University of Southern Queensland

Faculty of Engineering and Surveying

Development of Quality Assurance Procedures For Cadastral Surveying using GPS Technology

A dissertation submitted by

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ABSTRACT

The aim of this thesis is to research, develop and assess a legally traceable set of Quality Assurance procedures for using RTK GPS when performing a cadastral survey. To create the QA procedures research was conducted on current legislation, governing bodies (literature) and best practice guidelines. ISO9000 guidelines were used for the development of the Quality Assurance procedures.

A comparison survey was carried out where by the same survey was performed using RTK GPS and a Total Robotic Station. This provided a point comparison between the two methods to determine the achievable accuracy, it also gave a good indication as to the cost efficiency of the two methods.

By using ISO9000 QA procedures the legal traceability of GPS observations can be greatly improved. The research also showed that depending on the size of the reinstatement needed, RTK GPS could achieve the desired level of accuracy at a increased level of efficiency. On a cost per job basis this would provide an overall increase in expected profitability.

This research is limited mostly by the legally untested use of ISO9000 QA procedures for DPS observations. Until either the government or a professional body produce a standard or "guide for best practice" for tracing GPS observations this research is not absolute.

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CERTIFICATION

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I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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NOMENCLATURE AND ACRONYMS (OR ABBREVIATIONS)

(If appropriate)

The following abbreviations have been used throughout the text and bibliography:-

ACSG	Australian Consulting Surveyors Association.
ACSQ	Association of Consulting Surveyors, Queensland.
CRSBANZ	Council of the Reciprocating Surveyors Boards of Australia and New Zealand
DNRM&W	Department of Natural Resources, Mines and Water
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
ICSM	Intergovernmental Advisory Committee on Surveying and Mapping
NMI	National Measurement Institute
OIP	Original Iron Pin
OP	Original Peg
OPM	Original Permanent Mark (Usually interchangeable with PSM)
PPK	Post Processed Kinematic
PSM	Permanent Survey Mark
QA	Quality Assurance
RTK	Real Time Kinematic
SBQ	Surveyors Board of Queensland
SP1	Special Protocol 1
SSI	Spatial Sciences Institute
TGO	Trimble Geomatics Office
TQM	Total Quality Management
USQ	University of Southern Queensland.
VRS	Virtual Reference Station

GLOSSARY OF TERMS

Accuracy: "*The agreement of a value, whether measured or computed, with the standard or accepted true value. In the absolute sense, the true value is unknown and therefore, accuracy can only be estimated. Nevertheless, in measurement, accuracy is considered to be directly proportional to the attention given to the removal of systematic errors and mistakes. In GPS specifically, the values derived are usually the position, time, or velocity at GPS receivers.*" (Sickle 2001, p. 241)

Cadastral Survey: "*Cadastral survey means any process of determining mapping or planning the boundaries of a piece of land or waters required or authorised*
a) Under any Act dealing with alienation, leasing and occupation of Crown lands or with mining, or affecting titles or land; or
b) By the proprietor, lessee or mortgagee under any Act affecting titles to land; or
c) By the owner, proprietor, lessee, mortgagee or occupier of, or any person holding a registered interest in, any land for the re-establishment of, or identification of, or adjustment of any boundary or such land; or
d) Under any Act to be made or certified by a licensed surveyor;"
(Surveyors Act 1977-83, s.5)

Cadastre: "*A **Cadastre** is normally a parcel based and up-to-date land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, and ownership or control of those interests, and often the value of the parcel and its improvements. It may be established for fiscal purposes (e.g. valuation and equitable taxation), legal purposes (conveyancing), to assist in the management of land and land use (e.g. for planning and other administrative purposes), and enables sustainable development and environmental protection.*" (International Federation of Surveyors, 1995)

Class of Survey: "*Class of survey is a means to generalize and prioritize the precision of surveys. The foundation of the categories are often taken from geodetic surveying classifications and supplemented with standards of higher precision applicable to GPS work. Different classifications frequently apply to horizontal and vertical surveys. The categories themselves, their notation, and accuracy tolerances are unique to each nation. A Class of Survey should reflect the quality of network design, the instruments, and methods used and processing techniques as well as the precision of the measurements.*" (Sickle 2001, p. 246)

Data set: "*An organised collection of related data compiled specifically for computer programming.*" (Sickle 2001, p. 248)

Datum: "*(1) Any reference point line or surface used as a basis for calculation or measurement of other quantise.*
(2) A means of relating coordinates determined by any means to a well-defined reference frame.
(3) The singular of data." (Sickle 2001, p. 248)

Cadastral Surveyor: "*Cadastral Surveyor" means a surveyor who holds a registration endorsement for carrying out cadastral surveys.* (Surveyors Act 2003, p.102)

Multipath: "*The error that results when a portion of the GPS signal is reflected…Multipath is mitigated with various preventative antenna designs and filtering algorithms.*" (Sickle 2001, p. 261-2)

Position: "*A description, frequently by coordinates, of the location and orientation of a point or object.*" (Sickle 2001, p. 265)

Quality: "*A principal that encourages excellence in everything: products, strategies, systems, processes, and people. There are many ways in which quality can be pursued and realized.*" (Bounds et al, 1994, p. 794)

Quality Assurance: "*Quality assurance is the ability to provide a formal assurance that goods and services to be supplied have been either:*

- *Assessed as meeting a relevant product standard; or*
- *Produced by a process assessed as meeting a relevant Quality System Standard.*" (Commonwealth Government of Australia, 1993, p.14)

Quality system: "*A quality system is a formal management system which ensures your goods and services will consistently meet your customers' requirements. It is also the way to meet your own quality objectives.*" (Commonwealth Government of Australia, 1993, p.33)

Standard: "*An acceptable level of quality*." (Commonwealth Government of Australia, 1993, p.xi)

Technology: "*The elements of applied science needed for doing the work to provide value in the goods and services produced; used to convert inputs into outputs. Includes two components: knowledge and tools.*" (Bounds et al, 1994, p. 796)

Total Quality Management: "*A people-focused management system that aims at continual increase in customer satisfaction at continually lower real cost. TQ is a total system approach (not a separate area or program) and an integral part of high-level strategy. It works horizontally across functions and departments, involving all employees, top and bottom, and extends backward and forward to include the supply chain and the customer chain.*" (Bounds et al, 1994, p. 796)

Survey quality: "*means the quality of the following—*
(a) The way in which the survey is carried out, including the survey marks used;
(b)The survey results, including the information collected and the accuracy level achieved;
(c)the plan of survey."
(Surveyors Act 2003, p.106)

CHAPTER 1

INTRODUCTION

As modern surveying equipment becomes more affordable and confidence and appreciation grows as to the inherent benefits, survey information will tend towards being gathered entirely in digital form. Operating in this new environment will require different procedures in creating, gathering management and distribution of data.

(Survey Practice Handbook - Victoria, 1997, Part 1-Section 3, p1)

The accurate measurement of length, dimensions, distances and shape is fundamental to a functioning society, with applications in land surveying, navigation, astronomy, engineering, and most areas of industry. The level of accuracy required has increased with increasing technological sophistication.

(National Measurement Institute, 2005, NMI 3)

Standards and conformance are the keys to ensuring the quality and consistency of physical, chemical and biological measurements throughout Australian society and the economy.

(National Measurement Institute 2005, Standards and Conformance infrastructure)

1.1 Introduction.

The above statements highlight the need to develop a method to ensure that the survey information captured using digital technology conforms to the standards required by society. Global Positioning Systems (GPS) is a method for capturing spatial data in digital format..

The GPS technique utilised for a project depends on factors such as: level of accuracy required, suitability of equipment, time, and satellite availability. Each of the different GPS techniques produces different types of digital data. As the technology advances the use of digital records have become more widespread, field books are being replaced by digital data files for an increasing number of surveys.

With increasing use of GPS surveying technology for cadastral surveys, the techniques involved do not provide the same field data records as traditional surveying methods i.e.: field notes/books. Many survey offices have already taken steps, such as quality manuals and procedures, to ensure the quality of their field practices meet the existing requirements or standards set out by governing bodies. Without the legal protection that the field books provide surveyors may become vulnerable to legal action due to lack of legal traceability when facing judicial bodies. Because without adequate records there is no documentation proving their measurements and calculations are justified.

With the rapid growth of GPS usage many institutions have not yet implemented or corrected their literature to suit the technical advancement. Such institutions include Surveyors Board of Queensland (SBQ), who provides surveyors with instructions as to how to perform cadastral surveys in accordance to the legislation.

1.2 Research Aim and Objectives

This dissertation includes the research and development of a set of procedures to ensure that the quality of the field data is protected while incorporating the interests of the survey office. The purpose and scope of the study is detailed in 1.2 Research Aim and Objectives.

The aim of this research is to develop a quality assurance procedure that can be used by surveyors intending to use GPS for cadastral surveys. These procedures will provide surveyors using GPS technology with a step-by-step manual to perform cadastral surveys within the requirements of prevailing legislation.

To develop this procedure it is necessary to research the quality assurance applications, and assess the standards for GPS surveying. A critical evaluation of the current cadastral surveying techniques will follow. The research and evaluation will identify areas where improvements or changes can be made to existing quality systems.

Having researched the guidelines set by the current standards it will then be possible to develop a set of quality assurance procedures for cadastral surveying using GPS technology. Once this has been completed the procedures will have to be tested for suitability, as well as functionality. The testing will be assessed by means of critical evaluation. The new quality assurance procedures will be required to be consistent with the governing bodies' legislation and regulations by which it is bound. If the current legislation and regulations are inadequate, or conflicting, then suggestions for the changes to the legislation and regulations will be made in Chapter 4.

The suggested changes to government legislation and regulations in Queensland will be critically discussed. Thus showing that the quality assurance procedures developed can be supported by the legislation so that the use of GPS technology is acknowledged as being a suitable and viable practice for cadastral surveyors.

1.3 Research Methodology

The methods for research that will be used in this dissertation will be aimed at achieving a realistic solution to the problem posed. This dissertation will be aimed at providing a set quality assurance procedures for use by cadastral surveyors, so it is necessary to conduct a critical evaluation of the existing documentation and final documents in a manner that is consistent with the relevant ISO9000 standard.

A critical assessment of the standards for GPS surveys along with the standards for cadastral surveys will be conducted, to gain an understanding of the capabilities and limitations of the applications of different GPS techniques to cadastral surveying. Following on from the assessment of standards the information will be used to develop the QA method, as described in the aims (Section 1.2). This method will then be tested by comparing two reinstatements; one by total station and then the same reinstatement will be performed using the GPS method developed. This comparison should provide an insight into the expected accuracy. The reinstatement using GPS will also be assessed for its practicality and functionality, to ensure that it is suitable for use in business.

Little literature of the past research in this area has been published. Many companies were approached for aid in this research but none were prepared to allow use of their procedures.

1.4 Scope and Limitations of Research

The research conducted in this dissertation will be comprised of identifying the problems, faults, benefits and suitability of the current uses of GPS technology for cadastral surveys. Suitability and limits of current legislation and regulations in these matters will be determined.

1.5 Consequences

The purpose of developing quality assurance procedure is to provide both the consumer and the surveyor with a practical level of documentary evidence and protection. Obviously the potential for change resulting from this research should not proceed past the eventual implementation of the quality assurance document, and possibly some technical changes to legislation. This should not cause major changes to the abilities and duties of surveyors, as it is intended to be an addition or augmentation to their business practices. This research is designed to enhance the current quality systems surveyors (using GPS) are employing when conducting a cadastral survey.

1.6 Conclusion: Chapter 1

The overall aim of this thesis is to develop a set quality assurance procedures for performing cadastral surveys using GPS technology. The development will include research and evaluation of the quality assurance applications to cadastral surveying and the use of GPS techniques for cadastral surveying.

Because the developed procedures are designed to be utilised by professionals, it is necessary to review the legislation that would effect the application of GPS technology to cadastral surveying. Documents from the SBQ as well as other professional bodies will be reviewed, as these documents could conflict with or support the applications. There will also be suggestions for changes to legislation as well as the other documentation as required.

A discussion and analysis of the outcomes of the quality assurance document and the effects that it might have on industry, legislation and governing bodies is included in the thesis. A conclusion to the research is included as chapter 6, discussing the overall outcomes and findings of the thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction.

This chapter is a review of the literature that will be used to establish the need and applications of quality assurance to a cadastral surveyor, both as a professional and as a business person. This chapter also includes a critical evaluation of the existing standards relevant to aims of the project.

Section 2.2 is a review of the literature which is provided by professional bodies, providing information on specific topics applicable to the development of a quality procedure. Section 2.3 is a review of the current standards applying to GPS surveying techniques and separately cadastral surveying; this provides the necessary information for the specific technical information pertaining to the development of the required procedures. Sections 2.2 and 2.3 are both aimed at the technical and ethical requirements of the proposed procedure. Section 2.4 is a review of the literature that will prove that quality assurance has applications to cadastral surveyors.

It is also necessary to evaluate the need for quality assurance in its application to a surveyor in a business sense. Section 2.4 is also a discussion on the applications of quality assurance to cadastral surveyors as business people.

2.2 Governing Bodies

As mentioned in section 2.1 this part of the chapter will be a review of the literature of the governing bodies. This is to provide ethical and technical issues that will be used to develop the quality assurance procedure in Chapter 4. The literature to be reviewed in this section includes: documents from the National Measurement Institute (NMI), legislation and recomendations from the SBQ.

2.2.1 National Measurement Institute (NMI)

A review of the documentation provided by the NMI is required because distance, length, area, angle and position are all covered by the regulations of the NMI making it a key body in the regulation of surveying. The NMI is a division within the Department of Industry, Tourism and Resources, and is responsible for Australia's national infrastructure in physical, chemical, biological and legal measurements. The NMI describes its role as:

> "*NMI is responsible for maintaining and developing the infrastructure and facilities for legally traceable measurements in Australia.*" (National Measurement Institute 2005)

The institute is also responsible for:

- Coordination of the nations measurement systems,
- Creation and maintenance of the legal units of measurements in Australia,
- Advising the government on the infrastructure and facilities required to make legally traceable measurements
- The development of measurement infrastructure to address new technologies and community needs.

The stance taken by the NMI on quality systems is described as:

> "*Quality system standards are adopted as a means of managing the quality of an organisations products and services.*" (National measurement institute, 2005, Standards and Conformance Infrastructure)

Thus proving that the NMI regards quality systems and standards as key functions of an organisations products and services, also being a key function of their best business practices.

Through their documentation, the NMI requires surveyors to provide legally traceable measurements and quality systems and standards that will ensure the products and services provided by an organisation are of a suitable quality. The NMI suggests that to provide a legally traceable measurement, the instrument used must be able to be calibrated.

> "*The hierarchy of standards (see diagram below) by which a physical measurement can be related back through the national metrology pyramid to the relevant SI unit is known as traceability.*" (National measurement institute, 2005)

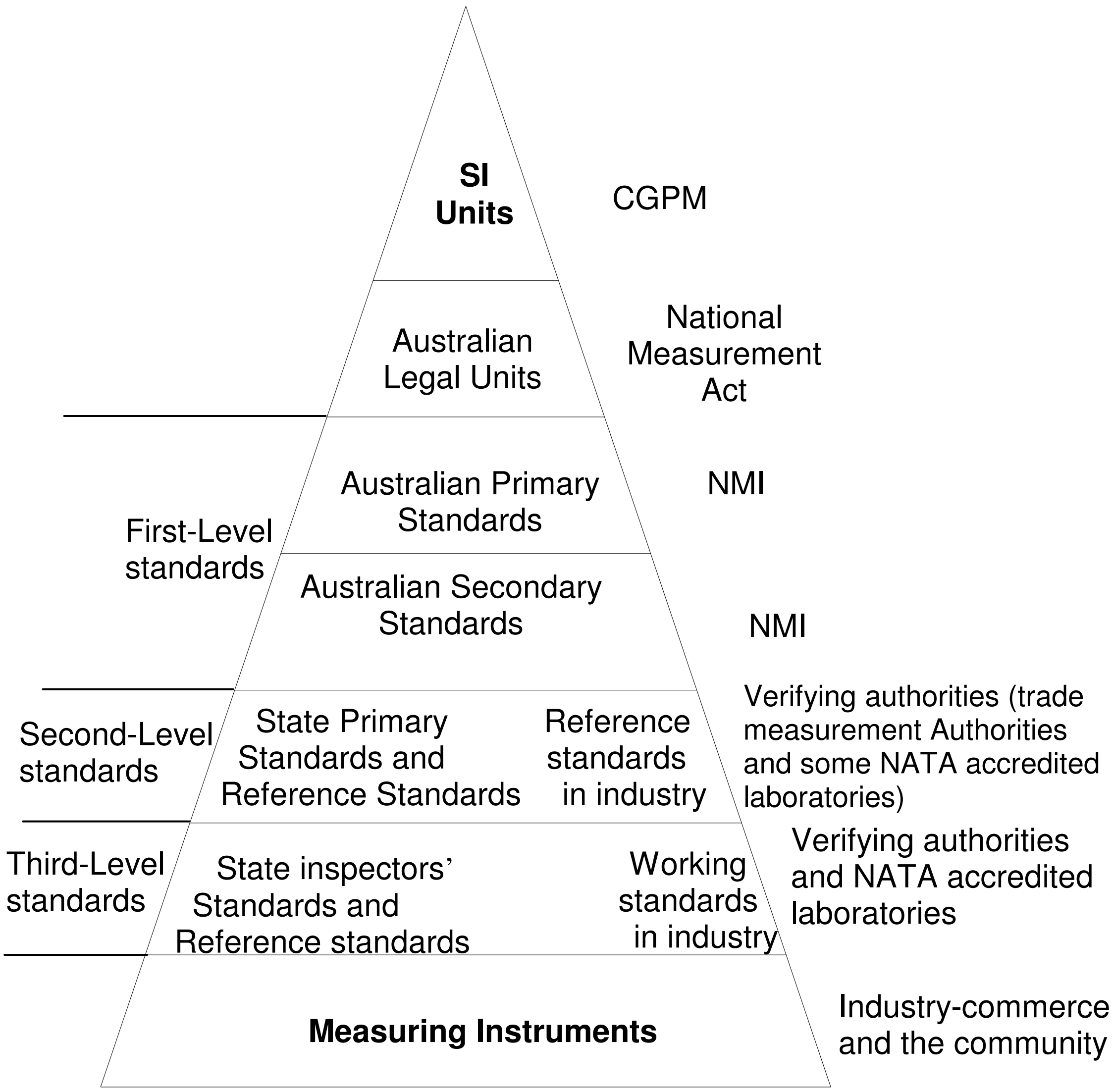

Figure 2.1 Hierarchy of Standards

The level that a surveyors' GPS equipment belongs to, in Figure 2.1, is the bottom one (measuring instruments). To calibrate any instrument in this level it is necessary to compare it to one from a higher level, either a third level standard or a second level standard is required. This pyramid system provides a tightly controlled series of standardised instruments as each layer is standardised by the one above, and the top layer is controlled by the NMI, making each calibration traceable back to the NMI, and hence providing legal traceability.

While traditionally survey measurements have been in bearings (degrees) and distances (meters). These being observed by a surveyor using an instrument that has been regularly calibrated using a base range. Base range information can be obtained from DNR&M. However GPS does not measure bearings and distances, it measures positions: Eastings, Northings and ellipsoid/geoid heights. The NMI recognises that position is an acceptable form of measurement but it does not explain how it should be measured or recorded.

2.2.2 Government Legislation

The legislation researched in this section is from the state government. This is because the state government has produced legislation that is pertinent to the aims of this dissertation. The Act being discussed is the Surveyors Act 2003.

Surveyors Act 2003: The purpose of this act as described in section 3 of the act:

> "*…is to protect the public by ensuring surveys are carried out by registrants in a professional and competent way; and… to uphold the standards of practice within the profession; and… to maintain public confidence in the profession.*" (Surveyors Act 2003, p.12)

The Surveyors Act 2003 main role is to establish the Surveyors Board of Queensland defining its role in matters such as:

- membership,
- the functions of the board,
- the boards relationship with the state, and
- the powers of the board,

The Act also provides for the: development of the surveyors code of practice, registration and endorsement of surveyors, the obligations of registrants, investigations into complaints about professional conduct and the conduction of the surveyors disciplinary committee. The code of practice will be reviewed in sub-section 2.2.3.

