Thesis B:

Software Ingestion of LandXML Files

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School of Civil and Environmental Engineering
University of New South Wales Sydney

By: Ahmed El-Kiki

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ABSTRACT

Since 2012, the NSW Land and Property Information (LPI) has accepted survey plans lodged using the LandXML file format through a system called EPlan. These files can then be requested from the LPI and used to populate data into surveying software through ingestion (i.e. importing files). The LPI has constantly urged software vendors to develop their software so that bearings and distances stored in a LandXML file can be used for ingestion. This is important as it is used by surveyors to define lot boundaries.

The methodology used for this research involved analysing three different types of surveying software which are currently used by the industry in order to determine the LandXML ingestion approach used in each, and to identify any problems associated with that particular approach. By modifying certain aspects of a LandXML file and then ingesting it into the software to examine the subsequent effect on the plotted linework of a survey plan, it was possible to determine the importing method used by each software.

Each software plotted the linework using the stored coordinates provided by a LandXML file. After discovering that the coordinate system used in a LandXML file may vary, this method of plotting linework was found to be often unreliable. For example, the coordinate system can be grid or ground, which means that grid distances are sometimes produced for the geometry of the plotted linework, which in turn means that surveyors have to deal with ambiguous data since only ground distances are used in survey plans. Other problems associated with using coordinates were also discovered, as will be discussed throughout the course of this research.

In order for surveyors to use LandXML data reliably in software, it is imperative that bearings and distances are used for ingestion rather than coordinates.

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ORIGINALITY STATEMENT

‘I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, or substantial proportions of material which have been accepted for the award of any other degree or diploma at UNSW or any other educational institution, except where due acknowledgement is made in the thesis. Any contribution made to the research by others, with whom I have worked at UNSW or elsewhere, is explicitly acknowledged in the thesis. I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation and linguistic expression is acknowledged.’

Signed ……Ahmed El-Kiki……………

Date ………24/10/2017…………………

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"It is important to view coordinates as simply being derived information, not the base reference material itself"

Michael Elfick

1 Introduction

1.1 Objectives of Thesis

The NSW Land and Property Information (LPI) has constantly urged surveying software vendors to develop their programs so that bearings and distances stored in a LandXML file are used for ingestion rather than coordinates. However, it has not provided any significant reasons as to why coordinates should not be used, which is what this research will seek to investigate.

The first objective of this thesis is to determine how some of the present software used by the NSW surveying industry ingest LandXML files in cases where coordinates are used. To achieve this objective, each software will be tested by modifying certain aspects of a LandXML file, before ingesting it into each software, to analyse the effect this has on the plotted survey plan linework. The software to be tested include:

1. LXML4AC;
2. Stringer ePlan; and
3. 12d Model.

The next objective is to explore why the currently used ingestion method (i.e. using coordinates) is not preferable for use in the above-mentioned software. This will be done by outlining some problems discovered through the use of coordinates. The research will indicate why using bearings and distances is a more preferable and reliable method. It will not, however, look at this method in detail.

1.2 Outline of Thesis

- A literature review of the traditional methods of plan lodgment in NSW, description of the background of the LandXML format, and the use of this file format for a new plan lodgment system called EPlan;

- An outline of the traditional method of capturing data from a cadastral plan into surveying software, and how this relates to the ingestion of LandXML files;
- An introduction to the experimentation, which will cover certain aspects of LandXML such as: a description of some of its structure and how to interpret data from this file format;
- Experimentation to determine the ingestion method used by the previously mentioned surveying software;
- Experimentation demonstrating some problems in using coordinates for LandXML ingestion; and
- Conclusions of all experimentation conducted.

2 Literature Review – Part A

2.1 Creation and Lodgment of Survey Plans in NSW

2.1.1 Introduction

Whenever a new land parcel is defined in New South Wales, a survey plan (or land title plan) is created in order to reference the boundaries of that parcel to survey marks, monuments or other physical features, so that the boundaries can be re-established over time. The survey plan “creates the legal identity of the land” (LPI, n.d.-d), so it is important that electronic data files which store the plan digitally, create an exact representation of the original plan when viewed using any surveying software.

The LPI is the organisation in charge of land titling and registration of land title plans in NSW. Their primary roles are to determine accuracy of boundary definitions in lodged plans, create new land titles for parcels in the plans and maintain the land title register (Deal, 2017b). The plans are also used by a Government Office to maintain and preserve the cadastre of the state (LPI, n.d.-a). A cadastre, according to Williamson (1985), is a “complete and up-to-date official register or inventory of land parcels in any state or jurisdiction containing information about the parcels regarding ownership, valuation, location, area, land use and any buildings or structures thereon.”

Registered surveyors are the only persons entitled to define and/ or adjust land parcel boundaries in NSW. When re-establishing title boundaries, they employ a combination of experience, fact and law to ensure that the most appropriate decisions are made (Hamer, 1967).

When defining boundaries, for land titling purposes, various types of survey plans are drafted and then lodged for registration. According to Deal (n.d.), there are about 42 different types of plans lodged at the LPI. These include:

1. "Deposited plans: which most commonly depict a subdivision of a parcel of land;
2. Strata plans: which depict the subdivision of a parcel of land to allow multiple occupancy and separate ownership of individual units, e.g. home unit and town house developments; and
3. Community plans: which depict the development of planned communities of any type where the use of some land is shared." (LPI, n.d.-d)

There are currently two methods in which these survey plans are lodged for registration in NSW (Deal, 2017b):

1. In a hardcopy form, by lodging a plan at LPI Queens Square or TIFF (Tagged Image File Format) image through ePlan portal on LPI Online; and
2. In digital form through EPlan, which may also involve lodging a LandXML file of a plan with or without an accompanying TIFF image.

During survey plan lodgment, there are also other administrative documents that must be lodged alongside the plan. However, this is beyond the scope of this study and as such, is only mentioned briefly.

Note that throughout this thesis, 'ePlan' with a lowercase 'e', refers to the traditional method of survey plan lodgment, whereas 'EPlan' with a capitalised 'E', refers to the LandXML method of survey plan lodgment. In Sections 2.1.3 and 2.4, each of the lodgment methods will be discussed. The LPI are planning to replace the ePlan method with EPlan (Choi et al., 2017a), as will be highlighted throughout the course of this literature review.

Figure 2.1 shows the total number of each type of survey plan lodged in LandXML. Based on this figure, 921 LandXML files have been lodged as at 12th September 2017.

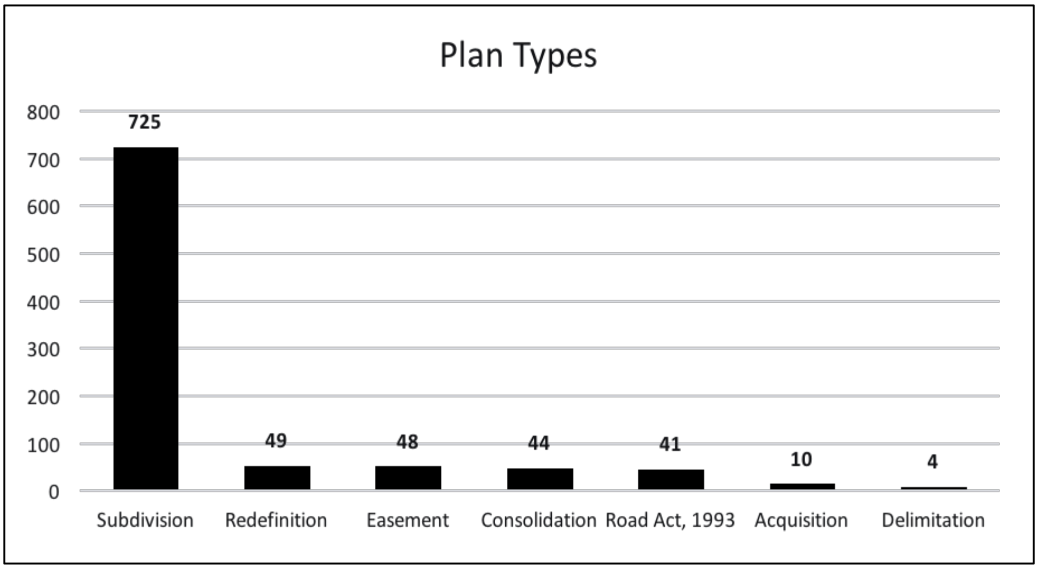


Figure 2.1: Total number of each plan type lodged in LandXML (Choi, 2017a)

2.1.2 Surveying Software Programs

There are many surveying software programs that can be used to draft the land title plans for lodgment. In NSW, some of the major software packages used are shown in Table 2.1. These software are also compatible with LandXML (Software Vendors, 2017, Wilcox et al., 2017) and are all classified as computer aided drafting (CAD) software, except for GeoCadastre (see Section 6.1.2).

Table 2.1: Surveying software used in NSW (LPI, n.d.-g)

Surveying Software
Landmark
Magnet Office
LXML4AC
Stringer ePlan
GeoCadastre
12d Model
LisCAD

Although the software programs shown in Table 2.1 are compatible with LandXML, there are still issues such as: loss of data, misrepresentation of survey layers and so forth, during the importing (or ingestion) and exporting of LandXML files (Deal, 2017b). Partenheimer (2005) states (regarding LandXML ingestion) that such issues occur depending on the software used, not because of the LandXML format itself. The survey data will be represented differently according to a surveying software's level of compatibility with LandXML. This research will focus on one problem in importing LandXML files.

Wady (2009) states that one of the purposes of LandXML was to enable digital data to be exchanged efficiently between different software environments without data loss. For this to be achieved, it is necessary that software vendors address the current problems within their software and update them to ensure full compatibility with LandXML.

Part B of this literature review will provide more details about the use of LandXML in software which will then lead on to the research completed.

2.1.3 Traditional Methods of Survey Plan Lodgment

Before introducing LandXML and outlining the need for this file format, it is necessary to firstly understand the traditional methods used for the lodgment of survey plans in NSW.

The two methods used to lodge survey plans at the LPI include (LPI, 2017a):

1. Submitting a hardcopy plan in person at the Plan Lodgment Counter, LPI Queens Square Sydney; and
2. Electronically (TIFF) through the ePlan portal (on LPI Online) website. Only a registered surveyor can lodge a survey plan using this method.

To successfully lodge a survey plan at the LPI for registration, there are various requirements detailed by LPI (2017a) that must be satisfied. This includes producing the appropriate documentation forms such as administration sheets.

Hobson (2005a) and LPI (2002) state that during survey plan lodgment, a ‘geometry file’ containing all the bearings, distances, lot areas and so forth, found in a cadastral plan, is also needed. However, this is contrary to what is detailed by LPI (2017a) and confirmed to be an outdated requirement by Deal (2017a).

After lodging a land title plan for registration, it is thoroughly examined to ensure accuracy and completeness for registration purposes (LPI, 2017a). Choi (2017b) states that the examination process is performed completely manually. LPI (n.d.-e) provides further details about survey plan examination by stating that “a plan is examined by LPI to ensure that legal boundaries have been established and correspond with the boundaries as marked on the ground. The plan examination process ensures existing interests are preserved from one generation of title to the next.”

The examination procedure involves checking prerequisites such as: evidence used to define boundaries (e.g. marks, monuments and occupations), plan drafting standard (e.g. linework, scale, lot numbering), comparing bearings and distances with previous plans and so forth (Deal, n.d.). This process can be extremely time-consuming especially if large survey plans consisting of numerous proposed lots, such as in a subdivision plan, need to be examined.

If a plan passes the examination process without requisitions, it is registered and stored as a TIFF image. A requisition is a letter raised against a plan lodgment outlining issues which need to be addressed before a plan can be further examined and eventually registered (see Section 2.2.2.1). Hobson (2005a) states that a plan which is lodged in person (i.e. hardcopy) is scanned before being stored as a TIFF file.

Overall, the traditional methods of plan lodgment ultimately rely on storing a survey plan as a TIFF file. The following section will introduce the LandXML file format which will eventually replace TIFF for plan lodgment.

2.2 LandXML

2.2.1 Introduction

LandXML (Land eXtensible Mark-up Language) is a digital data exchange format which enables survey and engineering data to be created, stored and exchanged between users. It is a text based format (ASCII) which is designed in the XML language (Nixon, 2017) and it is primarily used in the land development and transportation industries (Isokangas et al., 2009, Landxml.org, n.d.).

To view an example of a LandXML file, refer to Appendix A. This file is a digital representation of the survey plan shown in Appendix B and contains all the information required to recreate this plan using the 'Rendering Service' (see Section 2.4.3) or through software ingestion (see Section 3.3.3). Section 4.2 provides details regarding the LandXML file structure and how to interpret some of its code, which is relevant to this research.

In NSW, LandXML is now being used to lodge land title plans digitally for registration through the LPI Online (EPlan) portal (which will be discussed in Section 2.4).

Other jurisdictions in Australia have also developed similar plan lodgment methods which are based on LandXML. For example, Victoria has developed an online 'SPEAR' service which enables survey plans to be submitted for registration and access to the Victorian digital cadastre (this is similar to the NSW DCDB – see Section 2.5.2). It also has similar services to the EPlan 'Validation' and 'Rendering' services described in Sections 2.4.2 and 2.4.3 respectively (Victorian Government, 2015, Victorian Government, 2014). This thesis will focus exclusively on the NSW EPlan plan lodgment system as it is relevant to the present study.

Before discussing this lodgment system however, it is necessary to review some of the problems associated with the traditional plan lodgment system, as well as their plans (see Section 2.1.3), to outline the need for a digital system.

2.2.2 The Need for a LandXML Lodgment System

2.2.2.1 Delays Due to Requisitions

Based on LPI's Key Performance Indicator (KPI), which is a length of time the LPI aims not to exceed for plan examination, it takes about 10-12 working days for a plan to be either registered or requisitioned after being lodged at the LPI (Choi et al., 2017b). The Registrar General's Directions state that a requisition is "a letter raised against a lodgment case setting out issues that need to be addressed by the lodging party before the case can proceed for further examination and registration" (LPI, n.d.-f). LPI (2017a) also states that requisitions "provide details of LPI requirements to put the plan in order".

If a plan is requisitioned, the surveyor is notified that certain aspects of the plan lodgment need to be reviewed and adjusted. The surveyor may then need another two weeks to re-lodge the plan for examination, after which it could be re-requisitioned if certain aspects of the plan have not yet been corrected. This process may need to be repeated, and as such, requisitions may result in costly delays to all stakeholders involved, especially if the survey plan is required for conveyancing purposes.

NSW Department of Lands (2007) states that, "a high proportion of plans [are] being requisitioned prior to registration". Choi et al. (2017b) confirms this by stating that about 75% of all survey plans lodged at the LPI are requisitioned. This large percentage of requisitions could be minimised by validating the plan prior to lodgment using LPI's 'Validation Service' (see Section 2.4.2) if it were in LandXML format (LPI, 2016, Olfat et al., 2016), therefore minimising the occurrence of costly delays.

2.2.2.2 Survey Plan Lodged in an 'Unintelligent' Form

Currently, survey plans are lodged at the LPI in either TIFF or hardcopy format and thus, cannot be validated electronically (NSW Department of Lands, 2007). Because they are not in a digital form, a plan examiner cannot fully 'interrogate' or validate the plans. The examination procedures rely primarily on visual inspection checks and comparisons (Deal, n.d.). As such, many errors can slip unnoticed in the plan examination process (Choi, 2017b).

In addition, this examination process is performed completely manually as mentioned in Section 2.1.3 (Choi, 2017b), and can therefore be very time-consuming.

By lodging a plan in LandXML format, it could instantly be checked against a multitude of criteria using the 'Validation Service' and then checked semi-automatically by the LPI, using a software called 'PlanTest' during the examination process (see Sections 2.4.2 and 2.4.4). This will minimise the occurrence of errors in survey plans and the time required for plan examination.

2.2.2.3 Delays Due to 'Double Handling'

Double handling is another significant factor which could potentially cause delays during the registration of survey plans (Choi et al., 2017b). This is linked to the previously discussed issue regarding requisitions (see Section 2.2.2.1).

After a plan has been lodged, it takes time for a plan examiner to complete the examination process of the cadastral plan. A notice of registration or requisition will then be sent to the lodging agent and/ or the surveyor (LPI, n.d.-e).

If a requisition is received, the surveyor in charge of the land title plan will require some time to correct the issue/s before re-lodgment. This is because more field observations may be needed, and issues involving: plan drafting, submission of relevant administration documents and so forth, may need to be corrected. After re-lodging the survey plan, it will then take more time for it to be re-examined (Deal, n.d.).

The delay caused due to double handling of a survey plan can be greatly reduced if LandXML is used, because requisitions will be minimised and plan examination times will be reduced, as mentioned in Sections 2.2.2.1 and 2.2.2.2.

2.2.2.4 Prepopulating Cadastral Plan Data

When starting a new survey, some surveyors manually capture a significant amount of the cadastral information (e.g. linework such as boundary lines) shown in previous and abutting land title plans of the subject parcel/s to be surveyed (Deal, 2017c). This is a very time-consuming and laborious process. Note that this captured data can be used for many different applications such as searching for survey marks (see Section 3.2).

If these plans were stored digitally in LandXML, the data could be directly ingested (i.e. imported) into a surveying software and the data prepopulated automatically. This will enable surveys and hence survey plans, to be completed and lodged quickly, thus enhancing the performance and efficiency of surveyors (Victorian Government, 2015).

LPI (2016) states that LandXML is supported by many surveying software used in NSW. Despite this, there are still problems related to the ingestion of LandXML files into software and this will form the focus of this research.

2.2.3 Challenges with Transitioning to a LandXML Lodgment System

Although there are numerous benefits of using LandXML for survey plan lodgment (as discussed in the previous section), there are still various challenges which need to be resolved in order to promote its uptake by surveyors. There are just over 900 registered surveyors in NSW (BOSSI, n.d.), but only about 240 of them are trained at using EPlan (Choi et al., 2017b).

The challenges which have affected the uptake of LandXML by NSW surveyors include (adapted from Olfat et al., 2016, Choi, 2017c, Colbert, 2015, Deal, 2017b, Wilcox et al., 2017):

1. The time-consuming nature of a business change (transitioning from TIFF to LandXML for plan lodgment);

2. Extensive training time is required for a surveyor to learn all the relevant aspects of LandXML, how to create these files for lodgment and so forth (see Section 3.2);
3. Surveyors using older software versions, will need to purchase costly licences to access newer versions which have LandXML functions. This will require them to learn how to use new features in the updated software which is also time-consuming;
4. Some surveying software are still not compatible with LandXML and thus surveyors will need to change to a different software package to use the LandXML features, which could be a costly and time-consuming business change;
5. Some of the vendors of software which support LandXML are very slow to introduce necessary changes to the software, making it unsuitable for their users to create valid LandXML plans;
6. The rendered plan using the 'Rendering Service', which is produced by converting a LandXML file into a plan (see Section 2.4.3), is unsuitable due to quality issues such as: text collision, poor diagramming, missing data and so forth. It also produces a plan which cannot be interpreted easily compared to a plan lodged in TIFF format. For example, distances and bearings from cadastral reference marks to corners are shown on a sheet separate to the plan, which is inconvenient to surveyors. Appendices B and C shows an original TIFF survey plan and rendered plan respectively;
7. Legal issues regarding distribution of LandXML data have not yet been accounted for; and
8. The LPI has not yet developed a proper LandXML data delivery system. Currently, users must contact the LPI each time access to lodged LandXML files is required, which is inconvenient to surveyors.

2.2.4 Conclusion

Although there are some challenges with transitioning to LandXML for plan lodgment, these are clearly outweighed by the numerous benefits. Because of this, the LPI has intended to eventually replace the traditional methods of survey plan lodgment (i.e. TIFF and hardcopy) with EPlan. All cadastral surveyors in NSW will soon be forced to adopt LandXML for plan lodgment (Choi et al., 2017a).

Before discussing this lodgment method however, it is necessary to review some of the background of LandXML to explain why this file format was initially chosen to be used in NSW, as well as how this format can be used to achieve data interoperability across surveying software.

2.3 Background of LandXML

2.3.1 Introduction

There are various spatial organisations relevant to LandXML and its implementation in NSW. The relevant organisations will be described and an outlook on the future of spatial interoperability using LandXML will be discussed. This will then be related to the NSW LandXML schema, which is the foundation of all LandXML files referred to in this research.

2.3.2 ICSM and eWG

The Intergovernmental Committee on Surveying and Mapping (ICSM) was established in 1988 and one of its primary roles is to support the "development and implementation of national and international standards for surveying" (ICSM, n.d.-b). ICSM is a standing committee of ANZLIC – the Spatial Information Council (ICSM, n.d.-a), which is the "peak intergovernmental organisation providing leadership in the collection, management and use of spatial information in Australia and New Zealand" (ANZLIC, n.d.).

Within the ICSM, there exists an ePlan Working Group (eWG). The role of this working group is to standardise the national format used for the exchange of digital cadastral data between the surveying industry and the government (ICSM, 2015, Olfat et al., 2017). Wady (2009) summarises the relationship between the different committees and the eWG, as shown in Figure 2.2.

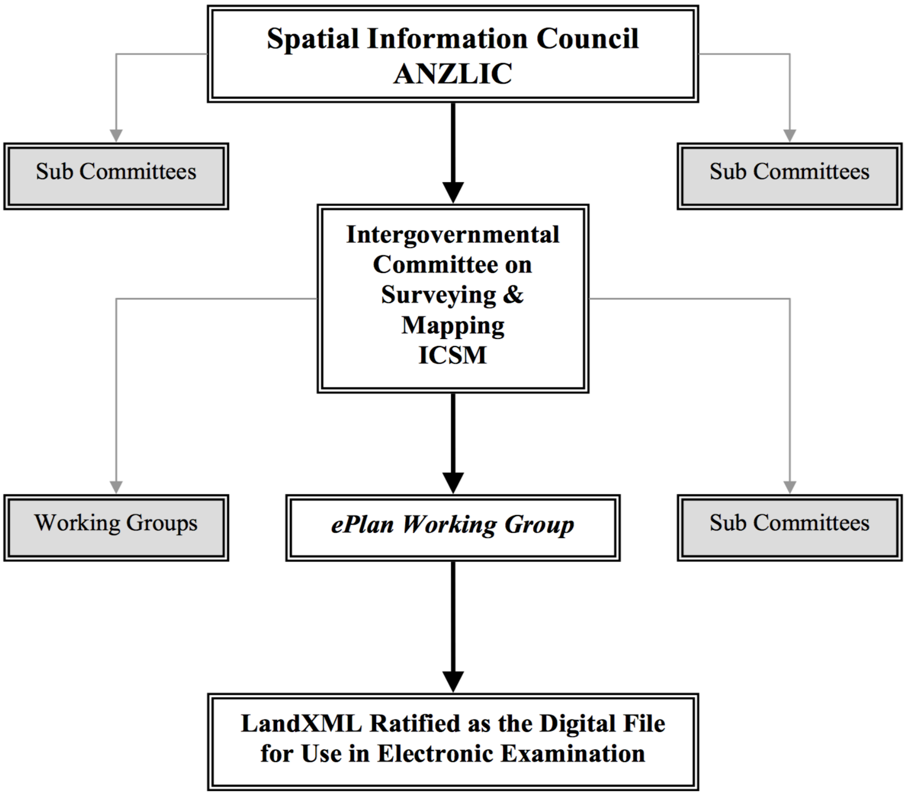


Figure 2.2: Relationship between ANZLIC, ICSM and the eWG (Wady, 2009)

In 2010, the eWG ratified the LandXML format as the Australasian standard for the digital lodgment of land title plans (Choi and Deal, 2017, Department of Lands, 2007, LPI, 2016, LPI, n.d.-c). Hobson (2005a) states that one of the reasons which has affected nationwide implementation of a digital system in Australia is that each state has different requirements and regulations regarding land title boundaries. The establishment of the eWG, within the ICSM, is indicative of an attempt to address this issue.

In 2009, the eWG developed an EPlan data model which incorporates the specific elements for each state and jurisdiction in Australia (Department of Lands, 2008). It also accommodates the different land title regulations of each jurisdiction. For example, in NSW, there are certain jurisdictional rules and regulations regarding cadastral plans which are different to other jurisdictions.

Some other abilities of the EPlan model include (ICSM, 2015):

- “Handle both the spatial and legal functions of the plan;
- Update cadastral mapping systems, survey indexes and searching tools [such as the NSW DCDB – see Section 2.5.2];
- Update survey control data sets;
- Update street address data sets; and
- Allow for generic and jurisdictional specific elements to be added.”

The LPI in NSW is continually participating in the eWG to facilitate the development and improvement of the EPlan model (Department of Lands, 2008). It has selectively implemented the EPlan model to suit NSW jurisdictional requirements as defined by the NSW LandXML Schema (see Section 2.3.6).

The collaboration of the previously mentioned organisations has brought about the new method of plan lodgment in NSW i.e. EPlan (see Section 2.4).

2.3.3 OGC

The Open Geospatial Consortium (OGC) is an international spatial organisation “committed to making quality open standards for the global geospatial community” (OGC, n.d.).

According to Scarponcini (2013), the OGC thoroughly reviewed LandXML and concluded that a new standard was needed. They claimed the schema had too many problems which could not be easily corrected. These include (Isokangas et al., 2009, Scarponcini, 2013):

- LandXML was not recognised and supported by a standards organisation such as the ISO – International Organisation for Standardisation;
- The LandXML format does not meet any of the OGC standards;
- LandXML is currently being developed by ‘self-appointed’ technologists with no coordinating body; and
- There are too many inconsistencies and issues with the LandXML schema.

The OGC has therefore developed a new standard called 'InfraGML' which has similar functions to LandXML (Scarponcini, 2013).

2.3.4 Future of Interoperability

Interoperability is defined as "the ability to freely and accurately exchange digital information between different software…" (Isokangas et al., 2009).

Scarponcini (2013) suggests, based on OGC's review of LandXML, that the LandXML schema should be charataterised as a "negotiable template rather than an interoperable standard", since the content within the schema can be modified to suit any user. This contradicts the original intent of developing LandXML. Isokangas et al. (2009) claims that LandXML was developed to achieve interoperability between the various software used by the land development and surveying industries.

Without the full cooperation of internationally recognised spatial organisations, true data interoperability will not be achieved. Crews (2003) confirms this by stating that interoperability is only possible if there are "…open cooperative efforts from members throughout the industry". OGC's rejection of LandXML highlights their lack of cooperation and collaboration with ICSM. This will negatively impact the future of spatially shared data.

Even though there are several issues with the LandXML schema as concluded by Scarponcini (2013), the eWG will continue to implement and develop it as part of the EPlan data model (see Section 2.3.2).

According to Olfat (2015) and Department of Lands (2007), the eWG has actually considered the infraGML format, but concluded that it currently does not suit the EPlan model since it does not meet certain requirements, e.g. supporting all the details for a survey plan. Other issues highlighted include (Olfat, 2015):

- Much money, time and effort has already been spent developing and implementing the EPlan model which is based on LandXML;

- Many surveying software used in Australia are currently in the process, or have already been developed, to support LandXML; and
- Many surveying firms have already changed their business methods to adopt the EPlan (LandXML) method of plan lodgment (see Section 2.4).

However, in an attempt to achieve interoperability, Olfat (2015) states that the eWG is willing to cooperate with the OGC in developing the infraGML model as long as certain requirements are satisfied. Some of these include (Olfat, 2015):

- The EPlan model must be fully covered by infraGML; and
- Future changes to the EPlan model must be reflected in the infraGML model.

2.3.5 Interoperability in NSW

Achieving interoperability at an international level seems quite difficult to achieve because each jurisdiction, let alone country, has a unique LandXML schema (see following section) which suits their unique rules and regulations regarding survey plans. For example, a software could be compatible with NSW LandXML files, but not Victorian files because the schemas in each of these states are different.

Nonetheless, it is hoped that by using LandXML, interoperability would be achieved across surveying software used in NSW. This will allow for these files to be interchanged between different software and ingested, which is useful for various applications (see Section 3.2). For this to be achieved however, it is important that software vendors develop the LandXML functions in their programs to suit the NSW LandXML schema.

2.3.6 NSW LandXML Schema

A LandXML schema specifies the structural requirements of a LandXML file (Hobson, 2005b). It “defines the data types that can be used in a LandXML file, including the allowed and required attributes and elements” (Hobson, 2005b). See Section 4.2.1 for more information about ‘attributes’ and ‘elements’.

The LPI has developed a schema to specifically meet NSW requirements called the NSW LandXML schema. Note that all LandXML files referred to in this research will be based on this schema. The features contained in this schema are outlined in the *NSW LandXML Recipe* document which will be partly described in Section 4.2.

For a LandXML file to be lodged successfully through the EPlan system, it must fulfil all of the NSW LandXML schema requirements. To ensure this occurs, there are various stages during an EPlan lodgment in which a LandXML file can be thoroughly checked, as will be discussed in the following section.

2.4 EPlan Method of Survey Plan Lodgment

2.4.1 Introduction

The EPlan method of plan lodgment was introduced by the LPI in 2012 (Choi, 2017c). It involves lodging a LandXML file for a plan as well as any associated administrative documents (in TIFF format). Currently, the LPI also require for the original TIFF plan (which is normally created alongside a LandXML file) to be lodged (see Section 2.4.3). This method of plan lodgment will eventually replace the traditional methods which were described in Section 2.1.3 (Choi et al., 2017a).

The LPI has developed tools which allow surveyors to validate or render LandXML files prior to lodgment for registration. These tools are available at the LPI Online (EPlan) portal but are restricted to surveyors who have the required level of user access (LPI, n.d.-b). They include:

1. Validation Service; and
2. Rendering Service.

After a LandXML file has been checked thoroughly using these tools, it can be lodged to the LPI for examination where a software called 'PlanTest' is used to perform further checks.

The following sections will describe each of these processes in greater depth.

2.4.2 Validation Service

The 'Validation Service', shown in Figure 2.3, enables LandXML files to be reviewed automatically prior to lodgment, by checking for "over 100 business and surveying rules and regulations allowing issues to be identified and addressed before the plan is lodged with LPI" (LPI, 2016).

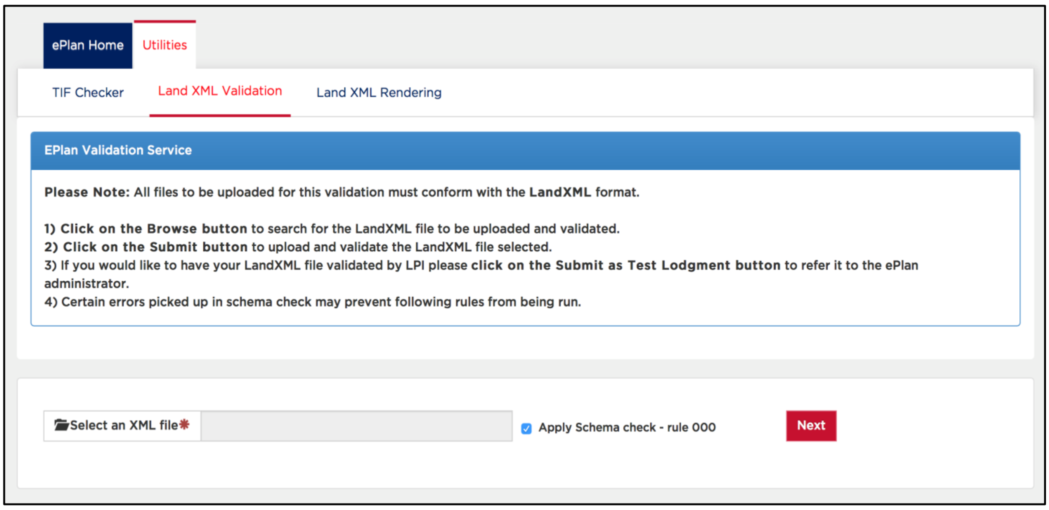


Figure 2.3: LandXML Validation Service available at LPI Online

This service will significantly reduce the amount of requisitions received by a surveyor which delay registration (see Section 2.2.2.1) (LPI, n.d.-b). The Validation Service also incorporates various mathematical checks to ensure the accuracy of a LandXML file (and hence a survey plan), some of which will be mentioned in Section 5.2.3.

According to Choi et al. (2017b), the Validation Service checks only a subset of all the existing plan examination criteria. During survey plan examination, the LPI conducts various other checks, including checks of: boundary definitions, administration files, as well as other plan lodgment requirements. This is completed using a software called 'PlanTest' which is described in Section 2.4.4 (Choi et al., 2017b).

The Validation Service can be used by surveyors as frequently as needed and at no cost (LPI, 2016). Once a LandXML file has been validated successfully, it can then be checked by the 'Rendering Service' which is described in the following section.

