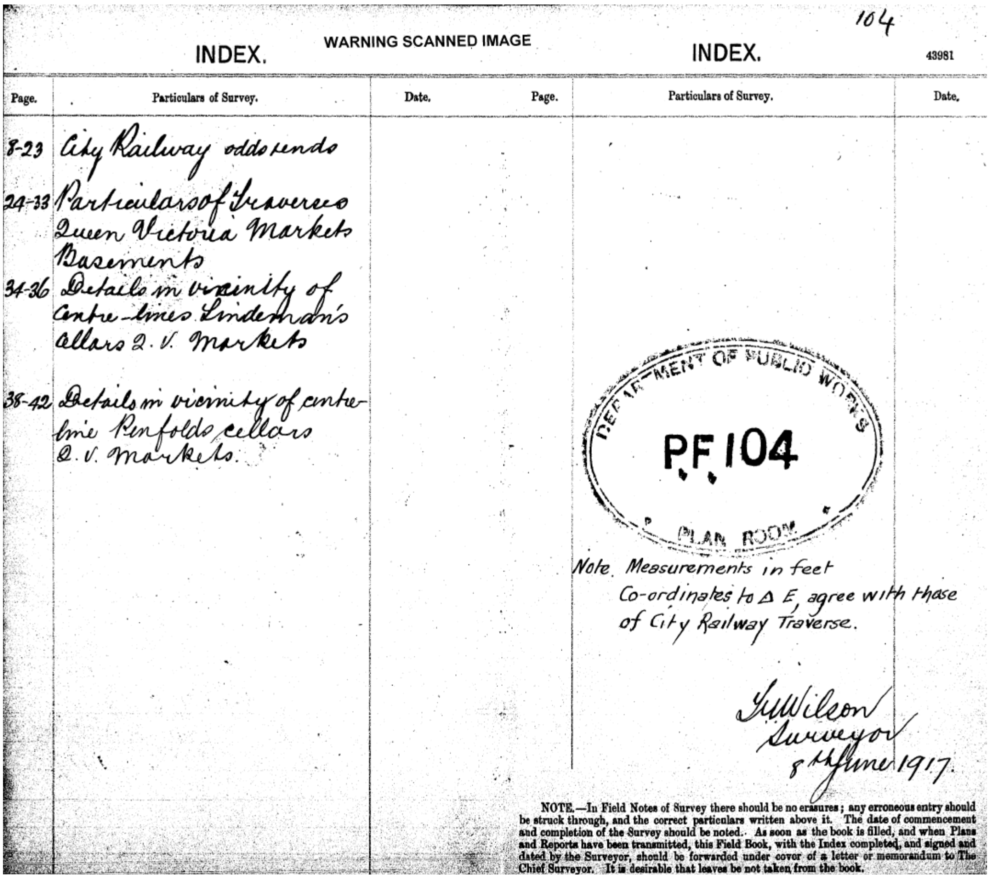
Understanding the processes that were used in these times helps with boundary definition in the re-establishment of the original alignment, which in-turn allows for a calculation of the likely original boundary intentions.

3 EARLY LOCAL COORDINATE SYSTEMS

In some areas, surveyors began to implement a coordinate system to aid in the process of planning, design and construction. Such systems seem to be varied in their application and foundation. Most of these systems appear to have been implemented for the purposes of a particular project. These systems were sometimes maintained and extended to adjoining areas by local survey staff. Over time, most of these systems have effectively been lost because the survey marks have been left undocumented, or the marks have been destroyed. It is also fair to say that the standards used for the survey control in these systems varied greatly, from high level instrumentation and methods to courser methods using lesser level instrumentation. There was rarely any network adjustment and traverse adjustment ranges from minimal to more thorough techniques.

A good example of an early coordinate system which can still be re-established is the coordinate system used for the design and construction of the City and Eastern Suburbs Railway. The control traverse extended through the city and out along the route to Bondi and then on to Randwick, Kensington and back through Sydenham and Erskineville. Records have been found showing this system in use as early as 1917.

Figure 1 shows a survey referring to Trig E and coordinates from the City Rail Way traverse. There are also many records showing traverse stations throughout the streets of the city on this coordinate system.



104

WARNING SCANNED IMAGE

INDEX. INDEX. 43981

Page.	Particulars of Survey.	Date.	Page.	Particulars of Survey.	Date.
8-23	City Railway odds & ends				
24-33	Particulars of Traverses Queen Victoria Markets Basements				
34-36	Details in vicinity of centre-lines Lindeman's cellars Q. V. Markets				
38-42	Details in vicinity of centre-line Penfolds cellars Q. V. Markets.				

