University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

DERIVING TRANSFORMATION PARAMETERS FOR EXISTING SURVEY CO-ORDINATE SYSTEMS IN THE AUSTRALIAN CAPITAL TERRITORY

A dissertation submitted by

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ABSTRACT

This project investigates and evaluates the use of the conformal, affine and projective transformation methods to derive parameters to convert three existing co-ordinate systems found within the Australian Capital Territory into the Geodetic Datum of Australia 1994 map projection Map Grid Australia. These existing co-ordinate systems are known as City Co-ordinates (CC), Preliminary Grid Co-ordinates (PGC) and Adjusted Grid Co-ordinates (AGC) and are located in separated zones through the ACT.

Three styles of transformation have been used in each of the three co-ordinate zones and analysis has been made into which method is most suited when a conversion from a 2D orthogonal co-ordinate system into another is required. Comparisons have also been made when using GPS observations and territory published values to derive parameters in converting values within each test area.

Effects of extrapolation have been investigated to determine the magnitude of error when parameters are used outside the region used to derive them. The error from the effects of extrapolation, have also been contrasted against acceptable limits defined from class and order of known published values.

Spatial information is at the forefront of industry and government and with the ever increasing quantity of available data to the spatial user, quality data is desirable and co-ordinate transformation offers a method to data users for the merging of data and co-ordinate system conversion within data sets.

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"Where there is chaos, there is ruin and poverty..."

Bob Geldof

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NOMENCLATURE

ACT	Australian Capital Territory
Affine	A six parameter, four step co-ordinate system transformation of non-orthogonal co-ordinates by X scale, Y scale, X translation, Y translation, origin rotation, and axis orthogonal correction and used in photogrammetry to co-ordinate imagery
AFN	Australian Fiducial Network; Initial network of eight continually operating GNSS stations used to define the Geodetic Datum of Australia
AGC	ACT Adjusted Grid Zone Co-ordinates. A modified map projection where scale at central meridian is equivalent to 1.000086
AGD66/88	Australian Geodetic Datum (1966/1988) is a Transverse Mercator map projection of the ANS ellipsoid
ANN	Australian National Network; An expansion of the AFN to an additional 78 stations to broaden the GDA definition
Belconnen	A town centre/district within the ACT and test site for PGC co-ordinate system
CITY	ACT City Zone Co-ordinates
Conformal	A four parameter, three step co-ordinate system transformation of standard orthogonal co-ordinates by scale, rotation, X translation and Y translation about the origin used with surveying co-ordinates
Co-ordinate System	A reference frame used to define a subject in a spatial context
Ellipsoid	An elliptical mathematical model depicting the size and shape of the Earth and used as a datum in map projections and co-ordinate systems
GDA	Geodetic Datum of Australia

Geoid	A mathematical model depicting the equipotential surface of the Earth's gravity field representing global mean sea level
GNSS	Global Navigation Satellite System
GPS	An American military derived constellation of satellites (Global Positioning System)
ICSM	Intergovernmental Committee on Surveying and Mapping
ITRF92	International Terrestrial Reference Frame 1992; used as an international standard for geocentric datum to ensure compatibility of co-ordinate systems
MGA	The GDA mapping projection Map Grid of Australia
Parameter	Mathematically derived value used in the transformation of spatial data
PGC	ACT Preliminary Grid Zone Co-ordinates
Projective	A multi parameter, co-ordinate system transformation of non-orthogonal co-ordinates by X scale, Y scale, X translation, Y translation, origin rotation, and axis orthogonal correction and used in conversion between mapping projections
SP1	ICSM Special Publication No.1 outlining recommendations on survey practice methods
Spheroid	A spherical mathematical model depicting the size and shape of the earth and used as a datum for the production of cartesian co-ordinate systems such as WGS84 used in GNSS
Transformation	The mathematical process to convert spatial data from one co-ordinate system to another
Trig Station	A co-ordinated control point with sighting target used to assist orientation in surveying
Weston Creek	A town centre/district within the ACT and test site for AGC co-ordinate system
Woden	A town centre/district within the ACT and test site for CITY co-ordinate system

CHAPTER 1 - INTRODUCTION

1.1 Project Aim

This project investigates three methods of co-ordinate transformation and applies each technique on three existing co-ordinate systems within the Australian Capital Territory (ACT). Conversion of test sites are made into the Australian geodetic standard mapping projection Map Grid Australia (MGA) by using computed transformation parameters. These conversion parameters are then used in an evaluation of error against known values for marks at increasing distances from the test sites used for their calculation. This aim is designed to evaluate the appropriateness of using parameters in transformation of large scale co-ordinate system conversion and quantify the limits of their application.

1.2 Justification

With three co-ordinate systems in the ACT, these systems create problems for users of published co-ordinates. With these systems divided by zone boundaries, crossing these boundaries in survey field work may result in sub-standard precision of data. This is caused from mixing control from a different datum during data acquisition, mixing previously surveyed data from multiple zones to compile a data set or performing engineering or construction works over multiple zones which utilize existing control. Each situation could result in poor quality survey data depending on the variance between co-ordinate systems.

Co-ordinate transformation is a process that is not fully understood by many users of spatial data. An understanding of appropriate application, implications of mixed use and limits of technique is a desirable product of this project. The successful application of a transformation allows a user to extrapolate an existing co-ordinate zone into another where points do not have multiple definitions. This skill is considered advantageous to users of spatial data.

1.3 Benefits

Unifying the co-ordinate systems in the ACT will result in many benefits to users of published survey control marks. This outcome would allow spatial data to be combined due to a common datum and remove confusion by users when using multiple co-ordinate systems. A common datum would allow for a compilation of multiple data currently held on separate systems and create opportunities for new technology to be realized.

1.4 Method

This project was divided into three parts consisting of; acquisition and processing of control observations using GPS receivers, computation of data to achieve parameters for use in conversion formulae and an application of parameters on control points and comparison with known values.

Data collection was required to achieve coincident values for points within two co-ordinate systems. These common points were used to compute the parameters necessary to convert from one system into another. The inclusion of GPS observations quantified the effects of using this technology to efficiently achieve common values compared to conventional traversing.

Computation of conversion parameters was performed using educational freeware. This was included to minimize the burden of longhand computations for multiple calculations. Software was considered essential to achieve project timelines.

Parameters computed were applied to points outside the test sites to determine error over distance. This was intended to quantify the limit and effect of applying conversion parameters outside the region used to calculate them.

CHAPTER 2 - LITERATURE REVIEW

2.1 Introduction

The literature review within this chapter will overview the historical development of the geodetic datum of Australia (GDA), research the development of existing co-ordinate systems in the ACT, and investigate the various styles in the transformation of survey co-ordinates and where these have been used in the past.

The aim of this literature review is to provide an understanding of what a co-ordinate system is and how it is defined with an analysis into how co-ordinate transformation is performed. This is achieved by providing an understanding of background, definition and history of survey co-ordinate systems and co-ordinate transformation. With this understanding, transformation styles are researched and evaluated for which method is best suited for conventional survey control.

Information into the definition and development of existing co-ordinate systems will be researched from government documentation and publications. The method of transformation style will be researched from publications used in scholastic tuition and from literature based on previous examples of application.

2.2 Class and Order

Determination of accuracy and precision of a survey point allows an understanding of how well the point ‘fits’ in relation to surrounding points and to the system in general. These can be viewed as relative and absolute positioning and are represented by a value of class and order (Intergovernmental Committee on Surveying and Mapping, 2004).

This evaluation is considered essential for the understanding of error and how this effects the results obtained in co-ordinate transformation. Points used as control to compute parameters which are of sub-standard accuracy will compound error through the conversion process resulting in diminished values.

Research into the definition and calculation of class and order is determined from the publication from the Intergovernmental Committee on Surveying and Mapping relating to standards and practices in control surveys. This document is referenced within the ACT surveying legislation (ACT Government -

Parliamentary Council, 2007) and bill(ACT Government - Parliamentary Council, 2007).

NSW surveying legislation (New South Wales Government, 2002) and regulations (New South Wales Government, 2006) also refer to this document for definition of standard surveying standards. NSW surveyor general's directions (New South Wales Surveyor General, Department of Lands) also use the SP1 document to provide a standard method of determining the quality of a survey.

2.2.1 Class

Evaluation of class determines the relationship of absolute positioning relative to the whole reference system. This quantity is used to evaluate a weight when using multiple points in transformation. Class is used to represent the point's accuracy which has been defined as;

> *"Accuracy is the measure of the absolute nearness of a measured quantity to its true value."*
> (Ghilani & Wolf, Adjustment Computations - Spatial Data Analysis, 2006)

> *"Accuracy is the relationship between the value of a measurement and the 'true' value of the dimension being measured."*
> (Kavanagh & Glenn Bird, 1996)

Calculation of the value for class of a point is made using equation 2-1 (Intergovernmental Committee on Surveying and Mapping, 2004) and is dependent on the surveys network design, practices adopted, equipment and reduction techniques used.

$$r = c\ (\ d + 0.2\ )$$ **Equation 2-1**

Where
r = length of maximum allowable semi-major axis in milimetres.
c = an empirically derived factor represented by historically accepted precision for a particular standard of survey.
d = distance to any station in kilometres.

CLASS	C (for one sigma)	Typical applications
3A	1	Special high precision surveys
2A	3	High precision National geodetic surveys
A	7.5	National and State geodetic surveys
B	15	Densification of geodetic surveys
C	30	Survey coordination projects
D	50	Lower CLASS projects
E	100	Lower CLASS projects

Table 1 - Classification of Horizontal Control Survey

Source: Special Publication Version 1.6 (ICSM, 2004)

Using Table 1, a value for constant ‘c’ is determined by analyzing the surveys purpose and technique. Calculation of the surveys maximum allowable error is determined and comparison made to achieved error. If achieved error exceeds maximum error, a lesser accuracy constant ‘c’ is chosen and re-evaluated until conformance is achieved. Conformance with maximum allowable error then enables quotation of class achieved for a survey position.

Computed results of class should not be quoted at greater values than control points used in the survey. This results in overconfidence in values and does not reflect the true accuracy of the point (Intergovernmental Committee on Surveying and Mapping, 2004).

2.2.2 Order

For the determination of order, the relationship of a point relative to the surrounding network is determined as precision and can be defined as;

> *"Precision is the degree of consistency between observations based on the size of the discrepancies in a data set…"*
> (Ghilani & Wolf, Adjustment Computations - Spatial Data Analysis, 2006)

> *"Precision describes the refinement with which a measurement is made."*
> (Kavanagh & Glenn Bird, 1996)

The value of order is dependent on the value of class and maximum values have been determined from historically acceptable practices (Intergovernmental Committee on Surveying and Mapping, 2004). This is represented by Table 2.

CLASS	ORDER
3A	00
2A	0
A	1
B	2
C	3
D	4
E	5

Table 2 - Class of a Survey: Highest Order Relationship

Source: Special Publication Version 1.6 (ICSM, 2004)

Evaluating the maximum order achievable from Table 2, equation 2-1 is again used to evaluate the maximum acceptable error associated with observations from the point evaluated. Selection of constant 'c' is taken from evaluation of Table 3 with consideration of maximum order from Table 2 and computation of 'r' is made using equation 2-1.

ORDER	**C value** (for one sigma)
00	1
0	3
1	7.5
2	15
3	30
4	50
5	100

Table 3 - Order of Horizontal Control Survey

Source: Special Publication Version 1.6 (ICSM, 2004)

Evaluation of each measurement from the point is made and consistently achieved results for acceptable error for each measurement from the point determines the overall value for the order achieved. For a point with numerous observations to achieve a position, the consistency in the acceptable error for each measurement is deemed to define the order achieved.

A presumption is made in the definition of 'consistency' to mean isolated events not meeting the evaluated standard may not be deemed to effect the overall result in order. This can be explained where a single observation having a greater error in measurement would be diluted from other measurements at that point. This has been highlighted in the SP1 documentation where order is determined to be more a subjective evaluation and determined by the individual.

> *"The ultimate responsibility for the assignment of ORDER to the stations in a survey network must remain within the subjective judgment of the geodesists of the relevant authority."*

Source: Special Publication Version 1.6, pp. A-10 (ICSM, 2004)

2.3 Datum

In attempting to represent the real world through the presentation of maps and electronic data, it is the underlining reference system that defines how each element is correlated to each other. By using a framework, the elements can be spatially referenced and defined by a datum.

Using co-ordinates as a reference system allows users to quantify the system used in the definition of spatial data. This definition is required for the comparison of data in which points can be directly evaluated when they are defined by the same system. When a conversion between systems is required, information from one system is compared to that of another by using co-ordinate transformation.

The research used to define mapping datum will be sourced from governmental, scholastic and public publications. These will be used to define the history of Australian datum, how they are defined and what benefit is derived by their use.

2.3.1 Australian Geodetic Datum (AGD)

Australia's first astronomically derived geodetic datum was defined and gazetted on October 6th 1966. This was a network of stations spanning the Australian continent comprised of over 2506 stations based on the origin of Johnston Trig (S 25° 56' 54.5515", E 133° 12' 30.0771"). The computations in the adjustment of the network utilized 500 Laplace astronomic stations and the adjustment software known as 'Varicord'(Geosciences Australia). This large scale adjustment was considered successful with the computational limitations of the day (Steed & Allman, 2005)

In 1984 additional observations were made to include geoid & ellipsoid separations and geodimeter distances into a new adjustment using the new software 'CHAOS'. This new adjustment increased the number of stations to 5498 and divided the network into 35 separate sections. This improved network was to supersede AGD66 and be known as AGD84.

Both AGD66 & AGD84 systems being based on the Australian National Spheroid (ANS) and astronomically derived from the Johnson origin were well suited for Australia but soon became obsolete with the wide spread use of Global Positioning Systems (GPS). This was considered to be a result of the AGD astronomical origin and localized ellipsoid definition (Collier P. , 2002). Because Australia needed a geodetic datum that was globally compatible and geocentric, this required a new datum to be established and was to be known as the Geodetic Datum of Australia which would be first realized in 1994 (GDA94).

2.3.2 Geodetic Datum of Australia (GDA)

With the requirement of a geocentric datum came a need for a new network of control stations. The Australian Fiducial Network was established from eight continuous GPS stations with one station each in New South Wales, Queensland, Tasmania & South Australia and two stations in each of the Northern Territory and Western Australia. These stations' co-ordinate values were computed using the International Terrestrial Reference Frame at the epoch 1994 to ensure a geocentric origin and compatibility with the WGS84 reference frame (Intergovernmental Committee on Surveying and Mapping, 1985). This Network was then expanded by GPS campaign between 1992 and 1994 to a further 78 stations across Australia. These additional stations were to be known as the Australian National Network (ANN).

The preliminary expansion of the ANN did not include Western Australia as part of the adjustment due to unavailability of their state GPS network. Although their 'Statefix' network was included, this was not part of the original ANN network (Stewart, Houghton, & Ding, 1997). The completed network was later propagated to co-ordinate the remaining ANN stations within Western Australia previously not observed (Stewart et al, 1997)

The rigorous adjustment of the AFN & ANN networks was computed using the NEWGAN Software to include more than 7000 stations and 71 390 observations. This adjustment used the same style of section method used in the AGD84 adjustment by dividing the data into 12 sections. This method used a 'free adjustment' of each section as a stage 1 adjustment. The common stations of adjoining sections were referred to as 'junction stations' and were then adjusted together as stage 2 adjustments to yield final positions for 'junction stations' which in turn were then held fixed as a stage 3 adjustment for the complete network.

This combined network forms the basis of the existing Geocentric Datum of Australia (GDA). This network as a datum differs from the previous AGD94 datum by approximately 200m (Intergovernmental Committee on Surveying and Mapping, 1997). The new GDA is used as the basis for the projection Map Grid of Australia which is a Transverse Mercator Projection and is now the base projection co-ordinates used in New South Wales and other states.

2.4 ACT Co-ordinate systems

Within the Australian Capital Territory, three separate co-ordinate systems exist and are used as survey control for the development of deposited plans and digital cadastre databases. These systems are isolated by co-ordinate zone boundaries and considered not compatible with each other. Their continued use and separation is considered an obstacle to the development of a unified state co-ordinate system which could be compliant with the Geodetic Datum of Australia standard.

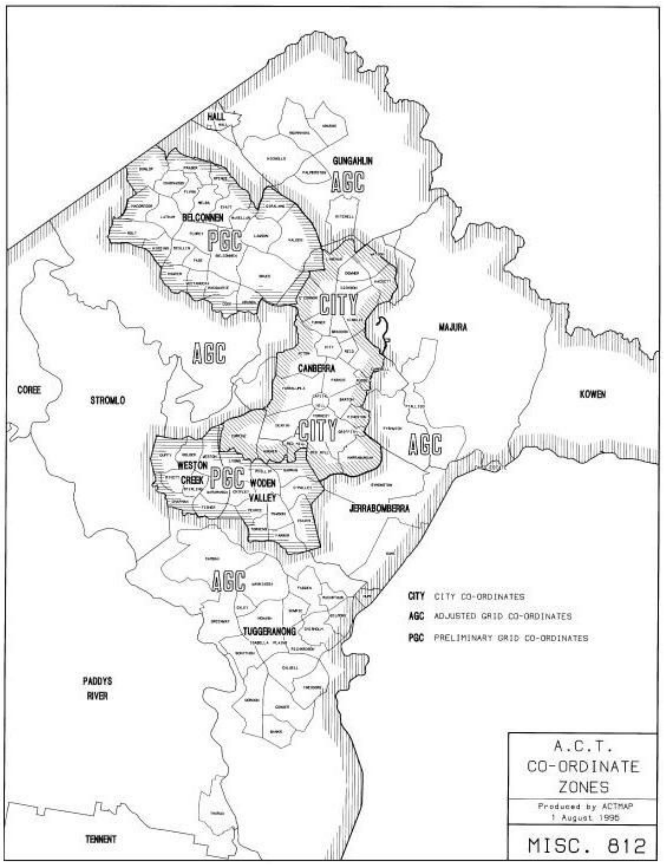

Figure 2-1 ACT Co-ordinate Zone Boundaries

Source: ACT Planning and Land Authority

This aim of the research into existing ACT co-ordinate systems is to determine how each system originated, what factors determined their development and why each system remained with the development and implementation of new systems. With an understanding of where these systems originated and how they developed, a reason may be concluded on why the territory has not formed a single co-ordinate system.

The research will be conducted by evaluating existing public and governmental publications relating to the existing co-ordinate systems and complimented by conducting personal interviews with individuals responsible for their development.

2.4.1 City Co-ordinates (CC)

The first co-ordinate system for the ACT was established from the surrounding New South Wales trigonometrical survey and used the Lake George baseline which was first measured in 1870 (Wellspring, Control Surveys for Satellite Cities, 1966). This frame work was expanded into the ACT and formed a radial network design which allowed further breakdown survey to be conducted.