2.4.3 Rendering Service

The 'Rendering Service', shown in Figure 2.4, enables LandXML files to be rendered onto an approved LPI plan form (i.e. it produces a TIFF plan from a LandXML file).

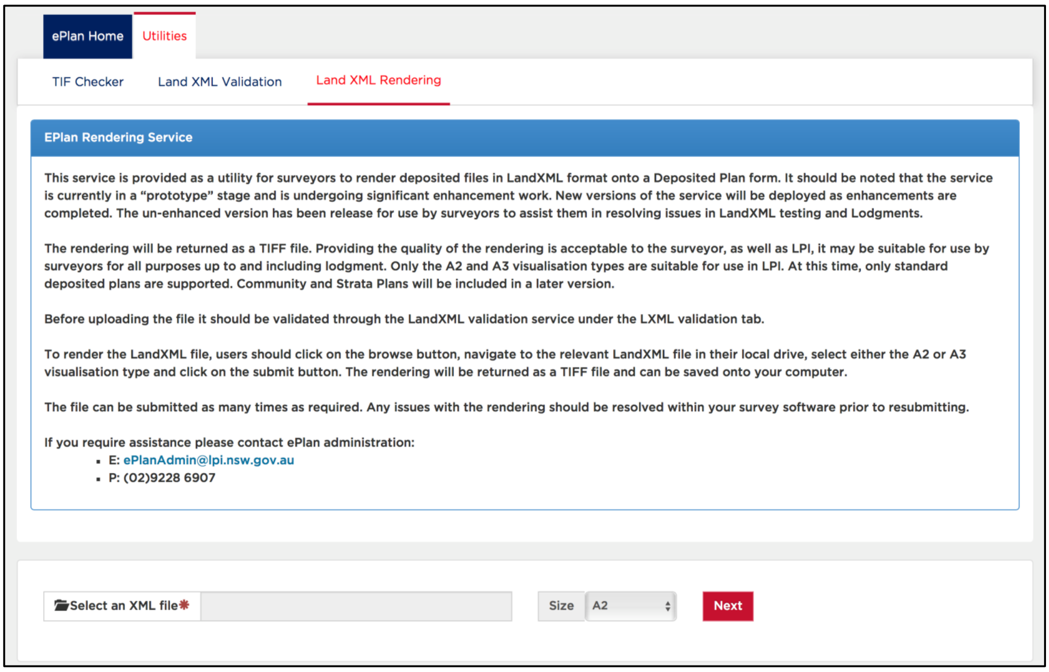


Figure 2.4: LandXML Rendering Service available at LPI Online

The idea behind the Rendering Service is that the stored data in a LandXML file can be converted or 'rendered' back to form a TIFF file, thus TIFF files will no longer need to be lodged. This concept is simplified in Figure 2.5.

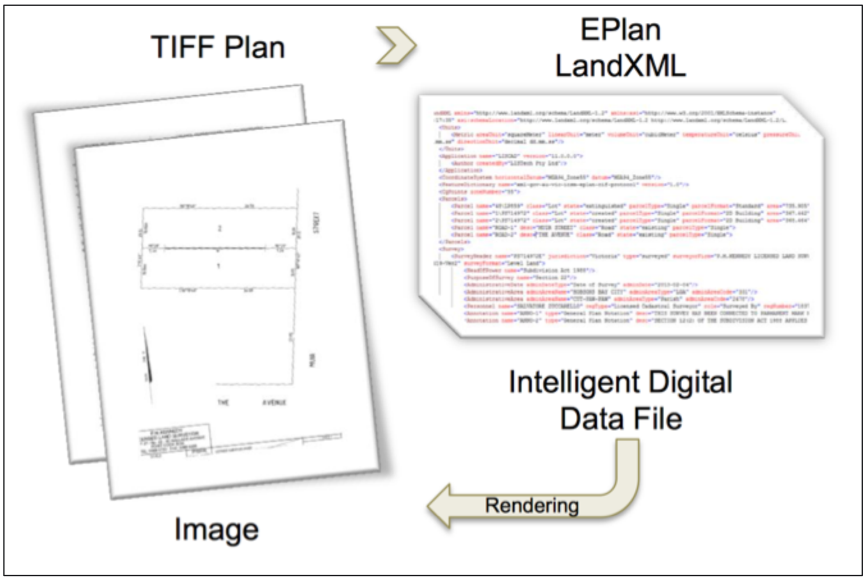


Figure 2.5: Summary of EPlan concept (adapted from Shojaei and Olfat, 2015)

However, the rendered TIFF plan does not yet replicate the original TIFF survey plan drafted by a surveyor. This is demonstrated in Appendices B and C, which show an original TIFF survey plan and rendered plan respectively. This is another significant issue which is yet to be resolved and is beyond the scope of this research.

At the present time, if a surveyor is satisfied with the rendering quality of a LandXML file, it is lodged along with the administration files to the LPI for registration (Choi, 2017c, Choi and Deal, 2017). On the other hand, if a surveyor is not satisfied with the rendering, the original TIFF file of the drafted plan must also be lodged. Note that if a rendered plan is not accepted by a surveyor, the LandXML file may be adjusted to potentially improve the rendering quality before re-lodgment. In the plan examination process, the LPI will also check the rendering quality of a LandXML file and may potentially reject it if certain standards are not met (LPI, n.d.-b).

According to Wilcox et al. (2017), most surveyors are currently unsatisfied with the rendering quality produced by the Rendering Service. This is because the service is currently in a ‘prototype’ stage and requires many more improvements before becoming fully functional, as stated by LPI (2016). Once the Rendering

Service is fully operational, a surveyor will no longer be required to submit a TIFF file of a survey plan in most cases (Choi and Deal, 2017, LPI, n.d.-b).

2.4.4 PlanTest

After a LandXML file has been checked thoroughly using the Validation and Rendering Services, it can then be lodged for LPI examination through the LPI Online (EPlan) portal.

Once a LandXML file has been lodged, the LPI use a software called 'PlanTest' to perform the examination procedures (see Figure 2.6).

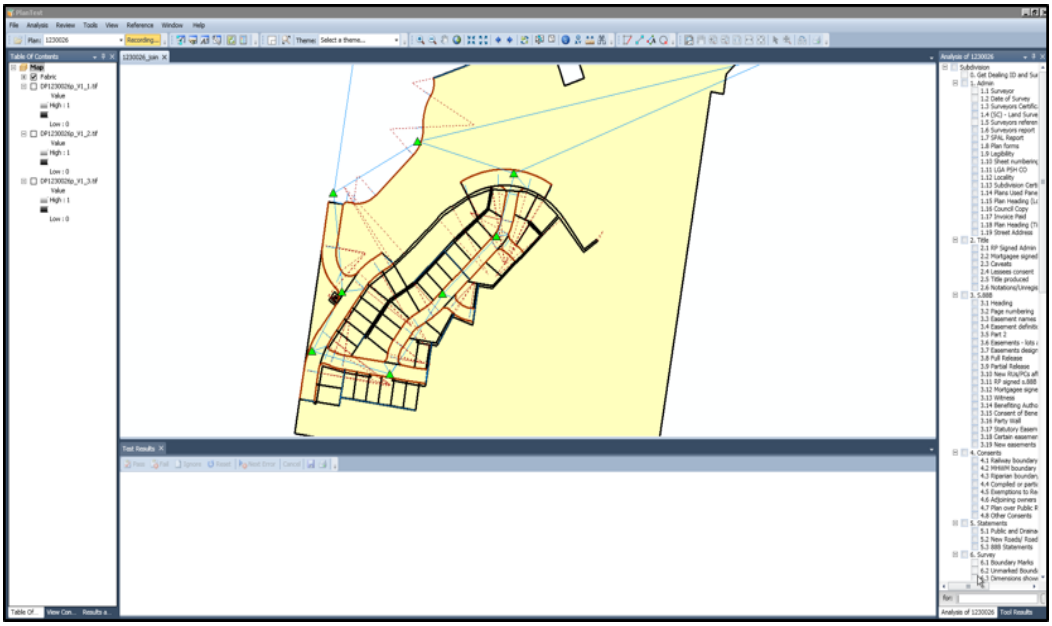


Figure 2.6: Screen capture of PlanTest

PlanTest enables an LPI plan examiner to check the survey work within the surrounding 'fabric'. This 'fabric' refers to the data collected from abutting and previous survey plans (such as cadastral reference marks, boundaries and so forth) of the lot/s which the newly lodged survey plan is defining, e.g. subdividing or consolidating (Choi et al., 2017b).

In addition, PlanTest automates many of the checks which are normally performed manually when a plan is lodged using traditional methods, e.g.

bearing and distance checks of each line (see Section 2.1.3). The examination process also involves rechecking all the criteria which have been checked by the Validation Service (see Section 2.4.2), as well as performing various other administrative checks of a survey plan.

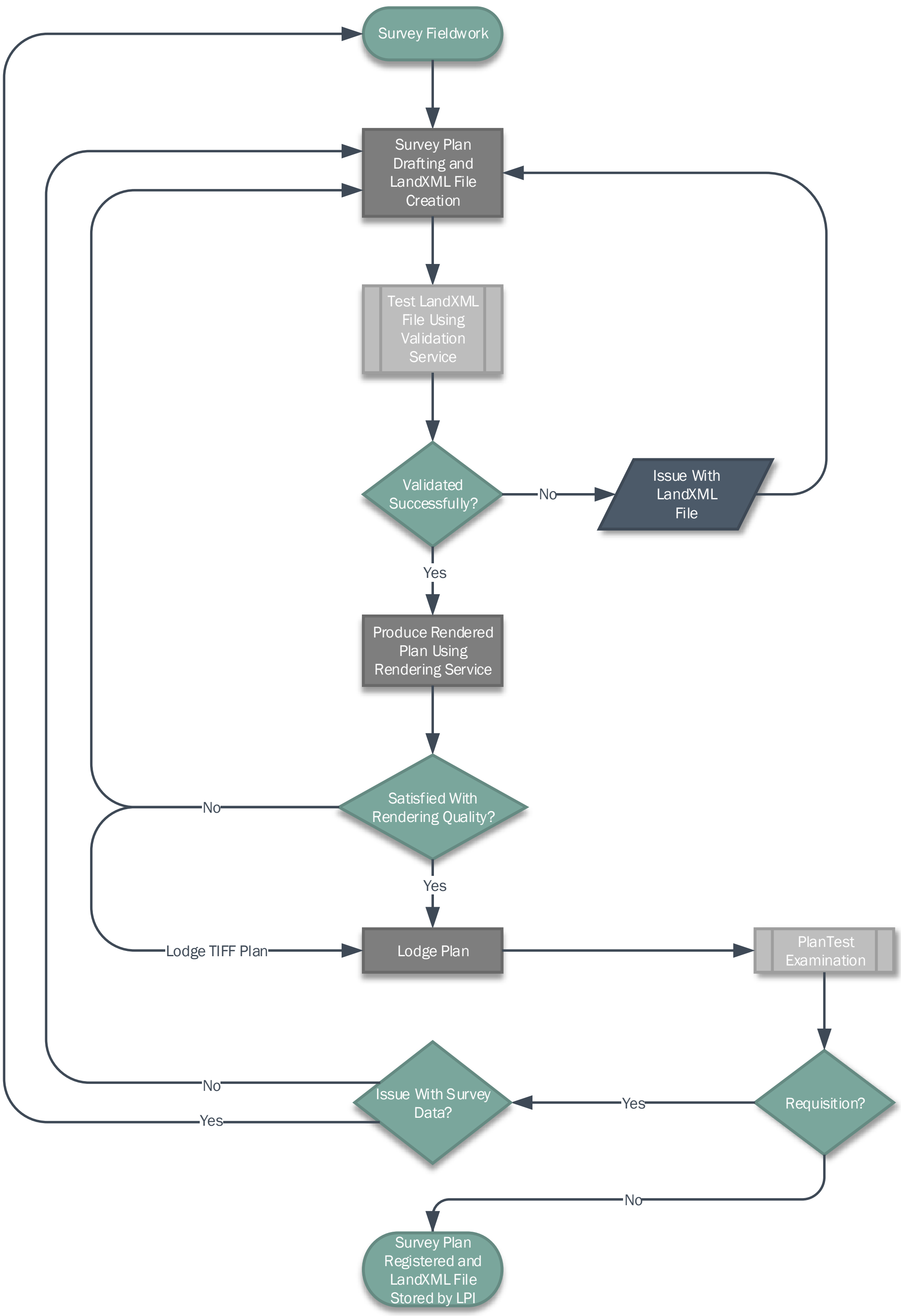
The benefit of using PlanTest for plan examination, compared to traditional examination methods, is that most errors will be detected (see Section 2.2.2.2). It also enables survey plans to be examined more efficiently since most of the checks are performed automatically (Choi et al., 2017b). An example of a check which is still performed manually is ensuring the administration sheets are in order, as they will still be stored in TIFF format (as mentioned in Section 2.4.1) and thus cannot be checked electronically (Choi, 2017c, Choi and Deal, 2017).

2.4.5 Conclusion

Once a LandXML file has passed the PlanTest examination without requisitions, it is stored in the LPI's database (Choi, 2017c). There are various end users who request this data for use in many different applications, as will be discussed in Section 2.5.

A summary of all the steps required for an EPlan lodgment is shown in the following section.

2.4.6 Summary of EPlan Method of Plan Lodgment



2.5 Cadastral Plan Use After Being Stored by LPI

2.5.1 Introduction

There are many end users of survey plans stored by the LPI. Traditionally, end users have been required to data capture the information from the TIFF plan relevant to them (Deal, 2017c). With LandXML files (which store plans digitally), end users are able to easily develop systems that can filter out the relevant plan data that is of interest to them automatically, and to populate their databases and systems. The end users of LandXML plan data include Public Authority bodies, NSW DCDB and Surveyors (Deal, 2017c).

Three of the main Public Authority bodies that can benefit from the use of LandXML data stored by the LPI are (Deal, 2017c):

1. Councils;
2. Water Authorities (e.g. Sydney Water); and
3. Valuer General.

These users extract all of the relevant plan attribute information stored in a LandXML file that is required for their particular needs. For example, the Valuer General would extract the relevant parcel attribute information, including: lot and plan number, dimensions, area and address of each new lot. Previously this information was captured by a team of data capture staff, making it prone to human error (Deal, 2017c). The concept of 'attributes' will be elaborated on in Section 4.2.1.

The two other most relevant uses for LandXML files to this research include:

1. Updating the NSW DCDB; and
2. Software ingestion of LandXML files by surveyors when starting a new survey.

The following section will discuss how LandXML files are used to update the NSW DCDB. Note that this thesis will focus on the use of LandXML files for software ingestion. As this topic is very broad and forms the focus of this research, it will be discussed separately in Part B of the literature review.

2.5.2 Updating the NSW DCDB

The NSW Digital Cadastral Database (DCDB) is a digital representation of the NSW cadastral map which was formed by the digitisation of cadastral plans (Terry, 2014).

The DCDB can be used to derive property boundaries and lots shown within deposited plans (Spatial Services NSW, n.d.). According to Harvey (2017) and Terry (2014), the DCDB was originally developed to obtain a graphically accurate cadastral map of NSW and is not yet survey accurate as a result. The DCDB, however, is constantly being upgraded to improve its accuracy (LPI, 2013).

With the advent of the EPlan method of plan lodgment in NSW, survey plans lodged in LandXML are ingested into the DCDB to update it once registered (Masson, 2017). This is slowly improving the accuracy of the DCDB. However, Terry (2014) suggests that achieving a survey accurate DCDB will take very long. Choi (2017c) confirms this by stating that a survey accurate DCDB of the entire state of NSW will not be possible as accuracy varies depending on the region. For example, accuracy levels in rural areas will remain much lower than in urban areas due to the infrequency of surveys in these areas.

The NSW Government is currently in the process of back-capturing old survey plans to update the DCDB. This involves manually converting existing hardcopy or TIFF survey plans into LandXML before ingesting them into the DCDB, which is a very laborious and time-consuming process (Choi et al., 2017b). If surveyors begin lodging their plans digitally through EPlan, it will eliminate the need for back-capturing of plans in the future.

3 Literature Review – Part B

3.1 Introduction

Part A of the literature review discussed the traditional methods of survey plan lodgment in NSW. It then introduced the LandXML format and outlined the new EPlan method of plan lodgment. This part of the literature review will shed greater light on the software aspect of LandXML relevant to this research.

3.2 LandXML Creation and its Use by Surveyors

There are many surveying software which can be used to create LandXML files for an EPlan lodgment (LPI, 2016). Examples of such software were previously mentioned in Table 2.1. Each software employs a unique set of procedures when creating these files. Colbert (2015) states, based on his study of two of the software methods, that although the user interface of each software is quite different, the structure to produce a LandXML file is essentially the same. Figure 3.1 shows the total number of LandXML files created by each of the different types of surveying software (accurate as at 12th September 2017).

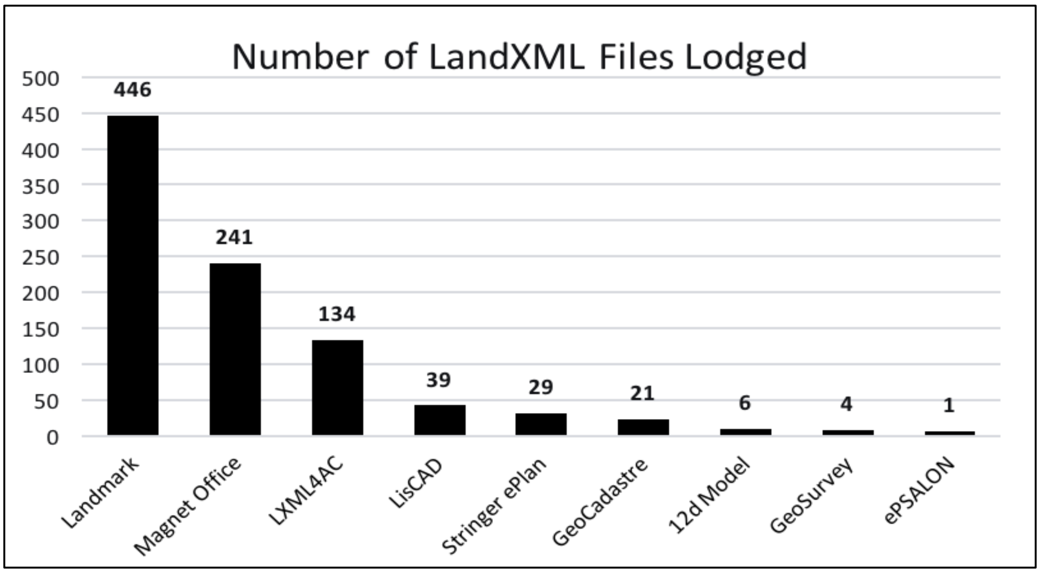


Figure 3.1: Number of LandXML files created by each software (Choi, 2017a)

There are training courses available to teach surveyors how to create and export LandXML files from some of the software, e.g. courses are available for Stringer ePlan and Magnet Office (Banks, 2017, Choi et al., 2017a). Once a LandXML file has been exported, it is lodged for LPI examination and if there are no requisitions, it is stored in the LPI's database (see Section 2.4 for more details). Based on Figure 3.1, there have been about 921 LandXML files lodged to the LPI as at 12th September 2017.

Any cadastral surveyor can then request to receive that lodged LandXML file to use for ingestion into their software when starting a new survey, as mentioned in Section 2.5.1. According to Choi et al. (2017a) and Coggins (2017), there is a variety of applications for which this data can be used, including: assisting in creating new survey plans for LPI lodgment, creating a draft subdivision plan for a client or searching for survey marks. The concept of LandXML ingestion into software will be elaborated further in the following section.

3.3 Prepopulating Cadastral Plan Data

3.3.1 Introduction

Since the LPI is planning to replace the traditional methods of survey plan lodgment (i.e. TIFF and hardcopy) with EPlan, all cadastral surveyors in NSW will eventually be forced to adopt LandXML for plan lodgment (Choi et al., 2017a). A key benefit of transitioning to EPlan is that all plans will ultimately be stored in LandXML, and thus, survey plans will no longer have to be manually captured, as mentioned in Section 2.2.2.4. The LandXML files can simply be ingested into any compatible software to populate the plan data automatically.

This research will focus on one problem found with ingesting LandXML files into some software. In order to understand how this problem could arise, it is necessary to review the traditional method of capturing cadastral plans then relate this to the ingestion of LandXML files into software. Note that this research will focus on deposited plans and that there are other plan types as mentioned in Section 2.1.1, which fall beyond the scope of this study.

3.3.2 Traditional Method of Capturing Cadastral Plan Data

To define lot boundaries in a survey plan, a series of bearings and ground distances, i.e. vectors, are used which refer to monuments or other ground features such as cadastral reference marks (Baxter, 2015). These may include: pegs, reference trees, drill hole and wings (DH&Ws), galvanised iron pipes (GIPs) and concrete blocks. These reference marks are defined under the provisions of the Surveying and Spatial Information Regulation 2017.

To capture survey plan data, surveyors use the bearings and distances shown on a hardcopy or TIFF plan to recreate the parcel boundaries, occupations, connections and so forth. Sometimes, data from more than one survey plan has to be captured and combined simultaneously. This normally involves swinging one plan onto the azimuth of another and then capturing all the information shown using common boundary lines or reference marks, to relate the plans to each other (Baxter, 2017). These processes are completed manually using various surveying software.

3.3.3 Ingestion of LandXML Files

The key difference between a LandXML file and a traditional plan is that once a LandXML file has been exported from a software, coordinates are stored for each point such as a corner of a lot or a reference mark. On the other hand, in a traditional survey plan, no coordinate information is stored (except for established marks, e.g. SSMs, PMs, etc.). However, both traditional survey plans as well as LandXML files provide line bearings and ground distances.

As mentioned above, surveyors in NSW have traditionally used the bearings and distances to capture survey plan data. This data is captured in a certain sequence which can also vary depending on the circumstances (e.g. road lines are usually captured before boundary lines) (Nixon, 2017). For a software to capture survey plan data accurately from a LandXML file (during ingestion), it must be programmed to emulate all these processes as precisely as possible using the bearings and distances, which can be difficult to achieve.

Since LandXML files store coordinates for all the points in a survey plan, these can also be used to recreate each plan feature, such as lines and parcels (which were originally defined using bearings and distances – see Section 4.3.1 for more details). This seems like an ideal solution to the problem with using bearings and distances to ingest LandXML files, because point coordinates are generally required in the majority of CAD software according to Baxter (2017).

However, Choi et al. (2017a) states that the LPI has constantly urged software vendors to develop their software to avoid relying on the coordinates stored in a LandXML file (specifically CgPoint coordinates – see Section 4.2.2) and to instead use the bearings and distances provided for ingestion. Doing so will ensure that the geometry of the plotted survey plan linework is based on the bearings and ground distances from the LandXML file (which are the quantities shown on a TIFF plan, as mentioned in Section 3.3.2). The plotted linework is what will be used by surveyors to derive coordinates in CAD for the various applications such as searching for survey marks (see Section 3.2). It is therefore crucial for its geometry to be based on the bearings and distances from the LandXML file to ensure that accurate coordinates can be derived from it, in order that, for instance, survey marks may be located.

There is currently an absence of research regarding the LandXML ingestion methods used by the present surveying software in NSW (i.e. whether coordinates are used or not). This research will attempt to fill in this knowledge gap. Note that this thesis will also focus particularly on why coordinates are not recommended to be used for ingesting LandXML files.

4 Introduction to Experimentation

4.1 Introduction

The literature review covered various concepts regarding LandXML in terms of its use for EPlan plan lodgment as well as for software ingestion after receiving existing files from the LPI. The outline of the main content covered by the literature review is shown in Figure 4.1.

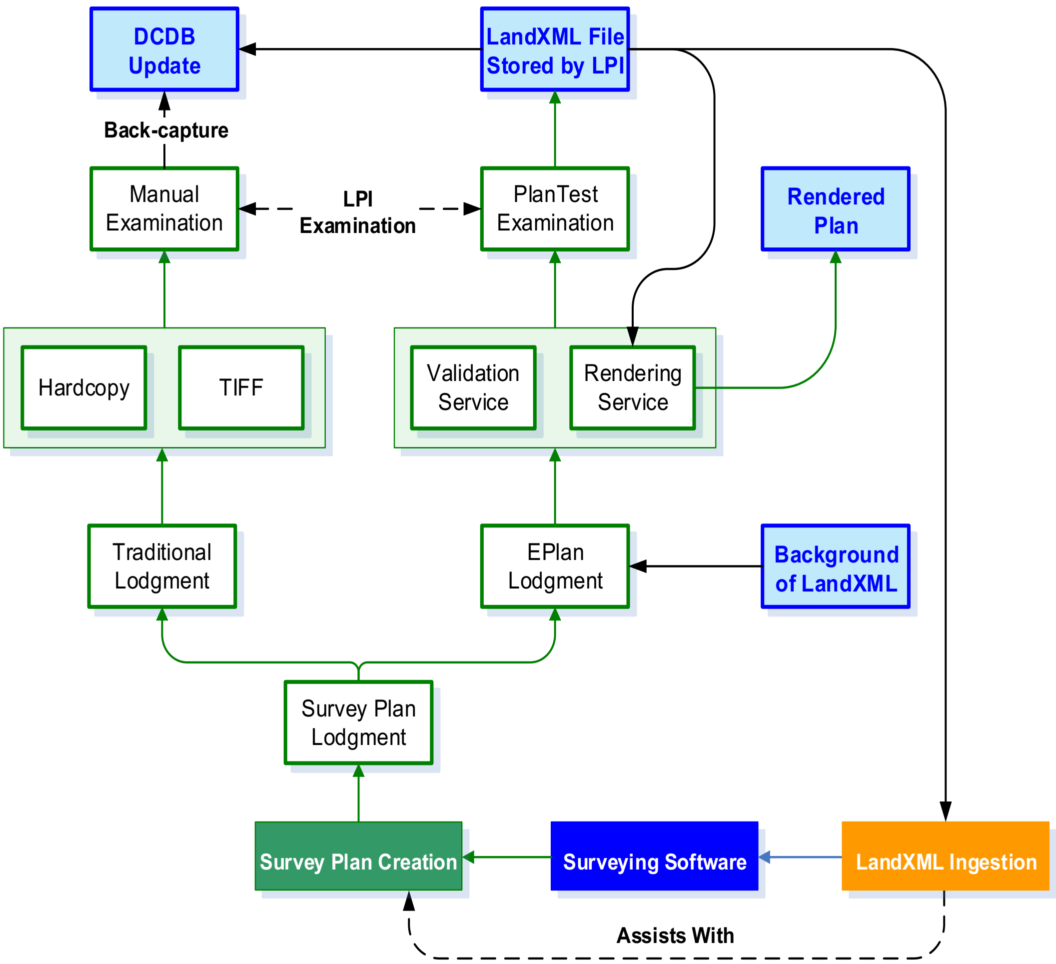


Figure 4.1: Outline of literature review content

As pointed out at the end of the literature review, the key focus of this research will be regarding LandXML use for software ingestion, i.e. prepopulating data into software, as illustrated in Figure 4.2.

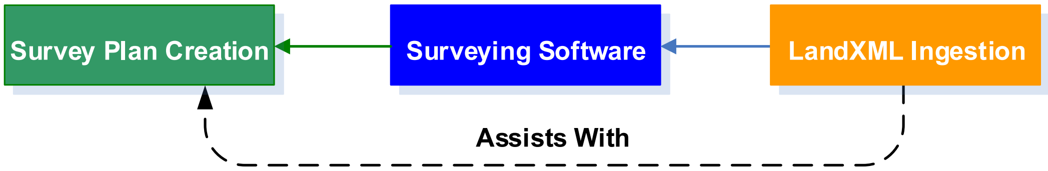


Figure 4.2: Focus of research

Prior to experimentation, it is necessary to describe some parts of the LandXML file structure and to explain some other concepts regarding this structure, in order to clarify the research that follows.

4.2 LandXML File Structure

This section will discuss some of the key components of the LandXML file structure which is based on the NSW LandXML schema (see Section 2.3.6). The information provided is a subset of that detailed by the *NSW LandXML Recipe* document (Choi and Deal, 2017) and has been tailored specifically for the purpose of this research. After the completion of this section, a reader should have a basic understanding of some of the features contained in a LandXML file as well as how to interpret LandXML code, which are requisite for the following research.

4.2.1 Introduction

A LandXML file consists of elements which correspond to: points, lines, parcels and so forth. Each element is defined using a set of attributes (Choi and Deal, 2017). For example, an attribute for a parcel could be its 'state'; whether the parcel is 'proposed', 'adjoining' or 'existing'. Figure 4.3 simplifies the relationship between 'elements' and 'attributes'.

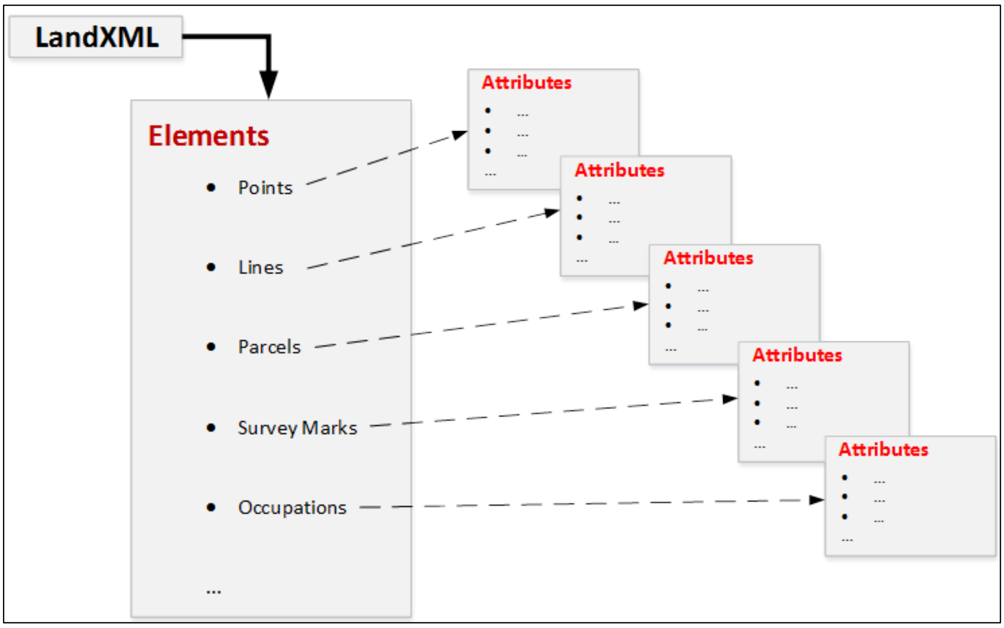


Figure 4.3: Relationship between elements and attributes (Choi, 2017a)

In LandXML, a point is represented by the element ‘CgPoint’ (similar to a coordinate geometry or COGO point), a line is defined by the connection between two CgPoints and a parcel is defined using a combination of lines. Each element in a LandXML file begins with an opening tag, <[element name], and ends with a closing tag, </[element name]>, as per all XML file structures (Choi, 2017b). The following discussion will elaborate further about some of the relevant attributes and elements which must be understood for this research. Note the following:

1. In the following figures, sections of LandXML code which are not relevant to this research (including irrelevant attributes and elements) are replaced by an ellipsis (...);
2. The following discussion will only consider data as being two-dimensional (even though LandXML can store three-dimensional data), to remain within the scope of this research; and
3. In the following figures, ‘elements’ will appear in brown font and ‘attributes’ will appear in red font for clarification purposes.

4.2.2 Point

Each point in a LandXML file is represented by a CgPoint under the ‘CgPoints’ element and is defined by a set of coordinates i.e. Northing followed by Easting separated by a single space (this is the adopted order for the coordinates). The CgPoints element is used to represent all points including: reference marks, permanent survey marks and boundary points (Choi and Deal, 2017). Other elements such as ‘Line’ use CgPoints to define them (see following section).

Figure 4.4 demonstrates how CgPoints are defined in NSW LandXML. In this example, the attribute ‘name’ is a unique identifier and stores the point number of the CgPoint i.e. point 822. Note that this will be referred to as a ‘CgPoint number’ for simplicity. The two values, i.e. 6257928.410 and 333988.599, are the ‘local’ Northing and Easting value of this CgPoint respectively (Choi and Deal, 2017). These values are not MGA coordinates although appearing to be so; they are still locally defined coordinates (see Section 4.3.1 for more information about what ‘locally defined’ means). The reason why they are close to MGA coordinates will be explained in Section 4.3.2.

```
<CgPoints … >
  <CgPoint
    name="822" … oID="22126">
    6257928.410 333988.599
  </CgPoint>
</CgPoints>
```

Figure 4.4: Contents of ‘CgPoints’ element

The attribute ‘oID’ stores the ID of the control point (survey control mark ID), such as an SSM or PM number. Non-control points such as the corners of lots, do not require this attribute. Figure 4.5 summarises the relationship between the CgPoints element and its attributes which were described.