DEPARTMENT OF PUBLIC WORKS PF104 PLAN ROOM

Note. Measurements in feet
Co-ordinates to Δ E, agree with those of City Railway Traverse.

T.W. Wilson
Surveyor
8th June 1917.

NOTE.—In Field Notes of Survey there should be no erasures; any erroneous entry should be struck through, and the correct particulars written above it. The date of commencement and completion of the Survey should be noted. As soon as the book is filled, and when Plans and Reports have been transmitted, this Field Book, with the Index completed, and signed and dated by the Surveyor, should be forwarded under cover of a letter or memorandum to The Chief Surveyor. It is desirable that leaves be not taken from the book.

Figure 1: Extract from PF104.

This coordinate system was a Cassini-Soldner coordinate system, and seems to have been used by the Public Works Department at the time. The railway records have not revealed the details of this projection except that its origin was Trig "E". By back calculation Trig "E" is the trigonometrical station at Sydney Observatory, on the same meridian as the transit telescope in the observatory. See Figure 2 for the current SCIMS record of Trig E.

Figure 2: SCIMS Record of Trig Station E.

This coordinate system had no false Eastings or Northings, so coordinates were north or south and east or west of the origin, and of course in feet.

Investigations completed by a number of railway staff over recent years have indicated that the results were comparable to today's methods and very reliable. Many of the surface control marks were later made into PMs and the railway description lived on in SCIMS, so both the original coordinate values and Integrated Survey Grid (ISG) values were available for many marks. After elimination of outliers a similarity transformation using a large number of common marks could be undertaken.

The Eastern Suburbs Rail Way records from the construction show the coordinates for the alignment and the traverse. The information is detailed and complete. There are also indications of miss closes that were measured in the tunnels during the construction.

The plans from the time indicate that there was a miss close in the traverse of 0.2 of a foot (about 0.060 m) at Central Station. It appears that there may have been two traverses that met at Central Station. Rather than adjusting the survey values, there were simply two sets of values at the overlap. Figure 3 shows how the different values were used. There are also two sets of coordinates for the traverse stations on either side of this divide. This is just an example of where the taking of coordinates at face value can be misleading.

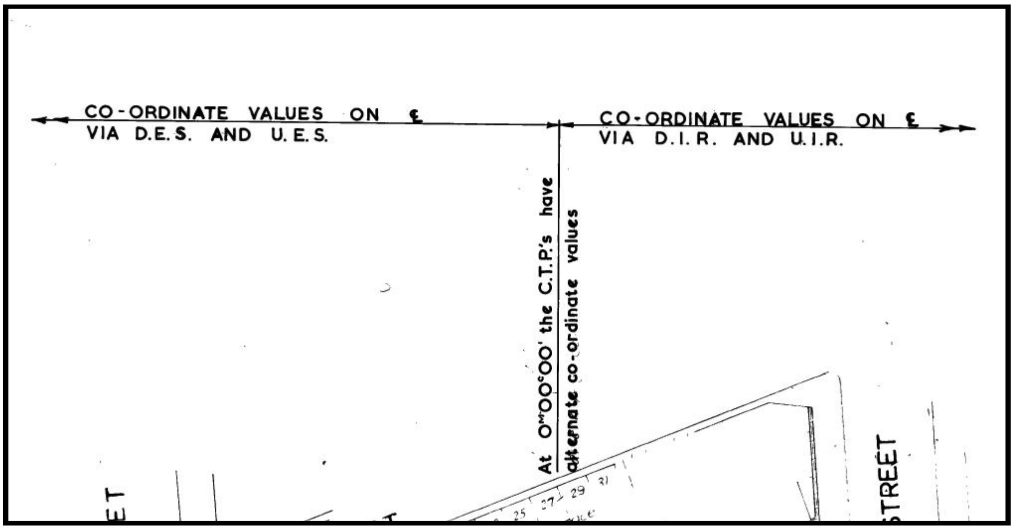


Figure 3: Extract from plan 2SS 1003.

4 INTRODUCTION OF ISG

The 1970s saw the introduction of the Integrated Survey Grid (ISG) (Lands, 1976). The development of this survey grid was seen by many railway surveyors as the way forward and a number of different implementations of ISG were made.