The Surveyors Act provides no ethical or technical sections that are pertinent to the development of a quality assurance procedure for GPS surveying techniques in cadastral surveying. This Act does however provide for the document that is key to this dissertation: the 'Cadastral Survey Requirements' by the Queensland Department of Natural Resources, Mines and Water. The 'Cadastral Survey Requirements' will be discussed further in section 2.3 (Standards).

2.2.3 Surveyors Board of Queensland

The SBQ's main function is to provide and control the registration of cadastral surveyors. By agreeing to the terms and conditions of registration a surveyor also agrees to abide by the 'Code of Practice for Surveyors' set out by the SBQ under section 80 of the Surveyors Act.

The code describes a surveyor's role towards public interests as:

> "*Professional surveyors recognise that their ethical responsibilities extend to the public, to their clients and employers, to their peers and to their employees. Accordingly, they acknowledge the need for integrity, independence, care and competence and a sense of duty.*" (Code of Practice for Surveyors, 2004, p. 1)

One such method for surveyors to ensure the provision of ethical and professional services to the public is through the use of quality assurance methods in their practices.

In section 2.2 of the code, Professional Competence, it is stated:

> "*In general, surveyors shall assist in maintaining the integrity and competence of the surveying profession, their own competence and also improving survey systems and must:*
>
> *a) Abide by the principles and standards of professional practice and apply best practice.*
>
> *b) Not accept assignments beyond the surveyors' professional competence…*

d) Maintain, for as long as is practicable and for a reasonable time, adequate records directly pertinent to the surveys undertaken, whilst in control of those records." (Code of Practice for Surveyors, 2004, p. 2)

The sub-section (a) states that surveyors are required to conduct 'best practice'. This professional standard of practice will be aided by the use of the QA procedures, by providing evidence of the accuracies and systems used for the cadastral survey.

From sub-section (b) of the "Code of Practice", proves that a surveyor must have competence in all aspects of the assignments to which they are undertaking. As cadastral surveys are now being conducted using GPS, then this statement must also apply to GPS surveying technology. It is evident that if a surveyor has not had professional training, then the surveyor should not be participating in such assignments. This is also shown by the Council of Reciprocating Surveyors Boards of Australia and New Zealand in their document on "Competency Assessment".

Sub-section (d) of the "Code of Practice", discusses the need for surveyors to maintain their records of each survey for as long as practicable. This would also include original field observations, as discussed in Chapter 1, digital data files are often taking the place of traditional field books. Hence it is be necessary to include in the procedures a method of protecting such files. Section 2.3 (Professional Conduct) sub-section (i) discusses the misuse or falsification of data.

"*(i) Not falsify any plan, document or data or knowingly misuse any data or misuse their position to achieve a predetermined result which is:*

(i) inconsistent with normally accepted survey practice…."(Code of Practice for Surveyors, 2004, p. 2)

It is normally accepted survey practice to maintain the originality of the field records when taken in a field book. This should also continue when using digitally collected data. Some software and data formats are automatically changed when downloaded from capture device to computer; it is argued that this could be construed as falsifying data.

2.2.4 Spatial Sciences Institute

The need for quality assurance in the spatial science professions is possibly best described by the Spatial Sciences Institute (SSI) as:

> "*The quality of services founded in the spatial sciences is not easy to discern by non-experts. Faults and failings may remain undetected for considerable periods; and the consequent effects may be of serious consequence to the community.*" (Code of Ethics, Spatial Sciences Institute, 2003)

The SSI Code of Ethics also covers the topic of 'only partaking assignments for which the surveyor has competence'. This code directs a surveyor who might not have the required competence to perform a task, to seek expert assistance when and where necessary.

2.3 Standards

Before developing a quality assurance document for use by surveyors using GPS technology for cadastral surveys, it is necessary to evaluate the relevant standards that apply. To this end, the standards that will be evaluated will be GPS standards and cadastral survey standards. The standard to be evaluated covering GPS surveying is the Standards and Practices for Control Surveys Version 1.6 (November 2004) known as SP1 (Special Protocol 1), produced by the Intergovernmental Committee on Surveying and Mapping (ICSM). The standard to be evaluated for cadastral surveying is the Cadastral Survey Requirements Version 4.0 (November 2005), produced by the Queensland Government Department of Natural Resources and Mines.

2.3.1 Evaluation of GPS Standards

SP1 Section 2.6, Global Positioning System (GPS), provides the guidelines for conducting GPS surveys using best practices. This section also notes that the guidelines <u>do not</u> provide legal traceability of measurements, which is an issue currently being pursued by the Geodesy Technical Sub-Committee of the ICSM. This is because:

> "*…approved methodologies for establishing legal traceability of length measurement for GPS do not currently exist under the Australian National Measurement Act (1960), GPS should not be used as the sole method of*

measuring length in legal surveys within Australia. Surveys using GPS for legal purposes within Australia must adhere to the requirements of the appropriate verifying authority in the State or Territory." (ICSM, P. B-27)

This quote has drastic implications for those who have been using GPS as a cadastral tool. There is no existing legally traceable method of GPS measurement for length. To that end GPS can only be used for cadastral surveys if a method(s) is recognised by the Surveyors Board of Queensland, and the Queensland Department of Natural Resources, Mines and Water (DNRM&W), as well as being recognised in their publications. This will be seen in the evaluation of the current cadastral survey regulations (Chapter 2.3.2). Even though calibration can not be performed for legal traceability, validation of the equipment can be performed.

SP1 section 2.6.4 "Equipment Validation" tells us that GPS equipment can be validated by testing by the equipment and software against existing high quality geodetic network marks. Another method for validating GPS antennae and receivers is to perform a 'Zero Baseline' measurement. The 'Zero Baseline' method involves using one antennae and a special split cable to two receivers, the difference between the position shown on each receiver should be less than 1cm, if the antennae and receivers are functioning correctly. These methods rely on the accuracy of the geodetic network and its availability, as well as on the user of the equipment.

SP1 section 2.6.3, Geodetic Datums and Geoid Separations, suggests that all of the horizontal survey observations using GPS should create a closed figure as well as being connected to at least two existing stations in the geodetic control network. This is to provide adequate redundancies for the least squares adjustment.

Section 2.6.7 of SP1, General Requirements for GPS Observations, recommends that for best practices it is necessary for the surveyor to:

- Be familiar with the equipment and software that is intended for use; and
- Ensure all ancillary equipment is in good adjustment; and
- Receivers and software should be of the geodetic type; and

- Satellite geometry must be adequate to ensure a suitable accuracy is achieved; and
- Elevation masks should be set no lower than 15°; and
- If selected availability (S/A) is turned off, then the starting coordinates given by a receiver generated position is suitable for starting. However if S/A is turned on then accurate starting coordinates, for a suitable mark(s), should be obtained from the relevant authority; and
- Real Time Kinematic (RTK) techniques do not require a least squares adjustment as RTK uses radiations from Base Station to Rover as measurements. Some RTK receivers may allow users to download GPS baseline components suitable for input into a least squares adjustment; and
- SP1 suggests that the GPS antennae should have a clear visibility to the sky in all directions down to the elevation mask and be free from obstructions like buildings, trees, fences and topography.

This last point is impractical for cadastral surveyors in most circumstances, as boundaries and the associated reference marks were often placed without consideration for GPS users. Even so multipath situations should be avoided where possible, if unavoidable longer occupation times will allow the space vehicle (SV) geometry to change. Enough time should be taken for the residuals to determine a position, using many epoch of data to minimise any multipath errors.

Section 2.6.8, Specific Observation requirements for Various Relative GPS Techniques, covers topics specific to the different carrier-phase observable techniques. Section 2.6.8.1 classic static baselines, this technique is primarily for the surveying of very long baselines (i.e. >10km) and thus has limited application to cadastral surveying applications. Classic static baseline technique requires extended occupation times and thus is most likely to be impractical and uneconomical to the cadastral surveyor.

Quick static baselines, also known as rapid static or fast static, technique is similar to the classic static baseline technique, but requires much shorter occupation times, resulting in a shortening in the baseline length. The time required for each occupation for both of these static methods is dependant on the manufacturers' specifications.

Section 2.6.8.3 covers Post Processed Kinematic (PPK) Baselines; also know as intermittent or stop/go technique requires four or preferably five common satellites to be used, because of the signal loss during transit between stations. PPK baselines might suit the cadastral application due to the environment in which a cadastral survey might be located. An example of this might be where it is necessary measure a baseline across a power line or bridge, where maintaining signal lock would almost be impossible. This technique requires initialisation to be performed for each kinematic chain of the survey, unless the receivers are capable of on-the-fly initialisations. The required occupation times for this technique are significantly shorter than static methods; this could create problems when occupying a point in a multipath environment as there is not enough occupation time for the multipath error to be resolved.

Real Time Kinematic (RTK) technique involves the transmition of data from the base station to the rover via radio telemetry, which is then processed in real time at the rover. This technique provides the positional solution in real time at the rover. This technique is most suited to cadastral surveyors as they need the solutions in real time for the calculations involved in reinstatement. Things to consider when using this technique:

- Single or dual frequency receivers may be used; however dual frequency receivers will mitigate the effects of the ionospheric delay on longer baselines.
- The typical range for RTK is 15km, this would be suitable for most cadastral applications, however the range might be limited by the accuracy required.
- Most manufacturers claim to be able to achieve 10mm ±2ppm; this accuracy is reliant on the satellite geometry, real time update rate and the manufacturer.
- Each occupation requires the ambiguities to be resolved.
- By re-occupying stations, allowing for significant satellite geometry changes, improves detection of errors such as multipath because of the independent ambiguity resolution.

- It is recommended that each new station has at least two independent re-occupations from two base stations. This is a reliable means of detecting systematic and gross errors.

This section (2.6.8.4) recommends that sufficient control points should be occupied to provide redundant connection and fitting to the datums in the project area. It also suggests that new base stations should be surveyed using either a classic static or quick static techniques before commencing the RTK section of the survey.

Section 2.6.9 Processing Baselines; discusses points to consider when processing baselines. As most of the suggestions are for lines of >10-15km, which have limited application to cadastral surveys, however the information in SP1's table 26 *Recommended Processing Requirements* will help determine the type of processing requirements necessary for each class of survey when using the RTK technique.

Table 2.1 RTK Recommended Processing Requirements

Table 26 RTK Recommended Processing Requirements

CLASS (Australia) c-values (one sigma)	**3A ≤1**	**2A ≤3**	**A ≤7.5**	**B ≤15**	**C ≤30**	**D ≤50**	**E ≤100**
CLASS (New Zealand) (see the New Zealand Web site for details)	B10	M1	M10	M100			
Baseline length	Recommended processing requirements						
<8 km	D*, DD, FX	D*, DD, FX	S, DD, FX	S, DD, FX	S, DD, FX	S, DD, FT	S, DD, FT
8-25 km	D, DD, FX	D, DD, FX	D, DD, FX	D, DD, FX	S, DD, FX	S, DD, FT	S, DD, FT
25-50 km	D, DD, FX(25)-FT(50)	D, DD, FX(25)-T(50)	D, DD, FX-FT	D, DD, FX-FT	D, DD, FX-FT	D, T	D, T
50-90 km	D, DD,FT	DD or T**, D, FT	DD or T**, D, FT,	DD or T**, D, FT,	DD or T**, D, FT	D, T, NCP	D, T, NCP
>90 km	D, T	D, T	D, T	D, T	D, T	D, T, NCP	D, T, NCP

Notes on Table 27:

S = single frequency D= dual frequency
DD = double differences FX= ambiguity fixed solution
FT = ambiguity float solution, with repaired cycle slips
T = triple difference solution with sufficient observation length, allowing change of geometry.
NCP= Narrow correlation, C/A code or Pseudorange methods, e.g. DGPS
* = L1 solution, from a dual frequency receiver, in order to enable ambiguity resolution by widelaning.
**= Double difference preferred, triple difference solution increasingly acceptable the longer the distance, if the observation length allows sufficient geometry change.

(Inter-Governmental Committee on Surveying and Mapping, P. B-24)

Section 2.6.10 Analysis Using Least Squares Adjustment; describes the processes that should be adhered to when reducing the captured field data. It includes unconstrained adjustment, minimally constrained adjustment, full constrained adjustments and analysis and testing of the survey. These processes will be described as needed later in the dissertation.

Determination of class, positional accuracy, local accuracy, is not necessary as the final set of accuracies that any cadastral survey must achieve is set out in the '*Cadastral Survey Requirements*'.

Section 2.6.12 covers field notes and data lodgement; this section is critical to the research. As mentioned earlier field notes and data files are a major section of providing legal traceability. The following quotes have been selected from section 2.6.12 as it is necessary to discuss their role in the research:

> "*Field observations recording sheets (log sheets) should be completed each session. The receiver type, serial number and software used for reductions should be recorded on these sheets.*" (Inter-Governmental Committee on Surveying and Mapping, P. B-29)

The above point is critical as it provides a traceable way to tie the actual field activities to a particular set of equipment, software, receiver and method of reduction. This will be one of many steps involved in providing the necessary legal traceability needed for the QA method developed.

> "*The GPS field recording sheets should be made available should an examining authority so request.*" (Inter-Governmental Committee on Surveying and Mapping, P. B-29)

This is also supported by the Code of Practice for Surveyors, as can be seen in section 2.2.3 Government Legislation, of this dissertation.

> "*Raw observational data should be archived in case an auditing process is required by the examining authority. (Note: Raw data is equivalent to the*

> *surveyor's field book and should be retained for the same length of time)*" (Inter-Governmental Committee on Surveying and Mapping, P. B-30)

This point proves that the raw field data captured is to be maintained and protected the same as a field book would be. This point supports the view taken in section 2.2.3 on the data collected in the field. Yet another critical step in providing legal traceability to GPS surveys and as such is be a key section of the QA method developed in this dissertation.

> "*If required by the examining authority, result files from the baseline processing and final adjustments MUST be supplied in digital form. The recipient may recommend the processing and/or adjustment software digital format. This enables automatic inclusion of the results in the recipient's data base systems.*" (Inter-Governmental Committee on Surveying and Mapping, P. B-30)

As cadastral surveys are currently required to be submitted in hard copy format (paper copy), it is not necessary to submit the result files to the Department of Natural Resources and Mines (DNR). This may change in the future depending on the technical advancements in the titles system, the Digital Cadastral Data Base (DCDB) and the plan lodgement process. However even though the DNR does not require them, they would provide evidence of the processes used for each survey to reduce the raw data and as such these records should be preserved and maintained just as the raw data.

Section 2.7 Internal Survey Systems; deals with the technical details of the internal aspects of control surveys, these will be discusses and included in Chapter 4 Method.

Part D Recommended Documentations Practices and Data Archiving Policy for a National Geodetic Data Base; discusses how valuable geodetic data becomes to the public when readily accessible from national data bases. Part D suggests the inclusion of the following information for horizontal control data elements:

- Station identification.

- Station Establishment Technique; this is to give subsequent users information about the methods and results used to create the station.
- Other Observations; used in the creation of the station.
- Responsible Authority; the authority responsible for the information must be recorded.
- Date of Currency.
- Last Visit.
- Station/Mark Description.
- The Horizontal Datum; needs to be adequately defined for calculation purposes.
- Output Coordinates; the final position for the station should be available in both geographic and grid coordinates.
- Horizontal Adjustment; information about the method of adjustment/s used in defining the class, positional and local uncertainties should be included.
- Class; of the survey creating the station.
- Positional and Local uncertainty.
- Field Records; an appropriate reference to the field records should be available.
- Additional Information; should be provided as necessary.
- Cadastral information; references to the property and the location of the station relative to a property corner would be helpful when searching for the monument.

The following few points are relevant to GPS data elements for archiving purposes.

- The Station Identifier.
- The antenna eccentricities.
- The receiver type.
- The antenna type.
- The GPS observables collected.
- The satellites observed
- Observation times.

The above points are considered relevant to the research and are included where necessary in the QA procedures. The next section, 2.3.2 Evaluation of Cadastral

Surveying Standards, will be a critical evaluation of the DNR's '*Cadastral Survey Requirements Version 4.0*', which provides the current standards and guidelines for conducting a cadastral survey in Queensland. The evaluation will include technical and ethical issues in the document.

2.3.2 Evaluation of Cadastral Surveying Standards

Chapter 1 of the '*Cadastral Survey Requirements*' (2005) refers to the *Survey and Mapping Infrastructure Act 2003* and how the document has been made to be compliant with the aforementioned act. It also describes how a surveyor may adopt another method or standard:

> "*A surveyor, surveying associate or surveying graduate may comply with a survey standard by adopting and following the following-*
>
> *(a) the ways stated in a survey guideline for complying with the standard; or*
>
> *(b) other ways that achieve an equal or better level of compliance.*"
>
> (Department of Natural Resources and Mines, 2005, p.1)

This means that the surveyor has a choice between following the recommended standards supplied in the document, or they can choose to use other ways to perform their duties as long as they equal or better the level of compliance set by the document. This of course would force the surveyor to be able to prove that the method used did equal or better the level of compliance.

Chapter 1.5 Departure from Standards describes how a surveyor may use any method or equipment to perform a cadastral survey, as long as the surveyor can prove that the equipment and/or method is able to satisfy the necessary standards. This could be interpreted as conflicting with the NMI which, earlier in the research, demonstrated that measurements need to be legally traceable upward on the hierarchy of standards (diagram 2.2.1).

Chapter 3 Survey covers the technical and legal responsibilities of a surveyor performing a cadastral survey, covering topics such as: accuracy, areas, coordinates, dimensions, survey reductions, meridians and survey records. The following paragraphs are a discussion and evaluation of the relevant information in the document.

Accuracy – section 3.4.2 of the '*Cadastral Survey Requirements*' states:

> "*The accuracy of a cadastral survey must be determined –*
>
> *(a) by computation of the angular and linear misclose in a surround; or*
>
> *(b) by comparison with coordinated permanent marks; or*
>
> *(c) by a method appropriate to the technology being used for the survey.*"
>
> (Department of Natural Resources and Mines, 2005, p.9)

This quote shows that the cadastral survey must meet the standards for closure by any of the methods described above, this allows for GPS technology to calculate its misclosure from either coordinated permanent marks, or by another appropriate method. The method that GPS technology would most likely be best suited to would be (c), determination by the class and positional and local uncertainties as discussed in SP1 (chapter 2.3.1 of this dissertation). The acceptable misclose for a survey is included in section 3.4.2, as these have been determined by the DNR and are now the accepted standard it is not part of this research to challenge these. Even though GPS is measuring position, boundaries which the survey is defining must still achieve an acceptable misclose. Having calculated the misclose of a survey allows other necessary tasks to be performed such as area calculations.

Coordinates – (Section 3.14 of the '*Cadastral Survey Requirements*') It is recommended that the coordinates shown on a cadastral plan should be on the GDA 94 datum, however if GDA 94 is not available other datums are able to be used. The information that is required to accompany coordinates, as shown by the '*Cadastral Survey Requirements*', is:

> "*Any coordinate GDA 94 or otherwise, should quote the datum, and provide sufficient information to permit subsequent re-occupation of the coordinates if the datum is provided. As a minimum, this information would be:*
>
> *(i) The connection between the survey and the coordinate source (eg PSM): and*
>
> *(ii) The coordinates and the datum of the coordinate source.*
>
> (Department of Natural Resources, 2005, p.27)

By following the above points it allows cadastral surveys to be on a coordinated system, making it possible for GPS surveys to be subsequently combined with other survey methods. This section of the '*Cadastral Survey Requirements*' goes on to describe how AMG and MGA grid coordinates can be calculated from GDA 94 datum, using the "GDA Technical Manual".

The accuracy of the coordinates is required to be tabulated on the face of the plan using the class and positional and local uncertainty as described by the methods shown in SP1.

Dimensions – (Section 3.18 of the '*Cadastral Survey Requirements*') Distances are required to be reduced so that they represent horizontal distance. This is to allow for area calculations and to lessen confusion amongst plan readers. The references to bearings in this section only relate to how they are to be shown on plans.

Meridian – The approved methods of determining the meridian of survey is clearly identified in section 3.23 of the '*Cadastral Survey Requirements*' which states:

> "*The meridian of a cadastral plan must be one of the following:*
>
> - *the MGA, to an accuracy of twenty seconds of arc, by derivation from either coordinated permanent marks or astronomical or GNSS observations;*
> - *County Arbitrary Meridian;*
> - *the meridian of the original survey;*
> - *the meridian of an adjoining survey.*"
>
> (Department of Natural Resources and Mines, 2005, p.37)

This allows for meridians to be determined through GPS observations, however it does not specify how the GNSS (Global Navigation Satellite System) observations are to be taken, or to what accuracy. This is a shortcoming on the part of the writers of the regulations, as the accuracy of the initial observations would reflect on the accuracy of any subsequent reinstatements. The regulations allow a surveyor to submit records to support the method used for determination of the meridian, which is shown in the following quote:

> "*Survey records may be supplied to support any determination of meridian, eg stellar observations, GPS information and adjustments.*"
>
> (Department of Natural Resources and Mines, 2005, P37)

All of the points identified in the above sections have been included because they will need to be addressed in the developed QA method. However it is also important to understand the need for QA as professional surveyors. The next section (section 2.4); will discuss the needs for QA from two points of view, business and professional.