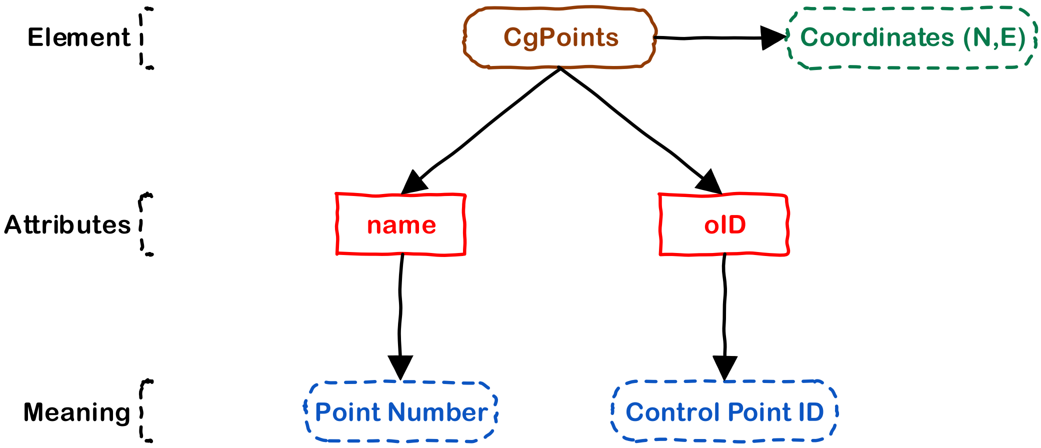


Figure 4.5: The 'CgPoints' element and some of its attributes

Established control points must also have MGA coordinates assigned to them (as well as CgPoint coordinates like any other point). These MGA coordinates are independent from the CgPoint coordinates. Note that the coordinate system of control points will be assumed to be MGA throughout this research even though other systems can be used, in order to remain within the scope of this research.

MGA coordinates for control points are defined using another element called 'RedHorizontalPosition', which stores the MGA Northing and Easting values using two other attributes: 'latitude' and 'longitude' respectively. For example, referring to Figure 4.6, the latitude value of 6363006.080 is the MGA Northing and the longitude value of 373418.490 is the MGA Easting.

```
<RedHorizontalPosition
  … setupID="IS31"
  latitude="6363006.080" longitude="373418.490" …
<RedHorizontalPosition/>
```

Figure 4.6: Content of 'RedHorizontalPosition' element

The 'RedHorizontalPosition' element has another attribute called 'setupID' which links to CgPoints using their corresponding numbers. Referring again to Figure 4.6, the value of the 'setupID' attribute has an extra 'IS' before identifying the CgPoint number it refers to. For example, IS31 means it refers to CgPoint 31. The purpose of the additional 'IS' is to indicate that the 'setupID' attribute does not refer directly to the 'CgPoint' element, but rather through another element called 'InstrumentSetup' and hence 'IS'. Deal and Choi (2017) state that this is purely a structural requirement of LandXML. Understanding this concept is, however, beyond the scope of this research and will therefore not be discussed further. Figure 4.7 summarises the relationship between the 'RedHorizontalPosition' element and its attributes which were described.

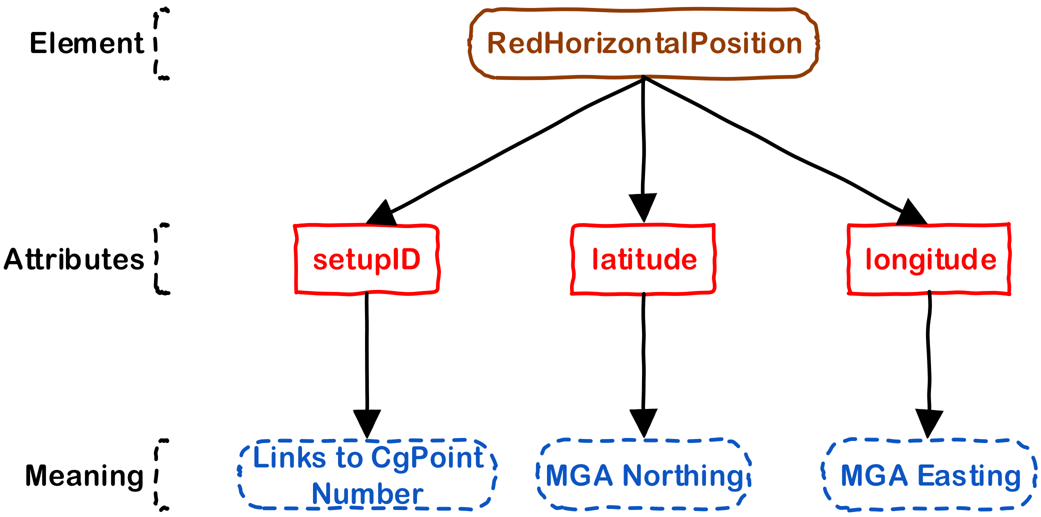


Figure 4.7: The 'RedHorizontalPosition' element and some of its attributes

4.2.3 Line

The following section will explain how bearings and distances, stored in a LandXML file, are related to each line and hence the associated CgPoints.

The 'Line' element is used to define a straight line between two CgPoints, by referring to a 'Start' and 'End' CgPoint number (see Figure 4.8). Multiple lines can be combined to construct parcels and other objects (Choi and Deal, 2017).

```
<Line
  … <Start … />
  <End … />
</Line>
```

Figure 4.8: Content of 'Line' element

Each line is also linked to a certain bearing and ground distance. These values are defined using ‘azimuth’ and ‘horizDistance’ respectively, which are attributes of another LandXML element called ‘ReducedObservation’ (see Figure 4.9). Note that the values of these attributes (i.e. bearing and ground distance) will sometimes be referred to as ‘observations’ throughout this research. Note also that ground distances are used as per survey plans, as discussed in Section 3.3.3.

```
<ReducedObservation
  …
  setupID="IS14" targetSetupID="IS15"
  azimuth="59.3032" horizDistance="324.525" …
  distanceAdoptionFactor="1.000240" …
<ReducedObservation />
```

Figure 4.9: Content of ‘ReducedObservation’ element

To link the ‘ReducedObservation’ element to an associated line (defined by two CgPoints), two other important attributes of the ‘ReducedObservation’ element are used: ‘setupID’ and ‘targetSetupID’. These attributes can be considered as the starting and ending points of a traverse leg, i.e. ‘setup station’ and ‘target station’ (see Figure 4.9). The purpose of designating a starting and ending point is to define which line a certain bearing (azimuth) and distance (horizDistance) will be assigned to. This is required by the ‘Rendering Service’ (see Section 2.4.3) to produce a rendered plan which shows the observation annotations in their correct location, as shown in Appendix C.

The ‘setupID’ and ‘targetSetupID’ attributes link to CgPoints using their corresponding numbers. Referring back to Figure 4.9, the values of these attributes have an extra ‘IS’ before stating the reference CgPoint number. The reason for this has previously been discussed in Section 4.2.2. The important point to note here is that the observations (bearings and distances) for each line have no direct link to the CgPoints which define each line; they are linked indirectly through the ‘InstrumentSetup’ element (see Section 4.2.2). In his opinion, Nixon (2017) says that the observations can simply be thought of as a "recording of textual information about a line". This has led to some problems in ingesting LandXML files, which are to be discussed throughout this research.

Another attribute of the 'ReducedObservation' element, which is relevant to this research, is the 'distanceAdoptionFactor' (see Figure 4.9). The purpose of this attribute is to store a combined scale factor (CSF) for connection lines between control points (Choi and Deal, 2017). This is required so that the Validation Service and PlanTest software can perform mathematical checks of a LandXML file to ensure the accuracy of a survey plan (see Sections 2.4.2 and 2.4.4). Note that a CSF is stored separately for each individual connection observation between control points (see Section 5.2.3 for more details).

To understand how the attributes: 'setupID', 'targetSetupID', 'azimuth', 'horizDistance' and 'distanceAdoptionFactor' are related in LandXML, refer to Figure 4.9. The values assigned to setupID and targetSetupID are IS14 and IS15, respectively. This indicates that the bearing (azimuth) of 59°30'32", ground distance (horizDistance) of 324.525m and CSF (distanceAdoptionFactor) of 1.000240, will be assigned to the line defined between CgPoints 14 and 15. Figure 4.10 summarises the relationship between the 'ReducedObservation' element and its attributes which were described.

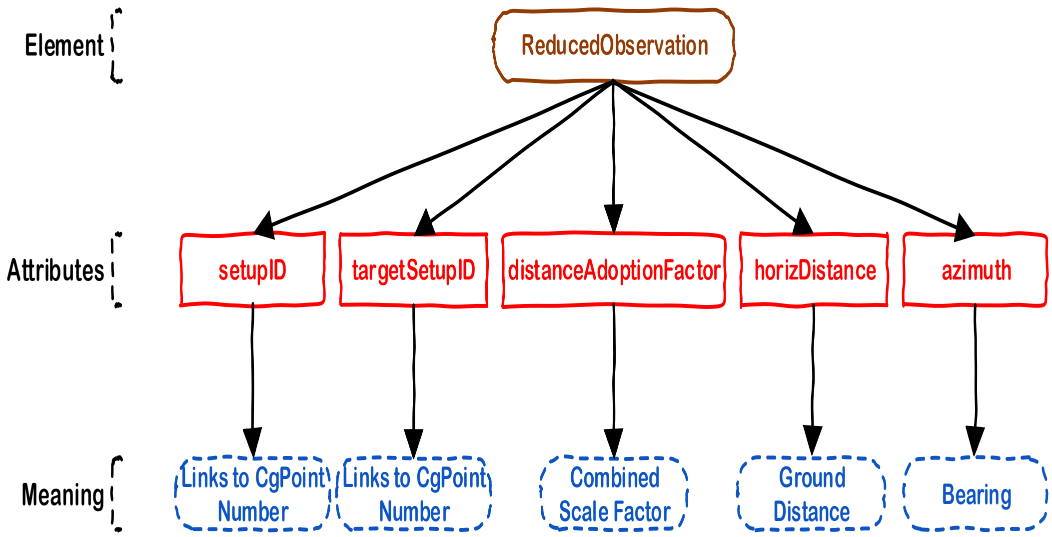


Figure 4.10: The 'ReducedObservation' element and some of its attributes

4.2.4 Summary

The previous sections described some aspects about the LandXML file structure as well as how to interpret LandXML code, which must be understood for the following experimentation. Some of the key points which should be remembered include:

1. CgPoints store coordinates for each point in a survey plan, which are locally defined;
2. MGA coordinates are stored separately from the CgPoint coordinates and are stored only for control points such as SSMs; control points have both CgPoint and MGA coordinates;
3. Bearings and distances (observations) are stored as attributes in a LandXML file which are indirectly linked to CgPoints; and
4. A CSF is stored as an attribute for connection lines between control points.

The following section will discuss other concepts regarding CgPoint coordinates which also need to be understood for this research.

4.3 CgPoint Coordinates

4.3.1 Local Ground or Locally Defined Coordinates

Normally, when a LandXML file is created using a software, the CgPoint coordinates are defined based on the endpoints of each line. Each line itself is originally defined by a certain bearing and ground distance. Since ground distances are used, the resulting coordinate system of the CgPoints will therefore be defined on the ground. For the sake of simplicity, coordinates defined in this manner will be referred to as 'local ground' or 'locally defined' coordinates throughout this thesis. This is based on what was mentioned in Section 4.2.2, that CgPoints contain local coordinates, as stated by Choi and Deal (2017).

Theoretically, if the join is computed between these coordinates (i.e. the inverse of the operation used to define the coordinates), the original observations (bearing and ground distance) of the line should be obtained. However, sometimes, due to factors such as rounding errors, there will be a small discrepancy involved. For example, observations stored in a LandXML file have to be rounded to a certain precision as stated by the Registrar General's Guidelines (LPI, 2017b), and this rounding process is sometimes completed after the CgPoint coordinates have already been defined (Choi et al., 2017a). As a result, if the join is computed between the CgPoint coordinates of a line's endpoints, the precision of the observations calculated may differ slightly from those stored in the LandXML file for that line. However, since the discrepancy usually falls within cadastral surveying tolerances, it can be disregarded.

The relevance of this discussion to the following experimentation is that if a software uses the CgPoint coordinates to plot the linework of a survey plan (as mentioned in Section 3.3.3), the resulting geometry (i.e. bearing and distance) of each line will be derived by computing the join between the coordinates rather than using the observations stored in a LandXML file. If the CgPoint coordinates were locally defined during ingestion, the ingested data will be reliable since the geometry of the plotted linework (which will consist of ground distances) will fall within reasonable tolerances, if not equivalent to the bearings and ground distances stored in the file.

4.3.2 Arbitrary CgPoint Coordinates

As mentioned in the previous section, CgPoints normally contain local ground coordinates due to the manner in which they are defined. These CgPoint coordinates may have values which are similar to the MGA coordinates of control points defined within the same LandXML file (as mentioned in Section 4.2.2), or even completely arbitrary (or assumed) values (i.e. they could potentially be thousands of metres different to MGA coordinates – see LandXML file provided in Appendix M).

The reason why CgPoints sometimes contain coordinates which are close to the MGA coordinates of control points in a LandXML file, is that surveyors sometimes choose to create a real-world CAD drawing using MGA or approximate MGA co-ordinates (Baxter, 2017). This data can then be exported and used in either a total station or a GNSS unit to find and measure the required cadastral monuments. This is exclusively based on a matter of a surveyor's opinion. A LandXML file created based on this data will thus contain CgPoint coordinates which have values close to MGA coordinates, even though they are still locally defined. This concept will be elaborated on in Section 6.2.1.1.

4.4 Conclusion

This chapter covered various aspects of LandXML including a description of some of its structural components and further details about CgPoints, which needs to be understood for the following experimentation.

5 Experimentation – Part A

5.1 Experiment 1: Simple Lot Test

5.1.1 Introduction

The aim of this experiment was to test the effect of modifying CgPoint coordinates and observations (bearings and distances) in a LandXML file on the ingested data (i.e. plotted linework) using a surveying software whose guidelines claimed to use CgPoints for ingestion. This would help ascertain the ingestion method used by the software. The software used for this experiment was LXML4AC.

5.1.2 LXML4AC

LXML4AC (LandXML for AutoCAD) is a simple add-on application tool developed for use by AutoCAD software. In this research, Version 1.9.2 of this application was used in AutoCAD 2015. For the sake of brevity, this application tool will be referred to as a 'software' throughout this thesis.

The LXML4AC software can be used to create LandXML files for an EPlan lodgment. There have been about 134 lodgments using this software as at 12th September 2017, according to the data shown in Figure 3.1.

The software guidelines state that there are two methods which can be used to import a LandXML file (Nixon, 2017). The first method imports LandXML data using CgPoint coordinates (by running the 'XIN' command) and the second method uses the observations (i.e. bearings and distances, by running the 'XINO' command). The second method generates new coordinates for the CgPoints during ingestion using the observations (Nixon, 2017). This research will focus on the former method.

5.1.3 Method

In order to ascertain the LandXML ingestion method used by the LXML4AC software, a LandXML file was created then various modifications were made to it. Each time a modification was made, it was ingested into the software to examine what effect that change had on the plotted linework. This method was adopted because it revealed the way in which the software ingests LandXML files.

The LandXML file created consisted of a perfectly square lot with 20m sides as shown in Figure 5.1. This lot had an area of 400m^2 and the bottom left corner of the lot was situated at the origin.

Note that throughout the remainder of this thesis, distances shown in all the survey plan diagrams provided in the relevant figures (such as that shown in Figure 5.1) are in metres, bearings are in degrees, minutes and seconds (whenever applicable) and North is up the page. In addition, the linework shown is the survey plan plotted after ingesting the relevant LandXML file.

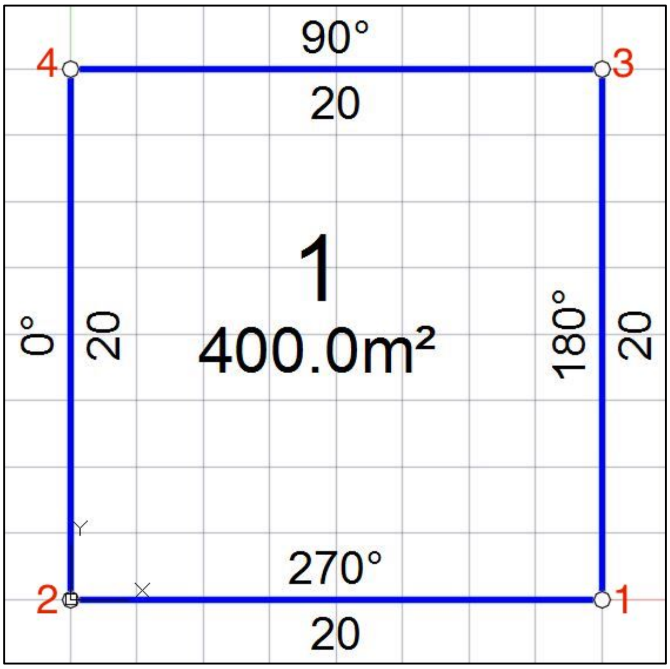


Figure 5.1: Square lot defined by the blue lines

The relevant extract of the LandXML file created is shown in Figure 5.2 with the essential sections highlighted in yellow. This figure shows the CgPoint coordinate and observation information only; the complete LandXML file can be found in Appendix D. Note that for all the LandXML files referred to in this thesis (provided in the Appendices), the relevant code sections will be highlighted in yellow. Also note that the CgPoint coordinates in this file were locally defined (i.e. local ground coordinates – see Section 4.3.1).

```
<CgPoints zoneNumber="56">
  <CgPoint state="proposed" pntSurv="boundary" name="1">0 20</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="2">0 0</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="3">20 20</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="4">20 0</CgPoint>
</CgPoints>

<ObservationGroup id="OG-1">
  <ReducedObservation name="1" desc="Boundary" setupID="IS1"
targetSetupID="IS2" azimuth="270" horizDistance="20" distanceType="Measured"/>
  <ReducedObservation name="2" desc="Boundary" setupID="IS3"
targetSetupID="IS1" azimuth="180" horizDistance="20" distanceType="Measured"/>
  <ReducedObservation name="3" desc="Boundary" setupID="IS4"
targetSetupID="IS3" azimuth="90" horizDistance="20" distanceType="Measured"/>
  <ReducedObservation name="4" desc="Boundary" setupID="IS2"
targetSetupID="IS4" azimuth="0" horizDistance="20" distanceType="Measured"/>
</ObservationGroup>
```

Figure 5.2: LandXML file extract

After interpreting Figure 5.2, the coordinate and observation data was tabulated as shown in Tables 5.1 and 5.2.

Table 5.1: CgPoint Coordinates

Point	Northing (m)	Easting (m)
1	0	20
2	0	0
3	20	20
4	20	0

Table 5.2: Line distances and bearings

Line	Distance (m)	Bearing
1–2	20	270°
3–1	20	180°
4–3	20	90°
2–4	20	0°

The following modifications were then made to the LandXML file (refer to Tables 5.1 and 5.2):

1. Distance of eastern boundary, i.e. Line 3-1, was increased by 5m (i.e. from 20m to 25m);
2. Bearing of eastern boundary, i.e. Line 3-1, was increased by 20° (i.e. from 180° to 200°); and
3. CgPoint coordinates of north-eastern corner (i.e. Point 3; see Figure 5.1), were changed from (20,20) to (30,30) (i.e. a 10m increase in both the Northing and Easting).

The reason for which the above-mentioned entities were specifically selected for modification was that they were the only quantitative entities in the present file which could affect the plotting of the linework. There are other quantitative entities which can appear in a LandXML file, as will be outlined in Section 5.1.5.

Every time the LandXML file was modified it was ingested into the LXML4AC software to plot the linework of the survey plan (defined by the file). The geometry of this linework was then checked using the software's inquiry tools to examine if there were any changes to the coordinates or observations, compared to the values stored in the LandXML file.

Note that each modification was made and tested separately using a copy of the original version of the LandXML file (provided in Appendix D) to maintain a controlled experiment. The results obtained are outlined in the following section.

5.1.4 Results

5.1.4.1 Modified Distance Test

The first modification made to the LandXML file (provided in Appendix D) is highlighted in Figure 5.3.

```
<ReducedObservation name="2" desc="Boundary" setupID="IS3"
targetSetupID="IS1" azimuth="180" horizDistance="25" distanceType="Measured"/>
```

Figure 5.3: Distance modification shown in red

After importing this file, the diagram produced (see Figure 5.4) appeared almost identical to the original LandXML file diagram (compare with Figure 5.1). The only difference found was that the annotated distance for Line 3-1, had changed from 20m to 25m.

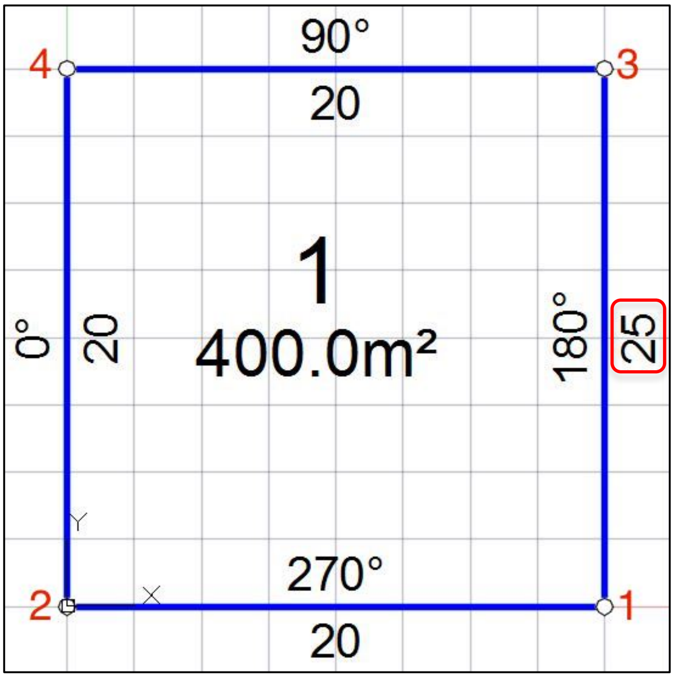


Figure 5.4: Diagram produced for modified distance test

The coordinate and observation differences between the values stored in the LandXML file and the inquired values (using the software's inquiry tools) were then computed as shown in Tables 5.3, 5.4 and 5.5.

Table 5.3: Differences between coordinates in LandXML file and inquired values

	Coordinates – file		Coordinates – inquired		Difference	
Point	N (m)	E (m)	N (m)	E (m)	ΔN (m)	ΔE (m)
1	0	20	0	20	0	0
2	0	0	0	0	0	0
3	20	20	20	20	0	0
4	20	0	20	0	0	0

Table 5.4: Differences between distances in LandXML file and inquired values

Line	Distance (m) – file	Distance (m) – inquired	|Difference| (m)
1–2	20	20	0
3–1	**25**	**20**	**5**
4–3	20	20	0
2–4	20	20	0

Table 5.5: Differences between bearings in LandXML file and inquired values

Line	Bearing – file	Bearing – inquired	|Difference|
1–2	270°	270°	0°
3–1	180°	180°	0°
4–3	90°	90°	0°
2–4	0°	0°	0°

5.1.4.2 Modified Bearing Test

The second modification made to the LandXML file (provided in Appendix D) is highlighted in Figure 5.5.

```
<ReducedObservation name="2" desc="Boundary" setupID="IS3"
targetSetupID="IS1" azimuth="200" horizDistance="20" distanceType="Measured"/>
```

Figure 5.5: Bearing modification shown in red

After importing this file, the diagram produced (see Figure 5.6) appeared almost identical to the original LandXML file diagram (compare with Figure 5.1). The only difference found was that the annotated bearing for Line 3-1, had changed from 180° to 200°.

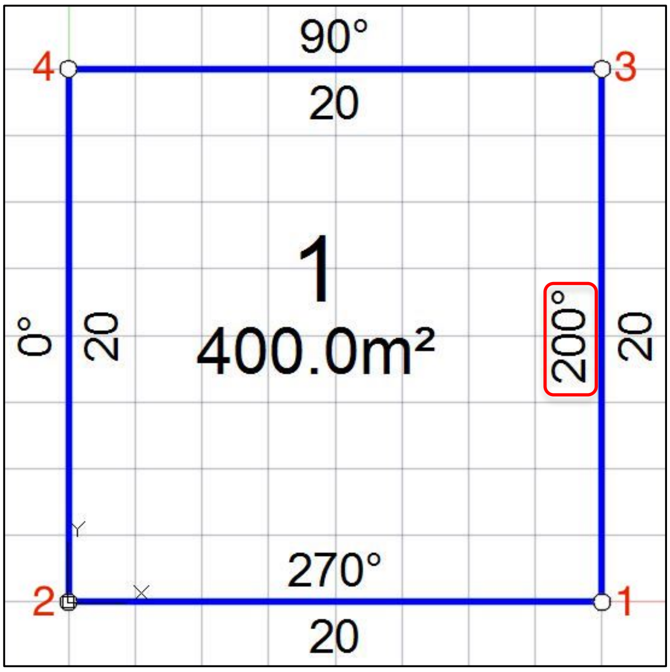


Figure 5.6: Diagram produced for modified bearing test

The coordinate and observation differences between the values stored in the LandXML file and the inquired values (using the software's inquiry tools), were then computed as shown in 5.6, 5.7 and 5.8.

Table 5.6: Differences between coordinates in LandXML file and inquired values

	Coordinates – file		Coordinates – inquired		Difference	
Point	N (m)	E (m)	N (m)	E (m)	ΔN (m)	ΔE (m)
1	0	20	0	20	0	0
2	0	0	0	0	0	0
3	20	20	20	20	0	0
4	20	0	20	0	0	0

Table 5.7: Differences between distances in LandXML file and inquired values

Line	Distance (m) – file	Distance (m) – inquired	|Difference| (m)
1–2	20	20	0
3–1	20	20	0
4–3	20	20	0
2–4	20	20	0

Table 5.8: Differences between bearings in LandXML file and inquired values

Line	Bearing – file	Bearing – inquired	|Difference|
1–2	270°	270°	0°
3–1	**200°**	**180°**	**20°**
4–3	90°	90°	0°
2–4	0°	0°	0°

5.1.4.3 Modified CgPoint Coordinates Test

The final modification made to the LandXML file (provided in Appendix D) is highlighted in Figure 5.7.

```
<CgPoint state="proposed" pntSurv="boundary" name="3">30 30</CgPoint>
```

Figure 5.7: CgPoint coordinate modification shown in red

After importing this file, the position of the north-eastern corner of the lot, connecting Lines 4-3 and 3-1, changed significantly as shown in Figure 5.8 (compare with Figure 5.1). However, the annotated distances and bearings for these lines remained unchanged.

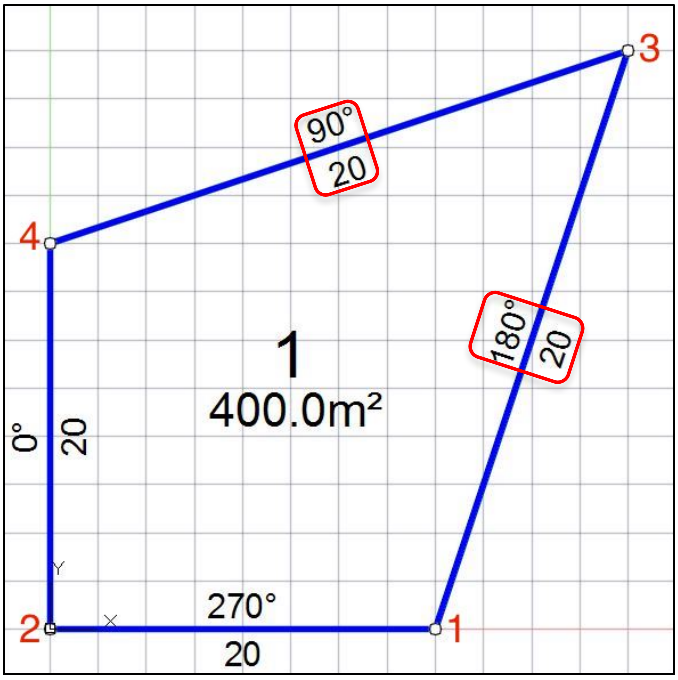


Figure 5.8: Diagram produced for modified CgPoint coordinates test

The coordinate and observation differences between the values stored in the LandXML file and the inquired values (using the software's inquiry tools) were then computed as shown in Tables 5.9, 5.10 and 5.11.

Table 5.9: Differences between coordinates in LandXML file and inquired values

	Coordinates – file		Coordinates – inquired		Difference	
Point	N (m)	E (m)	N (m)	E (m)	ΔN (m)	ΔE (m)
1	0	20	0	20	0	0
2	0	0	0	0	0	0
3	**30**	**30**	**30**	**30**	**0**	**0**
4	20	0	20	0	0	0

Table 5.10: Differences between distances in LandXML file and inquired values

Line	Distance (m) – file	Distance (m) – inquired	|Difference| (m)
1–2	20	20	0
3–1	**20**	**31.623**	**11.623**
4–3	**20**	**31.623**	**11.623**
2–4	20	20	0

Table 5.11: Differences between bearings in LandXML file and inquired values

Line	Bearing – file	Bearing – inquired	|Difference|
1–2	270°	270°	0°
3–1	**180°**	**198°26'06"**	**18°26'06"**
4–3	**90°**	**71°33'54"**	**18°26'06"**
2–4	0°	0°	0°

Overall, it was found that the inquired distances and bearings of Lines 3-1 and 4-3 differed significantly to the values stored in the LandXML file.

5.1.5 Discussion

Analysing the results obtained for this experiment led to the following findings.

The results obtained after modifying the distance of Line 3-1 (from 20m to 25m - see Section 5.1.4.1) indicated that the distances stored in the LandXML file had no effect on the plotted linework. This is because the inquired distance value for this line remained unchanged (as shown in Table 5.4) despite the distance of this line being modified in the imported file.

This indicates that when the data was ingested, the software used the CgPoint coordinates to plot the linework (shown in Figure 5.4) then calculated the linework geometry by computing the join between the CgPoint coordinates (see Section 4.3.1). Since the coordinates in the LandXML file were local ground coordinates (as mentioned in Section 5.1.3) and were unmodified in this test, the resulting distances computed were equivalent to the original (unmodified) distances shown in Table 5.2. This explains the difference found between the distance in the LandXML file and the inquired distance of Line 3-1 shown in Table 5.4.

In addition, coordinate and bearing differences were not found between the data contained in the ingested LandXML file and the inquired values shown in Tables 5.3 and 5.5 respectively. These results were expected since the CgPoint coordinates and bearings were unmodified in this test.

The same discussion can be applied to the results obtained for the second test (see Section 5.1.4.2) where the bearing of Line 3-1 was modified. The only change in this case was that instead of there being a distance difference between the LandXML file and the geometry of the plotted linework (as per the above discussion), a bearing difference was instead computed as shown in Table 5.8. This was also due to the linework of the ingested file being plotted using the CgPoints (which were unmodified in this test) and after computing the join between their coordinates, the resulting bearings were equivalent to the original (unmodified) bearings shown in Table 5.2. No coordinate or distance differences were found between the data in the ingested LandXML file and the inquired values as shown in Tables 5.6 and 5.7 respectively. This was yet another expected result since the CgPoint coordinates and distances were unmodified in this test.

In addition, the fact that the coordinates did not change after ingesting the modified LandXML files (i.e. distance and bearing modifications) in both of the previously mentioned tests (see Tables 5.3 and 5.6), further indicates that the CgPoint coordinates were used to plot the linework.

The results obtained after modifying the CgPoint coordinates of Point 3 (see Section 5.1.4.3) provide further verification of the interpretations made so far. After ingesting the LandXML file, it was found that the inquired geometry (bearing and distance) for Lines 3-1 and 4-3 differed significantly to the observation values in the LandXML file, as shown in Tables 5.10 and 5.11. This change was due to the software plotting the linework using the CgPoints (one of which was modified) and subsequently calculated the geometry for these lines by computing the join, as explained previously. Also, the lack of change in the CgPoint coordinates of the imported file (which had modified coordinates) and the inquired values shown in Table 5.9 indicates that the software used the CgPoints for plotting the linework.

Furthermore, since the inquired linework geometry changed only after modifying the CgPoint coordinates out of all three tests, indicates that the observations in the LandXML file had no effect on the plotted linework.

Overall, it can be concluded that the LXML4AC software used only CgPoint coordinates from the LandXML file for plotting the survey plan linework during ingestion, and that the observations had no effect on this linework. These results were somewhat expected since the software guidelines claimed that the LXML4AC software uses CgPoint coordinates for LandXML ingestion (see Section 5.1.2).