One of the key properties of ISG was the scale factor which was designed to be close to unity and as such should not need to be considered. This scale factor was however enough to cause some concern and there were cases where ISG values were adopted for a central mark and azimuth, the coordinates extended with a unity scale factor. The coordinates were sometimes, but not always, truncated to remove confusion. However, the origin of the coordinates was not always well documented, i.e. it was not always clear which system a coordinate came from since the values for common marks (and alignment points) would be similar when such systems joined.

4.1 Lands Department Support

Preceding planned upgrading works along many railway corridors, the Lands Department of the time was requested to supply ISG control that could be further broken down by the railway surveyors. As this was the early days of the roll-out of ISG, it was often necessary for the surveyors to place most of this control and carry out all the necessary observations to provide the required ISG coordinates.

The control provided by Lands was up to the task of the time but, as with all control, could be improved if additional resources were available. As further development of the network of ISG around the rail corridors proceeded, it was necessary to readjust the networks, altering the coordinates that had been adopted by the railways. Due to the vast amount of work undertaken by the railways and the engineering designs and plans produced from this work, the values from later adjustments of the survey observations were not used and the original coordinates were held fixed.

4.2 Scale Factors

Scale factors are the issue most often quoted as the reason not to use coordinate systems. Many people struggle with the concept of a scale factor between the coordinate plane and the ground. Engineers want to know that 100 m on a design is able to be measured as 100 m on the ground. This issue is one that needs to be carefully managed. Surveyors need to take care of these issues and ensure that prefabricated pieces of infrastructure will fit on foundations constructed to the design.

Although this particular issue has much merit, it can be worked around during the construction phase (a concrete road, pipeline or rail track that is different in length by the scale factor presents no issues to the correct operation of the asset).

4.3 Refining the Network

Over time the survey control network includes further observations, additional marks, extra legs and connecting lines, strengthening the network. Readjustments and changing of coordinates is a natural consequence of the process.

The railway breakdown of control, engineering observations and design calculations has all been based on the original coordinates and now differs from the ones available from SCIMS.

The process of the infill survey, design and design documentation effectively holds control fixed with the original values, and the railways' version of ISG and SCIMS grow apart. (This may also happen with MGA but the hope is that a stronger initial network will minimise both the frequency and magnitude of this separation.)

The result of the further refinement is a measurable difference in the coordinates available from SCIMS and those used by the railways. This has caused some outside surveyors to spend much time questioning both the survey skills and supplied data. These are easily cleared up once the full history is known but can lead to tensions in the short term.

5 RAILWAY INTEGRATED GRID

The Railway Integrated Grid (RIG) was developed to differentiate railway coordinates from ISG coordinates. A RIG coordinate can be identified by its coordinate values. A RIG coordinate has a false Easting set at 800,000 m and the false Northing was set at 700,000 m. All other grid factors are the same as ISG. Two major uses of RIG are briefly explained in the following sections.

5.1 Approximate ISG

In many areas there was insufficient control available to establish ISG along the railway corridor. There was still a desire to use the principles of ISG but no reliable origin was available in the area. In these cases a common practice was to establish the ISG value of some point from whatever was available. Sometimes this could be sourced from SCIMS where a mark had only a low order coordinate and at times the best method available was to scale a coordinate off the topographic mapping of the area.

Once a coordinate was available, the next step was to determine an azimuth. An azimuth could be determined using the above methods, a magnetic compass or sometimes a sun observation. As in the previous case, the control was then densified and the coordinates altered by the different false Eastings and Northings.

5.2 Frozen ISG

Where ISG control was available the values were adopted and densification of the control undertaken. To identify this as railway control and remove the effect of updates to the ISG network, the values were changed by adding to the false Eastings and false Northings. This control was then used for railway engineering purposes and maintained using only the original and derived survey information.

6 AMG IN QLD

During this time the NSW railways were responsible for the standard gauge railway line from the NSW border through to Brisbane. The exact boundary between QLD and NSW responsibility changed but the effect was the same. QLD did not adopt ISG but an unpublished half-degree overlap of ISG/AMG stations in QLD was available from LIC and used to push ISG over the border. There were sections of track being maintained that lay outside the extent of ISG. Within these areas, the Australian Map Grid was used where available (along with its much larger scale factor).

7 RAIL MAPPING IN MID 1990s

In 1994 a project was undertaken to map particular railway infrastructure throughout NSW. Details of this project were presented to APAS in 1995 (Latella, 1985). One of the by-products of this project was the establishment of pairs of PMs or SSMs in public lands adjacent to railway locations at an interval of approximately 50 km along each rail line. The effect of this was to make the introduction of coordinates along a number of lines a real prospect and together with the then new geodetic GPS receivers, railway surveyors were able to move further towards their goal of coordinated alignment throughout the network.