The original framework used for control in the CITY district experienced difficulty in expansion due to urban growth (Wellspring, Personal Interview, 2007). Monumentation was frequently disturbed with the installation of road frontage services which affected angle measurement from major radial lines. Back bearings would be taken from marks on the radial and street frontages turned which would be propagated through the suburb. Connection between streets frequently highlighted error from the degraded control.

Urban infrastructure was always inherent but the progression of development also aided in the degradation of the CITY system (Wellspring, Personal Interview, 2007). With inherent error in street frontages and degraded co-ordination of monumentation, the need to service the growing suburbs resulted in control being '*cantilevered*' into the new suburbs. This only compounded error with distance and was considered "*economically accurate enough for the growth then envisioned*" (Taylor, 1980).

This 'Ad-hoc' development of the CITY co-ordinate system resulted from limitations of survey equipment used at that time and pressure from rate of growth required by development. Difficulties and experiences with this co-ordinate system have been mirrored with that of Victorian co-ordinate systems (Collier & Leahy, Re-Adjustment of Melbourne's Survey Control Network, 1992). The

Victorian experience also shows early degradation of control resulting from growth and downsizing of government qualified personnel.

With expansion into the Woden and Belconnen valleys, a need to service these satellite cities lead to the development of a new co-ordinate system known as Preliminary Grid Co-ordinates (PGC) and confined the existing CITY system into a zone (Wellspring, Control Surveys for Satellite Cities, 1966).

2.4.2 Preliminary Grid Co-ordinates (PGC)

From the experiences of error associated with the development of the CITY co-ordinate system, the PGC system was designed by defining the region envisioned to experience the most probable growth. This was defined by the Woden and Belconnen valleys and a grid system was established to cover this region using the existing trigonometrical framework.

The origin of the PGC system originated from the Mt. Stromlo trigonometrical station which had known latitude and longitude defined by the Stromlo observatory located adjacent to the station. Using a Transverse Mercator map projection, the zone definition of longitude origin was determined through Stromlo trig and a false easting and northing in Imperial units of E0.000 N0.000 used. This definition also used a modified sea level of 610m equating to a combined scale factor of 1.000086 to allow ground distances to be used as grid distances(Taylor, 1980).

With the Australian conversion from imperial to metric units, the conversion was made of the false origin for the PGC system. The E0.000 & N0.000 used previously would periodically produce negative co-ordinates depending on the region. This was fixed by the conversion to the metric system where the false origin was changed to E200,000 & N600,000. This value allowed for a positive co-ordinate regardless of position within the Woden and Belconnen valleys(Wellspring, Some Aspects of the Conversion from Imperial to Metric Co-ordinates in the Australian Capital Territory, 1973). Variance between the CITY and newly created PGC system has been determined to vary up to the definition of an imperial measure foot(Nicolson, Unknown).

2.4.3 Adjusted Grid Co-ordinates (AGC)

With the growth of Canberra expanding past the Belconnen and Woden valleys, the regions of Gungahlin and Tuggeranong were selected to accommodate the new satellite cities. This required a broader approach to the ACT co-ordinate system to enclose all regions of the territory which would potentially be used for urban growth. The creation of the Adjusted Grid Co-ordinates was so declared(Taylor, 1980).

The AGC system definition was again defined by the modified Transverse Mercator map projection based on the Stromlo origin and used the trigonometrical baselines between One Tree, Coree and Tennant to form a closed figure. This new network used the existing trigonometrical stations but incorporated Laplace corrections so adjustment would not be required in the future. Advances in computing power enabled broad scale network adjustment using least squares techniques with a program called ‘Varicord’ (Wellspring, Personal Interview, 2007).

The development of a new system would allow existing co-ordinates to be retained by isolating the previous systems into co-ordinate zones. This rationale was considered necessary because any change in co-ordinate value of a monument would require updating of deposited plans located in the land titles office used to define title of leased property. This was considered a deterrent to changing existing co-ordinate values and re-defining them (Wellspring, Personal Interview, 2007).

2.5 Transformation Methods

Selection of method used in co-ordinate transformation influences the accuracy of output values and is dependent on the existing co-ordinate system matched to the transformation style. From the literature review into the methods used in co-ordinate transformation, it has been determined that matching the appropriate method with existing and desired co-ordinate systems enables an increase in accuracy of results.

Using definitions of transformation styles (Ghilani & Wolf, Adjustment Computations - Spatial Data Analysis, 2006), three methods were evaluated for this project. These were selected and evaluated into how parameters are calculated and thus derived (University of Southern Queensland, 2004)(University of Southern Queensland, 2005).

Calculation from long hand computations is considered necessary to prove results but is costly in time required to compute numerous calculations. Using electronic software for this component achieved a timely and accurate result compared to manual methods which is prone to human error. Selection of the software application ‘ADJUST’ was made (Ghilani & Wolf, Free Goodies, 2008) to aid in computations and methods researched for the calculation of parameters.

2.5.1 Conformal Transformation

This method of transformation is designed to maintain the shape and relationship of points before and after the conversion process. For this project, existing co-ordinate systems used for the test sites were considered as conventional 2D systems and determined to benefit from this style of transformation method.

The equations used for the calculation of a conformal transformation are given in equation 2.1 and equation 2.2 and include the four unknowns ***a, b, c*** and ***d.*** (Ghilani & Wolf, Adjustment Computations - Spatial Data Analysis, 2006);

$$ax - by + c = X + v_x$$

Equation 2-2

$$ay + bx + d = Y + v_y$$

Equation 2-3

Where,

x = Original easting, y = Original northing
a, b, c, d = Four unknown parameters
v_x, v_y = Transformed residuals
X = Transformed easting
Y = Transformed northing

From equations 2.1 and 2.2 the values of ***a, b, c*** and ***d*** must first be known to convert desired points. These values can be computed using the ‘ADJUST’ software application using control points with known values in both systems used in the transformation. These control points are input using a text file with both system co-ordinates and processing determines unknowns using an iterative process.

Inclusion of additional points for conversion can be made into the input files making transformation a one-step process. Evaluating output files summarize values used for control with parameters used in the conversion. Converted points in pre-transformation and post-transformation values are also listed in the output file.

2.5.2 Affine Transformation

Application of this transformation is used in the conversion of 2D photogrammetric co-ordinates and requires a minimum of three control points for a unique solution. Aerial imagery is prone to distortion due to a tilted horizontal plane making co-ordinate axis non-orthogonal. The result of this is a scale in each of the two axis'. The effect of separate scale is corrected by the inclusion of two additional parameters for each axis as compared to the conformal transformation.

Equations used for this transformation are summarized in equations 2.4 and 2.6 and include six unknowns. (Ghilani & Wolf, Adjustment Computations - Spatial Data Analysis, 2006)

$$ax + by + c = X + v_x$$

Equation 2-4

$$dx + ey + f = Y + v_y$$

Equation 2-5

Where,

x = Original easting, y = Original northing
a, b, c, d, e, f = Six unknown parameters
v_x, v_y = Transformed residuals
X = Transformed easting
Y = Transformed northing

From equations 2-4 and 2-5, the values of unknowns must also be known first to compute transformed values. From the application of software, values are derived for the six unknowns allowing each equation to be solved. Application of equation 2-4 and 2-5 is identical to equation 2-2 and 2-3 with the inclusion of parameters 'e' and 'f'. If the original co-ordinate system does not have unequal scales for each axis, the use of the affine method of transformation would have minimal effect on results compared to the conformal method described in section 2.6.1.

2.5.3 Projective Transformation

This method of transformation is designed for the conversion of map projections and a minimum of four control points are required for a unique solution. Example uses of this style may include conversion from Australian Map Grid co-ordinates to Map Grid Australia co-ordinates or 2D photo co-ordinates into another 2D photo co-ordinate system. Both examples are projections of the real earth onto mapping planes.

The equations used in the projective transformation include eight parameters and are summarized in equations 2-6 and 2-7 (Ghilani & Wolf, Adjustment Computations - Spatial Data Analysis, 2006). These are similar to the affine method should the values for $\boldsymbol{a_3}$ and $\boldsymbol{b_3}$ equate to zero.

$$\frac{a_1x + b_1y + c_1}{a_3x + b_3y + 1} = X + v_x$$

Equation 2-6

$$\frac{a_2x + b_2y + c_2}{a_3x + b_3y + 1} = Y + v_y$$

Equation 2-7

Where,

x = Original easting, y = Original northing
$a_1, b_1, c_1, a_2, b_2, c_2, a_3, b_3$ = Eight unknown parameters
v_x, v_y = Transformed residuals
X = Transformed easting
Y = Transformed northing

Using equations 2-6 and 2-7 require the values for the eight unknowns to be first known. This is computed from the processing of the control points within the 'ADJUST' software application. Control is again input by text files and additional conversion points added with output values in text format in the converted system. Parameters for the unknowns are also summarized from output files. These can then be used for equations 2-6 and 2-7 for additional conversion.

2.6 Previous Transformations

By examining the experiences of past co-ordinate conversion, an understanding can be achieved into the requirements and expectations of the conversion process. By examining the past applications, knowledge is gained into why systems have developed into the systems found today.

Using past experience in conversion of co-ordinates enables a better insight into why specific methods are selected and an appreciation is gained for the processes of each. Better understanding by the user enables better judgment of process selection.

The research of past examples of co-ordinate conversion will be taken from journal articles and reports. These are considered evidence of experience from previous attempts at co-ordinate conversion and are detailed testimony of direct application.

2.6.1 North American Datum

The geodetic datum used in North America was initially defined as the North American Datum of 1927 (NAD27). This datum was found to have numerous inconsistencies and errors in magnitude of up to 30 meters(Junkins & Farley, 1995). This original definition is based upon astronomical origins with a localized ellipsoid and a conversion was requested by the United States National Geodetic Survey to correct these anomalies. The new datum was to be referred to as NAD83.

The process of a defining a new datum for North America involved defining a new co-ordinate system by the selection of an earth centered ellipsoid. This did not equate to a transformation, but instead used original observations and re-adjustment of the original network. This task involved 272,000 stations and 180,000 measurements across the North American continent (Collier, Leahy, & Argeseanu, Transition to the Geocentric Datum of Australia - Consultants report to the Office of the Surveyor General, Victoria, 1996).

With the datum re-defined, a conversion of data sets in the old NAD27 system required updating. This process used a grid shift while incorporating a distortion model through interpolation using a software package called National

Transformation Version 2 (NTv2). The distortion model is considered to be a "high accuracy transformation" (Intergovernmental Committee on Surveying and Mapping, 1985) and is used in conjunction with the NTv2 software.

With the conversion from NAD27 to NAD83, changes in the co-ordinates ranged up to 250m(Junkins & Farley, 1995). This was a result of bringing the new datum in-line with a geocentric datum and brought numerous benefits. Some of these included a definition of an international ellipsoidal standard, removal of significant distortions, compatibility with GPS operations and increases in precision.

2.6.2 Geodetic Datum of Australia

Using the North American experience, a re-definition from AGD66 and AGD84 into a geocentric datum was completed in 1994 with the creation of the Geodetic Datum of Australia (GDA94). This definition linked the Australian network into the International Terrestrial Reference Frame (ITRF) through the preliminary Australian Fiducial Network (AFN) comprised of eight GPS operating stations. Expansion involved the sub-network of 78 geodetic stations known as the Australian National Network (ANN). This was later broken down into state and territory geodetic networks.

With the creation of GDA94, a conversion was made of the preliminary AFN. This involved a re-adjustment rather than a transformation. Using original observations and measurements, the network was recommended to be re-adjusted to form the fixed network from which sub networks could be linked (Collier, Leahy, & Argeseanu, Transition to the Geocentric Datum of Australia - Consultants report to the Office of the Surveyor General, Victoria, 1996). This allowed for the original observations to define the network.

With the transition of large scale networks and datasets to the new datum, processing software was designed using distortion modeling to interpolate shifts for data. This was developed using the North American experience using the NTv2 software application. Different states and territories were recommended to use specific distortion models unique to their region (Collier P. , 2002) and development of specific conversion software (Collier & Mitchell, 2000). Where control networks were complex, recommendations were made to use the interpolation software rather than incorporate the re-adjustment using original observations.

Conversion of datum was considered to be best achieved by re-adjustment of original observations (Collier, Leahy, & Argeseanu, Transition to the Geocentric Datum of Australia - Consultants report to the Office of the Surveyor General, Victoria, 1996). With large scale networks and paper based mapping, conversion by this method was considered impractical. Transformation using block shift methods by incorporating distortion modeling through software application was therefore adopted.

2.7 Conclusion

From the literature review, an understanding has been achieved into the background of the quality of positional control, development of existing co-ordinate systems, definition of current systems used, methods used in transformation and past application of co-ordinate conversion.

Using this background as a foundation, this project has applied this knowledge in the conversion of the CITY, PGC and AGC co-ordinate systems found in the Australian Capital Territory into Map Grid Australia. Evaluation of results will use the knowledge acquired to determine this application in large scale conversion of co-ordinate systems.

CHAPTER 3 - METHODOLOGY

3.1 Introduction

Examination of methodology within this chapter will detail the procedures used to acquire common data between co-ordinate systems, outline the steps of calculation for parameter calculation and define how derived parameters were applied to convert existing co-ordinates into MGA values.

The aim of this chapter is to define the methods performed resulting in parameter calculation and conversion of test co-ordinates. This is demonstrated to highlight the steps necessary to achieve a successful conversion. The procedures outlined show how data was collected, processed and computed and the calculations performed

The methodology will describe the selection of test sites, method used in data gathering, processing method on acquired data, processes used in calculation of transformations and conversion of external points to test sites.

3.2 Test Sites

ACT co-ordinate systems were represented by the selection of a test site located within each co-ordinate zone. These sites were chosen for availability of minimum class and order B/2 marks that existed, were accessible and in favorable condition. Geometry was evaluated for those potential points and site visits confirmed condition and access.

3.2.1 Belconnen – PGC Co-ordinate System

This region was found to have adequate marks but many sites were not suitable due to their proximity to major roads. Concern for damage or vandalism of equipment was a major concern. The selected suburb of Lawson has a large region of open space and a major control point being Reservoir trig located in the middle of the site. The perimeter of the suburb has a dense network of class B/2 marks with adequate geometry. This site was chosen for its major control point and geometry of secure marks.

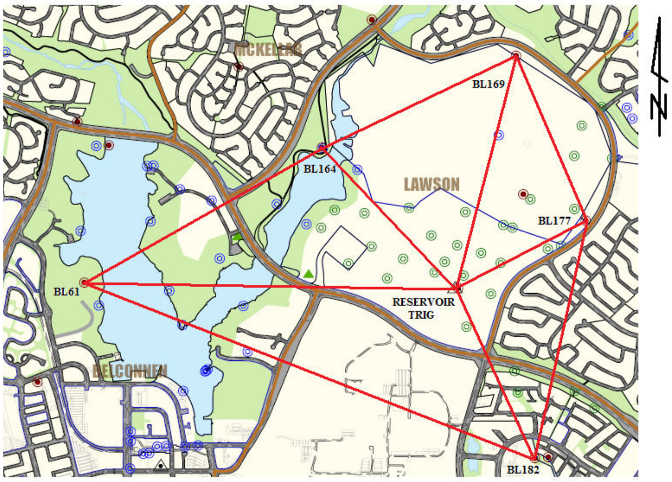

Figure 3-1 Belconnen Vector Geometry

Source: (ACT Planning and Land Authority, 2007)

3.2.2 Weston Creek – AGC Co-ordinate System

This test site has the benefit of multiple trigonometric stations located around the perimeter of the town region. These marks provided a safe location for equipment to log GPS data while transferring between stations. With these marks being located on hill tops, difficulty was experienced in shuttling equipment up steep slopes. These marks were selected on their proximity to main roads to minimize access distances, baseline geometry and class/order minimum B/2 standards.

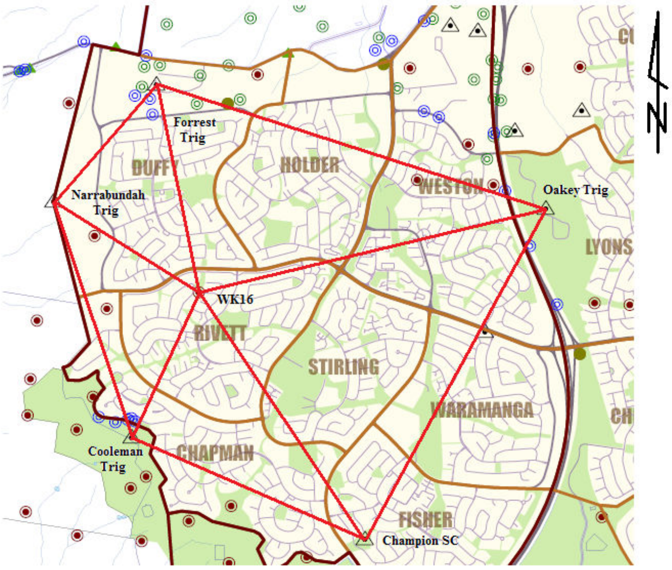

Figure 3-2 Weston Creek Vector Geometry

Source: (ACT Planning and Land Authority, 2007)

3.2.3 Woden – CC Co-ordinate System

The availability of marks in this zone with published CC values was the influencing factor of mark selection. Published values are decreasingly available with ongoing conversion by the government survey office. The marks selected satisfy the class and order B/2 minimum with geometry improved by using braced baselines for improving processing results. The marks are located at street level and equipment was carefully monitored to prevent random acts of vandalism. Additional help was utilized to minimize receiver movement and maximize observed baselines. This allowed for best fit by selection from redundant baselines in processing.

Figure 3-3 Woden Vector Geometry

Source: (ACT Planning and Land Authority, 2007)

3.3 Data Processing

After test sites had been chosen and control points selected, baselines were observed using GPS receivers. The data vector collection formed closed figures in network geometry to allow network adjustment of processed vectors over the sites.

3.3.1 Data collection

Observation sessions used multiple receivers over different test sites. The Belconnen test site used two Thales GPS receivers over twenty minute overlapping sessions. The Woden and Weston test sites utilized an additional two

Leica GPS receivers totaling four receivers to 'leap-frog' between observation times. These additional receivers reduced total observation time by less than half.

The inclusion of additional receivers and personnel was designed to reduce exposure of equipment to vandalism and theft. Oakey trig used in the Weston and Woden sites is situated upon a hill frequented by bush walkers and the GPS base was victim to minor tampering during the Weston observation session.

3.3.2 Processing

Downloaded raw data was processed using the proprietary software from Magellan *GNSS solutions*. This package allows processing of vector data and network least squares adjustment. After vectors had been processed between control points, closed figures were checked for loop closure values. A network adjustment was then performed using the least squares engine within the software and results of processing with network adjustment for each test site were exported as a report and detailed in Appendix B.

3.3.3 Class and Order

Adjusted values from the network adjustment were given a class and order value to determine if post processed data was suitable for calculation purposes. This was determined to be necessary to minimize the effects of error propagation introduced from the data collected.