There are various problems associated with using CgPoints from a LandXML file to plot the linework of a survey plan, which will be discussed in Chapter 6. However, in order to realise the extent of these problems, other surveying software used in NSW must also be checked to verify if the same ingestion method is used. This experimental limitation will be addressed by the following experiment.

Another limitation of this experiment was that it involved a very simplified LandXML file which did not contain various quantitative entities such as: control points (with MGA coordinates) and a combined scale factor (CSF). These entities are normally present in a real LandXML file used for an EPlan lodgment. It is currently unknown if these additional entities have any effect on the plotted linework (e.g. scaling effects following ingestion into LXML4AC). This needs to be ascertained to validate the interpretations made from this experiment. The implications of the results of this experiment will therefore be accounted for after conducting the following experiment.

To conclude this discussion, one final note should be made regarding the annotations shown in the diagrams provided in Section 5.1.4 (see Figures 5.4, 5.6 and 5.8). It was found that the bearing and distance annotations shown for the linework were based on the observations stored in the LandXML file, since they only changed whenever the observations in the file were modified (see Sections 5.1.4.1, 5.1.4.2 and 5.1.4.3). Regarding the annotated area shown for the lots in the same figures mentioned above, the reason for the lack of change in spite of all the tests mentioned previously, will not be discussed since this concept is beyond the scope of this study.

5.2 Experiment 2: Further Software Testing

5.2.1 Introduction

The primary aim of this experiment was to test other surveying software to determine how they ingest LandXML files (i.e. plot the linework). The software which were tested included:

1. LXML4AC (was re-tested, see below);
2. Stringer ePlan; and
3. 12d Model.

An introduction to each software is provided in the following section. Note that other software could not be tested due to factors such as: lack of access to the software or lack of LandXML import functionality built into the software. For example, Magnet Office has not yet developed LandXML import functions (Banks, 2017).

Another aim of this experiment was to test a more comprehensive LandXML file which contained additional quantitative entities, such as those mentioned at the end of Section 5.1.5, to simulate a real file. The file was also checked by the Validation Service to ensure compliance with the LPI requirements defined by Choi and Deal (2017), as is usually performed with real files for an EPlan lodgment (see Section 2.4.2).

5.2.2 Software Introduction

5.2.2.1 LXML4AC

The LXML4AC software was introduced in Section 5.1.2 and tested in the previous experiment. The following experiment will re-test this software to determine if ingesting a more comprehensive LandXML file (which includes additional entities) has any effect on the results.

5.2.2.2 Stringer ePlan

Stringer ePlan is an application developed for use by various CAD software (e.g. BricsCAD and AutoCAD). For this research, Stringer ePlan 2017 was used in AutoCAD Civil 3D 2017. For the sake of simplicity, this application will be referred to as a 'software' throughout this research.

This software can be used to create LandXML files for an EPlan lodgment. There have been about 29 lodgments using Stringer ePlan as at 12th September 2017, based on the data shown in Figure 3.1.

This software has only one method of importing LandXML files which will be tested in this experiment. Note that the researcher found no published documents outlining the fine details on how this software ingests LandXML files.

5.2.2.3 12d Model

12d Model is a software program which can be used to create LandXML files for an EPlan lodgment. There have been about 6 lodgments using this software as at 12th September 2017, based on the data shown in Figure 3.1. For this research, Version 12.0 of 12d Model was used.

This software also has only one method of importing LandXML files which will be tested in this experiment. Note that the researcher found no published documents outlining the fine details on how this software ingests LandXML files.

5.2.3 Method

In order to determine the LandXML ingestion method used by each software, a LandXML file was created and then various modifications were made to it. Each time a modification was made, it was ingested into each software to examine what effect that change had on the plotted linework. This method was adopted because it revealed the way in which each software ingests LandXML files.

The LandXML file created consisted of a perfectly square lot with 20m sides as shown in Figure 5.9 (this lot was geometrically identical to the one tested in the previous experiment, also having an area of 400m² as shown). The lot also contained connections to three SSMs with MGA coordinates as well as a CSF of 0.9996 since it was situated along the central meridian of Zone 56.

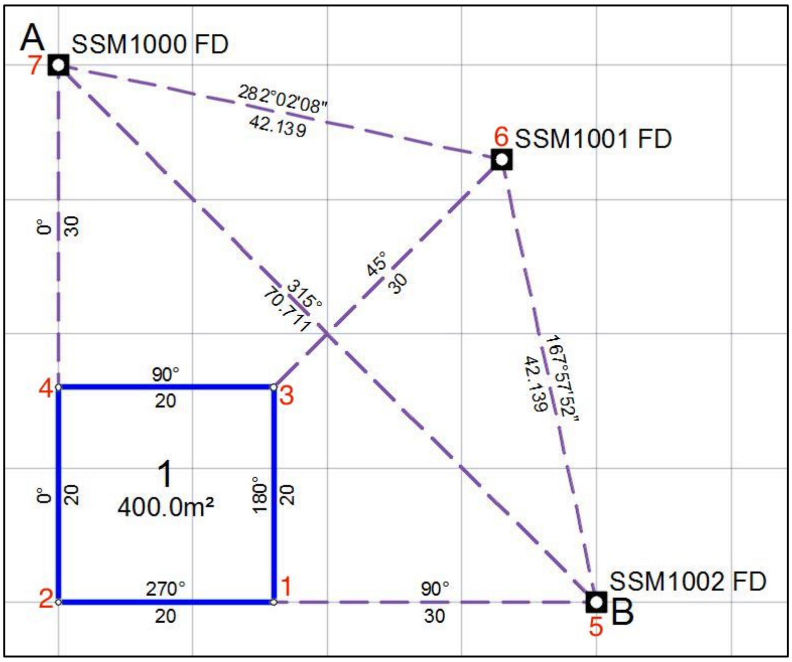


Figure 5.9: Lot defined by the blue lines and SSM connections shown in purple

After interpreting the LandXML file created (see Appendix E), the relevant data was tabulated as shown in Tables 5.12, 5.13 and 5.14.

Table 5.12: CgPoint coordinates

Point	Northing (m)	Easting (m)
1	6000000	500020
2	6000000	500000
3	6000020	500020
4	6000020	500000
5	6000000	500050
6	6000041.213	500041.213
7	6000050	500000

Table 5.13: Line distances and bearings

Line	Distance (m)	Bearing
1–2	20	270°
3–1	20	180°
4–3	20	90°
2–4	20	0°
4–7	30	0°
1–5	30	90°
3–6	30	45°
6–7	42.139	282°02'08"
6–5	42.139	167°57'52"
5–7	70.711	315°

Table 5.14: MGA coordinates of control points

Point	SSM ID	Northing (m)	Easting (m)
5	1002	6000000.021	500049.979
6	1001	6000041.217	500041.196
7	1000	6000050.000	500000.000

Since there were only three control points (SSMs), only three points contained MGA coordinates as shown in Table 5.14. In addition, because there were only three connection lines (as shown in Figure 5.9), only three observations had a CSF assigned to them, which can be interpreted from the LandXML file provided in Appendix E (see Sections 4.2.2 and 4.2.3 for more information on how to interpret LandXML code). Note that the CgPoint coordinates in this file (shown in Table 5.12) were locally defined (i.e. local ground coordinates – see Section 4.3.1).

The LandXML file was then checked by the Validation Service, but not all of its rules could be satisfied since an experimental file was used. For example, since made-up SSMs were used in the LandXML file, the Validation Service detected that they did not exist in the SCIMS database and, as such, it failed this check (see 'Rule #26' in the validation report provided in Appendix F). The other validation rules which did not pass failed for a similar reason.

However, all the mathematical checks of the Validation Service passed (e.g. 'Misclose' and 'PMs & traverse loops close' - refer to Appendix F). For this to occur, the LandXML file had to be meticulously created to ensure the MGA coordinates, CSF, ground distances of each line, and so forth, were mathematically in agreement with each other. For example, if a grid distance was calculated between any two control points (by computing the join between their MGA coordinates) and then scaled to its ground distance (using the CSF), then this value must fall within a reasonable tolerance range of the ground distance value stored in the LandXML file for that line. This is a simplified example demonstrating how the various quantities in a LandXML file must be mathematically in agreement with each other, in order for the Validation Service to pass all the mathematical checks (such as those mentioned above).

Note that the LandXML file tested in the previous experiment (see Section 5.1) would not have passed many of the Validation Service checks since it did not contain certain entities such as MGA coordinates, CSF and so forth.

The following modifications were then made to the LandXML file (refer to Tables 5.12, 5.13 and 5.14):

1. Distance of eastern boundary, i.e. Line 3-1, was increased by 5m (i.e. from 20m to 25m);
2. Bearing of eastern boundary, i.e. Line 3-1, was increased by 20° (i.e. from 180° to 200°);
3. CgPoint coordinates of north-eastern corner (i.e. Point 3; see Figure 5.9), were changed from (6000020,500020) to (6000030,500030) (i.e. a 10m increase in both the Northing and Easting);

4. CSF (shown in Appendix E) was changed from 0.9996 to 1.0000; and
5. MGA coordinates of Point 6 (i.e. SSM1001; see Figure 5.9), were changed from (6000041.217,500041.196) to (6000051.217,500051.196) (i.e. a 10m increase in both the MGA Northing and Easting).

The reason for which these entities were specifically selected for modification, was that they are the only quantitative entities in a real LandXML file which could potentially affect the plotting of the linework during ingestion.

Each time the LandXML file was modified it was ingested into each software to plot the survey plan's linework (defined by the file). The geometry of this linework was then checked using each software's inquiry tools to examine if there were any changes to the coordinates or observations, compared to the values stored in the ingested LandXML file.

Note that each modification was made and tested separately using a copy of the original version of the LandXML file (provided in Appendix E) to maintain a controlled experiment. The results obtained are outlined in the following section.

5.2.4 Results

After conducting this experiment, it was found that each software (i.e. LXML4AC, Stringer ePlan and 12d Model) obtained the same quantitative results (which have been tabulated in the following subsections).

The only difference between the diagrams produced using each software was in terms of how the observations from the LandXML file were used. That is, the LXML4AC and 12d Model annotated each line with the observations, whereas Stringer ePlan instead stored the observations as part of each line's data (this did not influence the geometry of the plotted linework in any way). Choi et al. (2017a) confirmed this to be the case with Stringer ePlan, but the reason is not relevant to this research.

Note that this section will only include the diagrams produced using LXML4AC whereas those produced using each of the other software (i.e. Stringer ePlan and 12d Model), are provided in Appendix G.

5.2.4.1 Modified Distance Test

The first modification made to the LandXML file (provided in Appendix E) is highlighted in Figure 5.10.

```
<ReducedObservation name="2" desc="Boundary" setupID="IS3" targetSetupID="IS1"
azimuth="180" horizDistance="25" distanceType="Measured"
```

Figure 5.10: Distance modification shown in red

After importing this file into each software, the diagrams produced (see Figure 5.11 and Appendix G) appeared almost identical to the original LandXML file diagrams (compare with Figure 5.9 and diagrams in Appendix G). The only difference found was that the annotated distance (or line data in Stringer ePlan) for Line 3-1, had changed from 20m to 25m.

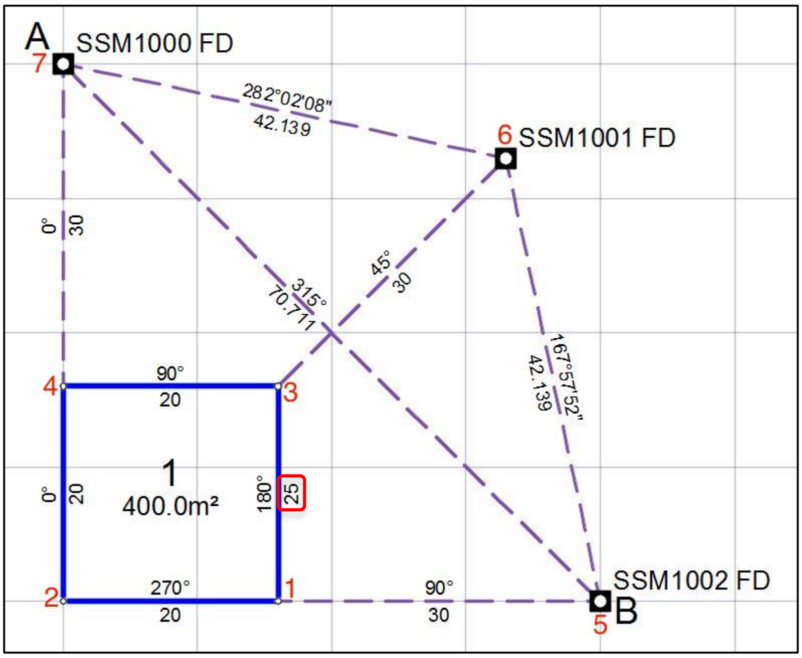


Figure 5.11: LXML4AC diagram for modified distance test

The coordinate and observation differences between the values stored in the LandXML file and the inquired values (using each software's inquiry tools), were then computed as shown in Tables 5.15, 5.16 and 5.17.

Table 5.15: Differences between CgPoint coordinates in LandXML file and inquired coordinate values

	Coordinates – file		Coordinates – inquired		Difference	
Point	N (m)	E (m)	N (m)	E (m)	ΔN (m)	ΔE (m)
1	6000000	500020	6000000	500020	0	0
2	6000000	500000	6000000	500000	0	0
3	6000020	500020	6000020	500020	0	0
4	6000020	500000	6000020	500000	0	0
5	6000000	500050	6000000	500050	0	0
6	6000041.213	500041.213	6000041.213	500041.213	0	0
7	6000050	500000	6000050	500000	0	0

Table 5.16: Differences between distances in LandXML file and inquired values

Line	Distance (m) – file	Distance (m) – inquired	|Difference|(m)
1–2	20	20	0
3–1	**25**	**20**	**5**
4–3	20	20	0
2–4	20	20	0
4–7	30	30	0
1–5	30	30	0
3–6	30	30	0
6–7	42.139	42.139	0
6–5	42.139	42.139	0
5–7	70.711	70.711	0

Table 5.17: Differences between bearings in LandXML file and inquired values

Line	Bearing – file	Bearing – inquired	∣Difference∣
1–2	270°	270°	0°
3–1	180°	180°	0°
4–3	90°	90°	0°
2–4	0°	0°	0°
4–7	0°	0°	0°
1–5	90°	90°	0°
3–6	45°	45°	0°
6–7	282°02'08"	282°02'08"	0°
6–5	167°57'52"	167°57'52"	0°
5–7	315°	315°	0°

5.2.4.2 Modified Bearing Test

The second modification made to the LandXML file (provided in Appendix E) is highlighted in Figure 5.12.

```
  <ReducedObservation name="2" desc="Boundary" setupID="IS3"
targetSetupID="IS1" azimuth="200" horizDistance="20" distanceType="Measured"
azimuthType="Measured" />
```

Figure 5.12: Bearing modification shown in red

After importing this file into each software, the diagrams produced (see Figure 5.13 and Appendix G) appeared almost identical to the original LandXML file diagrams (compare with Figure 5.9 and diagrams in Appendix G). The only difference found was that the annotated bearing (or line data in Stringer ePlan) for Line 3-1 had changed from 180° to 200°.

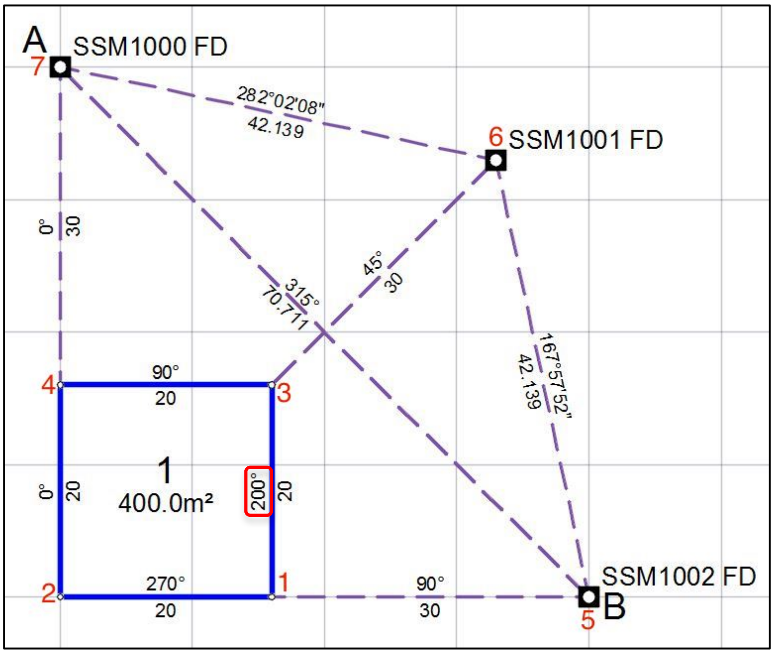


Figure 5.13: LXML4AC diagram for modified bearing test

The coordinate and observation differences between the values stored in the LandXML file and the inquired values (using each software's inquiry tools), were then computed as shown in Tables 5.18, 5.19 and 5.20.

Table 5.18: Differences between CgPoint coordinates in LandXML file and inquired coordinate values

	Coordinates – file		Coordinates – inquired		Difference	
Point	N (m)	E (m)	N (m)	E (m)	ΔN (m)	ΔE (m)
1	6000000	500020	6000000	500020	0	0
2	6000000	500000	6000000	500000	0	0
3	6000020	500020	6000020	500020	0	0
4	6000020	500000	6000020	500000	0	0
5	6000000	500050	6000000	500050	0	0
6	6000041.213	500041.213	6000041.213	500041.213	0	0
7	6000050	500000	6000050	500000	0	0

Table 5.19: Differences between distances in LandXML file and inquired values

Line	Distance (m) – file	Distance (m) – inquired	|Difference| (m)
1–2	20	20	0
3–1	20	20	0
4–3	20	20	0
2–4	20	20	0
4–7	30	30	0
1–5	30	30	0
3–6	30	30	0
6–7	42.139	42.139	0
6–5	42.139	42.139	0
5–7	70.711	70.711	0

Table 5.20: Differences between bearings in LandXML file and inquired values

Line	Bearing – file	Bearing – inquired	|Difference|
1–2	270°	270°	0°
3–1	**200°**	**180°**	**20°**
4–3	90°	90°	0°
2–4	0°	0°	0°
4–7	0°	0°	0°
1–5	90°	90°	0°
3–6	45°	45°	0°
6–7	282°02'08"	282°02'08"	0°
6–5	167°57'52"	167°57'52"	0°
5–7	315°	315°	0°

5.2.4.3 Modified CgPoint Coordinates Test

The third modification made to the LandXML file (provided in Appendix E) is highlighted in Figure 5.14.

```
<CgPoint state="proposed" pntSurv="boundary" name="3">6000030 500030</CgPoint>
```

Figure 5.14: CgPoint coordinate modification shown in red

After importing this file into each software, the position of the north-eastern corner of the lot, connecting Lines 4-3, 3-1 and 3-6, changed significantly as shown in Figure 5.15 and Appendix G (compare with original diagrams in Figure 5.9 and Appendix G). However, the annotated distances and bearings (or line data in Stringer ePlan) for these lines remained unchanged.

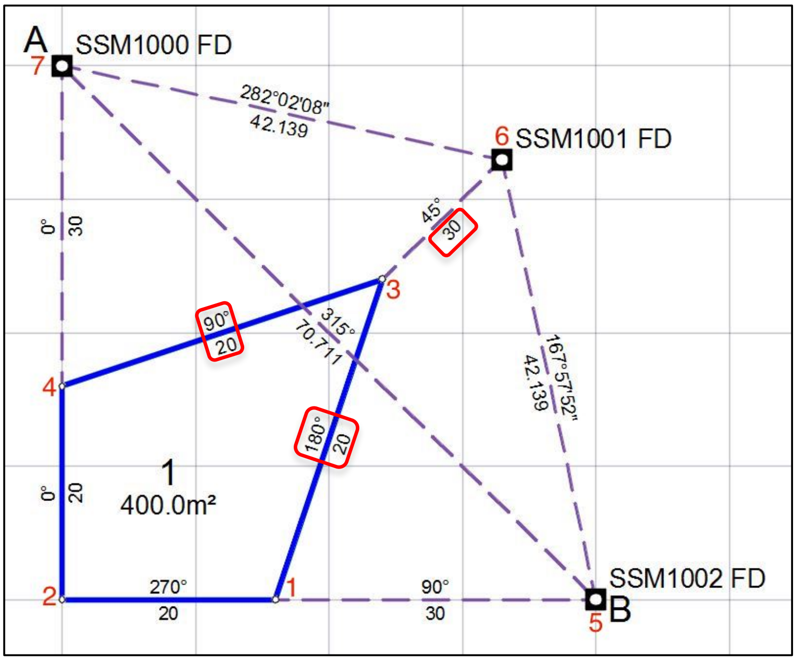


Figure 5.15: LXML4AC diagram for modified CgPoint coordinates test

The coordinate and observation differences between the values stored in the LandXML file and the inquired values (using each software's inquiry tools), were then computed as shown in Tables 5.21, 5.22 and 5.23.

Table 5.21: Differences between CgPoint coordinates in LandXML file and inquired coordinate values

	Coordinates – file		Coordinates – inquired		Difference	
Point	N (m)	E (m)	N (m)	E (m)	ΔN (m)	ΔE (m)
1	6000000	500020	6000000	500020	0	0
2	6000000	500000	6000000	500000	0	0
3	**6000030**	**500030**	**6000030**	**500030**	**0**	**0**
4	6000020	500000	6000020	500000	0	0
5	6000000	500050	6000000	500050	0	0
6	6000041.213	500041.213	6000041.213	500041.213	0	0
7	6000050	500000	6000050	500000	0	0

Table 5.22: Differences between distances in LandXML file and inquired values

Line	Distance (m) – file	Distance (m) – inquired	|Difference| (m)
1–2	20	20	0
3–1	**20**	**31.623**	**11.623**
4–3	**20**	**31.623**	**11.623**
2–4	20	20	0
4–7	30	30	0
1–5	30	30	0
3–6	**30**	**15.858**	**14.142**
6–7	42.139	42.139	0
6–5	42.139	42.139	0
5–7	70.711	70.711	0

Table 5.23: Differences between bearings in LandXML file and inquired values

Line	Bearing – file	Bearing – inquired	|Difference|
1–2	270°	270°	0°
3–1	**180°**	**198°26'06"**	**18°26'06"**
4–3	**90°**	**71°33'54"**	**18°26'06"**
2–4	0°	0°	0°
4–7	0°	0°	0°
1–5	90°	90°	0°
3–6	45°	45°	0°
6–7	282°02'08"	282°02'08"	0°
6–5	167°57'52"	167°57'52"	0°
5–7	315°	315°	0°

Overall, it was found that the inquired distances and/ or bearings of a few lines differed significantly from the values stored in the LandXML file.

5.2.4.4 Modified CSF and MGA Coordinates Tests

This section combines the results obtained after modifying the CSF and MGA coordinates because the outcome for both tests was identical. Note that the experimentation, however, was performed separately for each modification.

The fourth modification (i.e. modified CSF) made to the LandXML file (provided in Appendix E) is highlighted in Figure 5.16.

```
  <ReducedObservation name="8" desc="Connection" setupID="IS6" targetSetupID="IS7"
azimuth="282.0208" horizDistance="42.139" distanceType="Measured"
azimuthType="Measured"  distanceAdoptionFactor="1.0000"/>
  <ReducedObservation name="9" desc="Connection" setupID="IS6" targetSetupID="IS5"
azimuth="167.5752" horizDistance="42.139" distanceType="Measured"
azimuthType="Measured"  distanceAdoptionFactor="1.0000"/>
  <ReducedObservation name="10" desc="Connection" setupID="IS5" targetSetupID="IS7"
azimuth="315" horizDistance="70.711" distanceType="Measured"  azimuthType="Measured"
distanceAdoptionFactor="1.0000"/>
```

Figure 5.16: CSF modification shown in red

The final modification (i.e. modified MGA coordinates) made to the LandXML file (provided in Appendix E) is highlighted in Figure 5.17.

```
<RedHorizontalPosition name="12" setupID="IS6" latitude="6000051.217"
longitude="500051.196" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-08-07"/>
```

Figure 5.17: MGA coordinates modification shown in red

After separately importing each modified file into each software, the diagrams produced (see Figure 5.18 and Appendix G) appeared identical to the original LandXML file diagrams (compare with Figure 5.9 and diagrams in Appendix G).

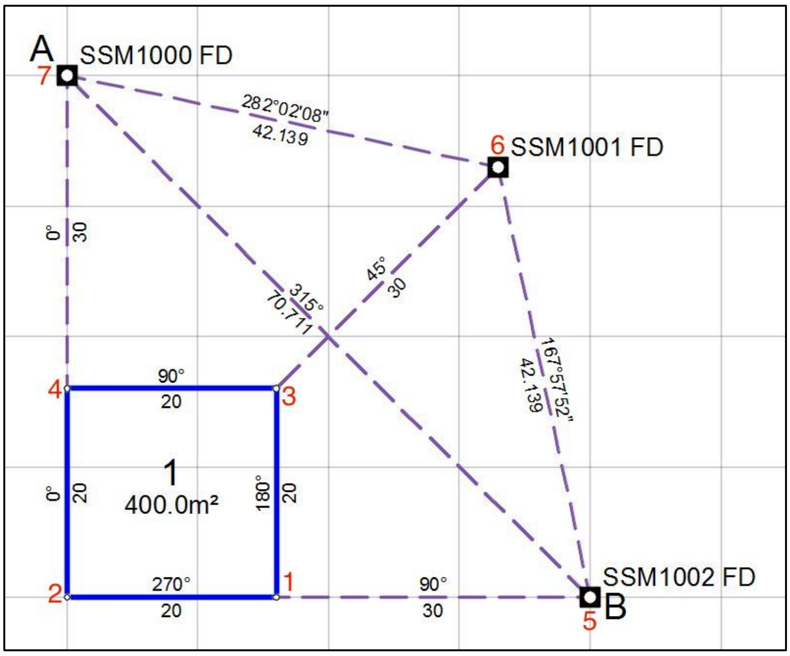


Figure 5.18: LXML4AC diagram for modified CSF and MGA coordinates tests

The coordinate and observation differences between the values stored in the LandXML file and the inquired values (using each software's inquiry tools) were then computed as shown in Tables 5.24, 5.25 and 5.26. Note that these results were for both the modified CSF and MGA coordinates tests.

Table 5.24: Differences between CgPoint coordinates in LandXML file and inquired coordinate values

	Coordinates – file		Coordinates – inquired		Difference	
Point	N (m)	E (m)	N (m)	E (m)	ΔN (m)	ΔE (m)
1	6000000	500020	6000000	500020	0	0
2	6000000	500000	6000000	500000	0	0
3	6000020	500020	6000020	500020	0	0
4	6000020	500000	6000020	500000	0	0
5	6000000	500050	6000000	500050	0	0
6	6000041.213	500041.213	6000041.213	500041.213	0	0
7	6000050	500000	6000050	500000	0	0

Table 5.25: Differences between distances in LandXML file and inquired values

Line	Distance (m) – file	Distance (m) – inquired	|Difference|(m)
1–2	20	20	0
3–1	20	20	0
4–3	20	20	0
2–4	20	20	0
4–7	30	30	0
1–5	30	30	0
3–6	30	30	0
6–7	42.139	42.139	0
6–5	42.139	42.139	0
5–7	70.711	70.711	0

Table 5.26: Differences between bearings in LandXML file and inquired values

Line	Bearing – file	Bearing – inquired	|Difference|
1–2	270°	270°	0°
3–1	180°	180°	0°
4–3	90°	90°	0°
2–4	0°	0°	0°
4–7	0°	0°	0°
1–5	90°	90°	0°
3–6	45°	45°	0°
6–7	282°02'08"	282°02'08"	0°
6–5	167°57'52"	167°57'52"	0°
5–7	315°	315°	0°

5.2.5 Discussion

Analysing the results obtained for this experiment led to the following findings.

The results obtained for the first three tests (see Sections 5.2.4.1, 5.2.4.2 and 5.2.4.3) were identical in nature to the results obtained for the three tests of the previous experiment (see Sections 5.1.4.1, 5.1.4.2 and 5.1.4.3). As such, the detailed discussions made in Section 5.1.5 can be applied to the results of the first three tests in this experiment.

To summarise some of the key points from the first three tests, it was found that the CgPoint coordinates were exclusively used to plot the linework of the LandXML file after being ingested into each software. This was concluded after observing that the linework geometry was not affected by any of the three modifications (i.e. distance, bearing and CgPoint coordinates), except after modifying the CgPoint coordinates as shown in Section 5.2.4.3. The observation differences computed between the data in the ingested LandXML file and the inquired geometry of the linework (using each software's inquiry tools) is shown in Tables 5.22 and 5.23.

One initially unexpected result found after this modification was that there was no change in the bearing of Line 3-6 even though its distance changed (see Tables 5.22 and 5.23). This was concluded to be due to the coordinates of Point 3 being modified equally in the Northing and Easting direction. Furthermore, since the bearing of Line 3-6 was 45°, the change in the coordinates of one of its endpoints caused its distance to be shortened in the same direction. This explains why there was no bearing change observed despite there being a distance change (see Figures 5.9 and 5.15).

The results obtained for the fourth and fifth tests (see Section 5.2.4.4) indicate that the CSF and MGA coordinates stored in the LandXML file had no effect on the plotted linework when ingested into any of the software tested. This is because no change was detected to the linework geometry after individually modifying each of these entities, as shown in Tables 5.24, 5.25 and 5.26. This result was unprecedented since the effects of these entities on the plotted linework was initially ambiguous.

In all five tests performed it was found that the bearing and distance annotations shown for the linework (or line data in Stringer ePlan as explained at the beginning of Section 5.2.4), were based on the observations stored in the LandXML file, since they only changed whenever the observations in the file were modified (see Sections 5.2.4.1, 5.2.4.2, 5.2.4.3 and 5.2.4.4). This finding agreed with that obtained in the previous experiment (see Section 5.1).

Overall, these results provide conclusive evidence that whenever a LandXML file is ingested into any of the software tested in this experiment (i.e. LXML4AC, Stringer ePlan or 12d Model), the CgPoint coordinates from the file were used to plot the survey plan linework. All other quantitative entities in the file such as: observations, MGA coordinates and CSF had no effect on this linework. These results were consistent with those obtained in the previous experiment (see Section 5.1).

In this experiment only two additional software were tested, in contrast to the previous one, therefore reliability was limited due to other existing software not being tested (the reason for this has been mentioned in Section 5.2.1). It is possible that other NSW CAD software exist which also use CgPoints for LandXML ingestion, since coordinates are generally required in surveying software (see Section 3.3.3) and thus, this is a potential area for future research. Note that this study focused only on software which are used by the NSW surveying industry. There are, however, other states and jurisdictions in Australia which use different surveying software and can also ingest LandXML files (the LandXML schema, however, will be different to the NSW schema, as mentioned in Section 2.3.5). This is another potential area for future research since these software can be tested to determine if they use CgPoints for ingestion.

In an attempt to understand why the vendors of the software tested in this experiment developed their software to use CgPoint coordinates for ingesting LandXML files (despite the LPI constantly urging them to instead use the observations – see Section 3.3.3), each vendor was personally contacted by the researcher (Software Vendors, 2017). It became apparent that one of the primary reasons for developing their software in such a manner was due to their assumption that all LandXML files ingested into their software will be created in the same way as files created by their own software. This involved assuming that the CgPoint coordinates will always be locally defined (i.e. CgPoints will derive ground distances when ingested), which is fairly plausible since this is indeed how CgPoints are normally defined (see Section 4.3.1). To further confirm the plausibility of this assumption, Choi (2017b) states that, in his opinion, the coordinates of CgPoints are locally defined in all LandXML files.

However, upon analysing a multitude of LandXML files, the researcher found that CgPoint coordinates are not always locally defined. This will consequently result in the distances computed for the linework geometry differing from the ground distances stored in the LandXML file if CgPoints are used for ingestion. The following chapter will discuss this problem, as well as other problems found with CgPoints, if they are used for importing LandXML files.

6 Experimentation – Part B

The previous chapter performed experiments which demonstrated that each of the software tested (i.e. LXML4AC, Stringer ePlan and 12d Model) exclusively use CgPoint coordinates to plot the survey plan linework when ingesting LandXML files. This chapter will demonstrate some of the problems associated with using this method for ingestion, which primarily relate to the coordinate system used by the CgPoints. It will then conclude by recommending the use of bearings and distances as a more preferable and reliable method, without further elaboration.