2.4 Application of Quality Assurance

The definition of a quality system that the Commonwealth Government published in "*How to Supply Quality*" (1993):

> "*A quality system is a formal management system which ensures your goods and services will consistently meet your customers' requirements. It is also the way to meet your own quality objectives.*" (Commonwealth Government of Australia, 1993, p.33)

The Commonwealth Government considers quality as ensuring the goods and services provided to consumers, both public and private, meet the customer's requirements. Proving the need for quality assurance will be achieved by reviewing the literature of relevant journal articles and any other professional documents, these will include:

- *Proposed Surveying (Cadastral Surveys) Regulations April 2005- Regulatory Impact Statement*, this is a report from 'The Allen Consulting Group' to the Victorian regulator body "Land Victoria".
- *National Model for Standard Practice in Surveying and Mapping*, produced by the 'Council of the Reciprocating Surveyors Boards of Australia and New Zealand' (CRSBANZ).

The following paragraphs will discuss how these documents provide the evidence for proving the need for QA, both as professionals and as businesses.

'*Proposed Surveying (Cadastral Surveys) Regulations April 2005- Regulatory Impact Statement*' from 'The Allen Consulting Group' to the Victorian regulator body makes the following statement in their report:

> "*Good business practices, such as Quality Assurance procedures like instrument and equipment calibration standardization, have been introduced to cadastral surveying firms to reduce insurance premiums.*"
> (Allen Consulting Group 2005, p.36)

> "*Ability to enforce QA processes reduces the risk to the cadastre.*"
> (Allen Consulting Group 2005, p.38)

The first of the above two quotes indicate that QA is recognized by insurance agencies as an asset, for protection against professional negligence claims.

The second of the quotes stems from a much longer discussion about the Surveyor Generals (Victorian) roles and powers. It suggests, as the quote reads, that the Surveyor General should be able to enforce the application of QA for the aim of protecting the cadastre against erroneous surveys. As described at the start of this section the goal of QA is to provide the customers with satisfactory goods/services. It is important to point out that in Queensland the DNRM&W are also a consumer of the survey plans that a cadastral surveyor might produce, as the DNRM&W are responsible for the re-selling of the information to the public.

The '*National Model for Standard Practice in Surveying and Mapping*', produced by the Council of the Reciprocating Surveyors Boards of Australia and New Zealand (CRSBANZ) is a model designed to address the needs of spatial scientists during the micro-economic reform in Australia and New Zealand. The objective of this is to establish and maintain a common market place in Australia and New Zealand in the areas of:

- Mutual recognition of qualifications;
- The development of National land data transfer policies;
- And the phasing out of intra-jurisdictional preferences in the supply of goods and services.

In section 3 (General Principals) of the aforementioned Model the following statement about QA is made.

> "*In the last five years a quality management revolution has occurred throughout the industry in Australia. This has seen the widespread adoption*

of the international standard for quality management systems. These standards are published in Australia and New Zealand as the AS/NZS/ISO 9000 series.

It is recommended that individual organizations seek quality accreditation."

(Council of the Reciprocating Surveyors Boards of Australia and New Zealand, 2001, p.3)

As seen in the quote QA has been accepted into surveying and spatial sciences as a management tool throughout the country. The CRSBANZ also indicates that each organization utilizing the QA systems must seek out their own accreditation. This reinforces the view taken by the Allen Consulting Group.

The Spatial Sciences Institute (SSI) provides the following point as part of its code of ethics:

"*Community", in the context of the Code, refers to all groups in society including members' own workplaces. The first three tenets of the Code refer to the Community and may be considered to include:*

- *Ensuring that work undertaken meets community expectations by adopting the norms of good practice; or communicating any attendant risks or limitations, and their effect, in any work undertaken which does not accord with convention*;"

(Spatial Sciences Institute, 2003, P3)

As determined above by the CRSBANZ, QA can be considered as part of the SSI's description of the "*norms of good practice*", as the CRSBANZ describes it as a "*revolution has occurred throughout the industry in Australia*".

These quotes from the different interest parties prove that from both a professional and a business perspective QA is required in surveying and spatial science.

2.5 Conclusion

As can be seen in this chapter there is a need for quality assurance in cadastral surveying. It is also clear that there is very little agreement between the relevant governing bodies as to the necessary standards that GPS technology must achieve to be accepted for cadastral surveys. By using the standards from SP1 and the information in the ‘Cadastral Survey Regulations’ it will be possible to develop the QA method to conduct a cadastral survey using GPS technology.

The specific requirements of the QA system will be discussed in Chapter 3 - Development of the Quality System. This will cover topics such as the GPS survey style, accuracies and reinstatement closures.

CHAPTER 3

METHOD

3.1 Introduction

The purpose for this chapter is to describe how the QA procedures have been developed and to provide the end user with an understanding of each of the points contained within. By doing this the user will have greater ease incorporating these new QA procedures into their QA documentation and, if necessary, have the ability to augment or modify the individual points to suit their individual needs.

The aim of this chapter is to fully explain the procedures involved in each section and the reason why each point is included. It is necessary for the user to be able to understand why each point is included and how it aids the legal traceability of the documentation resulting from the process, so that the users may have faith in the QA process. This will also reinforce the understanding of the QA procedures if they are ever challenged, as the user will be able to explain exactly what each point means and how it relates to the jigsaw framework of QA.

Quality Assurance has been referred to as a jigsaw in the above paragraph because of the way each section, and point, helps support and completes the picture of legal traceability as a whole. This will become clearer once it is understood how the QA procedures have been developed, that is by dismantling the whole process of a GPS survey into its three major sections: pre-survey, field survey and post-survey. The three procedures have been written using the *ISO 9001:2000(E)* standard, along with the book "*The ISO 9000 Documentation Toolkit*" by JL Novack, so that the end user will have confidence in the knowledge that the process used is designed to suit the modern QA environment.

Each of the three procedures have five headings:

- Purpose: This sub-section outlines the specific purpose of the implementation of the procedure.

- Scope: Outlines the people or staff involved in the process of using GPS for cadastral surveys.
- Responsibilities: Is the sub-section which defines the specific responsibilities of each of the involved persons in the procedure
- Procedure: Describes the actual procedure for the pre-survey section of the QA process and is where the specific steps are detailed.
- Related Documentation: Lists the specific documents that are associated with this procedure and are necessary for the legal traceability of the process.

A detailed explanation of each of the points contained in the three procedures can be found in Chapters 3.3, 3.4 and 3.5. Chapter 3.2 describes the technical details needed to form part of the QA procedures.

3.2 Requirements for Development of the Quality System

3.2.1 Survey Style

One of the key reasons a surveyor would employ GPS is because of its economic benefits, as it is a much faster style of surveying than total stations as there is less time involved in traversing between reference marks. From the literature review, it has been determined that the style of GPS measurement that is best suited to this application is RTK. This is because observations can be made rapidly wile maintaining a suitable accuracy. RTK is a fast kinematic style of GPS surveying which is necessary for it compete against total stations.

3.2.2 Specifications of Accuracy

Cadastral Surveys: Section 3.4.2 of the '*Cadastral Survey Requirements*' (DNR) describes the method for determining the angular misclose as:

> "*The angular misclose in a surround or the angular deviation from the adopted meridian must not exceed the lesser of-*
>
> *(d) 2.5 times ten seconds of arc multiplied by the square root of the number of angles; or*
>
> *(e) 2 minutes;"*

(Department of Natural Resources, 2005, p.9)

The linear misclose is determined by:

> "*The linear misclose in a surround must not exceed-*

(f) 10mm plus 1 part in 5000 of the total distance traversed; or

(g) 20mm plus 1 part in 2500, if the survey is in rough or broken terrain; or

(h) 20mm plus 1 part in 2000, if another surveyor's work is included in the surround; or

(i) 20mm plus 1 part in 1000, if a survey is effected before 1890 is included in the surround.

All survey lines (e.g. boundary lines, connections) must have a vector accuracy of 10mm +50ppm."

(Department of Natural Resources and Mines, 2005, p.9)

These quotes clearly define the accuracies (linear and angular) that a cadastral survey must achieve. The accuracy of a reinstatement using GPS can be assessed in this way.

RTK: As can be seen in table 26 (chapter 2.3.1 Evaluation of GPS Standards) of SP1 for baseline lengths less than 8km the requirements for achieving up to class A include:

- A single frequency receiver,
- Double differencing
- And a fixed ambiguity solution.

These requirements are achievable by most types of modern GPS equipment.

3.2.3 Processing

Once the survey data file is downloaded into the software, minimal processing should be done, this is to ensure that the observations remain in their most original form. The software should be able to accept inputs of a local coordinate system with its own calculated scale factor from an observed point. This is so that the observations on the surface represent a plan measurement, not a measurement on the ellipsoid. Once the processing has been completed it is recommended to attend to the preservation and printing of the data records.

3.2.4 Data Records

The data records are in essence a replacement for the field books used by the traditional methods. Because of this it is necessary to protect their originality i.e. it is important to protect them from alterations and changes by software. If the data records are to have any substance, in the event of an investigation, then they need to represent the original measurements that were taken. This issue is dealt with in the 'Post-Survey' procedure which will be covered later in this chapter.

3.3 Pre-Survey

A critical part of performing a GPS survey is planning. The first step for planning is to choose the appropriate GPS surveying technique; this will probably be determined by the required accuracy and the allowable positional uncertainty of the survey. The accuracy and positional uncertainty for this project has been determined by the evaluation of the cadastral survey regulations (Chapter 2.3.2). The planning should provide a minimised error budget, achieved by an adequate number of redundancies in the observations. Legal traceability and a certain level of quality assurance can also be provided to all GPS surveys by connecting them to the state control network where available.

This section is an explanation of the attached document in Appendix B (Quality Assurance Procedure: Pre Survey). This document is to be used as the first stage in the quality assurance process for conducting a cadastral survey using GPS technology. The section headings (in the Procedures Appendices B, C and D) 1.Purpose and 2.Scope are the same for all three procedures; this is because they relate to the three procedures acting as a whole. The other headings: 3-Responsibilities, 4- Procedure and 5- Related Documentation, change as each is tailored to suit the needs of each procedure. The following paragraphs will explain the points in each of the five headings.

1. Purpose – This heading contains the following bullet points to explain the purpose for the procedures:

- To control the process by which measurements that allow for reinstatement can be carried out using RTK-GPS as a measurement tool.

- To record the prescribed instructions and thorough documentation of adequate process information. Meaning that one of the purposes of instituting QA is: - ensuring that suitable records of the process are documented to prove that the instructions were carried out fully.

- To initiate a change in a process that is not meeting 100% customer and governmental quality, by providing a mechanism to achieve accepted standards for cadastral surveys.

- To ensure that the surveyor has recorded information in a way that is consistent.

- To initiate the process that will provide the required legal traceability of a cadastral survey.

- To define the method for establishing the required information needed for the "field survey" and subsequent "post survey" sections of the cadastral survey.

2. Scope – This section identifies the people to who the procedures apply, the following points set out how this is achieved:

- The surveyors and associated staff, who are involved in the capture and manipulation of field data.

- The staff in charge of maintaining digital data and its storage.

3. Responsibilities – This section identifies the specific responsibilities that each person has in the procedure it includes:

- The calibration and related documentation of the field equipment

- It identifies the reasons for and frequency of the calibration techniques that apply.
- It identifies the surveyor's responsibility for determining and documenting the local scale factor and zone number for the survey area.

4. Procedure – This section describes the processes that need to be observed for the:

- Calibration of the equipment.
- Recording the calibration.
- Standards of the calibration.
- Identification of the persons responsible for maintaining the records and the identification of equipment.
- Observing the environmental restrictions of the equipment.
- Scheduling the equipment for calibration and assigning new and suspect equipment for calibration.
- Adequacy of the calibration system/methods to be used for determining:
    - The suitability of the current system.
    - The equipment's achievable accuracy.
    - The assessment of practicality of new calibration systems/methods.
    - And the ability of the current equipment to achieve the required standards as they change.
- This section also describes the procedure for the discovery of erroneous equipment.

5. Related Documentation – By identifying the related documentation of the procedure it creates the traceability of each document and how it relates to other documents produced. This includes recording the name and locations (archive, file or folder labels/numbers) for the calibration logbook, calibration records and any audits of external calibration facilities.

By following this procedure of documentation surveyors should be able to clearly state the accuracies, and standards to which the equipment has been calibrated. This is one of the first key stages for providing legal traceability. The next chapter will explain the procedure for the field survey and how it relates to the whole process.

3.4 Field Survey

This procedure defines the necessary observations to be recorded during the field survey section of cadastral surveys using RTK GPS, a copy of this procedure can be found in Appendix C. This procedure as mentioned above (chapter 3.3) is separated into the five headings; the first two 1.Purpose and 2.Scope are the same as the pre-survey procedure and will not be discussed again in this chapter. However there are changes in headings 3.Responsibilities, 4.Procedure and 5.Related Documentation, these will be discussed in the following paragraphs.

3. Responsibilities – This section, similar to that in the pre-survey responsibilities identifies the specific responsibilities that each person has in the procedure, it includes:

- Identifying the responsibilities of the surveyor for carrying out and documenting the observations.
- This heading also identifies the surveyors' responsibility for identifying any equipment which might be or suspected of being out of adjustment.
- It also identifies the surveyors' responsibility for checking the survey style, coordinate system, zone number, coordinate shifts and data logging information.
- The surveyor is also responsible for determining the time spent at each station while recording measuring data, in an effort to minimise or eliminate errors such as multipath.
- It also indicates that there is a need for the surveyor to re-measure some observations using a total station or other calibrated equipment.
- This heading indicates that it is the surveyors' responsibility for determining the suitability of GPS for the required survey.
- Finally, this heading states that it is the surveyor who is responsible for the information collected is of satisfactory accuracy.

4. Procedure – This heading covers the procedures involved including:

- Equipment: must be traceable to a nation standard of accuracy.

- Records: of the original data file, the uploaded reinstatement file, the original survey search, copies of the certificates of title and any other associated digital files of the captured field data.
- Standards: should be in accordance with SP1 and the 'Cadastral Survey Requirements' of the DNRM&W.
- Environment: the surveyor should not be using the equipment outside of the recommended operational temperatures given by the manufacturers of the survey equipment. The surveyor should also be mind-full of the possibility of multipath at each station intended to be measured.
- Schedule: also broken into three stages (office, on site and the reinstatement) which cover the steps involved. These are:

  Office-

  - Drafting and checking of the reinstatement file before leaving the office.
  - Checking for adequate survey search.
  - As well as checking that they have the specific technical information needed e.g.: zone, scale, geoid and grid settings.

  On Site-

  - The surveyor is responsible for the setting of the base station and its operation.
  - Next the surveyor should check that the RTK base is setup and operating correctly (with the correct technical details) and selecting the appropriate survey style for the reinstatement.

  The Reinstatement-

  - It is recommended that a minimum of two rounds of observations should be observed, while allowing the satellites to change configuration significantly between the rounds i.e.: morning and afternoon, or different days. (A round being the occupation and recording of data at each survey mark for the survey.)
  - By observing at least two rounds, each reference mark should be measured twice. Satellite and radio lock

should be established and maintained for each observation period. Thus providing a check to each reference mark.

- Some of the observations, should be checked/observed using a total station, this should also apply to any marks which the surveyor decides is not suitable/capable of being measured using RTK.
- The surveyor should be careful to identify marks which may be vulnerable to multipath error and as needed the observation time should be increased to suit.

5. Related Documentation – As discussed before this procedure identifies the traceability of each document and how it relates to other documents produced. These include the same records as the pre-survey procedure with the addition of the digital reinstatement files and the records containing the zone, scale, grid, false coordinates etc. (these will mostly be contained in the 'Field Check Sheet' in Appendix E).

By following the procedure a surveyor will be able to conduct a cadastral reinstatement using RTK, knowing that the necessary observations and data has been captured and recorded. The next sub-chapter, 3.5 Post-Survey is a description of the procedure for the downloading, manipulation, and storage of the collected data.

3.5 Post-Survey

The Post-Survey procedure (appendix D) describes the processes that should be observed once the field survey has been completed and the surveyor has returned to the office. When complete the necessary documents for legal traceability should be available.

Procedure headings 1.Purpose and 2.Scope are the same as those in chapter 3.3 Pre-Survey, however the three other headings will describe how the legal traceability is achieved and the following points will clarify this.

3. Responsibilities – This heading covers the responsibilities each person has in the post-survey procedure:

- The surveyor/assistant is responsible for the downloading and immediate back up of the original data files and recording the associated file names.
- The surveyor is responsible for the reduction and associated manipulation of the field data.
- The surveyor is also responsible for the calculation of the class, positional and local uncertainties of the field observations.
- The surveyor is also responsible for calculating the close of the survey and ensuring that it meets all appropriate requirements.
- The surveyor is responsible for ensuring that the information produced is of satisfactory accuracy and that the information is displayed correctly on the face of the survey plan.

4. Procedure – This covers the steps that are necessary to complete the legal traceability of the survey. The following points describe the steps involved in each section of this heading:

- Original information: The measured points are now referred to as original information. The job file from the data recorder should be downloaded immediately and backed up before it is used for any data manipulation or calculations. Once this is done the data file can now be used in the computer software, where the site calibration coordinate system should be accepted.
- Adjustments: Select a point central to the project site and at an average RL for the site. Create a local plane projection in the CAD package centered about this point. Use the CAD package to produce a point report from the RTK observations. The reports made by the software should be printed and filed. If there are adjustments to make to the observations then they should be made only once the first report has been saved and/or printed. Each

change to the observations should also be recorded so that any future investigation of the file will show exactly the steps that have been taken. Once any adjustments are made a new report should be processed and saved or printed.

- Calculations: Using the final coordinates, the average of the two points (for each reference mark) should be used to calculate the reinstatement, including any/all of the total-station observations as checks. It may be necessary to adjust the bearings (derived from the positional information) so that they align with the original survey meridian. Alternatively a note can be made on the face of the plan stating that the meridian has been determined by GPS and the meridian has been calculated from positional information observed at a specified date.

- Adequacy: Care should be taken to check that the reinstatement calculation closes within acceptable standards of the 'Cadastral Survey Requirements' of the DNRM&W.

- Plan: The survey plan should be produced in accordance with the 'Cadastral Survey Requirements' of the DNRM&W, with the addition of one table. This table should include the geodetic model, local scale factor and the zone. (This is so any subsequent surveyor can replicate the information used).

5. Related Documentation – As discussed before this procedure identifies the traceability of each document and how it relates to other documents produced. These include the same records as the pre-survey and field survey procedures with the addition of the original controller files, back up files, software reports and the plan of survey, the full list of these can be found at the end of Appendix D.

To aid in the continuity of data capture a 'Field Check Sheet' has been included in the procedures. This is so that most of the relevant technical information is located on a single check sheet. The 'Field Check Sheet' (Appendix E) will be explained in the next sub-chapter 4.5.

3.6 Check Sheet

The Check Sheet is designed to contain as much of the technical information for the reinstatement as possible on one sheet. It is not designed to replace the field book where a surveyor would record his measurements, but it is designed to supplement the data files created during the survey. The Check Sheet has been broken into several headings these will be discussed in the following points.

- Job Info- includes the job identification number for the business references; the names of the surveyor and assistants, the date of the survey and its location.
- Equipment- this section is where the serial numbers of the equipment is recorded. It allows for numbers for the Base station, the Rover unit, a total station and data recorder numbers.
- Datum- the geodetic information should be recorded here including: datum, zone, base/control point (for the survey meridian), true easting and northing, and the related false easting and northing that might be applied to the local plane coordinates.
- File Info- is simply a record of the file name given to the controller job file and also the computer job file, as well as a tick box for the backing up of these files.
- Client Info – includes the clients' name, contact phone number and their postal address. This is so any information that needs to be transferred between the client and the surveyor can be done in a pre-arranged manner.
- Progress- this is a record of the progress steps that should be observed throughout the processes. These are:
    - Client Instructions – any instructions from the client should be checked to be clear and concise to avoid any misunderstandings over the service and products to be provided.
    - CAD reinstatement plan – this is the preliminary plan to be used for the reinstatement, to aid the surveyor in finding the reference marks. The check boxes for this plan include the drafting and the uploading of the plan.
    - Reinstatement – this is just a progress report of how many rounds of observations have been completed.