Class was determined using the formulae 2-1 discussed in chapter 2 and each leg of the network geometry was evaluated for achieved error from post processed adjusted results and compared to maximum acceptable limit for corresponding class values.

Order was also determined using equation 2-1 used in the class calculation with use of a different constant for the value of 'c'. This maximum order value was compared to the achieved results and the observed order was determined for each test site. The summary of calculations for class and order are detailed in Appendix G.

3.4 Parameter Calculation

Calculation of specific parameters was determined using the academic adjustment software ADJUST from the Pennsylvania state university Geomatics department. This package is a freeware package used to adjust survey data and has a transformation application (Ghilani & Wolf, Free Goodies, 2008).

Processed and adjusted data for each test site was compiled into individual text files with survey data compiled into input files. File formats must include fixed co-ordinates of control points in each of the systems converted from and converted into. Processing each file successfully results in conversion parameters used to convert from one system into another. Parameter results for each test site are summarized in figures 4-1, 4-2 and 4-3.

3.5 Point Conversion

Conversion of additional points using transformation parameters is performed by inclusion of co-ordinates within the input files of the ADJUST program. The points are added to the end of the file and re-processing input file with additional points will output converted points in report format with conversion parameters also included from control used.

Points outside the co-ordinate zone test sites were selected for conversion based on criteria of known values in MGA and distance from calculation test site. This would allow a direct comparison to known values when parameters are used to convert points at increasing distances from each test site. The results of these comparisons are discussed in chapter four.

3.6 Conclusion

This chapter has discussed the method used in the collection, processing and calculation of data to determine parameters used in the transformation of survey control points from three co-ordinate zones found in the ACT into the map projection MGA using test sites to represent each zone. The method used software to batch process points to minimize computational overload and processing results have been tabulated in appendix B.

CHAPTER 4 - RESULTS

4.1 Introduction

The results outlined in this chapter provide a detailed analysis of the processing of collected data, calculation of parameters and the results obtained from transformation using these parameters.

The aim of this chapter is to quantify the results obtained from application of locally derived parameters from each of the test sites representing the existing co-ordinate systems found in the ACT.

Results of post processing will be evaluated for conformance with class and order minimum acceptable error. Achieving acceptable results, a computation of parameters is made and used in the conversion of external points outside the local test site. Converted values are then compared to known values and errors are contrasted against acceptable limits.

4.2 Processing Results

The evaluation of results includes identification of the quality of GPS processing results achieved by calculating a value for the class and order for the survey (ICSM, 2004). These values determine the relative and absolute accuracies for the MGA co-ordinates computed.

4.2.1 Class Evaluation

The calculation of class uses formulae 2-1 and uses various values for constant 'C' taken from the publication SP1 found in "Table 1 – Classification of horizontal Control Surveys" (ICSM,2004). This constant is considered to achieve a "*historically accepted precision for a particular standard of survey*" which relates to past experience. The value of class determines the planned and perceived precision of the network observed in a survey. This value relies upon the design of network, practices employed, equipment used and technique used in processing results. The statement of class can be thought as an absolute position of a point within a network.

From the mission planning described in section 3.2, marks selected included territory published class B co-ordinates. From the application of formulae 2-1 it was determined that the achieved class B was achieved for all points computed for each test site. Summary of calculation of class for all points is summarized in appendix E.

4.2.2 Order Evaluation

With the calculation of order, the same formulae is applied as in the calculation of class. Due to the order being a function of class the maximum order is determined from "*Table 2 Survey of a CLASS - Highest ORDER Relationship*" (ICSM, 2004). This limits the order value from its correlation to class and determines which value for constant 'C' is to be applied as outlined in "*Table 3 ORDER of Horizontal Control Survey*" (ICSM, 2004). The value of order can be thought of as relative position to the surrounding network.

With the appropriate constant determined and applied in formulae 2-1, the maximum acceptable semi-major axis value for the confidence error ellipse was determined and compared to observed results. From the summary outlined in appendix G it was determined that the order achieved resulted in a value of 2 and this is equivalent to the published control marks observed.

4.2.3 Class and Order Summary

Using the observed values for class and order in the achieved results, the processed MGA co-ordinates were assessed to determine if they would be appropriate for calculation of transformation values. The conclusion was determined that these points would not introduce error as a result of the post processing results due to their equivalent precision to surrounding control used. These marks were produced with final MGA values of class B and order 2 results achieved. To determine the effects of using GPS processed co-ordinates, comparison with known values was evaluated.

From the results, the precision for the majority of values observed had a conformance with class 'A' standard. Because fixed control was published to a class and order of B/2 standard, quotation of result was limited to this standard. Adoption of a class 'A' standard would have satisfied the ICSM recommendation under the definition of *consistency* as discussed in section 2.2.2.

4.3 Parameter Results

With MGA values achieved for control points in the test site co-ordinate systems, the calculations of transformation parameters were then performed. Text files were produced outlining the processed MGA co-ordinates with the published zone co-ordinates for each test site. These files were then processed by the 'ADJUST' software application (Ghilani & Wolf, Adjustment Computations - Spatial Data Analysis, 2006) for each of the methods of transformation evaluated.

4.3.1 Conformal Transformation

From the conformal method within the ADJUST software input text files were processed for each test site. From the output report values were computed for each of the four unknown parameters of a, b, Tx and Ty as defined in equations 2-2 and 2-3. These values representing the conformal method of transformation are summarized in Table 4-1 for each of the test sites selected.

CONFORMAL	a	b	Tx	Ty
AGC - Weston	0.99973	-0.02029	470647.143	5494256.988
PGC - Belconnen	0.99975	-0.02024	470673.885	5494235.228
CITY - Woden	0.99974	-0.02028	470652.959	5494251.476

Figure 4-1 Conformal Parameters

4.3.2 Affine Transformation

Using the observed processed values of MGA co-ordinates and known zone co-ordinates for the control points within each test site, values were entered into text files to summarize common control points for each site. These files were then processed by the ADJUST software application and an output report generated. Values for the unknowns from equations 2-4 and 2-5 used in the affine method of transformation were determined and a summary is provided in Table 4-2.

AFFINE	a	b	c	d	e	f
AGC - Weston	0.99973	0.02029	470645.238	-0.02028	0.99973	5494257.630
PGC - Belconnen	0.99975	0.02023	470675.811	-0.02024	0.99975	5494235.567
CITY - Woden	0.99973	0.02026	470661.664	-0.02028	0.99974	5494251.777

Figure 4-2 Affine Parameters

4.3.3 Projective Transformation

With the MGA co-ordinates derived for each test site and the known values in each co-ordinate zone, the final input file was compiled. This file was processed by the ADJUST software application using the projective method of transformation. The output reports summarized each of the eight unknowns in equations 2-6 & 2-7 and are summarized in Table 4-3.

PROJECTIVE	a1	b1	c1	a2	b2	c2	a3	b3
AGC - Weston	0.99748	0.02048	470727.357	-0.03687	1.00113	5494481.505	0	0
PGC - Belconnen	1.00168	0.02172	470361.260	-0.01588	1.01404	5493367.396	0	0
CITY - Woden	1.01022	0.03476	468052.610	-0.03341	1.13768	5487157.076	0	0

Figure 4-3 Projective Parameters

4.4 Parameter Application

Using the parameters derived for each test site to convert control points from existing co-ordinates to MGA map projection values, the direct application was made to convert points external to the test sites. These points had co-ordinates in the system used to derive the parameters.

Selection was determined by selecting points at an increasing radius from the test sites. These marks were then converted into MGA values and compared to known values for each. Comparisons were made and differences were compared to acceptable limits determined by application of class and order.

Using the distances from each test site to individual points, the co-ordinates between known and converted MGA values was compared. The tolerance for the acceptable error was calculated and based upon the class and order value from parameter control points used. This value was derived using equation 2-1 and dictated by the radius from the test site for calculation purposes.

4.4.1 AGC Parameters: Conformal, Affine & Projective

For the Weston test site representing the AGC co-ordinate zone, points external to the test site were converted using the parameters derived using the conformal, affine and projective method of transformation.

The distances of selected points would not be considered appropriate for conversion due to the small sample size of the test site but effectively represent the trend resulting from a cantilevered extension of parameters from the test site for each method examined.

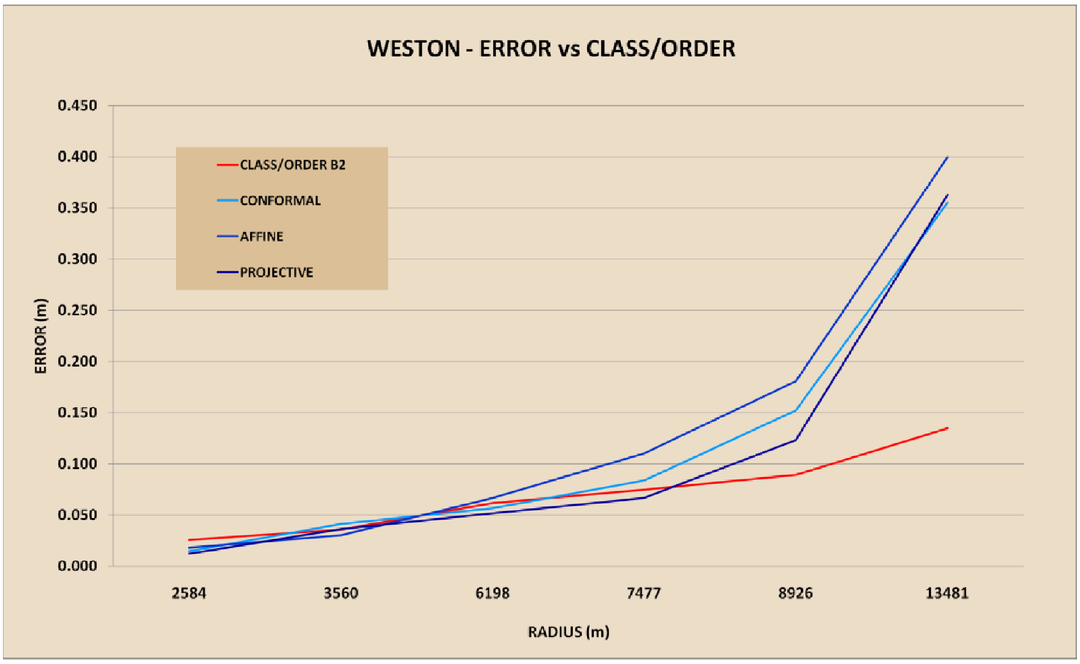

Figure 4-4 AGC Co-ordinate Zone Error vs. B/2 Class & Order

In figure 4-4 the plot of observed error against acceptable error as determined from the B/2 standard shows the application of the projective method of transformation with the least error of the three methods. Applying a trend curve to the examined points, results in the effect of local influence of individual points being reduced. This is represented in figure 4-5.

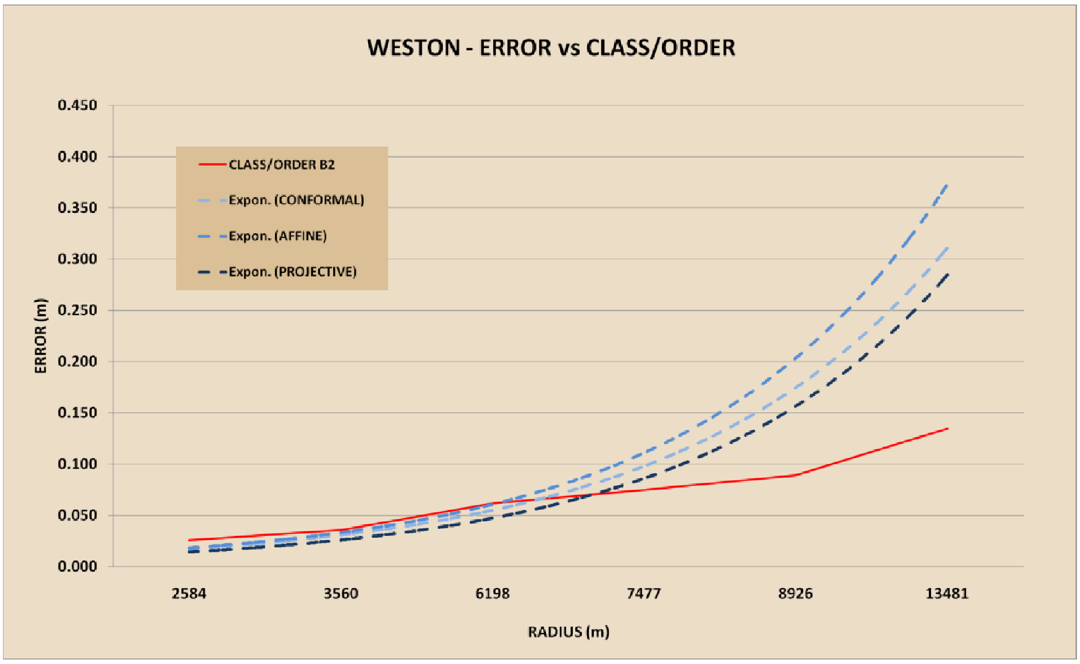

Figure 4-5 AGC Co-ordinate Zone Trend

Examining figures 4-4 and 4-5 it is shown the AGC parameters for the conformal, affine and projective method of transformation can be seen to have a varied result in error with distance from the test site. From these figures, the method resulting in the least error from the application of derived parameters of the sample AGC test site at increasing distances is determined as the projective method of transformation.

4.4.2 PGC Parameter: Conformal, Affine & Projective

For the Belconnen test site representing the PGC co-ordinate zone, selected points at increasing radii from the test site were converted using the parameters derived from the conformal, affine and projective method of transformation into MGA values. These converted points were then compared to known published values and evaluated against the B/2 standard from the testing site.

Sufficient distance was selected for the range of points converted from the test site to highlight the effect of the extrapolation from the test site of the parameters used. It is again noted that these distances would not be appropriate for application of the derived parameters due to the small area used in their calculation.

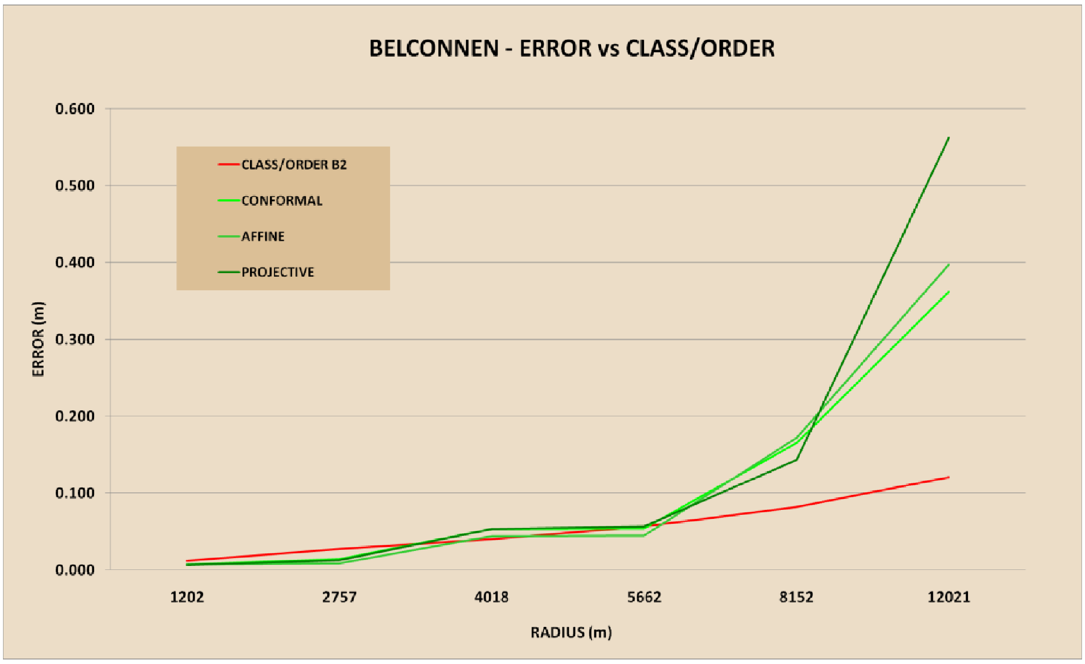

Figure 4-6 PGC Co-ordinate Zone Error vs. B/2 Class & Order

Examining figure 4-6, the point converted at the 4018m mark has distorted the curve with a possible over-confidence in the published MGA value. This effect of local distortion is again removed with the application of a trend curve to assess the results of each method. This is represented in figure 4-7 and results indicate a close correlation between each transformation method applied for this co-ordinate zone.

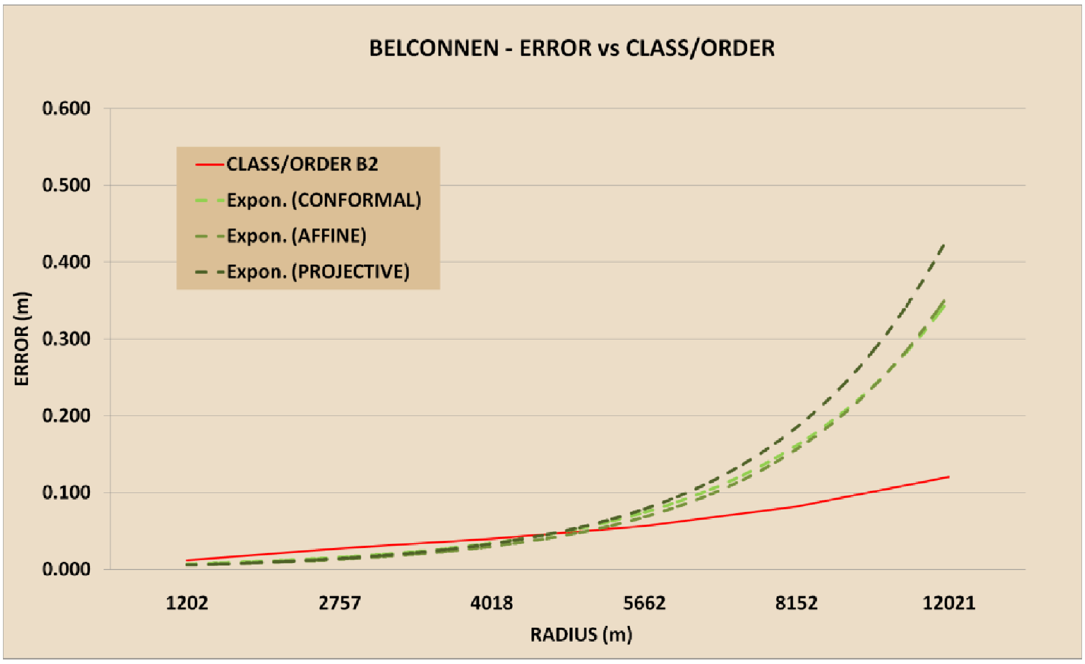

Figure 4-7 PGC Co-ordinate Zone Trend

4.4.3 CITY Parameters: Conformal, Affine & Projective

For the Woden test site representing the CITY co-ordinate zone, parameters for three transformation methods were applied to points outside the testing site. The selection of points included marks of lesser precision compared to points used in the test site due to lack of published values available. Marks in this zone have known issues with precision resulting in class and order values not being available. History of this co-ordinate zone's development has been highlighted in section 2.4.1.