6.1 Experiment 3: Ingesting Grid CgPoint Coordinates

6.1.1 Introduction

After analysing many LandXML files exported from a software program called GeoCadastre, it was found that the CgPoint coordinates consisted of MGA grid rather than local ground coordinates (the files analysed were sourced directly from the LPI). This is contrary to what was previously stated in Section 4.2.2 that CgPoints contain local coordinates, which is also in accordance with the claims made by Choi and Deal (2017).

The aim of this experiment was to ascertain whether the resulting coordinate system of CgPoints in a LandXML file exported from GeoCadastre, is indeed on MGA. Another purpose of this experiment was to demonstrate the effect this had on the plotted linework when ingested into a software which uses CgPoints for ingestion.

6.1.2 GeoCadastre

GeoCadastre is a software program which can be used to create LandXML files for an EPlan lodgment. For this research, Version 5.82 of this software was used.

This software was originally developed for cadastral modelling and thus is not a CAD software. However, surveyors are currently using this software to create and export LandXML files after a TIFF plan has been drafted. Note that this is because both a TIFF and LandXML file currently need to be lodged for an EPlan lodgment (see Section 2.4.3). There have been about 21 LandXML lodgments using GeoCadastre as at 12th September 2017, based on the data shown in Figure 3.1.

One of the methods adopted by surveyors to create a LandXML file from GeoCadastre is to manually capture data from an existing TIFF plan into the software (Baxter, 2017). Doing so will also allow for any plan drafting errors to be detected. After the data has been captured it is adjusted by least squares to fit any available control points. Elfick (2017a) claims that when a least squares adjustment (LSA) is performed in GeoCadastre, the control points are adopted as 'fixed' and the adjusted coordinates for all the points (which will be CgPoints after creating the LandXML file) will be on the control point datum. For example, if the datum of the control points used in the adjustment is on MGA, the resulting coordinate system for all the CgPoints will be on MGA.

The control point datum could be: Local, MGA, ISG and so forth. In NSW, the control point datum used in most LandXML files is usually MGA, as stated by Choi (2017b). The following experiment will therefore use a LandXML file containing control points on MGA since this is the case with most real files.

Elfick (2017b) further claims, regarding the LSA in GeoCadastre, that the original bearings and distances of inputted data are retained in GeoCadastre and are not adjusted by the LSA. The specific details on how GeoCadastre performs the LSA will not be discussed since this falls beyond the scope of this study.

6.1.3 Method

In order to determine if LandXML files created from GeoCadastre contain MGA coordinates for the CgPoints, a LandXML file was firstly created (using LXML4AC) and then ingested into GeoCadastre. Note that the data could have also been manually captured into the software (see previous section), but there would have been no difference on account of the method used. An LSA was then performed on the data before exporting a new LandXML file from GeoCadastre to examine if there were any changes to its contents.

The exported file was then ingested into LXML4AC (since it was known to use CgPoints for LandXML ingestion) and the geometry of the plotted linework was analysed. Note that any of the other software tested previously (i.e. Stringer ePlan or 12d Model – see Section 5.2) could have been used since they also use CgPoints for ingestion.

The original LandXML file created (see Appendix I) consisted of a rectangular lot with an area of 1000m² as shown in Figure 6.1 (Appendix H provides an enlarged view of this figure). The eastern and western boundaries were 10m in length whilst the northern and southern boundaries were 100m. The lot also contained connections to three SSMs with MGA coordinates as well as a CSF of 0.9996 since it was situated along the central meridian of Zone 56. The width of the lot was purposely elongated to magnify suspected scaling effects in the results.

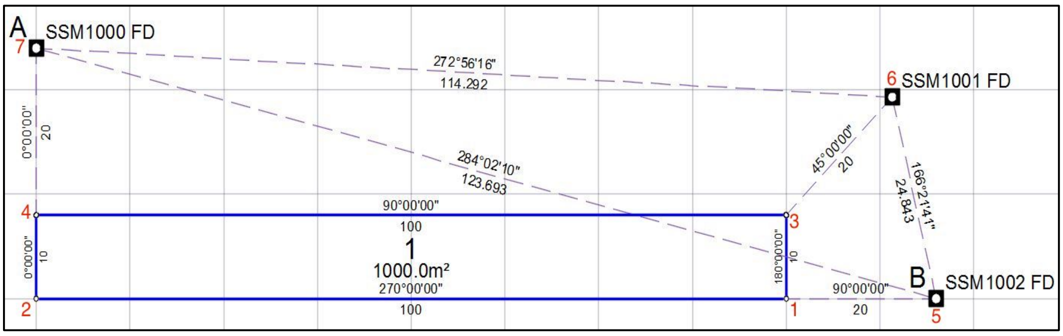


Figure 6.1: Lot defined by the blue lines and SSM connections shown in purple

After interpreting the LandXML file created (see Appendix I), the relevant data was tabulated as shown in Tables 6.1, 6.2 and 6.3.

Table 6.1: CgPoint coordinates

Point	Northing (m)	Easting (m)
1	6000000	500100
2	6000000	500000
3	6000010	500100
4	6000010	500000
5	6000000	500120
6	6000024.142	500114.142
7	6000030	500000

Table 6.2: Line distances and bearings

Line	Distance (m)	Bearing
1–2	100	270°
3–1	10	180°
4–3	100	90°
2–4	10	0°
4–7	20	0°
1–5	20	90°
3–6	20	45°
6–7	114.292	272°56'16"
6–5	24.843	166°21'41"
5–7	123.693	284°02'10"

Table 6.3: MGA coordinates of control points

Point	SSM #	Northing (m)	Easting (m)
5	1002	6000000.012	500119.952
6	1001	6000024.145	500114.097
7	1000	6000030	500000

Note that the CgPoint coordinates in this LandXML file were locally defined (i.e. local ground coordinates – see Section 4.3.1). As was the case in the previous experiment, this file was also checked by the Validation Service to ensure that it cleared all the mathematical checks before proceeding with the experimentation (see Appendix J for the validation report). Also note that not all the Validation Service rules were satisfied due to the same reasons outlined in Section 5.2.3.

The file was then ingested into GeoCadastre and the diagram produced is as shown in Figure 6.2 (Appendix H provides an enlarged view of this figure).

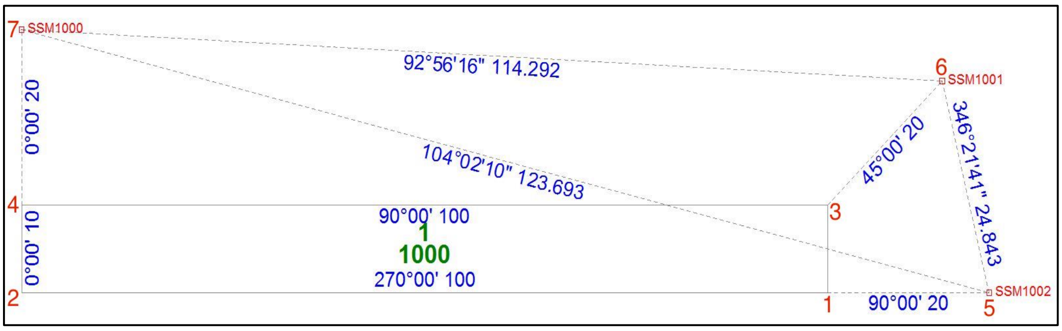


Figure 6.2: Diagram created after ingesting the LandXML file into GeoCadastre

An LSA was then performed whilst holding the three control points (i.e. SSMs) fixed. Note that the LSA procedure adopted was based on the recommendations of Baxter (2017) and Elfick (2017a) who are both registered surveyors that use GeoCadastre for creating LandXML files.

After the adjustment process, a new LandXML file was exported from GeoCadastre (see Appendix K) and comparisons were made between the data contained in this file and the original file (which was ingested into GeoCadastre – see Appendix I), to determine whether there were any changes to the CgPoint coordinates and observations. These were specifically chosen to be analysed to verify Elfick's claims which were mentioned in Section 6.1.2.

The exported LandXML file from GeoCadastre was then ingested into the LXML4AC software and the plotted linework checked using the software inquiry tools, to examine if there were any changes to its geometry.

6.1.4 Results

The CgPoint coordinate and observation differences between the imported and exported LandXML files from GeoCadastre were calculated as shown in Tables 6.4, 6.5 and 6.6.

Table 6.4: Differences between CgPoint coordinates in imported and exported LandXML files

	Imported CgPoint Coord's		Exported CgPoint Coord's		Diff (mm)	
Point	N (m)	E (m)	N (m)	E (m)	ΔN	ΔE
1	6000000	500100	6000000.012	500099.96	**12**	**40**
2	6000000	500000	6000000.012	500000	**12**	**0**
3	6000010	500100	6000010.008	500099.96	**8**	**40**
4	6000010	500000	6000010.008	500000	**8**	**0**
5	6000000	500120	6000000.012	500119.952	**12**	**48**
6	6000024.142	500114.142	6000024.145	500114.097	**3**	**45**
7	6000030	500000	6000030	500000	**0**	**0**

Table 6.5: Differences between distances in imported and exported LandXML files

Line	Distance (m) – imported	Distance (m) – exported	|Difference| (m)
1–2	100	100	**0**
3–1	10	10	**0**
4–3	100	100	**0**
2–4	10	10	**0**
4–7	20	20	**0**
1–5	20	20	**0**
3–6	20	20	**0**
6–7	114.292	114.292	**0**
6–5	24.843	24.843	**0**
5–7	123.693	123.693	**0**

Table 6.6: Differences between bearings in imported and exported LandXML files

Line	Bearing – imported	Bearing – exported	|Difference|
1–2	270°	270°	**0°**
3–1	180°	180°	**0°**
4–3	90°	90°	**0°**
2–4	0°	0°	**0°**
4–7	0°	0°	**0°**
1–5	90°	90°	**0°**
3–6	45°	45°	**0°**
6–7	272°56'16"	272°56'16"	**0°**
6–5	166°21'41"	166°21'41"	**0°**
5–7	284°02'10"	284°02'10"	**0°**

The differences between the CgPoint and MGA coordinates of the control points in the LandXML file exported from GeoCadastre, were also calculated as shown in Table 6.7.

Table 6.7: Differences between exported CgPoint coordinates and MGA coordinates of control points

		MGA Coordinates		Exported CgPoint Coord's		Diff (mm)	
Pt	SSM #	Northing (m)	Easting (m)	Northing (m)	Easting (m)	ΔN	ΔE
5	1002	6000000.012	500119.952	6000000.012	500119.952	**0**	**0**
6	1001	6000024.145	500114.097	6000024.145	500114.097	**0**	**0**
7	1000	6000030	500000	6000030	500000	**0**	**0**

After importing the LandXML file (created using GeoCadastre) into LXML4AC, the differences between the observations in the imported file and the geometry of the plotted linework (which was determined using the software inquiry tools), were calculated as shown in Tables 6.8 and 6.9.

Table 6.8: Differences between distances in LandXML file and inquired values

Line	Distance (m) – file	Distance (m) – inquired	|Difference| (m)	$\left(\frac{\text{inquired}}{\text{file}}\right)$
1–2	100	99.96	**0.04**	**0.9996**
3–1	10	9.996	**0.004**	**0.9996**
4–3	100	99.96	**0.04**	**0.9996**
2–4	10	9.996	**0.004**	**0.9996**
4–7	20	19.992	**0.008**	**0.9996**
1–5	20	19.992	**0.008**	**0.9996**
3–6	20	19.992	**0.008**	**0.9996**
6–7	114.292	114.247	**0.045**	**0.9996**
6–5	24.843	24.833	**0.01**	**0.9996**
5–7	123.693	123.644	**0.049**	**0.9996**

Table 6.9: Differences between bearings in LandXML file and inquired values

Line	Bearing – file	Bearing – inquired	|Difference|
1–2	270°	270°	**0"**
3–1	180°	180°00'01"	**1"**
4–3	90°	90°	**0"**
2–4	0°	0°	**0"**
4–7	0°	0°00'01"	**1"**
1–5	90°	90°	**0"**
3–6	45°	45°00'02"	**2"**
6–7	272°56'16"	272°56'15"	**1"**
6–5	166°21'41"	166°21'46"	**5"**
5–7	284°02'10"	284°02'10"	**0"**

6.1.5 Discussion

Analysing the results obtained for this experiment led to the following findings.

After comparing the CgPoint coordinates in the imported and exported LandXML files from GeoCadastre, it was found that these values differed slightly as shown in Table 6.4. In addition, after comparing the CgPoint coordinates of Points 5, 6 and 7 (control points) with their respective MGA coordinates in the exported file, it was found that these values were equivalent as shown in Table 6.7.

These results indicate that the CgPoint coordinates in the imported file (which were originally local ground coordinates, as mentioned in Section 6.1.3) changed to MGA grid coordinates after being exported from GeoCadastre, and this resulted from conducting an LSA. It was also observed that the observations remained unchanged between the imported and exported LandXML files, as shown in Tables 6.5 and 6.6, indicating that they were not adjusted by the LSA.

These results validate the claims made by Elfick which were mentioned in Section 6.1.2.

This outcome demonstrates that by following a normal procedure taken by surveyors to create LandXML files from GeoCadastre, the resulting CgPoint coordinates will indeed consist of MGA coordinates. Note that this is contrary to what was stated by Choi and Deal (2017) and Choi (2017b); that CgPoint coordinates in a LandXML file are locally defined. The effect of storing MGA coordinates for the CgPoints, rather than local ground coordinates, was demonstrated by the second part of the experiment.

After ingesting the LandXML file (created using GeoCadastre) into LXML4AC, it was found that the inquired distances of the linework (determined using the software inquiry tools) differed from those stored in the file by a factor of 0.9996, as shown in Table 6.8. Note that this value is equivalent to the CSF used for the original LandXML file (see Section 6.1.3).

This indicates that the distance of each plotted line in LXML4AC had been scaled by a factor of 0.9996 (compared to those stored in the file) and this was due to the CgPoints (which consisted of MGA coordinates) being used to plot the linework during ingestion. As a result, the software produced linework geometry consisting of MGA grid distances, derived by computing the join between the coordinates (see Section 4.3.1). This explains why the inquired distances differed by a factor of 0.9996 compared to the values in the imported file (which remained as ground distances as mentioned previously).

This result clearly demonstrates that importing a LandXML file, created using GeoCadastre, into a software which uses CgPoints for ingestion, results in the linework geometry being comprised of grid rather than ground distances. This outcome was somewhat expected since it was already known that LXML4AC uses CgPoints for ingestion, rendering the effect of using MGA grid coordinates for the CgPoints somewhat predictable.

Although no significant difference was found between the inquired distances of the linework and those stored in the file (see Table 6.8), the error would be far more significant had these results been extrapolated over much longer distances. For example, if a 1000m line was scaled by 0.9996, the error in the resulting distance (compared to its original value) would be 400mm, which does not fall within reasonable cadastral surveying tolerances. If this concept is applied to an entire LandXML file (consisting of long lines), it would be found that the resulting distances for each plotted line differs significantly from the ground distances stored in the file.

Unexpectedly, the results obtained after computing the difference between the inquired bearings (of the linework) and those stored in the file (see Table 6.9), show that there was a small difference between these values. These differences were caused by rounding off errors during the computation of each line's bearing from the grid coordinates by the software (see Section 4.3.1 for more details). However, by considering the fact that 1' of arc over 100m develops approximately 29mm in error, it was concluded that all the bearing differences found were negligible. Note that this could potentially become a more serious problem in the case of larger LandXML files (which may involve longer lines).

There are many problems to consider in using the plotted linework of a survey plan which consists of grid distances. Firstly, it should be noted that a great deal of ambiguity is involved as it will not be immediately known that grid distances are being used for the linework; a surveyor may assume that LandXML files always derive ground distances when ingested (since this is what survey plans use). This will not be known without thoroughly comparing the linework geometry with the observations provided in the LandXML file. Note that comparisons should also be made based on the original TIFF plan which is the current legal plan document in NSW.

Another problem to be considered is the fact that many registered surveyors do not deal with MGA coordinates or scale factors in their day-to-day work according to Chami (2017). This, therefore, will need to be considered if the plotted linework is not already in ground distances since the data will need to be unscaled (from grid distances) before being used; this will impact the instant usability of ingested LandXML data.

Note that if GeoCadastre was used to ingest its own files (which contain MGA grid coordinates for the CgPoints), the linework will be plotted accurately since it normally stores the MGA coordinates of points in its database (assuming the control point datum is on MGA – see Section 6.1.2). On the other hand, if a LandXML file containing locally defined CgPoints was ingested, the linework geometry will be inaccurate when initially ingested since the software will assume the CgPoint coordinates are in MGA. Elfick (2017a) therefore recommends that an LSA is performed whenever a LandXML file is ingested into GeoCadastre since it also analyses how everything fits together.

Although this experiment demonstrated that LandXML files created using GeoCadastre contain MGA coordinates for the CgPoints, it is currently unknown if this problem is also prevalent among other available software. It is possible that other software create LandXML files containing CgPoints with various other problems not investigated in this study. This is a potential area for future research; the plotted linework geometry will be affected depending on the CgPoint coordinates used, when ingested in a software that uses CgPoints and this is why this ingestion method is not reliable.

Thus far, the focus of this research has been on the ingestion of single LandXML files. The following experiment will analyse another problem discovered when ingesting more than one LandXML file using CgPoints.

6.2 Experiment 4: Ingesting More Than One LandXML File

6.2.1 Introduction

6.2.1.1 Background

As mentioned in Section 3.3.2, surveyors sometimes capture more than one survey plan simultaneously, rather than just a single plan, when starting a new survey. This experiment will therefore investigate any problems associated with ingesting more than one LandXML file using CgPoints. However, before doing so it is important to discuss how each LandXML can contain its own coordinate reference system (CRS) for the CgPoints to understand the following experiment.

This discussion will be based on a single method out of the various methods in which survey plans (and hence LandXML files) are created by surveyors. Note that understanding the concept of 'locally defined' coordinates, which was described in Section 4.3.1, is requisite for the following discussion.

Consider a scenario where two surveyors used a GNSS unit to conduct adjoining surveys which will derive MGA coordinates for control points as well as other surveyed features. The following assumptions would be observed:

- The CSF was *not* 1;
- Both surveys observed two common control points called (a) and (b) which are on MGA, such that the azimuth of the resulting survey plans will be the same; and
- The surveyed MGA coordinates for each control point (i.e. (a) and (b)) was equivalent to their SCIMS MGA coordinates for simplicity (i.e. no errors).

When each plan is drafted in CAD, both surveyors scale their observations (which consist of grid distances if the join is computed between the MGA coordinates of surveyed points) to ground distances, since this is what survey plans use (see Section 3.3.2). To complete this process, each surveyor begins scaling their observations from a certain origin, which could be either one of the control points (i.e. (a) or (b)). Suppose the first surveyor chooses to scale their observations from point (a) and the second surveyor chooses to do so from point (b). This process will result in all the points in each survey adopting a new set of coordinates except for the origin points (i.e. (a) and (b) in the first and second surveys respectively), which will retain their surveyed MGA coordinates. This also results in the second surveyed control point (i.e. (b) and (a) in the first and second surveys respectively) adopting a new set of coordinates.

Overall, since different origins were used to perform the scaling process for each survey, the coordinates of all the points from the first survey will no longer be in the same CRS as those from the second survey (i.e. each survey contains a unique set of locally defined coordinates for the points).

If a LandXML file is then created for each survey, the CgPoints in each file will adopt the locally defined coordinates of the points from their respective surveys (note that this is the procedure adopted by most software such as: Stringer ePlan and Magnet Office) (Banks, 2017, Choi et al., 2017a). Each LandXML file will therefore contain its own CRS for the CgPoints due to the method in which the coordinates were originally defined. Thus, the CgPoint coordinates from each file cannot be related to each other unless those from one file are transformed into the CRS of the other.

To clarify this problem, consider Figure 6.3, which shows an extract of the LandXML file provided in Appendix E. Note that only the control point data is shown since only control points contain both CgPoint and MGA coordinates, as mentioned in Section 4.2.2.

```
  <CgPoint state="existing" pntSurv="control" oID="1002" desc="B"
name="5">6000000 500050</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1001" name="6">6000041.213
500041.213</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1000" desc="A"
name="7">6000050 500000</CgPoint>

  <RedHorizontalPosition name="11" setupID="IS5" latitude="6000000.021"
longitude="500049.979" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-08-07"/>
  <RedHorizontalPosition name="12" setupID="IS6" latitude="6000041.217"
longitude="500041.196" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-08-07"/>
  <RedHorizontalPosition name="13" setupID="IS7" latitude="6000050.000"
longitude="500000.000" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-08-07"/>
```

Figure 6.3: LandXML file extract from Appendix E

Figure 6.3 shows that the only control point which has equivalent CgPoint and MGA coordinates is Point 7, since this point was used as the origin in the scaling process described previously (note that the CSF is 0.9996). Suppose this LandXML file had an adjoining file containing the same control points and that the scaling process was performed starting from Point 5 as the origin, instead of Point 7. This will result in each point (except for Point 5) adopting a new set of coordinates for the CgPoints which differs from their respective MGA coordinates, as shown in Figure 6.4.

```
  <CgPoint state="existing" pntSurv="control" oID="1002" desc="B"
name="5">6000000.021 500049.979</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1001" name="6">6000041.234
500041.192</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1000" desc="A"
name="7">6000050.020 499999.980</CgPoint>

  <RedHorizontalPosition name="11" setupID="IS5" latitude="6000000.021"
longitude="500049.979" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-08-07"/>
  <RedHorizontalPosition name="12" setupID="IS6" latitude="6000041.217"
longitude="500041.196" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-08-07"/>
  <RedHorizontalPosition name="13" setupID="IS7" latitude="6000050.000"
longitude="500000.000" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-08-07"/>
```

Figure 6.4: Adjoining LandXML file

After comparing the CgPoint coordinates in Figures 6.3 and 6.4, it can be observed that each file contains a unique set of locally defined coordinates for the CgPoints (and hence a unique CRS), since the scaling process was conducted from different origins. This concept will be applied in the following experiment.

6.2.1.2 The Experiment

The aim of this experiment was to analyse how well more than one LandXML file would fit together when ingested into a software using their CgPoint coordinates, and this was performed using two adjoining LandXML files. The CgPoints in both files were defined in the same manner as that described in the previous section (i.e. each file had its own CRS and the CgPoint coordinates were close to MGA coordinates).

6.2.2 Method

In order to analyse how well more than one LandXML file would fit together using CgPoint coordinates, two adjoining files were acquired from the LPI and then ingested into LXML4AC. This demonstrated whether or not more than one LandXML file can be related, when ingested using the CgPoints.

The LXML4AC software was chosen to be used for this experiment since it was known to use CgPoints for LandXML ingestion. Note that any of the other software tested previously (i.e. Stringer ePlan or 12d Model) could have also been used, since they were previously shown to use CgPoints for ingestion (see Section 5.2).

The two deposited plans (DPs) (which consisted of both LandXML and TIFF files for each plan) acquired were: DP1215315 and DP1218302. These files were created using the Landmark and Magnet Office software respectively and have a CSF of 1.00006. Furthermore, the azimuth of these files was the same (i.e. MGA), since their control points were on MGA. Note that the actual LandXML files have not been included in this thesis due to their size, but their associated TIFF plans have been provided in Appendix L.

The two LandXML files (of the DPs) were then ingested into LXML4AC and comparisons were made between the plotted coordinates (which were based on the CgPoints contained in each file) of common control points and cadastral reference marks identified in both plans (these have been circled and labelled in red on the plans shown in Appendix L). The coordinates were determined using the LXML4AC software's inquiry tools.

6.2.3 Results

Table 6.10 shows the results obtained after comparing the coordinates of common points found in the adjoining LandXML files.

Table 6.10: Differences between coordinates of common points in the two DPs

		DP1215315		DP1218302		Diff (mm)	
Pt	Mark	Northing (m)	Easting (m)	Northing (m)	Easting (m)	ΔN	ΔE
1	SSM	6268955.935	304466.92	6268955.967	304466.892	**32**	**28**
2	SSM	6268962.505	304388.784	6268962.534	304388.757	**29**	**27**
3	SSM	6268983.074	304232.917	6268983.099	304232.896	**25**	**21**
4	PM	6269081.938	304244.893	6269081.961	304244.859	**23**	**34**
5	DH&W	6268928.24	304222.336	6268928.261	304222.322	**21**	**14**
6	DH&W	6268918.348	304296.437	6268918.376	304296.409	**28**	**28**
7	DH&W	6268915.565	304305.377	6268915.594	304305.348	**29**	**29**
8	GIP	6268910.182	304345.353	6268910.215	304345.331	**33**	**22**
9	DH&W	6268897.579	304426.545	6268897.619	304426.513	**40**	**32**

6.2.4 Discussion

Analysing the results obtained for this experiment led to the following findings.

It was found that there was some variation between the coordinates of common points shown in both DPs (see Table 6.10) and this was expected since each LandXML file had its own CRS, as mentioned in Section 6.2.1.2.

The maximum difference found between the two sets of coordinates was for Point 9, which differed by 40mm in the Northing and 32mm in the Easting. This indicates that the CRS of the CgPoints in both LandXML files was fairly close and by considering the applications of LandXML files (see Section 3.2), the CgPoints from both files can be treated as though they are related to the same CRS. This is because if the CgPoint coordinates from both LandXML files were used to search for survey marks, for example, a surveyor would still be able to locate most, if not all the marks due to the small difference found between the coordinates of the adjoining files (see Table 6.10). However, if there was a larger difference found, it would undoubtedly cause difficulty when searching for survey marks (especially for underground mark types such as GIPs or concrete blocks).

Overall, it was expected that the adjoining LandXML files analysed in this experiment would fit quite well together, since the CgPoint coordinates in both files were already close to the MGA coordinates of their control points (some of which were common to both files). Note however, that some LandXML files can contain arbitrary (or assumed) CgPoint coordinates which could be thousands of metres different to the MGA coordinates of their control points, as mentioned in Section 4.3.2. The coordinates used for the CgPoints depends exclusively on the method in which a LandXML file is created; whether a surveyor chooses to work near MGA or adopt arbitrary coordinates. This is one of the limitations of this experiment, since it did not demonstrate the problem with ingesting adjoining LandXML files containing arbitrary CgPoint coordinates. Had this been the case for this experiment, the data from the adjoining files would have been separated completely from each other after ingestion, due to the large difference between each file's CRS for the CgPoints. Appendix M provides an extract of a LandXML file containing arbitrary CgPoint coordinates. This appendix shows that the CgPoint and MGA coordinates of the control points differ significantly.

Other limitations of this experiment include:

- It did not demonstrate the case where a LandXML file created using GeoCadastre (which contains MGA coordinates for the CgPoints, as shown in the previous experiment) and an adjoining file containing local ground coordinates for the CgPoints were ingested together using their CgPoints. Had this been the case, it would not be possible to relate each data set unless coordinate transformations are completed;
- It did not demonstrate the problem with ingesting LandXML files which are on different azimuths using the CgPoints. Had this been the case, the ingested data from each file would differ by a certain azimuth swing which would need to be applied in order for the files to be related to one another; and
- It did not demonstrate the case where the CSF of adjoining LandXML files was 1. Had this been the case, there would be no difference found between the CgPoint and MGA coordinates in each file (i.e. no scaling would be needed since grid and ground distances would be equivalent – see Section 6.2.1.1), and thus the CgPoint coordinates of common points in both files would be equivalent (assuming no errors occur).

Overall, there are various factors which must be considered when ingesting more than one LandXML file using CgPoints, which affects the instant usability of the data, hence its reliability, since a surveyor needs to be aware of all these previously mentioned factors. The following section will briefly outline a few other problems found with CgPoints during the course of this research.

6.3 Other Problems Associated with CgPoints

A few other problems found with ingesting LandXML files using CgPoints include:

- CgPoint coordinates are not checked by the LPI during the examination process of an EPlan lodgment and thus are not verified;
- When drafting a survey plan in CAD, surveyors sometimes manually modify the surveyed position of certain points for drafting purposes. For example, suppose an SSM was located a long way from a surveying site (e.g. 1.5km) and the resulting survey plan was to be plotted at a scale of 1:100, while the survey consisted of a single 20 by 50m block, then the position (and hence CgPoint coordinates) of the SSM and any lines that come from it, can be manually changed to be closer to the block. Note however, that the original bearings and distances for these lines will be retained. This file would pass LPI examination since only the bearings and distances are checked (Deal, 2017c). If this file is then ingested into a software which uses CgPoints, the geometry of the plotted linework (for the lines that come from the SSM), will be incorrect since the CgPoint coordinates of the SSM were modified;
- If adjoining LandXML files (at zone boundaries) exist in separate zones, the CgPoint coordinates of one file must be transformed into the zone of the other for them to be related. This will impact the instant usability of ingested LandXML data; and
- CgPoint coordinates are only static in time and therefore, as survey plans are updated, they will change. Problems could therefore arise when trying to relate between an old and new plan using CgPoint coordinates (especially if a new LandXML file for a plan, adopts arbitrary coordinates which are completely different to those used in a previous LandXML file).

6.4 Conclusion

It can be clearly seen that ingesting LandXML files using CgPoints causes numerous problems which affect the instant usability and reliability of the ingested data.

In order for the linework of a survey plan to be plotted accurately from a LandXML file in a software, it is crucial that the observations are exclusively used for ingestion. This is because only the observations, and not CgPoint coordinates, are verified by the LPI during examination of a LandXML file (see Section 2.4.4).

The author found two software which were able to ingest LandXML files using the observations and these included Landmark and LXML4AC (using the 'XINO' function; see Section 5.1.2) (Nixon, 2017, Sacilotto, 2017). It was found that each of these software had a different method of ingesting LandXML files using the observations, which is, however, beyond the scope of this research. This is therefore a potential area for future research as their ingestion methods can be compared. It was also found that each software had a slightly different approach at handling more than one LandXML file, which can also be investigated.

7 Conclusions

The aim of this research was to investigate potential problems associated with using coordinates when ingesting LandXML files into surveying software. To achieve this aim, the research first performed some experimentation to determine the LandXML ingestion method of three different software used by the NSW surveying industry including:

1. LXML4AC;
2. Stringer ePlan; and
3. 12d Model.

The outcome of the tests performed on these software indicated that they each used CgPoint coordinates from a LandXML file to plot the survey plan linework.

The researcher found that this method of ingestion was unreliable after discovering numerous problems associated with CgPoint coordinates which can occur without a surveyor realising. Some of the key findings included:

- CgPoint coordinates in LandXML files, exported from a software called GeoCadastre, consist of MGA grid rather than locally defined coordinates (see Section 6.1). Ingesting these files into software which use CgPoints results in the plotted linework geometry being comprised of grid rather than ground distances; and
- Relating LandXML files to each other after ingesting them into a software (using CgPoint coordinates) is usually not possible, since each file contains its own CRS for the CgPoints (see Section 6.2). In addition, CgPoints can sometimes use arbitrary values for their coordinates which will subsequently result in adjoining files becoming completely separated after ingestion.

For LandXML files to be ingested and used reliably, it is crucial that software vendors develop their surveying programs to exclusively use observations (bearings and distances) from a LandXML file rather than CgPoint coordinates, for plotting the linework. This will ensure the accuracy of the ingested data since only observations, and not CgPoint coordinates, are verified by the LPI during the examination of a LandXML file.

The plotted linework is what will be used by surveyors to derive coordinates in CAD for various applications such as searching for survey marks. By using verified quantities for plotting the linework, the accuracy of its geometry will be ensured, allowing for reliable coordinates to be derived in order that, for instance, survey marks may be located.

These findings coincide with Elfick's (n.d.) opinion that "coordinates should be viewed as simply being derived information, not the base reference material itself". The observations from a LandXML file should instead be used as the base reference material as used by survey plans.

There were various limitations associated with the experiments conducted in this research which have been highlighted in the experimental discussions. Some of the overall limitations of this research include:

- That it did not investigate the LandXML ingestion methods used by other software (apart from LXML4AC, Stringer ePlan and 12d Model) which may also use CgPoints. This was however beyond the control of the researcher due to the reasons mentioned in Section 5.2.1; and
- That it did not investigate all the potentially existing problems associated with ingesting single or more than one LandXML file using CgPoints. It is likely, however, that the problems found in this research were the primary and current ones. This is because only a small set of surveying software have been developed to create LandXML files (see Figure 3.1). The problems with ingesting these files into software which use CgPoints, were mostly investigated in this research.