8 INDUSTRY SLIPPING BACK TO LOCAL COORDINATES

During recent years there has been a trend of putting major infrastructure development out to private industry to construct and deliver the project. As survey is a small and almost not mentioned part of these projects, the specifications have often not included things like coordinate systems. In these cases the projects often decide to implement a local coordinate system. The reasons often include the removal of scale factors, the use of smaller numbers in the documentation, and the reduction in effort in calculations. All these factors are of course easily overcome using modern computer systems.

The reasons for adopting local systems often seem strong when viewed from the project perspective. When the “life-of-asset” view is taken, there are much stronger arguments to adopt the common coordinate systems of the locality. A number of these arguments are covered in section 10.

9 RAIL SAFETY ACT AND ITS IMPLICATION ON COORDINATE SYSTEMS

The Rail Safety Act 2008 No 97 strengthened the constraints on entering the rail corridor, which has implications for the use of PMs and SSMs that have been placed within the rail corridor. This has brought a change to the practice of placement of survey marks, with PMs and SSMs being placed outside the corridor but within line of sight of the rail corridor.

Access to those marks within the rail corridor can be arranged through the local authority, with appropriate safety arrangements made. This restriction covers RailCorp, Australian Rail Track Corporation (ARTC), Country Rail Infrastructure Authority (CRIA), other private railways and those run by Victoria.

10 ARRIVAL OF MGA

With the introduction of the Geocentric Datum of Australia (GDA) and the associated Map Grid of Australia (MGA, see ICSM, 2006), RailCorp and ARTC are slowly converting the survey infrastructure and associated design information to MGA. This is occurring through primarily project works and is destined to leave significant sections in their current coordinate systems. Converting to MGA has a number of advantages beyond the integration to state based coordinate systems. Some of these advantages are discussed below.

10.1 Definition of Railway Boundaries

Many surveys for projects need to include boundary definition. Existing information on land boundaries is often available in MGA. There are significant advantages in being able to overlay the boundary information over detail mapping. These advantages stem from the freedom of many to see impacts of proposed activities near boundaries.

Being able to use the detail survey information of tracks and alignment monuments also allows the cadastral surveyor to utilise this information in the determination of the railway boundaries without having to have two separate survey data sets.

10.2 Cadastral Footprint for Proposed Works

Where proposed works extend to near or beyond the railway corridor, it can be necessary to acquire land or lease land during the construction program. The surveyor needs to prepare plans showing the proposed acquisition or lease so that property negotiations can be undertaken with adjoining land holders. The extent of the acquisition or lease is dependent on the extent of works for cuttings, embankments, access roads, construction and maintenance compounds, drainage structures and utility installation. There are advantages to the project of having the proposed work and the cadastral surveys on the same coordinate system helps to make this process as smooth and seamless as possible.

10.3 Environmental Approvals – Foot Prints

The environmental approval process is a long lead time process. Early level plans, overlaid on cadastral information and existing environmental data sets, are extensively used to efficiently identify the environmental impact of the works and areas where alternatives should be examined. There are also requirements to provide mapping to support the environmental approval process.

10.4 Underground Services

Underground services are a significant asset and can have a significant impact on design and construction of railway projects. The location of underground services is critical to the success of a project, and having this location based on the same coordinate system as other project information allows the early detection of clashes. To this end the services need to be mapped by coordinates and not just a line on a plan as errors can occur when interpreting plans and trying to put two disparate sets of data together.

Where the mapping has been carried out using a different coordinate system, it is essential that sufficient common points exist between the underground services data set and the detail mapping data sets. The best such common point are survey control points but other include significant infrastructure which is clearly identifiable in each data set.

10.5 Long Term Maintenance

The long term maintenance of the railway infrastructure is aided by the use of a suitable and long term coordinate system. There will always be improvements made in the value of coordinates of survey control marks, but if the differences are kept to a minimum and the adopted values are recorded with the design and boundary definition, the future survey task will be kept to a manageable and affordable level.

11 CONCLUDING REMARKS

There are a number of different coordinate systems that have been used within the rail environment. The casual user might assume that these coordinates match those generally available outside of the rail corridor, but this assumption can cause problems in the detail. The basis of coordinates on a plan needs to be included on the face of the plan. The use of MGA throughout the railways should be encouraged. This should also be extended to other infrastructure projects.

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