Similar to the AGC and PGC co-ordinate zones, marks were also selected at increasing distances from the testing site. These points were then converted using parameters derived for the transformation methods researched. These points then having MGA values were then compared to known published values for each. With the evaluation of the B/2 class and order standard from the test site, formulae 2-1 was applied to determine acceptable error for each mark and results are outlined in figure 4-8.

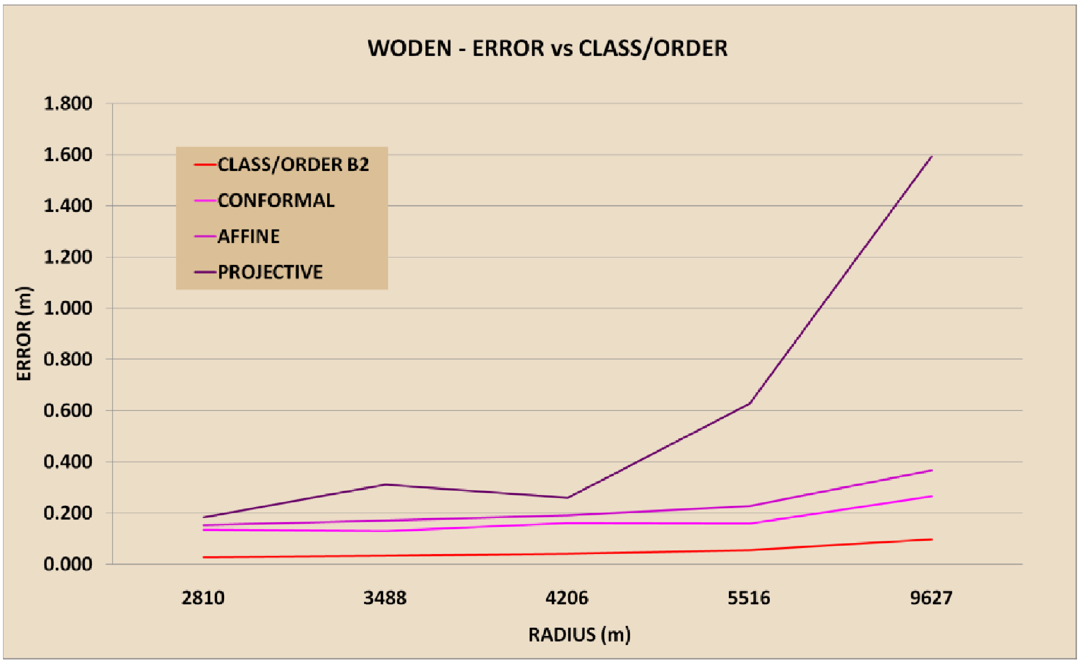

Figure 4-8 CITY Co-ordinate Zone Error vs. B/2 Class & Order

Evaluating figure 4-8, the application of the projective parameters yields a spike in the point evaluated at the 3488m radius. Because this is not represented in the conformal and affine method, this is not determined to result from an over confidence in the published value and isolated to the method of transformation. To eliminate this influence a trend curve is again applied and represented in figure 4-9.

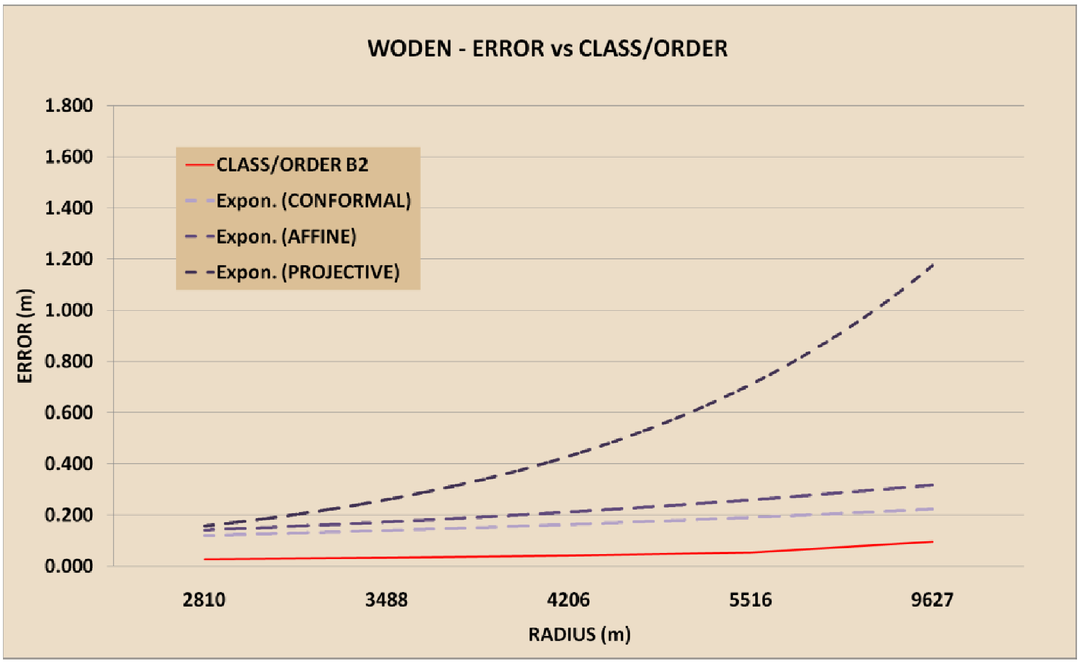

Figure 4-9 CITY Co-ordinate Zone Trend

Examining figure 4-9, the error observed does not conform to B/2 minimum standards at any radius from the testing site. This is a result of known precision errors within the co-ordinate system and can be used to justify the post development of the newer co-ordinate systems being PGC and AGC.

4.4.4 GPS Parameters vs. Known Parameters

Using GPS processed MGA co-ordinates in the calculation of transformation parameters enables efficiency in control definition. To examine the amount a processed control point will affect the transformation process, comparison has been made using known value control points to compute parameters and convert external points. Due to limitation of published MGA values for the Woden test site representing the CITY zone, only remaining AGC and PGC zones were evaluated.

Examining the AGC co-ordinate zone, points were converted external to the Weston test site. This was achieved by using parameters from calculations using known control points and calculations using GPS observed control points. This comparison is examined in figure 4-10.

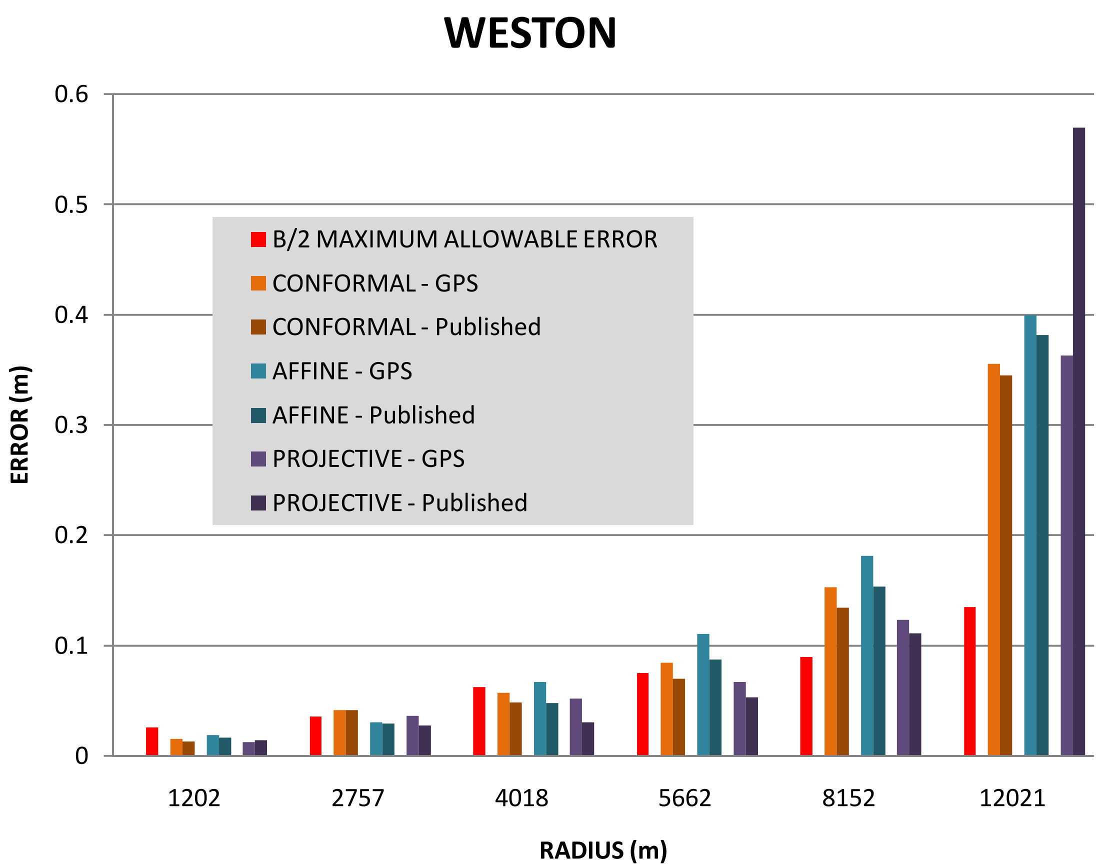

Figure 4-10 AGC Transformed Points

From the results indicated in figure 4-10, points converted using GPS derived parameters consistently have a small increase in error when compared to points converted using known value control point parameters. This is considered to be a result of the GPS observations and post processing results. Evaluating the results in close proximity to the test site, this difference is minimal and increases in magnitude with distance.

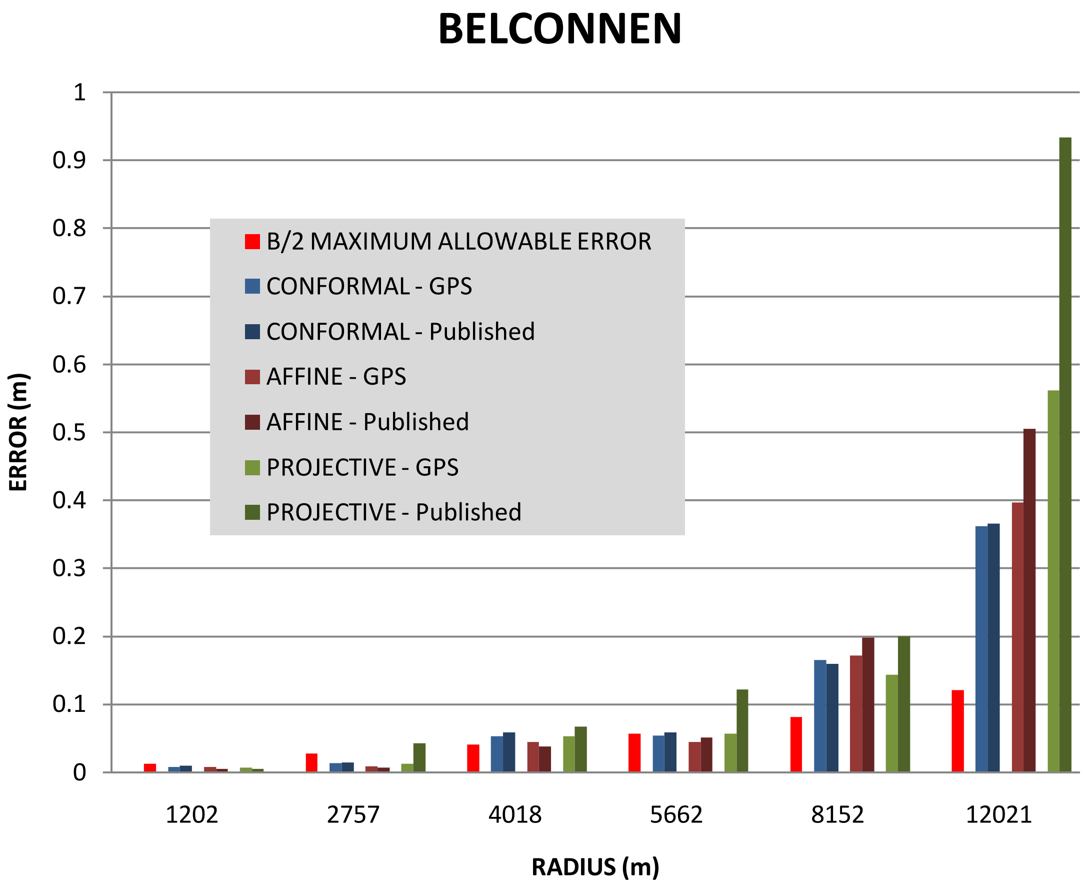

Figure 4-11 PGC Transformed Points

Evaluating the comparison in the PGC co-ordinate zone from figure 4-11, the trend of converted points having less error is reversed. This is again considered to be a result of processing of observations but is consistent in having minimal difference at close proximity to the test site.

Comparing both figure 4-10 and figure 4-11, the use of GPS to convert points within short distances from test sites can be seen to have minimal impact on converted results. This is conditional on results from post processing and the quality of control points used. Using GPS derived MGA co-ordinates, parameters were computed and points converted at increasing distances from test sites.

4.5 Conclusion

The preceding chapter has summarized and detailed the results found within this project being the processing results of data collection, parameter calculation results for test sites, evaluation of effects from using GPS observations and transformation methods and effects of application of parameters to external points to the testing sites.

The processing results using GPS data collection techniques to derive MGA co-ordinates have been found to conform to minimum class B and order 2 precision standards. This has allowed for the minimization of the effect of processing error in the influencing transformation results as shown in figure 4-10 and figure 4-11.

Parameter calculation using the ADJUST software (Ghilani & Wolf, Free Goodies, 2008) within test sites for the conformal, affine and projective transformation method has been determined using selected control points. These points have values in two co-ordinate systems allowing a conversion from one system into another by application of the derived parameters.

Testing of parameter application has been demonstrated by converting points found external to the test site at increasing radius. The error from conversion was determined by comparison with known values in MGA. The difference in values representing this error was then compared to application of B/2 class and order standards for distances from the test sites and plotted for comparison.

CHAPTER 5 - DISCUSSION

5.1 Introduction

The discussion of results in this chapter is intended to provide a qualitative analysis of the results obtained during this project being the conversion of known co-ordinates within each of the local test sites onto the MGA projection.

The aim of evaluating the results is to obtain an understanding of how each of the transformation styles affect a conversion and quantify the limits in distance in using locally derived parameters.

Discussion on outcomes will provide insight into how the inclusion of GPS/GNSS observation techniques effect transformation, what are the effects of selecting a conformal, affine or projective style in a transformation of a data set, what distance limit can be expected in parameter application in a transformation conversion and what should be considered best practice in calculation of parameters for transformation.

5.2 GPS/GNSS Data Acquisition

With co-ordinate conversion, regardless of style selected, common control points must be present which represent both systems in the conversion. This situation is presented as an ideal situation but realistically may not always be achievable. When coincident points are required, conventional survey techniques can be employed through the conventional traverse. This may present difficulty in certain circumstances and result in timely field work. The inclusion of GPS/GNSS observation can improve this obstacle.

From the results presented within this project, the inclusion of GPS observations has been observed to achieve acceptable co-ordination results. This is evaluated using the class and order method of describing the precision acquired. Results have shown by achieving equal or better results in post processing of observed data, a minimum effect on transformation is achieved.

The evaluation of the application of derived parameters within this project have shown acceptable error in close proximity to testing areas for the proven PGC and AGC co-ordinate systems compared to similar class and order standards at various distances. Evaluation of application to the CITY system was found to be unreliable and supports researched background into the co-ordinate system development.

5.3 Transformation Style

The styles of co-ordinate transformation used in this project have specific application on spatial data. Conformal methods have an intended use on conventional 2D systems, affine on aerial photography and projective on map projections. By application of each style on the three existing co-ordinate systems found within the ACT, an obvious error was expected to be observed once evaluated.

5.3.1 AGC Co-ordinate zone

For the AGC co-ordinate zone represented by the Weston test site, results indicate the projective style achieved the better results at larger distances outside the testing area. This would appear to be consistent with the definition as this system is a modified map projection. Conversion from the modified AGC map projection into the MGA map projection has the best results from use of the projective style of transformation.

5.3.2 PGC Co-ordinate zone

In the PGC co-ordinate zone represented by the Belconnen test site, the results were not as clearly identified. This conversion had a close relationship between each style at varying distances from the test site. Due to the lack of significant discrepancies, a clear decision is not concluded. Using the extreme distances of points converted, the conformal method appears to achieve the better of results.

5.3.3 CITY Co-ordinate zone

Using the CITY co-ordinate zone represented by the Woden test site, results were also not conclusive due to lack of published precision of control points used in the test area. Treatment of system is considered local and qualitative analysis has not shown any acceptable conversion into the MGA system. This is thought to be a result of the original development of the system by using a cantilevered approach to the expansion of co-ordinates during the early development of Canberra.

5.3.4 Style Summary

With the evaluation of points in close proximity to the test areas, variance in error between styles is considered minimal regardless of style used. With application of parameters outside the testing area, errors associated with style become evident. Quantity of errors is closely correlated to precision of control points used and varies with selection and inclusion of individual control points.

5.4 Parameter limit of application

With the conversion of points external to a testing area, the method used in the transformation results in different errors. The evaluation of an acceptable limit of distance was tested for each transformation style in this project against the class and order from the control points used. Using this standard, a limit was determined for each co-ordinate zone and evaluated against observed error.

5.4.1 AGC co-ordinate zone

In the Weston test site, a limit of approximately 6km to achieve acceptable conversion was observed. This limit was determined as the point where each method evaluated exceeded the class and order maximum error. Influence of individual points at closer distances exceeded maximum error but this was a result of style only and was incorporated by application of trend curves.

5.4.2 PGC co-ordinate zone

For the PGC co-ordinate zone represented by the Belconnen test site, the limit of maximum distance was determined to be approximately 5km. Again this limit is seen as the maximum distance at which acceptable error is achieved in each of the methods evaluated. A point included at the 4km radius exceeded acceptable class and order limits and was considered as over-confident in the MGA value. Application of trend curves is applied to average observed errors.

5.4.3 CITY co-ordinate zone

For the CITY co-ordinate system represented by the Woden test site, no limit achieved acceptable standards. This is again a result of the precision of points selected. Trend curves have been included to smooth graphing and show relationship between styles of transformation.