7.1 Further Research

There are various potential areas for future research which can be derived from this study, some of which have already been mentioned throughout this thesis. These include:

- Investigating which other NSW surveying software use CgPoints for ingesting LandXML files as well as software used in different jurisdictions (although they will use a schema different to the NSW LandXML schema);
- Discovering other problems in using CgPoints for the ingestion of LandXML files;
- Analysing the current software which can ingest LandXML files using the observations and determining how they can be improved. These software include: Landmark and LXML4AC (using the 'XINO' function; see Section 6.4);
- Comparing these two software methods in terms of which approach is more suitable or reliable;
- Determining how these software deal with more than one LandXML file, e.g. how they deal with plans on different azimuths and old/ new plans (the researcher found that Landmark has developed a suitable method of doing so, but has not investigated this further);
- Assisting software vendors, who have developed their software to use CgPoints for LandXML ingestion, to update their software to instead use the observations;
- Developing innovative methods on how to ingest LandXML files using the observations, which is difficult to automate (see Section 3.3.3); and
- Investigating problems associated with ingesting different types of LandXML files, e.g. strata plans (which are now being lodged).

It is likely that, as an outcome of this research, software vendors may update their software ingestion functions to exclusively use the observations from a LandXML file. If this occurs, these software methods can also be analysed and compared with existing methods.

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Appendix A: Example LandXML File

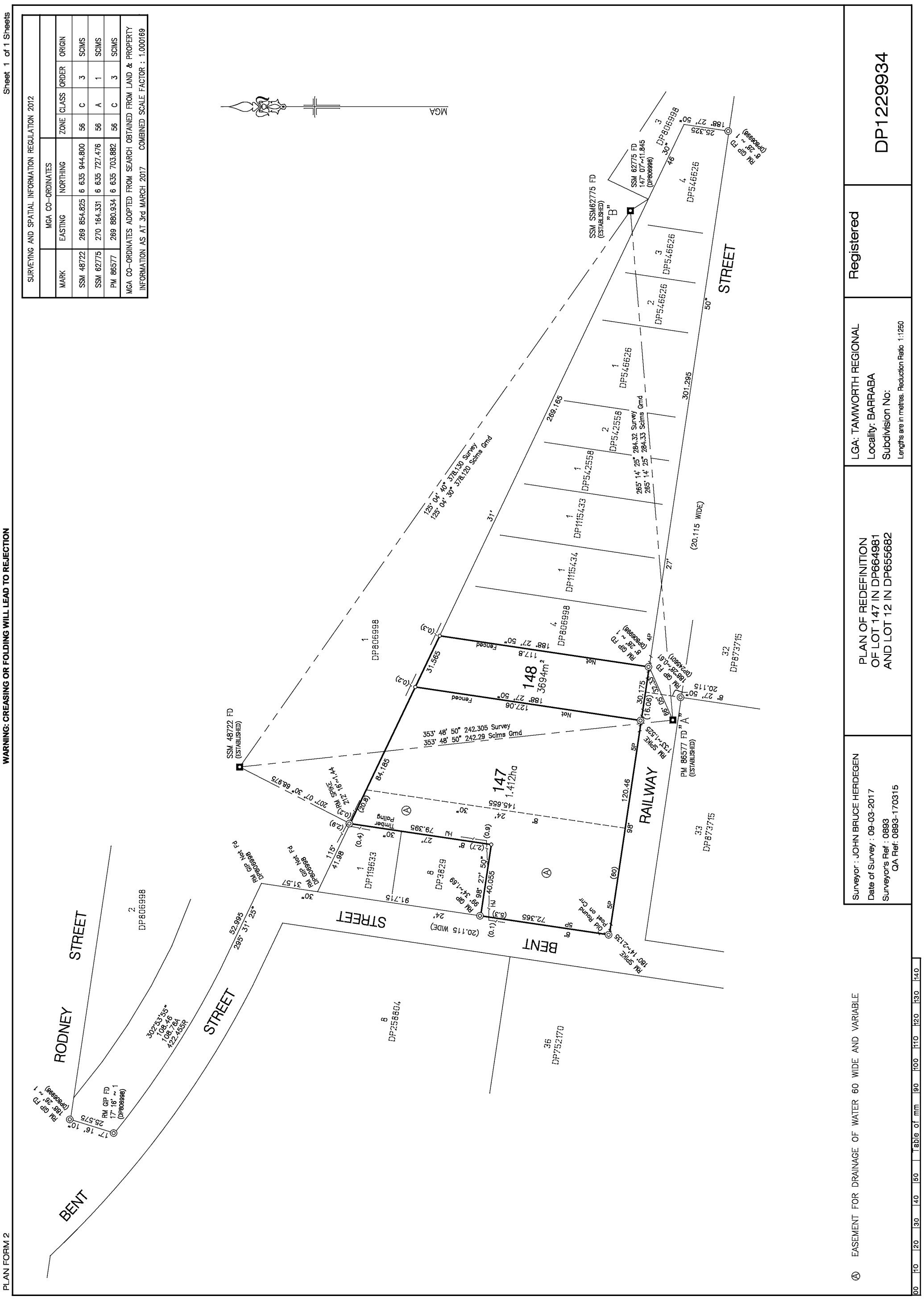
Note that the following Appendix shows an extract of the original LandXML file. Sections of LandXML code which have been truncated are indicated by an ellipsis (…).


```
<?xml version="1.0" encoding="UTF-8"?>
<LandXML version="1.0" date="2017-04-21" time="09:16:07"
 xmlns="http://www.landxml.org/schema/LandXML-1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.landxml.org/schema/LandXML-1.2
http://www.landxml.org/schema/LandXML-1.2/LandXML-1.2.xsd">
<Units>
  <Metric linearUnit="meter" temperatureUnit="celsius" volumeUnit="cubicMeter"
areaUnit="squareMeter" pressureUnit="milliBars" angularUnit="decimal dd.mm.ss"
directionUnit="decimal dd.mm.ss" />
</Units>
<CoordinateSystem datum="MGA" horizontalDatum="Local" />

<Application name="GeoCadastre" version="5.72" />
<FeatureDictionary name="ReferenceDataContext" version="NSW-101013" >
<DocFileRef name="au-gov-nsw-icsm-cif-enumerated-types.xsd"
location="http://www.lpi.nsw.gov.au/__data/assets/xml_file/0010/137368/xml-govau-
nsw-icsm-eplan-cif-referencedata-101013.xml" />
</FeatureDictionary>
<CgPoints zoneNumber="56" >

  <CgPoint state="proposed" pntSurv="boundary" name="1">6635739.152600
269761.466281</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="2">6635810.755671
269772.051626</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="3">6635804.858655
269811.681171</CgPoint>
...
</CgPoints>

<Parcels>
  <Parcel name="147" class="Lot" state="proposed" parcelType="Single"
parcelFormat="Standard" area="14120">
    <Center pntRef="36"/>
    <CoordGeom name="1471229934">
      <Line>
        <Start pntRef="1"/>
        <End pntRef="2"/>
      </Line>
      <Line>
        <Start pntRef="2"/>
        <End pntRef="3"/>
      </Line>
      <Line>
```

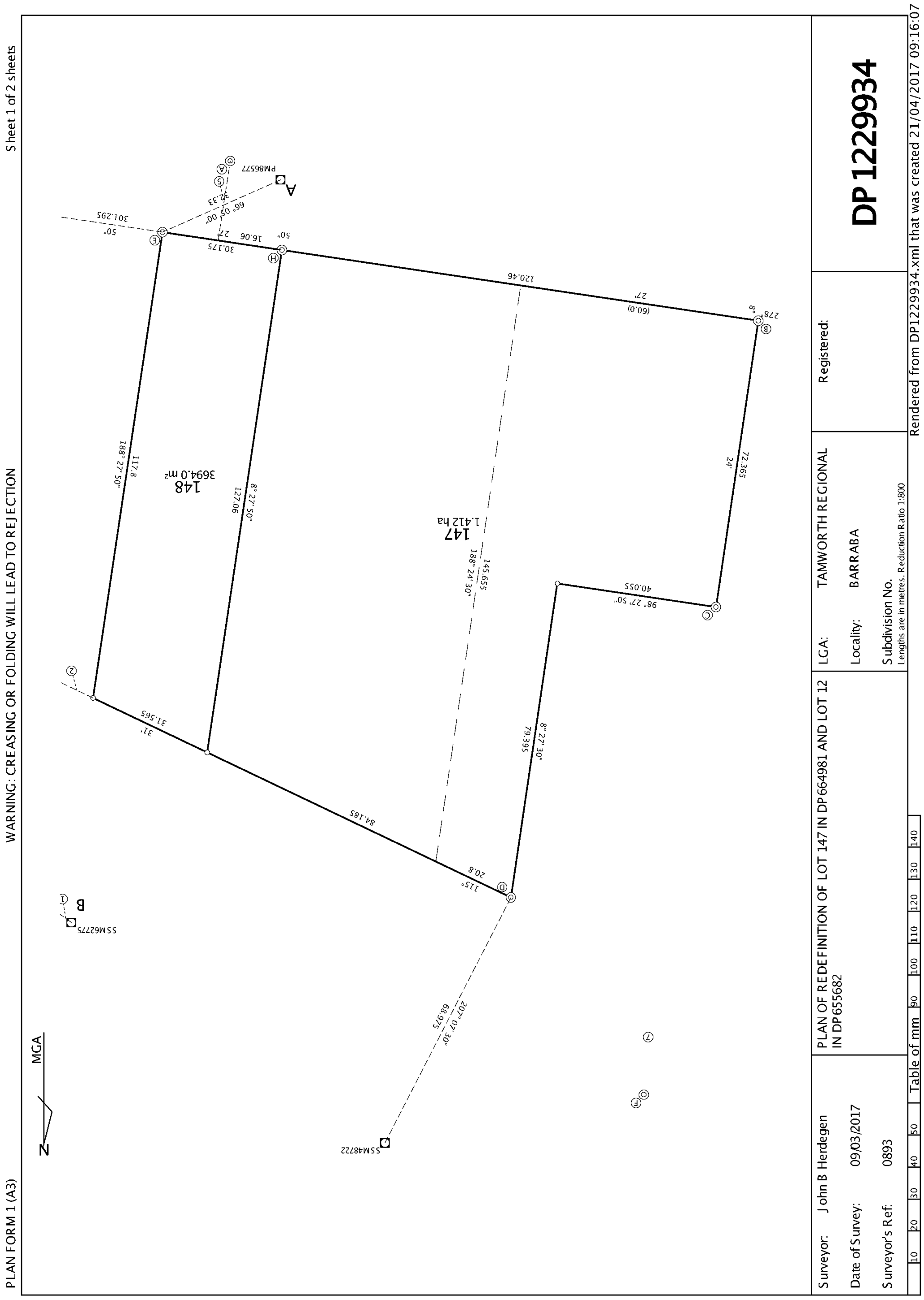
```
        <Start pntRef="3"/>
        <End pntRef="4"/>
      </Line>
      <Line>
        <Start pntRef="4"/>
        <End pntRef="5"/>
      </Line>
      <Line>
        <Start pntRef="5"/>
        <End pntRef="6"/>
      </Line>
      <Line>
        <Start pntRef="6"/>
        <End pntRef="1"/>
      </Line>
    </CoordGeom>
  </Parcel>
...
</Parcels>
<Survey>
  <SurveyHeader name="1229934" jurisdiction="New South Wales" desc="PLAN OF
REDEFINITION OF LOT 147 IN DP664981 AND LOT 12 IN DP655682" surveyorFirm="Baxter
Geo Consulting" surveyorReference="0893" surveyFormat="Standard" type="surveyed">
    <AdministrativeDate adminDateType="Date Of Survey" adminDate="2017-03-09" />
  <Personnel name="John B Herdegen" />
    <Annotation type="Plans Used" name="1" desc="DP3829, DP4096, DP119633,
DP245601, DP563553, DP664981, DP806998, DP873715"/>
    <PurposeOfSurvey name="Redefinition"/>
    <AdministrativeArea adminAreaType="Locality" adminAreaName="Barraba"/>
    <AdministrativeArea adminAreaType="Local Government Area"
adminAreaName="Tamworth Regional"/>
    <AdministrativeArea adminAreaType="Parish" adminAreaName="Barraba"/>
    <AdministrativeArea adminAreaType="County" adminAreaName="Darling"/>
    <AdministrativeArea adminAreaType="Survey Region" adminAreaName="Urban"/>
  </SurveyHeader>
  <InstrumentSetup id="IS1" stationName="1" instrumentHeight="0">
<InstrumentPoint pntRef="1"/>
</InstrumentSetup>
  <InstrumentSetup id="IS2" stationName="2" instrumentHeight="0">
<InstrumentPoint pntRef="2"/>
</InstrumentSetup>
  <InstrumentSetup id="IS3" stationName="3" instrumentHeight="0">
<InstrumentPoint pntRef="3"/>
</InstrumentSetup>
...
<ObservationGroup id="OG-1">
  <ReducedObservation name="1" desc="Boundary" setupID="IS6" targetSetupID="IS5"
azimuth="8.275" horizDistance="127.060"  distanceType="Measured"/>
  <ReducedObservation name="2" desc="Boundary" setupID="IS5" targetSetupID="IS20"
azimuth="115.313" horizDistance="31.565"  distanceType="Measured"/>
  <ReducedObservation name="3" desc="Boundary" setupID="IS20" targetSetupID="IS21"
azimuth="188.275" horizDistance="117.800"  distanceType="Measured"/>
  <ReducedObservation name="4" desc="Road" setupID="IS21" targetSetupID="IS6"
azimuth="278.275" horizDistance="30.175"  distanceType="Measured"/>
```

```
...
  <ReducedObservation name="10" desc="Connection" setupID="IS25"
targetSetupID="IS26" azimuth="265.1425" horizDistance="284.320"
distanceAdoptionFactor="1.00016900"/>
  <ReducedObservation name="11" desc="Connection" setupID="IS26"
targetSetupID="IS27" azimuth="353.485" horizDistance="242.305"
distanceAdoptionFactor="1.00016900"/>
...
  <RedHorizontalPosition name="41" setupID="IS27" latitude="6635944.800000"
longitude="269854.825000" class="C" order="3" currencyDate="2017-03-03"
horizontalFix="SCIMS" horizontalDatum="MGA"/>
  <RedHorizontalPosition name="42" setupID="IS25" latitude="6635727.476000"
longitude="270164.331000" class="A" order="1" currencyDate="2017-03-03"
horizontalFix="SCIMS" horizontalDatum="MGA"/>
  <RedHorizontalPosition name="43" setupID="IS26" latitude="6635703.882000"
longitude="269880.934000" class="C" order="3" currencyDate="2017-03-03"
horizontalFix="SCIMS" horizontalDatum="MGA"/>
</ObservationGroup>
</Survey>
<Monuments>
  <Monument name="1" pntRef="25" type="SSM" desc="SSM62775" state="Found"
originSurvey="DP806998" />
  <Monument name="2" pntRef="28" type="GIP" state="Found" originSurvey="DP806998"
/>
  <Monument name="3" pntRef="29" type="GIP" state="Found" originSurvey="DP806998"
/>
...
</Monuments>
</LandXML>
```

Appendix B: Original Survey Plan



Appendix C: Rendered Survey Plan



PLAN FORM 1 (A3) WARNING: CREASING OR FOLDING WILL LEAD TO REJECTION Sheet 2 of 2 sheets

Easement Information
E1 EASEMENT FOR DRAINAGE OF WATER 60 WIDE AND VARIABLE

UNLABELLED BEARING AND DISTANCES

NO.	BEARING	DISTANCE
1	147° 07' 00"	11.845
2	115° 31' 30"	269.165
3	115° 31' 30"	46
4	188° 27' 50"	25.325
5	188° 27' 50"	20.115
6	17° 16' 10"	25.575
7	188° 24' 30"	31.57

TRAVERSES ETC

LINE	BEARING	DISTANCE
6-31	98° 27' 50"	16.06
10-12	17° 16' 10"	25.575
20-22	115° 31' 30"	269.165
22-23	115° 31' 30"	46
23-24	188° 27' 50"	25.325
24-21	278° 27' 50"	301.295
31-32	188° 27' 50"	20.115

SURVEYING AND SPATIAL INFORMATION REGULATION 2012: CLAUSE 61(2)

MARK	M.G.A. CO-ORDINATES		CLASS	ORDER	METHOD
	EASTING	NORTHING			
PM86577	269 880.934	6 635 703.882	C	3	SCIMS
SSM48722	269 854.825	6 635 944.8	C	3	SCIMS
SSM62775	270 164.331	6 635 727.476	A	1	SCIMS

COMBINED SCALE FACTOR 1.000169
SOURCE: MGA CO-ORDINATES ADOPTED FROM SCIMS AS AT 2017-03-03

PM CONNECTIONS

CONNECTION	BEARING	DISTANCE
SSM48722 to SSM62775	125° 04' 40"	378.13
SSM62775 to PM86577	265° 14' 25"	284.32
PM86577 to SSM48722	353° 48' 50"	242.305

SCHEDULE OF REFERENCE MARKS

MARK NO.	BEARING	DISTANCE	FROM	ORIGIN	STATE
A	188° 28' 00"	0.61	GIP	DP245601	Found
B	180° 14' 00"	2.135	Spike		Placed

SCHEDULE OF REFERENCE MARKS

MARK NO.	BEARING	DISTANCE	FROM	ORIGIN	STATE
C	99° 34' 00"	1.69	GIP		Placed
	188° 24' 30"	91.715	GIP	DP806998	Not Found
D	212° 16' 00"	1.44	Spike		Placed
	115° 31' 30"	41.98	GIP	DP806998	Not Found
E	8° 28' 00"	1	GIP	DP806998	Found
F	188° 24' 30"	31.57	GIP	DP806998	Not Found
	188° 24' 30"	31.57	GIP	DP806998	Not Found
G	295° 31' 25"	52.995	GIP	DP806998	Not Found
H	1° 33' 00"	1.525	Spike		Placed
I	17° 16' 00"	1	GIP	DP806998	Found
J	188° 26' 00"	1	GIP	DP806998	Found
K	8° 28' 00"	1	GIP	DP806998	Found

Surveyor: John B Herdegen Date of Survey: 09/03/2017 Surveyor's Ref: 0893	PLAN OF REDEFINITION OF LOT 147 IN DP664981 AND LOT 12 IN DP655682	LGA: TAMWORTH REGIONAL Locality: BARRABA Subdivision No. Lengths are in metres. Reduction Ratio 1:800	Registered: **DP1229934**

10 20 30 40 50 Table of mm 90 100 110 120 130 140

Rendered from DP1229934.xml that was created 21/04/2017 09:16:07

Appendix D: LandXML File for Experiment 1

Note that the relevant sections of the LandXML code are highlighted in yellow.


```
<?xml version="1.0" encoding="UTF-8"?>
<LandXML version="1.0" date="2017-07-29" time="19:56:04"
xmlns="http://www.landxml.org/schema/LandXML-1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.landxml.org/schema/LandXML-1.2
http://www.landxml.org/schema/LandXML-1.2/LandXML-1.2.xsd">
<Units>
<Metric linearUnit="meter" temperatureUnit="celsius" volumeUnit="cubicMeter"
areaUnit="squareMeter" pressureUnit="milliBars" angularUnit="decimal dd.mm.ss"
directionUnit="decimal dd.mm.ss" />
</Units>
<CoordinateSystem datum="MGA" horizontalDatum="Local" verticalDatum="AHD" />

<Application name="Landxml for Autocad" version="1.8.6" />
<FeatureDictionary name="ReferenceDataContext" version="NSW-101013" >
<DocFileRef name="au-gov-nsw-icsm-cif-enumerated-types.xsd"
location="http://www.lpi.nsw.gov.au/__data/assets/xml_file/0010/137368/xml-govau-
nsw-icsm-eplan-cif-referencedata-101013.xml" />
</FeatureDictionary>
<CgPoints zoneNumber="56">
  <CgPoint state="proposed" pntSurv="boundary" name="1">0 20</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="2">0 0</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="3">20 20</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="4">20 0</CgPoint>
  <CgPoint state="proposed" pntSurv="sideshot" name="5">10.545978
9.297224</CgPoint>
</CgPoints>

<Parcels>
  <Parcel name="1" class="Lot" state="proposed" parcelType="Single"
parcelFormat="Standard" area="400.000">
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    <CoordGeom name="1">
      <Line>
        <Start pntRef="2"/>
        <End pntRef="4"/>
      </Line>
      <Line>
        <Start pntRef="4"/>
        <End pntRef="3"/>
      </Line>
      <Line>
        <Start pntRef="3"/>
        <End pntRef="1"/>
      </Line>
```

```
        <Line>
          <Start pntRef="1"/>
          <End pntRef="2"/>
        </Line>
      </CoordGeom>
    </Parcel>
  </Parcels>
  <Survey>
    <SurveyHeader name="1000" jurisdiction="New South Wales" desc="Subdivision"
surveyorFirm="55 The Corso"  surveyorReference="1000"  surveyFormat="Standard"
type="surveyed">
      <AdministrativeDate adminDateType="Date Of Survey" adminDate="2015-09-10" />
      <AdministrativeDate adminDateType="Registration Date" adminDate="2017-05-10"/>
      <Personnel name="Ahmed" />
      <PurposeOfSurvey name="Subdivision"/>
      <Annotation type="Subdivision Number" name="1" desc="10000"/>
      <AdministrativeArea adminAreaType="Survey Region" adminAreaName="Urban"/>
      <AdministrativeArea adminAreaType="Locality" adminAreaName="Greenacre"/>
      <AdministrativeArea adminAreaType="Local Government Area"
adminAreaName="Greenacre"/>
      <AdministrativeArea adminAreaType="Parish" adminAreaName="Aberfoil"/>
      <AdministrativeArea adminAreaType="County" adminAreaName="Bathurst"/>
      <AdministrativeArea adminAreaType="Terrain" adminAreaName="Level-Undulating"/>
    </SurveyHeader>
    <InstrumentSetup id="IS1" stationName="1" instrumentHeight="0">
  <InstrumentPoint pntRef="1"/>
  </InstrumentSetup>
    <InstrumentSetup id="IS2" stationName="2" instrumentHeight="0">
  <InstrumentPoint pntRef="2"/>
  </InstrumentSetup>
    <InstrumentSetup id="IS3" stationName="3" instrumentHeight="0">
  <InstrumentPoint pntRef="3"/>
  </InstrumentSetup>
    <InstrumentSetup id="IS4" stationName="4" instrumentHeight="0">
  <InstrumentPoint pntRef="4"/>
  </InstrumentSetup>
  <ObservationGroup id="OG-1">
    <ReducedObservation name="1" desc="Boundary" setupID="IS1" targetSetupID="IS2"
azimuth="270" horizDistance="20" distanceType="Measured"/>
    <ReducedObservation name="2" desc="Boundary" setupID="IS3" targetSetupID="IS1"
azimuth="180" horizDistance="20" distanceType="Measured"/>
    <ReducedObservation name="3" desc="Boundary" setupID="IS4" targetSetupID="IS3"
azimuth="90" horizDistance="20" distanceType="Measured"/>
    <ReducedObservation name="4" desc="Boundary" setupID="IS2" targetSetupID="IS4"
azimuth="0" horizDistance="20" distanceType="Measured"/>
  </ObservationGroup>
  </Survey>
</LandXML>
```

Appendix E: LandXML File for Experiment 2

Note that the relevant sections of the LandXML code are highlighted in yellow.

```
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xsi:schemaLocation="http://www.landxml.org/schema/LandXML-1.2
http://www.landxml.org/schema/LandXML-1.2/LandXML-1.2.xsd">
<Units>
<Metric linearUnit="meter" temperatureUnit="celsius" volumeUnit="cubicMeter"
areaUnit="squareMeter" pressureUnit="milliBars" angularUnit="decimal dd.mm.ss"
directionUnit="decimal dd.mm.ss" />
</Units>
<CoordinateSystem datum="MGA" horizontalDatum="Local" verticalDatum="AHD" />

<Application name="Landxml for Autocad" version="1.9.2" />
<FeatureDictionary name="ReferenceDataContext" version="NSW-101013" >
<DocFileRef name="xml-gov-au-nsw-icsm-eplan-cif-protocol-1.0.xsd"
location="http://www.lpi.nsw.gov.au/__data/assets/xml_file/0010/137368/xml-gov-au-
nsw-icsm-eplan-cif-protocol-1.0.xsd" />
</FeatureDictionary>
<CgPoints zoneNumber="56">
  <CgPoint state="proposed" pntSurv="boundary" name="1">6000000 500020</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="2">6000000 500000</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="3">6000020 500020</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="4">6000020 500000</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1002" desc="B" name="5">6000000
500050</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1001" name="6">6000041.213
500041.213</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1000" desc="A" name="7">6000050
500000</CgPoint>
  <CgPoint state="proposed" pntSurv="sideshot" name="8">6000010 500010</CgPoint>
</CgPoints>

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parcelFormat="Standard" area="400.0">
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        <End pntRef="2"/>
      </Line>
      <Line>
        <Start pntRef="2"/>
        <End pntRef="4"/>
```

```
      </Line>
      <Line>
        <Start pntRef="4"/>
        <End pntRef="3"/>
      </Line>
      <Line>
        <Start pntRef="3"/>
        <End pntRef="1"/>
      </Line>
    </CoordGeom>
  </Parcel>
</Parcels>
<Survey>
  <SurveyHeader name="1000" jurisdiction="New South Wales" desc="PLAN OF
SUBDIVISION"  surveyorFirm="UNSW"  surveyorReference="72-10-1343-Ver"
surveyFormat="Standard" type="surveyed">
    <AdministrativeDate adminDateType="Date Of Survey" adminDate="2017-08-07" />
    <Personnel name="Ahmed " />
    <PurposeOfSurvey name="Subdivision"/>
    <Annotation type="Plan Note" name="1" desc=" "/>
    <AdministrativeArea adminAreaType="Survey Region" adminAreaName="Urban"/>
    <AdministrativeArea adminAreaType="Locality" adminAreaName="PENRITH"/>
    <AdministrativeArea adminAreaType="Local Government Area"
adminAreaName="PENRITH CITY COUNCIL"/>
    <AdministrativeArea adminAreaType="Parish" adminAreaName="CASTLEREAGH"/>
    <AdministrativeArea adminAreaType="County" adminAreaName="CUMBERLAND"/>
  </SurveyHeader>
  <InstrumentSetup id="IS1" stationName="1" instrumentHeight="0">
<InstrumentPoint pntRef="1"/>
</InstrumentSetup>
  <InstrumentSetup id="IS2" stationName="2" instrumentHeight="0">
<InstrumentPoint pntRef="2"/>
</InstrumentSetup>
  <InstrumentSetup id="IS3" stationName="3" instrumentHeight="0">
<InstrumentPoint pntRef="3"/>
</InstrumentSetup>
  <InstrumentSetup id="IS4" stationName="4" instrumentHeight="0">
<InstrumentPoint pntRef="4"/>
</InstrumentSetup>
  <InstrumentSetup id="IS5" stationName="5" instrumentHeight="0">
<InstrumentPoint pntRef="5"/>
</InstrumentSetup>
  <InstrumentSetup id="IS6" stationName="6" instrumentHeight="0">
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</InstrumentSetup>
  <InstrumentSetup id="IS7" stationName="7" instrumentHeight="0">
<InstrumentPoint pntRef="7"/>
</InstrumentSetup>
<ObservationGroup id="OG-1">
  <ReducedObservation name="1" desc="Boundary" setupID="IS1" targetSetupID="IS2"
azimuth="270" horizDistance="20" distanceType="Measured"  azimuthType="Measured"
/>
```

```
  <ReducedObservation name="2" desc="Boundary" setupID="IS3" targetSetupID="IS1"
azimuth="180" horizDistance="20" distanceType="Measured"  azimuthType="Measured"
/>
  <ReducedObservation name="3" desc="Boundary" setupID="IS4" targetSetupID="IS3"
azimuth="90" horizDistance="20" distanceType="Measured"  azimuthType="Measured" />
  <ReducedObservation name="4" desc="Boundary" setupID="IS2" targetSetupID="IS4"
azimuth="0" horizDistance="20" distanceType="Measured"  azimuthType="Measured" />
  <ReducedObservation name="5" desc="Connection" setupID="IS4" targetSetupID="IS7"
azimuth="0" horizDistance="30" distanceType="Measured"  azimuthType="Measured" />
  <ReducedObservation name="6" desc="Connection" setupID="IS1" targetSetupID="IS5"
azimuth="90" horizDistance="30" distanceType="Measured"  azimuthType="Measured" />
  <ReducedObservation name="7" desc="Connection" setupID="IS3" targetSetupID="IS6"
azimuth="45" horizDistance="30" distanceType="Measured"  azimuthType="Measured" />
  <ReducedObservation name="8" desc="Connection" setupID="IS6" targetSetupID="IS7"
azimuth="282.0208" horizDistance="42.139" distanceType="Measured"
azimuthType="Measured"  distanceAdoptionFactor="0.9996"/>
  <ReducedObservation name="9" desc="Connection" setupID="IS6" targetSetupID="IS5"
azimuth="167.5752" horizDistance="42.139" distanceType="Measured"
azimuthType="Measured"  distanceAdoptionFactor="0.9996"/>
  <ReducedObservation name="10" desc="Connection" setupID="IS5"
targetSetupID="IS7" azimuth="315" horizDistance="70.711" distanceType="Measured"
azimuthType="Measured"  distanceAdoptionFactor="0.9996"/>
  <RedHorizontalPosition name="11" setupID="IS5" latitude="6000000.021"
longitude="500049.979" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-08-07"/>
  <RedHorizontalPosition name="12" setupID="IS6" latitude="6000041.217"
longitude="500041.196" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-08-07"/>
  <RedHorizontalPosition name="13" setupID="IS7" latitude="6000050.000"
longitude="500000.000" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-08-07"/>
</ObservationGroup>
</Survey>
<Monuments>
  <Monument name="1" pntRef="5" type="SSM" state="Found"/>
  <Monument name="2" pntRef="6" type="SSM" state="Found"/>
  <Monument name="3" pntRef="7" type="SSM" state="Found"/>
</Monuments>
</LandXML>
```

Appendix F: Validation Report for Experiment 2

Land and Property Information Division
ABN: 23 519 493 925
GPO BOX 15
Sydney NSW 2001
DX 17 SYDNEY Telephone: 1300 052 637

NSW GOVERNMENT | Land & Property Information

Land XML Validation Results

Validation Result Rejected
File Name Experiment 2.xml

#	Rule:	Rule Description:	Status:	Error Message
	0	Schema check	Passed	
	1	Plan purpose	Passed	
	2	Plan give effect to purpose	Passed	
	3	Lot numbering	Passed	
	4	Valid secondary parcels	Passed	
	5	Parcel attributes	Passed	
	6	Valid parish	Passed	
	7	Valid County	Passed	
	8	Valid LGA	Passed	
	9	Valid Locality	Passed	
	10	Valid Areas	Passed	
	11	Multipart lot areas	Passed	
	12	New lot area shown	Passed	
	13	Parcel overlaps	Passed	
	14	Multipart lot attributes	NotApplicable	
	15	Parcel topology	Passed	
	16	Misclose	Passed	
	17	Line attributes	Passed	
	18	Valid Instrument point	Passed	
	19	All points used	Passed	
	20	RM/PM dimensions	Passed	
	21	SCIMS Date vs Survey Date	Passed	
	22	SCIMS sketch	Passed	
	23	Offset boundary mark	Passed	
	24	unmarked boundary	Passed	

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Sydney NSW 2001
DX 17 SYDNEY Telephone: 1300 052 637

Land XML Validation Results

Validation Result	Rejected
File Name	Experiment 2.xml

#	Rule:	Rule Description:	Status:	Error Message
	25	RMs within 30m	Passed	
	26	SCIMS details	Failed	The coordinates for SCIMS mark 'SSM1001' didn't match. LandXML latitude/longitude was '6000041.217'/'500041.196', SCIMS latitude/longitude was '6375986.0'/'681302.0' The coordinates for SCIMS mark 'SSM1000' didn't match. LandXML latitude/longitude was '6000050.0'/'500000.0', SCIMS latitude/longitude was '6377572.0'/'681933.0' The order for SCIMS mark 'SSM1002' didn't match the current value. LandXML order was '4', SCIMS order was '2' The order for SCIMS mark 'SSM1001' didn't match the current value. LandXML order was '4', SCIMS order was '5' The order for SCIMS mark 'SSM1000' didn't match the current value. LandXML order was '4', SCIMS order was 'U' The coordinates for SCIMS mark 'SSM1002' didn't match. LandXML latitude/longitude was '6000000.021'/'500049.979', SCIMS latitude/longitude was '6374525.604'/'680813.532'
	27	Close points	Passed	
	28	Datum terminals	Failed	Datum point A is not an established mark Datum point B is not an established mark
	29	Datum dimensions	Passed	
	30	Verifying radiation	Failed	The datum line should be verified by connection to one other established control mark
	31	RMs for urban plan no road frontage	Failed	Survey contains no roads or proposed roads. Must connect to two reference marks.
	32	Found RM origin	Passed	
	33	RM connect to one boundary point	Failed	No placed monuments were found
	34	PMs new road	Passed	
	35	RMs road frontage terminals	Passed	
	36	RMs for total road frontage	Passed	
	37	PM to PM dimensions	Passed	
	38	PM connect to survey	Passed	
	39	PMs & traverse loops close	Passed	
	40	Marks exist	Passed	
	41	MM Radial Search	Passed	
	42	PMs required for number of parcels	Passed	