- Calculate reinstated boundaries – these are check boxes for recording this important stage of the reinstatement process.
- Incorporate Subdivision Design – this is where the proposed subdivision should be incorporated into the reinstated boundaries and checked for the necessary accuracies of the drafting.
- Upload Subdivision into the data recorder – this check box is the progression of the previous one. It is supposed to check that the file containing the final subdivision, or set out file has been uploaded into the data recorder correctly.
- Final plan production – This is to check that the final plan of subdivision has been completed and is ready to be sent to the client or other appropriate party.

There is also allocation of the making of notes at the bottom of both of the two pages. This is so that any other relevant information not already contained in the check sheets can be recorded for any future file references.

The three developed procedures and the check sheet all form part of the QA method that is designed to satisfy the aim of the research. Once developed it is necessary to test the whole process.

3.7 Testing

To test the new QA procedures developed, a reinstatement of a property was carried out using both total station and RTK. The testing was designed to assess the suitability and the functionality of using RTK for a cadastral survey, while employing the QA methods developed.

To test for the suitability and functionality of the system it was necessary to first carry out the reinstatement using a total station. By doing this it identified any differences from the plan that might exist i.e.: excesses or shortages. This was also done to give an approximate time to the field work, so that a comparison could be made against the RTK method. Once the reinstatement was completed using the total station, the same reinstatement was carried out using RTK and the QA method.

A spread sheet (Table 3.1) has been prepared comparing, the positions of reference marks, as measured by both Total Station and RTK GPS.

3.8 Results

The results of the testing indicate that while RTK GPS is able to achieve radio and satellite lock then it is capable of achieving the required accuracies for conducting a cadastral survey. Table 3.1 shows a simple statistical assessment of the eastings and northings as measured by the two different systems (when using the same coordinate system.)

Table 3.1 Coordinate Comparison

(RTK GPS – Total station)

Reference Mark	RTK GPS Easting	Total Station Easting	Difference	RTK GPS Northing	Total Station Northing	Difference
5-OIP	394725.882	394725.871	0.011	6945457.24	6945457.24	-0.007
4-OPM	394753.056	394753.029	0.027	6945301.15	6945301.18	-0.023
4-OPM	394788.123	394788.097	0.026	6945350.41	6945350.42	-0.007
2-OIP	394799.135	394799.123	0.012	6945688.56	6945688.58	-0.016
7-OPM	394544.471	394544.457	0.014	6945680.42	6945680.49	-0.069
Average		Easting	0.018		Northing	-0.0244
Standard Deviation			0.007842			0.025822

As seen above the average eastings and northings are <30mm. RTK GPD does not measure a traversed system of connections and radiations to marks, but measures their position directly. This means that a RTK survey will be less likely to observe an erroneous measurement, and hence affecting the quality of the cadastre.

To determine the accuracy of the survey the method specified in section 2.3.2 of this dissertation was used. Where the observed position of three coordinated permanent marks are used to determine the accuracy.

From the data collected through both surveys can be seen in Appendix G (Total Station and Appendix H (RTK GPS). In these two appendixes the data is organised so that the raw data/field notes are first followed by the final plan. Investigation of the final plans shows that there is little difference between the two surveys.

The most significant result from the testing was that overall there was only a slight difference in the time taken to perform the different surveys. Using the RTK GPS was faster overall, but when the added time of waiting for the satellite constellation to change is added in it became significantly slower. The time that was used for the completion of the QA check sheets was negligible to the overall time taken for the survey.

The resultant affect that these differences would make on a 1m OIP reference would be nominal at most, except for the occasional observation like that of 7-OPM. It is up to the surveyor using the system to assess the observation quality that is recorded. It is recommended that if a surveyor finds one or two reference marks which have significant or unexpected differences then they would check the accuracy of the GPS position by total station.

3.9 Conclusion

It should now be clear to any one who intends to use the QA procedures developed for this dissertation, exactly what each section of the three procedures is intended for. It should also be evident that RTK GPS is a viable tool for the measurement of cadastral marks. A further discussion of the process for testing the QA method will be included in chapter 4–Discussion and Analysis. Chapter 4 also includes a discussion on the suggested changes to legislation, guidelines and standards.

CHAPTER 4

DISCUSSION AND ANALYSIS

4.1 Introduction

This chapter will be a discussion and analysis of the results of the testing procedure that was carried out on the new QA method. Also it will be including suggestions for changes to the relevant legislation and regulations which were included in chapter 2 – Literature Review.

4.2 Testing of the QA Method

In section 1.2 (Research Aims and Objectives) it was explained that the new QA method would have to be tested for suitability and functionality. This was to be done by critical testing and validation. To critically evaluate the new method it was necessary for it to be compared to the process that it is primarily replacing – total station surveys using field books. The following two sub sections are a discussion on the outcomes of the two surveys.

4.2.1 Results of Total Station Survey

This survey was approximately 4.5 hours in duration, a considerable amount of time was used to traverse around the lot. It also took longer to connect to any of the buried marks as meridian had to be established and connections to each of the marks needed to be calculated. The results of the survey can be seen in appendix G (Reinstatement –Total Station). By comparing the reinstated boundaries (using total station) to the information on RP902071 (a copy of this can be found in Appendix F – Survey Search), it can be seen that there is only 0.007m of excess in the boundary along Baker Street. The measured road boundary along West Street agreed with RP902071.

These differences were not serious. The only problem encountered in conducting the survey occurred when trying to connect to the corner west of station 1 (represented on the plan in Appendix G). The problem was that a student had parked their car over the screw in concrete that had been placed as a reference mark to that corner. Several attempts were made to contact the owner of the car, when it came time to finish the field work and pack up, the owner of the car still had not returned. The decision was made to leave the two boundaries in question as original boundaries. The original information used was obtained from IS127502; the bearings have been adjusted to AMG. A copy of IS127502 can be found in Appendix F.

The measurements made during the reinstatement conform to the specifications of accuracy set out by the '*Cadastral Survey Requirements*' (DNRM&W) as discussed in Chapter 3.2.2 Specifications of Accuracy. Evidence of this is the way in which the measurements primarily agreed with those of the original plan information. The calculation of the measured misclose and the allowable misclose can be seen below.

Table 4.1 Total Station Survey Miscloses

Measured Misclose		
Bearing	Distance	Ratio
22°25'	0.014m	1:58412
Angular Misclose		
5"		
(Calculated by subtraction of bearings along West Street)		

Allowable Misclose	
Angular	56"
(The lesser of the two allowable methods of calculation)	
Linear	
10mm plus 1 part in 5000 of the total distance traversed	= 0.178m
20mm plus 1 part in 2000 if another surveyors work is included in the surround	= 0.441m
All survey lines achieved a vector accuracy better than 10mm + 50ppm evident in the agreement with plan distances.	

This table proves that the reinstatement conducted using a total station achieved the required accuracy's set by the DNRM&W.

4.2.2 Results of RTK Survey

The survey using RTK was conducted on consecutive days as specified in the QA procedure – Field Survey. On the first day the base station ANANGA (USQ's permanent base station) was used as it is a permanent base. The base station does not have to be set over a cadastral mark, although if one is available it should be used as it would provide an accurate position for that mark. The base should otherwise be located near the survey in a suitable location. The purpose of using ANANGA was because it is a known high accuracy mark. A full round of observations was completed in approximately 2 hours. All marks were searched for, including ones that were known to be missing or inaccessible, from the total station survey. The occupation time that was used for each mark was between 2 and 4 minutes. This was because the both road frontages (Lot 2 on RP115043 and Lot 368 on RP902071) had high man-proof fences, known to cause multipath errors. It should be mentioned that the problem with the students' car obscuring a reference mark remained a constant throughout the testing.

On the second day a base station was set on PSM 40424. This was soon abandoned, as for an unknown reason radio lock was lost whenever the rover was taken across either West Street or Nelson Street. It is presumed that there may have been radio interference caused by the overhead power lines, but there is no evidence to prove this. In the interests of 'real life solutions' the decision was made to re-use ANANGA for the second round of observations. The reason another PSM was not used was because the other PSM's did not have very good locations for setting a base station, i.e. trees or fences obstructing the view of the satellite constellation. Once again observation times for each mark were between 2 and 4 minutes, depending on the location.

Two marks were not able to be measured using RTK, these were the OIP's at stations 1 and 3. These were reinstated by using the measurements made previously by total station. The same observations were used for these two OIP's because there seemed very little point in re-measuring the same marks again using the same equipment only to achieve the same results.

The differences in dimensions that were measured are only found on West Street. The bearing along West Street is -15" to the original information on RP902071, this is close to that measured by total station. 0.001m Shortage was also measured along West Street, this shortage was taken in the subject lot because there was no evidence to suggest it should be taken by the adjoining lot, Lot 368 on RP902071. The reason the decision for the shortage to be taken in the subject lot was because the OIP and OP at station 2 (refer to the plan in Appendix H) was clearly disturbed. The OP and OIP were clearly not straight when they were connected to; this is confirmed by the change in the reference to the OIP at station 2 and the reference on the OP.

When both rounds of observations were completed the data file was downloaded, backed up and then processed using Trimble Geomatics Office (TGO). Where the software was used to produce the reports found as part of Appendix H. The two reports used were the 'GPS Vector Data' report and the 'Point Derivation Report'. The 'GPS Vector Data' report was used to asses the quality of the GPS baselines, the 'Point Derivation Report' provided the coordinates for calculating the position of the marks measured.

The RTK measurements made during the reinstatement have been assessed for accuracy by using the bearings and distances calculated from the 'Point Derivation Report' and the specifications of accuracy set out by the '*Cadastral Survey Requirements*' (DNR). Like the total station survey, the RTK survey agrees with the dimensions of the original plan information. Table 3.1 proves that the developed method of capturing and processing the GPS data can achieve the required accuracy as set by the '*Cadastral Survey Regulations*' (DNR). This accuracy is subject to: the surveyors' estimation of the time of occupation at each station, environmental conditions and satellite geometry.

4.2.3 Outcomes of the testing

The following points have been noted about the new QA procedures, the testing process and the results of the testing.

- The new QA procedures are a good way of ensuring that the RTK observations are suitable to the survey. However they are not a perfect system, it is recommended that any one intending to use this system have them audited by a professional QA auditor/s.

- The new QA method does fill in some of the gaps left by the lack of paperwork created by traditional survey methods.
- The accuracy of the whole system is entirely dependant on the surveyor using it.
- The RTK method was by far faster, only taking 2 hours per round, when only taking into account the field time and the amount of time spend calculating solutions. The plan drafting (1.5 hours) and preparation time for each was approximately the same. The difference is made when the RTK method is spread over two days, or morning and afternoon, as there is no point in calculating solutions when only half of the data is received (as it is averaged). If the RTK method is taken over two days then the time gained is lost and takes longer overall.

It is suggested that surveyors keep using GPS for cadastral surveys, as it is this kind of use that will make it necessary for Universities, Government Departments and the National Measurement Institute to develop a calibration system for different types of GPS technologies.

4.2.4 Alternative Solutions

Alternative solutions to the problem of using GPS technology for cadastral surveys are already in place in some states (i.e. Victoria). An assessment of their effectiveness has not been done due to the lack of literature on the topic.

> "*Ability to enforce QA processes reduces the risk to the cadastre.*"
> (Allen Consulting Group 2005, P38)

As can been seen in the quote from 'The Allen Consulting Group' (Chapter 2.4), they recommended that the Surveyor General be able to enforce the use of QA to effectively reduce the risk to the cadastre.

Alternatives to using RTK could be to use a Post Processed Kinematic style of survey; this would require software that is capable of post processing and would not be able to set out any subdivision pegs. Virtual Reference Stations (VRS) could also be used with the RTK to conduct this kind of survey. VRS is currently only available in South Eastern Queensland and would not be an alternative in other parts of Queensland; this might be a different case in other states.

Other alternatives to the ISO9000 series of Quality Management programs exist and are recognised by many different authorities. The next section, 4.3 Suggested Changes to Legislation, is a discussion of some suggested changes to regulations and current practices.

4.3 Suggested Changes to Regulations

This section will be a discussion of suggested changes to regulations that control the cadastral surveying profession. No suggestions have been made for any legislation, as the legislation does not directly specify the guidelines, standards and other technical details. The legislation does direct readers to the associated regulations, it is to these regulations that suggestions of change will be made.

4.3.1 Regulations

The suggested changes in this section will include suggestions for the 'Survey and Mapping Infrastructure Regulation 2004', the 'National Measurement Regulations 1999' and the 'Cadastral Survey Requirements'.

- The 'Survey and Mapping Infrastructure Regulation 2004', (Queensland) defines the surveyors requirements to accuracy as:

  > ***"21 Survey accuracy***
  > *A cadastral surveyor who carries out, or is responsible for carrying out, a cadastral survey must ensure any survey equipment used for the survey is—*
  > *(a) calibrated and standardised; and*
  > *(b) capable of achieving the accuracy stated in the relevant survey standard for cadastral surveys.*"
  > (Queensland Government, 2004, P14)

  This does not allow for the use of GPS at this point in time as, already stated in chapter 2, GPS has no method of calibration. This quote is evidence that any surveyor who has used GPS or is using GPS is currently not conforming to the state regulations for conducting a cadastral survey. The suggestion for change to this is that there is another section created specifically dealing with the use of GPS technology for cadastral surveys.

The 'National Measurement Regulations 1999' should be amended to include a SI unit (in Schedule 1) for describing position, as position can be described in different ways. An example of this would be:

Geodetic Datum:	GDA 94
Grid Projection:	MGA 1994
Zone:	Zone Number (i.e. 56)
Coordinates:	Easting & Northing

By using the above way of describing a position the information can be traced back to know reference surfaces.

- In the 'Cadastral Survey Requirements' (DNRM&W), section 1.5 '*Departure from Standards*' the following statement is made:

  "*A surveyor may use any method and/or equipment in performing a survey where it can be demonstrated that such method and/or equipment is capable of achieving the survey standard.*

  Where a surveyor uses methods and/or equipment which involve a significant departure from conventional survey practice, the surveyor shall submit with the survey records sufficient information to identify the methods and/or equipment used."
  (Department of Natural Resources and Mines, 2005, P1)

This gives the cadastral surveyor a way of circumventing the regulation (Survey and Mapping Infrastructure Regulation 2004). This allows surveyors to use GPS technology, but it does not give instructions as to what information is need for the stated submission. The 'Cadastral Survey Requirements' (DNRM&W) need to consider GPS as a viable technology for cadastral surveys; they also need to develop their requirements so that surveyors know exactly what is needed for submissions.

4.4 Implications

The interpretations of the implications described in this section are speculations only and are the result of the information found in the literature review.

The expected implications of the application of the new QA method developed for this dissertation are:

- When integrated into existing QA systems it becomes a useful tool for helping to protect the surveyor against litigation.
- If a QA system is not already in use in a survey practice, then this document might encourage the managers of a survey practice to initiate QA throughout their practice.
- Survey practices may review their exiting QA system and begin to update and revise their procedures.
- After significant changes to QA systems, independent auditing is recommended.
- The use of QA systems should create an environment of client satisfaction, protection against errors and security from litigation.
- Changes may occur to regulations, directly accepting the use of GPS technology.
- The eventual development of a calibration/standardisation method for GPS techniques may be developed.
- The possible enforcement of QA by the Surveyor General in cadastral surveying.

From the previous sections of this chapter it is recognised that there is the need for further research and some recommendations.

4.5 Further research and recommendations

The following points include recommendations for further research and testing

- There are clear signs that there needs to be significant research and testing conducted for the creation of calibration/standardisation methods for GPS technology.

- The testing of the QA method could have included the set out and marking or a subdivision including new reference marks.
- Further research into digital survey records and their associated legal traceability would help in the protection that QA provides.
- It is recommended that further research into other methods of QA is investigated, as ISO9000 is not the only method.
- Research into the use of VRS for cadastral surveying is recommended, as VRS is a new form of GPS technology and has many possible applications.
- Once a calibration/standardisation method for GPS technology has been developed, a review of the QA method developed for this dissertation could be completed.

These points clearly indicate that there are significant areas where further research can be carried out. The most significant of these is the need for the development of calibration/standardisation methods for GPS technology.

4.6 Conclusion

Chapter 4 established that RTK is capable of achieving cadastral survey standards and as such is a viable tool for the cadastral surveyor. Chapter 4 also highlighted the need for further research to be carried out in both QA and GPS areas. Suggestions for changes to regulations were made in the hope that the governing bodies heed the message and begin reviewing their regulations.

The research outcomes were that GPS is a valuable tool for surveyors and that the technology has grown faster than the legislation and regulations could keep up with. The new QA method developed will be of benefit to any cadastral surveyors who wishes to initiate a change in their practices. It would also benefit surveyors who wish to upgrade, improve or change their existing QA system. The new QA method developed for conducting cadastral surveys using GPS technology will provide a solution to a difficult problem.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In conclusion the aims and objectives described in chapter 1 have been met these are:

- The research and development of a set of QA procedures to ensure that the quality of the field data is protected while incorporating the interests of the survey office.
- To develop a quality set assurance procedures that can be used by surveyors intending to use GPS for cadastral surveys.
- To research the quality assurance applications, and assess the standards for GPS surveying.
- To test the procedures for suitability, as well as functionality.
- To suggested changes to government legislation and regulations in Queensland.

Three procedures and check sheets (Appendixes C-E) were developed, using ISO9000, for conducting cadastral surveys while using GPS technology.
The QA procedures were tested for its suitability. Where it was found that: depending on environmental conditions, that RTK GPS is suitable for cadastral surveys. RTK GPS can improve the efficiency of a cadastral survey, by saving significant time on traversing, but looses its efficiency when waiting for the satellite constellation to change.

Suggestions for changes to regulations were made, with the goal of improving the cadastral surveying environment. The most significant of these include:

- The upgrading/reviewing of literature from SBQ
- The improvement of the 'Survey and Mapping Infrastructure Regulation 2004', (Queensland) to include regulations for the use and calibration of GPS equipment.

- The ‘National Measurement Regulations 1999’ should be amended to include a SI unit (in Schedule 1) for describing position.
- The ‘Cadastral Survey Requirements’ (2005) should be reviewed to define the appropriate use of GPS.

The implications of this research for using RTK GPS to perform a cadastral survey were defined as:

- If a QA system is not already in use in a survey practice, then this document might encourage the managers of a survey practice to initiate QA throughout their practice.
- After significant changes to QA systems, independent auditing is recommended.
- The eventual development of a calibration/standardisation method for GPS techniques may be developed.
- The possible enforcement of QA by the Surveyor General in cadastral surveying.

Recommendations were made for future research into the areas where there was clearly a shortcoming in the current literature. These include:

- There are clear signs that there needs to be significant research and testing conducted for the creation of calibration/standardisation methods for GPS technology.
- Further research into digital survey records and their associated legal traceability would help in the protection that QA provides.

Finally it is recommended that RTK is a powerful surveying tool which has both accuracy and economic benefits, when used correctly. This includes the use of QA procedures for the clear and concise arrangement of survey evidence, which has been achieved by the procedures developed in this dissertation.

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APPENDIX A

Project Specification

University of Southern Queensland

Faculty of Engineering and Surveying

ENG4111/ENG4112
Project Specification

FOR:	Andrew Worrall
TOPIC:	Development of a Quality Assurance Method for cadastral surveying using GPS technology.
SUPERVISOR:	Shane Simmons, BSur(UQ), GDipSur(QUT), MISAust.
ENROLMENT:	ENG4111 – S1, ONC, 2006 ENG4112 – S2, ONC, 2006
PROJECT AIM:	The aim of this project is to develop quality assurance methods for legal traceability for conducting cadastral surveys with GPS techniques.
PROGRAMME:	Issue A, 27th March 2006

1. Research quality assurance applications and standards for GPS surveying.
2. Critically evaluate the standards and requirements for GPS surveying for a cadastral system.
3. Critically evaluate current cadastral GPS surveying techniques by means of risk assessment.
4. Develop initial quality assurance systems for survey and legal traceability.
5. Conduct testing of the quality system and critically asses the quality assurance method developed.
6. Critically discus changes required to government legislation/regulations in Queensland.
7. Produce a quality assurance document for use by cadastral surveyors.