5.4.4 Application Limit Summary

In the evaluation of a limit of parameter application an assumption is made that acceptable limits represent maximum error. Limits are considered a guide and effort should be made into minimizing error. Observed limits reach maximum error past 4km external to test site regardless of style and are dependent on precision of control used. The results in distances outside the testing area are found to be increasing in error. This leads to an evaluation of minimizing the distance required outside a test site with best results achieved by not transforming points external to the control network.

5.5 Best Practice Guidelines

With the use of transformation in the conversion of existing co-ordinates into another co-ordinate system, best practice guidelines can be used to maximize precision of results. The outcomes from this project have highlighted specific areas of choice which effect overall results. This includes selection of transformation style, geometry with precision of control points used and distance limits applied to points converted.

5.5.1 Style Selection

From the results, it can be seen that the selection of style can affect the results of conversion. Using the analysis in chapter 2, the style chosen for transformation should be matched to the co-ordinate system being converted. Transformation style can be best applied to conventional 2D survey systems using a conformal method, aerial photography to the affine method and map projection co-ordinate systems with the projective method.

5.5.2 Control Points

Selection of points used as control between co-ordinate systems should be evaluated based on precision of known values. This requires a comparison of class and order of known values and selection given to points with the highest level of precision. This is intended to minimize the effect of sub standard control.

To compliment the precision, geometry of control should be evaluated in relation to remaining marks requiring conversion. Location of control would ideally be situated surrounding points to be converted. Using the convention of working “from the whole to the part” eliminates the effect of error extrapolation external to the region used as the control. Points external to the test site should undergo evaluation of distances for effect of error on post transformation results.

5.5.3 Conversion Limit

With extrapolation, error is compounded with distance and should ideally be kept to a minimum. From the results, limits of 4km to 5km as a maximum have achieved acceptable results. This limit is at the extreme end of allowable error and not recommended as an applicable distance from the control region.

5.6 Conclusion

From the evidence found during the course of this project, three outcomes have been discussed in this chapter. These relate to the use of GPS/GNSS in data acquisition for transformation purpose, style selection in the transformation of AGC, PGC or CITY co-ordinates into the MGA system and what is the maximum acceptable distance in parameter application. Recommendations have also been discussed relating to best practice in the use and calculation of transformation parameters.

CHAPTER 6 - CONCLUSIONS

6.1 Introduction

In the conclusion of results from the investigation of this project, four outcomes have been determined relating to the use of transformation parameters in the conversion of survey co-ordinates. These results relate to the control observation, parameter calculation, application for transformation parameters and recommendations into best practice techniques in the conversion of AGC, PGC and CITY co-ordinates into MGA values.

6.2 Control Observation

Inclusion of GPS observations for control observations has been determined to have minor influence in the addition of error due to post processing results. This relationship is true if conditions are met relating to techniques used and quality of existing control used.

Techniques for GPS/GNSS observations should use closed figure network observations to allow minimally and fully constrained adjustment. Adjusted results can then be evaluated for conformance with existing standards of precision to an equal or better quality achieving minimal error in transformations.

Using fixed control of equal or better precision in parameter calculation compared to points converted results in maximizing precision achievable. Inclusion of lower precision control points degrades the parameter solution and affects the results of transformed points.

6.3 Parameter Calculation

This project has determined which style evaluated achieved the best results when evaluating the conformal, affine and projective methods of transformation in the conversion of AGC, PGC and CITY co-ordinates into MGA values.

For the AGC co-ordinate system, the projective method of transformation has achieved the best results for distances past the test site at various distances. This is considered to result from the conversion of one map projection (AGC) into another (MGA) which is the intended application of the method.

For the PGC Co-ordinate system, the conformal method of transformation has achieved the best results. This is thought to suggest that this system is closely related to a conventional grid system and benefit from this style of transformation.

In the CITY co-ordinate system, no style has achieved an acceptable result. This has supported the decision of the development of the newer co-ordinate systems and isolation of this zone. The results also highlight the effect of the cantilevered expansion of the system during the early development of the Canberra region.

6.4 Parameter Application

With the calculation of transformation parameters, application has been evaluated and distances tested outside the region used in their calculation. The application outside the test site has an exponential effect in error and increases with distance. Maximum distances for each test site has been determined.

In the AGC test site, the maximum distance for application of parameters is approximately 6km as shown in figure 4-5. This is the distance where error begins to exceed the acceptable limit imposed by the class and order used in parameter calculation. Being the extreme limit, it is not recommended conversion upto and beyond this distance.

For the PGC test site, a comparable distance is seen in the range of 5km as shown in figure 4-7. This is also the maximum distance where error begins to exceed maximum acceptable limits imposed by the class and order used in parameter calculation. Again, this is not recommended upto and beyond this distance for conversion of points.

Examining the CITY test site, no distance is achieved where acceptable error is seen. This is indicated in figure 4-9 and supports the unreliable nature of this co-ordinate system. Treatment of co-ordinate values in this system are considered local only and do not have reliable values in relative and absolute precision.

6.5 Best Practice Recommendations

From the investigation of this project, recommendations have been determined to achieve best possible results in the transformation of co-ordinates. These include observation techniques, selection of control, methods used in transformation and application of computed parameters.

In the use of GPS/GNSS observations to determine coincident control points, network observation and closed figure baselines should be used. This ensures the ability of closed figure evaluation and adjustment by a least squares method. The adjustment should be proven using a minimally constrained method to determine erroneous observations then a fully constrained method as a final output. The inclusion of GPS/GNSS also increases efficiency compared to conventional traversing in larger scale projects.

The selection of control should include known published values of suitably determined class and order. This is to deter the effect of sub-standard control in the calculation of parameters. With degraded parameters, a degraded result is achieved in the transformation output.

For the methods used in co-ordinate transformation, the conformal method is best suited to conventional grid co-ordinates to ensure the relationship of the points converted is retained. In the use of the affine method, application can be used in a conventional grid system because the correction for an orthogonal axis is minimal. This has little effect on the results but is better suited for aerial photography where this occurs. Using the projective method in conversion of a projected grid system achieves better results compared to the conformal and affine methods. This is where one projection is converted into the system of another projection.

Parameter application is best suited to points in the immediate area used in their calculation. Points achieve the best results when contained within the area of control. The application outside this region also achieves adequate results but is limited to a maximum distance determined from evaluating the method used, quality of control selected, techniques used in conversion. For best results, "*working from the whole to the part*" is recommended.

6.6 Further Research

From the limited size of test sites used, further research is recommended into the expansion of test sites to cover whole co-ordinate zones. This would allow an evaluation into the effectiveness of using co-ordinate transformation in making the separate co-ordinate zones throughout the ACT co-incident with the geodetic standard of Australia. This aim would enable the implementation of a GNSS CORS network to be realized. Future consideration can then be evaluated into the cost benefit analysis in the adoption of legal parcel co-ordinates in the definition of cadastral parcel boundaries.

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APPENDIX A – Project Specification

University of Southern Queensland
Faculty of Engineering and Surveying

ENG4111/4112 RESEARCH PROJECT
PROJECT SPECIFICATION

FOR:	**Jason Peter Steger - W0023198**
TOPIC:	Deriving coordinate transformation parameters for survey coordinate systems in the Australian Capital Territory
SUPERVISOR:	Assoc Prof, Kevin McDougall
ENROLMENT:	ENG 4111, S1 2008 EXT ENG4112, S2 2008 EXT
PROJECT AIM:	This project aims to derive a set of transformation parameters that can be used in the conversion of three existing coordinate systems in the ACT into the Geodetic Datum of Australia's map projection MGA.
PROGRAMME:	25th March 2008

1. Research the historical nature of the existing coordinate zones in place in the ACT and the rationale for the continued use and separation of these zones.
2. Research and contrast the various methods used for coordinate transformation and the establishment of control networks.
3. Collect GNSS data over a site for each of the primary coordinate systems using an appropriate class and order and connect these points to an existing 1st order MGA network.
4. Reduce, adjust and analyse field observations using a Least Squares statistical adjustment against the existing MGA network.
5. Derive a set of parameters to enable the transformation of the coordinate system from each test site into the Geodetic Datum of Australia (GDA) map projection Map Grid Australia (MGA).
6. Apply transformation parameters to external control points of test site and derive transformed MGA values and contrast with GNSS processed values of same.
7. Discuss the application of transformation parameters for the conversion of entire coordinate systems and make recommendations on establishing a single consistent coordinate framework.

If time permits:

8. Test application of transformation parameters by contrasting observed against transformed values of parcel coordinates in the ACT's DCDB known as ACTMAP.

AGREED:

__________, Student 25th / 03 / 2008

__________, Supervisor 31 / 3 / 2008

EXAMINER: 1/4/08

APPENDIX B – Post Processing Report

Land Survey Overview

GNSS Solutions, Copyright (C) 2007 Magellan Navigation, Inc. 24/02/2008 5:54:09 PM
www.pro.magellanGPS.com
Project Name: Dissertation
Spatial Reference System: AUSTRALIA/GDA94/MGA zone 55
Time Zone: (GMT+10:00) Canberra, Melbourne, Sydney
Linear Units: Meters

Co-ordinate System Summary

Co-ordinate system

Name :	AUSTRALIA/GDA94/MGA zone 55
Type :	Projected
Unit name :	Meters
Meters per unit :	1
Vertical datum :	SI55
Vertical unit :	Meters
Meters per unit :	1

Datum

Name :	GDA94
Ellipsoid Name :	GRS 1980
Semi-major Axis :	6378137.000 m
Inverse Flattening :	298.257222101
DX to WGS84 :	0.0000 m
DY to WGS84 :	0.0000 m
DY to WGS84 :	0.0000 m
RX to WGS84 :	0.000000 "
RY to WGS84 :	0.000000 "
RZ to WGS84 :	0.000000 "
ppm to WGS84 :	0.000000000000

Projection

Projection Class :	Transverse_Mercator
latitude_of_origin	0° 00' 00.00000"N
central_meridian	147° 00' 00.00000"E
scale_factor	0.999600000000
false_easting	500000.000 m
false_northing	10000000.000 m

```
Control Points      :   2
Reference Points    :   0
Logged Points       :  16
Target Points       :   0
Intermediate Points :   0
```

Control Points

Name		Components	95% Error	Status
OAKEY	East	687943.294	0.000	FIXED
	North	6087541.934	0.000	FIXED
	Ortho height	628.302	0.000	Adjusted
Reservoir	East	690175.945	0.000	FIXED
	North	6099353.756	0.000	FIXED
	Ortho height	581.562	0.042	Adjusted

Logged Points

Name		Components	95% Error	Status
BL164	East	689368.488	0.005	Adjusted
	North	6100244.417	0.005	Adjusted
	Ortho height	529.391	0.042	Adjusted
BL169	East	690584.494	0.005	Adjusted
	North	6100789.994	0.005	Adjusted
	Ortho height	536.149	0.042	Adjusted
BL177	East	690996.321	0.003	Adjusted
	North	6099757.947	0.003	Adjusted
	Ortho height	550.718	0.042	Adjusted
BL182	East	690650.564	0.004	Adjusted
	North	6098289.692	0.004	Adjusted
	Ortho height	570.256	0.042	Adjusted
BL61	East	687877.468	0.007	Adjusted
	North	6099435.963	0.008	Adjusted
	Ortho height	527.896	0.043	Adjusted
CHAPMAN	East	686364.856	0.010	Adjusted
	North	6084799.790	0.010	Adjusted
	Ortho height	617.649	0.017	Adjusted
COOLEMAN	East	684420.396	0.010	Adjusted
	North	6085693.139	0.010	Adjusted
	Ortho height	669.426	0.014	Adjusted
FORREST	East	684688.793	0.009	Adjusted
	North	6088649.375	0.008	Adjusted
	Ortho height	552.610	0.015	Adjusted
NARRABUND	East	683803.167	0.010	Adjusted
	North	6087686.029	0.010	Adjusted
	Ortho height	632.000	0.014	Adjusted
STR2	East	682733.885	0.014	Adjusted
	North	6090040.863	0.012	Adjusted
	Ortho height	726.139	0.021	Adjusted
WK16	East	685011.323	0.008	Adjusted
	North	6086900.811	0.008	Adjusted
	Ortho height	568.073	0.013	Adjusted
YA22	East	690087.257	0.006	Adjusted
	North	6088083.403	0.006	Adjusted
	Ortho height	527.946	0.014	Adjusted
YA28	East	691106.623	0.008	Adjusted
	North	6088249.201	0.008	Adjusted
	Ortho height	579.749	0.016	Adjusted
YA36	East	689340.170	0.005	Adjusted
	North	6089004.438	0.005	Adjusted
	Ortho height	527.248	0.011	Adjusted
YA37	East	688256.250	0.004	Adjusted
	North	6088725.874	0.004	Adjusted
	Ortho height	557.308	0.010	Adjusted
YA41	East	689209.110	0.004	Adjusted
	North	6087616.911	0.004	Adjusted
	Ortho height	545.583	0.010	Adjusted

Files

Name	Start Time	Sampling	Epochs	Size (Kb)	Type
B___2B07.125	07/05/05 14:11	1	1838	1405	L1/L2 GPS
B___3D07.125	07/05/05 15:01	1	1855	1789	L1/L2 GPS
B___4F07.125	07/05/05 15:52	1	1794	1700	L1/L2 GPS
B___6G07.125	07/05/06 07:35	1	2038	1904	L1/L2 GPS
B___7H07.125	07/05/06 08:38	1	2342	2365	L1/L2 GPS
B___8I07.125	07/05/06 09:25	1	5826	4926	L1/L2 GPS
B___9A07.126	07/05/06 10:02	1	1256	1089	L1/L2 GPS
B__10C07.126	07/05/06 10:42	1	4219	3527	L1/L2 GPS
BOAKYB07.153	07/06/02 10:45	1	4648	3626	L1/L2 GPS
BYA22D07.153	07/06/02 12:24	1	4005	2851	L1/L2 GPS
BYA41B07.153	07/06/02 10:21	1	12153	8368	L1/L2 GPS
BYA28007.153	07/06/02 12:17	1	4933	2461	L1/L2 GPS
BYA36007.153	07/06/02 10:56	1	9259	4364	L1/L2 GPS
BYA37007.153	07/06/02 10:20	1	6096	2970	L1/L2 GPS
B___6C07.162	07/06/11 17:25	1	4947	5095	L1/L2 GPS
oak_1620.07o	07/06/11 13:33	1	9382	6205	L1/L2 GPS
oak_1620[1].07o	07/06/11 16:11	1	10451	6687	L1/L2 GPS
WK161620.07o	07/06/11 13:08	1	18848	12312	L1/L2 GPS
B___3B07.162	07/06/11 14:05	1	5116	5160	L1/L2 GPS
B___4A07.162	07/06/11 14:33	1	8291	8648	L1/L2 GPS
B___5D07.162	07/06/11 15:54	1	9295	9537	L1/L2 GPS
B__13D07.126	07/05/06 13:13	1	2095	1724	L1/L2 GPS
B__11B07.126	07/05/06 11:30	1	4530	3728	L1/L2 GPS
B__12E07.126	07/05/06 12:16	1	5929	5178	L1/L2 GPS
B___5D07.125	07/05/06 07:05	1	9268	9398	L1/L2 GPS
B___1C07.125	07/05/05 13:20	1	23895	24323	L1/L2 GPS
str21251.07o	07/05/05 13:20	30	840	1320	L1/L2 GPS
str21252.07o	07/05/06 07:00	30	841	1153	L1/L2 GPS
str21531.07o	07/06/02 10:00	30	481	666	L1/L2 GPS
str21621.07o	07/06/11 13:00	30	721	1135	L1/L2 GPS

Occupations

Site	Start Time	Time span	Type	File
BL177	5 May 2007 14:11:20.00	00:31:38.00	Static	B___2B07.125
BL169	5 May 2007 15:01:08.00	00:30:54.00	Static	B___3D07.125
BL164	5 May 2007 15:52:27.00	00:29:53.00	Static	B___4F07.125
BL61	6 May 2007 07:35:31.00	00:33:57.00	Static	B___6G07.125
BL182	6 May 2007 08:38:20.00	00:39:01.00	Static	B___7H07.125
BL182	6 May 2007 09:25:25.00	01:36:59.00	Static	B___8I07.125
BL177	6 May 2007 10:02:21.00	00:20:55.00	Static	B___9A07.126
BL61	6 May 2007 10:42:06.00	01:10:18.00	Static	B__10C07.126
OAKEY	2 June 2007 10:45:16.00	01:17:27.00	Static	BOAKYB07.153
YA22	2 June 2007 12:24:38.00	01:06:44.00	Static	BYA22D07.153
YA41	2 June 2007 10:21:13.00	03:21:31.00	Static	BYA41B07.153
YA28	2 June 2007 12:17:54.00	01:22:12.00	Static	BYA28007.153
YA36	2 June 2007 10:56:48.00	02:34:18.00	Static	BYA36007.153
YA37	2 June 2007 10:20:31.00	01:41:35.00	Static	BYA37007.153
CHAPMAN	11 June 2007 17:25:53.00	01:22:26.00	Static	B___6C07.162
OAKEY~1	11 June 2007 13:33:54.00	02:36:21.00	Static	oak_1620.07o
OAKEY~2	11 June 2007 16:11:25.00	02:11:14.00	Static	oak_1620[1].07o
WK16	11 June 2007 13:08:39.00	05:14:07.00	Static	WK161620.07o
FORREST	11 June 2007 14:05:49.00	01:25:15.00	Static	B___3B07.162
NARRABUND	11 June 2007 14:33:39.00	02:18:10.00	Static	B___4A07.162
COOLEMAN	11 June 2007 15:54:31.00	02:34:54.00	Static	B___5D07.162
BL177	6 May 2007 13:13:34.00	00:34:54.00	Static	B__13D07.126
BL164	6 May 2007 11:30:48.00	01:15:29.00	Static	B__11B07.126
BL169	6 May 2007 12:16:49.00	01:38:48.00	Static	B__12E07.126
RESERVOIR	6 May 2007 07:05:31.00	02:34:27.00	Static	B___5D07.125
RESERVOIR	5 May 2007 13:20:17.00	06:38:14.00	Static	B___1C07.125
STR2	5 May 2007 13:20:30.00	06:59:30.00	Static	str21251.07o
STR2	6 May 2007 07:00:00.00	07:00:00.00	Static	str21252.07o
STR2	2 June 2007 10:00:00.00	04:00:00.00	Static	str21531.07o
STR2	11 June 2007 13:00:00.00	06:00:00.00	Static	str21621.07o

Processes

Reference	Reference File	Rover	Rover File	Mode	Num
OAKEY	oak_1620.07o	NARRABUND	B___4A07.162	Static	1
OAKEY	oak_1620.07o	FORREST	B___3B07.162	Static	2
OAKEY	oak_1620.07o	COOLEMAN	B___5D07.162	Static	3
OAKEY	oak_1620.07o	WK16	WK161620.07o	Static	4
OAKEY	oak_1620.07o	STR2	str21621.07o	Static	5
OAKEY	oak_1620[1].07o	CHAPMAN	B___6C07.162	Static	6
OAKEY	oak_1620[1].07o	NARRABUND	B___4A07.162	Static	7
OAKEY	oak_1620[1].07o	COOLEMAN	B___5D07.162	Static	8
OAKEY	oak_1620[1].07o	WK16	WK161620.07o	Static	9
OAKEY	oak_1620[1].07o	STR2	str21621.07o	Static	10
OAKEY	BOAKYB07.153	YA36	BYA36007.153	Static	11
OAKEY	BOAKYB07.153	YA41	BYA41B07.153	Static	12
OAKEY	BOAKYB07.153	STR2	str21531.07o	Static	13
OAKEY	BOAKYB07.153	YA37	BYA37007.153	Static	14
Reservoir	B___1C07.125	BL164	B___4F07.125	Static	15
Reservoir	B___1C07.125	STR2	str21251.07o	Static	16
Reservoir	B___1C07.125	BL177	B___2B07.125	Static	17
Reservoir	B___1C07.125	BL169	B___3D07.125	Static	18
Reservoir	B___5D07.125	BL182	B___8I07.125	Static	19
Reservoir	B___5D07.125	BL182	B___7H07.125	Static	20
Reservoir	B___5D07.125	STR2	str21252.07o	Static	21
Reservoir	B___5D07.125	BL61	B___6G07.125	Static	22
STR2	str21252.07o	BL177	B__13D07.126	Static	23
STR2	str21252.07o	BL177	B___9A07.126	Static	24
STR2	str21252.07o	BL169	B__12E07.126	Static	25
STR2	str21252.07o	BL182	B___7H07.125	Static	26
STR2	str21252.07o	BL164	B__11B07.126	Static	27
STR2	str21252.07o	BL182	B___8I07.125	Static	28
STR2	str21252.07o	BL61	B___6G07.125	Static	29
STR2	str21252.07o	BL61	B__10C07.126	Static	30
STR2	str21251.07o	BL169	B___3D07.125	Static	31
STR2	str21251.07o	BL164	B___4F07.125	Static	32
STR2	str21251.07o	BL177	B___2B07.125	Static	33
STR2	str21621.07o	FORREST	B___3B07.162	Static	34
STR2	str21621.07o	CHAPMAN	B___6C07.162	Static	35
STR2	str21621.07o	WK16	WK161620.07o	Static	36
STR2	str21621.07o	NARRABUND	B___4A07.162	Static	37
STR2	str21621.07o	COOLEMAN	B___5D07.162	Static	38
STR2	str21531.07o	YA28	BYA28007.153	Static	39
STR2	str21531.07o	YA36	BYA36007.153	Static	40
STR2	str21531.07o	YA41	BYA41B07.153	Static	41
STR2	str21531.07o	YA22	BYA22D07.153	Static	42
STR2	str21531.07o	YA37	BYA37007.153	Static	43
YA41	BYA41B07.153	YA22	BYA22D07.153	Static	44
YA41	BYA41B07.153	YA37	BYA37007.153	Static	45
YA41	BYA41B07.153	YA28	BYA28007.153	Static	46
YA41	BYA41B07.153	YA36	BYA36007.153	Static	47
WK16	WK161620.07o	COOLEMAN	B___5D07.162	Static	48
WK16	WK161620.07o	NARRABUND	B___4A07.162	Static	49
WK16	WK161620.07o	FORREST	B___3B07.162	Static	50
WK16	WK161620.07o	CHAPMAN	B___6C07.162	Static	51
COOLEMAN	B___5D07.162	NARRABUND	B___4A07.162	Static	52
COOLEMAN	B___5D07.162	CHAPMAN	B___6C07.162	Static	53
YA36	BYA36007.153	YA22	BYA22D07.153	Static	54
YA36	BYA36007.153	YA37	BYA37007.153	Static	55
YA36	BYA36007.153	YA28	BYA28007.153	Static	56
NARRABUND	B___4A07.162	FORREST	B___3B07.162	Static	57
BL182	B___8I07.125	BL177	B___9A07.126	Static	58
BL182	B___8I07.125	BL61	B__10C07.126	Static	59
BL177	B__13D07.126	BL169	B__12E07.126	Static	60
BL169	B__12E07.126	BL164	B__11B07.126	Static	61
BL164	B__11B07.126	BL61	B__10C07.126	Static	62
YA28	BYA28007.153	YA22	BYA22D07.153	Static	63

Processed vectors

Vector Identifier Solution	Vector Length	95% Error	Vector Components		95% Error	SV	PDOP	QA
Reservoir - STR2 Fixed	11923.056	0.058	X	8314.746	0.023	11	1.4	
07/05/05 10:01			Y	3465.931	0.023			
			Z	-7810.991	0.023			
Reservoir - BL61 Fixed	2300.708	0.011	X	1202.618	0.005	9	1.9	
07/05/06 07:18			Y	1960.485	0.005			
			Z	58.877	0.005			
Reservoir - STR2 **No** Fixed	11923.054	0.058	X	8314.780	0.024	11	1.4	
07/05/06 05:49			Y	3465.907	0.024			
			Z	-7810.963	0.023			
Reservoir - BL182 Fixed	1165.239	0.006	X	274.357	0.002	10	1.4	
07/05/06 08:18			Y	-743.464	0.002			
			Z	-854.267	0.002			
Reservoir - BL182 Fixed	1165.233	0.006	X	274.349	0.002	9	1.6	
07/05/06 09:18			Y	-743.461	0.002			
			Z	-854.264	0.002			
Reservoir - BL177 Fixed	915.105	0.005	X	-603.904	0.002	7	2.5	
07/05/05 13:55			Y	-584.522	0.002			
			Z	362.010	0.002			
Reservoir - BL164 Fixed	1203.390	0.006	X	28.636	0.002	9	1.7	
07/05/05 15:37			Y	945.655	0.002			
			Z	743.682	0.002			
Reservoir - BL169 Fixed	1493.986	0.007	X	-877.379	0.003	9	2.0	
07/05/05 14:45			Y	84.440	0.003			
			Z	1206.263	0.003			
BL177 - BL169 Fixed	1111.326	0.005	X	-273.462	0.002	8	1.8	
07/05/06 12:56			Y	668.961	0.002			
			Z	844.249	0.002			
BL169 - BL164 Fixed	1332.876	0.007	X	906.032	0.003	8	2.7	
07/05/06 12:02			Y	861.211	0.003			
			Z	-462.580	0.003			
BL164 - BL61 Fixed	1696.195	0.008	X	1173.965	0.003	9	1.5	
07/05/06 11:20			Y	1014.834	0.003			
			Z	-684.832	0.003			
BL182 - BL177 Fixed	1508.616	0.007	X	-878.234	0.003	7	2.3	
07/05/06 09:51			Y	158.919	0.003			
			Z	1216.295	0.003			
BL182 - BL61 Fixed	3001.126	0.015	X	928.283	0.006	7	2.5	
07/05/06 10:31			Y	2703.925	0.006			
			Z	913.146	0.006			
OAKEY - YA37 Fixed	1226.742	0.006	X	-688.932	0.002	7	2.4	
07/06/02 10:06			Y	76.869	0.002			
			Z	1012.107	0.002			
OAKEY - YA41 Fixed	1270.809	0.006	X	-642.105	0.003	7	2.4	
07/06/02 10:06			Y	-1088.851	0.003			
			Z	130.614	0.003			
OAKEY - FORREST	3438.855	0.017	X	1222.518	0.007	9	2.1	

Fixed							
07/06/11 13:23			Y	3087.909	0.007		
			Z	892.182	0.007		
OAKEY - CHAPMAN	3164.255	0.015	X	2166.473	0.006	10	1.7
Fixed							
07/06/11 16:57			Y	474.858	0.006		
			Z	-2256.859	0.006		
OAKEY - WK16	3002.082	0.015	X	1891.094	0.006	10	1.6
Fixed							
07/06/11 15:05			Y	2268.758	0.006		
			Z	-537.588	0.006		
OAKEY - COOLEMAN	3979.102	0.019	X	2716.551	0.008	11	1.5
Fixed							
07/06/11 15:05			Y	2433.573	0.008		
			Z	-1591.016	0.008		
OAKEY - NARRABUND	4142.986	0.020	X	2099.191	0.008	10	2.2
Fixed							
07/06/11 13:45			Y	3571.504	0.008		
			Z	45.694	0.008		
OAKEY - NARRABUND	4142.987	0.020	X	2099.212	0.008	11	1.5
Fixed							
07/06/11 15:51			Y	3571.493	0.008		
			Z	45.706	0.008		
OAKEY - COOLEMAN	3979.101	0.019	X	2716.551	0.008	8	3.1
Fixed							
07/06/11 15:46			Y	2433.576	0.008		
			Z	-1591.007	0.008		
OAKEY - YA36	2025.068	0.010	X	-1371.258	0.004	7	2.2
Fixed							
07/06/02 10:23			Y	-770.900	0.004		
			Z	1275.251	0.004		
OAKEY - WK16	3002.080	0.015	X	1891.091	0.006	9	2.1
Fixed							
07/06/11 12:15			Y	2268.758	0.006		
			Z	-537.586	0.006		
YA41 - YA36	1393.901	0.007	X	-729.155	0.003	7	2.4
Fixed							
07/06/02 09:39			Y	317.957	0.003		
			Z	1144.637	0.003		
YA41 - YA22	994.569	0.005	X	-674.300	0.002	7	2.7
Fixed							
07/06/02 11:51			Y	-608.142	0.002		
			Z	405.771	0.002		
YA41 - YA37	1462.231	0.007	X	-46.830	0.003	5	3.3
Fixed							
07/06/02 10:00			Y	1165.721	0.003		
			Z	881.488	0.003		
YA41 - YA28	2000.488	0.010	X	-1325.184	0.004	7	2.7
Fixed							
07/06/02 12:03			Y	-1402.275	0.004		
			Z	528.646	0.004		
YA28 - YA22	1034.113	0.005	X	650.886	0.002	7	2.7
Fixed							
07/06/02 11:51			Y	794.128	0.002		
			Z	-122.869	0.002		
YA36 - YA37	1119.609	0.005	X	682.326	0.002	6	2.4
Fixed							
07/06/02 10:42			Y	847.768	0.002		
			Z	-263.142	0.002		
WK16 - CHAPMAN	2499.955	0.012	X	275.384	0.005	10	1.7
Fixed							
07/06/11 16:57			Y	-1793.902	0.005		
			Z	-1719.259	0.005		
WK16 - FORREST	1778.264	0.009	X	-668.566	0.003	9	2.1
Fixed							
07/06/11 13:23			Y	819.143	0.003		
			Z	1429.773	0.003		

WK16 - COOLEMAN	1348.425	0.007	X	825.459	0.003	10	1.7
Fixed							
07/06/11 14:40			Y	164.811	0.003		
			Z	-1053.425	0.003		
WK16 - NARRABUND	1442.448	0.007	X	208.105	0.003	9	1.7
Fixed							
07/06/11 13:24			Y	1302.740	0.003		
			Z	583.281	0.003		
NARRABUND - FORREST	1311.091	0.006	X	-876.665	0.003	9	2.2
Fixed							
07/06/11 14:04			Y	-483.594	0.003		
			Z	846.496	0.003		
CCOOLEMAN - NARRABUND	2086.820	0.010	X	-617.352	0.004	9	1.7
Fixed							
07/06/11 15:25			Y	1137.922	0.004		
			Z	1636.712	0.004		
COOLEMAN - CHAPMAN	2140.673	0.010	X	-550.077	0.004	10	1.7
Fixed							
07/06/11 16:54			Y	-1958.713	0.004		
			Z	-665.838	0.004		
STR2 - BL164	12173.487	0.059	X	-8286.115	0.024	9	1.7
No Fixed							
07/05/05 15:37			Y	-2520.272	0.024		
			Z	8554.666	0.024		
STR2 - BL164	12173.478	0.059	X	-8286.099	0.024	9	1.5
No Fixed							
07/05/06 10:53			Y	-2520.275	0.024		
			Z	8554.668	0.024		
STR2 - BL182	11435.155	0.055	X	-8040.430	0.022	10	1.4
Fixed							
07/05/06 08:36			Y	-4209.368	0.022		
			Z	6956.687	0.022		
STR2 - BL169	13313.166	0.065	X	-9192.142	0.026	9	2.0
Fixed							
07/05/05 14:45			Y	-3381.477	0.026		
			Z	9017.234	0.026		
STR2 - BL177	12757.207	0.062	X	-8918.665	0.025	7	2.5
Fixed							
07/05/05 13:55			Y	-4050.435	0.025		
			Z	8172.987	0.025		
STR2 - FORREST	2406.055	0.012	X	-229.448	0.005	9	2.1
Fixed							
07/06/11 13:23			Y	-2175.258	0.005		
			Z	-1002.351	0.005		
STR2 - NARRABUND	2588.214	0.013	X	647.219	0.005	10	1.6
Fixed							
07/06/11 13:24			Y	-1691.663	0.005		
			Z	-1848.847	0.005		
STR2 - COOLEMAN	4664.208	0.023	X	1264.570	0.009	10	1.6
Fixed							
07/06/11 14:37			Y	-2829.588	0.009		
			Z	-3485.561	0.009		
STR2 - BL61	10713.694	0.052	X	-7112.131	0.021	9	1.5
No Fixed							
07/05/06 10:06			Y	-1505.447	0.021		
			Z	7869.844	0.021		

Repeat vectors

Repeat Vector		Difference	Length	QA
Reservoir - STR2	X	-0.034	11923.056	
07/05/05 10:01	Y	0.024		
07/05/06 05:49	Z	-0.028		
Reservoir - BL182	X	0.008	1165.239	
07/05/06 08:18	Y	-0.002		
07/05/06 09:18	Z	-0.003		
OAKEY - WK16	X	-0.003	3002.080	
07/06/11 12:15	Y	-0.001		
07/06/11 15:05	Z	0.002		
OAKEY - NARRABUND	X	-0.021	4142.986	
07/06/11 13:45	Y	0.011		
07/06/11 15:51	Z	-0.012		
OAKEY - COOLEMAN	X	0.000	3979.102	
07/06/11 15:05	Y	-0.004		
07/06/11 15:46	Z	-0.009		
STR2 - BL164	X	-0.016	12173.487	
07/05/05 15:37	Y	0.003		
07/05/06 10:53	Z	-0.002		

Adjusted vectors

Vector Identifier	Vector Length	Length Resid.		Vector Components	Resid.	Tau Test	QA
Reservoir - STR2	11923.052	0.024	X	8314.761	0.015		
07/05/05 10:01			Y	3465.919	-0.012		
			Z	-7810.975	0.015		
Reservoir - BL61	2300.706	0.014	X	1202.615	-0.003		
07/05/06 07:18			Y	1960.485	0.000		
			Z	58.864	-0.014		
Reservoir - STR2	11923.052	0.026	X	8314.761	-0.019		
07/05/06 05:49			Y	3465.919	0.012		
			Z	-7810.975	-0.013		
Reservoir - BL182	1165.235	0.011	X	274.347	-0.010		
07/05/06 08:18			Y	-743.458	0.006		
			Z	-854.269	-0.002		
Reservoir - BL182	1165.235	0.006	X	274.347	-0.002		
07/05/06 09:18			Y	-743.458	0.004		
			Z	-854.269	-0.005		
Reservoir - BL177	915.109	0.007	X	-603.903	0.001		
07/05/05 13:55			Y	-584.526	-0.005		
			Z	362.015	0.005		
Reservoir - BL164	1203.388	0.015	X	28.650	0.014		
07/05/05 15:37			Y	945.652	-0.003		
			Z	743.683	0.001		
Reservoir - BL169	1493.982	0.006	X	-877.374	0.006		
07/05/05 14:45			Y	84.438	-0.002		
			Z	1206.262	-0.001		
BL177 - BL169	1111.329	0.009	X	-273.471	-0.009		
07/05/06 12:56			Y	668.964	0.003		

			Z	844.248	-0.001
BL169 - BL164	1332.872	0.009	X	906.024	-0.008
07/05/06 12:02			Y	861.214	0.003
			Z	-462.579	0.001
BL164 - BL61	1696.189	0.013	X	1173.965	-0.000
07/05/06 11:20			Y	1014.833	-0.001
			Z	-684.820	0.013
BL182 - BL177	1508.618	0.023	X	-878.250	-0.016
07/05/06 09:51			Y	158.932	0.013
			Z	1216.284	-0.011
BL182 - BL61	3001.133	0.026	X	928.268	-0.015
07/05/06 10:31			Y	2703.942	0.017
			Z	913.133	-0.013
OAKEY - YA37	1226.742	0.001	X	-688.933	-0.001
07/06/02 10:06			Y	76.870	0.000
			Z	1012.106	-0.000
OAKEY - YA41	1270.810	0.002	X	-642.104	0.001
07/06/02 10:06			Y	-1088.852	-0.001
			Z	130.615	0.001
OAKEY - FORREST	3438.855	0.013	X	1222.528	0.009
07/06/11 13:23			Y	3087.904	-0.005
			Z	892.189	0.006
OAKEY - CHAPMAN	3164.250	0.008	X	2166.474	0.000
07/06/11 16:57			Y	474.859	0.001
			Z	-2256.852	0.008
OAKEY - WK16	3002.082	0.003	X	1891.091	-0.003
07/06/11 15:05			Y	2268.760	0.002
			Z	-537.587	0.000
OAKEY - COOLEMAN	3979.100	0.003	X	2716.549	-0.002
07/06/11 15:05			Y	2433.573	0.000
			Z	-1591.014	0.003
OAKEY - NARRABUND	4142.983	0.008	X	2099.195	0.005
07/06/11 13:45			Y	3571.498	-0.006
			Z	45.695	0.001
OAKEY - NARRABUND	4142.983	0.021	X	2099.195	-0.016
07/06/11 15:51			Y	3571.498	0.005
			Z	45.695	-0.011
OAKEY - COOLEMAN	3979.100	0.008	X	2716.549	-0.001
07/06/11 15:46			Y	2433.573	-0.004
			Z	-1591.014	-0.006
OAKEY - YA36	2025.067	0.003	X	-1371.259	-0.001
07/06/02 10:23			Y	-770.898	0.003
			Z	1275.250	-0.001
OAKEY - WK16	3002.082	0.003	X	1891.091	0.000
07/06/11 12:15			Y	2268.760	0.002
			Z	-537.587	-0.002
YA41 - YA36	1393.898	0.003	X	-729.155	0.000
07/06/02 09:39			Y	317.955	-0.003
			Z	1144.635	-0.002
YA41 - YA22	994.570	0.001	X	-674.300	0.000

07/06/02 11:51			Y	-608.143	-0.001
			Z	405.772	0.001
YA41 - YA37	1462.234	0.004	X	-46.829	0.002
07/06/02 10:00			Y	1165.722	0.001
			Z	881.491	0.003
YA41 - YA28	2000.486	0.006	X	-1325.185	-0.002
07/06/02 12:03			Y	-1402.272	0.003
			Z	528.642	-0.005
YA28 - YA22	1034.113	0.002	X	650.885	-0.000
07/06/02 11:51			Y	794.129	0.001
			Z	-122.870	-0.001
YA36 - YA37	1119.608	0.002	X	682.326	-0.000
07/06/02 10:42			Y	847.767	-0.001
			Z	-263.144	-0.002
WK16 - CHAPMAN	2499.958	0.006	X	275.383	-0.001
07/06/11 16:57			Y	-1793.901	0.001
			Z	-1719.265	-0.005
WK16 - FORREST	1778.266	0.004	X	-668.563	0.003
07/06/11 13:23			Y	819.144	0.001
			Z	1429.776	0.003
WK16 - COOLEMAN	1348.426	0.002	X	825.458	-0.001
07/06/11 14:40			Y	164.813	0.002
			Z	-1053.427	-0.002
WK16 - NARRABUND	1442.446	0.002	X	208.105	-0.000
07/06/11 13:24			Y	1302.738	-0.002
			Z	583.282	0.001
NARRABUND - FORREST	1311.092	0.003	X	-876.668	-0.003
07/06/11 14:04			Y	-483.594	0.000
			Z	846.494	-0.002
COOLEMAN - NARRABUND	2086.819	0.006	X	-617.354	-0.002
07/06/11 15:25			Y	1137.925	0.004
			Z	1636.709	-0.004
COOLEMAN - CHAPMAN	2140.673	0.002	X	-550.076	0.001
07/06/11 16:54			Y	-1958.714	-0.001
			Z	-665.838	0.001
STR2 - BL164	12173.478	0.010	X	-8286.110	0.005
07/05/05 15:37			Y	-2520.267	0.005
			Z	8554.659	-0.007
STR2 - BL164	12173.478	0.017	X	-8286.110	-0.011
07/05/06 10:53			Y	-2520.267	0.007
			Z	8554.659	-0.009
STR2 - BL182	11435.159	0.026	X	-8040.414	0.016
07/05/06 08:36			Y	-4209.377	-0.009
			Z	6956.706	0.019
STR2 - BL169	13313.164	0.010	X	-9192.134	0.008
07/05/05 14:45			Y	-3381.482	-0.004
			Z	9017.238	0.004
STR2 - BL177	12757.211	0.011	X	-8918.663	0.001
07/05/05 13:55			Y	-4050.445	-0.010
			Z	8172.990	0.003

STR2 - FORREST	2406.055	0.002	X	-229.449	-0.001
07/06/11 13:23			Y	-2175.258	0.001
			Z	-1002.352	-0.002
STR2 - NARRABUND	2588.214	0.001	X	647.218	-0.000
07/06/11 13:24			Y	-1691.663	-0.001
			Z	-1848.846	0.000
STR2 - COOLEMAN	4664.205	0.007	X	1264.572	0.002
07/06/11 14:37			Y	-2829.589	-0.001
			Z	-3485.555	0.006
STR2 - BL61	10713.697	0.020	X	-7112.146	-0.014
07/05/06 10:06			Y	-1505.435	0.013
			Z	7869.839	-0.005

APPENDIX C – Transformation Comparisons – GPS

EXTERNAL TEST MARKS TRANSFORMED (GNSS) vs PUBLISHED MGA COORDINATES:

BELCONNEN

		TRANSFORMED MGA		PUBLISHED MGA		DELTA		RADIUS	ERROR VECTOR		1:100,000	
		EASTING	NORTHING	EASTING	NORTHING	ΔE	ΔN	m	R	Az°	ALLOW	ACCEPT
CONFORMAL	BL164	689368.487	6100244.411	689368.486	6100244.418	0.001	-0.007	1202	0.007	172	0.012	T
	BL187	692875.442	6098792.159	692875.451	6098792.149	-0.009	0.010	2757	0.013	318	0.028	T
	BL156	688409.493	6102962.958	688409.443	6102962.940	0.050	0.018	4018	0.053	70	0.040	F
	BL201	686958.042	6104012.150	686957.998	6104012.119	0.044	0.031	5662	0.054	55	0.057	T
	BL234	683827.758	6104467.757	683827.775	6104467.593	-0.017	0.164	8152	0.165	354	0.082	F
	OAKEY	687943.625	6087541.788	687943.294	6087541.934	0.331	-0.146	12021	0.362	114	0.120	F
AFFINE	BL164	689368.485	6100244.411	689368.486	6100244.418	-0.001	-0.007	1202	0.007	188	0.012	T
	BL187	692875.446	6098792.156	692875.451	6098792.149	-0.005	0.007	2757	0.009	324	0.028	T
	BL156	688409.483	6102962.958	688409.443	6102962.940	0.040	0.018	4018	0.044	66	0.040	F
	BL201	686958.028	6104012.152	686957.998	6104012.119	0.030	0.033	5662	0.045	42	0.057	T
	BL234	683827.741	6104467.761	683827.775	6104467.593	-0.034	0.168	8152	0.171	349	0.082	F
	OAKEY	687943.665	6087541.793	687943.294	6087541.934	0.371	-0.141	12021	0.397	111	0.120	F
PROJECTIVE	BL164	689368.488	6100244.412	689368.486	6100244.418	0.002	-0.006	1202	0.006	162	0.012	T
	BL187	692875.443	6098792.158	692875.451	6098792.149	-0.008	0.009	2757	0.012	318	0.028	T
	BL156	688409.496	6102962.940	688409.443	6102962.940	0.053	0.000	4018	0.053	90	0.040	F
	BL201	686958.054	6104012.124	686957.998	6104012.119	0.056	0.005	5662	0.056	85	0.057	T
	BL234	683827.783	6104467.736	683827.775	6104467.593	0.008	0.143	8152	0.143	3	0.082	F
	OAKEY	687943.607	6087541.467	687943.294	6087541.934	0.313	-0.467	12021	0.562	146	0.120	F

WESTON

		TRANSFORMED MGA		PUBLISHED MGA		DELTA		RADIUS	ERROR VECTOR		1:100,000	
		EASTING	NORTHING	EASTING	NORTHING	ΔE	ΔN	m	R	Az°	ALLOW	ACCEPT
CONFORMAL	WK9	687303.465	6088094.400	687303.455	6088094.411	0.010	-0.011	2584	0.015	138	0.026	T
	WK30	687563.300	6084419.058	687563.259	6084419.054	0.041	0.004	3560	0.041	84	0.036	F
	YA70	689726.920	6082877.862	689726.895	6082877.811	0.025	0.051	6198	0.057	26	0.062	T
	YA73	691052.334	6082494.336	691052.333	6082494.252	0.001	0.084	7477	0.084	1	0.075	F
	WANNIASSA	692098.351	6081473.773	692098.339	6081473.621	0.012	0.152	8926	0.152	5	0.089	F
	RESERVOIR	690176.233	6099353.548	690175.945	6099353.756	0.288	-0.208	13481	0.355	126	0.135	F
AFFINE	WK9	687303.473	6088094.407	687303.455	6088094.411	0.018	-0.004	2584	0.018	103	0.026	T
	WK30	687563.288	6084419.063	687563.259	6084419.054	0.029	0.009	3560	0.030	73	0.036	T
	YA70	689726.898	6082877.878	689726.895	6082877.811	0.003	0.067	6198	0.067	3	0.062	F
	YA73	691052.310	6082494.360	691052.333	6082494.252	-0.023	0.108	7477	0.110	348	0.075	F
	WANNIASSA	692098.320	6081473.801	692098.339	6081473.621	-0.019	0.180	8926	0.181	354	0.089	F
	RESERVOIR	690176.305	6099353.582	690175.945	6099353.756	0.360	-0.174	13481	0.400	116	0.135	F
PROJECTIVE	WK9	687303.467	6088094.409	687303.455	6088094.411	0.012	-0.002	2584	0.012	99	0.026	T
	WK30	687563.295	6084419.050	687563.259	6084419.054	0.036	-0.004	3560	0.036	96	0.036	F
	YA70	689726.944	6082877.828	689726.895	6082877.811	0.049	0.017	6199	0.052	71	0.062	T
	YA73	691052.390	6082494.287	691052.333	6082494.252	0.057	0.035	7477	0.067	58	0.075	T
	WANNIASSA	692098.438	6081473.694	692098.339	6081473.621	0.099	0.073	8926	0.123	54	0.089	F
	RESERVOIR	690176.293	6099353.653	690175.945	6099353.756	0.348	-0.103	13481	0.363	106	0.135	F

WODEN

		TRANSFORMED MGA		PUBLISHED MGA		DELTA		RADIUS	ERROR VECTOR		1:100,000	
		EASTING	NORTHING	EASTING	NORTHING	ΔE	ΔN	m	R	Az°	ALLOW	ACCEPT
CONFORMAL	RED HILL ECCE	692006.462	6088966.981	692006.591	6088966.943	-0.129	0.038	2810	0.134	286	0.028	F
	SR1183	692051.408	6090419.612	692051.536	6090419.620	-0.128	-0.008	3488	0.128	266	0.035	F
	WEST OF SCHOOL	693347.355	6089358.915	693347.512	6089358.883	-0.157	0.032	4206	0.160	282	0.042	F
	SR1229	693348.915	6092027.947	693349.056	6092028.018	-0.141	-0.071	5516	0.158	243	0.055	F
	AINSLIE	696316.609	6094873.839	696316.765	6094874.053	-0.156	-0.214	9627	0.265	216	0.096	F
	W7	696542.902	6096606.491	696542.969	6096606.844	-0.067	-0.353	11030	0.359	191	0.110	F
	W1	697339.117	6097396.838	697339.215	6097397.197	-0.098	-0.359	12150	0.372	195	0.121	F
	W30	697004.680	6098242.659	697004.765	6098243.036	-0.085	-0.377	12587	0.386	193	0.126	F
AFFINE	RED HILL ECCE	692006.439	6088966.968	692006.591	6088966.943	-0.152	0.025	2810	0.154	279	0.028	F
	SR1183	692051.366	6090419.601	692051.536	6090419.620	-0.170	-0.019	3488	0.171	264	0.035	F
	WEST OF SCHOOL	693347.320	6089358.895	693347.512	6089358.883	-0.192	0.012	4206	0.192	274	0.042	F
	SR1229	693348.846	6092027.931	693349.056	6092028.018	-0.210	-0.087	5516	0.227	247	0.055	F
	AINSLIE	696316.489	6094873.811	696316.765	6094874.053	-0.276	-0.242	9627	0.367	229	0.096	F
	W7	696542.759	6096606.464	696542.969	6096606.844	-0.210	-0.380	11030	0.434	209	0.110	F
	W1	697338.960	6097396.808	697339.215	6097397.197	-0.255	-0.389	12150	0.465	213	0.121	F
	W30	697004.513	6098242.632	697004.765	6098243.036	-0.252	-0.404	12586	0.476	212	0.126	F
PROJECTIVE	RED HILL ECCE	692006.409	6088966.958	692006.591	6088966.943	-0.182	0.015	2810	0.183	275	0.028	F
	SR1183	692051.246	6090419.511	692051.536	6090419.620	-0.290	-0.109	3488	0.310	249	0.035	F
	WEST OF SCHOOL	693347.254	6089358.871	693347.512	6089358.883	-0.258	-0.012	4206	0.258	267	0.042	F
	SR1229	693348.544	6092027.657	693349.056	6092028.018	-0.512	-0.361	5516	0.626	235	0.055	F
	AINSLIE	696315.594	6094872.972	696316.765	6094874.053	-1.171	-1.081	9626	1.594	227	0.096	F
	W7	696541.573	6096605.116	696542.969	6096606.844	-1.396	-1.728	11028	2.221	219	0.110	F
	W1	697337.525	6097395.195	697339.215	6097397.197	-1.690	-2.002	12147	2.620	220	0.121	F
	W30	697002.994	6098240.694	697004.765	6098243.036	-1.771	-2.342	12584	2.936	217	0.126	F

APPENDIX D – Transformation Comparisons – Fixed

EXTERNAL TEST MARKS TRANSFORMED (FIXED) vs PUBLISHED MGA COORDINATES:

	BELCONNEN	TRANSFORMED MGA		PUBLISHED MGA		DELTA		RADIUS	ERROR VECTOR		1:100,000	
		EASTING	NORTHING	EASTING	NORTHING	ΔE	ΔN	m	R	Az°	ALLOW	ACCEPT
CONFORMAL	BL164	689368.492	6100244.411	689368.486	6100244.418	0.006	-0.007	1202	0.009	139	0.012	T
	BL187	692875.444	6098792.161	692875.451	6098792.149	-0.007	0.012	2757	0.014	330	0.028	T
	BL156	688409.499	6102962.955	688409.443	6102962.940	0.056	0.015	4018	0.058	75	0.040	F
	BL201	686958.049	6104012.147	686957.998	6104012.119	0.051	0.028	5662	0.058	61	0.057	F
	BL234	683827.767	6104467.752	683827.775	6104467.593	-0.008	0.159	8152	0.159	357	0.082	F
	OAKEY	687943.634	6087541.799	687943.294	6087541.934	0.340	-0.135	12021	0.366	112	0.120	F
AFFINE	BL164	689368.488	6100244.414	689368.486	6100244.418	0.002	-0.004	1202	0.004	153	0.012	T
	BL187	692875.457	6098792.151	692875.451	6098792.149	0.006	0.002	2757	0.006	72	0.028	T
	BL156	688409.465	6102962.971	688409.443	6102962.940	0.022	0.031	4018	0.038	35	0.040	T
	BL201	686958.003	6104012.170	686957.998	6104012.119	0.005	0.051	5662	0.051	6	0.057	T
	BL234	683827.715	6104467.782	683827.775	6104467.593	-0.060	0.189	8152	0.198	342	0.082	F
	OAKEY	687943.765	6087541.752	687943.294	6087541.934	0.471	-0.182	12021	0.505	111	0.120	F
PROJECTIVE	BL164	689368.487	6100244.413	689368.486	6100244.418	0.001	-0.005	1202	0.005	169	0.012	T
	BL187	692875.491	6098792.136	692875.451	6098792.149	0.040	-0.013	2757	0.042	108	0.028	F
	BL156	688409.505	6102962.916	688409.443	6102962.940	0.062	-0.024	4018	0.066	90	0.040	F
	BL201	686958.103	6104012.057	686957.998	6104012.119	0.105	-0.062	5662	0.122	121	0.057	F
	BL234	683827.974	6104467.605	683827.775	6104467.593	0.199	0.012	8152	0.199	87	0.082	F
	OAKEY	687943.592	6087541.049	687943.294	6087541.934	0.298	-0.885	12022	0.934	161	0.120	F

	WESTON	TRANSFORMED MGA		PUBLISHED MGA		DELTA		RADIUS	ERROR VECTOR		1:100,000	
		EASTING	NORTHING	EASTING	NORTHING	ΔE	ΔN	m	R	Az°	ALLOW	ACCEPT
CONFORMAL	WK9	687303.465	6088094.403	687303.455	6088094.411	0.010	-0.008	2584	0.013	129	0.026	T
	WK30	687563.300	6084419.049	687563.259	6084419.054	0.041	-0.005	3560	0.041	97	0.036	F
	YA70	689726.927	6082877.847	689726.895	6082877.811	0.032	0.036	6198	0.048	42	0.062	T
	YA73	691052.344	6082494.321	691052.333	6082494.252	0.011	0.069	7477	0.070	9	0.075	T
	WANNIASSA	692098.364	6081473.753	692098.339	6081473.621	0.025	0.132	8926	0.134	11	0.089	F
	RESERVOIR	690176.245	6099353.586	690175.945	6099353.756	0.300	-0.170	13481	0.345	120	0.135	F
AFFINE	WK9	687303.471	6088094.411	687303.455	6088094.411	0.016	0.000	2584	0.016	FAIL	0.026	T
	WK30	687563.288	6084419.051	687563.259	6084419.054	0.029	-0.003	3560	0.029	96	0.036	T
	YA70	689726.903	6082877.858	689726.895	6082877.811	0.008	0.047	6198	0.048	10	0.062	T
	YA73	691052.318	6082494.338	691052.333	6082494.252	-0.015	0.086	7477	0.087	350	0.075	F
	WANNIASSA	692098.331	6081473.774	692098.339	6081473.621	-0.008	0.153	8926	0.153	357	0.089	F
	RESERVOIR	690176.305	6099353.630	690175.945	6099353.756	0.360	-0.126	13481	0.381	109	0.135	F
PROJECTIVE	WK9	687303.468	6088094.416	687303.455	6088094.411	0.013	0.005	2584	0.014	69	0.026	T
	WK30	687563.285	6084419.045	687563.259	6084419.054	0.026	-0.009	3560	0.028	109	0.036	T
	YA70	689726.906	6082877.839	689726.895	6082877.811	0.011	0.028	6198	0.030	21	0.062	T
	YA73	691052.333	6082494.305	691052.333	6082494.252	0.000	0.053	7477	0.053	FAIL	0.075	T
	WANNIASSA	692098.354	6081473.731	692098.339	6081473.621	0.015	0.110	8926	0.111	8	0.089	F
	RESERVOIR	690176.406	6099354.091	690175.945	6099353.756	0.461	0.335	13482	0.570	54	0.135	F

	WODEN	TRANSFORMED MGA		PUBLISHED MGA		DELTA		RADIUS	ERROR VECTOR		1:100,000	
		EASTING	NORTHING	EASTING	NORTHING	ΔE	ΔN	m	R	Az°	ALLOW	ACCEPT
CONFORMAL	CB93	690949.312	6091818.969	690949.195	6091818.807	0.117	0.162	2386	0.200	36	0.024	F
	SR1229	693349.121	6092028.013	693349.056	6092028.018	0.065	-0.005	2683	0.065	94	0.027	F
	AINSLIE	696316.975	6094873.973	696316.765	6094874.053	0.210	-0.080	6725	0.225	111	0.067	F
	W7	696543.304	6096606.692	696542.969	6096606.844	0.335	-0.152	8257	0.368	114	0.083	F
	W1	697339.563	6097397.058	697339.215	6097397.197	0.348	-0.139	9357	0.375	112	0.094	F
	W30	697005.125	6098242.918	697004.765	6098243.036	0.360	-0.118	9893	0.379	108	0.099	F
AFFINE	CB93	690949.296	6091818.937	690949.195	6091818.807	0.101	0.130	2386	0.165	38	0.024	F
	SR1229	693349.112	6092027.983	693349.056	6092028.018	0.056	-0.035	2683	0.066	122	0.027	F
	AINSLIE	696316.963	6094873.913	696316.765	6094874.053	0.198	-0.140	6725	0.242	125	0.067	F
	W7	696543.284	6096606.610	696542.969	6096606.844	0.315	-0.234	8257	0.392	127	0.083	F
	W1	697339.541	6097396.968	697339.215	6097397.197	0.326	-0.229	9357	0.398	125	0.094	F
	W30	697005.097	6098242.817	697004.765	6098243.036	0.332	-0.219	9893	0.398	123	0.099	F
PROJECTIVE	CB93	690949.487	6091818.691	690949.195	6091818.807	0.292	-0.116	2385	0.314	112	0.024	F
	SR1229	693348.836	6092027.645	693349.056	6092028.018	-0.220	-0.373	2682	0.433	211	0.027	F
	AINSLIE	696315.245	6094872.119	696316.765	6094874.053	-1.520	-1.934	6723	2.460	218	0.067	F
	W7	696540.938	6096603.423	696542.969	6096606.844	-2.031	-3.421	8253	3.978	211	0.083	F
	W1	697336.502	6097393.002	697339.215	6097397.197	-2.713	-4.195	9352	4.996	213	0.094	F
	W30	697001.958	6098237.942	697004.765	6098243.036	-2.807	-5.094	9887	5.816	209	0.099	F

APPENDIX E – GPS Receiver Logging Summary

FIELD OBSERVATIONS SUMMARY

Control

Point	Coord System	Easting	Northing	Class/Order
RESERVOIR	AGC	207220.462	609463.777	B 2 2
	PGC	207220.406	609463.829	B 2 2
	MGA94	690175.945	6099353.756	A 1 1
OAKEY	AGC	205227.490	597608.544	A 1 1
	PGC	205227.498	597608.578	A 1 1
	MGA94	687943.294	6087541.934	A 1 1

PGC - Belconnen

Point	File	Date	Start	Stop	Time	Antenna	Pos	Type	Meas	Rad	Corr'n	O/S	MRP	TRUE
RESERVOIR	B__1C07.125	5 May 2007	1:20:17 PM	7:58:31 PM	6:38:14	ZMax SHORT	M.Plate	SLANT	1.512	0.090	-0.003		0.3660	1.875
BL177	B__2B07.125	5 May 2007	2:11:20 PM	2:42:58 PM	0:31:38	AT2775-45	Slant	SLANT	1.681	0.079	-0.002	-0.037	0.0656	1.708
BL169	B__3D07.125	5 May 2007	3:01:08 PM	3:32:02 PM	0:30:54	AT2775-45	Slant	SLANT	1.617	0.079	-0.002	-0.037	0.0656	1.644
BL164	B__4F07.125	5 May 2007	3:52:27 PM	4:22:20 PM	0:29:53	AT2775-45	Slant	SLANT	1.711	0.079	-0.002	-0.037	0.0656	1.738
RESERVOIR	B__5D07.125	6 May 2007	7:05:31 AM	9:39:58 AM	2:34:27	ZMax SHORT	M.Plate	SLANT	1.547	0.090	-0.003		0.3660	1.910
BL61	B__6G07.125	6 May 2007	7:35:31 AM	8:09:28 AM	0:33:57	AT2775-45	Slant	SLANT	1.679	0.079	-0.002		0.0656	1.743
BL182	B__7H07.125	6 May 2007	8:38:20 AM	9:17:21 AM	0:39:01	AT2775-45	Slant	SLANT	1.633	0.079	-0.002	-0.037	0.0656	1.660
BL182	B__8I07.125	6 May 2007	9:25:25 AM	11:02:24 AM	1:36:59	AT2775-45	Slant	SLANT	1.515	0.079	-0.002	-0.037	0.0656	1.542
BL177	B__9A07.126	6 May 2007	10:02:21 AM	10:23:16 AM	0:20:55	ZMax SHORT	M.Plate	SLANT	1.619	0.090	-0.003		0.3660	1.982
BL61	B__10C07.126	6 May 2007	10:42:06 AM	11:52:24 AM	1:10:18	ZMax SHORT	M.Plate	SLANT	1.584	0.090	-0.003		0.3660	1.947
BL164	B__11B07.126	6 May 2007	11:30:48 AM	12:46:17 PM	1:15:29	AT2775-45	Slant	SLANT	1.634	0.079	-0.002	-0.037	0.0656	1.661
BL169	B__12E07.126	6 May 2007	12:16:49 PM	1:55:37 PM	1:38:48	ZMax SHORT	M.Plate	SLANT	1.561	0.090	-0.003		0.3660	1.924
BL177	B__13D07.126	6 May 2007	1:13:34 PM	1:48:28 PM	0:34:54	AT2775-45	Slant	SLANT	1.623	0.079	-0.002	-0.037	0.0656	1.650

CITY - Woden

Point	File	Date	Start	Stop	Time	Antenna	Pos	Type	Meas	Rad	Corr'n	O/S	MRP	TRUE
YA41	BYA41B07.153	2 June 2007	10:21:13 AM	1:42:44 PM	3:21:31	AT2775-45	Slant	SLANT	1.713	0.079	-0.002	-0.037	0.0656	1.740
OAKY	BOAKYB07.153	2 June 2007	10:45:16 AM	12:02:43 PM	1:17:27	ZMax SHORT	M.Plate	SLANT	1.511	0.090	-0.003		0.3660	1.874
YA22	BYA22D07.153	2 June 2007	12:24:38 PM	1:31:22 PM	1:06:44	ZMax SHORT	M.Plate	SLANT	1.425	0.090	-0.003		0.3660	1.788
YA28	BYA28007.153	2 June 2007	12:33:51 PM	1:40:06 PM	1:06:15	AT502 TRIPOD	H.Hook	VERT	1.203	0.080	0.000	0.360	0.0618	1.625
YA37	BYA37007.153	2 June 2007	10:20:31 AM	12:02:06 PM	1:41:35	AT502 TRIPOD	H.Hook	VERT	1.212	0.080	0.000	0.360	0.0618	1.634
YA36	BYA36007.153	2 June 2007	11:10:21 AM	1:31:06 PM	2:20:45	AT502 POLE	Slant	SLANT	1.700	0.080	-0.002	-0.035	0.0618	1.725

AGC - Weston Creek

Point	File	Date	Start	Stop	Time	Antenna	Pos	Type	Meas	Rad	Corr'n	O/S	MRP	TRUE
WK16	WK161620.07o	11 June 2007	1:08:39 PM	6:22:46 PM	5:14:07	AT502 TRIPOD	H.Hook	VERT	1.220	0.080	0.000	0.360	0.0618	1.642
OAKEY	oak_1620.07o	11 June 2007	1:33:54 PM	4:10:15 PM	2:36:21	AT502 POLE	Slant	SLANT	1.636	0.080	-0.002	-0.035	0.0618	1.661
OAKEY	oak_1620[1].07o	11 June 2007	4:11:25 PM	6:22:39 PM	2:11:14	AT502 POLE	Slant	SLANT	1.636	0.080	-0.002	-0.035	0.0618	1.661
FORREST	B__3B07.162	11 June 2007	2:05:49 PM	3:31:04 PM	1:25:15	AT2775-45	Slant	SLANT	1.595	0.079	-0.002	-0.037	0.0656	1.622
NARRABUNDAH	B__4A07.162	11 June 2007	2:33:39 PM	4:51:49 PM	2:18:10	ZMax SHORT	M.Plate	SLANT	1.522	0.090	-0.003		0.3660	1.885
COOLEMAN	B__5D07.162	11 June 2007	3:54:31 PM	6:29:25 PM	2:34:54	AT2775-45	Slant	SLANT	1.609	0.079	-0.002	-0.037	0.0656	1.636
CHAPMAN	B__6C07.162	11 June 2007	5:25:53 PM	6:48:19 PM	1:22:26	ZMax SHORT	M.Plate	SLANT	1.631	0.090	-0.002		0.3660	1.995

APPENDIX F – GPS Class Calculation

VECTOR CLASS: r = c (d + 0.2)

r = length of maximum allowable semi-major axis in mm.
c = an empirically derived factor represented by historically accepted precision for a particular standard of survey.
d = distance to any station in km.

						CLASS: 3A		CLASS: 2A		CLASS: A		CLASS: B		
						C: 1		C: 3		C: 7.5		C: 15		
	FROM	**-**	**TO**	**LENGTH**	**+/-**	**LIMIT**	**MET**	**LIMIT**	**MET**	**LIMIT**	**MET**	**LIMIT**	**MET**	**CLASS**
BELCONNEN	Reservoir	-	BL182	1165.235	0.012	0.001	F	0.004	F	0.010	F	0.020	T	**B**
	Reservoir	-	BL61	2300.705	0.014	0.003	F	0.008	F	0.019	T	0.038	T	**B**
	Reservoir	-	BL182	1165.235	0.007	0.001	F	0.004	F	0.010	T	0.020	T	**B**
	Reservoir	-	BL177	915.109	0.007	0.001	F	0.003	F	0.008	T	0.017	T	**B**
	Reservoir	-	BL164	1203.389	0.013	0.001	F	0.004	F	0.011	F	0.021	T	**B**
	Reservoir	-	BL169	1493.982	0.006	0.002	F	0.005	F	0.013	T	0.025	T	**B**
	BL169	-	BL164	1332.872	0.011	0.002	F	0.005	F	0.011	T	0.023	T	**B**
	BL169	-	BL177	1111.329	0.009	0.001	F	0.004	F	0.010	T	0.020	T	**B**
	BL164	-	BL61	1696.189	0.013	0.002	F	0.006	F	0.014	T	0.028	T	**B**
	BL182	-	BL177	1508.619	0.022	0.002	F	0.005	F	0.013	F	0.026	T	**B**
	BL182	-	BL61	3001.132	0.025	0.003	F	0.010	F	0.024	F	0.048	T	**B**
WESTON	WK16	-	OAKEY	3002.082	0.015	0.003	F	0.010	F	0.024	T	0.048	T	**B**
	WK16	-	CHAMPION	2499.955	0.012	0.003	F	0.008	F	0.020	T	0.040	T	**B**
	WK16	-	COOLEMAN	1348.425	0.007	0.002	F	0.005	F	0.012	T	0.023	T	**B**
	WK16	-	NARRABUNDAH	1442.448	0.007	0.002	F	0.005	F	0.012	T	0.025	T	**B**
	WK16	-	FORREST	1778.264	0.009	0.002	F	0.006	F	0.015	T	0.030	T	**B**
	OAKEY	-	CHAMPION	3164.255	0.015	0.003	F	0.010	F	0.025	T	0.050	T	**B**
	CHAMPION	-	COOLEMAN	2140.673	0.01	0.002	F	0.007	F	0.018	T	0.035	T	**B**
	COOLEMAN	-	NARRABUNDAH	2086.82	0.01	0.002	F	0.007	F	0.017	T	0.034	T	**B**
	NARRABUNDAH	-	FORREST	1311.091	0.006	0.002	F	0.005	F	0.011	T	0.023	T	**B**
	FORREST	-	OAKEY	3438.855	0.017	0.004	F	0.011	F	0.027	T	0.055	T	**B**
WODEN	OAKEY	-	YA41	1270.809	0.006	0.001	F	0.004	F	0.011	T	0.022	T	**B**
	OAKEY	-	YA37	1226.742	0.006	0.001	F	0.004	F	0.011	T	0.021	T	**B**
	YA37	-	YA41	1462.231	0.007	0.002	F	0.005	F	0.012	T	0.025	T	**B**
	YA37	-	YA36	1119.609	0.005	0.001	F	0.004	F	0.010	T	0.020	T	**B**
	YA36	-	YA41	1393.901	0.007	0.002	F	0.005	F	0.012	T	0.024	T	**B**
	YA22	-	YA28	1034.113	0.005	0.001	F	0.004	F	0.009	T	0.019	T	**B**
	YA22	-	YA41	994.569	0.005	0.001	F	0.004	F	0.009	T	0.018	T	**B**
	YA28		YA41	2000.488	0.01	0.002	F	0.007	F	0.017	T	0.033	T	**B**

MGA94 COORDINATES; PUBLISHED vs. POST PROCESSED:

Station	Value Type	Published	Processed	Delta
Reservoir	E	690175.945	690175.945	0.000
	N	6099353.756	6099353.756	0.000
	Class/Order	A/1	B/2	
BL61	E	687877.48	687877.471	0.009
	N	6099435.964	6099435.964	0.000
	Class/Order	A/1	B/2	
BL164	E	689368.486	689368.489	-0.003
	N	6100244.418	6100244.418	0.000
	Class/Order	A/1	B/2	
BL169	E	690584.497	690584.495	0.002
	N	6100790.000	6100789.992	0.008
	Class/Order	A/1	B/2	
BL177	E	690996.326	690996.321	0.005
	N	6099757.946	6099757.947	-0.001
	Class/Order	A/1	B/2	
BL182	E	N/A	690650.563	N/A
	N	N/A	6098289.692	N/A
	Class/Order	N/A	B/2	

APPENDIX G – GPS Order Calculation

VECTOR ORDER r = c (d + 0.2)

r = length of maximum allowable semi-major axis in mm.

c = an empirically derived factor represented by historically accepted precision for a particular standard of survey.

d = distance to any station in km.

Class B Maximum Allowable order = 2

	Class B Maximum Allowable order = 2					ORDER: 00		ORDER: 0		ORDER: 1		ORDER: 2		
						C: 1		C: 3		C: 7.5		C: 15		
	FROM	**-**	**TO**	**LENGTH**	**+/-**	**LIMIT**	**MET**	**LIMIT**	**MET**	**LIMIT**	**MET**	**LIMIT**	**MET**	**ORDER**
BELCONNEN	Reservoir	-	BL177	915.109	0.007	0.001	F	0.003	F	0.008	T	0.017	T	2
		-	BL169	1493.982	0.006	0.002	F	0.005	F	0.013	T	0.025	T	
		-	BL164	1203.389	0.013	0.001	F	0.004	F	0.011	F	0.021	T	
		-	BL61	2300.705	0.014	0.003	F	0.008	F	0.019	T	0.038	T	
		-	BL182	1165.235	0.012	0.001	F	0.004	F	0.010	F	0.020	T	
	BL177	-	BL182	1508.619	0.022	0.002	F	0.005	F	0.013	F	0.026	T	2
		-	Reservoir	915.109	0.007	0.001	F	0.003	F	0.008	T	0.017	T	
		-	BL169	1111.329	0.009	0.001	F	0.004	F	0.010	T	0.020	T	
	BL169	-	BL164	1332.872	0.011	0.002	F	0.005	F	0.011	T	0.023	T	2
		-	Reservoir	1493.982	0.006	0.002	F	0.005	F	0.013	T	0.025	T	
		-	BL177	1111.329	0.009	0.001	F	0.004	F	0.010	T	0.020	T	
	BL164	-	BL169	1332.872	0.011	0.002	F	0.005	F	0.011	T	0.023	T	2
		-	Reservoir	1203.389	0.013	0.001	F	0.004	F	0.011	F	0.021	T	
		-	BL61	1696.189	0.013	0.002	F	0.006	F	0.014	T	0.028	T	
	BL61	-	BL164	1696.189	0.013	0.002	F	0.006	F	0.014	T	0.028	T	2
		-	Reservoir	2300.705	0.014	0.003	F	0.008	F	0.019	T	0.038	T	
		-	BL182	3000.126	0.015	0.003	F	0.010	F	0.024	T	0.048	T	
	BL182	-	BL61	3000.126	0.015	0.003	F	0.010	F	0.024	T	0.048	T	2
		-	Reservoir	1165.233	0.006	0.001	F	0.004	F	0.010	T	0.020	T	
		-	BL177	1508.616	0.007	0.002	F	0.005	F	0.013	T	0.026	T	
WESTON	WK16	-	OAKEY	3002.082	0.015	0.003	F	0.010	F	0.024	T	0.048	T	2
		-	CHAMPION	2499.955	0.012	0.003	F	0.008	F	0.020	T	0.040	T	
		-	COOLEMAN	1348.425	0.007	0.002	F	0.005	F	0.012	T	0.023	T	
		-	NARRABUNDAH	1442.448	0.007	0.002	F	0.005	F	0.012	T	0.025	T	
		-	FORREST	1778.264	0.009	0.002	F	0.006	F	0.015	T	0.030	T	
	OAKEY	-	CHAMPION	3164.255	0.015	0.003	F	0.010	F	0.025	T	0.050	T	2
		-	FORREST	3438.855	0.017	0.004	F	0.011	F	0.027	T	0.055	T	
		-	WK16	3002.082	0.015	0.003	F	0.010	F	0.024	T	0.048	T	
	CHAMPION	-	COOLEMAN	2140.673	0.01	0.002	F	0.007	F	0.018	T	0.035	T	2
		-	WK16	2499.955	0.012	0.003	F	0.008	F	0.020	T	0.040	T	
		-	OAKEY	3164.255	0.015	0.003	F	0.010	F	0.025	T	0.050	T	
	COOLEMAN	-	NARRABUNDAH	2086.82	0.01	0.002	F	0.007	F	0.017	T	0.034	T	2
		-	WK16	1348.425	0.007	0.002	F	0.005	F	0.012	T	0.023	T	
		-	CHAMPION	2140.673	0.01	0.002	F	0.007	F	0.018	T	0.035	T	
	NARRABUNDAH	-	FORREST	1311.091	0.006	0.002	F	0.005	F	0.011	T	0.023	T	2
		-	WK16	1442.448	0.007	0.002	F	0.005	F	0.012	T	0.025	T	
		-	COOLEMAN	2086.82	0.01	0.002	F	0.007	F	0.017	T	0.034	T	
	FORREST	-	OAKEY	3438.855	0.017	0.004	F	0.011	F	0.027	T	0.055	T	2
		-	WK16	1778.264	0.009	0.002	F	0.006	F	0.015	T	0.030	T	
		-	NARRABUNDAH	1311.091	0.006	0.002	F	0.005	F	0.011	T	0.023	T	
WODEN	OAKEY	-	YA41	1270.809	0.006	0.001	F	0.004	F	0.011	T	0.022	T	2
		-	YA37	1226.742	0.006	0.001	F	0.004	F	0.011	T	0.021	T	
	YA37	-	YA41	1462.231	0.007	0.002	F	0.005	F	0.012	T	0.025	T	2
		-	YA36	1119.609	0.005	0.001	F	0.004	F	0.010	T	0.020	T	
		-	OAKEY	1226.742	0.006	0.001	F	0.004	F	0.011	T	0.021	T	
	YA36	-	YA41	1393.901	0.007	0.002	F	0.005	F	0.012	T	0.024	T	2
		-	YA37	1119.609	0.005	0.001	F	0.004	F	0.010	T	0.020	T	
	YA22	-	YA28	1034.113	0.005	0.001	F	0.004	F	0.009	T	0.019	T	2
		-	YA41	994.569	0.005	0.001	F	0.004	F	0.009	T	0.018	T	
	YA28	-	YA41	2000.488	0.01	0.002	F	0.007	F	0.017	T	0.033	T	2
		-	YA22	1034.113	0.005	0.001	F	0.004	F	0.009	T	0.019	T	