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Land XML Validation Results

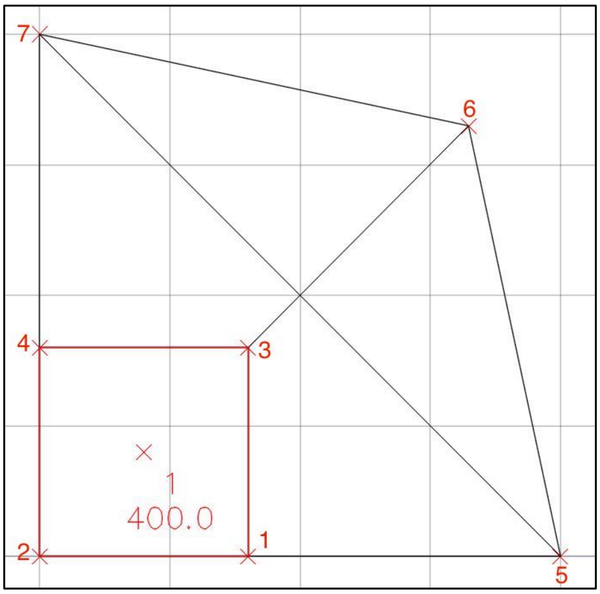
Validation Result	Rejected
File Name	Experiment 2.xml

#	Rule:	Rule Description:	Status:	Error Message
	43	Surveyor name	Passed	
	44	Surveyor reference	Passed	
	45	Numbering of new lots	Passed	
	46	Combined scale factor	Passed	
	47	Natural boundaries	Passed	
	48	Plans used	Failed	Plans used is missing
	49	Urban or Rural	Passed	
	50	Occupations	Passed	
	51	Line Type	Passed	

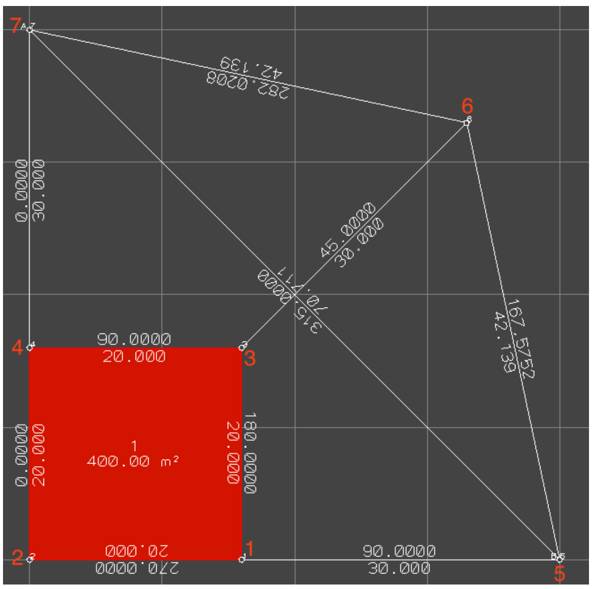
Appendix G: Software Diagrams for Experiment 2 Results

Original Diagrams

Stringer ePlan

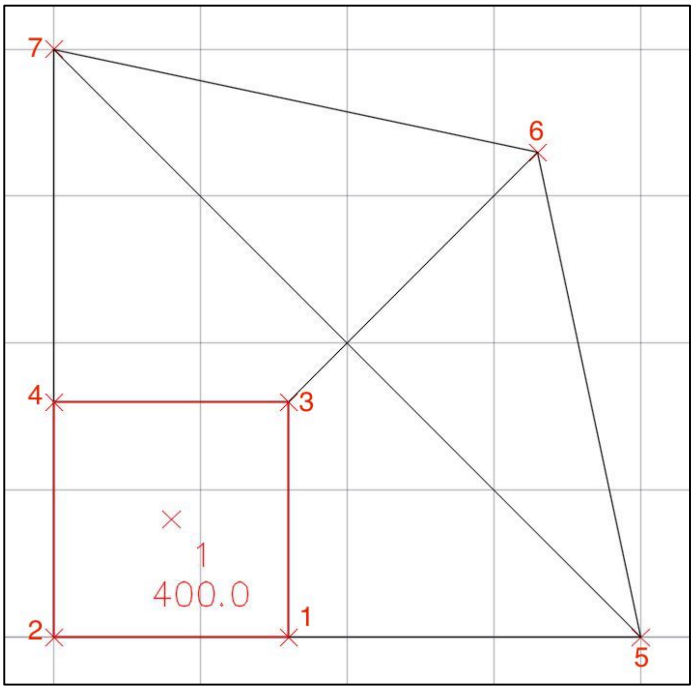


12d Model

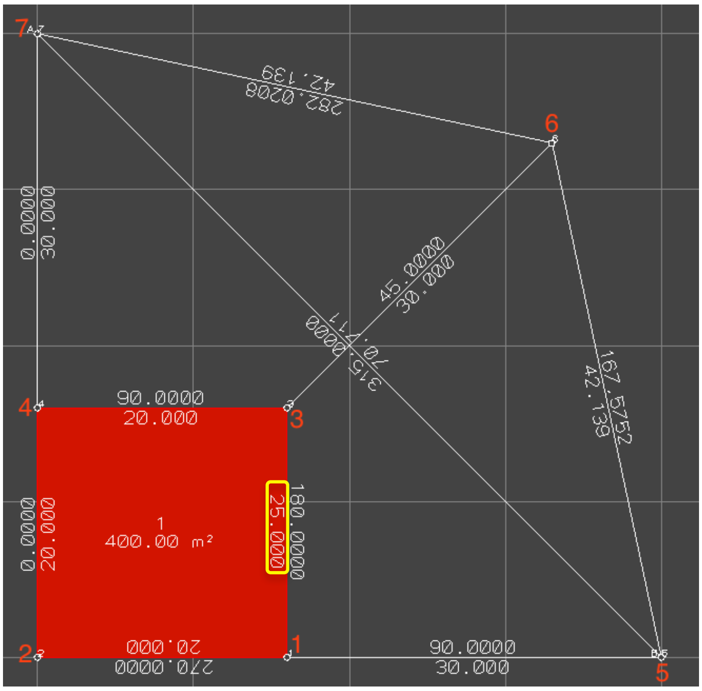


Modified Distance Test

Stringer ePlan

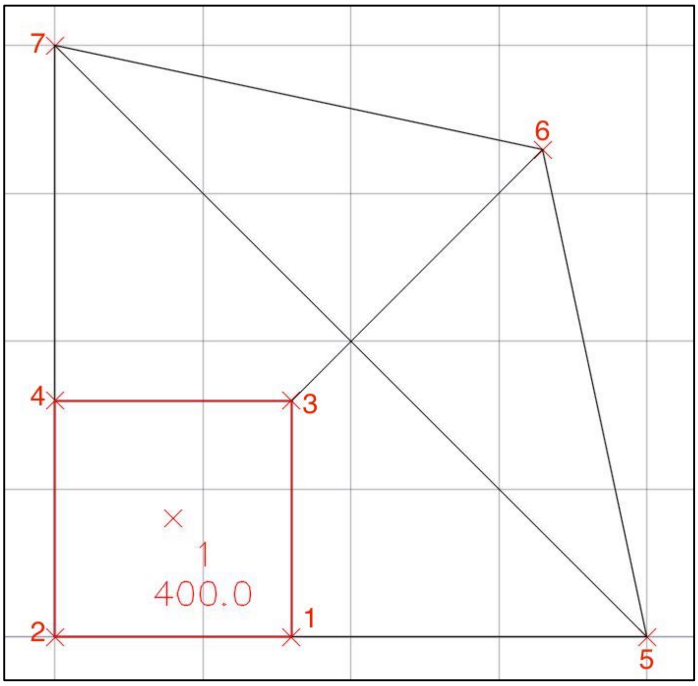


12d Model

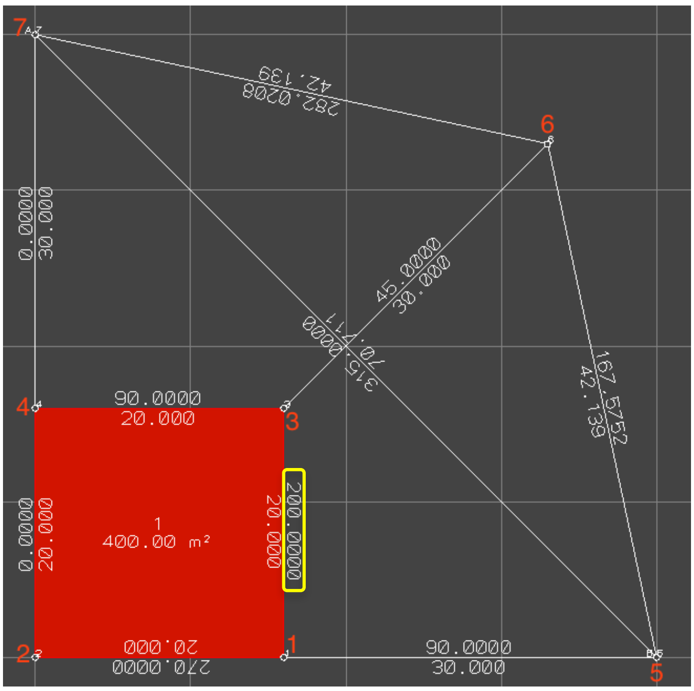


Modified Bearing Test

Stringer ePlan

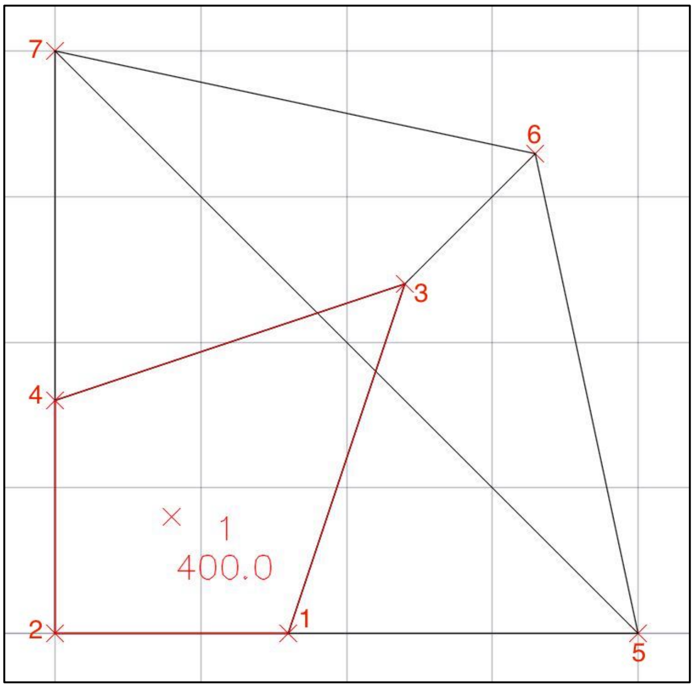


12d Model

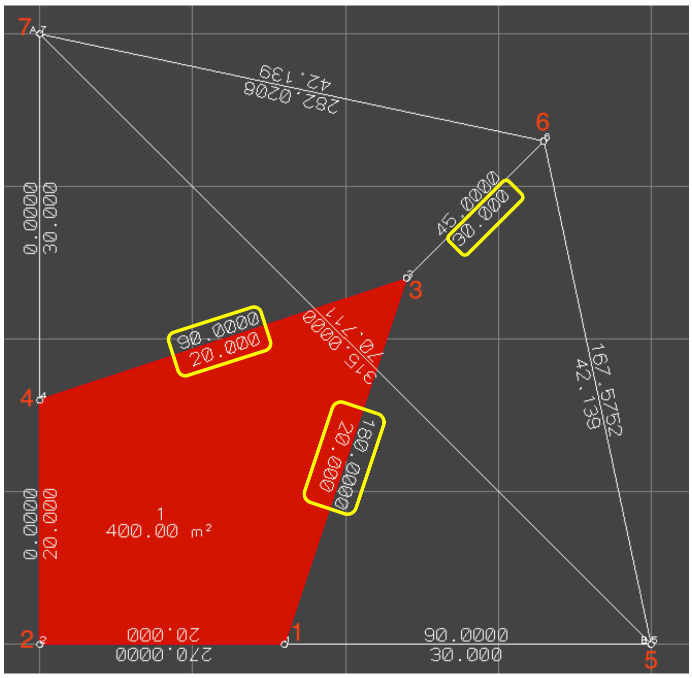


Modified CgPoint Coordinates Test

Stringer ePlan



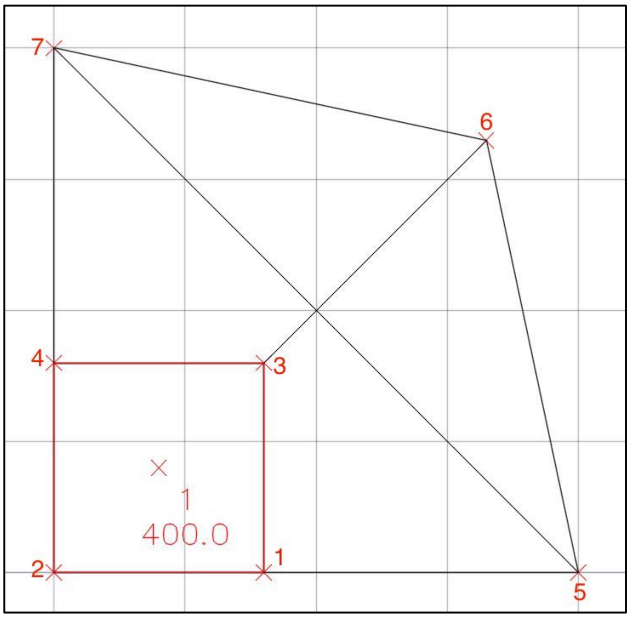
12d Model



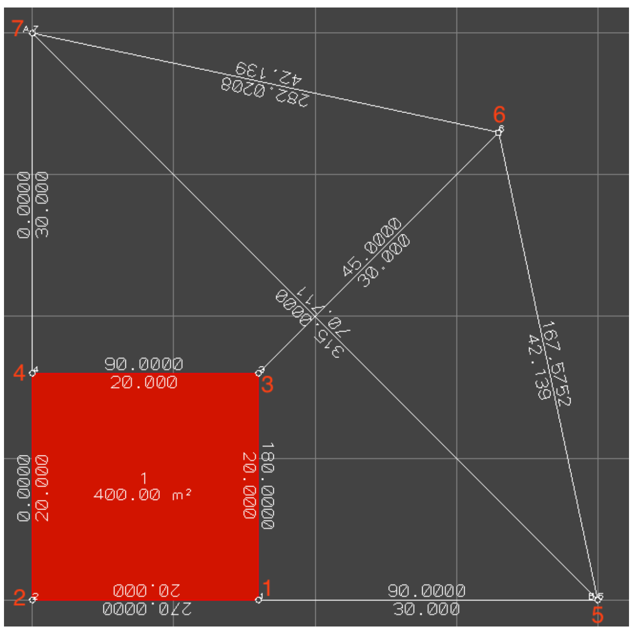
Modified CSF and MGA Coordinates Tests

Since the results for the modified CSF and MGA coordinates tests were identical (as mentioned in Section 5.2.4.4), their diagrams have been combined here.

Stringer ePlan

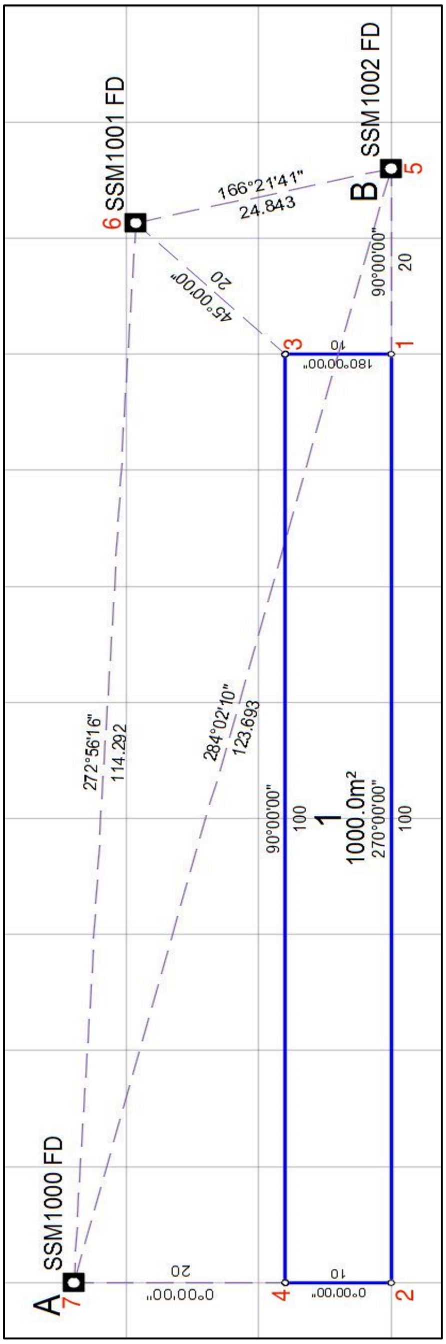


12d Model

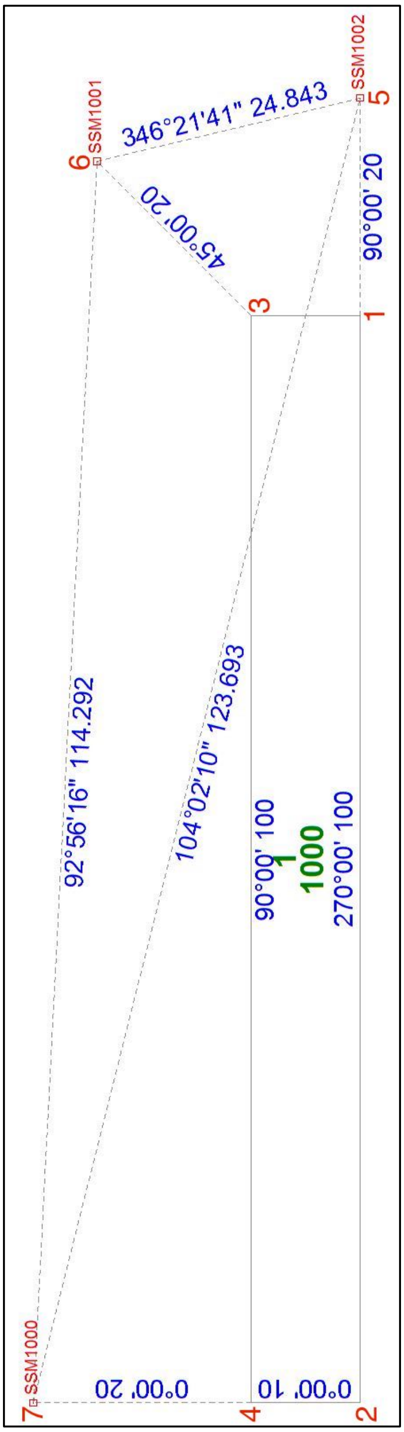


Appendix H: Enlarged View of Figures from Experiment 3

Enlarged view of Figure 6.1



Enlarged view of Figure 6.2



Appendix I: Original LandXML File for Experiment 3

Note that the relevant sections of the LandXML code are highlighted in yellow.

```
<?xml version="1.0" encoding="UTF-8"?>
<LandXML version="1.0" date="2017-09-09" time="08:48:44"
xmlns="http://www.landxml.org/schema/LandXML-1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.landxml.org/schema/LandXML-1.2
http://www.landxml.org/schema/LandXML-1.2/LandXML-1.2.xsd">
<Units>
<Metric linearUnit="meter" temperatureUnit="celsius" volumeUnit="cubicMeter"
areaUnit="squareMeter" pressureUnit="milliBars" angularUnit="decimal dd.mm.ss"
directionUnit="decimal dd.mm.ss" />
</Units>
<CoordinateSystem datum="MGA" horizontalDatum="Local" verticalDatum="AHD" />

<Application name="Landxml for Autocad" version="1.9.2" />
<FeatureDictionary name="ReferenceDataContext" version="NSW-101013" >
<DocFileRef name="xml-gov-au-nsw-icsm-eplan-cif-protocol-1.0.xsd"
location="http://www.lpi.nsw.gov.au/__data/assets/xml_file/0010/137368/xml-gov-au-
nsw-icsm-eplan-cif-protocol-1.0.xsd" />
</FeatureDictionary>
<CgPoints zoneNumber="56">
  <CgPoint state="proposed" pntSurv="boundary" name="1">6000000 500100</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="2">6000000 500000</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="3">6000010 500100</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="4">6000010 500000</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1002" desc="B" name="5">6000000
500120</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1001" name="6">6000024.142
500114.142</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1000" desc="A" name="7">6000030
500000</CgPoint>
  <CgPoint state="proposed" pntSurv="sideshot" name="8">6000005 500050</CgPoint>
</CgPoints>

<Parcels>
  <Parcel name="1" class="Lot" state="proposed" parcelType="Single"
parcelFormat="Standard" area="1000.0">
    <Center pntRef="8"/>
    <CoordGeom name="1">
      <Line>
        <Start pntRef="1"/>
        <End pntRef="2"/>
      </Line>
      <Line>
        <Start pntRef="2"/>
        <End pntRef="4"/>
```

```
      </Line>
      <Line>
        <Start pntRef="4"/>
        <End pntRef="3"/>
      </Line>
      <Line>
        <Start pntRef="3"/>
        <End pntRef="1"/>
      </Line>
    </CoordGeom>
  </Parcel>
</Parcels>
<Survey>
  <SurveyHeader name="1001" jurisdiction="New South Wales" desc="PLAN OF
SUBDIVISION"  surveyorFirm="UNSW"  surveyorReference="72-10-1343-Ver"
surveyFormat="Standard" type="surveyed">
    <AdministrativeDate adminDateType="Date Of Survey" adminDate="2017-09-09" />
    <Personnel name="Ahmed " />
    <PurposeOfSurvey name="Subdivision"/>
    <Annotation type="Plan Note" name="1" desc=" "/>
    <AdministrativeArea adminAreaType="Survey Region" adminAreaName="Urban"/>
    <AdministrativeArea adminAreaType="Locality" adminAreaName="CUMBERLAND"/>
    <AdministrativeArea adminAreaType="Local Government Area"
adminAreaName="PENRITH CITY COUNCIL"/>
    <AdministrativeArea adminAreaType="Parish" adminAreaName="CASTLEREAGH"/>
    <AdministrativeArea adminAreaType="County" adminAreaName="CUMBERLAND"/>
  </SurveyHeader>
  <InstrumentSetup id="IS1" stationName="1" instrumentHeight="0">
<InstrumentPoint pntRef="1"/>
</InstrumentSetup>
  <InstrumentSetup id="IS2" stationName="2" instrumentHeight="0">
<InstrumentPoint pntRef="2"/>
</InstrumentSetup>
  <InstrumentSetup id="IS3" stationName="3" instrumentHeight="0">
<InstrumentPoint pntRef="3"/>
</InstrumentSetup>
  <InstrumentSetup id="IS4" stationName="4" instrumentHeight="0">
<InstrumentPoint pntRef="4"/>
</InstrumentSetup>
  <InstrumentSetup id="IS5" stationName="5" instrumentHeight="0">
<InstrumentPoint pntRef="5"/>
</InstrumentSetup>
  <InstrumentSetup id="IS6" stationName="6" instrumentHeight="0">
<InstrumentPoint pntRef="6"/>
</InstrumentSetup>
  <InstrumentSetup id="IS7" stationName="7" instrumentHeight="0">
<InstrumentPoint pntRef="7"/>
</InstrumentSetup>
<ObservationGroup id="OG-1">
  <ReducedObservation name="1" desc="Boundary" setupID="IS1" targetSetupID="IS2"
azimuth="270.0000" horizDistance="100" distanceType="Measured"
azimuthType="Measured" />
```

```
  <ReducedObservation name="2" desc="Boundary" setupID="IS3" targetSetupID="IS1"
azimuth="180.0000" horizDistance="10" distanceType="Measured"
azimuthType="Measured" />
  <ReducedObservation name="3" desc="Boundary" setupID="IS4" targetSetupID="IS3"
azimuth="90.0000" horizDistance="100" distanceType="Measured"
azimuthType="Measured" />
  <ReducedObservation name="4" desc="Boundary" setupID="IS2" targetSetupID="IS4"
azimuth="0.0000" horizDistance="10" distanceType="Measured"
azimuthType="Measured" />
  <ReducedObservation name="5" desc="Connection" setupID="IS4" targetSetupID="IS7"
azimuth="0.0000" horizDistance="20" distanceType="Measured"
azimuthType="Measured" />
  <ReducedObservation name="6" desc="Connection" setupID="IS1" targetSetupID="IS5"
azimuth="90.0000" horizDistance="20" distanceType="Measured"
azimuthType="Measured" />
  <ReducedObservation name="7" desc="Connection" setupID="IS3" targetSetupID="IS6"
azimuth="45.0000" horizDistance="20" distanceType="Measured"
azimuthType="Measured" />
  <ReducedObservation name="8" desc="Connection" setupID="IS6" targetSetupID="IS7"
azimuth="272.5616" horizDistance="114.292" distanceType="Measured"
azimuthType="Measured"  distanceAdoptionFactor="0.99960"/>
  <ReducedObservation name="9" desc="Connection" setupID="IS6" targetSetupID="IS5"
azimuth="166.2141" horizDistance="24.843" distanceType="Measured"
azimuthType="Measured"  distanceAdoptionFactor="0.99960"/>
  <ReducedObservation name="10" desc="Connection" setupID="IS5"
targetSetupID="IS7" azimuth="284.0210" horizDistance="123.693"
distanceType="Measured"  azimuthType="Measured"
distanceAdoptionFactor="0.99960"/>
  <RedHorizontalPosition name="11" setupID="IS5" latitude="6000000.012"
longitude="500119.952" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-09-09"/>
  <RedHorizontalPosition name="12" setupID="IS6" latitude="6000024.145"
longitude="500114.097" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-09-09"/>
  <RedHorizontalPosition name="13" setupID="IS7" latitude="6000030.000"
longitude="500000.000" class="U"  order="4" horizontalFix="SCIMS"
horizontalDatum="MGA" currencyDate="2017-09-09"/>
</ObservationGroup>
</Survey>
<Monuments>
  <Monument name="1" pntRef="5" type="SSM" state="Found"/>
  <Monument name="2" pntRef="6" type="SSM" state="Found"/>
  <Monument name="3" pntRef="7" type="SSM" state="Found"/>
</Monuments>
</LandXML>
```

Appendix J: Validation Report for Experiment 3

Land and Property Information Division
ABN: 23 519 493 925
GPO BOX 15
Sydney NSW 2001
DX 17 SYDNEY Telephone: 1300 052 637

NSW GOVERNMENT | Land & Property Information

Land XML Validation Results

Validation Result Rejected

File Name Experiment 3.xml

# Rule:	Rule Description:	Status:	Error Message
0	Schema check	Passed	
1	Plan purpose	Passed	
2	Plan give effect to purpose	Passed	
3	Lot numbering	Passed	
4	Valid secondary parcels	Passed	
5	Parcel attributes	Passed	
6	Valid parish	Passed	
7	Valid County	Passed	
8	Valid LGA	Passed	
9	Valid Locality	Passed	
10	Valid Areas	Passed	
11	Multipart lot areas	Passed	
12	New lot area shown	Passed	
13	Parcel overlaps	Passed	
14	Multipart lot attributes	NotApplicable	
15	Parcel topology	Passed	
16	Misclose	Passed	
17	Line attributes	Passed	
18	Valid Instrument point	Passed	
19	All points used	Passed	
20	RM/PM dimensions	Passed	
21	SCIMS Date vs Survey Date	Passed	
22	SCIMS sketch	Passed	
23	Offset boundary mark	Passed	
24	unmarked boundary	Passed	

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Land and Property Information Division
ABN: 23 519 493 925
GPO BOX 15
Sydney NSW 2001
DX 17 SYDNEY Telephone: 1300 052 637

Land XML Validation Results

Validation Result Rejected

File Name Experiment 3.xml

#	Rule:	Rule Description:	Status:	Error Message
	25	RMs within 30m	Passed	
	26	SCIMS details	Failed	The coordinates for SCIMS mark 'SSM1001' didn't match. LandXML latitude/longitude was '6000024.145'/'500114.097', SCIMS latitude/longitude was '6375986.0'/'681302.0' The coordinates for SCIMS mark 'SSM1000' didn't match. LandXML latitude/longitude was '6000030.0'/'500000.0', SCIMS latitude/longitude was '6377572.0'/'681933.0' The order for SCIMS mark 'SSM1002' didn't match the current value. LandXML order was '4', SCIMS order was '2' The order for SCIMS mark 'SSM1001' didn't match the current value. LandXML order was '4', SCIMS order was '5' The order for SCIMS mark 'SSM1000' didn't match the current value. LandXML order was '4', SCIMS order was 'U' The coordinates for SCIMS mark 'SSM1002' didn't match. LandXML latitude/longitude was '6000000.012'/'500119.952', SCIMS latitude/longitude was '6374525.604'/'680813.532'
	27	Close points	Passed	
	28	Datum terminals	Failed	Datum point A is not an established mark Datum point B is not an established mark
	29	Datum dimensions	Passed	
	30	Verifying radiation	Failed	The datum line should be verified by connection to one other established control mark
	31	RMs for urban plan no road frontage	Failed	Survey contains no roads or proposed roads. Must connect to two reference marks.
	32	Found RM origin	Passed	
	33	RM connect to one boundary point	Failed	No placed monuments were found
	34	PMs new road	Passed	
	35	RMs road frontage terminals	Passed	
	36	RMs for total road frontage	Passed	
	37	PM to PM dimensions	Passed	
	38	PM connect to survey	Passed	
	39	PMs & traverse loops close	Passed	
	40	Marks exist	Passed	
	41	MM Radial Search	Passed	
	42	PMs required for number of parcels	Passed	

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Land and Property Information Division
ABN: 23 519 493 925
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Sydney NSW 2001
DX 17 SYDNEY Telephone: 1300 052 637

Land XML Validation Results

Validation Result Rejected

File Name Experiment 3.xml

#	Rule:	Rule Description:	Status:	Error Message
	43	Surveyor name	Passed	
	44	Surveyor reference	Passed	
	45	Numbering of new lots	Passed	
	46	Combined scale factor	Passed	
	47	Natural boundaries	Passed	
	48	Plans used	Failed	Plans used is missing
	49	Urban or Rural	Passed	
	50	Occupations	Passed	
	51	Line Type	Passed	

Appendix K: Exported LandXML File from GeoCadastre for Experiment 3

Note that the relevant sections of the LandXML code are highlighted in yellow.