Agreed: AWorrall (student) ____________ (supervisor)

Dated 27/ 3 / 06.

APPENDIX B

Quality Assurance Procedure

Pre-Survey

((PLACE ORGAISATION LOGO))
((OR BUSINESS NAME HERE))

GPS – Pre Survey

Approved:

_
title Name

Approved:

__
title Name

Approved:

_
title Name

Approved:

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title Name

Approved:

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title Name

Change Record

Rev	Date	Responsible Person	Description of Change
A		Name	Initial Release

Distribution List

(list the departments that receive controlled copies)

This procedure should be read as the <u>first</u> part of the process for cadastral reinstatement using RTK-GPS technique.

1. Purpose

- To control the process by which cadastral field data collection can be carried out using RTK-GPS as a measurement tool.
- To record the clients instructions and thorough documentation of adequate process information.
- To ensure that the surveyor has recorded information in a way that is consistent.
- To enhance the process that will provide the required legal traceability for a cadastral survey.
- To define the method for establishing the required information needed for the "field survey" and subsequent "post survey" sections of the cadastral survey.

2. Scope

This procedure applies to:

- The surveyors and associated staff, who are involved in the capture and manipulation of field data.
- The staff in charge of maintaining digital data and its storage.

3. Responsibilities

<u>Pre-Survey</u> – The surveyor is responsible for carrying out and documenting calibrations of the field equipment semi-annually, this involves both the "zero baseline technique" and the "comparison technique". If at any time the surveyor has reasonable suspicion of any equipment, then the surveyor is required to re-calibrate the equipment using the aforementioned methods.

The surveyor is also responsible for determining and documenting the local scale factor and zone number for the survey.

4. Procedure

4.1 Calibration

Any equipment used for the measurement of a property boundary must be able to be traced back to a standard of the National Measurement Institute. To achieve this, the following methods of GPS calibration must be employed:

- "Zero Baseline" method as per SP1
- "Comparison Technique" where the measurements of the RTK receiver and the base stations are compared against the known coordinates of the Queensland Fiducial Network.
- Comparisons should also regularly be made against distances measured by a total station.

NB: As yet there is <u>no</u> accepted method for the calibration of GPS equipment. These methods are only included as a partial solution to the problem and should only be used to detect gross errors in the equipment.

Any EDME or total stations used as support equipment for additional measurements must also be traceable back to the National Measurement Institutes standards.

4.2 Records

The results of the above calibrations should be kept in a file (either computer or paper) with the other calibration information from other equipment. Care should be taken to identify the most recent calibration information for each individual piece of equipment.

The survey records need for the "field survey" include:

- Job Identification
- Local scale factor (to the survey site)
- Local zone information (to the survey site)
- Planned or requested grid and datum information
- Documented changes for false Eastings and Northings.

The original survey plan information should be used to create a CAD file which can later be uploaded into the GPS controller for use in the "field survey" section. This information should be checked and confirmed as consistent with the information supplied on the original plans and should easily cover the expected extents of the survey. This will become the basis of part of the "post survey" section of the process.

4.3 Standards

The calibration should result in achieving accuracies relative to those specified in SP1 for the RTK type receiver, also the base station should comply with the accuracies of those set in SP1.

This should result in all measurements being able to achieve a 95% confidence interval. The calibration should be aimed at Class C classification.

Measurement standards are accurate relative to the intended use on the equipment.

4.4 Identification

The organization is responsible for maintaining the master list of all equipment in the calibration system. The <name of master list> needs to include all the equipment used for measuring a property boundary.

The organization is responsible for storing the <name of master list> in <location> for as long as legally required.

A non-removable calibration label is affixed to all equipment in the calibration system. The label should also identify individual equipment numbers to avoid confusion if there are multiples of the same types.

If it is impractical to apply the label to the item, it is should be attached to the packaging.

4.5. Environment

Care should be taken to observe the correct range of environmental conditions to which equipment can be used.

4.6 Schedule

Items should be scheduled for calibration semi-annually or annually depending on the frequency of use and type of equipment.

New equipment is inspected and calibrated prior to use.

If the equipment is suspected of being out of adjustment, at any time, then it should be identified as such and should not be used until it is re-calibrated or repaired.

4.7 Adequacy

The surveyor is required to review test equipment and measurement standards six-monthly to assess the calibration system. The following is determined during the review:

- Suitability of current system
- The equipments achievable accuracy

- The practicality of new calibration systems/methods

- Can the existing equipment achieve the new standards?

For in-house calibrations, items found to be out-of-tolerance are adjusted if possible; otherwise they are to be sent to the recommended repairer of <type> equipment.

Failures are reported to management who determines whether to re-inspect all instruments calibrated with the faulty test equipment or measuring device.

5. Related Documentation

<Calibration Logbook>
<Calibration Record>
<Audit of External Calibration Facility>
(The end user should enter the correct document name/number for the above section as it will be different for each individual organization.)

APPENDIX C

Quality Assurance Procedure

Field Survey

((PLACE ORGAISATION LOGO))
((OR BUSINESS NAME HERE))

GPS – Field Survey

Approved:

____

title   Name

Approved:

____

title   Name

Approved:

____

title   Name

Approved:

____

title   Name

Approved:

____

title   Name

Change Record

Rev	**Date**	**Responsible Person**	**Description of Change**
A		Name	Initial Release

Distribution List

(list the departments that receive controlled copies)

This procedure should be read as the second part of the process for cadastral reinstatement using RTK-GPS technique.

1. Purpose

- To control the process by which cadastral field data collection can be carried out using RTK-GPS as a measurement tool.
- To record the clients instructions and thorough documentation of adequate process information.
- To ensure that the surveyor has recorded information in a way that is consistent.
- To enhance the process that will provide the required legal traceability for a cadastral survey.
- To define the method for establishing the required information needed for the "field survey" and subsequent "post survey" sections of the cadastral survey.

2. Scope

This procedure applies to:

- The surveyors and associated staff, who are involved in the capture and manipulation of field data.
- The staff in charge of maintaining digital data and its storage.

3. Responsibilities

Field Survey –

The surveyor is responsible for carrying out and documenting the observations made using the field equipment. If at any time the surveyor has reasonable suspicion of any equipment, then the surveyor is required to re-calibrate the equipment using the methods suggested in Pre-Survey.

The surveyor is also responsible for checking the survey style, coordinate system, zone settings, coordinate shifts and data logging information.

Field Survey –

The surveyor is responsible for documenting and setting the following information:

- Grid
- Zone
- Scale Factor

- Use of ground Coordinates
- Setting of offset coordinates (if necessary)
- Station information (such as point description)

The surveyor is responsible for determining the time spent at each station to minimize errors such as multipath.

The surveyor is responsible for determining which lines should be re-measured using total station.

The surveyor is responsible for determining if GPS is a suitable tool for the required tasks.

The surveyor is responsible for ensuring that the information produced is of satisfactory accuracy and that the information collected is accurate.

4. Procedure

4.1 Equipment

Any equipment used for the measurement of a property boundary must be able to be traced back to a standard of the National Measurement Institute. It must also be able to achieve suitable accuracy.

4.2 Records

The survey records include:

- The original data file from the RTK controller
- digital file for reinstatement
- Original survey search
- Copies of certificates of title
- Digital files of the captured field data

It is managements' responsibility to store the <name of records> in <location> for <length of time>.

4.3 Standards

Reinstatement should be conducted in accordance with SP1, to achieve at least a Class C rating.

The reinstatement must close to satisfy the requirements of the 'Cadastral Survey Requirements'.

4.4 Environment

The surveyor must consider the environment in which they are to operate the equipment. The surveyor must evaluate the likelihood of multipath and other such problems.

4.6 Schedule

Before leaving the office

- The surveyor must upload the reinstatement file (created in the pre-survey stage).
- The surveyor must also check that they have adequate search.
- Batteries should be checked for charge.
- The surveyor must also check that they have all the technical information needed (such as zone, scale, geoid and grid settings).

On site

- The surveyor must set up the base station and ensure that its settings are correct.
- The surveyor must then set up the RTK receiver and check that it is operating correctly.
- The surveyor can then begin the reinstatement.
- The surveyor should select a site calibration type method of survey for measuring the reference marks.

The reinstatement

- A minimum of two rounds of observations are required, allowing the satellite configuration to change significantly between rounds.
- The surveyor should connect to each reference mark and corner twice as a minimum, while maintaining lock on the satellites and the base station for the whole observation.
- The surveyor is required to measure some of the observations with a total station as a check. (some GPS software allows for total station observations to be included in the reductions)
- Care should be taken to increase the observation time where obstructions or multipath is likely to occur.

NB: the reductions and assessment of the reinstatement will be covered in the third procedure “post survey”.

The RTK software in the controller should have a site calibration measurement style; this should be used where possible to swing the survey (field) onto the meridian of the uploaded co-ordinate file. Once two or more points have been located, the set-out or stakeout method can then be used to guide the surveyor to the next reference mark. Once all the relevant marks have been found and measured, the relevant ones should then be entered into the site calibration.

5. Related Documentation

Pre-Survey Procedure:

<Calibration Logbook>
<Calibration Record>
<Audit of External Calibration Facility>
<Digital reinstatement file>
<Records of Zone information, scale, false coordinates>
Field Check Sheet

Post Survey Procedure

APPENDIX D

Quality Assurance Procedure

Post Survey

((PLACE ORGAISATION LOGO))
((OR BUSINESS NAME HERE))

GPS – Post Survey

Approved:

_
title Name

Approved:

__
title Name

Approved:

_
title Name

Approved:

_
title Name

Approved:

_
title Name

Change Record

Rev	Date	Responsible Person	Description of Change
A		Name	Initial Release

Distribution List

(list the departments that receive controlled copies)

This procedure should be read as the last part of the process for cadastral reinstatement using RTK-GPS technique.

1. Purpose

- To control the process by which cadastral field data collection can be carried out using RTK-GPS as a measurement tool.
- To record the clients instructions and thorough documentation of adequate process information.
- To ensure that the surveyor has recorded information in a way that is consistent.
- To enhance the process that will provide the required legal traceability for a cadastral survey.
- To define the method for establishing the required information needed for the "field survey" and subsequent "post survey" sections of the cadastral survey.

2. Scope

This procedure applies to:

- The surveyors and associated staff, who are involved in the capture and manipulation of field data.
- The staff in charge of maintaining digital data and its storage.

3. Responsibilities

Post-Survey – The surveyor/assistant is responsible for the downloading and immediate back up of the original data files and documenting the associated file names.

The surveyor is responsible for the reduction and associated manipulation of the field data.

The surveyor is also responsible for the calculation of the class and positional and local uncertainties of the field observations.

The surveyor is also responsible for calculating the close of the survey and ensuring that it meets all appropriate requirements.

The surveyor is responsible for ensuring that the information produced is of satisfactory accuracy and that the information is displayed correctly on the face of the survey plan.

4. Procedure

4.1 Original information

- Download the job file and accept the site calibration coordinate system from the GPS controller

- The original file information should be backed up as soon as it is down-loaded from the GPS controller.

- A copy of the original controller file should be used for the survey reductions.

4.2 Adjustments

- Select a point central to the project site and at an average RL for the site. Create a local plane projection in the Cad package centered about this point.

- Use the CAD package to produce a point report from the RTK observations.

- The reports made by the software should be printed and filed

- If there are adjustments to make to the observations then they should be made only once the first report has been saved and/or printed. Each change to the observations should also be recorded so that any future investigation of the file will show exactly what steps have been taken.

- Once any adjustments are made a new report should be processed and saved or printed.

4.4 Calculations

- Using the final coordinates, the average of the two points (for each reference marks)should be used to calculate the reinstatement, including any/all of the total-station observations as checks.

- It may be necessary to adjust the bearings (derived from the positional information) so that they align with the original survey meridian.

- Alternatively a note can be made on the face of the plan stating that the meridian has been determined by GPS and the meridian has been calculated from positional information observed at a specified date.

4.7 Adequacy

- Care should be taken to check that the reinstatement closes within acceptable standards of the 'Cadastral Survey Requirements'.

4.8 Plan

- The survey plan should be produced in accordance with the 'Cadastral Survey Requirements', with the addition of one table. This table should include the geodetic model, local scale factor and the zone. (This is so that any subsequent survey can replicate the information used).

5. Related Documentation

<Calibration Logbook>
<Calibration Record>
<Audit of External Calibration Facility>
<Original controller files>
<Backup controller files>
<Software reports>
<Plan of survey>

Document and Data Control
Process Control
Inspection and Testing
Inspection and Test Status
Quality Records

<list work instructions>

APPENDIX E

Quality Assurance Procedure

Check Sheet

Job Info

Job ID: ____ Date: ____
Surveyor: ____ Location: ____
Assistant: ____

Equipment

Base

Base Antennae Type/Model: ____

Base Station Serial Number: ____

Base Controller: ____

Rover

Rover Antennae: ____
Rover Reciever: ____
Rover Controller: ____

Total Station

Total Station type/model number: ____
Prism type/model number: ____

Data recorder type/model number: ____
or Field Book Number: ____

Datum info:

Datum: ____ Zone: ____
Base/Control Point (for survey meridian): ____
Easting: ____ Northing: ____
False Easting: ____
False Northing: ____

File Info:

Controller job File: ____ Backup ____

Computer Job File: ____ Backup ____

Notes:

Client Info

Client Name:	
Contact Phone:	
Postal Address:	

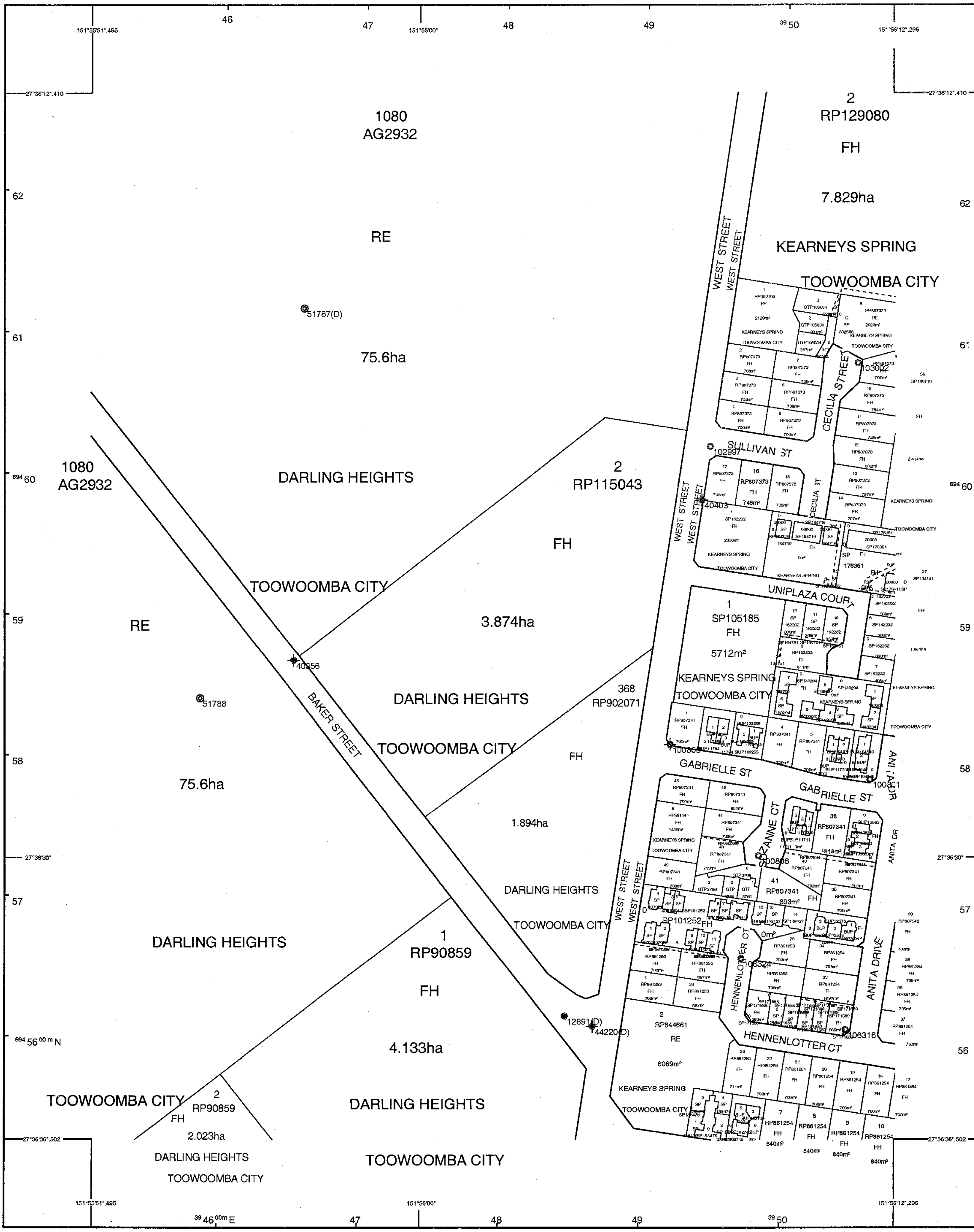
Progress

	Done	Check
Client Instructions		
Search Titles		
Plans		
Form 6		
Other		
CAD reinstatement plan		
Drafting		
Upload to data recorder		
Reinstatement		
first round obs		
Second round obs		
Calculate reinstated boundaries		
Incorporate subdivision design		
Upload subdivision to data recorder		
Peg subdivision		
round of check obs		
second round of check obs (for reference marks)		
Final plan production		

Notes:

APPENDIX F

Survey Search



HORIZONTAL DATUM:GDA94 ZONE:56 SCALE 1 : 2500

STANDARD MAP NUMBER
9242-11321

MAP WINDOW POSITION & NEAREST LOCATION

151°56'01".895
27°36'24".456
KEARNEYS SPRING
0.77 KM

GDA

SUBJECT PARCEL DESCRIPTION

DCDB

Lot/Plan	2/RP115043
Area/Volume	3.874ha
Tenure	FREEHOLD
Local Government	TOOWOOMBA CITY
Locality	DARLING HEIGHTS
Parish	DRAYTON
County	AUBIGNY
Parcel/Segment	145/2893
SCDB Permanent Marks	

CLIENT SERVICE STANDARDS

PRINTED (dd/mm/yyyy) 30/10/2006

DCDB 27/10/2006
SCDB 30/10/2006;

Users of the information recorded in this document (the Information) accept all responsibility and risk associated with the use of the Information and should seek independent professional advice in relation to dealings with property.

Despite Department of Natural Resources, Mines and Water(NRMW)'s best efforts, NRMW makes no representations or warranties in relation to the Information, and, to the extent permitted by law, exclude or limit all warranties relating to correctness, accuracy, reliability, completeness or currency and all liability for any direct, indirect and consequential costs, losses, damages and expenses incurred in any way (including but not limited to that arising from negligence) in connection with any use of or reliance on the Information

For further information on SmartMap products visit http://www.nrm.qld.gov.au/property/mapping/blinmap

SmartMap
An External Product of
SmartMap Information Services

Based upon an extraction from the
Digital Cadastral Data Base

Queensland Government
Natural Resources, Mines and Water

QUEENSLAND GOVERNMENT

CURRENT TITLE SEARCH

NATURAL RESOURCES, MINES & WATER, QUEENSLAND

Request No: 1166637
Search Date: 30/10/2006 2:00 pm

Title Reference: 14208040
Date Created: 30/08/1968

Previous Title: 12872151

REGISTERED OWNER

Dealing No: 700550862 14/03/1995

KELLY CONSOLIDATED PTY LTD A.C.N. 050 719 321

ESTATE AND LAND

Estate in Fee Simple

LOT 2 REGISTERED PLAN 115043
County of AUBIGNY Parish of DRAYTON
Local Government: TOOWOOMBA CITY

EASEMENTS, ENCUMBRANCES AND INTERESTS

1. Rights and interests reserved to the Crown by Deed of Grant No. 10021103 (POR 368)

2. MORTGAGE No 702390071 11/12/1997 at 11:41
NATIONAL AUSTRALIA BANK LIMITED A.C.N. 004 044 937

ADMINISTRATIVE ADVICES - NIL
UNREGISTERED DEALINGS - NIL

CERTIFICATE OF TITLE ISSUED - No

Caution - Charges do not necessarily appear in order of priority

** End of Current Title Search **

Requested By: CASH SALE

Survey Search Detail Report

Details of Registered Number: 40424

Current Information

Administrative

Alternate Name(s)	TW 217 WEST/NELSON
Parish	DRAYTON
Town	TOOWOOMBA
Local Authority	TOOWOOMBA
Locality Description	WEST & NELSON ST
Related Information	

Mark Details

Mark Type	STAND	**Mark Condition**	GOOD
Installed By	DMS	**Installed Date**	01/01/1975
Last Visited	01/12/2005	**Sketch Available**	YES
Connection(s)	SP189204 SP176411 SP176361 SP164751 RP217585		

Horizontal

Datum	GDA94		
Latitude	27°36' 37.8305" S	**Longitude**	151°56' 4.2208" E
Easting	394860.175	**Northing**	6945489.266
Zone	56		
Order	1st ORDER	**Class**	CLASS A
Adjustment Name	GDA - QLD SUPPLEMENTARY AREA 2 AND 3	**Fixed By**	GPS
Prominent Feature	NO		

Vertical

Height	683.293	**Datum**	AHD
Order	4th ORDER	**Class**	Class D
Fixed By	SPIRIT LEVELLING	**Origin**	LEAD21
Geoid/Ellipsoid Separation(N)	14.489		
Model	AUSGEOID98		

CONTROL STATION SUMMARY 01770

PREPARED BY THE DEPARTMENT OF MAPPING AND SURVEYING, BRISBANE.

STATION NAME: TW 217 NO: PSM 40424

ESTABLISHED BY	DMS	DATE	1975	PARISH	COUNTY	C.P.O. MAP	1:250,000	HEIGHT	HEIGHT Datum	ORDER
REOCCUPIED BY		DATE		DRAYTON	AUBIGNY	TOOWOOMBA TOWN SH.25	1:100 000 9242 TOOWOOMBA	683.276m	AHD Toowoomba PSA I	

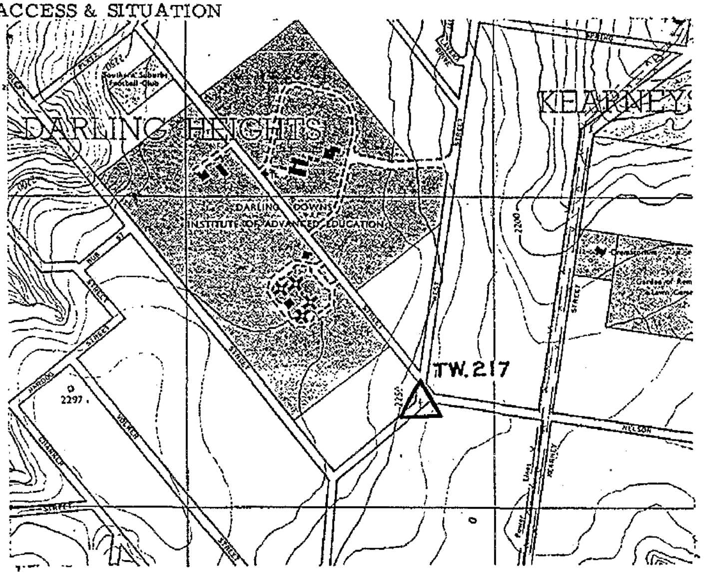
CO-ORDINATES:-

LATITUDE	LONGITUDE	ZONE	EASTING	NORTHING	CONVERGENCE	TYPE	CO-ORDINATE ORIGIN
27°36'43.5098"	151°56'00".3290	56	394 754.618	6 945 303.009	+0°29'39.79"	AMG	SE QLD 78 TOOWOOMBA 19/3/79

STATION MARKING

Standard PSM *Field Checked Oct 1982*

ACCESS & SITUATION



COMPILED FROM 1:15 000

TRIG CARD	A. A. 29	FILE 100/2	AAF/03	F/B	
				CL.638	Form 6

OBSERVED STATIONS TOOWOOMBA BREAKDOWN SEQLD78 DATE 79/03/19

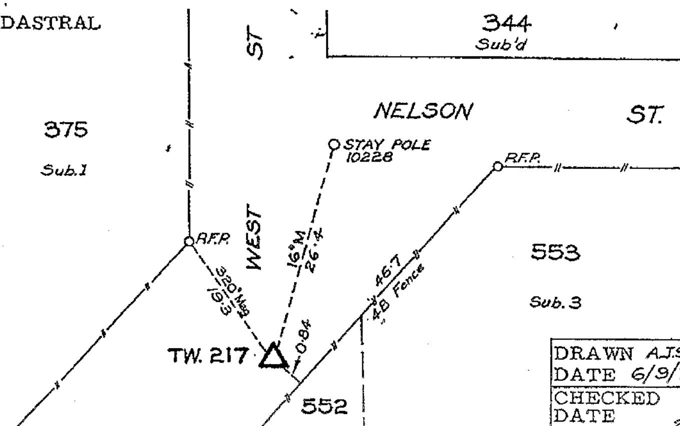
AT 40424 CONV. +0 29 39.79

SEQLD78 LATITUDE LONGITUDE

394754.618 E 6945303.009 N ZONE 56 (27 36 43.5098 S 151 56 .3290 E)

	GRID BEAR D	M	S	SPHD DIST
TO * E2GABBINBAR	91	25	37.38	1911.650 MS
* WTPICNIC	55	57	17.95	6282.236 MS
* 40426	269	6	3.14	964.128 MS
* 40430	41	31	40.43	3492.310 MS

REF. MARKS & CADASTRAL

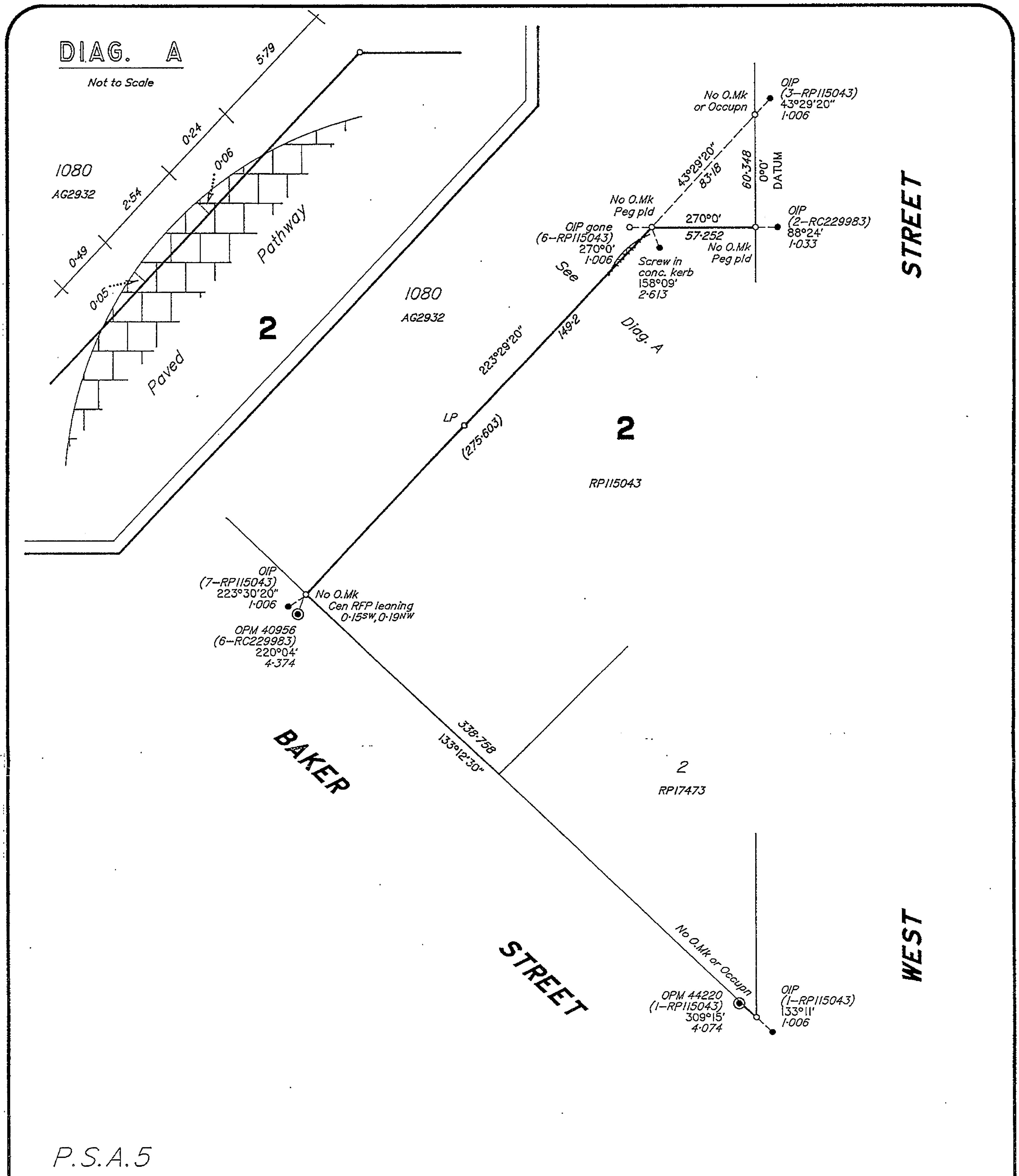


Not to Scale
Distances in Metres.

DRAWN A.J.S.
DATE 6/9/79
CHECKED LJG
DATE 20.9.79

40424

SCS040424



I, Douglas Stuart PARKINSON hereby certify that I have surveyed the land comprised in this plan personally, that the plan is accurate, that the said survey was performed in accordance with the Surveyors Act 1977 and the Surveyors Regulation 1992 and that the said survey was completed on 15/4/96.

Licensed Surveyor

Date 22/4/96

This plan is of an Identification Survey only, and as such is not examined for registration. It is lodged with the Department of Lands for survey information only, in accordance with the Surveyors Regulation 1992. No responsibility can therefore be accepted for any future difference in boundary definition, which may result from resurveys of adjoining lands or subsequent registration of new survey plans.

PARKINSON & PARKINSON PTY LTD
Licensed Consulting Surveyors
185 HERRIES ST, TOOWOOMBA, QLD.
Telephone: 076 323 244 ; Facsimile: 076 393 257

PLAN OF IDENTIFICATION SURVEY OF North West and Northern Boundaries of Lot 2 on RP115043

ORIGINAL Por. 368

PARISH DRAYTON
COUNTY Aubigny
~~TOWN~~ / LOCALITY DARLING HEIGHTS
LOCAL GOVERNMENT TOOWOOMBA C.C.
LANDS REGION DARLING DOWNS
MINING DISTRICT

MERIDIAN of RP115043	MAP REF 9242–11321	SCALE 1:2000	ENDORSED	ARCHIVED BRISBANE	IS 127502

9388A

0 10 20 30 40 50 60 70 80 90 100mm

CISP 2/7/96

LAND TITLE ACT 1994

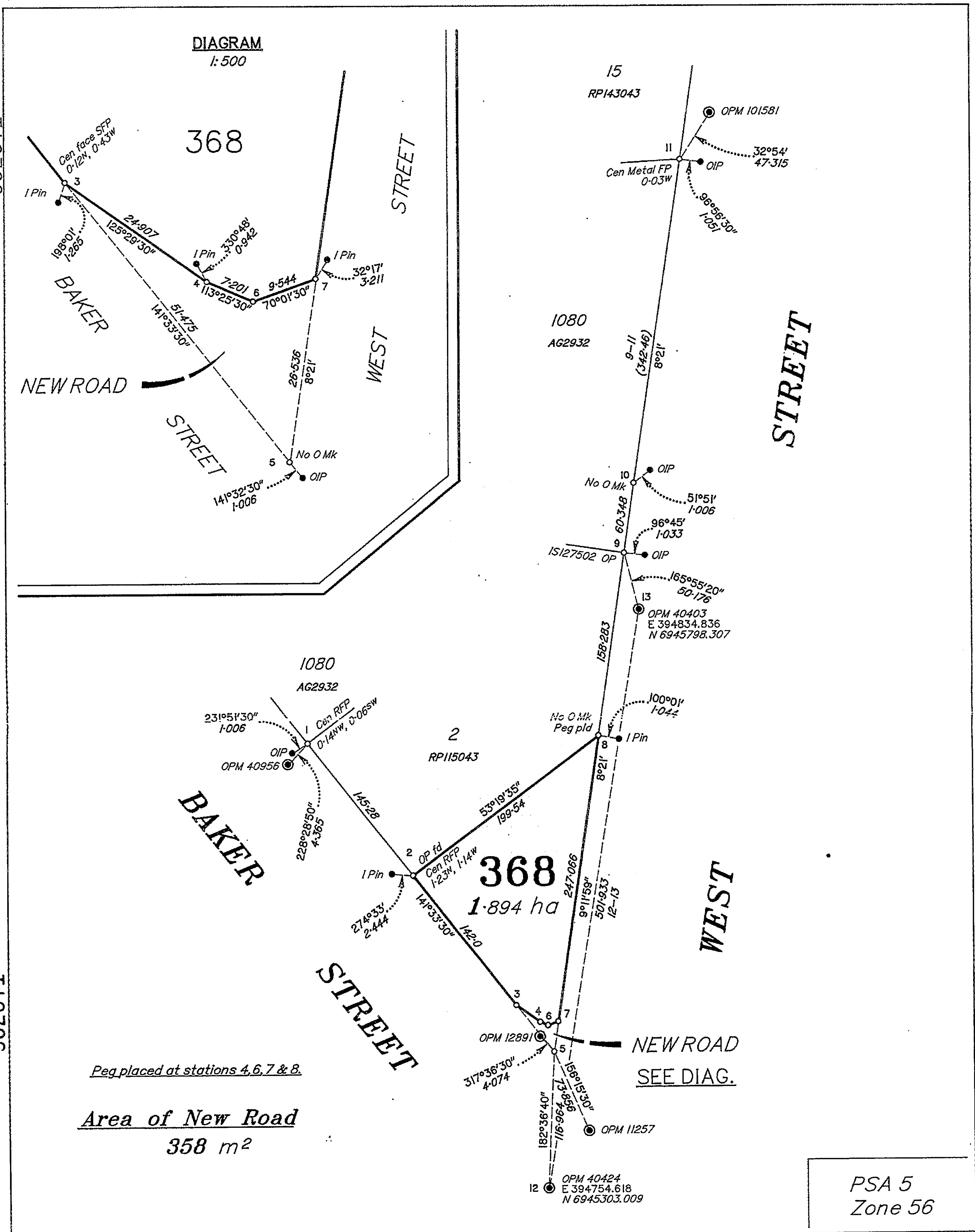
SURVEY PLAN

FORM 21 VERSION 1

902071

WARNING - PLAN MAY BE ROLLED - A FOLDED OR MUTILATED PLAN WILL NOT BE ACCEPTED

PLAN MUST BE DRAWN WITHIN BLACK LINES



I, John Roger COOK hereby certify that I have surveyed the land comprised in this plan personally, ~~for whose work~~ and that the plan is accurate, that the said survey was performed in accordance with the Surveyors Act 1977 and the Surveyors Regulation 1992 and that the said survey was completed on 23/7/1996

J. R. Cook. ~~Director &~~ Licensed Surveyor

~~Director~~ Date 2/8/1996

PLAN OF

Lot 368

Cancelling Lot 2 on RP17473

ORIGINAL PORTION 368.

PARISH	DRAYTON
COUNTY	AUBIGNY
TOWN/LOCALITY	DARLING HEIGHTS
LOCAL GOVERNMENT	TOOWOOMBA C. C.
LANDS REGION	DARLING DOWNS
MINING DISTRICT	

NO SURVEY RECORDS DEPOSITED

MERIDIAN	MAP REF	SCALE	ENDORSED	ARCHIVED
AMG	9242–11321 9242–11322	1:3000	ACCREDITED	BRISBANE

REGISTERED PLAN 902071

0 10 20 30 40 50 60 70 80 90 100mm

WARNING - PLAN MAY BE ROLLED - A FOLDED OR MUTILATED PLAN WILL NOT BE ACCEPTED

701587603
$256.00
07/10/1996 12:53
TA 400 NT PLAN OF SURV ORIG

Lodged by
HEDE + BYRNE SOLICITORS PH: 076)382600
24 BOWEN ST WB:CM
TOOWOOMBA QLD 4350 951081
(Include address, phone number and reference)

Particulars ~~entered in the Register~~ on the Titles listed below,

REGISTERED 11 OCT 1996 EXAM. INITS MC

Title Reference	Description	Road
13451110	Lot 2 on R.P.17473	New Road

F.O.L.R. CISP

I/We Kelly Consolidated Pty Ltd. A.C.N. 050 719 312

(Names in full)

* As Registered Owner of this land ~~* As Lessee/s of Miners Homestead~~ agree to this Plan, # and dedicate the Public Use Land as shown hereon in accordance with Section 50 of the Land Title Act 1994.

Signature of * Owner/s ~~* Lessee/s~~

KELLY CONSOLIDATED PTY LTD A.C.N. 050 719 312 — Director, Director

* Rule out whichever is inapplicable
\# NOTE: A Lessee of a Miners Homestead is unable to dedicate Public Use Land.

* Toowoomba City Council
certifies that all the requirements of this Council, the Local Government Act 1993, the Local Government (Planning and Enviroment) Act 1990 and all Local Laws, # and the City of Brisbane Act 1924 and all Ordinances thereunder, have been complied with and approves this plan of Subdivision, SUBJECT TO

Dated this 27th day of August 1996

Mayor
~~# Appointed Officer~~
~~Chief Executive Officer~~
Authorised Signatory

* Insert the name of the Local Government
\# Delete for Local Governments other than the City of Brisbane

For Additional Plan & Document Notings Refer to CISP

SURVEY EXAMINATION	ORIGINAL GRANT	CHARTING	LODGEMENT FEES	REFERENCES
Exam. Fee $	DG10021103 (Por 368)	Charted	Survey Exam $ 115	Lands File
Receipt No.			Lodg, Exam & Ass $ 87	Local Government Reference
Date			1 New Titles $ 40	Surveyors Reference
Deposited			Photocopy $ 14	
Examined J.R.L. 12/9/96			Postage $	
Passed J.R.L. 12/9/96			TOTAL $ 256	REGISTERED PLAN 902071

902071

This plan MUST NOT BE FOLDED but may be rolled.

115043

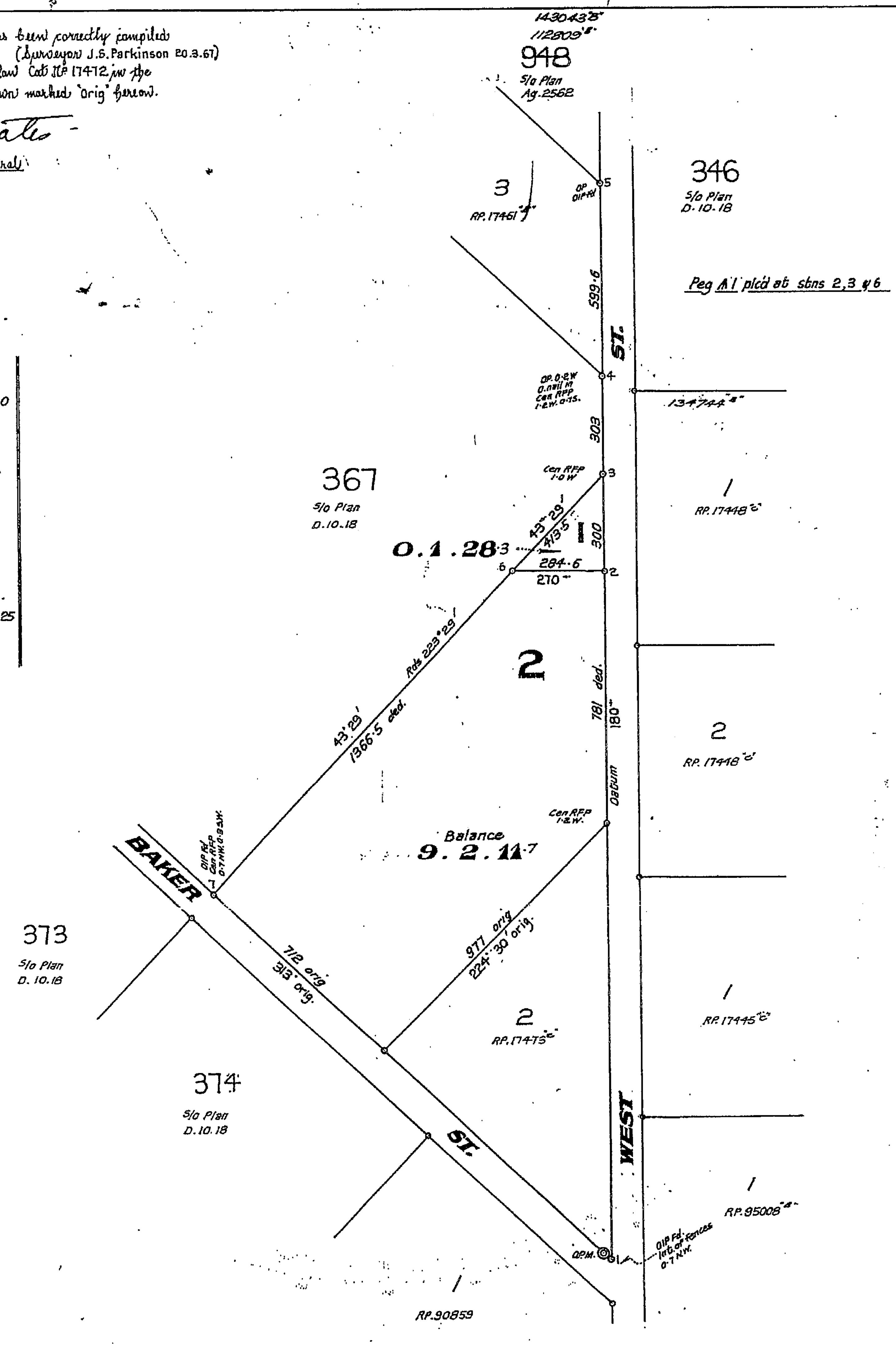
Drawing of Plan must be restricted to the space inside the blue lines

I certify that this plan has been correctly compiled from plan Cat No Ag.2698 (Surveyor J.S. Parkinson 20.3.67) in the Survey Office, and plan Cat No 17472 in the Titles Office, Brisbane, as shown marked "orig" hereon.