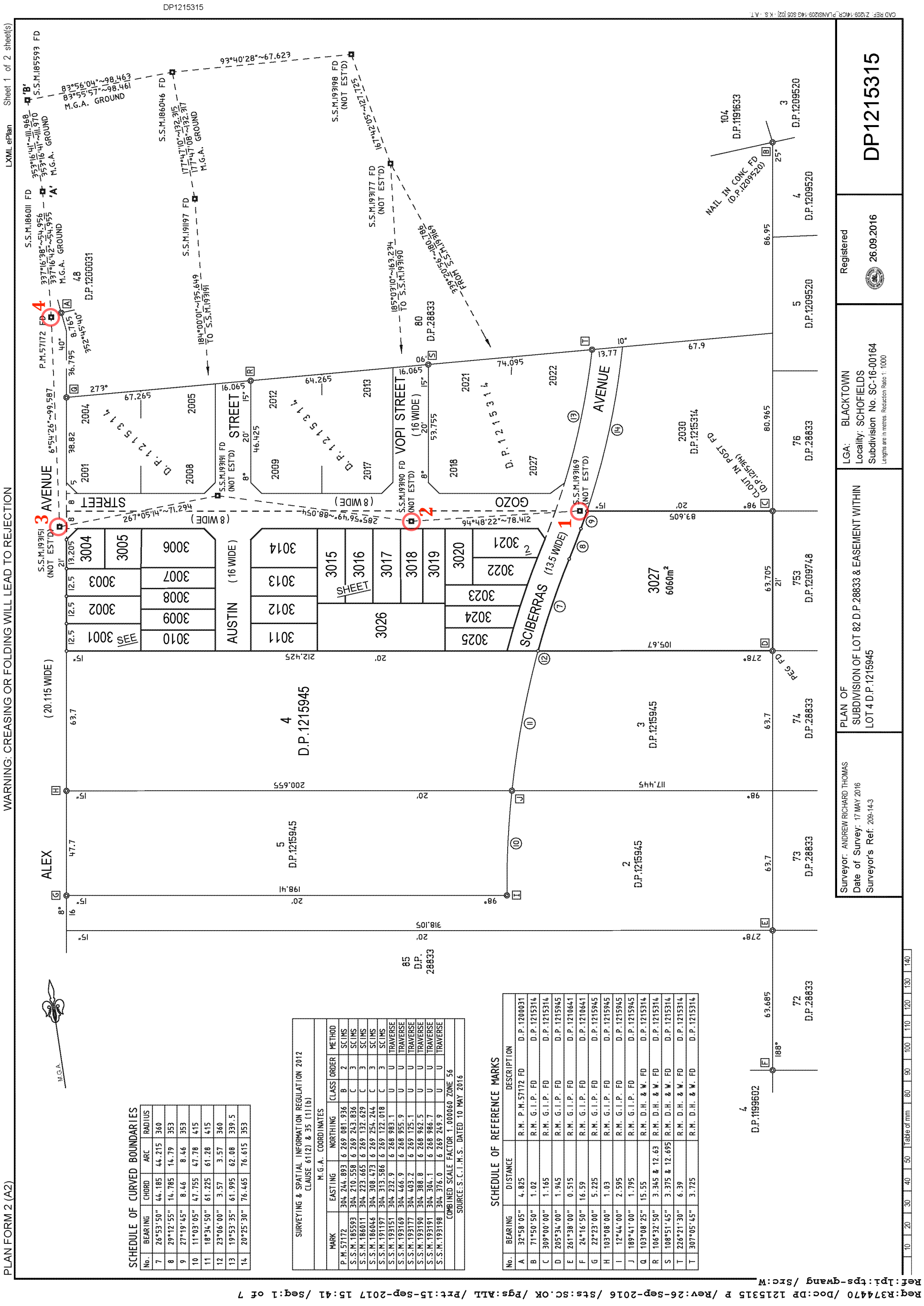

```
<?xml version="1.0" encoding="UTF-8"?>
<LandXML version="1.0" date="2017-09-09" time="11:22:00"
 xmlns="http://www.landxml.org/schema/LandXML-1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.landxml.org/schema/LandXML-1.2
http://www.landxml.org/schema/LandXML-1.2/LandXML-1.2.xsd">
<Units>
  <Metric linearUnit="meter" temperatureUnit="celsius" volumeUnit="cubicMeter"
areaUnit="squareMeter" pressureUnit="milliBars" angularUnit="decimal dd.mm.ss"
directionUnit="decimal dd.mm.ss" />
</Units>
<CoordinateSystem datum="MGA" horizontalDatum="Local" />

<Application name="GeoCadastre" version="5.82" />
<FeatureDictionary name="ReferenceDataContext" version="NSW-101013" >
<DocFileRef name="au-gov-nsw-icsm-cif-enumerated-types.xsd"
location="http://www.lpi.nsw.gov.au/__data/assets/xml_file/0010/137368/xml-govau-
nsw-icsm-eplan-cif-referencedata-101013.xml" />
</FeatureDictionary>
<CgPoints zoneNumber="56" >

  <CgPoint state="proposed" pntSurv="boundary" name="1">6000000.012104
500099.960054</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="2">6000000.012328
499999.999919</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="3">6000010.008332
500099.960109</CgPoint>
  <CgPoint state="proposed" pntSurv="boundary" name="4">6000010.008350
499999.999917</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1002" desc="B"
name="5">6000000.012000 500119.952000</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1001" name="6">6000024.145000
500114.097000</CgPoint>
  <CgPoint state="existing" pntSurv="control" oID="1000" desc="A"
name="7">6000030.000000 500000.000000</CgPoint>
</CgPoints>

<Parcels>
  <Parcel name="1" class="Lot" state="proposed" parcelType="Single"
parcelFormat="Standard" area="1000.0">
    <CoordGeom name="11001">
      <Line>
        <Start pntRef="1"/>
        <End pntRef="2"/>
      </Line>
```

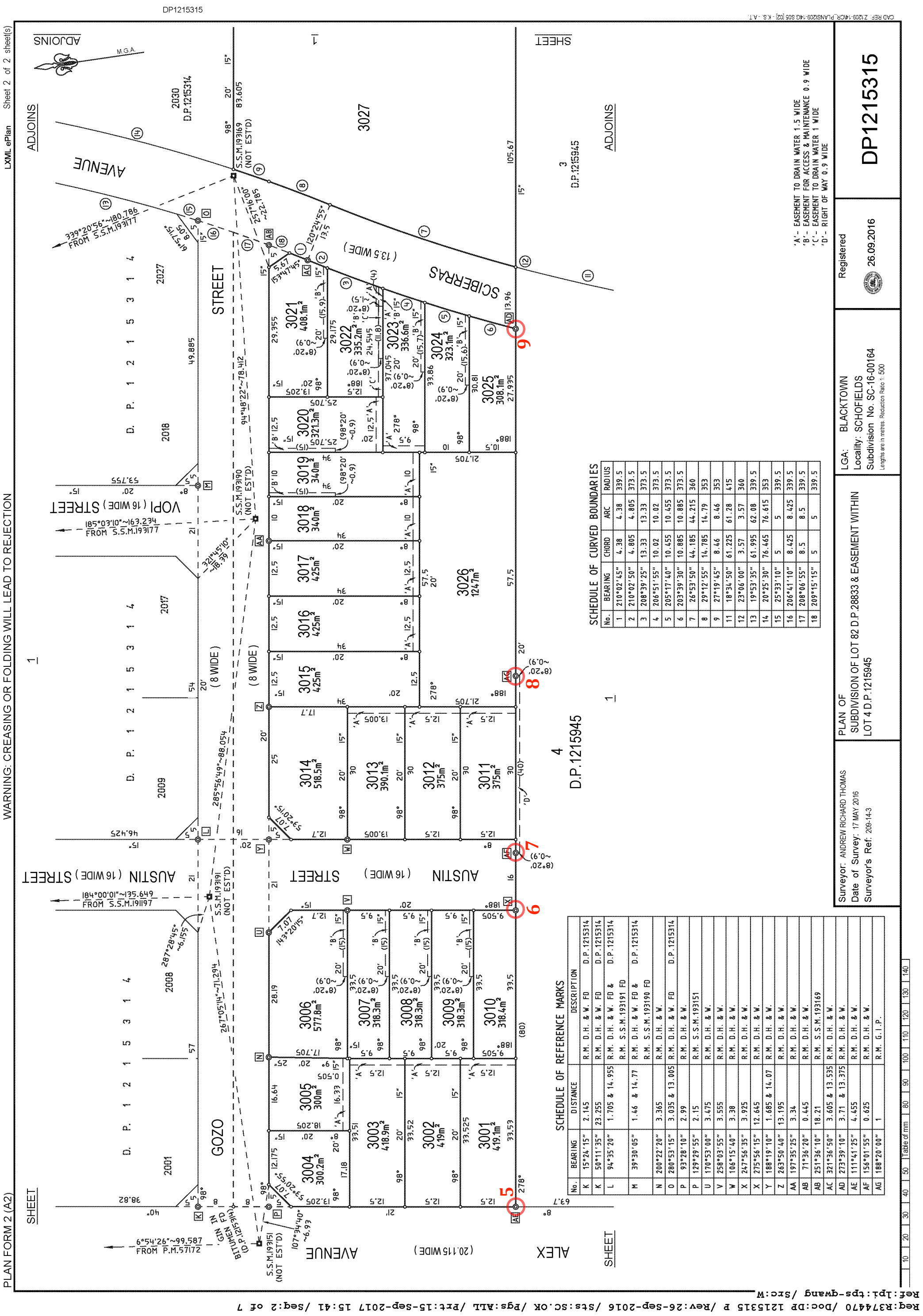
```
      <Line>
        <Start pntRef="2"/>
        <End pntRef="4"/>
      </Line>
      <Line>
        <Start pntRef="4"/>
        <End pntRef="3"/>
      </Line>
      <Line>
        <Start pntRef="3"/>
        <End pntRef="1"/>
      </Line>
    </CoordGeom>
  </Parcel>
</Parcels>
<Survey>
  <SurveyHeader name="1001" jurisdiction="New South Wales" desc="PLAN OF
SUBDIVISION" surveyorFirm="UNSW" surveyorReference="72-10-1343-Ver"
surveyFormat="Standard" type="surveyed">
    <AdministrativeDate adminDateType="Date Of Survey" adminDate="2017-09-09" />
  <Personnel name="Ahmed " />
    <PurposeOfSurvey name="Subdivision"/>
    <AdministrativeArea adminAreaType="Locality" adminAreaName="CUMBERLAND"/>
    <AdministrativeArea adminAreaType="Local Government Area"
adminAreaName="PENRITH CITY COUNCIL"/>
    <AdministrativeArea adminAreaType="Parish" adminAreaName="CASTLEREAGH"/>
    <AdministrativeArea adminAreaType="County" adminAreaName="CUMBERLAND"/>
    <AdministrativeArea adminAreaType="Survey Region" adminAreaName="Urban"/>
  </SurveyHeader>
  <InstrumentSetup id="IS1" stationName="1" instrumentHeight="0">
<InstrumentPoint pntRef="1"/>
</InstrumentSetup>
  <InstrumentSetup id="IS2" stationName="2" instrumentHeight="0">
<InstrumentPoint pntRef="2"/>
</InstrumentSetup>
  <InstrumentSetup id="IS3" stationName="3" instrumentHeight="0">
<InstrumentPoint pntRef="3"/>
</InstrumentSetup>
  <InstrumentSetup id="IS4" stationName="4" instrumentHeight="0">
<InstrumentPoint pntRef="4"/>
</InstrumentSetup>
  <InstrumentSetup id="IS5" stationName="5" instrumentHeight="0">
<InstrumentPoint pntRef="5"/>
</InstrumentSetup>
  <InstrumentSetup id="IS6" stationName="6" instrumentHeight="0">
<InstrumentPoint pntRef="6"/>
</InstrumentSetup>
  <InstrumentSetup id="IS7" stationName="7" instrumentHeight="0">
<InstrumentPoint pntRef="7"/>
</InstrumentSetup>
<ObservationGroup id="OG-1">
  <ReducedObservation name="1" desc="Boundary" setupID="IS1" targetSetupID="IS2"
azimuth="270" horizDistance="100.000"  distanceType="Measured"/>
```

```
  <ReducedObservation name="2" desc="Boundary" setupID="IS2" targetSetupID="IS4"
azimuth="0" horizDistance="10.000"  distanceType="Measured"/>
  <ReducedObservation name="3" desc="Boundary" setupID="IS4" targetSetupID="IS3"
azimuth="90" horizDistance="100.000"  distanceType="Measured"/>
  <ReducedObservation name="4" desc="Boundary" setupID="IS3" targetSetupID="IS1"
azimuth="180" horizDistance="10.000"  distanceType="Measured"/>
  <ReducedObservation name="5" desc="Connection" setupID="IS4" targetSetupID="IS7"
azimuth="0" horizDistance="20.000"  distanceType="Measured"/>
  <ReducedObservation name="6" desc="Connection" setupID="IS1" targetSetupID="IS5"
azimuth="90" horizDistance="20.000"  distanceType="Measured"/>
  <ReducedObservation name="7" desc="Connection" setupID="IS3" targetSetupID="IS6"
azimuth="45" horizDistance="20.000"  distanceType="Measured"/>
  <ReducedObservation name="8" desc="Connection" setupID="IS6" targetSetupID="IS7"
azimuth="272.5616" horizDistance="114.292"  distanceAdoptionFactor="0.99960000"/>
  <ReducedObservation name="9" desc="Connection" setupID="IS6" targetSetupID="IS5"
azimuth="166.2141" horizDistance="24.843"  distanceAdoptionFactor="0.99960000"/>
  <ReducedObservation name="10" desc="Connection" setupID="IS5"
targetSetupID="IS7" azimuth="284.0210" horizDistance="123.693"
distanceAdoptionFactor="0.99960000"/>
  <RedHorizontalPosition name="11" setupID="IS5" latitude="6000000.012000"
longitude="500119.952000" horizontalFix="SCIMS" class="U" order="4"
currencyDate="2017-09-09" horizontalDatum="MGA"/>
  <RedHorizontalPosition name="12" setupID="IS6" latitude="6000024.145000"
longitude="500114.097000" horizontalFix="SCIMS" class="U" order="4"
currencyDate="2017-09-09" horizontalDatum="MGA"/>
  <RedHorizontalPosition name="13" setupID="IS7" latitude="6000030.000000"
longitude="500000.000000" horizontalFix="SCIMS" class="U" order="4"
currencyDate="2017-09-09" horizontalDatum="MGA"/>
</ObservationGroup>
</Survey>
<Monuments>
  <Monument name="1" pntRef="5" type="SSM" state="Found" />
  <Monument name="2" pntRef="6" type="SSM" state="Found" />
  <Monument name="3" pntRef="7" type="SSM" state="Found" />
</Monuments>
</LandXML>
```

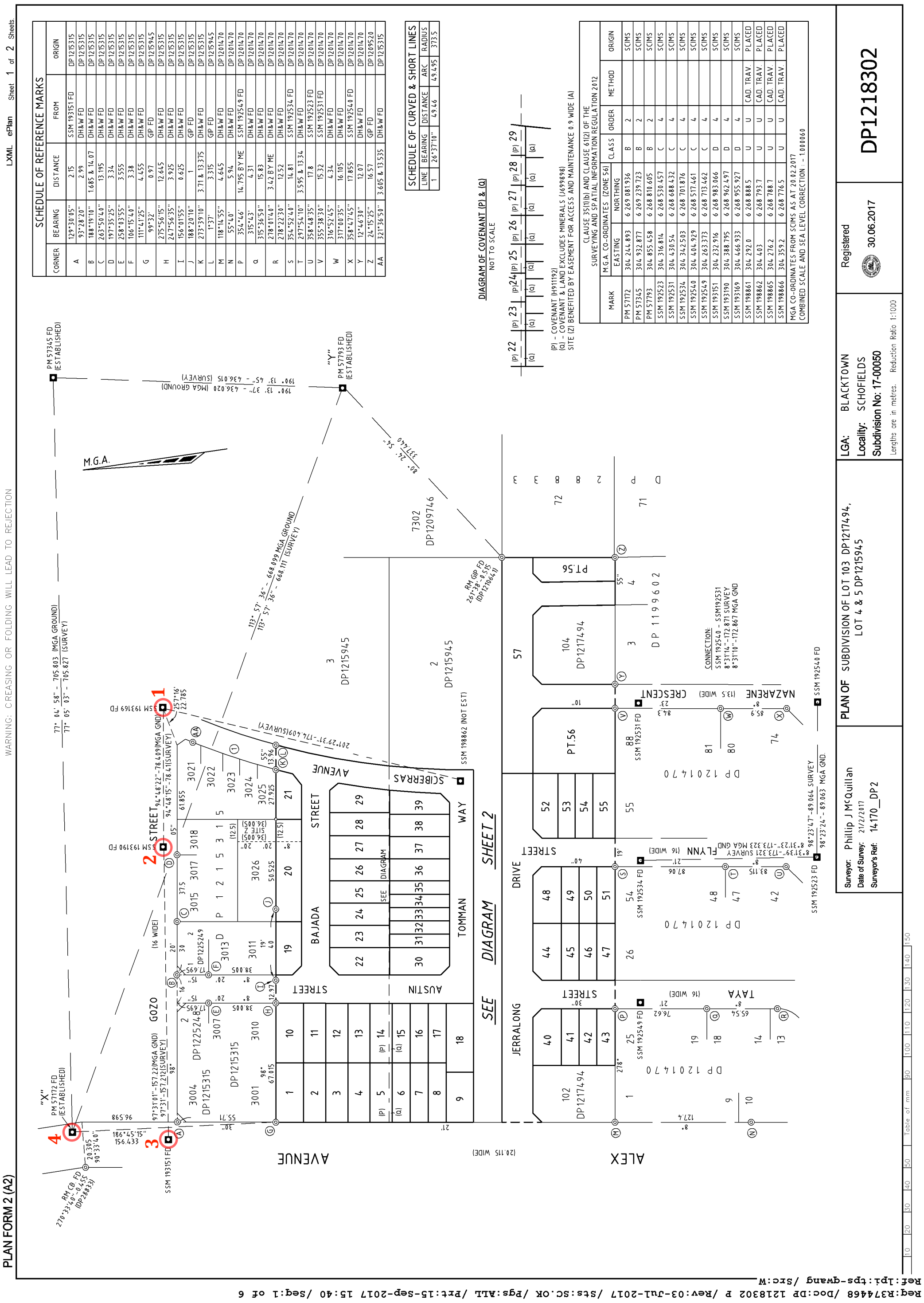
Appendix L: Deposited Plans for Experiment 4

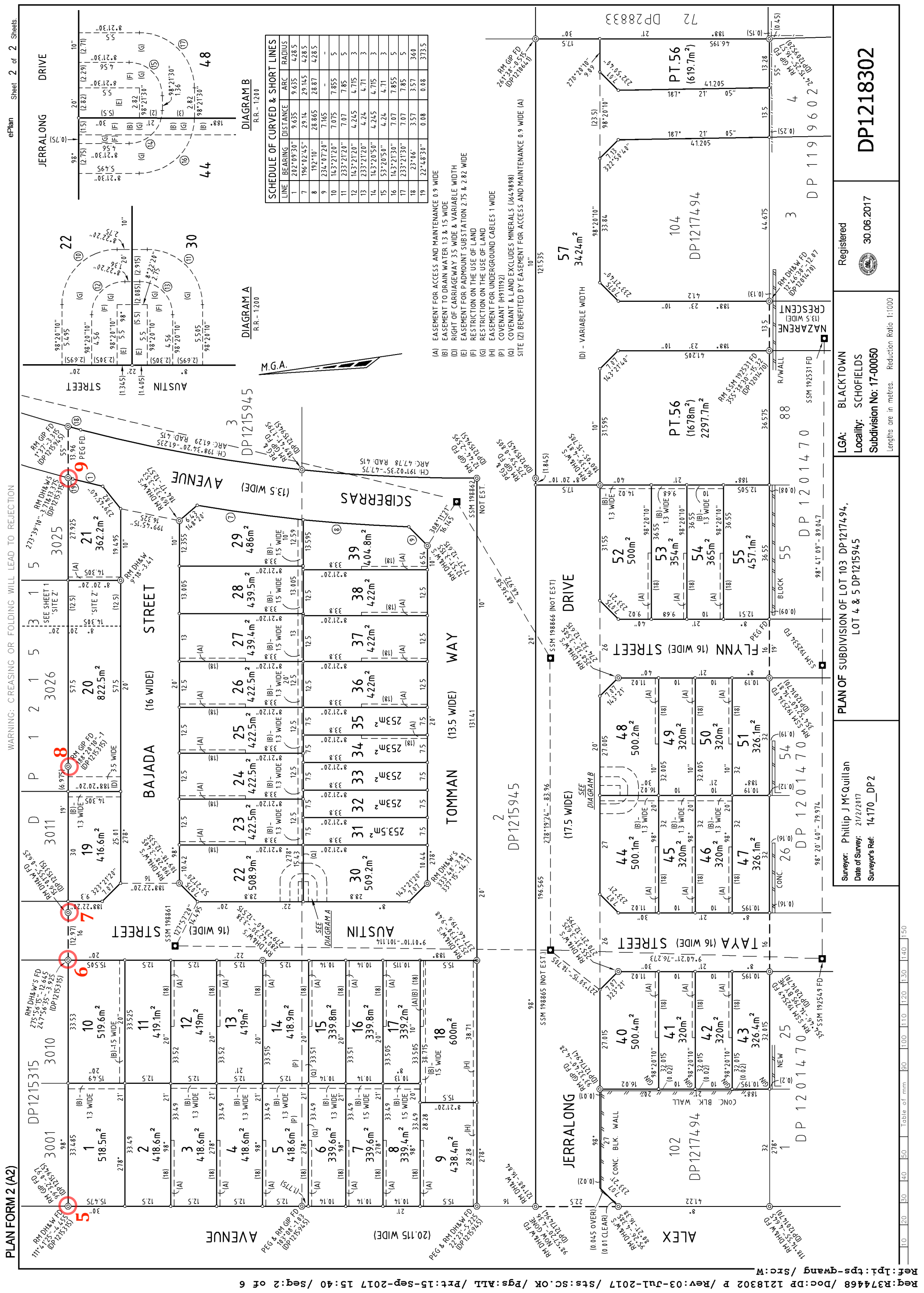
DP1215315




DP1215315
PLAN FORM 2 (A2)
WARNING: CREASING OR FOLDING WILL LEAD TO REJECTION
LXML ePlan Sheet 2 of 2 sheet(s)
ADJOINS
SHEET
GOZO STREET
AUSTIN STREET
VOPI STREET
SCIBERRAS AVENUE
ALEX AVENUE
4
D.P.1215945
3
D.P.1215945
SCHEDULE OF CURVED BOUNDARIES
SCHEDULE OF REFERENCE MARKS
'A' - EASEMENT TO DRAIN WATER 1.5 WIDE
'B' - EASEMENT FOR ACCESS & MAINTENANCE 0.9 WIDE
'C' - EASEMENT TO DRAIN WATER 1 WIDE
'D' - RIGHT OF WAY 0.9 WIDE
Surveyor: ANDREW RICHARD THOMAS
Date of Survey: 17 MAY 2016
Surveyor's Ref: 209-14-3
PLAN OF SUBDIVISION OF LOT 82 D.P.28833 & EASEMENT WITHIN LOT 4 D.P.1215945
LGA: BLACKTOWN
Locality: SCHOFIELDS
Subdivision No. SC-16-00164
Registered
26.09.2016
DP1215315

DP1218302


PLAN FORM 2 (A2)
WARNING: CREASING OR FOLDING WILL LEAD TO REJECTION
LXML ePlan Sheet 1 of 2 Sheets
SCHEDULE OF REFERENCE MARKS
SCHEDULE OF CURVED & SHORT LINES
DIAGRAM OF COVENANT (P) & (Q)
NOT TO SCALE
M.G.A.
AVENUE
STREET
BAJADA
TOMMAN
WAY
SCIBERRAS
AVENUE
GOZO
JERRALONG
DRIVE
ALEX
FLYNN
TAYA
CRESCENT
NAZARENE
SEE DIAGRAM SHEET 2
PLAN OF SUBDIVISION OF LOT 103 DP1217494, LOT 4 & 5 DP1215945
LGA: BLACKTOWN
Locality: SCHOFIELDS
Subdivision No: 17-00050
Lengths are in metres. Reduction Ratio 1:1000
Surveyor: Phillip J McQuillan
Registered 30.06.2017
DP1218302


DP1218302
PLAN OF SUBDIVISION OF LOT 103 DP1217494, LOT 4 & 5 DP1215945
LGA: BLACKTOWN
Locality: SCHOFIELDS
Registered 30.06.2017
PLAN FORM 2 (A2)
WARNING: CREASING OR FOLDING WILL LEAD TO REJECTION
SCHEDULE OF CURVED & SHORT LINES
DIAGRAM A
DIAGRAM B
Surveyor: Phillip J McQuillan

Appendix M: LandXML File with Arbitrary CgPoint Coordinates

Note that the following Appendix shows an extract of the original LandXML file. Sections of LandXML code which have been truncated are indicated by an ellipsis (...) and the relevant sections of the code are highlighted in yellow.


```
<?xml version="1.0" encoding="utf-8"?>
<LandXML xmlns="http://www.landxml.org/schema/LandXML-1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.landxml.org/schema/LandXML-1.2
http://www.landxml.org/schema/LandXML-1.2/LandXML-1.2.xsd" version="1.0"
date="2017-07-14" time="09:46:26">
  <Units>
    <Metric linearUnit="meter" temperatureUnit="celsius" volumeUnit="cubicMeter"
areaUnit="squareMeter" pressureUnit="milliBars" angularUnit="decimal dd.mm.ss"
directionUnit="decimal dd.mm.ss" />
  </Units>
  <CoordinateSystem datum="MGA" horizontalDatum="Local" verticalDatum="AHD" />
  <Application name="MAGNET Office" version="v 4.3">
    <!--Project: 206147_02a_landxml-->
  </Application>
  <FeatureDictionary name="ReferenceDataContext" version="NSW-101013">
    <DocFileRef name="au-gov-nsw-icsm-cif-referencedata-101013.xml"
location="http://www.lpma.nsw.gov.au/__data/assets/xml_file/0010/137368/xml-govau-
nsw-icsm-cif-eplan-referencedata-101013.xml" />
  </FeatureDictionary>
  <CgPoints zoneNumber="55">
...
    <CgPoint name="54621" state="existing" pntSurv="control"
oID="54621">8035.705163 3693.742128</CgPoint>
    <CgPoint name="54623" state="existing" pntSurv="control" oID="54623"
desc="A">7951.814629 3650.959336</CgPoint>
    <CgPoint name="54625" state="existing" pntSurv="control"
oID="54625">7866.152421 3709.845571</CgPoint>
    <CgPoint name="54629" state="existing" pntSurv="control"
oID="54629">7996.501543 3785.962044</CgPoint>
    <CgPoint name="54630" state="existing" pntSurv="control"
oID="54630">7912.310845 3854.620521</CgPoint>
    <CgPoint name="54631" state="existing" pntSurv="control"
oID="54631">7816.781868 3847.158145</CgPoint>
    <CgPoint name="54632" state="existing" pntSurv="control"
oID="54632">8043.276572 3873.538341</CgPoint>
    <CgPoint name="56291" state="existing" pntSurv="control" oID="56291"
desc="B">7743.658331 3813.820037</CgPoint>
    <CgPoint name="195713" state="existing" pntSurv="control"
oID="195713">7766.114424 3930.646382</CgPoint>
  </CgPoints>
```

```
...
    <SurveyHeader name="1233465" jurisdiction="New South Wales"
surveyFormat="Standard" type="surveyed" desc="PLAN OF SUBDIVISION OF LOT 158 IN
DP1207987" surveyorReference="206147_02A" surveyorFirm="GEOLYSE">
      <Personnel name="SAMUEL BYRNES" />
      <AdministrativeArea adminAreaType="Locality" adminAreaName="ORANGE" />
      <AdministrativeArea adminAreaType="Parish" adminAreaName="ORANGE" />
      <AdministrativeArea adminAreaType="County" adminAreaName="WELLINGTON" />
      <AdministrativeArea adminAreaType="Local Government Area"
adminAreaName="ORANGE" />
      <AdministrativeArea adminAreaType="Survey Region" adminAreaName="Urban" />
      <Annotation type="Plans Used" name="1" desc="DP534381 DP816985 DP1065578
DP1154466 DP1202584 DP1207987" />
      <Annotation type="Plan Note" name="2" desc="Policy 3, (DP1207987)" />
      <PurposeOfSurvey name="Subdivision" />
      <AdministrativeDate adminDate="2017-06-23" adminDateType="Date Of Survey" />
 ...
    <ObservationGroup id="OG-1">
      ...
      <RedHorizontalPosition name="396" setupID="IS54621" latitude="6318035.685"
longitude="693693.755" horizontalDatum="MGA" horizontalFix="Traverse"
currencyDate="2017-05-01" class="U" order="U" />
      <RedHorizontalPosition name="397" setupID="IS54632" latitude="6318043.255"
longitude="693873.535" horizontalDatum="MGA" horizontalFix="Traverse"
currencyDate="2017-05-01" class="D" order="U" />
      <RedHorizontalPosition name="398" setupID="IS54623" latitude="6317951.80"
longitude="693650.975" horizontalDatum="MGA" horizontalFix="Traverse"
currencyDate="2017-05-01" class="U" order="U" />
      <RedHorizontalPosition name="399" setupID="IS54630" latitude="6317912.30"
longitude="693854.62" horizontalDatum="MGA" horizontalFix="Traverse"
currencyDate="2017-05-01" class="D" order="U" />
      <RedHorizontalPosition name="400" setupID="IS54629" latitude="6317996.485"
longitude="693785.965" horizontalDatum="MGA" horizontalFix="Traverse"
currencyDate="2017-05-01" class="D" order="U" />
      <RedHorizontalPosition name="401" setupID="IS54625" latitude="6317866.14"
longitude="693709.855" horizontalDatum="MGA" horizontalFix="Traverse"
currencyDate="2017-05-01" class="U" order="U" />
      <RedHorizontalPosition name="402" setupID="IS54631" latitude="6317816.78"
longitude="693847.16" horizontalDatum="MGA" horizontalFix="Traverse"
currencyDate="2017-05-01" class="D" order="U" />
      <RedHorizontalPosition name="403" setupID="IS56291" latitude="6317743.655"
longitude="693813.823" horizontalDatum="MGA" horizontalFix="SCIMS"
currencyDate="2017-05-01" class="B" order="2" />
      <RedHorizontalPosition name="404" setupID="IS195713" latitude="6317766.11"
longitude="693930.64" horizontalDatum="MGA" horizontalFix="Traverse"
currencyDate="2017-05-01" class="D" order="U" />
    </ObservationGroup>
  </Survey>
  ...
</LandXML>
```

Appendix N: Thesis Time Sheet

Semester 1

Total Hours	**169**	
Week	**Hours**	**Description**
0	2	❖ LPI meeting about LandXML
1	6	❖ Some research into LandXML ❖ Thesis meeting with Craig
2	10	❖ More research into topic (trying to define goals) ❖ Thesis meeting with Craig
3	6	❖ Spoke with Peter Baxter about LandXML issues and goals for thesis ❖ Thesis meeting with Craig
4	7	❖ Learnt LXML4AC software ❖ Thesis meeting with Craig
5	12	❖ Started on literature review ❖ Attended course on how to search for literature ❖ Thesis meeting with Craig
6	21	❖ Fixed up referencing (using EndNote) ❖ Continued with literature review ❖ Found more literature and made summary notes ❖ Attended eWG meeting at LPI ❖ Thesis meeting with Craig
7	5	❖ Reviewed literature review work
Mid-sem break	10	❖ Wrote up problem statement as requested by Craig ❖ Started looking at Stringer ePlan and 12d Model software ❖ Thesis meeting with Craig

8	3	❖ Fixed up literature review ❖ Thesis meeting with Craig
9	6	❖ Continued with literature review ❖ Thesis meeting with Craig
10	14	❖ Continued with thesis writing ❖ Visited LPI about PlanTest ❖ Attended Magnet Office demo at UNSW ❖ Thesis meeting with Craig
11	12	❖ Started finalising literature review for thesis ❖ Thesis meeting with Craig
12	8	❖ Finalised literature review for submission ❖ Thesis meeting with Craig
13	6	❖ Investigated issue outlined by Peter Baxter ❖ Performed some software tests
14	9	❖ Got Thesis checked by Mark Deal ❖ Continued reviewing thesis ❖ Performed more software tests
Mid-year break	0	❖ Break
Mid-year break	0	❖ Break
Mid-year break	9	❖ Attended intro to 12d Model course ❖ Stringer ePlan webcast
Mid-year break	13	❖ Attended Magnet Office EPlan course ❖ Started experimentation write up ❖ Started learning how to interpret LandXML code
Mid-year break	10	❖ Thesis report writing ❖ Continued learning how to interpret LandXML code

Semester 2

Total Hours	277	
Week	**Hours**	**Description**
0	11	❖ Thesis report writing (worked on experiment 1)
1	25	❖ Meeting with Michael Elfick (GeoCadastre) ❖ Meeting with Peter Baxter ❖ Attended Stringer ePlan course ❖ Thesis meeting with Craig ❖ Thesis report writing
2	24	❖ Thesis report writing ❖ Software testing (discovered problem with outputted data from GeoCadastre)
3	21	❖ Thesis report writing ❖ Computer work ❖ Thesis meeting with Craig
4	10	❖ Decided on scope of thesis ❖ Thesis report writing
5	17	❖ Thesis report writing (worked on experiment 2) ❖ Thesis meeting with Craig ❖ Computer work
6	12	❖ Thesis report writing
7	13	❖ Thesis report writing (started on experiment 3) ❖ Reviewed thesis writing ❖ Computer work
8	24	❖ Thesis report writing ❖ Thesis meeting with Craig ❖ LPI meeting
9	22	❖ Thesis report writing ❖ Finalised abstract

Mid-sem break	12	❖ Thesis report writing (started on experiment 4 and reviewed thesis) ❖ Computer work
10	23	❖ Thesis report writing ❖ Thesis meeting with Craig
11	22	❖ Thesis report writing
12	27	❖ Thesis report writing ❖ Thesis meeting with Craig
13	14	❖ Thesis report writing (submission week - due on Friday)
Grand Total	**446**	