A B Yeates

Acting Surveyor General

3rd August, 1967.



Iron Pins		
1 - OIP	133°11'	5·0
2 - IP	90°	"
3 - "	43°29'	"
5 - OIP	90°	"
6 - IP	270°	"
7 - OIP	233°30'	"

Perm. Mk.		
1 - OPM.	309°15'	20·25

115043

Cat

Lots 1 & 2

Orig. Portion 368

Orig. Grant 6338

Cancelling Lot Sub 1 on RP.17472

Town of

Parish of DRAYTON County of Aubigny

SCALE 3 chains to an inch

Surveyed by / /19

CROWN COPYRIGHT RESERVED REGISTRAR OF TITLES, QUEENSLAND

REGISTERED PLAN 115043

P.M.

This plan MUST NOT BE FOLDED but may be rolled. *Y&&to H(sby)* 2848

....of.............................

Authorised Surveyor, do hereby solemnly and sincerely declare that I have faithfully and truly surveyed, measured and marked on the ground the parcel of land herein referred to, and that the measurements and boundaries given in this plan are correct, and do not to the best of my belief in any way interfere with the rights or property of any persons, owners or occupiers of the land adjoining the above land, and described in the said plan; and I make this solemn declaration conscientiously believing the same to be true, and by virtue of the provisions of the "Oaths Acts, 1867-1960"

....
Authorised Surveyor

Made and Signed at...this..............day of..............
19...., before me.

....
Signature of Registrar of Titles or of a Magistrate.

– FOR SURVEYOR'S USE ONLY –

SURVEY OF *Lot 1 & 2*

County of *Aubigny* Parish of *Drayton*

Town of...To the Depth of..............

Cancelling *Sub 1 on RP 17472*

Orig. Grant *6338* Orig. Portion *368*

The Council of the *City* of *Toowoomba* certifies that all the requirements of this Council, the Local Government Acts of 1936 to 19*67* and all By-Laws have been complied with and approves this Plan of Subdivision subject to *the amalgamation of Lot 1 herein with Portion 367 on S/O Plan D.10.18*

Dated this *31st* day of *October* 19*67*

Hess E. Robinson ~~Chairman~~ or Mayor

[signature] Town or ~~Shire~~ Clerk

– FOR OFFICE USE ONLY –

Previous Title *C.T. Vol. 2872 Fol. 151* *17472 "C"*

As Proprietor of this land, I agree to this Plan of subdivision, and dedicate the new roads shown hereon to public use

GIVEN under the Official Seal for Queensland of THE UNION-FIDELITY TRUSTEE COMPANY OF AUSTRALIA LIMITED by order of the Board under the hands of two Directors of the Company and the Manager for Queensland, in the presence of:

Signature of Proprietor *[signature]* Director

[signature] Director

[signature] ACTING Manager

V.H. Woodhouse J.P.

The Union-Fidelity Trustee Company of Australia Limited

Lot	Vol.	Fol.
2	4208	40.

REGR. OF TITLES RECEIVED

1968 JUL 26 AM 11:23

D617482

NIL *28/6/68 HH*

56258

$13.00 *1.00* *6.00*

For Additional Plan & Document Notings Refer to CISP

Calc. Bk. No. *R56/73*
Examined *21/8/68*
Passed *21/8/68*
Charted *4/9/68*
Located *PM Part A*

Particulars entered in Register Book
Vol. *2872* Folio *151*

the *28* day of *Aug* 19*68* at *3.0*

[signature]
REGISTRAR OF TITLES

Lodged by *Crown Solicitor*

REGISTERED PLAN 115043

QIT Tba-EDIC-

APPENDIX G

Reinstatement – Total Station

1 Folio 1

Commencing at OPM 40956

Atmospherics: Set in Instrument / ~~Included in Reduction~~

Prism Type: set 6

Additive Constant: 0 MM

Scale Factor: 1

Type: S6

Serial No:

EDME Standardisation:

~~Theodolite:~~

~~Standard Tension:~~

~~Standard Temperature:~~

~~Cross Section:~~

~~Weight:~~

~~Band No~~

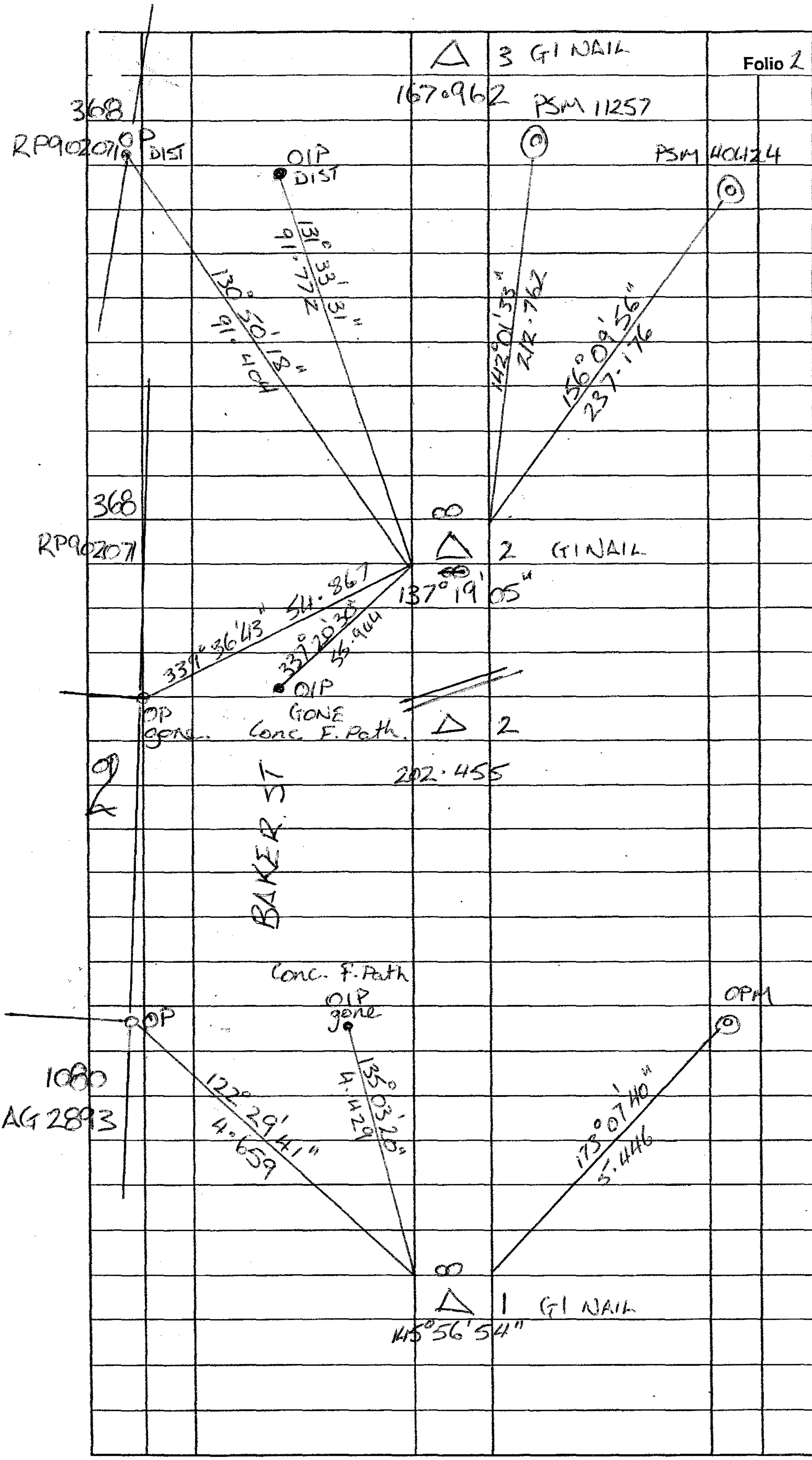
~~Chain Standardisation:~~

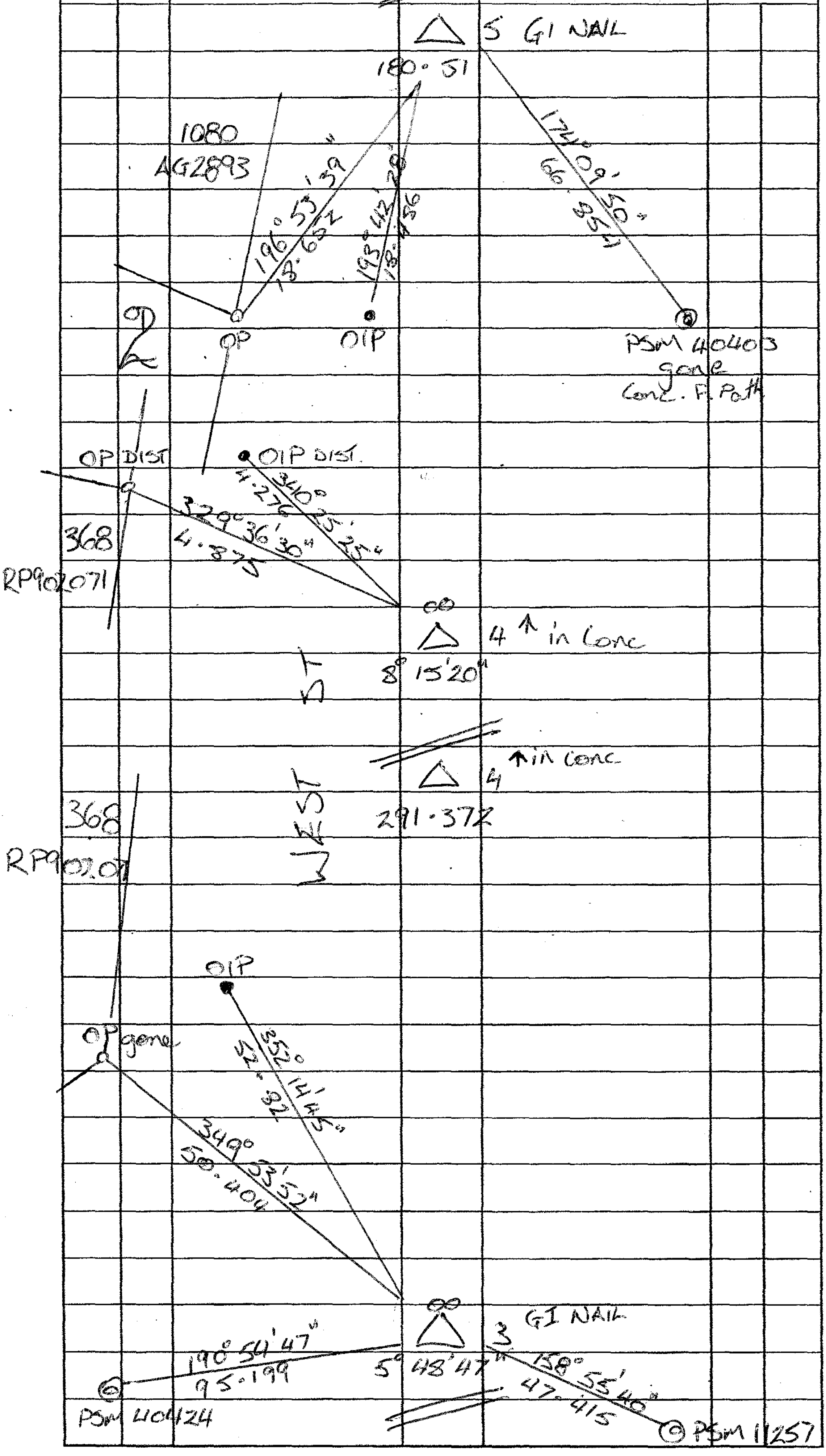
Date: 8-Sept 2006

Chainman: MDP

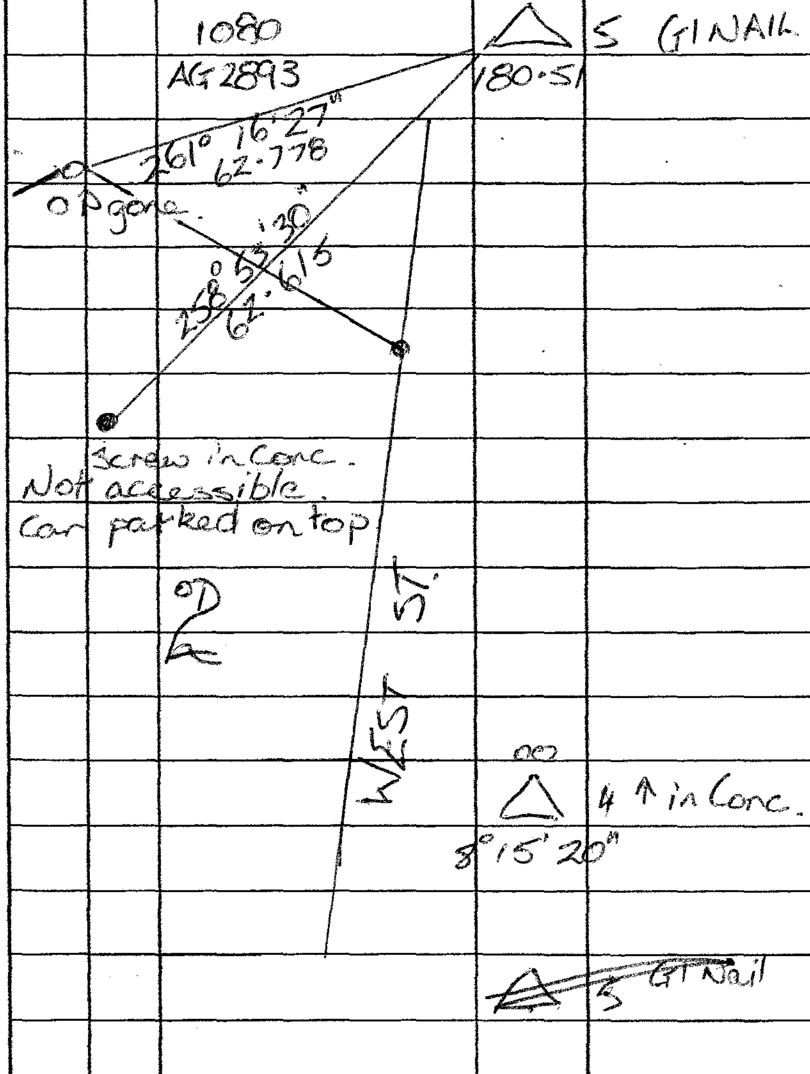
Surveyor: AJW.

Survey of Lot 2 on RP115043


3 GI NAIL
167.962
PSM 11257
368
RP902071
OP DIST
OIP DIST
PSM 40424
131°33'31"
91.772
130°50'18"
91.404
142°01'33"
212.762
156°09'56"
237.176
368
RP902071
2 GI NAIL
137°19'05"
339°36'43"
54.867
337°20'35"
55.944
OIP GONE
OP gone.
Conc. F. Path.
2
202.455
BAKER ST
Conc. F. Path
OIP gone
OP
OPM
1080
AG 2893
122°29'41"
4.659
135°03'20"
4.429
173°07'40"
5.446
1 GI NAIL
145°56'54"

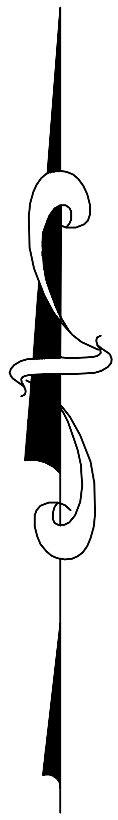


5 GI NAIL
180° 51
1080
AG2893
196° 53' 39"
13.652
193° 42' 20"
18.436
174° 09' 50"
66.854
OP
OIP
PSM 40403
gone
Conc. F. Path
OP DIST
OIP DIST.
340° 25' 25"
4.276
329° 36' 30"
4.875
368
RP902071
4 in Conc
8° 15' 20"
ST
WEST
4 in Conc
291.372
368
RP902071
OIP
OP gone
352° 14' 45"
32.92
349° 33' 52"
50.404
GI NAIL
3
190° 54' 47"
95.199
5° 48' 47"
158° 55' 40"
47.415
PSM 40424
PSM 11257

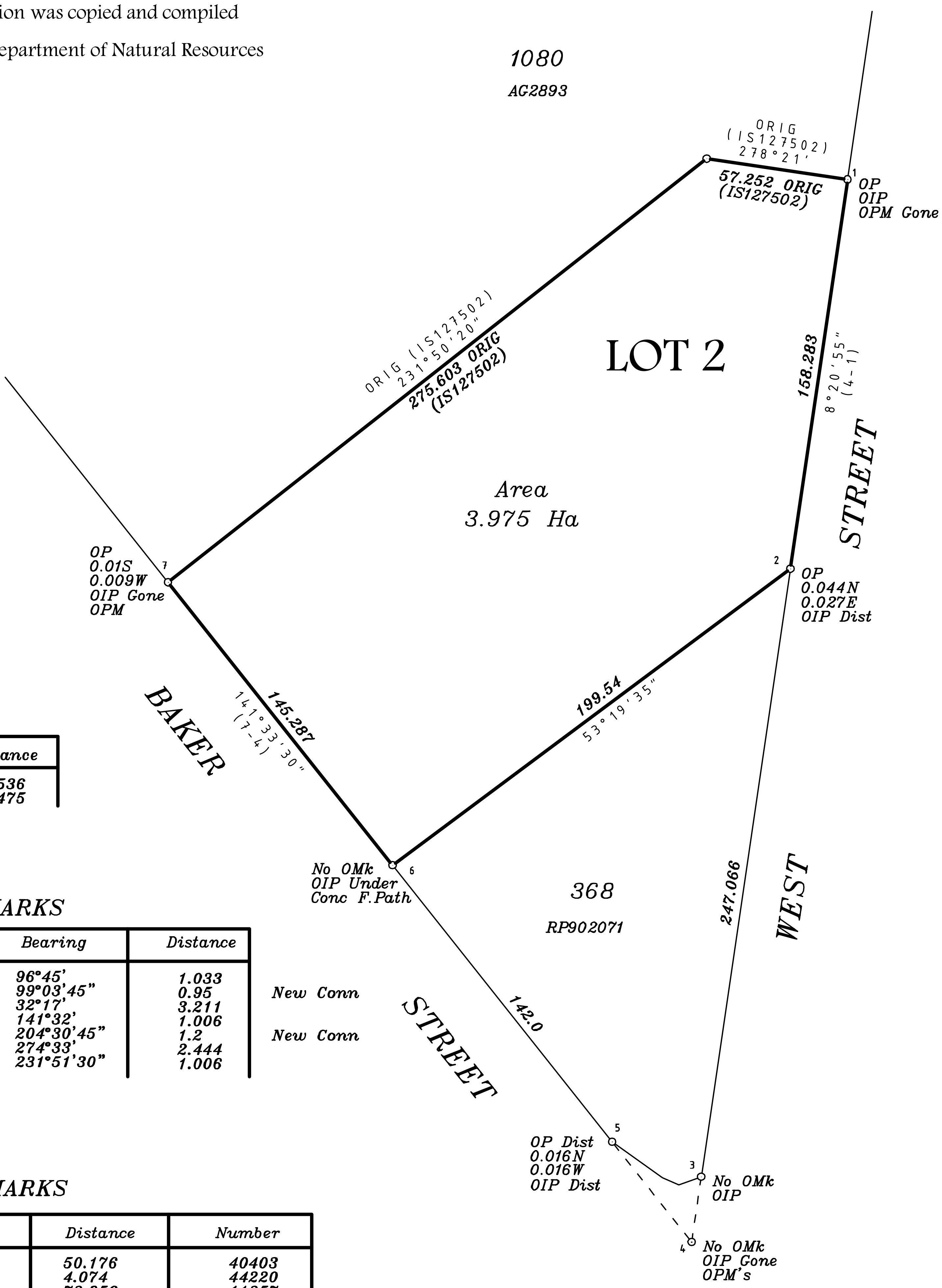

1080
AG 2893
5 GI NAIL
180·51
261° 16' 27"
62·778
0 P gone
130
258° 53'
62·615
screw in Conc.
Not accessible.
Car parked on top
WEST ST.
4 ↑ in Conc.
8° 15' 20"
5 GI Nail

SURVEY PLAN

Sheet 1 Of 1



Note: Original information was copied and compiled from IS127502 in the Department of Natural Resources Mines and Water.



TRAVERSES

Line	Bearing	Distance
3–4	188°21'05"	26.536
4–5	321°33'30"	51.475

REFERENCE MARKS

Stn	To	Origin	Bearing	Distance	
1	OIP	RC229983	96°45'	1.033	
2	OIP Dist	RP902071	99°03'45"	0.95	New Conn
3	OIP	RP902071	32°17'	3.211	
4	OIP gone	RP115043	141°32'	1.006	
5	OIP Dist	RP902071	204°30'45"	1.2	New Conn
6	OIP gone	RP902071	274°33'	2.444	
7	OIP gone	RP115043	231°51'30"	1.006	

PERMANENT MARKS

PM	Origin	Bearing	Distance	Number
1–OPM gone	RP902071	165°55'20"	50.176	40403
4–OPM gone	RP115043	309°15'	4.074	44220
4–OPM	RP902071	156°15'30"	73.856	11257
4–OPM	RP902071	182°36'40"	116.964	40424
7–OPM	RC229983	228°28'50"	4.365	40956

Scale 1: 2000

0 50 100 200 300 400

I, Andrew Jonathan Worrall hereby certify that the land comprised in this plan was surveyed by me personally and that the plan is accurate, that the said survey was performed in accordance with the Survey and Mapping Infrastructure Act 2003 and Surveyors Act 2003 and associated Regulations and Standards and that the said survey was completed on 8/9/2006.

A J Worrall

LOT 2

on Registered Plan RP115043

PARISH: DRAYTON COUNTY: AUBIGNY

Scale: 1:2000

Format: Standard

SP(Number)

Meridian: AMG Vide RP902071

F/N's:

Plan Status:

PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT

APPENDIX H

Reinstatement - GPS (RTK)

Job Info

Job ID:	ENG 4112	Date:	13-9-06
Surveyor:	AJW	Location:	Cor Baker + West
Assistant:	MDP + BDS		

Equipment

Base

Base Antennae Type/Model:	Compact L1/L2 w/ Ground plane
Base Station Serial Number:	ANANGA
Base Controller:	

Rover

Rover Antennae:	Zephyr
Rover Reciever:	Trimble 5700
Rover Controller:	TSCE - 6

Total Station

Total Station type/model number:	Trimble S6
Prism type/model number:	set 6

Data recorder type/model number:	-
or Field Book Number:	AJW - 1

Datum info:

Datum:	AMG Vide RP902071	Zone:	56
Base/Control Point (for survey meridian):	PSM 40424		
Easting:	394860·175	Northing:	6945489·266
False Easting:	—		
False Northing:	—		

File Info:

Controller job File:	AJW-Reinstate-2	Backup	✓
Computer Job File:	AJW-Reinstate	Backup	✓

Notes: The unit manager in the subject lot was not going to allow me entrance to conduct the survey.

Client Info

Client Name: ______ Contact Phone: ______

Postal Address: ______

Progress

		Done	Check
Client Instructions			
Search	Titles	✓	✓
	Plans	✓	✓
	Form 6	✓	✓
	Other		
CAD reinstatement plan			
	Drafting	✓	✓
	Upload to data recorder	✓	✓
Reinstatement			
	first round obs	✓	
	Second round obs	✓	
Calculate reinstated boundaries		✓	✓
Incorporate subdivision design			
Upload subdivision to data recorder			
Peg subdivision			
	round of check obs		
	second round of check obs (for reference marks)		
Final plan production		✓	✓

Notes: second round of Obs - could not maintain radio lock with base-station set on OPM 40424, decided to re-use ANANGA for second round.

Point Derivation Report

Project : Final Reinstatement

User name	q9821908	**Date & Time**	2:35:07 PM 9/10/2006
Coordinate System	Australian Map Grid(at ground)	**Zone**	Zone 56
Project Datum	AGD 1984 (Higgins)		
Vertical Datum		**Geoid Model**	AUSGEOID98 (Australia)
Coordinate Units	Meters		
Distance Units	Meters		
Height Units	Meters		

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Point Derivations

Observations or coordinates in red are out of tolerance. They have not been used to determine the coordinate of the point.

Resultant coordinates for point : 1

Northing	Easting	Elevation	Height
6946302.920m	394479.738m	720.804m	735.296m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Heigh
CW29 DC file (AJWreinstate-3.dc)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 40835

Northing	Easting	Elevation	Height
6945301.152m	394753.056m	683.268m	697.755m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height

B18 (1-40835)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 40836

Northing	Easting	Elevation	Height
6945350.411m	394788.123m	682.869m	697.356m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B19 (1-40836)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 40837

Northing	Easting	Elevation	Height
6945457.237m	394725.882m	684.444m	698.933m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B20 (1-40837)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 44125

Northing	Easting	Elevation	Height
6945457.214m	394725.875m	684.458m	698.946m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B21 (1-44125)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 44126

Northing	Easting	Elevation	Height
6945458.313m	394726.408m	684.530m	699.018m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B22 (1-44126)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 40838

Northing	Easting	Elevation	Height
6945680.423m	394544.471m	689.759m	704.250m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B23 (1-40838)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 44127

Northing	Easting	Elevation	Height
6945683.316m	394547.763m	689.958m	704.448m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B24 (1-44127)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 40839

Northing	Easting	Elevation	Height
6945688.563m	394799.135m	684.897m	699.384m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B25 (1-40839)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 44128

Northing	Easting	Elevation	Height
6945688.762m	394798.102m	685.126m	699.612m

ID	Used to calc.	Status	∆ North	∆ East	Distance (Horiz)	∆ Elevation	∆ Height
B26 (1-44128)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 44129

Northing	Easting	Elevation	Height
6945845.318m	394821.072m	684.941m	699.427m

ID	Used to calc.	Status	∆ North	∆ East	Distance (Horiz)	∆ Elevation	∆ Height
B27 (1-44129)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 44130

Northing	Easting	Elevation	Height
6945845.318m	394821.061m	684.940m	699.426m

ID	Used to calc.	Status	∆ North	∆ East	Distance (Horiz)	∆ Elevation	∆ Height
B28 (1-44130)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 44131

Northing	Easting	Elevation	Height
6945683.344m	394547.737m	689.965m	704.456m

ID	Used to calc.	Status	∆ North	∆ East	Distance (Horiz)	∆ Elevation	∆ Height
B29 (1-	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

44131)

Resultant coordinates for point : 40840

Northing	Easting	Elevation	Height
6945680.429m	394544.471m	689.801m	704.292m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B30 (1-40840)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 44132

Northing	Easting	Elevation	Height
6945458.297m	394726.379m	684.560m	699.048m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B31 (1-44132)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 44133

Northing	Easting	Elevation	Height
6945457.237m	394725.849m	684.437m	698.926m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B32 (1-44133)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 40841

Northing	Easting	Elevation	Height
6945350.406m	394788.127m	682.831m	697.318m

Used

ID	to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B33 (1-40841)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

Resultant coordinates for point : 40844

Northing	Easting	Elevation	Height
6945301.165m	394753.056m	683.261m	697.748m

ID	Used to calc.	Status	Δ North	Δ East	Distance (Horiz)	Δ Elevation	Δ Height
B34 (1-40844)	NEeh	Enabled	0.000m	0.000m	0.000m	0.000m	0.000m

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Survey Data

Observations

GPS Baselines

ID	Source	From Pt	To Point	Solution/Quality	Ratio	Reference Variance	RMS	Slope Distance
B18	DC file (AJWreinstate-3.dc)	1	40835	Fixed	?	?	0.006m	1039.061m
B19	DC file (AJWreinstate-3.dc)	1	40836	Fixed	?	?	0.003m	1001.903m
B20	DC file (AJWreinstate-3.dc)	1	40837	Fixed	?	?	0.003m	881.525m
B21	DC file (AJWreinstate-3.dc)	1	44125	Fixed	?	?	0.003m	881.544m
B22	DC file (AJWreinstate-3.dc)	1	44126	Fixed	?	?	0.002m	880.636m

B23	DC file (AJWreinstate-3.dc)	1	40838	Fixed	?	?	0.024m	626.622m
B24	DC file (AJWreinstate-3.dc)	1	44127	Fixed	?	?	0.006m	624.089m
B25	DC file (AJWreinstate-3.dc)	1	40839	Fixed	?	?	0.004m	693.352m
B26	DC file (AJWreinstate-3.dc)	1	44128	Fixed	?	?	0.009m	692.688m
B27	DC file (AJWreinstate-3.dc)	1	44129	Fixed	?	?	0.006m	572.009m
B28	DC file (AJWreinstate-3.dc)	1	44130	Fixed	?	?	0.006m	572.002m
B29	DC file (AJWreinstate-3.dc)	1	44131	Fixed	?	?	0.003m	624.058m
B30	DC file (AJWreinstate-3.dc)	1	40840	Fixed	?	?	0.003m	626.614m
B31	DC file (AJWreinstate-3.dc)	1	44132	Fixed	?	?	0.004m	880.642m
B32	DC file (AJWreinstate-3.dc)	1	44133	Fixed	?	?	0.002m	881.516m
B33	DC file (AJWreinstate-3.dc)	1	40841	Fixed	?	?	0.004m	1001.911m
B34	DC file (AJWreinstate-3.dc)	1	40844	Fixed	?	?	0.003m	1039.049m

Coordinates

ID	Point Name	Source	Latitude	Longitude	Height	Elevation
C29 (geod-WGS)	1	DC file (AJWreinstate-3.dc)	27° 36'05.21482"S	151° 55'54.57112"E	762.769m	? ?

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```
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10NMAJW-reinstate   121221
13TSTime Date 09/12/2006 Time 10:52:36
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00.00000000000000
D8TM
64TM30.0000000000000153.0000000000000.00000000000000010000000.0000000500000.0000000
000.00000000000000.99960000000000.000000000000000.00000000000000
C8NM4Map Grid of Australia (GDA)     Zone 56                           ITRF

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69KI        PSM112576945538.50826579394895.242674254
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69KI        1005     6945632.37858275394869.358027349
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69KI        1006     6945876.85169411394905.240708519
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69KI        1007     6946033.47354629394928.228970724
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50KI

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56KI156.00000000000000
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57KI0.000000000000001
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11
57KI0.000000000000001
66FD        1       -27.601448561722151.931825311812762.768990641460
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E2SI4700              012 Compact L1/L2 w/Ground Plane
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                          1392180537.0000000001392180663.0000000001
59NM070.021962616592650.00000647107936-0.00000438573030.000005494139710.00000677787
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B1CB        40836          PSM1125730.00000000000000

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PSM4042440.000000000000000.000000000000000.00000000000000
B1CB   40836   PSM1125730.00000000000000

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56KI156.00000000000000
82KI4
57KI0.000000000000001
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E2SI4700   012 Compact L1/L2 w/Ground Plane
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808-0.00000100805150.00000645505406
67TP   44125   261.109340945259-409.87537343241-735.39138210472OIP
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B1CB        40838           PSM4095630.00140630809807

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82KI4
57KI0.000000000000001
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E2SI4700              012 Compact L1/L2 w/Ground Plane
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67TP        44129   56.0111342808232-412.19541070005-392.43980352022OP
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67CN        40841   277.425141663291-488.07574669551-829.75398688531PSM
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B1CB        40836           PSM1125730.00990666943745

B1CB        40838           PSM4095630.01670345733829

B1CB        40839           OIP6    30.01834913648703

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B1CB        40839           OIP6    30.01834913648703

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GPS Vector data

Project : Final Reinstatement

User name	q9821908	**Date & Time**	2:43:56 PM 9/10/2006
Coordinate System	Australian Map Grid(at ground)	**Zone**	Zone 56
Project Datum	AGD 1984 (Higgins)		
Vertical Datum		**Geoid Model**	AUSGEOID98 (Australia)
Coordinate Units	Meters		
Distance Units	Meters		
Height Units	Meters		

From Point Name	To Point Name	DeltaX	DeltaY	DeltaZ	Slope Distance	RMS	Ratio	Ref Var
1	40835	315.401m	-468.099m	-872.384m	1039.061m	0.006m	?	?
1	40836	278.995m	-488.908m	-828.819m	1001.903m	0.003m	?	?
1	40837	262.707m	-410.735m	-734.417m	881.525m	0.003m	?	?
1	44125	262.709m	-410.728m	-734.443m	881.544m	0.003m	?	?
1	44126	261.950m	-410.938m	-733.507m	880.636m	0.002m	?	?
1	40838	251.089m	-201.146m	-537.727m	626.622m	0.024m	?	?
1	44127	248.202m	-203.366m	-535.280m	624.089m	0.006m	?	?
1	40839	132.619m	-426.649m	-530.207m	693.352m	0.004m	?	?
1	44128	132.841m	-425.598m	-530.129m	692.688m	0.009m	?	?
1	44129	57.611m	-413.048m	-391.492m	572.009m	0.006m	?	?
1	44130	57.617m	-413.039m	-391.491m	572.002m	0.006m	?	?
1	44131	248.197m	-203.334m	-535.259m	624.058m	0.003m	?	?
1	40840	251.054m	-201.127m	-537.741m	626.614m	0.003m	?	?
1	44132	261.947m	-410.904m	-733.534m	880.642m	0.004m	?	?
1	44133	262.728m	-410.709m	-734.413m	881.516m	0.002m	?	?
1	40841	279.025m	-488.929m	-828.806m	1001.911m	0.004m	?	?
1	40844	315.401m	-468.099m	-872.369m	1039.049m	0.003m	?	?

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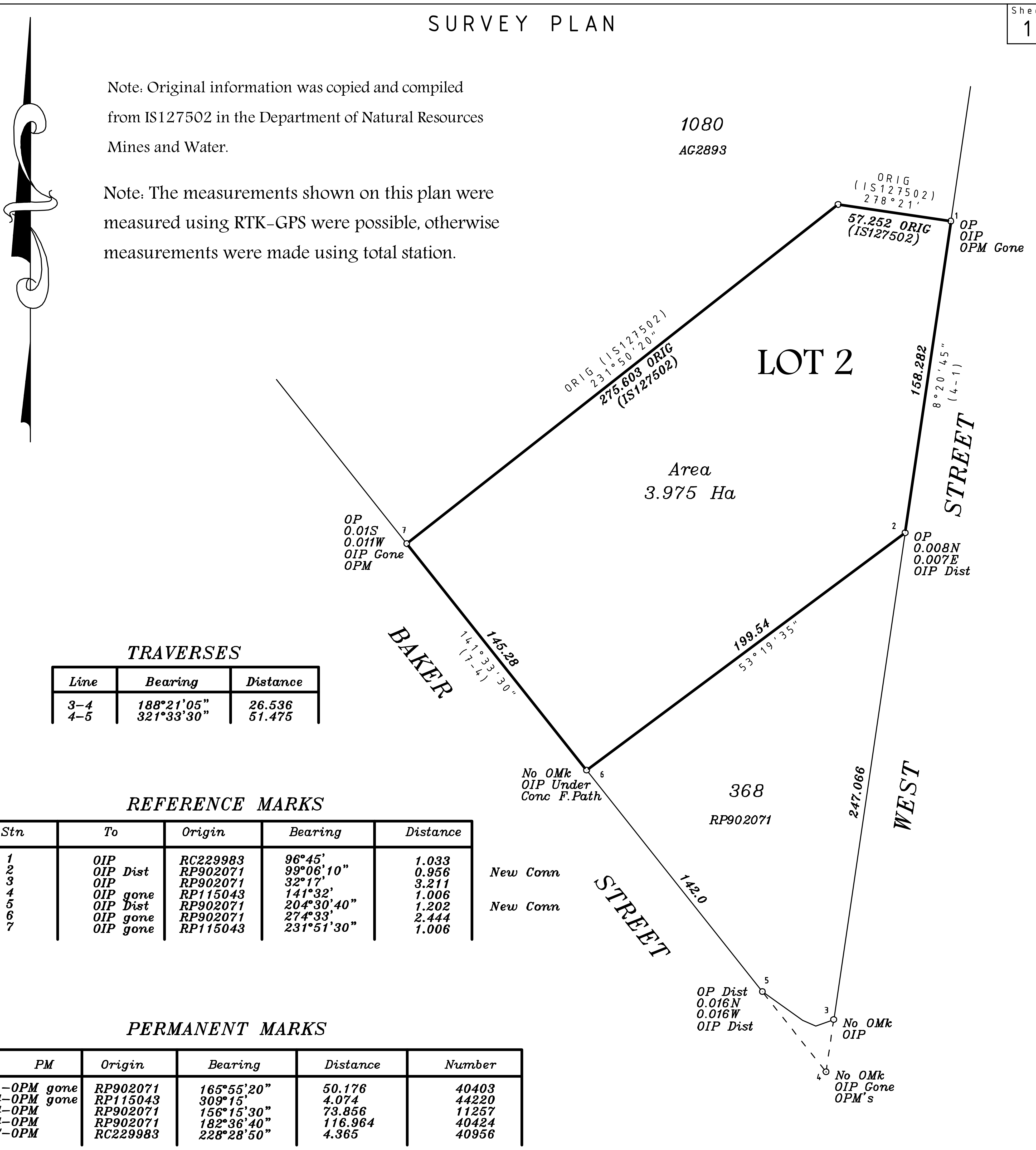
SURVEY PLAN

Note: Original information was copied and compiled from IS127502 in the Department of Natural Resources Mines and Water.

Note: The measurements shown on this plan were measured using RTK-GPS were possible, otherwise measurements were made using total station.



TRAVERSES

Line	Bearing	Distance
3–4	188°21'05"	26.536
4–5	321°33'30"	51.475

REFERENCE MARKS

Stn	To	Origin	Bearing	Distance	
1	OIP	RC229983	96°45'	1.033	
2	OIP Dist	RP902071	99°06'10"	0.956	New Conn
3	OIP	RP902071	32°17'	3.211	
4	OIP gone	RP115043	141°32'	1.006	
5	OIP Dist	RP902071	204°30'40"	1.202	New Conn
6	OIP gone	RP902071	274°33'	2.444	
7	OIP gone	RP115043	231°51'30"	1.006	

PERMANENT MARKS

PM	Origin	Bearing	Distance	Number
1–OPM gone	RP902071	165°55'20"	50.176	40403
4–OPM gone	RP115043	309°15'	4.074	44220
4–OPM	RP902071	156°15'30"	73.856	11257
4–OPM	RP902071	182°36'40"	116.964	40424
7–OPM	RC229983	228°28'50"	4.365	40956

Scale 1:2000

0 50 100 200 300 400

I, Andrew Jonathan Worrall hereby certify that the land comprised in this plan was surveyed by me personally and that the plan is accurate, that the said survey was performed with due concideration to accuracy and precision and that the said survey was completed on 13 September 2006.

A J Worrall

LOT 2

on Registered Plan RP115043

PARISH: DRAYTON COUNTY: AUBIGNY

Meridian: AMG Vide RP902071

F/N's:

Scale: 1:2000

Format: Standard

SP(Number)

Plan Status: