University of Southern Queensland

Faculty of Engineering and Surveying

Application of Geographical Information System in Underground Coal Mine to assist Operational Management

A dissertation submitted by

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In fulfilment of the requirements of

Courses ENG4111 and 4112 Research Project

Towards the degree of

Bachelor of Spatial Science (Surveying)

November 2006

Abstract

This research investigation aims to expand on a current Geographical Information System (Autodesk Map 3D 2007) at an underground coal mine in NSW (Metropolitan Colliery). The current GIS is only used for the sole purpose of producing ArcView shape files for the Department of Primary Industries (DPI) -Titles & Charting Branch for input into their GIS. The shape files are only used for mine plan (map) updates. The GIS is being under utilised and management may not beware of the potential that GIS can bring to the decision making process at the mine.

The project will explore other potential applications of GIS for an underground coal mine that will be a benefit for decision making and the possibility of further expansion of the current GIS.

The GIS implementation process starts with the initial decision to use a GIS; it then proceeds through system selection, installation, data base development and product generation. The research project discusses considerations related to each phase and focus on other areas of GIS pertinent to under ground coal mine planning and management. The research involved reviewing literature relating to implementing GIS to underground mines and in the resource sector. The research then explores the capabilities of GIS presently used at the coal mine site and compares that system to other systems on the market. Develop a program of data collection. Evaluate the existing data and acquire data from various sources. The project intends to produce thematic maps of various themes with all maps compiled on the same co-ordinate system so the may be overlaid and produce suitable reports to assist mine management with decision making.

GIS has the capacity to put together information from a variety of sources into a spatial context and is well suited to support decision making procedures. GIS can act as a tool in helping the decision-makers evaluate alternatives and explore certain alternatives.

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Acknowledgements

This research was carried out under the principal supervision of Dr Badri Basnet of the faculty of engineering and Surveying, University of Southern Queensland.

Appreciation is also due to Helensburgh Coal Pty Ltd for the use of the surveying and computer equipment necessary for the successful completion of the project and the permission for the use of mine data and entry onto the mine site.

Thanks must be also being extended to Yvette, Paris and Xavier Fabian-Carter for their support and patience throughout the research project. Without their support and patience this project could not have been completed.

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1 Introduction

1.1 Introduction

"The use of Geographical Information Systems (GIS) as a powerful tool to analyse and display data is gathering momentum in the mining industry. Of particular interest is the capability of geographical information systems to link spatial features and tabular data." A.D.Hammond 2006.

> *"GIS is a hot application area for digital technology. Its software industry has been growing at more than 20% a year for many years and recent figures for total annual sales of GIS software exceed $800 million." (T.Bernhardsen 2002)*

Geographical Information systems are one of the fastest growing computer based technologies. They are being used in diverse application areas related to the resource sector such as land resources management, environmental monitoring, utilities, financial planning, transportation and market research. The GIS use has expanded in society in the last decade faster than any other analytical information technology.

This trend has not been reflected directly in the underground coal mining industry of the resource sector. Most of the computer technologies investigated by coal mining professionals focus on the descriptive aspect of the data, although vast amounts of mining data can be spatially referenced.

1.2 Outline of the Study

GIS technology capability in the underground coal mining industry has not been fully realised. This technology provides adequate capabilities for solving problems that involves the integration and analysis of spatial and descriptive data from a variety of sources.

"Actually, there are often many truths in a place or an area right before our eyes, and yet we're not aware of those truths (or features, or facts) until a depiction or symbol or even a diagram shows them to us. That is one reason why we need maps not only of far away places we've never seen but of the very regions we live in." (Greenhood 1964, p. x – xi.)

Greenhood (1964) clearly states that maps are an important element in enhancing the representation of facts and situations not only of far away places but also in regions we are living in or even work. Representation of the truth can raise awareness and understanding to people about facts occurring in their communities, neighborhoods, work place and some other such places.

ESRI President Jack Dangermond (2001) indicates that GIS plays an important role in supporting informed decision making when dealing with certain problems which could include population distributions, resource use, pollution management and social security matters. GIS technology can create a large framework from which activities can be coordinated and results can be represented graphically.

This research project intends to focus upon the expansion and use of GIS to assist management with its decision making process by presenting information as thematic maps at Metropolitan Colliery located at Helensburgh New South Wales. This will help management in decision making process at the mine as most decisions involve complex data. Thematic maps will allow management to make confident and sound decisions about the mine and its operations with complex data being displayed in a friendly graphical format which will be different to the current decision making process.

1.3 *Metropolitan* Colliery

As for many South Coast mines of New South Wales Metropolitan Colliery has a long history of production, commencing in 1888. Developed in rugged country at Heathcote where Charles Harper carried out drilling in 1884 with in the land owned by the Cumberland Coal & Iron Mining Company, the mine was to supply the railways and Port Jackson with coal.

Figure 1 Metropolitan Colliery – Southern Coal Fields

The mine has had a number of owners, the majority being recent and the mine has had a checkered history recently, however production and personnel have stabilised.

Time line of Metropolitan Colliery Ownership:

- 1883 - 1888 Cumberland Coal & Iron Mining Co & Metropolitan Coal Co. of Sydney
- 1921 - 1961 Haddart Parker Ltd, a shipping company
- 1961 – 1965 Boral Ltd.
- 1965 - 1985 AIS
- 1985 – 1987 Corporate Development Ltd
- 1987 – 1989 Savage Resources
- 1989 – 1996 Denehurst Ltd
- 1997 – 1998 Allied Meridian
- 1999 – 2002 Helensburgh Coal (SADA)
- 2002 – Oct 2006 South Coal Pty Ltd (Excel P/L)
- Oct 2006- Present Peabody

The current lease has approx. 40 million tonnes of recoverable reserves, giving a 15 year life with some 35 longwall blocks to be extracted. The colliery can access adjoining leases to the West, should this be needed. All the current coal is planned to be mined by the longwall method.

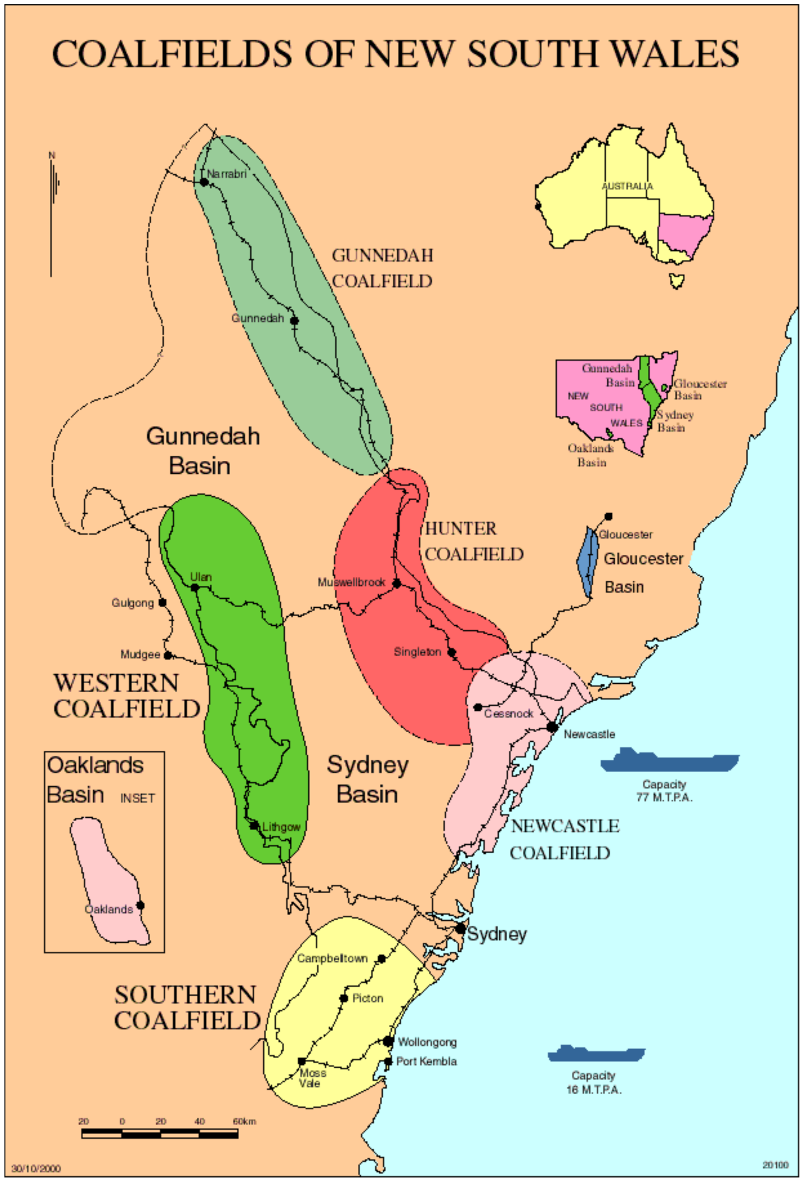


Figure 2 Coal fields of N.S.W

The seam varies in thickness from 2.8 to 3.4 metres with localised thickening, and gently dips to the North. The quality is uniform and will provide a constant product for the life of the mine.

The mine currently exports 90% of the product to 10 markets in 8 countries; the remaining 10% goes to local markets. The coal quality is good, with 55% sold as hard coking coal, the remaining as soft medium coking coal.

1.4 The Problem

The use of geographical information systems in the natural resource industry is widely recognised, however its use (in technical applications) in the mining industry is relative limited compared to other disciplines in the natural resource industry. A reason for the delay with using GIS may be due to some extent to the popularity of computer aided drafting (CAD) and its interface with speciality mining software. Typical mining packages in the mine planning process and geological modelling (eg Vulcan, Minesight, Surpac, Datamine) are all powerful and feature rich in their internal modelling and evaluation processes but have little or no focus on how to manage the data and in particular how to inter-operate with other systems to develop a complete mine plan. These mining packages cost thousands of dollars to acquire and even more dollars with setup costs, training and ongoing maintenance obligations.

The research project aims to expand on the current Geographical Information System (Autodesk Map 3D 2007) at the underground coal mine. The current GIS is only used for the sole purpose of producing ArcView shape files for the Department of Primary Industries (DPI) -Titles & Charting Branch for input into their geographical information system. These shape files are only used for mine plan (map) updates. The current GIS is not used for any other purpose. The GIS is being under utilised and management may not realise the potential GIS can bring to the decision making and management of the mine.

With demanding time restraints, high safety expectations and production goals to meet, mine management often have to make decisions quickly with the information that is made available at the time. Reliable data leads to trustworthy information and reduced uncertainty in decision making. Therefore data should be considered an important resource, one that should be well managed to maximise efficient decision making.

Multifaceted problems involving large amounts of information can be made simpler by presenting data in a different format. These formats are more often in a graphical form like a graph, map or diagram. GIS has the ability to display complex problems in a graphical format and makes a very useful tool for decision making

At Metropolitan Colliery decisions have been made, that in hindsight may have produced a different outcome if the information available or presented at the time was presented in a more precise format.

The project intends to acquire a vast amount of data from several sources to be geocoded into the existing system. Some data will be linked through a database to the GIS. The acquired data will increase the capabilities of the GIS and allow further implementation at the mine. Metropolitan Colliery has some of the required data. However, sixty percent of the data is in Hard Copy format which leads to conversion problems from hard copy to digital format. Representing technical data in a geographical location is one of the most important aspects of the project. The data input (geocoding) will take up the majority of the project tasks. Another issue to be considered is that a lot the data available is in different co-ordinate systems and will require datum transformation to allow all data to be represented on the same datum.

Overall the research project aims to expand the current GIS, gather all relevant data and input this data into the GIS so that it can be used to produce thematic maps from the results of detailed analysis to present technical problems in a graphical format and allow management to make decisions based on the graphical representation of that data.

1.5 Research Objectives

The objective of this research is to implement a geographical information system at Metropolitan Colliery to assist the operational management in decision making. The decision making is to be implemented in the five technical areas of the mine operations;

- Leases and mine holdings,
- Exploration in regard to exploration boreholes and related data,
- Areas of authorisation for approved mine roof support,
- Permits to mine first workings and lastly
- Mine safety.

In order to achieve these objectives four major activities need to be considered:

- Consider which geographical information system would be suitable (if Map 3D 2007 is not appropriate) to fulfil the objectives of this research.
- Develop a programme for data compilation. Evaluate existing data, acquire data from an assortment of sources
- Produce various thematic maps that cover the five technical fields for the aid in planning and decisions making process.
- Setup a monthly reporting system that produces thematic maps of suitable themes and reports (containing relevant statistical information to aid in end of month reporting and planning).

1.6 Conclusion

This dissertation aims to demonstrate the importance of spatial information in the mining sector. This will be highlighted by implementing a GIS in the five technical fields mention above in (section 1.5). The implemented GIS will supply thematic maps to better represent complex data in a way that is presented more clearly, allow for better understanding of the problem at hand and assist with enhanced decision making.

2 Literature Review

2.1 Introduction

Becoming familiar with GIS is not a matter of treating GIS as a black box that transform existing hard copy maps and tabular data into digital products. Any new user to GIS should lay down a good foundation of knowledge by putting aside enough time and energy in order to gain a solid understanding of the character, capabilities and costs of GIS.

Typically GIS users get much of their information on GIS from software vendors. Although vendors can be a very useful source of information on the capabilities of their specific product, they generally are unable to educate potential users on general principles and concepts of geographical information systems. As a result many users gain only a smattering of knowledge, through trial and error use of the GIS package, relying on vendor supplied manuals for guidance.

This chapter will review literature to determine how GIS can best be implement into an under ground coal mine. The purpose of this chapter is to explore how GIS can enhance decision making in a managerial role and discuss how GIS is being used in the resource industry and finally what makes up a Geographical Information System

2.2 GIS in the Mining Industry

"The application of GIS in environmental, mine remediation and reclamation has been extensively tested and documented. However, the same is not true in the area of technical mining applications" (A.D Hammond 2006)

The increasing popularity and advances in the development of GIS in recent years has complemented the design capabilities of CAD with GIS's link between spatial and tabular components. These features make GIS as the preferred tool for planning and analysis, allowing the integration of communication across departmental and corporate boundaries. This cross-boundary integration is unquestionably the way present and future communications will flow in the mining industry as the commodities market, environmental regulations, and government policies force mining companies to become more competitive and cost-effective. The Federal and State government departments and agencies involved in the mine approval process are adopting the GIS format as the standard format when it comes to spatial data in mining application documentation for example in such areas as exploration licences, Lease applications.

A lot of literature is available on GIS and its use in the resource sector. The majority of the literature is on GIS and the monitoring of the environment in and around mine sites. The studies concentrate on the effects that mining has on the environment by monitoring the change over time. Other articles on the subject of the environment range from mine site rehabilitation to monitoring soil sediment run off into neighbouring stream systems.

GIS and satellite imagery is being investigated to see how effective the imagery can be used to measure land subsidence caused from underground mining. This research is looking promising as it can cover large areas quickly but it does lack the accuracy that traditional methods can obtain

GIS is extensively used in the exploration of mineral resources. This involves satellite imagery, aerial photography, and Magnetic surveys overlay. There are many advantages of GIS's link between spatial and tabular data to access specific information some benefits are geotechnical, cadastral, metallurgical, environmental, soil types, vegetation, cultural, wildlife, slope and aspect surfaces and other thematic layers of interest. Likewise, the exploration can benefit from GIS's powerful 3D capabilities in performing visibility analysis of surface installations and display underground features in 3D.

2.3 Key Elements in Decision Making

An information technology that can be potentially be exploited to facilitate computer supported approach to spatial decision making is geographical information systems (GIS). (P.Jankowski, T Nyerges 2001).

Spatial decision making problems commonly involve three categories of participants, stake holders, decision makers and technical specialist. This is definitely the case when it comes to mining with the participants being the community and employees. The Stakeholders are the mining company, shareholders and the government. The technical specialists are consultants for both the participants and stake holders.

Decision making is the process that leads to a choice between a set of alternatives. Geographical decision making means analysing and interpreting geographical information that is related to the alternatives in question.

"The uses of GIS are limited only by the available data" (J.M. Matty 2003)

All decision making has some uncertainty, ranging from predictable (deterministic) situation to uncertain situation (Malczewski, 1999). Consequently, particularly in uncertain situations, decision making involves risk of making a wrong decision, because the information gathered is insufficient or the approach to the decision was inappropriate.

Decision making is a sequential process (based on Malczewski, 1999):

- Defining the decision problem (objective)
- Determining the set of evaluation criteria to be used
- Weighting the criteria generating alternatives
- Applying decision tools
- Recommending the best solution to the problem

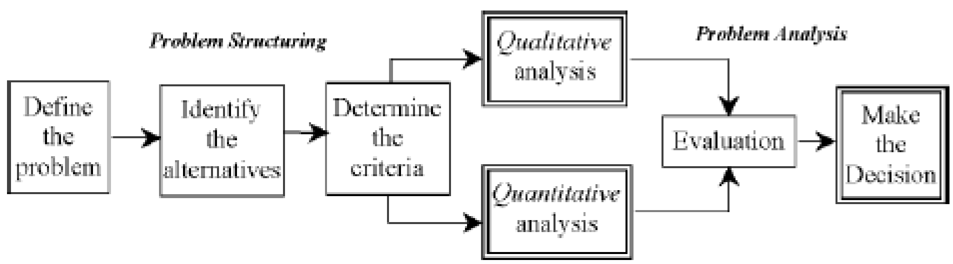


Figure 3 Decision making process

Any decision-making process starts with defining the problem or the objective to be reached. Once the decision problem is defined, what follows is setting up a set of criteria that reflects all concerns of the problem. Alternatives are often determined by constraints, which limit the decision of alternatives. Decision rules integrate criteria, weights and preferences to generate an overall assessment of the alternatives. Recommendations are based on a ranking of the alternatives, with reference to possible uncertainties or sensitivities. Sensitivities are changes in the input of the analysis that bias the outcome.

GIS has the capacity to put together information from a variety of sources into a spatial context and is well suited to support decision making procedures. GIS can act as a tool in helping the decision-makers evaluate alternatives and explore certain alternatives.

Technology Review

A tool is only as good as the person using it, and GIS is no different. GIS technology is only successful when qualified people manage and run the system. As is the case with most technologies user expertise varies depending on the needs of the system.

A reason why GIS is not fully utilised in underground coal mining may be due to some extent to the popularity of computer aided drafting (CAD) and its interface with speciality mining software (see figure4). Typical mining packages in the mining planning process and geological modelling (eg Vulcan, Minesight, Surpac, Datamine) are all powerful and feature rich in their internal modelling and evaluation processes but have little or no focus on how to mange the data and in particular how to inter-operate with other systems to develop a complete mine plan.

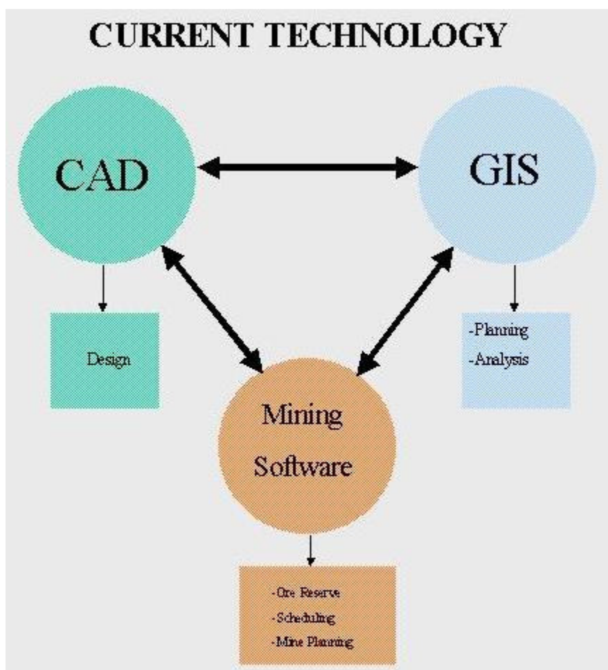


Figure 4 Link between GIS and CAD in Mining Industry

A GIS depends on qualified operators to design, develop and implement a GIS. It takes a well designed plan that must operate within set business rules, models and operating practices unique to the organisation.

Today, profitable businesses are integrating CAD and GIS within their organisations so that engineering, GIS technicians, surveying and IT departments need to collaborate and share geographic and design data.

2.3.1 Fundamental Components of an GIS

Effective GIS is a system that combines all the fundamental system elements of hardware, software, data, people and procedures. These are considered the essential components of an effective geographical information system.

Figure 5 GIS Components

GIS software provides the functions and tools needed to store, analyse, and display geographical information. Characteristics of most GIS software include:

- Database management systems (eg Oracle, SQL, Microsoft Access)
- Analysis, query and visualization tools (eg Arc/info, MGE, Arcview, GeoMedia, Mapinfo and Autodesk Map 3D 2007)
- Plug-ins and supplemental tools (eg Spatial analysis, GeoFRAMME, ERDAS, Mr. sid)

The hardware and software tasks of GIS Software are:

- Acquisition and verification
- Compilation
- Storage
- Updating and changing
- Management and exchange
- Retrieval and presentation
- Analysis and combination

2.3.2 Hardware and Software

Hardware is one of the most important GIS Components. GIS hardware are the computers and devices on which GIS operates. In the past GIS was associated with expensive and hard to use UNIX workstations. Today, GIS is used on a wide range of available and affordable computer systems. Desktop configurations and notebook computers are the new platforms for GIS.

The typical GIS hardware solution is made up of:

- The computer (PC, Mac, or Unix)
- Input Devices (Mouse, Digitiser, Scanner, Keyboard)
- Storage Devices (Hard drives, Zip Drives)
- Output devices (printers/Plotters, CD recorders, DVD, Monitor)

The technical equipment needed for a GIS must have enough power to run the software and enough memory to store large amounts of data. These are very important in regards to the hardware as the faster the system is, the quicker the performance and the sooner the results can be revealed. Ram has more weighting than processing speed when it comes to GIS hardware.

Software is essential in a spatial analyses system because it provides the ability to store, analyse and display geographical information graphically. It also allows for data input, data management, data transformation and data output.

2.3.3 Data, Data Structure and Data Types

"The uses of GIS are limited only by the available data" (J.M. Matty 2003) so it is imperative to thoroughly search all avenues for data sources, otherwise essential data may not be included in GIS analysis and resulting in a poor model.

Sources of data used in GIS maybe:

- In various digital forms: vector, raster, databases, spreadsheet, satellite
- Non digital graphics, such as maps, photographs, schematic diagrams
- Conventional documents in registers and files
- Compilation in scientific reports
- Collection of survey measurements expressed in co-ordinates or other units

"The data sources for comprehensive GIS are probably more numerous and of greater variety than for most other information systems" (T.Bernhardsen, 2002). Bernhardsen suggests that the data available for use in GIS is not limited by traditional database technology and may only be limited by the GIS users ability.

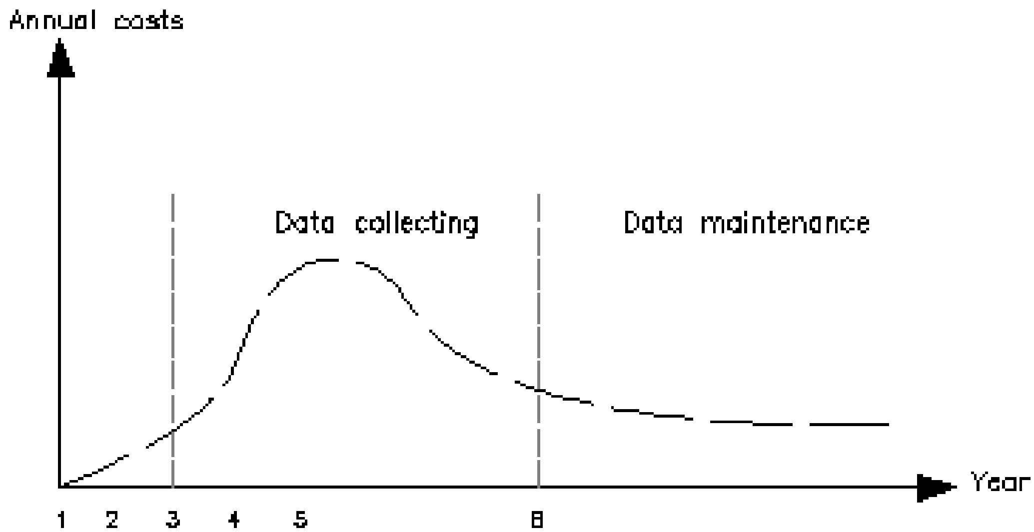


Figure 6 Data collection verus implementation time

The mix of data available to GIS caused problems with earlier systems during the 1970's. Now the issues of a mixed data system have been identified and resolved. Data collection still remains the most expensive and time consuming aspect of setting up a GIS. Data collection accounts for 60% to 80% of the total cost (time & money) see the above figure 6. Hardware and software account for 10% to 30%. Other costs are training, and administration.

"Digital map data for GIS really falls into two categories. Either the data already exists and all we have to do is find or buy the data, or they don't exist and we have to geocoded paper maps or maps on some other medium. A third case is that the maps don't even exist" (Clark 2003).

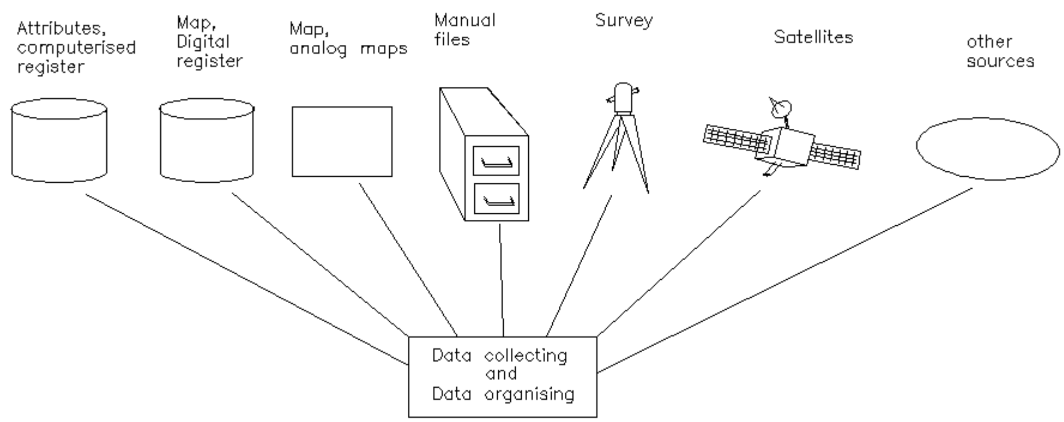


Figure 7 Sources Of Attribute Data

Sources of digital data include (see above figure)

- Existing digital data that is purchased or downloaded
- Digital data that is created for the project from existing hard copy maps or plans
- Digital data created from remotely sensed data
- Digital data gathered in the field i.e. GPS, Survey

A lot of time and money can be wasted by seeking to build a database which includes all known data about an area. It is important to determine what questions the GIS will be answering and what data is needed to answer those questions.

“The uses of GIS are limited only by the available data” (J.M. Matty 2003) so it is imperative to thoroughly search all avenues of information sources, otherwise important data may not be included in GIS analysis

Geographical data comes in three basic forms:

- *Map Data* – Contains the location and shape of geographic features. Map use three basic shapes to present real world features points, lines, and areas (polygons).
- *Attribute Data* – (tabular) data is the descriptive data that GIS links to map features. Attribute data is collected and compiled for specific areas like states, census tracts, cities, and so on and often comes packaged with map data. When implementing a GIS, the most common sources of attribute data are your own

organisation's database combined with data sets you buy or acquire from other sources to fill in gaps.

- *Image Data* – Ranges from satellite images and aerial photographs to scanned maps (maps that have been converted from printed to digital format).

An important component of any GIS is its data. GIS data is organised into two formats, or models Vector or Raster. These two data models depict events and or features that occur on the earth.

Vector Data Model represents data as a point, line or polygon feature. Characteristics of vector data are:

- Feature driven (point, line, polygons objects)
- Represented by non-continuous surfaces (identifies specific features)
- Associated easily to a database (easy to query and analyse)

Raster Data Model uses a uniform grid that contains cells. The cells are used to represent data. Characteristics of raster data are:

- Depicted by continuous features (difference between surface types)
- Represented as satellite and or aerial imagery
- Associated easily with databases.

Both models are used to emphasize spatial relationships among objects. For example in vector data model, a line is used to represent a road can also be identified as the border between government areas. In raster data models, cell values can be organised by classifying an area into distinct groups (water Vs Vegetation, Population Density Vs Crime)

2.3.4 File Formats

When you work with other departments, companies or contractors on projects you must often read data supplied in a different file formats from other applications. GIS need to be able to import data from several different external file formats.

When importing data you want to maintain the integrity and nature of the mapping and GIS data from the other applications and put data into data structure as similar as possible to the original file structure.

2.3.4.1 GIS File Formats

A GIS format is a standard of encoding geographical information into a file. They are created mainly by government mapping agencies or by GIS software developers. Popular GIS file formats are:

Raster Formats

- ECW – Enhanced Compressed Wavelet (ER Mapper)
- GeoTIFF – TIFF variant enriched with GIS relevant metadata
- IMG – ERDAS IMAGINE image file format
- MrSID – Multi Resolution Seamless Image Database (Lizardtech)

Vector formats

- DXF – AutoCAD DXF Format
- SHP – ESRI's vector data format using SHP, SHX and DBF files
- TAB – MapInfo's vector data format using TAB, DAT, ID and MAP Files
- NTF – National Transfer Format
- TIGER – Topological Integrated Geographic Encoding & Referencing

Grid Formats

- DEM – The USGS Digital Elevation Model
- SDTS – The USGS successor to DEM.

It is of a great importance that a GIS user recognises file formats so when receiving data they know what type of file it is and whether it is compatible with the GIS user's software.

2.3.4.2 Other Data formats

Although graphical data is an important part of mapping, your data can be more effective at presenting information when linked to textual data. You can use textual data as the basis for analysis in many applications such as council management, oil and mineral exploration, business and environment monitoring. You can directly link drawing objects to an external data source, such as database, spreadsheet or text files.

A database is an efficient method of storing tables and information. With the majority of GIS application, a database can be viewed and linked to a drawing / map. Linking database data is one of the steps for using GIS as a powerful analysis and presentation tool and makes GIS data more accessible and useful to more people within the organisation. Majority of GIS applications can link by
Universal Data Link (UDL) to the following external databases including

- Microsoft Access and Excel'
- dBase III and V,
- Oracle
- Microsoft Fox Pro 6,
- Paradox 7,
- Microsoft SQL Server 7 and
- Other ODBC compliant Databases.

2.3.5 Software for the Project

A comparative study needs to be taken on the available software to determine which software will best perform the particular analysis and mapping. A comparison was under taken between Arcview GIS, ArcGIS and Autodesk Map 3D 2007.

The comparison between the software will be base on the following essential features:

- Software Interface
- Importing and Exporting of GIS file formats
- Creating and editing spatial data
- Map layout ability
- Styles and Symbols

The results showed that all GIS would be suitable for the research project as all had the features that would be required for the research projects thematic mapping, analysis and co-ordinate conversion.

*2.4 **Thematic Mapping***

2.4.1 What's in a Map

"A map can be defined as a graphic depiction of all or part of a geographic realm in which real world features have been replaced by symbols in their correct spatial location at a reduced scale" (Clarke.2003 pg182).

A map requires proper design in order for it to effectively communicate the results of the geographic analysis. Poor design will inhibit the map from communicating the desired information or in some cases the wrong information is interpolated instead. Maps require the following basic elements for them to be effective (see figure next page):

- Title -
- Scale
- Sources – should be referenced
- Projection
- Orientation
- Legend
- Location – Inset map or by description in title, or by datum grid

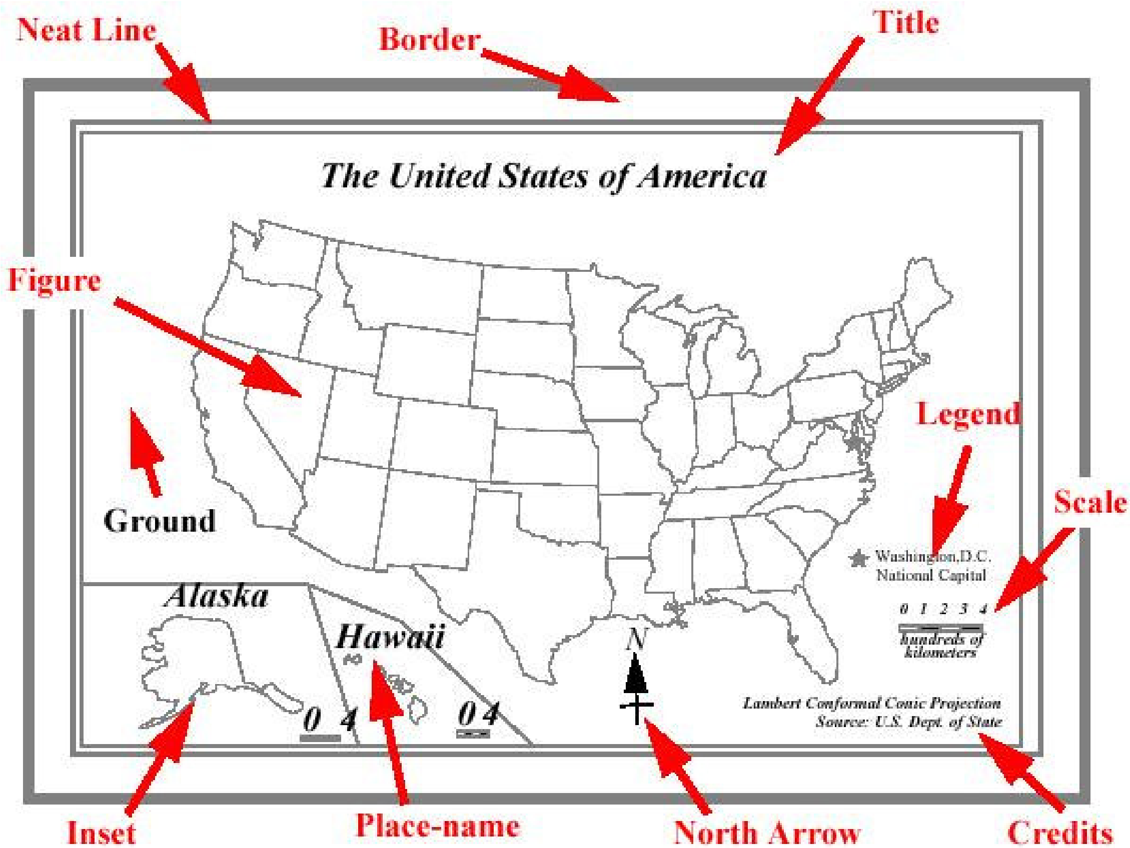


Figure 8 Essential Features of a map

Using maps is an excellent technique towards making better presentations. Thematic maps concentrate on showing the geographical occurrence and variation of a simple phenomenon, or at most a very few (Robison, Author H, 1982). These maps can reveal trends and patterns which are not obvious from a listed data in a database.

Thematic maps are tools that researchers, senior management, environmentalist, governments and commercial business may use to represent how a set of attribute data is distributed spatially. Not to be confused with reference or topographical maps, thematic maps are not generally used for navigation. Any place names that they may be included are only added for the purpose of orientation. Instead thematic maps usually convey information about a single theme.

2.4.2 Uses of Thematic Maps

"Thematic maps serve three primary purposes. First, they provide specific information about particular locations. Second, they provide general information about spatial patterns. Third, they can be used to compare patterns on two or more maps. When designing a thematic map, cartographers must keep in mind certain conventions in order to effectively represent the data." (Thematic map – Wikipedia)

Of equal importance is audience. Who will read the thematic map and for what purpose helps define how it should be designed. For example a political scientist may prefer having information mapped within county boundaries (Choropleth maps).

2.4.3 Types of Thematic Maps

There are many methods to create thematic maps but five techniques are especially noted

Choropleth Maps - Most commonly used method of thematic mapping. Choropleth maps are great to chart phenomena that are evenly distributed within each enumeration unit (set area). Choropleth maps work best with discrete data

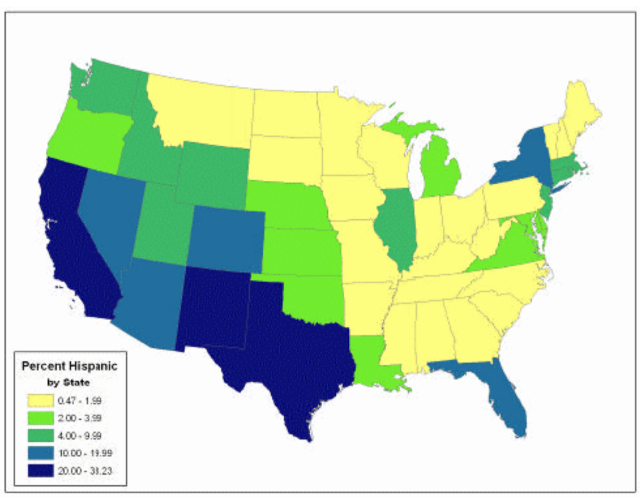


Figure 9 Choropleth Map
Figure sourced from GIS Resource Document 05-70 Brian McManus

Graduated Symbol Maps – Very similar to the Choropleth map, the graduated symbol map uses symbols of varying size, rather than colour, placed within a region to denote the value assigned to it. Often the symbol selected is a circle but is up to the map maker.

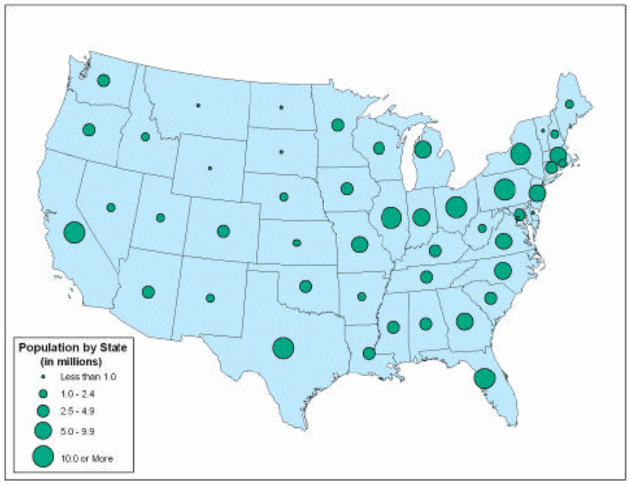


Figure 10 Graduated Symbol Map
Figure sourced from GIS Resource Document 05-70 Brian McManus

Dot Maps – a point is placed on the map to indicate the phenomenon being map to the corresponding location on earth. The dot is of uniform size, which should be relatively small. Concentrations of dots reveal abundance of the occurrence being studied.

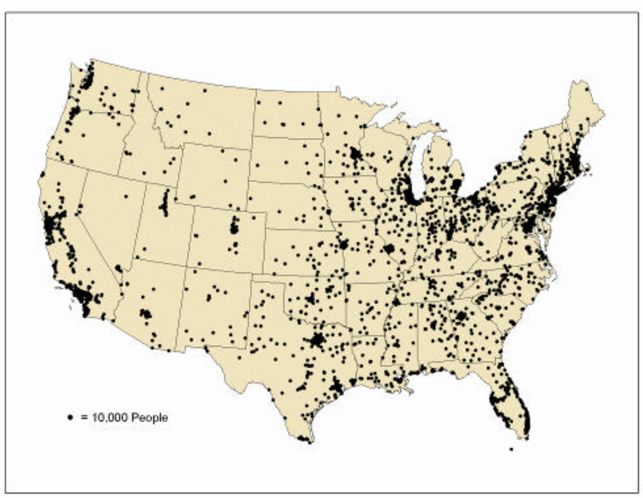


Figure 11 Dot Map
Figure sourced from GIS Resource Document 05-70 Brian McManus

Isopleth or Isoline Maps – Provide a useful way to display continuous data that has been broken down into classes. Lines are drawn to connect all points of a certain value.

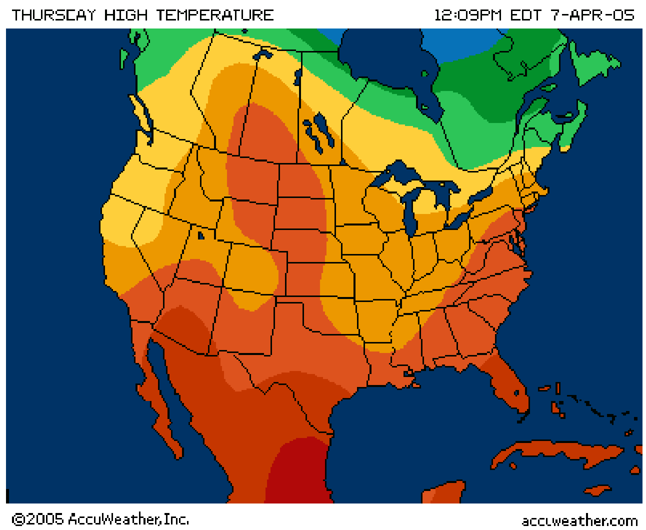


Figure 12 Isopleth Maps

Figure sourced from GIS Resource Document 05-70 Brian McManus

2.5 Information Sources

2.5.1 Reference Books

Numerous sources of information exist about GIS. Books on the subject of GIS exist for beginner's right through to the most experienced users of GIS. Books on the subject can be borrowed from libraries and purchased or ordered through good book stores, university co-op book shops. Examples of some books on the subject Geographical Information Systems: Principles and Applications (Maguire et al, 1991), an excellent two volume set Geographic Information Systems: An Introduction (Stars and Estes 1990) which includes coverage of the relationship between remote sensing and GIS. Geographic Information's Systems (GIS) Bookstore has an arrangement with amazon.com and lists GIS books alphabetically.

2.5.2 Journals and trade magazines

Several GIS Journals and trade publications are available including the international Journal of Geographic Information Systems, GIS world, the primary trade publication for GIS. Directions Magazine is an internet centred publication delivering news, analysis, commentary and product information. Electronic Transactions is a British international quarterly journal of geographical research. Geo Info Systems Online is a magazine that covers applications and trends in GIS and related spatial technologies

2.5.3 Conferences

Annual conferences devoted to GIS and related subjects are usually hosted by professional societies.

2.5.4 Users Groups

Several users groups for specific GIS hold annual meetings including ARC/INFO, from environmental Systems Research institute (ESRI), MGE from Intergraph Corporation and GRASS. These meetings allow users to discuss ideas and topic relating to there systems.

2.6 Summary

The literature review has shown that GIS has been implemented into mining scenarios. Most of the scenarios have concentrated on the effects mining has on the surrounding environment or monitoring change to the environment over a period of time near the mining activities.

Worldwide, GIS applications have been utilised to enhance the decision making process. GIS offers an ability to link spatial referenced data to its attributes which enable for effective communication of complex data.

GIS can produce thematic maps and graphics. Thematic maps are used to display objects by using a theme of graphical display characteristics. This makes it easier to visualise tabular data without the need for extensive annotation. This can be particularly useful for presenting graphics and reports and for quickly finding spatial patterns in drawing geometry.

3 Methodology

3.1 Introduction

The chapter will discuss why Map 2007 was selected for the project and then move onto the processes in how data was acquired. The Processes involved in the forming of data sets from different data formats, sources and the availability of data for the research project. The chapter then discusses data entry, geocoding and the co-ordinate system that was used for all datasets.

The discussion then moves on to discuss thematic mapping concepts and how thematic mapping helps analysis with the datasets. During the discussion, methods of how the thematic mapping was performed will be explained. The basis for the themes and certain maps types chosen for the project will also be conversed in the chapter. Lastly in the chapter what attributes where required to make up the datasets and how they are used with the thematic maps.

3.2 Research Project GIS Software Choice

The chosen software for the research project was to use the current software that is in place at the colliery, Autodesk Map 3D 2007. The choice has been taken not on the basis that it is the best software available for the proposed objectives of the project but on the following criteria:

- The software Map 3D 2007 is in place and requires no further funding or investment from the Helensburgh Coal P/L.
- Some data is already available as attribute data associated within Map 3D 2007
- Map 2007 has been made available for the use of the project under the mines current licensing agreement.

- The Survey personnel at the mine already have undertaken training and have knowledge about the software and its use and can assist with my questions on the use of the program.

- The Map 2007 still allows for the Survey personnel to perform its CAD obligations for various other duties carried out on the mine site.

3.2.1 Key Features of Autodesk Map 3D 2007

- Autodesk Map 3D 2007 is a desktop based GIS software that can perform mapping, geographic data creation, management, integration and analysis. It is tightly coupled with AutoCAD a computer aided design and allows migration from CAD environment to more GIS analysis capabilities.

- Autodesk Map 3D 2007 software is built on the AutoCAD 2007 platform. This connects CAD and GIS by providing editing tools for GIS as well as the geospatial features that mapping and CAD require.

- Map 3D 2007 can read, write and transform GIS industry standard formats including SHP, ArcInfo coverage's, E00, TAB, Mapinfo MIF/MID, GML, and Microstation DGN formats.

- Link external databases to drawing objects by Universal Data Link (UDL)

- Supports for 3000 global projections and co-ordinate systems

- Create point, line and polygon topology

- Map 3D 2007 has GIS capabilities such as topology for performing analysis including buffers, overlays, dissolves, and network analysis.

- Allows query functions

- Using Autodesk Map 3D, you can work with both CAD objects and geospatial features. You can combine them in your map, edit either type of object, and even move objects from one format to the other.

- Map 3D 2007 has Thematic Mapping capabilities.

- Have the full ability of AutoCAD and its CAD functionality

- Work within very large and/or multiple drawings environment

3.3 *Data Acquisition*

The backbone to a good GIS is accurate data. Inaccurate data can result in inaccurate models and maps. These inaccurate models and maps can distort analysis results and ultimately result in poor decision making. "*Garbage in, garbage out*", as the adage says.

Mine management require up to date data that covers all facets of the mining cycle to make sound decisions. In order to make good decisions relating to safe production, efficient resource extraction and maintaining the mines infrastructure the data needs to be correct and the most up to date available. The expansion of the current geographical information system of the mine will enable the management to make decisions in regard to mine planning by providing up to date data that will be visually presented as thematic maps

Data acquisition was divided into three stages

- Preparation
- Entering Data
- Editing and quality enhancement.

3.3.1 Preparation

A lot of time and money can be wasted by seeking to build a database which includes all known data about an area. It is important to determine what questions the GIS will be answering and what data is needed to answer those questions. By answering this question, the answer will provide what type of attribute data will be required for the research project.

Knowing what attribute data was required for the research project was the first stage in determining what type of data was needed to be sourced. The next stage was finding the required attribute data from the stored information at Helensburgh Coal P/L archives. This took some time as a lot of documentation had to be searched through. Copies of documents required where taken and the originals returned to back to the file after being copied.

The digital data available from the colliery was supplied by the survey department. They provided the shape files that are currently required by Survey and Drafting Directions for Mine Surveyors issued pursuant to Part 7, Clause64, of the Coal Mines (General) Regulations 1999 N.S.W. The survey department also supplied the documentation required for gas drainage and permit to mine themes. The data was available in digital and analogue mediums and had to be sorted by hole number and permit numbers and then complied into groups for the correct attribute tables.

The CAD mine plans and other CAD drawings required for the research project where provided also by the survey department. The surveyors allowed access to all the hard copy plans and maps that where required for scaling and copying through out the project.

Attribute data has been collect from within the mine site. An assortment of paper medium documents has been collected to build up the required attribute data for the required datasets of the research project.

Geological data was the hardest to come across, especially coal quality documentation. A range of geological film and paper maps collected where considered unreliable due to there age and condition. Other geological plans where found to be conflicting with one another. The conflict between plans was explained as different opinions and interpretations from different geologists that have served at the Colliery

Data had been purchased from the Departments of Lands in Arcshape file format. Data purchased was Cadastral Data (DCDB) and topological datasets (DTDB) in GDA 94 Datum. Orthorectified imagery was also purchased covering the lease holdings but at a low resolution (1x1m pixel).

3.3.2 Entering Data

Data geocoding – entering information into the GIS consumed much of the research project time. The software allowed a variety of methods of entering data into the GIS depending on what digital format the data is stored.

A lot of data had to be transformed from paper medium documents into a digital format. Most of this type of geocoding was done using Microsoft excel. Microsoft excel was chosen as it was simple to set up in tabular data format for attribute data entry. This process of data entry was very time consuming as the entered data had to be correct and error free. Map 2007 has the ability to view and link to excel worksheets through the use of a Universal Data Link (UDL). The figure below shows the process of creating a link template for the excel spreadsheet.

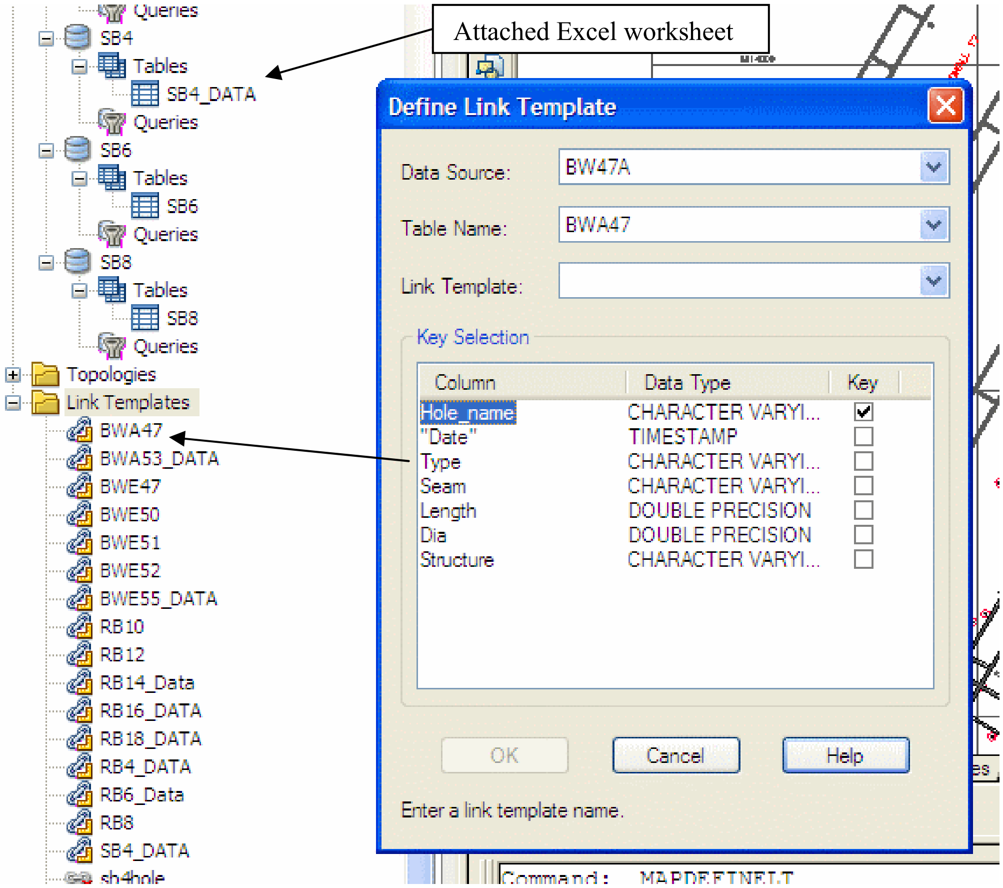


Figure 13 Defining a link template for an excel spreadsheet for inseam drill hole attribute data

Once the database has been attached to the drawing (excel worksheet in this case) the next step is to create a link template to generate a link from the database to drawing objects. (See the figure 13)

By storing the textual data and linking the records have numerous benefits:

- File sizes are kept to a minimum, a link adds only a few bytes.
- The same table can be used with more than one Map 2007 file
- The data can be used in more than one application. Eg the excel data could be linked to a word document and the data can be edited in excel without having to open up Map 2007.
- Can access the data through Map2007 and not have to know how to use excel
- Deleting an object in Map2007 does not delete the data record.

Once the link is setup between objects and the worksheet, it is relatively easy to access and use the data.

No digitizing or scanning equipment was used in the research project. Unfortunately a digitizer or scanner was not available for data entry. A number of companies exist that specialise in digital scanning in both raster and vector formats, the cost of these services was at a reasonable cost per scan but the sheer number of maps to be scanned would of made it an expensive exercise that would of cost close to eight hundred dollars so this option was not considered. Scaling and the use of CAD drafting was used to get the essentially needed data into a digital format. Accuracy loss was considered to be acceptable due to the scale of the plans being used. Scales of 1:10,000 and even 1:25,000 was used.

A lot of paper and film plans and maps where made available for use, but due to time restraints not all the data was used. A lot of the plans and maps where of geological data provided on a number of different datum's and scales. Plotting some of the more important data from these plans was performed by using the plans datum grid on the plans and using a scale to draw some of the important geological data in CAD. This was a long process and positional accuracy was lost in the scaling. The attribute data was added by creating an internal Object Data Table. This is similar to setting out a table in excel spreadsheet and is best described by the figures below.

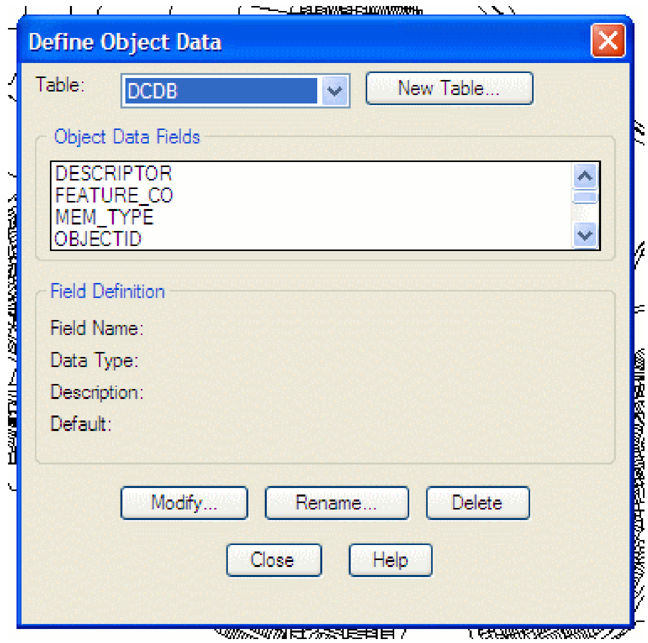


Figure 14 create a new object table and define attributes for the object table

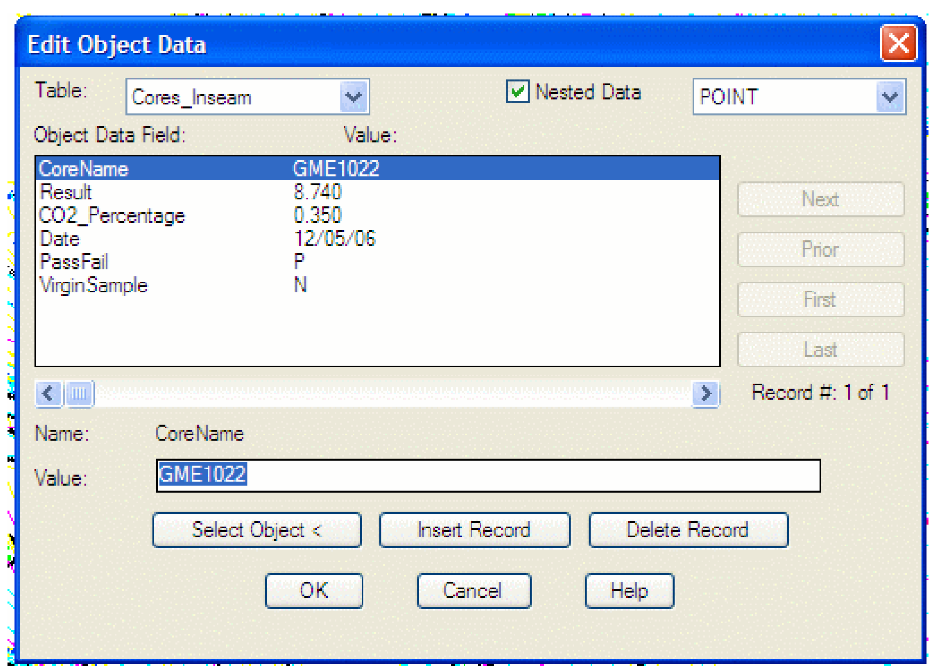


Figure 15 Data Edit and Entry of Object Data

The data inherited within the current GIS was tabulated within Map2007 drawing files database. This did raise some problems as the project did not want to work with any original digital files that the mine owned, so copies of all appropriate files where taken and stored in a separate location. The tabulated data within Map2007 made some tasks difficult as it was in different table formats than what the project required. This meant a lot of the data had to be edited and new attribute tables constructed within Map2007. An effort was made to export the tabular data into excel and then edit the data in excel. This made the editing of data and tables quite simple, but the data then had to be re-linked back to objects within drawings so there was no real advantage with this method.

Importing other GIS software formats into Map 2007 can be performed by two methods.

The first method is by importing the format by using a format driver that converts the incoming file and attribute data into map 2007 format.

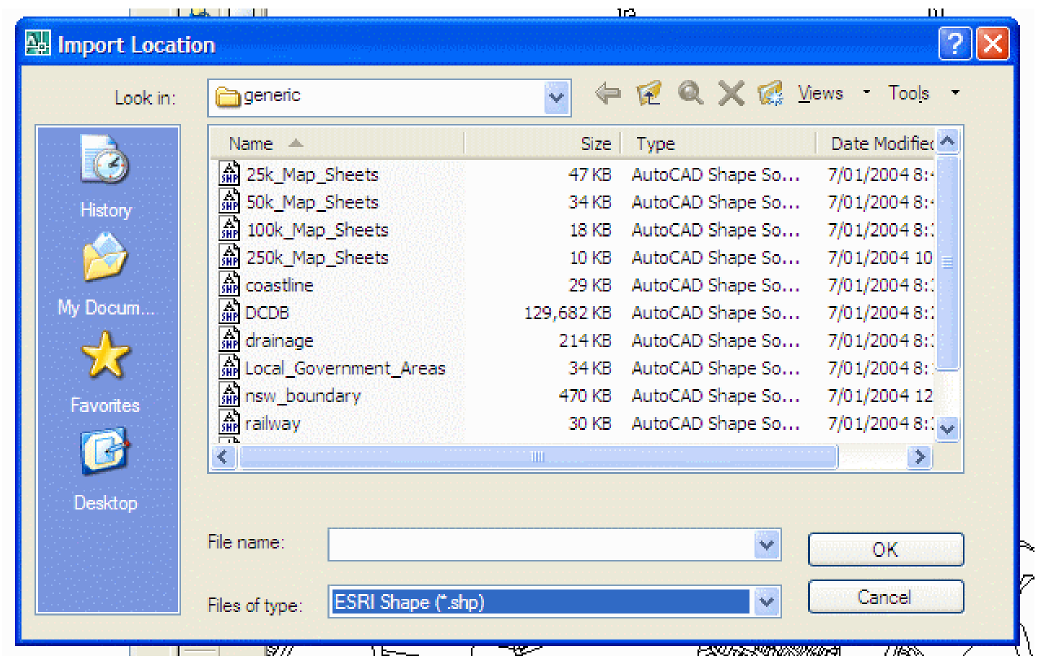


Figure 16 Method 1: Importing a File and converting

The second method uses a link to connect to the other format file. The link then allows for Map2007 to read and write thru the link in the native format of the linked file. This is a good feature if other users are also linked to the same data file as it enables the one file to be updated for all users to use. This enables all users to have access to the most current file for their use.

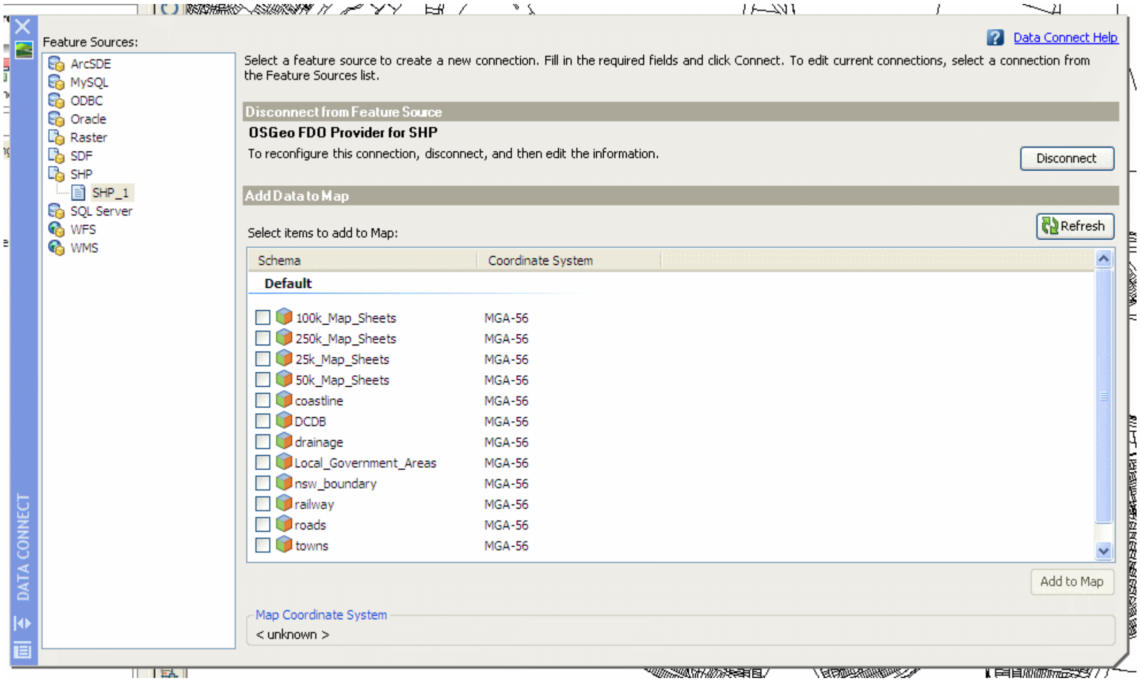


Figure 17 Method 2: Linking SHP file with map2007 allows updating and file sharing

3.4 Data Validation and Errors

"Anything we can do in geocoding process that reduces errors, or that makes errors easily detectable, we should indeed do" (Clarke 2003). The statement suggests that if error detection or quality controls can be put in place during geocoding then it should be implemented as it will benefit the GIS user. It is the data that GIS relies on to produce reliable analysis and map products. The easiest way to avoid errors in data entry should be that errors are detected as soon as it is entered and then to make there correction as easy as possible process. Audio feed back or error messages are essential for data entry errors.

An automatic verification function is a method for controlling in correct information from being entered. These functions can detect errors such as numeric data entered into a character field, but they do not detect wrong spelling or wrong name entered into a name field. These types of errors can only be spotted by manual proof reading. Major errors and meaningless text are easily detected, but incorrect spelling, inversions, omissions and other less obvious errors are more difficult to detect.

A method of checking that entered data is correct, is to print attribute data listing reports, most data management systems have the ability to generate such reports. These reports usually list the attribute data in a table or neat listing. The data geocoder should than go through the data line by line and check for errors in attribute and values. This practice was not carried out on all the data geocoded for the research project as there was a limiting time line to adhere to. The proof reading of the attribute data was carried out on a quarter of the attribute data entered for the project. Though some errors in data entry have been found during processing and during use of the GIS, these errors have been corrected as being discovered.

Other sources of errors in GIS geocoding are slivers, spikes, inversions, lines that are not ended and unsnapped nodes. Spikes are random hardware or software errors in which a zero or extremely large data value replaces the real value in one of the co-ordinates.

The CAD drawing that was performed for the project was checked for drafting errors, through Map 2007 drawing cleanup tool. Time constraints restricted the learning of the effective use of the function. Figure 18 shows of one of the steps involved with the cleanup tool.

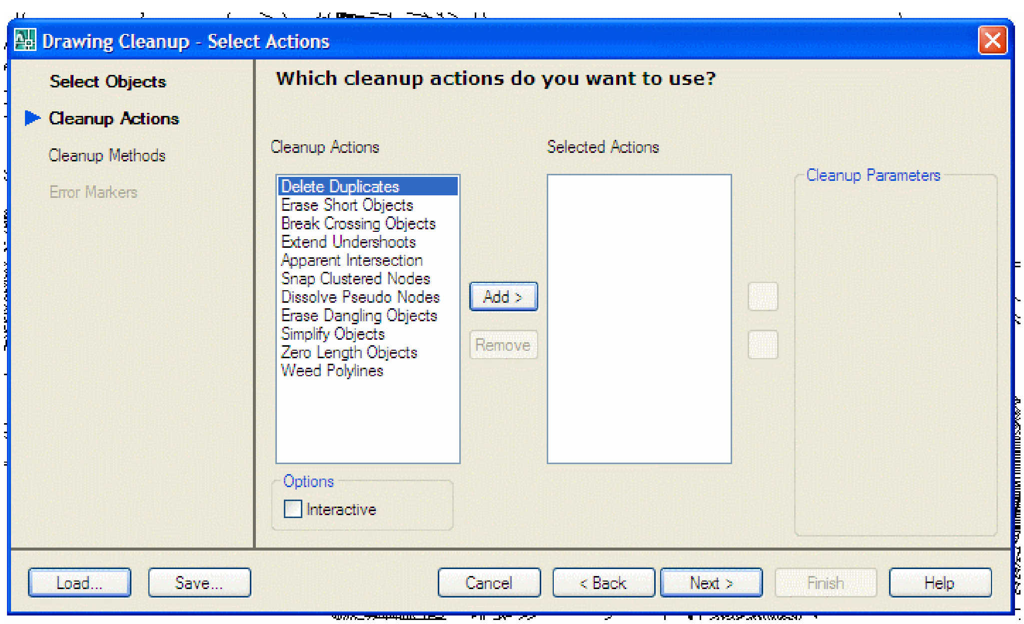


Figure 18 Drawing cleanup Tool

Drawing cleanup is extremely important when creating topologies, to produce correct topologies the drawing line work, points and polygons have to be error free. Topology was created for gas drainage, mine rescue, Inrush potential and mine permit authorisation themes and this is discussed in more detail later.

GIS user should know and understand the amount and distribution of error in a GIS database. Many source errors are due to the method and process of geocoding. Some errors multiply as the data is processed through the stages of data management, storage, retrieval and analysis. The understanding of error is important when working with GIS.

When data is captured, the user should consider if the data should be captured with either a relative accuracy or absolute accuracy. Accuracy will often depend on the purpose of the data's use and what other data is being used. The data with the lowest accuracy will dictate the best accuracy achievable.

3.5 Co-ordinate System

A co-ordinate system is the method of representing part or all the curved surface of the earth on a flat plane. Co-ordinate systems are used for creating two dimensional representations of geographical areas that curve with the earth's surface. The ability to convert data mapped in different co-ordinate systems is a major component of mapping. With Autodesk Map 3D 2007, you can combine data from maps using different coordinate systems. Map 2007 converts objects from source drawings to the global co-ordinate system of the project drawing.

Data for this project has been found in several datum's being, the Integrated Grid of New South Wales (ISG) zone 56/1, Australian Map Grid (AGD) and Map grid Australia (GDA) datum's. The project will be using Map Grid of Australia (GDA94) MGA Zone 56 as the base datum for all maps shown in the project.

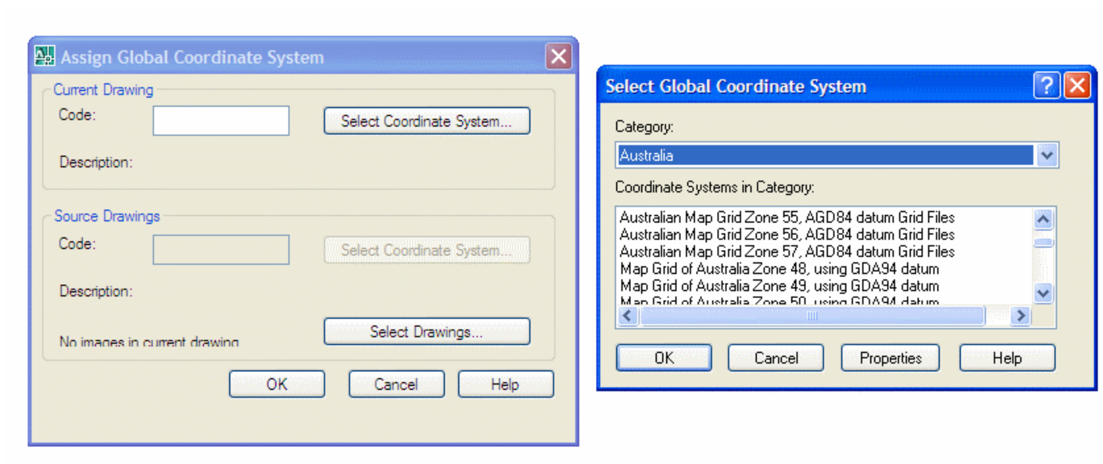


Figure 19 Global Co-ordinates System selections Tool

The nature in which Map2007 works with datum's has made planning thematic maps a key task. Map 2007 does not let you open an ISG based map directly into a GDA datum. It has to be created by opening a base map (Project Drawing) with GDA as its set datum (global co-ordinate system see figure above). The ISG map is then attached to the GDA project drawing as a source drawing. The ISG drawing is overlayed on the ‘project drawing” in the projects datum. Another method to get an ISG drawing into a MGA datum was to create a new empty drawing and query into the new clean drawing the ISG drawing. When the ISG drawing is queried into the new drawing the ISG drawing is transformed into GDA. This effectively creates a copy of the ISG drawing but into an MGA datum. This procedure was primarily used for the research project as it was an uncomplicated procedure and robust.

3.6 *Datasets*

3.6.1 Introduction

Map themes or layers are the fundamental elements that allow GIS practitioners to perform all the statistical and spatial analysis required for the work at hand. Without map layers and datasets relevant to the purpose of study, the analyst will not be able to analysis the assigned project.

GIS does not store maps, a GIS stores themes that can be assembled into a map

To create a range of thematic maps to cover the areas of interested of the research project - Leases and mine holdings, Exploration in regard to exploration boreholes and related data, Areas of authorisation for approved mine roof support, Permits to mine first workings and lastly Mine safety. The research project requires a number of datasets:

- Colliery holding
- Mining Titles
- Workings
- Geology
- Approvals (Coal Extraction)
- Support Approval (Roof Support)
- Permit to mine Approval (1st Workings)
- Inrush
- Boreholes (Surface to Underground)
- Inseam Bore Holes (Gas Drainage)
- Core Sample
- Barriers
- 2nd Workings (Coal Extraction)
- Local Government Boundaries
- National Park and state recreation reserves
- Parish and County Boundaries

This chapter will discuss the details of each of the data sets individually.

3.6.2 Colliery Holdings Dataset

Colliery Holdings data set gives details of the colliery holding as per the Survey and Drafting Directions for mine Surveyors (N.S.W) 2000 Section 4.2.1(a). It is the outline of all the mine titles that make up the mines Holdings. The Holdings is a polygon Feature type. The attributes of this layer consist of what can be seen in Figure 21 Holdings Attributes

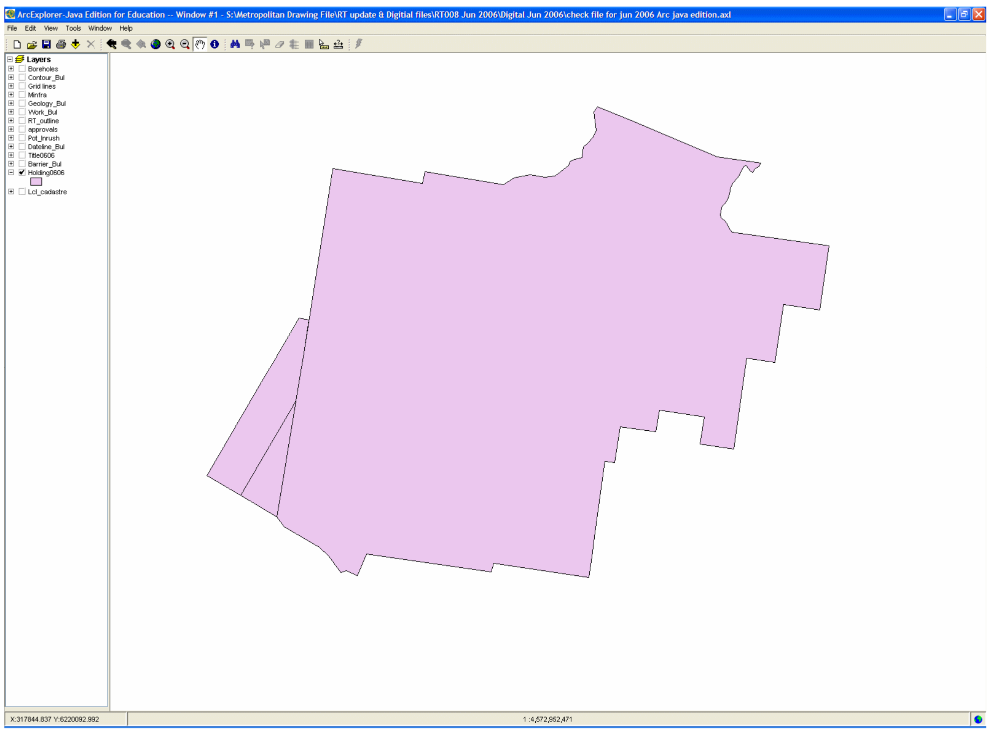


Figure 20 Colliery Holdings Metropolitan Colliery

Survey and Drafting Directions Section 4.2.1(a) Colliery Holding boundary.

					Application	DRT	
Theme	Digital Record Tracing - Colliery Holding	Sub Type of		Records	75	Growth (%pa)	5% pa
Description	Details of the Colliery Holding Boundary Naming convention must be in the form holdingmmyy						

Attributes

Name	Opt. (Y/N)	Domain	Format	Max Lgth	Notes	Full Defn(✓)	Unique Id(✓)
Colliery_Holding_name	N		Character	50	Name of Colliery Holding		
Mine_Name	Y		Character	50	Mine Name		
Seam_name	Y		Character	50	May be used to delimit overlying Colliery Holdings		
RT_No	N		Character	10	Record Tracing number		
Source	N		Character	10 0	DCDB, Survey-own, keyed original bearing distance, coordinate entry		
Coord_System	Y		Character	50	Coordinate System used eg Mapping Grid of Australia (MGA)		
Endorsements	Y		Character	200	Comments, remarks or endorsements		
Disk_name	N		Character	30	Colliery name month year Acme 1201		
File_name	N		Character	20	In form holdingmmyy eg holding1201		

Notes:
1. There may be a single mine or a number of mines operating within a Colliery Holding.
2. The internal boundary between mines should be shown.

Figure 21 Holdings Attributes

3.6.3 Mining Titles Dataset

Mining titles dataset gives details on mining titles, that is freehold/ leasehold lands that make up the colliery Holding. The attribute Data is as per the Survey and Drafting Directions for mine Surveyors (N.S.W) 2000 Section 4.2.1(b). It is the outline of all the mine titles that make up the mines Holdings. The Mining Titles is a polygon Feature type.

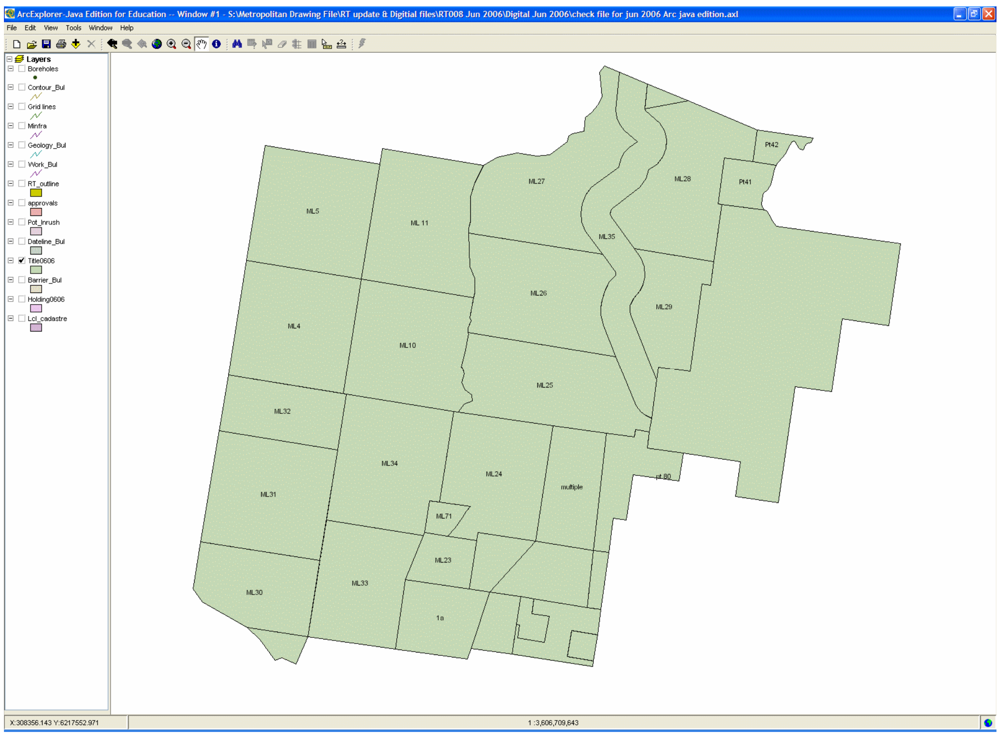


Figure 22 Titles

Survey and Drafting Directions Section 4.2.1(b) Mining Lease boundaries.

						Application	DRT		
Theme	Digital Record Tracing -Titles		Sub Type of		Records	75	Growth (%pa)	5% pa	
Description	Details of the Mining Titles and Freehold/leasehold land recorded within a colliery holding. Naming convention titlemmyy								

Attributes

Name	Opt. (Y/N)	Domain	Format	Max Lgth	Notes	Full Defn(✓)	Unique Id(✓)
Colliery_Holding_name	N		Character	50	Name of Colliery Holding		
Mine_Name	Y		Character	50	Mine Name		
Seam_name	Y		Character	50	May be used to delimit overlying Colliery Holdings		
RT_No	N		Character	10	Record Tracing number		
Portion_no	N		Character	25	Mines portion No or Lot/dp ML 6 1/750320		
Title_name	N		Character	25	Mining Lease identifier or Folio identifier ML 2314 1992 15/823123		
Plan_catalogue_no	Y		Character	25	Survey plan catalogue		
Source	N		Character	10 0	DCDB, Survey-own, keyed original bearing distance, coordinate entry		
Endorsements	Y		Character	200	Comments, remarks or endorsements		
Disk_name	N		Character	30	Colliery name month year Acme1201		
File_name	N		Character	20	In form title mmyy title1201		

Notes:
1: This theme identifies the Mining titles and the freehold land which make up the title to the Colliery Holding. Mining titles and freehold land may extend outside the Colliery Holding.
2: Naming conventions for mining titles
3: Naming conventions for folio identifiers

Figure 23 Titles Attributes

3.6.4 1st Workings Dataset

Working dataset gives details on first workings that make up the colliery roadways (Tunnels). The attribute Data is as per the Survey and Drafting Directions for mine Surveyors (N.S.W) 2000 Section 4.2.1(c), (d), (e), (o) & (p). The workings are a line feature type

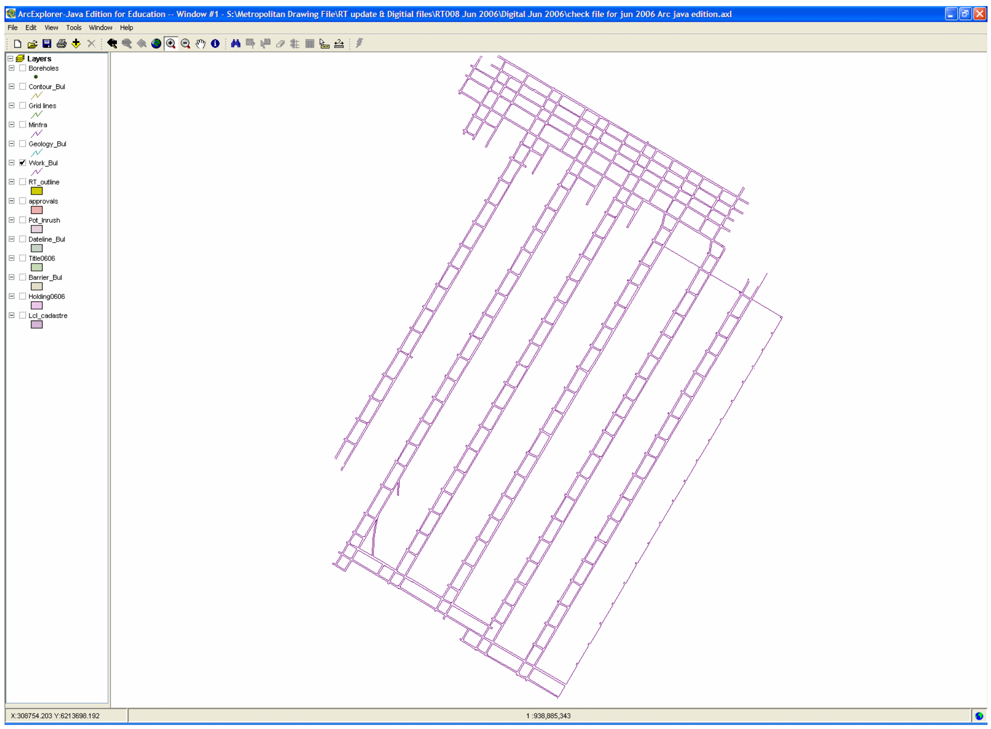


Figure 24 1st Workings

Survey and Drafting Directions Section 4.2.1(c), (d), (e), (o) and (p) Workings.

						Application	DRT	
Theme	Digital Record Tracing - Workings		Sub Type of		Records	75	Growth (%pa)	5% pa
	Description		Details of the workings of a seam of an underground colliery or bench worked of an open cut. Naming convention **Must be in the form work_seam abbreviation**					
Attributes								
Name	Opt.(Y/N)	Domain	Format	Max Lgth	Notes		Full Defn(✓)	Unique Id(✓)
Mine_name	N		Character	50	Name of Colliery or mine			
RT_No	N		Character	10	Record Tracing number			
Seam_name	N		Character	50	Name of Seam being worked			
Date_worked	Y		Date	8/10	Date worked			
Work	Y		Character	5	1st Workings U/G (1st); 2nd Workings U/G (2nd) ; Auger/ Highwall Mining (Hwall).			
Status	N		Character	1	Working, Discontinued or Abandoned (W, D or A)			
Initials	N		Character	3	Initials of Mining Surveyor			
Endorsement	Y		Character	200	Additional reference about workings			
Disk_name	N		Character	30	Name of colliery month year Acme0902			
File_name	N		Character	20	Work_seam abbreviation			

Notes:
1. For open cut workings work field should be left blank
2. Goaf areas should be represented by a polygon and either shaded or hatched to represent the void
3. Adjacent workings in the same seam must be shown.
4. Adjacent workings in different seams are subject to a further theme.

Figure 25 1stWorkings Attributes

3.6.5 Geology Dataset

Geology dataset gives details on geology encountered in the mine workings. The attribute Data is as per the Survey and Drafting Directions for mine Surveyors (N.S.W) 2000 Section 4.2.1(g). It is a line feature type

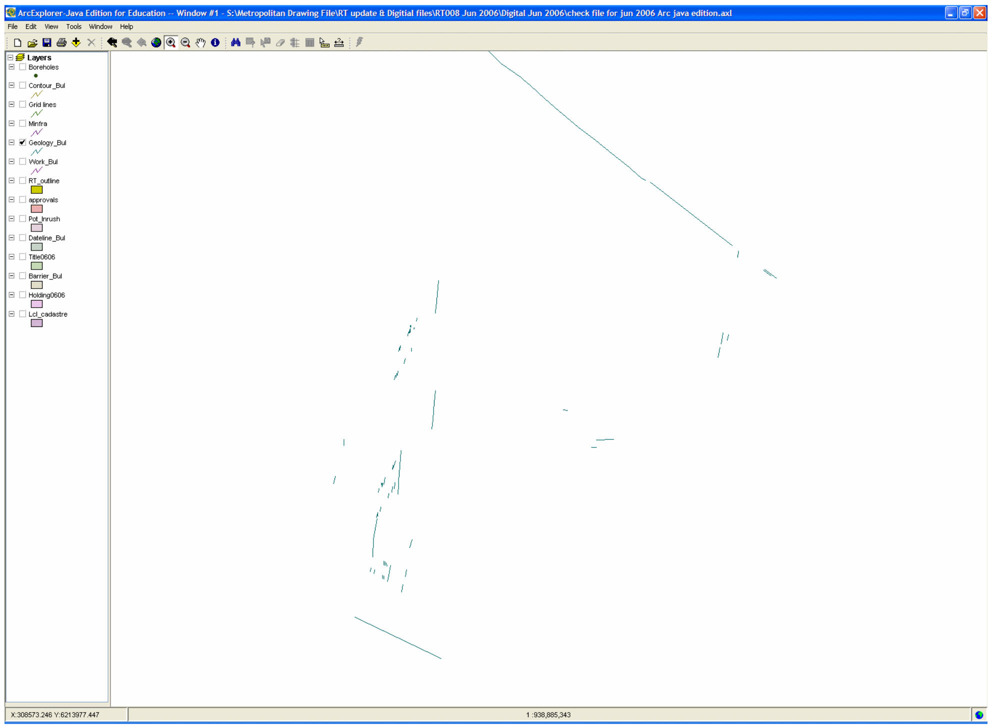


Figure 26 Geology

Survey and Drafting Directions Section 4.2.1(g) Geology

				Application	DRT		
Theme	Digital Record Tracing - Geology	Sub Type of		Records	75	Growth (%pa)	5% pa
Description	Details of the geology of seam or section workings of a mine Naming convention **Must be in the form geology_seam abbreviation**						

Attributes

Name	Opt. (Y/N)	Domain	Format	Max Lgth	Notes	Full Defn(✓)	Unique Id(✓)
Mine_name	N		Character	50	Name of Colliery or mine		
RT_No	N		Character	10	Record Tracing number		
Seam_name	N		Character	30	Name of Seam being worked		
Charted_date	Y		Date	8/10	Charted date. Date workings charted to		
Code_no	N		Character	12	Code of symbol. Refer to AS 2916 and AS 4368		
Feature_width	Y		Character	10	Displacement or width of geological feature in metres		
Endorsement	Y		Character	200	Additional information		
Disk_name	N		Character	30	Colliery name month year Acme0902		
File_name	N		Character	20	Geology_seam abbreviation		

Notes:
1. The 'teeth' of a dyke or similar feature must indicate the downside.

Figure 27 Geology Attributes

3.6.6 Approvals (Coal Extraction) Datasets

Approvals dataset gives details on coal extraction approvals (Sect138 Coal mines regulation act NSW). The attribute Data is as per the Survey and Drafting Directions for mine Surveyors (N.S.W) 2000 Section 4.2.1(i). It is a polygon feature type

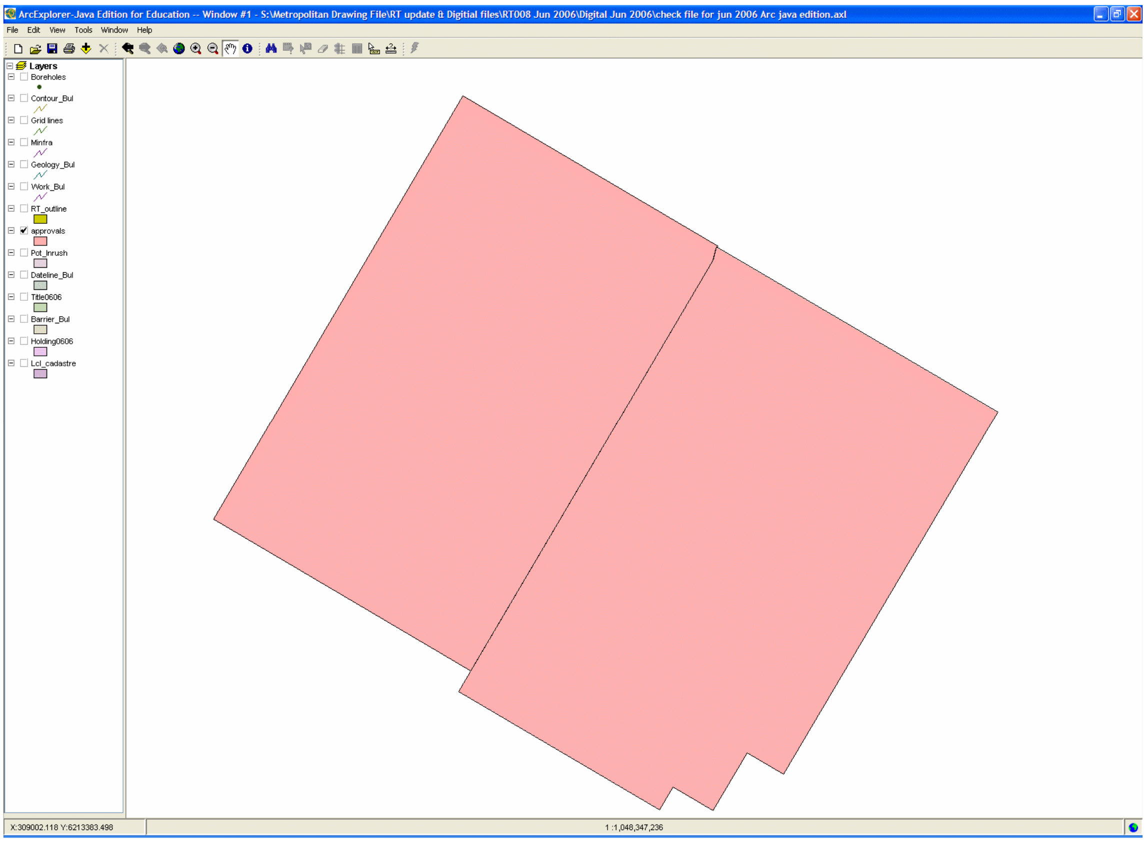


Figure 28 Approvals (Extraction)

Survey and Drafting Directions Section 4.2.1(i) Mining approvals.

				Application	DRT		
Theme	Digital Record Tracing - Approvals	Sub Type of		Records	75	Growth (%pa)	5% pa
Description	Details of the Second working approvals or Section 138 approvals of a colliery **Naming convention Must be in the form approval_seam abbreviation**						

Attributes

Name	Opt.(Y/N)	Domain	Format	Max Lgth	Notes	Full Defn(✓)	Unique Id(✓)
Mine_name	N		Character	50	Name of Colliery or mine		
RT_No	N		Character	10	Record Tracing number		
Seam_name	Y		Character	50	Name of Seam approval restricted to; if not restricted, insert all		
Approval_date	N		Date	8/10	Date of approval or acceptance		
End_date	Y		Date	8/10`	End date of approval		
DMR_file_no	N		Character	10	File number CM86/0366		
Endorsements	Y		Character	200	Summary of conditions imposed on approval or acceptance of mine operations plan		
Disk_name	N		Character	30	Colliery name month year Acme0902		
File_name	N		Character	20	approval_seam abbreviation		

Notes:
1. To be used to record Section 138 CMR Act approvals and acceptance of Mining Operation Plans.
2. Where the approval is not restricted to a seam or seams the file name should be approval_all

Figure 29 Approvals (Extraction) Attributes

3.6.7 Inrush Datasets

Inrush dataset gives details on inrush potentials into the mine workings. The attribute Data is as per the Survey and Drafting Directions for mine Surveyors (N.S.W) 2000 Section 4.2.1(k). It is a polygon feature type

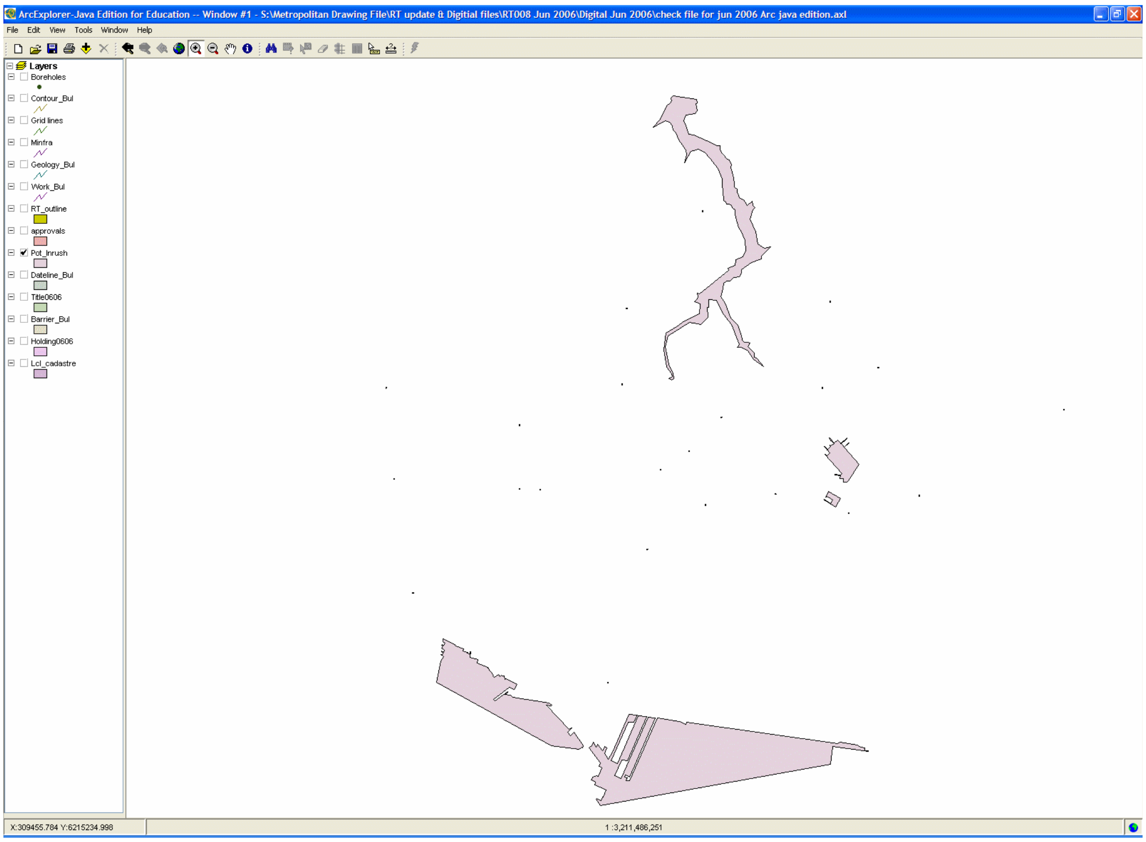


Figure 30 Inrush

Survey and Drafting Directions Section 4.2.1(k) Potential Sources of Inrush

				Application		DRT	
Theme	Digital Record Tracing - Inrush	Sub Type of		Records	75	Growth (%pa)	5% pa
	Description	Details of potential sources of inrush Naming convention **Must be in the form pot_inrush.**					

Attributes

Name	Opt. (Y/N)	Domain	Format	Max Lgth	Notes	Full Defn(✓)	Unique Id(✓)
Mine_name	N		Character	50	Name of Colliery or mine		
RT_No	N		Character	10	Record Tracing number		
Name	N		Character	50	Name to identify potential inrush		
Seam_name	Y		Character	30	Name of seam or surface where potential inrush is sourced		
Endorsement	Y		Character	200	Particulars to identify potential source of inrush.		
Disk_name	N		Character	30	Name of disc Acme1201		
File_name	N		Character	20	Pot_inrush		

Notes:
1. This theme will include workings which have the potential to flood.
2. This theme will also include the area defining surface dams and reservoirs, unconsolidated deposits and boreholes suspected of containing water.

Figure 31 Inrush Attributes

3.6.8 Barriers Dataset

Barriers dataset gives details on barriers in place in the mine holdings. The attribute Data is as per the Survey and Drafting Directions for mine Surveyors (N.S.W) 2000 Section 4.2.1(r). It is a polygon feature type

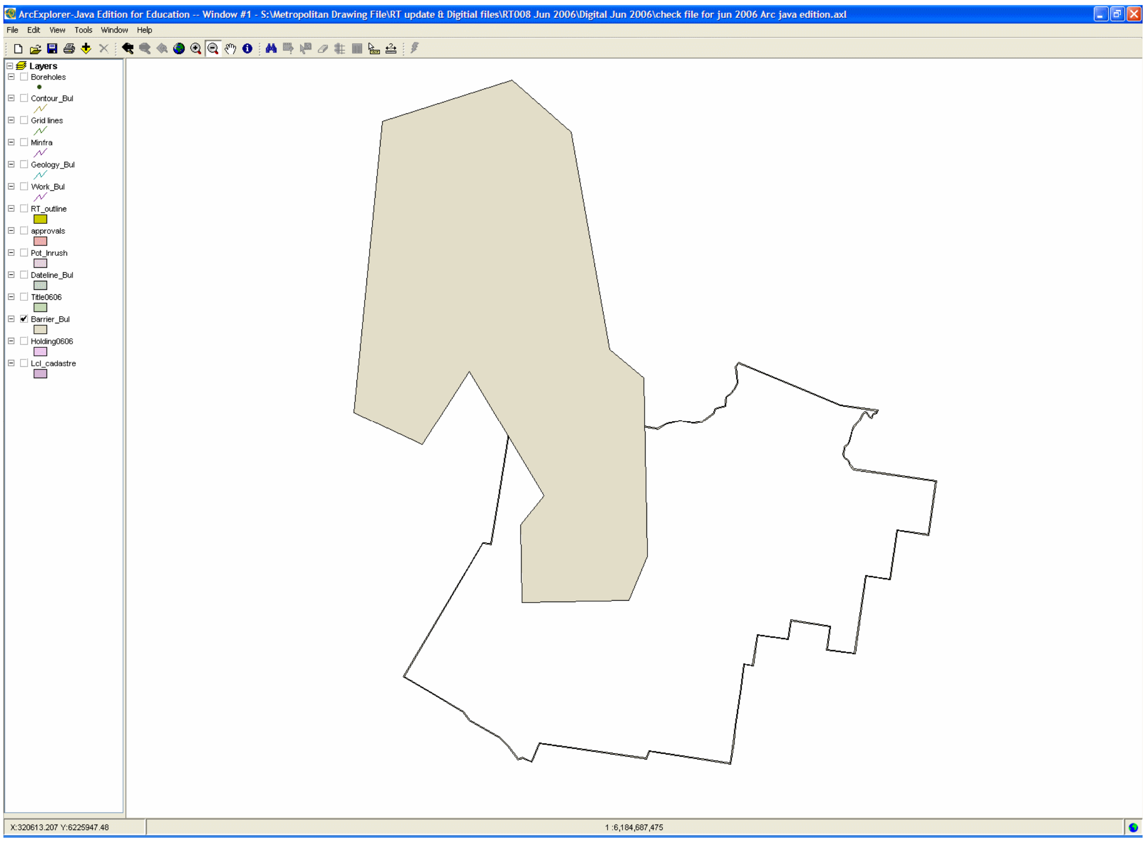


Figure 32 Barriers Dataset

Survey and Drafting Directions Section 4.2.1(r) Barriers and restricted zones.

					Application	DRT	
Theme	Digital Record Tracing - Barriers		Sub Type of		Records	75	Growth (%pa) 5% pa
Description			Details of the barriers provided by a colliery **Naming convention Must be in the form barrier_seam abbreviation**				
Attributes							
Name	Opt.(Y/N)	Domain	Format	Max Lgth	Notes	Full Defn(✓)	Unique Id(✓)
Mine_name	N		Character	50	Name of Colliery or mine		
RT_No	N		Character	10	Record Tracing number		
Seam_name	N		Character	30	Name of Seam being worked		
Barrier_type	N		Character	50	Type of Barrier eg external, adjacent workings foreshore protection zone, special, angle of draw zone, protective,		
Charted_date	Y		Date	8/10	Charted date.		
Approval_date	N		Date	8/10	Date of approval if other than external		
DMR_file_no	Y		Character	10	File number		
Endorsements	Y		Character	300	Conditions imposed on approval		
Disk_name	N		Character	30	Colliery name month year Acme0902		
File_name	N		Character	20	Barrier_bul.e00		

Figure 33 Barriers Dataset

3.6.9 Boreholes (Surface to Underground)

Boreholes dataset gives details on Boreholes in place in the mine holdings. It gives details on the purpose and depth etc. The attribute Data is as per the Survey and Drafting Directions for mine Surveyors (N.S.W) 2000 Section 4.2.1(i). It is a point feature type

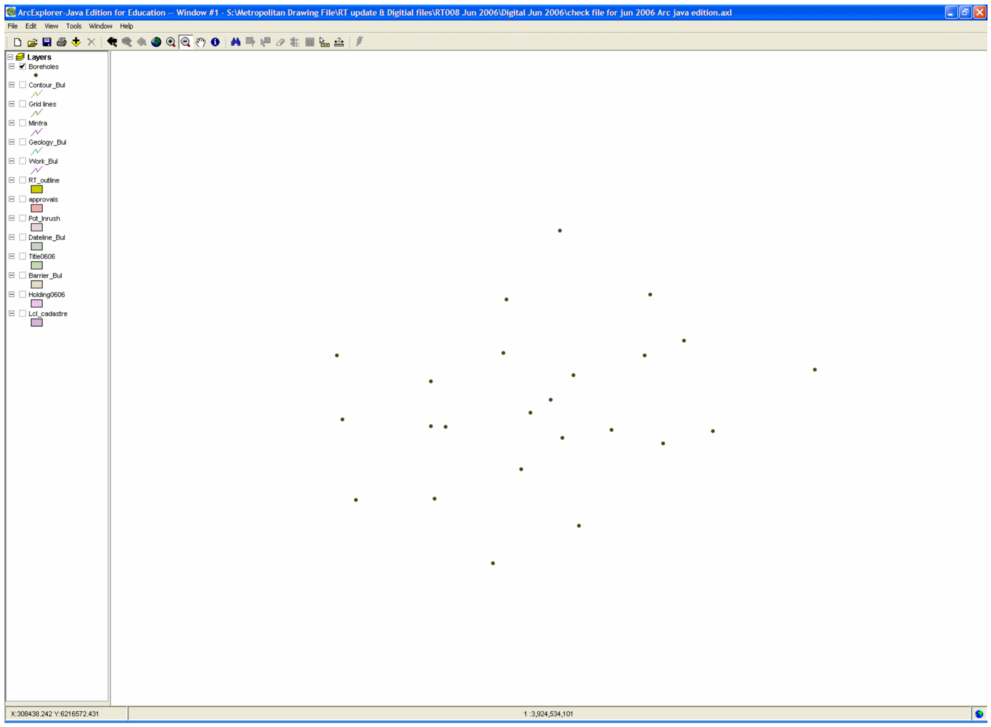


Figure 34 Borehole Dataset

Theme	Digital Record Tracing - Boreholes	Sub Type of		Records	75	Application	DRT	Growth (%pa)	5% pa
Description	Details of boreholes within a colliery holding Naming convention **Must be in the form boreholes.**								

Attributes

Name	Opt.(Y/N)	Domain	Format	Max Lgth	Notes	Full Defn(✓)	Unique Id(✓)
Colliery_name	N		Character	50	Name of Colliery or mine		
RT_No	N		Character	10	Record Tracing number		
Borehole_name	N		Character	30	Name of borehole		
Borehole_diam	N		Character	30	Diameter of borehole in millimetres.		
Code_no	N		Character	4	Code of symbol refer to AS 2916 and AS 4368		
Easting	N		Number	6.3	Easting of Collar		
Northing	N		Number	7.3	Northing of Collar		
Collar_rl	N		Number	4.3	1234.123		
Depth	N		Number	4.3	Depth or finish RL		
Azimuth	Y		Number	3.3	Not used if borehole vertical		
Dip	Y		Number	3.3	Decimal degrees,0 horizontal, 90 up -90 down		
Borehole_status	N		Character	200	Descriptive text purpose, open, sealed with 20m concrete etc		
Disk_name	N		Character	30	Name of disc Acme1201		
File_name	N		Character	20	boreholes		

Notes:
1. Boreholes which have been 'mined out' should not be shown.
2. Remnant boreholes should be shown.
3. Boreholes that carry utilities should be included in both the 'minnfra' and 'borehole' themes.

Figure 35 Borehole Attribute Data

3.6.10 Roof Support Application Approval Datasets

Roof Support Approval gives details on what working sections of the mine have approved roof support systems from the Department of Primary Industries. It is a polygon feature type. It is shown in a thematic style below with the green representing areas of approved support and pink hatch areas that have no approved roof support assigned to the zone.

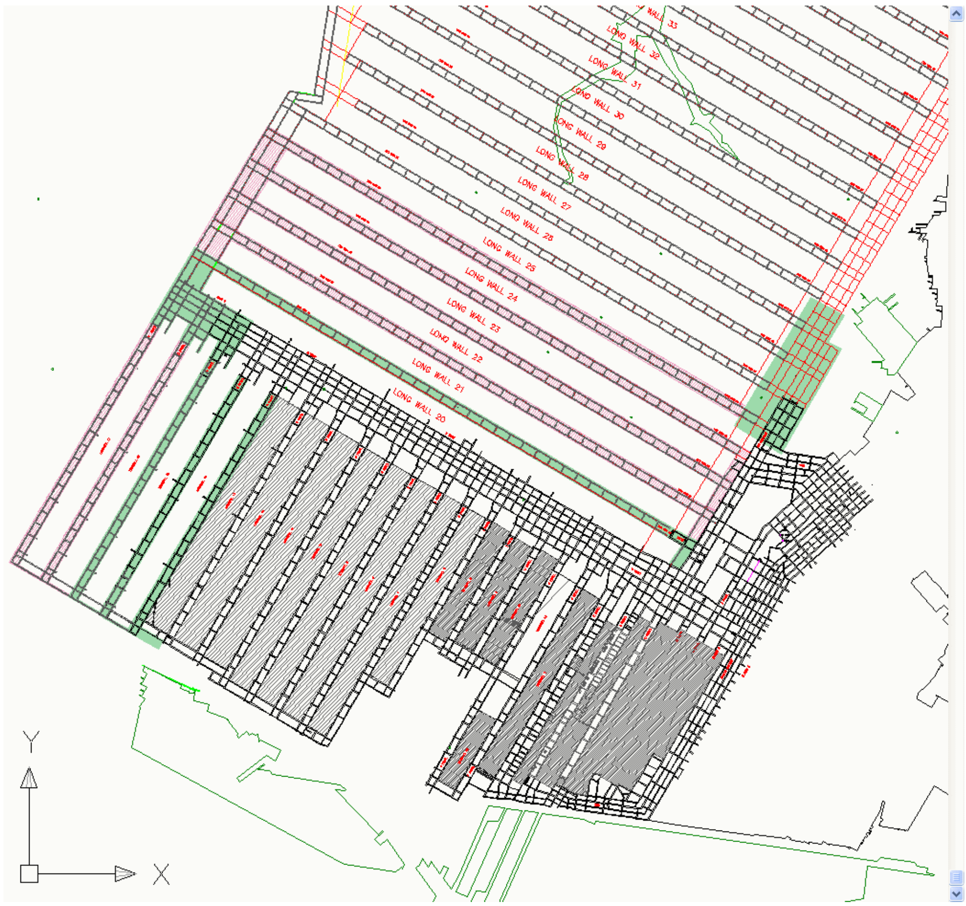


Figure 36 Roof Support Approvals

Panel_Name	Support_Approved	Date_Approved	DPI_File_No	DPI_Ref_Number	Plan_Numbers	Seam
Q	Yes	16/03/2004	C03/0266	290138000	M178	Bulli
R	Yes	17/12/2004	CO/0266	317517963001_3117001	M323	Bulli
S	Yes	27/09/2005	C05/2775	317524026001_7536001	M377	Bulli
T	Yes					Bulli
U	No					Bulli
V	No					Bulli
W	No					Bulli
X	No					Bulli
						Bulli
B WEST 53-63	Yes	11/07/2005	C05/2775	3175227660001_6424001	M368-374	Bulli
B WEST FUTURE	No					Bulli
NWR 21CT	Yes	20/03/2003	C96/0211-5	233507000_259801000	TD201-207	Bulli
NWR FUTURE	No					Bulli
						Bulli
						Bulli
MG20	Yes	22/12/2004	C03/0266	317518097001_3174001	M329	Bulli
MG21	No					Bulli
MG22	No					Bulli

Figure 37 Roof Support Application Attribute Data example

3.6.11 Inseam Gas Drainage Boreholes Dataset

Inseam Gas Drainage Boreholes gives details on gas drainage of the mine. It shows the actual borehole as well comments from the drillers drilling the hole. The comments help identify areas of concern when mining, for example if a geological structure was encountered during drilling. It is a line feature type. It is shown in a thematic style below with the cyan lines representing drainage holes and magenta lines are holes that have had cores taken in them.

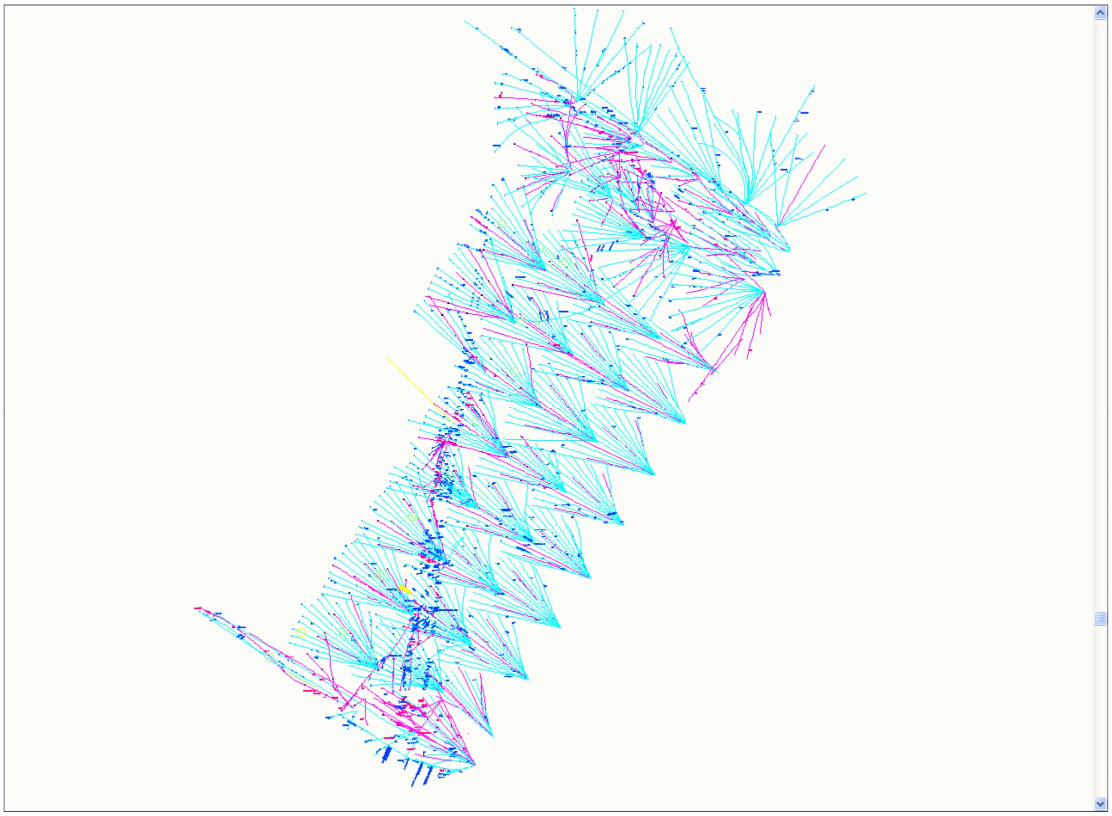


Figure 38 Inseam Gas drainage boreholes

Hole_name	Date	Type	Seam	Length	Dia	Structure
BWA47-01	14/05/2004	Drainage	Bulli	246	0.96	N
BWA47-02	19/05/2004	Drainage	Bulli	258	0.96	N
BWA47-03	19/05/2004	Drainage	Bulli	240	0.96	N
BWA47-04	20/05/2004	Drainage	Bulli	672	0.96	N
BWA47-05	24/05/2004	Drainage	Bulli	275	0.96	N
BWA47-06	24/05/2004	Drainage	Bulli	281	0.96	N
BWA47-07	24/05/2004	Drainage	Bulli	282	0.96	N
BWA47-08	25/05/2004	Drainage	Bulli	218	0.96	N
BWA47-09	27/05/2004	Drainage	Bulli	215	0.96	N
BWA47-10	28/05/2004	Drainage	Bulli	203	0.96	N
BWA47-11	29/05/2004	Drainage	Bulli	203	0.96	N
BWA47-12	31/05/2004	Drainage	Bulli	200	0.96	N
BWA47-13	13/05/2005	Core	Bulli	131	0.96	N
		Drainage	Bulli		0.96	N

Figure 39 Inseam Gas Drainage Attribute Data example

3.6.12 Core Samples (Inseam) dataset

Inseam Core Sample gives details on core samples taken within the seam of the mine. The dataset shows the actual core position. It has been set as both point and polygon feature type.

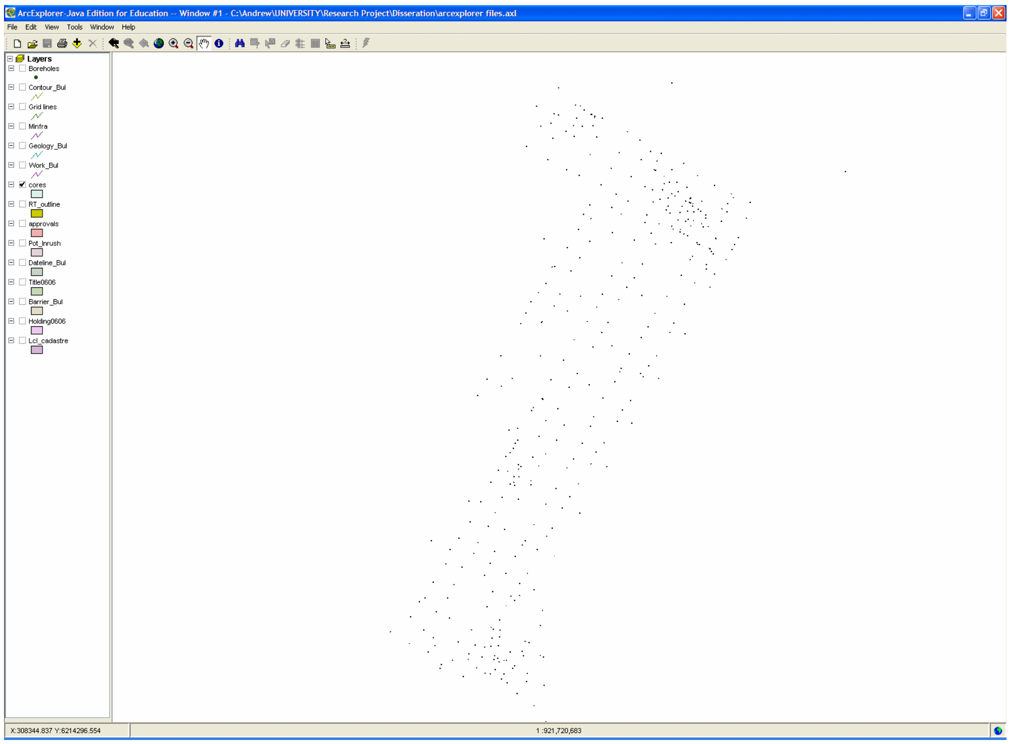


Figure 40 Inseam Core Sample Dataset

Core_Number	Date	Result	CO2	Virgin_Sample	Close_Structure	P_F
GME1000	3/04/2006	5.73	2.70	N	Y	P
GME1001	4/04/2006	2.45	0.16	N	N	P
GME1002	6/04/2006	1.88	1.65	N	N	P
GME1003	6/04/2006	4.43	0.61	N	Y	P
GME1004	9/04/2006	0.81	7.06	N	Y	P
GME1005	12/04/2006	9.65	0.90	N	Y	F
GME1006	13/04/2006	9.70	1.04	N	Y	F
GME1007	18/04/2006	3.89	2.00	N	Y	P
GME1008	23/04/2006	1.30	3.79	N	N	P
GME1009	24/04/2006	3.45	0.40	N	N	P
GME1010	27/04/2006	7.78	0.46	N	Y	P
GME1011	28/04/2006	12.82	0.88	N	Y	F
GME1012	1/05/2006	10.22	0.52	N	Y	F
GME1013	2/05/2006	2.70	0.18	N	N	P
GME1014	3/05/2006	3.25	0.12	N	N	P
GME1015	4/05/2006	2.48	0.13	N	N	P
GME1016	3/05/2006	1.61	0.16	N	N	P
GME1017	5/05/2006	5.75	0.70	N	N	P
GME1018	5/05/2006	11.24	0.60	N	Y	F
GME1019	9/05/2006	4.32	1.36	N	Y	P
GME1020	9/05/2006	8.17	2.89	N	Y	P
GME1021	10/05/2006	1.19	0.36	N	Y	P

Figure 41 Inseam core Sample Attribute Data

3.6.13 Permit to Mine Dataset

Permit to mine gives details on whether or not mining is safe from the effects of gas outbursts. Without a permit to mine there is no production in the area, only when it has been assessed as safe and a permit is generated then mining will commenced. It is a polygon feature type.

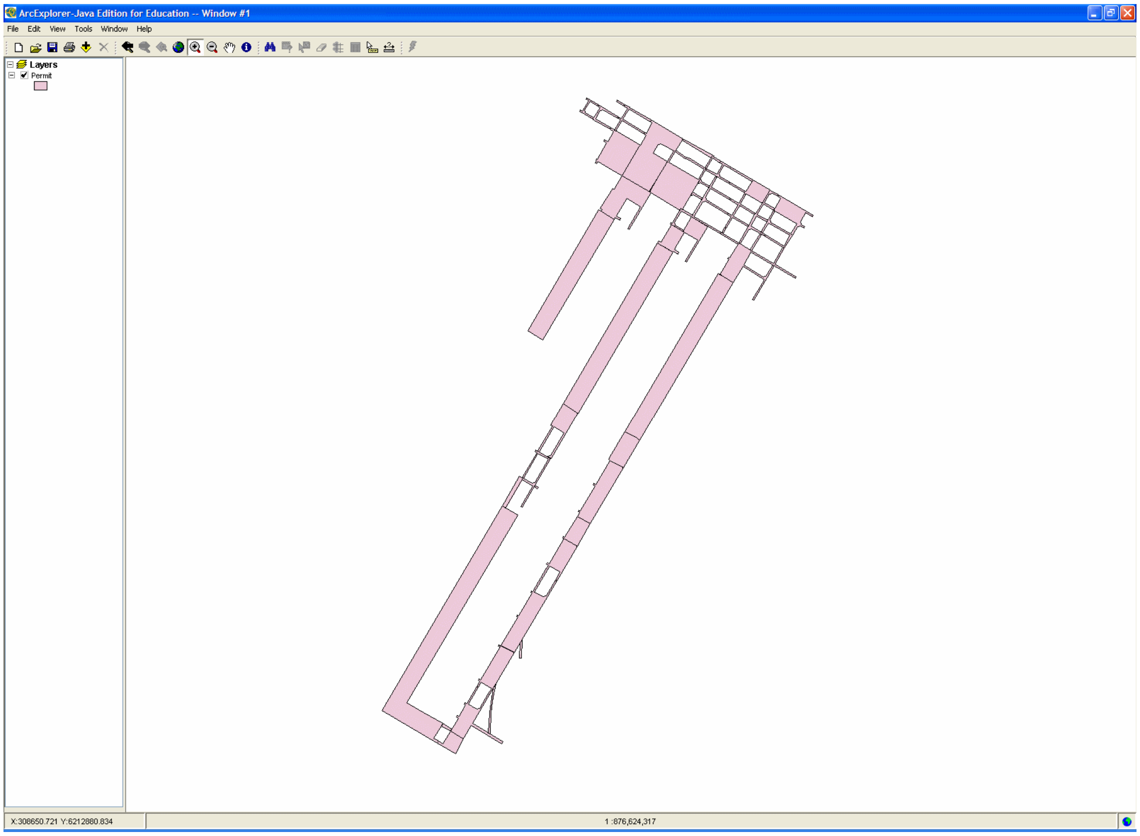


Figure 42 Permit to mine Dataset

3.6.14 2nd Workings (Extraction) Dataset

2nd Workings gives details on coal extraction. The attributes for the theme are exactly the same as for 1st working. It is a polygon feature type.

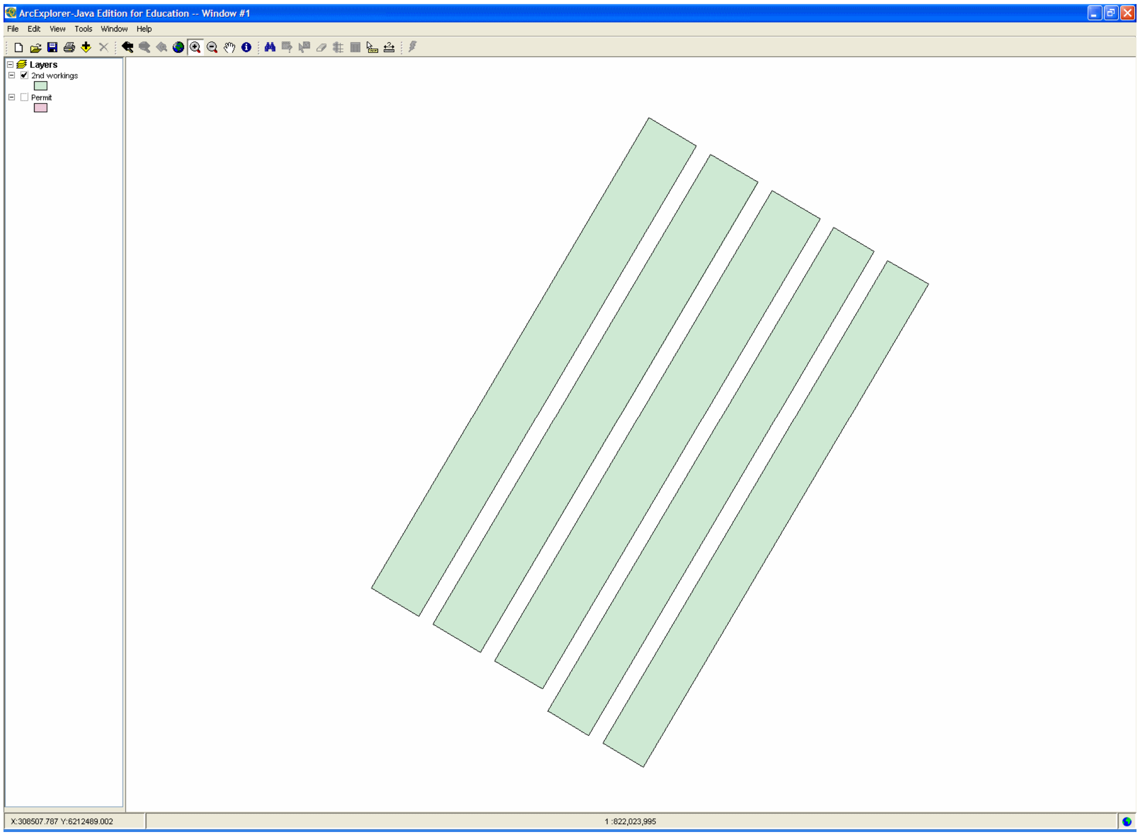


Figure 43 2nd Workings Dataset

3.7 Topology Created for the project

Before any thematic mapping could take place the topology had to be created within the different themes of the project. Topologies where created for points, lines and polygons geometry.

Before any topology was created it was important to make sure that drawing cleanup tools were used to clean up the map from drafting errors. This is to stop errors from becoming apart of the topology and giving incorrect analysis results when working with the topology.

Several topologies where required for most themes of the project and a brief description of each is discussed below.

For the Inrush Series of Maps, the topology created was:

- Old workings topology – This was created from Old workings outline. It is a Polygon topology
- Dam Topology – This topology was created from the outline of Woronora Dam. It is a Polygon Topology
- Surface to Underground Borehole Topology – Point Topology

For the Gas- drainage Series of Maps, the topology created was:

- Inseam Drill Hole Topology – This was created for each group of holes drilled from a set drilling location. It is a Line Topology or also know as a network
- Inseam Core Topology – Created from core positions points. It is a point Topology.

Emergency Evacuation using CABA equipment Series of maps, the Topology create:

- Centreline of workings topology- This was created from the centre lines of the mine workings. It is a line network Topology.

Permit to Mine Series of maps, the topology created:

- Approved Roof Support topology. This was created from the approved Roof Support Theme. It is a polygon topology.

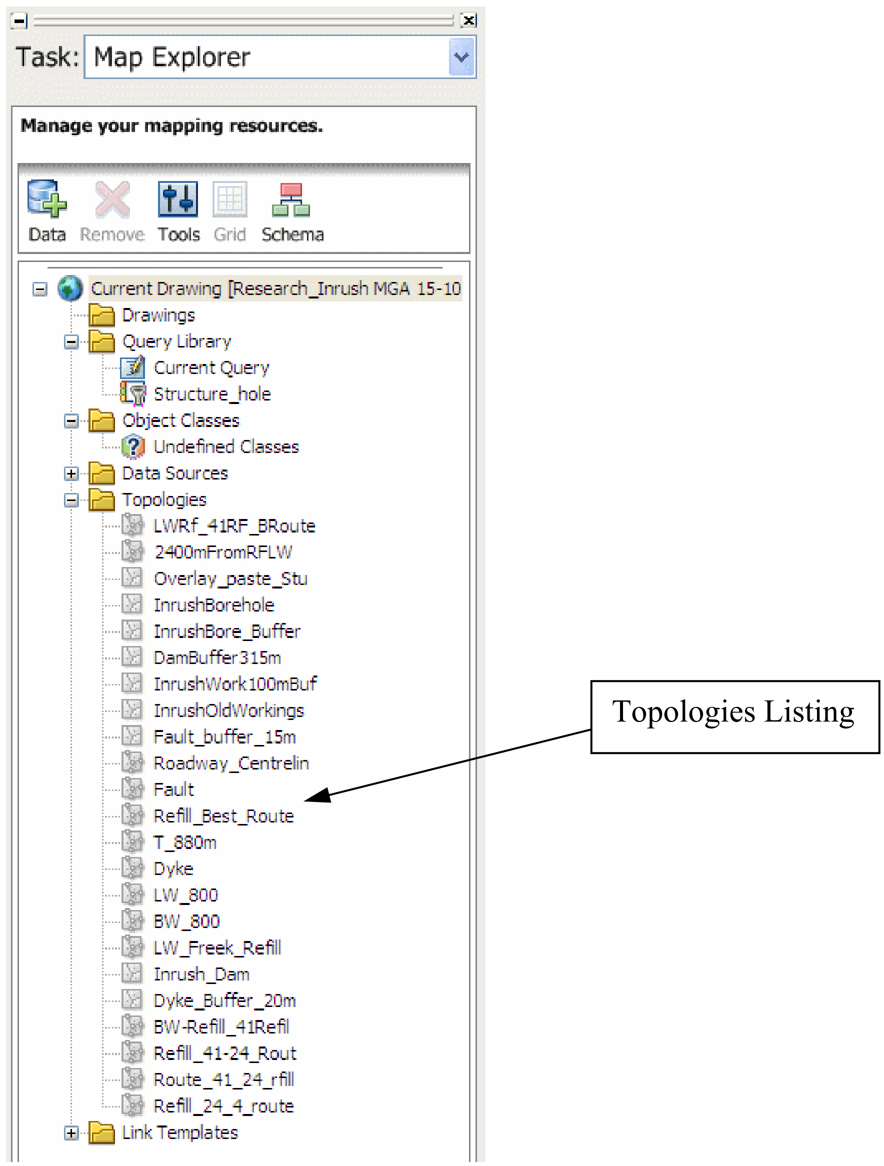


Figure 44 List of some Topologies created in Map 2007

The topology in Map 2007 was created through “Select Topology dialog Box”. The dialog box is used to select the type of topology to create and to specify the topology name and description. Topology type selection is either node (point), network (line), or polygon.

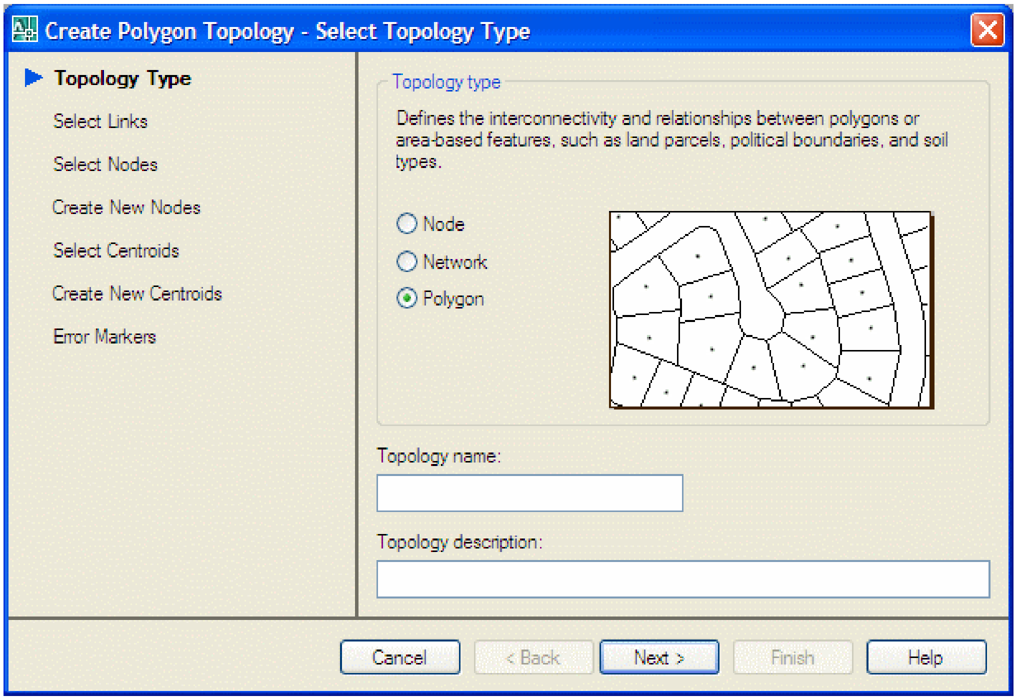


Figure 45 Create Topology Dialog Box

After naming and selecting the type of topology, the selection of drawing objects to be included in the topology is carried out. The drawing objects can be selected by theme (layer), class or by manual selection via the mouse. There are two more steps necessary which allow for nodes, centroids to be created and some more advanced options that were not used in the project.

3.8 Analysis of Topology

Once topology has been created, the topology can be analysed for spatial relationships between the different drawing objects. Topology allows:

- Extract or create new information about a set of objects
- Determine the distribution of an object, or objects, over a network or area
- Manage relationships between objects
- Analyse the location, proximity, and orientation of objects
- Evaluate suitability and capability, estimate, predict, and interpret

- Identify conditions at a geographic location, in a spatial area, or along a linear network, and predict effects of future events on these items

Topology analysis used in the project was:

- Buffering
- Network – Flood Trace
  Best Route
  Shortest Route
- Overlay – by union

Buffering will be the most used analysis tool. Mining deals with numerous types of barriers and limiting factors on resource extraction. Buffering helps show these limitations and no mining zones graphically on maps.

Flood trace analysis will be performed on some mine escape scenarios to demonstrate that First Response Evacuation Equipment Kit (FREEK) are not placed to far away from the working face in an event they may be required for use. The flood trace will be used to determine whether the CABA equipment and air refill stations are not placed too far apart so that CABA tanks will not empty before reaching the refill station.

Best Route will also be used for studying the best 2^{nd} egress in the mine for cases of emergency evacuation. Shortest route studies will be carried out on quickest ways from FREEK station to Refill stations.

Over lay analysis will be performed to determine what parts of the mine have all the criteria in order for it to be mined.

3.9 Types of Themes Required

Thematic maps are used to display objects by using a theme of graphical display characteristics. This makes it easier to visualise tabular data without the need for extensive annotation. This can be particularly useful for presenting graphics and reports and for quickly finding spatial patterns in your drawing geometry.

The research project necessitates several categories of thematic themes. Thematic themes required are based around the five technical areas of the Collieries operations;

- Leases and mine holdings,
- Exploration in regard to exploration borehole
- Areas of approved mine roof support,
- Permits to mine first workings and lastly
- Mine safety.

Choropleth maps will be required for Mine holdings to discriminate between freehold land held by the mining company, Mining titles and surface rights.

Areas of approved mine roof support will also be displayed as a Choropleth maps highlighting approved, not approved and approval pending (under consideration from the department of primary industries –Minerals).

Exploration themes will largely depend on the attribute data made available

Permit to mine is an extremely complex theme as it has to consider a lot of information, geology, inseam drainage and inseam cores make the core of the data required. The type of map required will need to be able to display the data clearly and allow overlays of all the data to build up a clear understanding of all the facts being presented, for the map to be effective for use as a tool in decision making process.

3.10 Summary

Towards the completion of the project many steps have been undertaken including data acquisition, data processing and data validation. The datasets have been obtained from the collieries archives, and the department of lands. There was problems gaining reliable geology data and this limited the number of thematic maps that could be produced to aid decision making process for exploration theme.

Data processing was carried out in three stages preparation, entering Data, editing and quality enhancement. All data was transformed to the same co-ordinate datum MGA 95 zone 56 by built in functions of Map 2007 global co-ordination system.

Thematic maps based on the same co-ordinate system where then prepared to cover the chosen themes of mining. Several thematic maps where produced to aid decision makers in the elected areas of the project.

The next chapter will discuss the results of the GIS expansion and the Thematic mapping and monthly reporting.

4 Results and Discussions

4.1 Introduction

This Chapter will highlight the final results of the expansion of the GIS and thematic mapping performed during the project. The Chapter will discuss expanding of the current GIS, about each of thematic maps produced for the five technical areas cover by the research and finally the monthly reporting.

4.2 Expansion of the Current GIS

Results

The expansion of the GIS was based around one question. What will the GIS be answering? The answer to this question gave the answer for what attribute data will be required for the research project.

Sourcing and Geocoding was the largest part of the project, it had taken up approximately two thirds of the time of the project. The problem with this stage was that the project could not achieve any of its other objectives until the GIS had data and drawing objects within it for its use. A lot of work and effort had been placed into the project and no results where shown until the implementation of the GIS is completed.

The validation of attribute data was a vital part of the expansion process as the GIS is only as good as the data within. There was some data entry typing mistakes found during the use of the GIS. Most errors found were miss spelling.

Discussion

The expansion of the GIS was an important role of the project as without the GIS expansion none of the projects objectives could be achieved. The problem with implementation of a GIS is that there is a lot of effort placed into the setting up of the GIS and no physical results are shown during this phase.

Sourcing some data was difficult to find at times due to how the documentation had been archived at the mine. Some of the documentation had not been filed correctly so searching through large amounts of documents was required for some themes in order to find the attribute data.

4.3 Mapping Leases and Mine Holdings

Results

The aim of the analysis was to extend on what was already being produced by the current GIS and aid in the decision making process. The Lease and Titles data is mandatory by the coal mining regulations Act NSW and has to be produced quarterly to the department of Primary Industries in N.S.W. The data and graphical elements were already in place, so to improve on the system the thematic mapping was introduced to produce two Choropleth maps and a symbol map see appendix Drawings 1, 2, and 3.

The theme was the least technical of the themes selected for the research and therefore produced maps that are unsophisticated and are understood without any obscurity.

Discussion

These maps could have been produced with any graphics type software. The advantage of using a GIS (map 2007) is not so much the maps in their printed state but in its electronic format. This allows the map to become dynamic as it can answer questions through querying the linked attribute data or by using the computers mouse and clicking on the individual titles to obtain the entire attribute data listed in a table format. The plans are of more importance digitally then in their analogue state. The maps produce do not particularly aid in the decision process but do allow for the information to be clearly conveyed.

4.4 Exploration

Results

(Drawings 3, 3A, 3B)

The current GIS is not used for any of the technical disciplines involved with mine planning. So adding attribute data from exploration and collaborating of old geological plans into the GIS increased the potential use of the GIS in this field.

A thematic map was produced that presents more of an overview of the exploration program required to verify the coal seam characteristic for the short (next 5years) and long term planning of the mine. It displays the range and influence of the seam samples taken and important surface features over the area like access to fire trials and drainage patterns via ortho rectified aerial photography.

The overlay with aerial photography shows the terrain and its relationship to the boreholes and mining titles.

Discussion

Australian guidelines for estimating and reporting of inventory coal, coal resources and coal reserves suggest a maximum of 500m spacing between seam samples to determine a reliable seam depiction.

The thematic map highlighted areas that required more work to define the seam characteristics for short term and long planning and the difficulty of obtaining some of the seam samples due to the terrain and special condition put in place on the surface as it is located in a Sydney water catchment area.

The map aids the decision making process as it highlights that the top northern end of the lease holdings borehole spacing is inadequate and the complexity in obtaining seam samples to fill in the missing pieces of information.

4.5 Approved Roof Support

Results

(Drawing 12)

The aim of the roof support theme was to display the regions of approved roof support and regions of no approved roof support. This would stop areas being accidentally mined without approved roof support or using the wrong roof support system in an approved zone.

The approved roof support regions had hyperlinks attached to it so the link pointed to PDF file that displayed the approved roof support diagrams of the region selected.

The theme can be used on its own for the purpose of displaying approved support and accessing the support diagrams or to be overlayed with other themes for further analysis.

Discussion

The hyperlink to the PDF roof support diagrams would perform remarkably well if the maps are made available via an intranet across the mine site both on the surface and underground.

The theme could be extended on by including zones of secondary support which is placed in the tailgate and maingate of the extracting longwall and moving onto small pillar applications

The real advantage of the theme is it electronic form, it is dynamic and can be queried unlike a paper print.

4.6 Permit to Mine

(Drawings 8, 9, 10)

Results

Permit to mine is the most complex theme as it combines many of the other themes into it. For a Permit to mine to be authorised many characteristic have to be looked at. These include Inseam drainage boreholes, Inseam Core samples, Geology, Long inseam drainage holes, and mining environment being developed. Due to the significant nature and the volume of data that is required to be investigated before a “Permit to Mine” can be approved the theme has been broken down into two simplified maps.

Drawing 8 concentrates on the inseam gas drainage but only in the current working area. That is the gas drainage across the current Longwall block and the gas drainage in front of the roadway development. Drawing 8 shows the inseam gas drainage, inseam drilling, comments logged by the drillers and geological structures intersected by the inseam drilling in a neat simplified form that relays the information without the decision maker having to search the map for the relevant data.

Drawing 9 breaks down drawing 8 by displaying the drained inseam gas zone buffers, inseam drill holes that intersected geological structures, drill holes where seam core samples have been taken, inseam core sample results and geological structures. This allows the map to be less cluttered but still displaying the required data for permit to mine authorisation process.

Drawing 10 is a display of all the information required if shown all at once. This is how the present permits are being generated. The drawing is very confusing at this scale. In practice the plan would zoom in more on the interested area that needs a permit for mining. Even after zooming in the information is over whelming and the decision makers have to search the plan for the information.

Drawing 11 shows the trends in CO2 gas percentages. The mapping is showing a trend of the CO2 levels are lower on the western side of the geological structure zone going through the longwall blocks. This information is vital as it shows the mine management what type of gas will be encounter whilst mining. The higher the CO2 level the lower the CH4 level and lower the CO2 higher the CH4 gas levels.

Drawing13 summarises the permits that have been approved into two categories Permits to Mine that do contain geological structures and those that do not contain geological structures. This theme has been setup to be overlayed with other themes to highlight areas that meet all the requirements for mining to proceed. A hyperlink was also setup with this map to link with PDF files of scanned permit to mine approval documents that had been signed by the mine manager.

Discussion

The Bulli Coal seams is know to “Outburst” which is the sudden violent emission of coal and seam gas that has been pressurised from the build up of gas behind geological structures. “Permit to mine” is an important part of the mine development cycle. Mining engineers and mine managers are involved with the “permit to mine” authorisation process and base their decisions on the information conveyed on the maps. These maps play a big role in the mining cycle at the colliery.

By breaking down the information into two thematic styled maps makes sure the information relayed from the maps is taken in more bite size pieces than one big bite that requires the decision makers to go searching for the information required from the map. The two maps definitely perform better in an electrotonic form as the data can be queried to show all long holes over 350m, or show only core samples that failed. At present a printed map has to be included as a part of the permit to mine documentation and signed according to the Collieries Outburst management plan.

By putting in place the attribute data for the theme it enable new ways at looking at gas trends and how it can be mapped. Mine management recognize the value of this new way of analysis of gas drainage data and have already started using drawing 11 from the project.

The hyperlink would be useful if the maps where available on an intranet. This would allow access to the maps and display what permits to mine cover the area of the query.

4.7 Mine Safety

Results

The mine safety theme used network analysis to check that the positioning of emergency evacuation equipment was not spaced out to far for it to be effective. The first analysis performed was a best route problem. The starting position was select at the first refill station of each production district. Then sites to visit along the way had to be selected. These sites to visit on the way where CABA refill stations and finally a finishing point was selected. The result of the analysis is shown on Drawing 4.

Analysis was performed to determine how far an injured person could travel from a working face position using a self contained rescuer to ensure that the FREEK stations are not spaced to far from the working face. This was solved by performing a flood trace of the line network. The results are shown on drawing 5. It demonstrates that an injured person walking at 0.8km/h would make the FREEK well before the self rescuer would run out of chemical oxygen.

FREEK stations contain CABA equipment for emergency evacuation. The CABA equipment has be designed to be refilled by a hose connection at Refill Stations. The next part of the study was to determine whether the FREEK and Refill Stations are not spaced to far apart so that the CABA equipment will not empty before reaching a refill station. The distance travelled was base on data that states a person with below average fitness should be able to walk 2.4km with a CABA suit on. The results showed that the below average fit person would almost be able to go pass the next two refill stations and almost make the third refill station on the evacuation route. It would seem that perhaps the refill stations are to close, but a safety factor has been used to allow for low visibility situation from smoke caused from a fire.

Inrush potentials are a hazard that needs to be avoided. Data was collected on inrush sources of the colliery and assembled into the GIS to produce a thematic map high lighting the possible sources of inrush. Drawing 7 displays the results of the potential inrush sources. Two buffers zones where placed around old workings. The first is a 50m barrier that Coal Mining Regulations in NSW stipulate must be maintained from an inrush source. The second Buffer is a 100m buffer that the manger rules call an inrush zone. When mining in these zones flanking drill holes have to be in place a minimum of 50m ahead of the workings at all times.

Discussion

The thematic maps produced with the line network did not function correctly when first analysed. The network for the roadway centre lines had drafting errors. After using drawing cleanup the topology still did not function. It was found that when using drawing clean up tolerances have to be set for certain drafting situations. After adjusting the cleanup tolerances and re creating the topology the analysis worked correctly. It is important to have line work that is error free in topology or results of analysis will definitely be incorrect.

The thematic maps and analysis performed for the safety theme is only a small field of what GIS can offer to the safety theme. The theme could be extended into mine fire fighting theme, first aid, emergency phones for example.

4.8 Monthly Reporting

Results

The reporting functions of Map 2007 are very limiting. The only reporting function available is a text file listing of the results of a query. The report function in the query mode allows for the attributes fields and drawing object properties to be selected as a part of the listing criteria to be included in the report template. The text file generated from the query can be imported into another application like excel to get statistical data out of the queried data.

Map had no statistical functions at all, except on topology and this was of limited use. The Figure 46 shows the statistical function for a topology. It is not very useful as it is only a listing of physical data related to the drawing objects.

Statistics summary

Extents		Object counts	
Lower left:	308430.6884, 6212898.3191	Nodes:	11
Upper right:	309466.6863, 6214847.9993	Links:	11
		Polygons:	2

	Area	Perimeter	Length
Total:	273902.592773	9148.796893	-
Average:	136951.296387	4574.398447	-
Minimum:	88273.641846	2263.379951	-
Maximum:	185628.950928	6885.416942	-
Variance:	2369514051.614460	5340806.485679	-
Deviation:	48677.654541	2311.018495	-

Figure 46 Statistical Information of a Topology

A monthly development map was created showing the development month by month for 2006. Drawing16 in the appendix shows the monthly development for 2006. The development map was created by using a thematic function on attribute data and then setting a range scale on the year 2006. The legend of the map would not sort in chronological order only by name ascending or descending. This makes the legend hard to use. It would not allow manual changes, but there must be some method available to have the legend list in chronological order.

Discussion

The monthly development map could easily be extended to include the monthly extraction. The GIS of the research project does not contain any attribute data on monthly extraction, but it would not be a lot of work to add this attribute data at some time in the future.

The GIS Map 2007 can not perform any statistical analysis on attribute data. So no end of month statistical information could be produced by the software. The only reporting capability the GIS has is by text file listing of queried data. The figure 47 shows the text file result of a query asking for the attributes of length, colour and layer of all holes over 350m in length in the gas drainage theme. The text file could be made into a monthly report by importing the text file into a secondary software like Microsoft excel or Microsoft word.

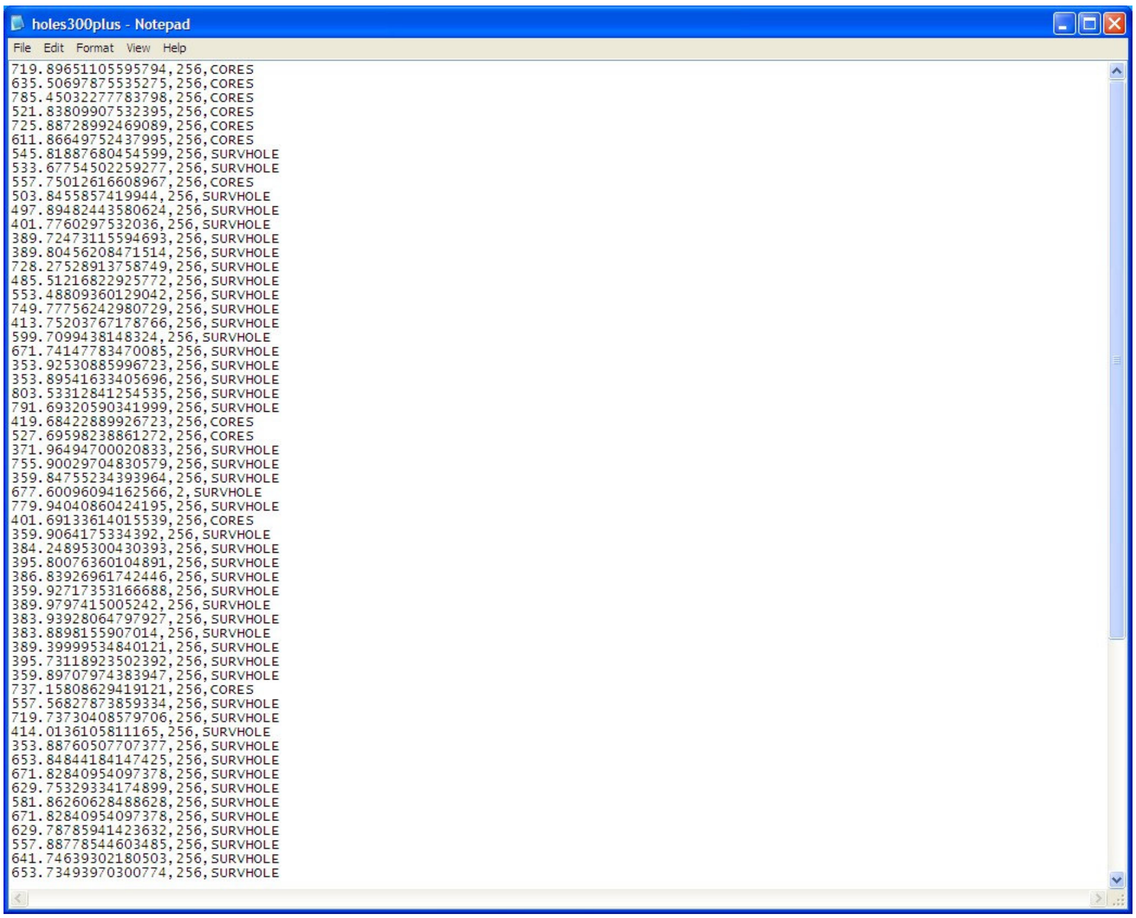


Figure 47 Text file of a query

4.9 Conclusion

The chapter has presented the results of the expanded GIS, Thematic Mapping of themes of the project and monthly reporting. The results exhibit that GIS can be successfully implemented as a tool to aid managerial decision making process. Thematic mapping made sophisticated data understandable due to its graphic nature. An advantage of the visual image is that non technical observers will be able to understand the information displayed with out needing technical training.

The monthly reporting is limited by the software Map 2007 reporting function in that a text file listing is produced and a second software would have to be used to produce a respectable report. Map 2007 has no statistical functions available in the software and any statistical work would require a report query to produce a text file of the required data and importing the text file into software for statistical analysis.

5 Conclusions and Recommendations

5.1 Introduction

The purpose of the chapter is to highlight concluding remarks on the findings of the research project and problems encountered that affect the expansion of the mines GIS. Further, the chapter will discus and recommend what should be done to further improve the expansion of the research GIS and what additional themes and mapping can be increased to broaden the scope of the GIS in relation to the colliery's decision making processes.

5.2 Findings of the Research Project

The objectives of the research was to expand the current GIS at Metropolitan Colliery, Produce thematic maps on the same co-ordinate system that aided the decision making process for management, and generate monthly reports containing relevant statistical information.

The findings of the research are that GIS does have a role at an underground coal mine as a tool to aid in managerial decision making. The major draw back of a GIS is the implementation. This takes time, money and man hours. Even when the GIS is up and running it will have to be maintained. GIS becomes a tool for decision making only when the system is up and running.

The biggest decision that a mine proposing to implement a GIS will have to answer is, what will the GIS be answering? This lays down the foundations of what the GIS is going to be used for and what attribute data will need to be sourced and geocoded into the GIS.

Thematic mapping can aid management with its decision making. It was found to be effective at displaying complex attribute data in a more user friendly form than placing all the data onto a map at the one time and having the decision makers search the map for the essential information. The thematic mapping display lay outs were limited by the learning and use of the software Map 2007. Some of the thematic maps produced in the report may well be improved by a GIS user with more experience with Map 2007.

A limiting factor to the research was the chosen software for the project as it is limited in terms of GIS functions. The nature of data storage available in map restricted its querying ability of the database. Date is an important attribute field for some of the datasets of the project and map 2007 built in database does not allow a date/time field. The only way a date could be queried was for the data to be linked externally and then use map 2007 SQL to retrieve date base queries involving the date field. This also affected the monthly reporting objective of the research. When dealing with data on a monthly basis for reporting the Date field becomes a useful attribute field to query with.

The reporting functions of Map 2007 where very limited as it produced a text file listing of the queried data only. So if any statistical analysis where to be carried out the txt file would be required to be imported into excel or some other statistical type software. Map 2007 does not have any statistical functions built into the software. The only type of statistical information relayed to the user was geometry based figures on topology.

The advantage the GIS gives decision makers is that GIS can be queried on several scenarios and give the decision maker data on those scenarios results. The data can be represented by a thematic map, graph, or a listing of relevant data. This allows decision makers the ability to trial some solutions to determine the most likely outcome based on the criteria that is in place and see what the result is.

The study has shown that GIS can be employed as a successful tool in decision making at an under ground Colliery. That thematic mapping can display complex data in a more user friendly format that aids decision making. Monthly reporting can be carried out through querying relevant data into a text file that can be further worked on by a second program. Map 2007 does not have any statistical functions and can only be carried out by creating a report file through querying and importing the report into a second program to perform statistical analysis.

5.3 Further Research and Recommendations

5.3.1 Further Research

In order to fulfil the main aim of the project to implement a GIS to aid management in the decision making process, a number of things may need to be considered for future work. The study could be furthered by using other GIS software that has reporting and statistical functions and graphing capabilities. This would benefit decision makers as they can have thematic maps, graphs and statistical information to base decisions on and all coming from the one program.

The GIS could be further expanded by adding more theme data that would assist the decision making process in regard to more mine planning issues. Asset management of colliery infrastructure maybe investigated as another extension of GIS use at a mine site.

As access to geological data was not achieved during the research it still requires further investigation. GIS has been used in mine exploration before and this could be further investigated to explore how to implement it more to an underground coal mine situation.

Further investigation is required to explore how Autodesk Map 2007 and Autodesk Map guide operate together. Map guide is a web based mapping solution that could be used to distribute maps internally and externally to end users.

5.3.2 Recommendations

Like any other computer technology, it is rather difficult to assess the full potential of GIS until a prototype system has been developed for a coal mine. It would be recommended that if implementation of a GIS into an underground coal mine be introduced that a fully operational GIS software that is capable of statistical and reporting functions be used.

Statistics are an important source of information that can assist decision makers. Tabulated data can be better interpolated by graphical representation of the statistical analysis of the data. An advantage of the visual image is that non technical observers will be able to understand the information displayed with out needing technical training.

Thematic maps can play a large role in decision making but when accompanied with statistical analysis in the form of graphs and read in conjunction with produced reports it can allow all levels of management a chance to understand what the problem on hand is really about and the type of solution that is required for the best result.

Before any implementation of a GIS a detailed analysis should be taken to determine the datasets and attributes required and have the attributes and datasets well refined before any data entry. Changing of dataset during implementation is time consuming, costly and extremely frustrating for the people involved with the geocoding.

Have all the data available for geocoding well before data entry so datasets are not changed due to lack of required data whilst be entered.

Implementation of a GIS requires good solid planning and a timeline to adhere to. If the planning and all the correct homework has been through then the implementation will run smoothly with minimal distributions.

6 Appendices

Appendix A:
Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/4112 Research Project
PROJECT SPECIFICATION

FOR:	ANDREW CARTER
TOPIC:	IMPLEMENTING A GIS FOR AN UNDERGROUND COALMINE THAT WILL AID OPERATIONAL MANAGEMENT
SUPERVISOR:	Dr Badri Basnet
PROJECT AIM:	The project aims to expand the current Geographical Information System from a single purpose system to a multi purpose system that will allow the mines Operational and Planning Management to have a Geographical Information System as a tool to help in the decision making roles and explore potential applications of GIS in an underground coal mine.
PROGRAMME:	Issue A - 23rd March. 2006

1. Research and review literature relating to the implementing of a Geographical Information System for an underground coal mine and research the capabilities of the current geographical information system – Autodesk Map 3D 2006 presently used at the mine site.
2. Consider other geographical Information system if Autodesk Map3D 2006 is not appropriate for project goals.
3. Develop a programme for data collection. Evaluate existing data, acquire data from various sources, collect (measure myself) data where necessary, digitise data if available in hardcopy format.
4. Produce thematic maps of various themes with all maps to be compiled on the same co-ordinate system so all maps produced can be overlayed.
5. Setup a monthly reporting system that will produce thematic maps that have suitable themes, and reports containing relevant statistical information for all mining departments to aid in end of month reporting and planning.

As time permits

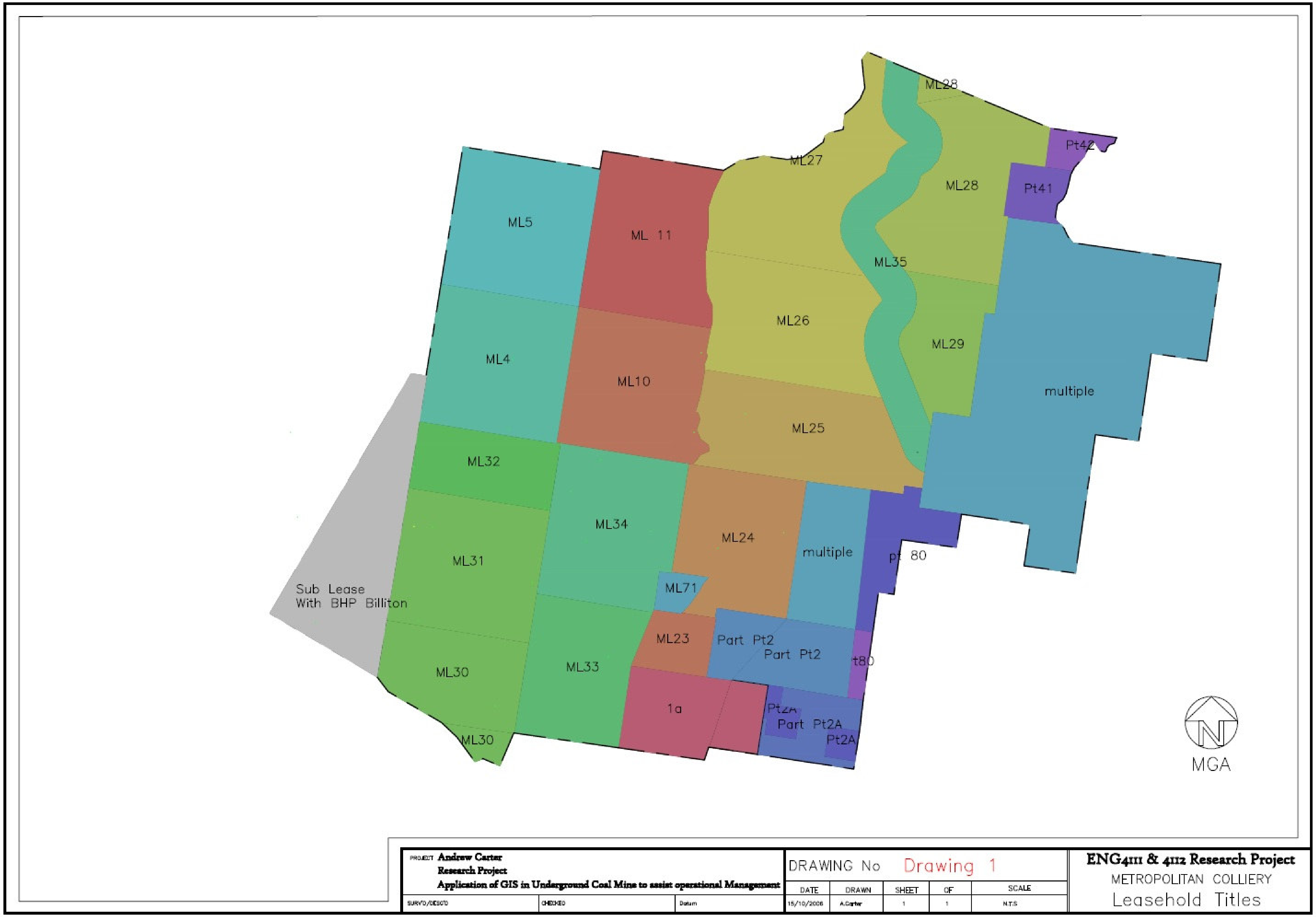
6. Incorporate aerial photography to highlight effects of mining on the environment and relate the mines position to surface features and infrastructure

AGREEDED

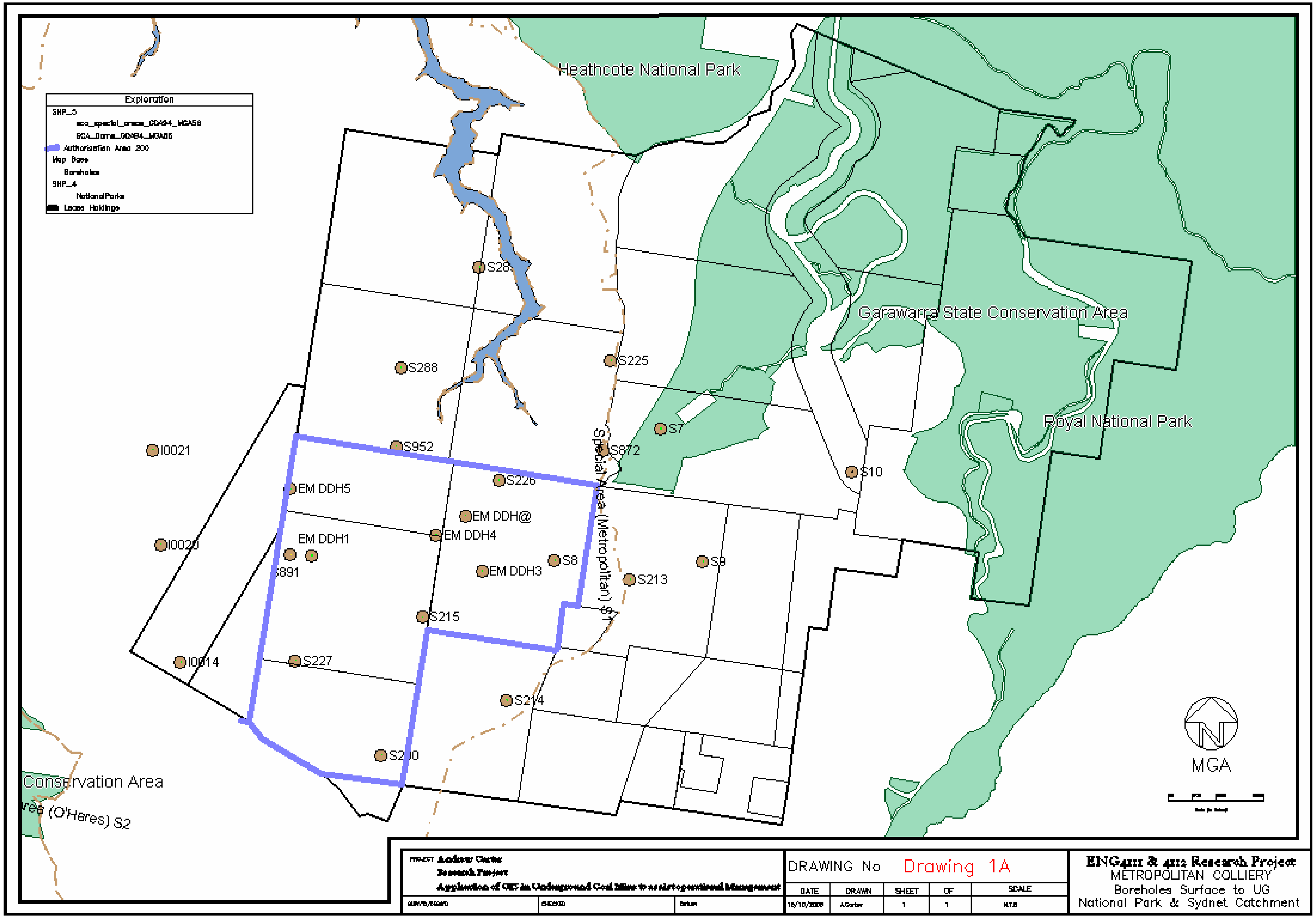
___________________(Student) ________________________(Supervisors)

_____/_____/2006 _____/_____/2006

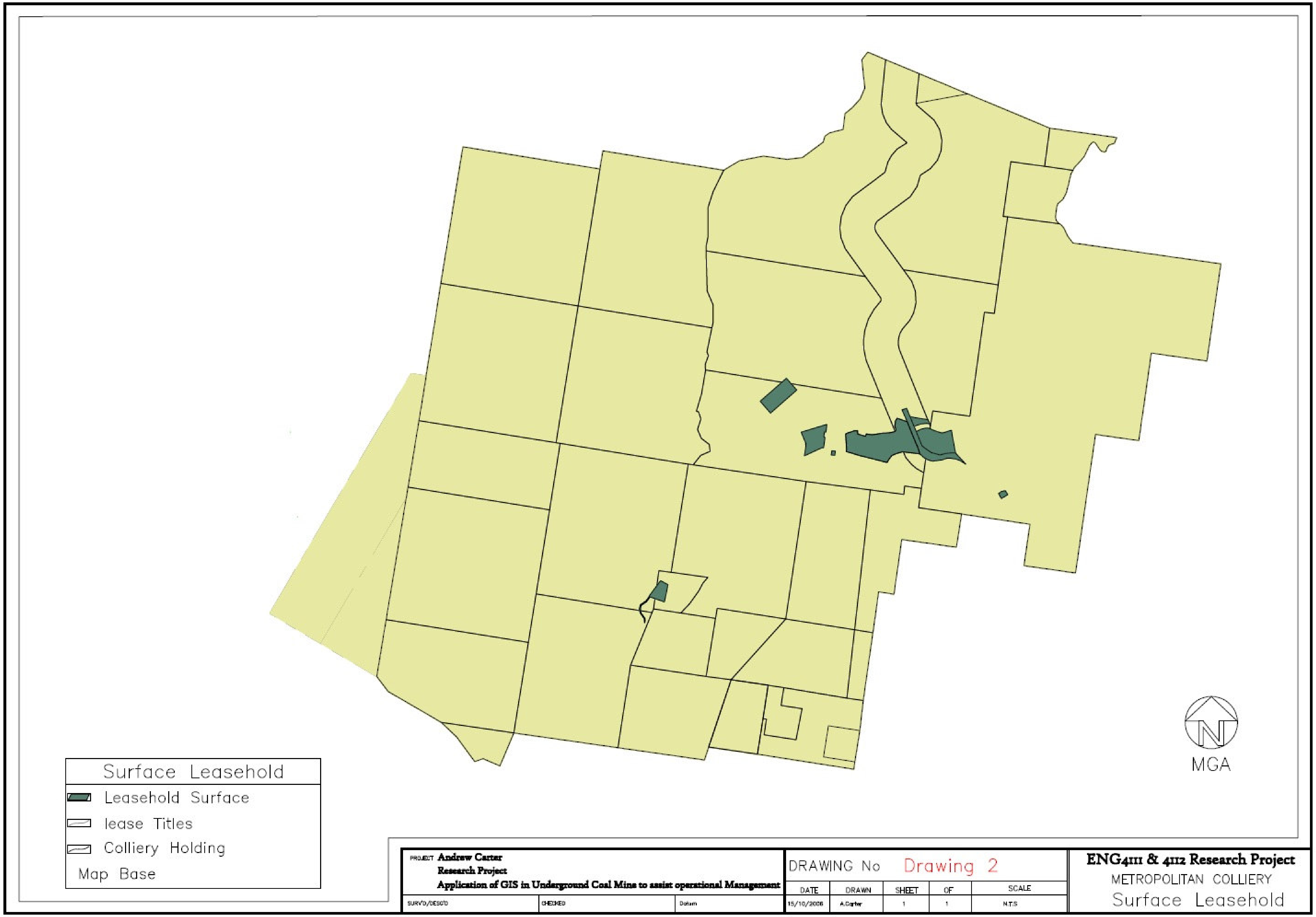
Appendix B:
Drawing 1 – Lease Hold titles


ML28
Pt42
ML27
ML28
Pt41
ML5
ML 11
ML35
ML26
ML29
ML4
ML10
multiple
ML25
ML32
ML34
ML24
multiple
pt 80
ML31
Sub Lease
With BHP Billiton
ML71
ML23
Part Pt2
Part Pt2
t80
ML30
ML33
1a
Pt2A
Part Pt2A
Pt2A
ML30
MGA
PROJECT Andrew Carter
Research Project
Application of GIS in Underground Coal Mine to assist operational Management
SURV'D/DESC'D
CHECKED
Datum
DRAWING No Drawing 1
DATE 15/10/2006
DRAWN A.Carter
SHEET 1
OF 1
SCALE N.T.S
ENG4111 & 4112 Research Project
METROPOLITAN COLLIERY
Leasehold Titles

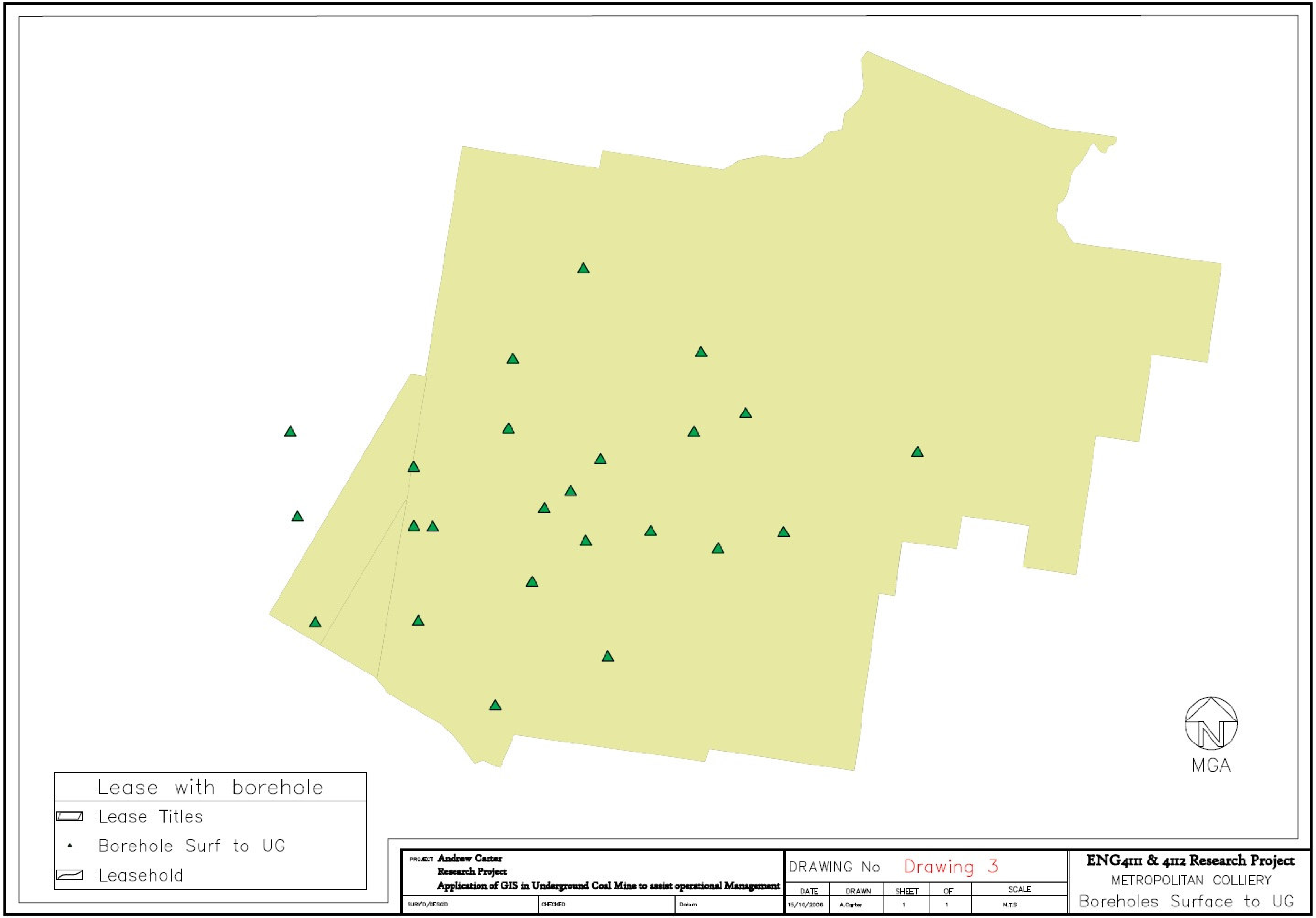
Appendix C:
Drawing 1A – Boreholes, National Park & Sydney Water Catchment


Heathcote National Park
Garawarra State Conservation Area
Royal National Park
Conservation Area
Special Area (Metropolitan) S1
S225
S288
S952
S7
S872
S10
I0021
EM DDH5
S226
EM DDH@
EM DDH1
EM DDH4
I0020
S8
S9
EM DDH3
S213
S215
I0014
S227
S214
MGA
Exploration
Authorisation Area 200
Map Base
Boreholes
NationalParks
Lease Holdings
DRAWING No Drawing 1A
DATE
DRAWN
SHEET
OF
SCALE
1
1
ENG4111 & 4112 Research Project
METROPOLITAN COLLIERY
Boreholes Surface to UG
National Park & Sydnet Catchment

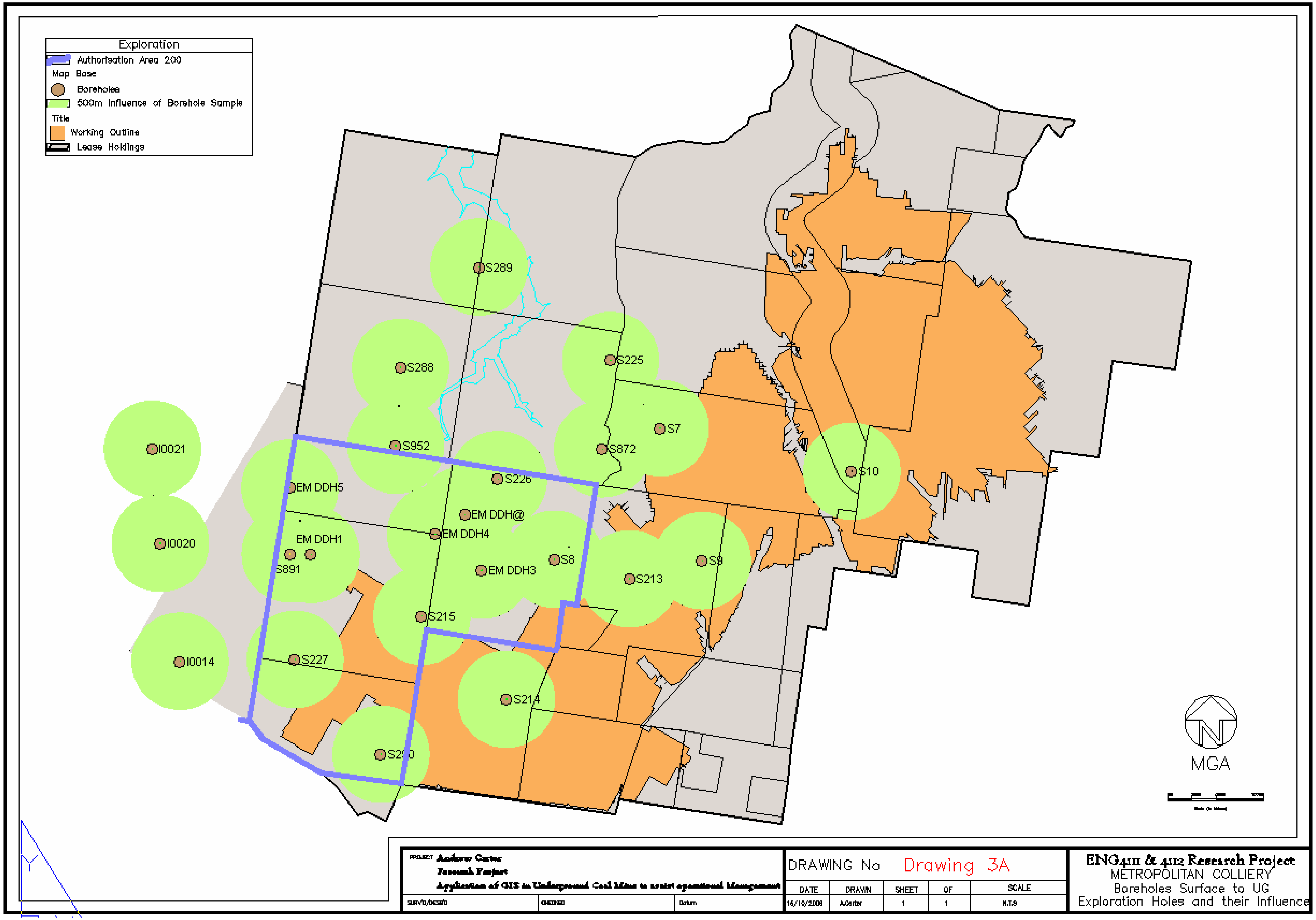
Appendix D:
Drawing 2 – Surface Lease Hold


MGA
Surface Leasehold
Leasehold Surface
lease Titles
Colliery Holding
Map Base
PROJECT Andrew Carter
Research Project
Application of GIS in Underground Coal Mine to assist operational Management
SURV'D/DESG'D
CHECKED
Datum
DRAWING No
Drawing 2
DATE
DRAWN
SHEET
OF
SCALE
15/10/2006
A.Carter
1
1
N.T.S
ENG4111 & 4112 Research Project
METROPOLITAN COLLIERY
Surface Leasehold

Appendix E:
Drawing 3 – Boreholes Surface to Underground

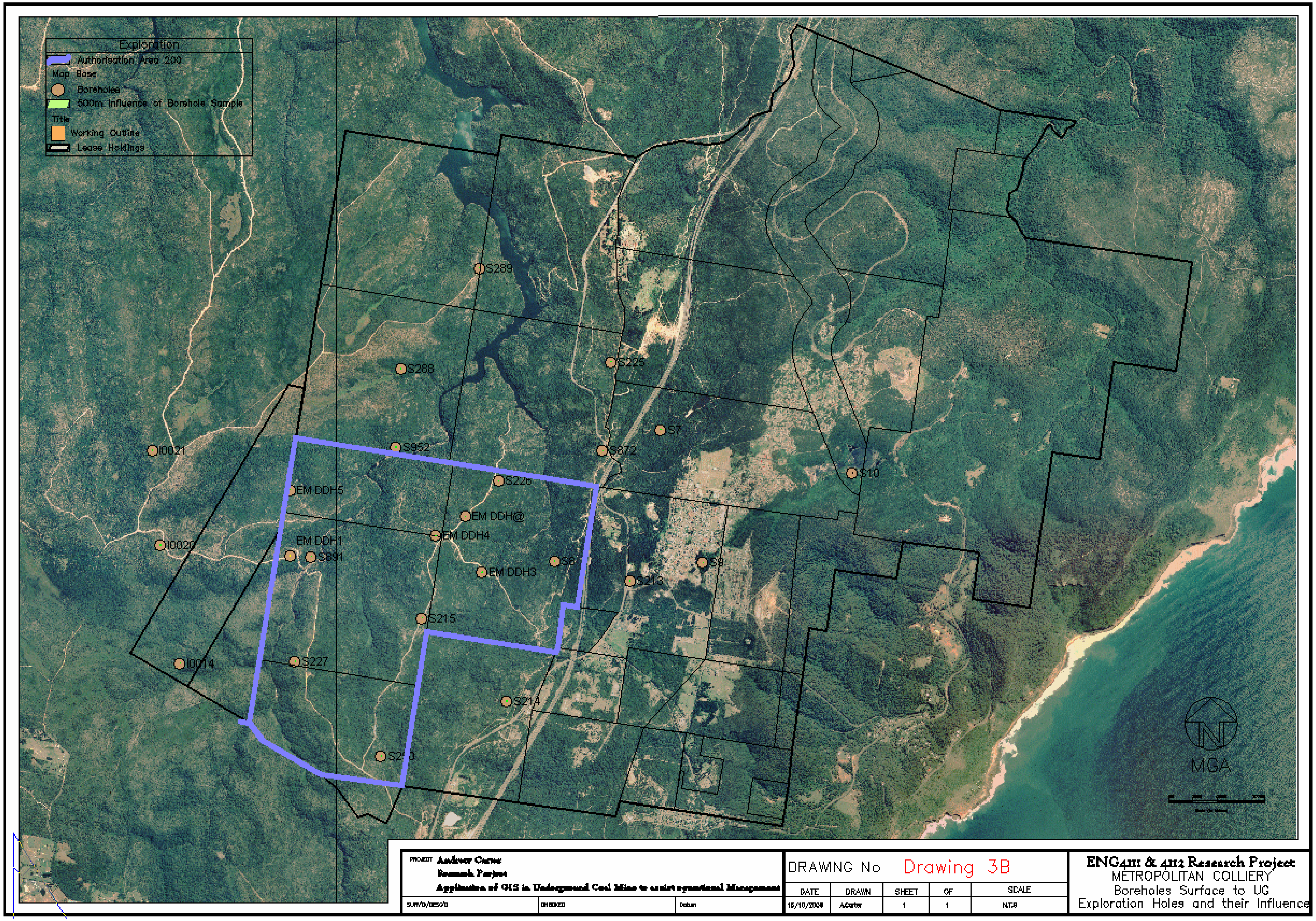

MGA
Lease with borehole
Lease Titles
Borehole Surf to UG
Leasehold
PROJECT Andrew Carter
Research Project
Application of GIS in Underground Coal Mine to assist operational Management
SURV'D/DESG'D
CHECKED
Datum
DRAWING No Drawing 3
DATE
DRAWN
SHEET
OF
SCALE
15/10/2006
A.Carter
1
1
N.T.S
ENG4111 & 4112 Research Project
METROPOLITAN COLLIERY
Boreholes Surface to UG

Appendix F:
Drawing 3A – Boreholes Exploration & Their Influence

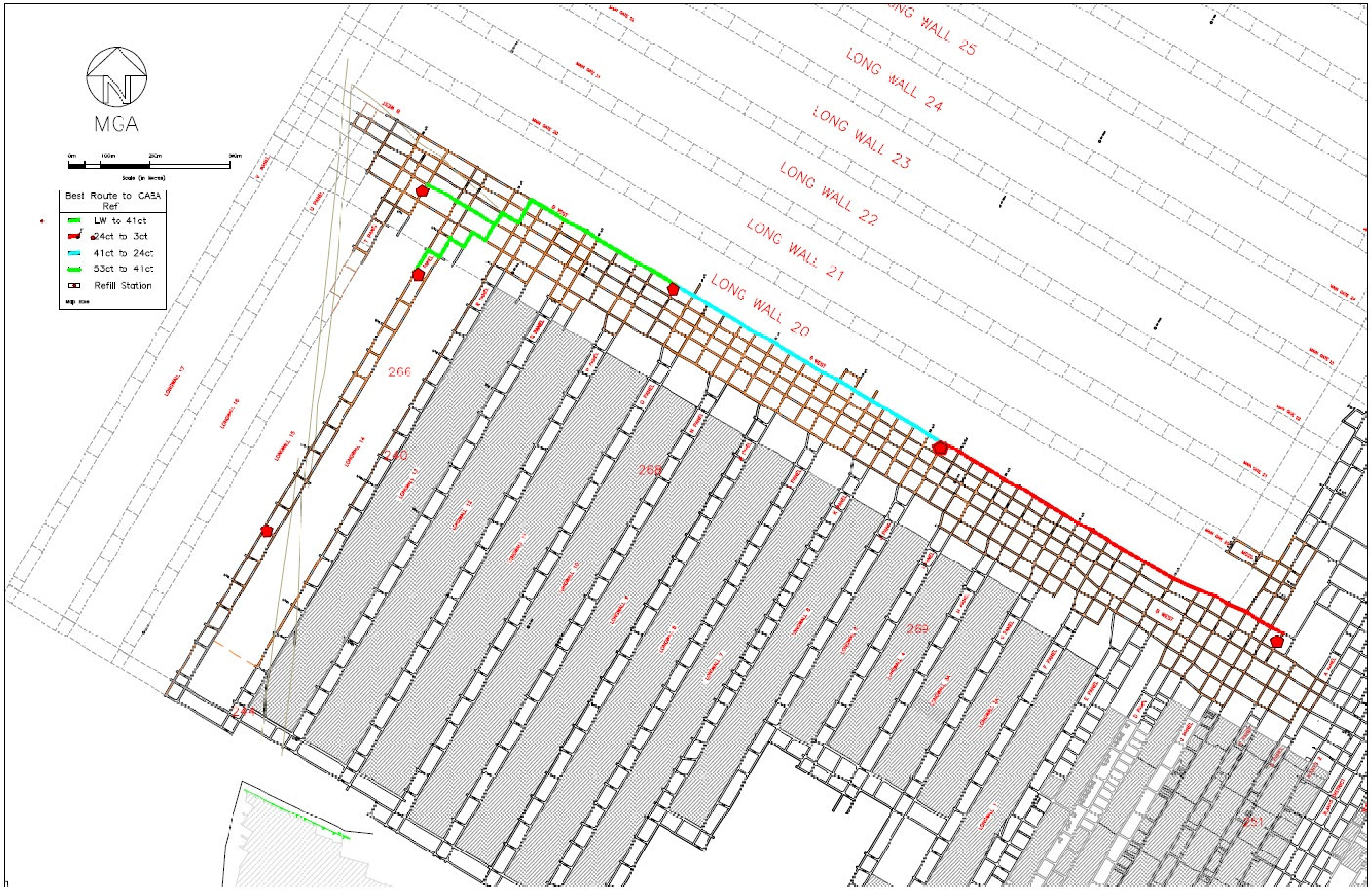


Exploration
Authorisation Area 200
Map Base
Boreholes
500m Influence of Borehole Sample
Title
Working Outline
Lease Holdings
S289
S288
S225
S952
S7
S872
I0021
S226
S10
EM DDH5
EM DDH@
EM DDH4
EM DDH1
I0020
S8
S9
S891
EM DDH3
S213
S215
I0014
S227
S214
MGA
DRAWING No Drawing 3A
DATE
DRAWN
SHEET
OF
SCALE
1
1
ENG4111 & 4112 Research Project
METROPOLITAN COLLIERY
Boreholes Surface to UG
Exploration Holes and their Influence

Appendix G:
Drawing 3B – Boreholes Exploration & Their Influence
& Aerial Photography underlay

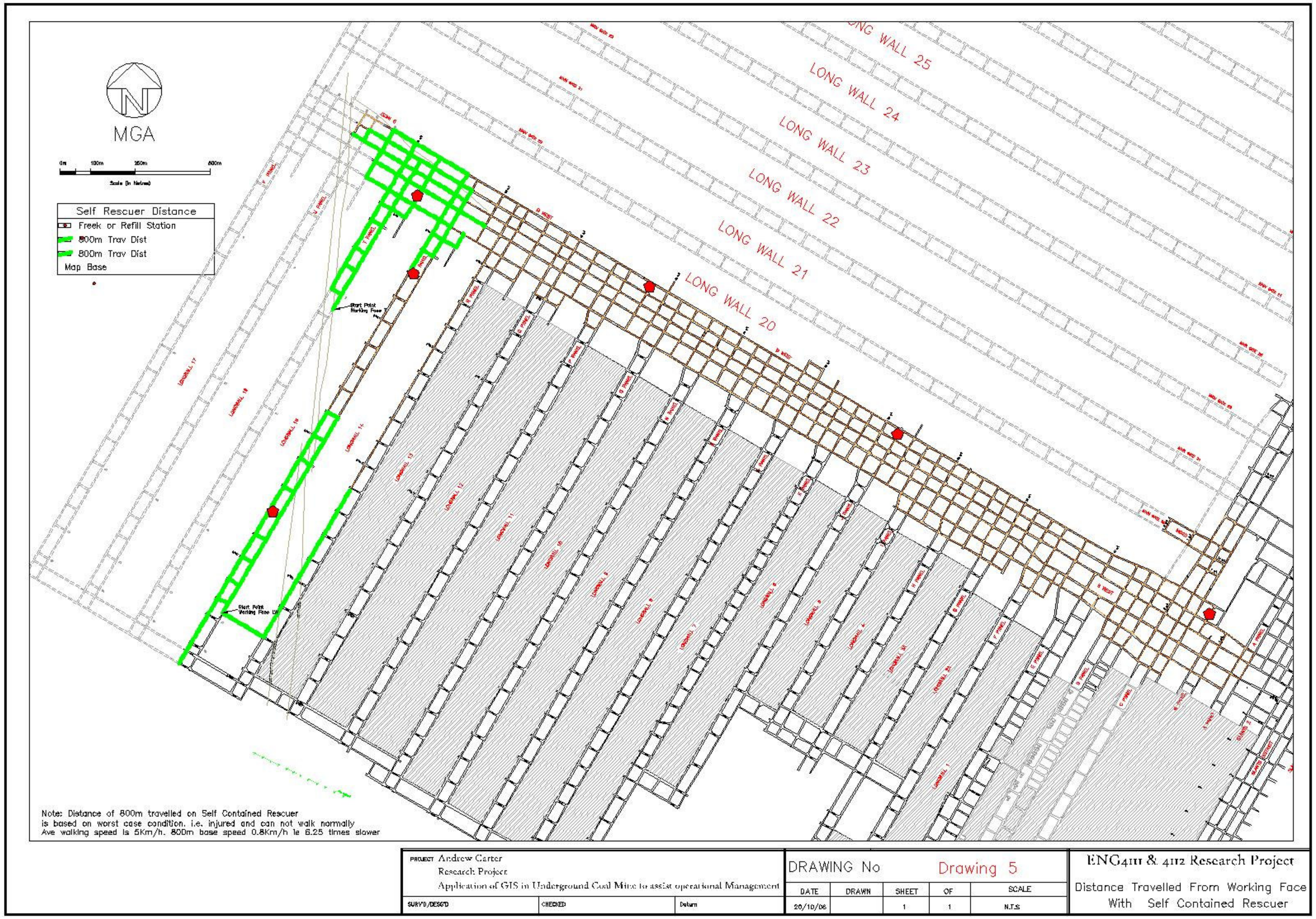

Exploration
Authorisation Area 200
Map Base
Boreholes
500m Influence of Borehole Sample
Title
Working Outline
Lease Holdings
S289
S268
S225
S7
S952
S872
S10
I0021
EM DDH5
S226
EM DDH@
EM DDH4
EM DDH1
I0020
S891
EM DDH3
S8
S9
S213
S215
I0014
S227
S214
MGA
PROJECT Andrew Carter
Research Project
Application of GIS in Underground Coal Mine to assist operational Management
DRAWING No Drawing 3B
DATE
DRAWN
SHEET
OF
SCALE
15/10/2008
ACarter
1
1
N.T.S
ENG4111 & 4112 Research Project
METROPOLITAN COLLIERY
Boreholes Surface to UG
Exploration Holes and their Influence

Appendix H:
Drawing 4 – Best Route from CABA Refill Station to 3c/t out bye

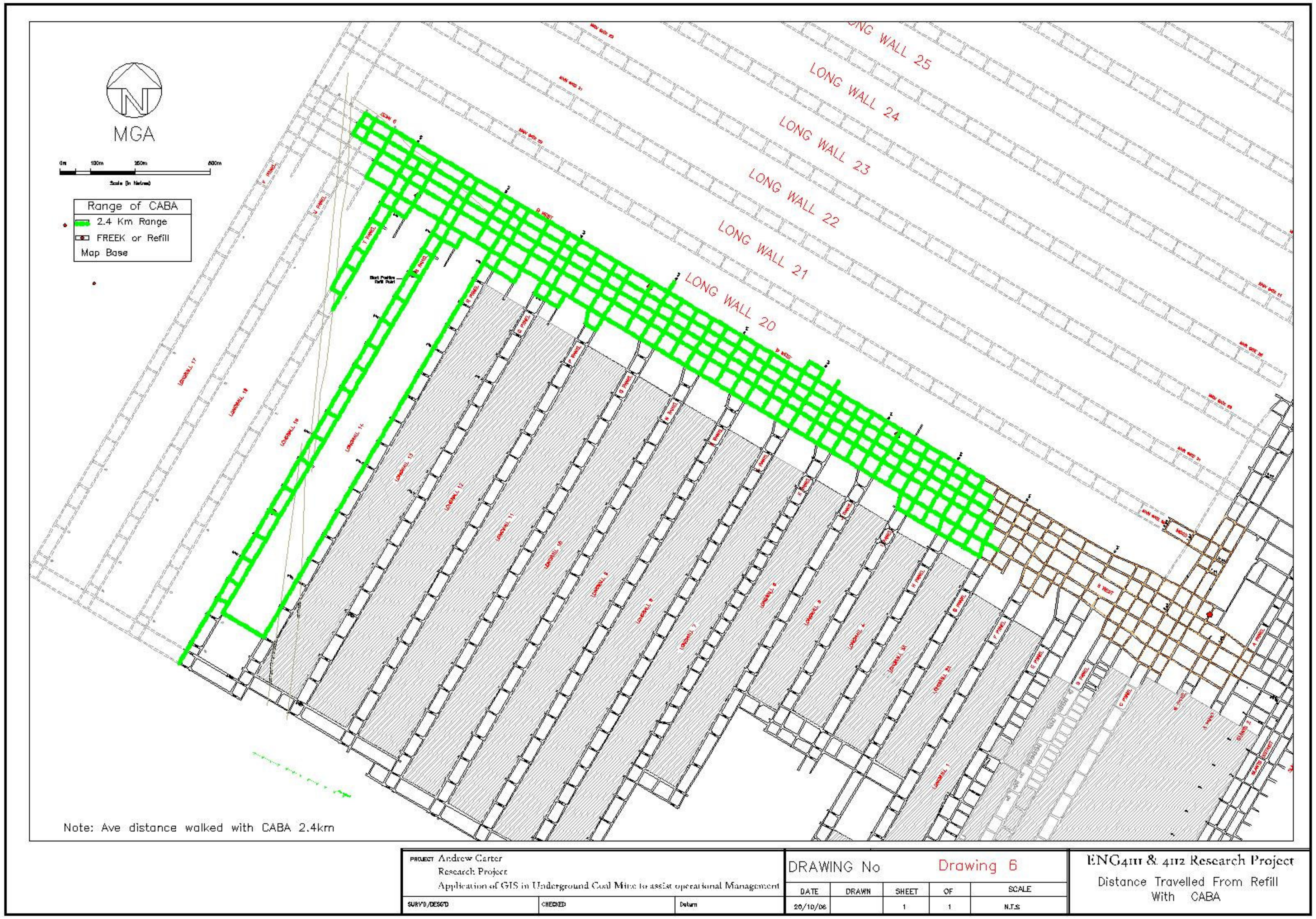


PROJECT **Andrew Carter** **Research Project** **Application of GIS in Underground Coal Mine to assist operational Management**			DRAWING No Drawing 4					**ENG4111 & 4112 Research Project** Best Route From CABA Refill Stations Outbye to 3ct B-West
SURV'D/DESG'D	CHECKED	Datum	DATE	DRAWN	SHEET	OF	SCALE	
			20/10/06		1	1	N.T.S	

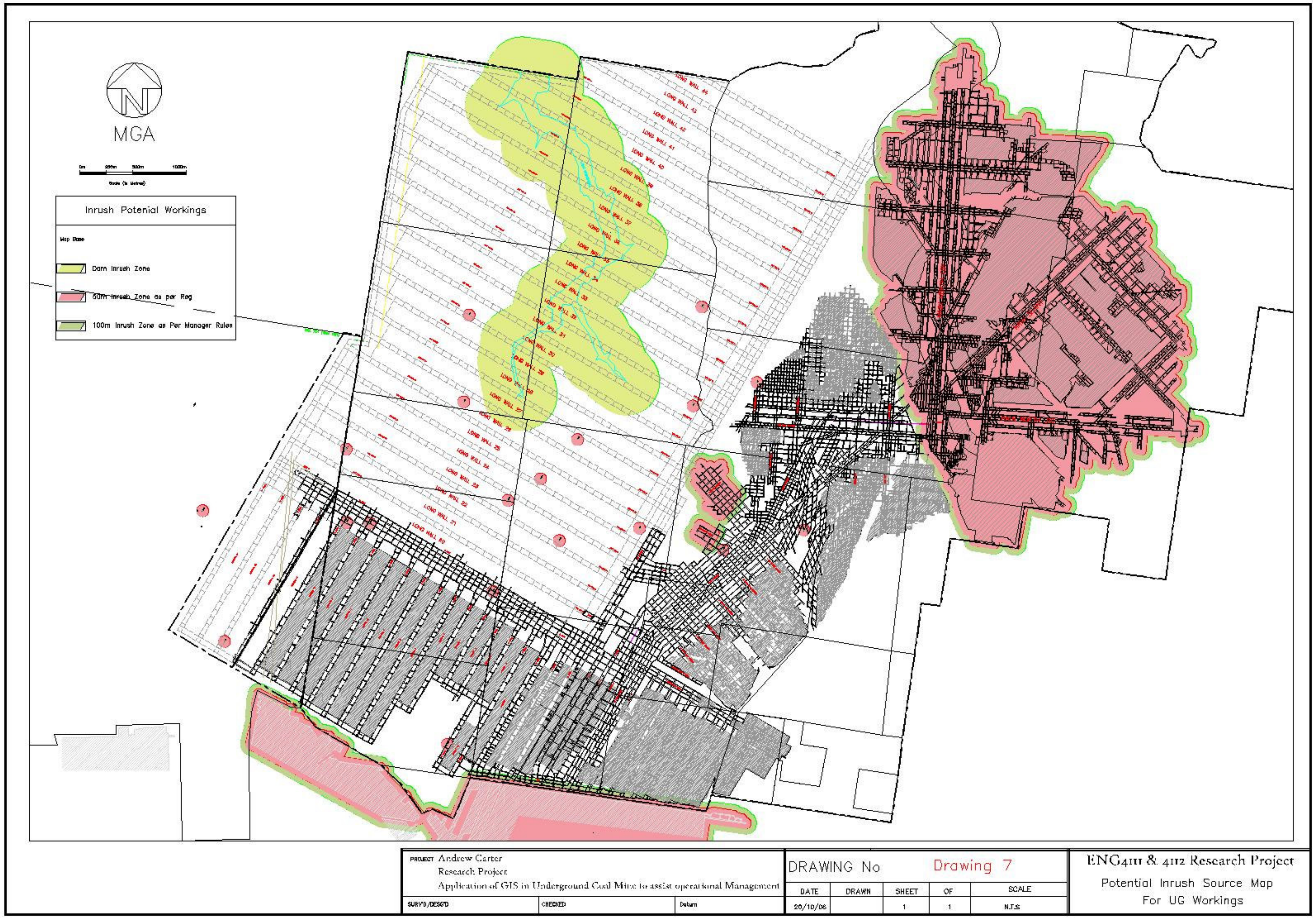
Appendix I:
Drawing 5 – Distance Travelled from working Face
/With Self Contained Rescuer


MGA
Self Rescuer Distance
Freek or Refill Station
800m Trav Dist
800m Trav Dist
Map Base
LONG WALL 25
LONG WALL 24
LONG WALL 23
LONG WALL 22
LONG WALL 21
LONG WALL 20
Start Point Working Face
Note: Distance of 800m travelled on Self Contained Rescuer
is based on worst case condition. i.e. injured and can not walk normally
Ave walking speed is 5Km/h. 800m base speed 0.8Km/h ie 6.25 times slower
PROJECT Andrew Carter
Research Project
Application of GIS in Underground Coal Mine to assist operational Management
SURV'D/DESG'D
CHECKED
Datum
DRAWING No
Drawing 5
DATE
DRAWN
SHEET
OF
SCALE
20/10/06
1
1
N.T.S
ENG4111 & 4112 Research Project
Distance Travelled From Working Face
With Self Contained Rescuer

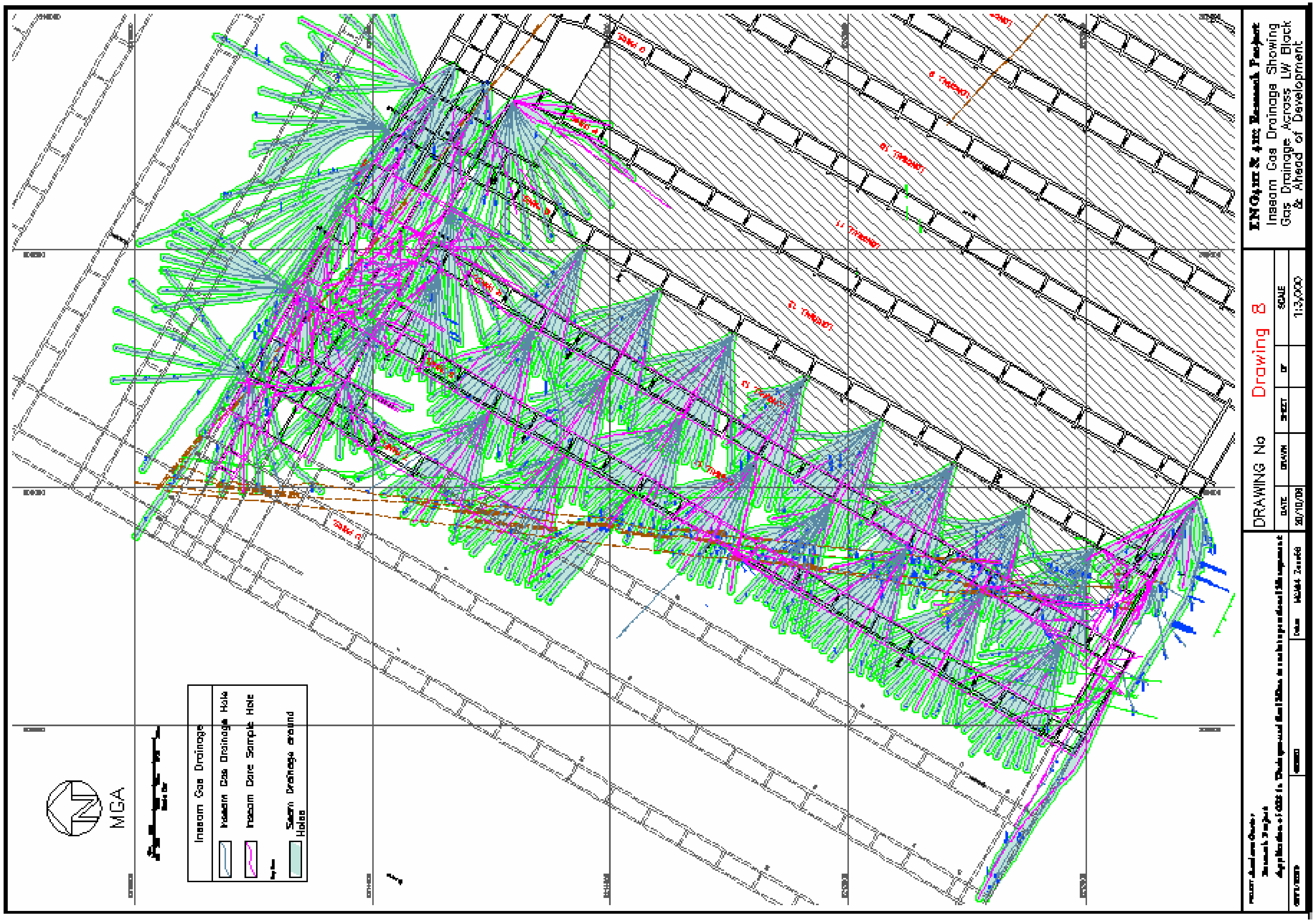
Appendix J:
Drawing 6 – Distance Travelled From Refill Station with CABA


MGA
Range of CABA
2.4 Km Range
FREEK or Refill
Map Base
LONG WALL 25
LONG WALL 24
LONG WALL 23
LONG WALL 22
LONG WALL 21
LONG WALL 20
Note: Ave distance walked with CABA 2.4km
PROJECT Andrew Carter
Research Project
Application of GIS in Underground Coal Mine to assist operational Management
SURV'D/DESG'D
CHECKED
Datum
DRAWING No
Drawing 6
DATE
DRAWN
SHEET
OF
SCALE
20/10/06
1
1
N.T.S
ENG4111 & 4112 Research Project
Distance Travelled From Refill With CABA

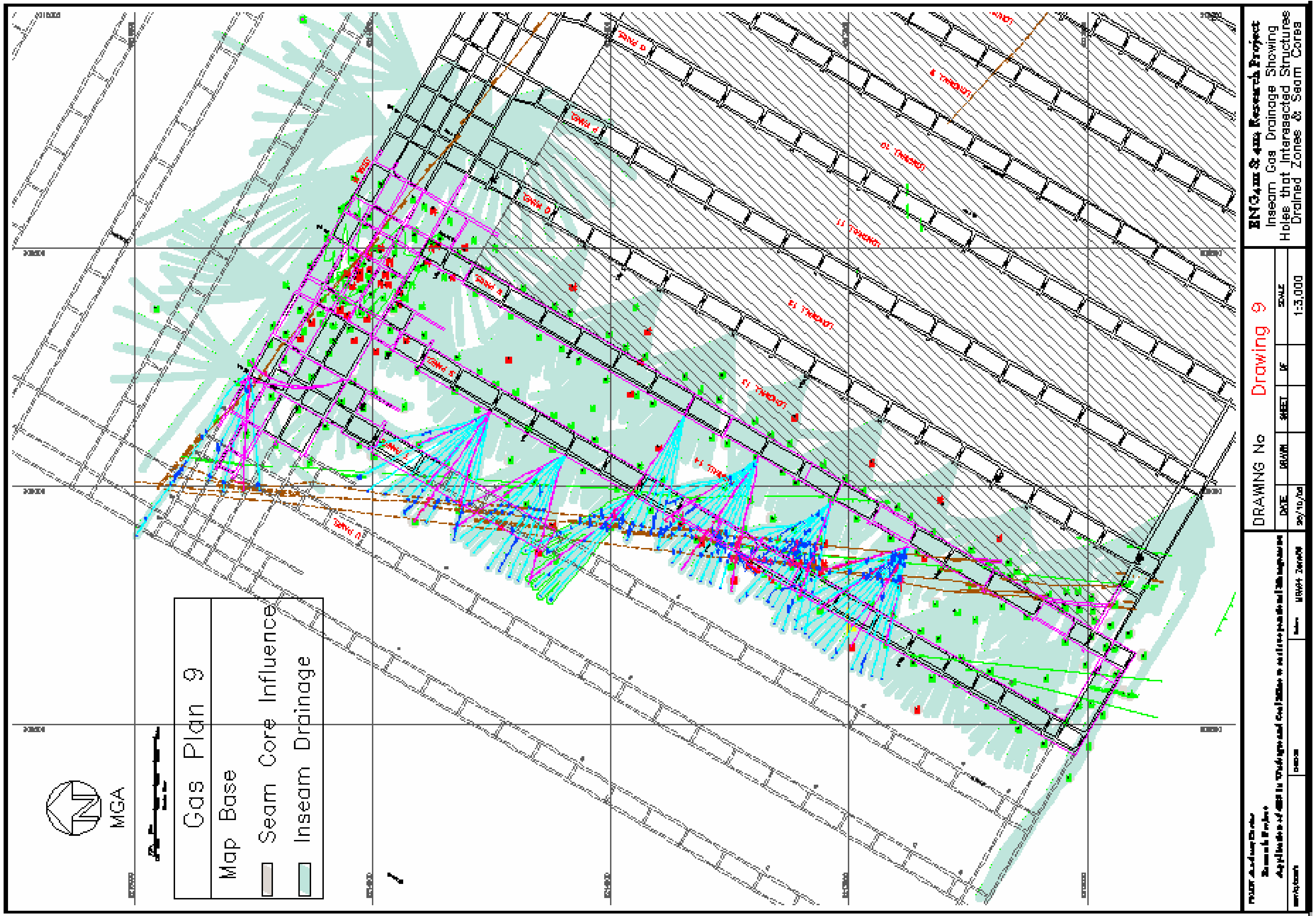
Appendix K:
Drawing 7 – Potential Inrush Source Map


MGA
0m
250m
500m
1000m
Inrush Potenial Workings
Map Base
Dam Inrush Zone
50m Inrush Zone as per Reg
100m Inrush Zone as Per Manager Rules
PROJECT Andrew Carter
Research Project
Application of GIS in Underground Coal Mine to assist operational Management
SURV'D/DESG'D
CHECKED
Datum
DRAWING No
Drawing 7
DATE
DRAWN
SHEET
OF
SCALE
20/10/06
1
1
N.T.S
ENG4111 & 4112 Research Project
Potential Inrush Source Map
For UG Workings

Appendix L:
Drawing 8 – Inseam Gas Drainage
Gas Drainage Across LW Block & Ahead of Development

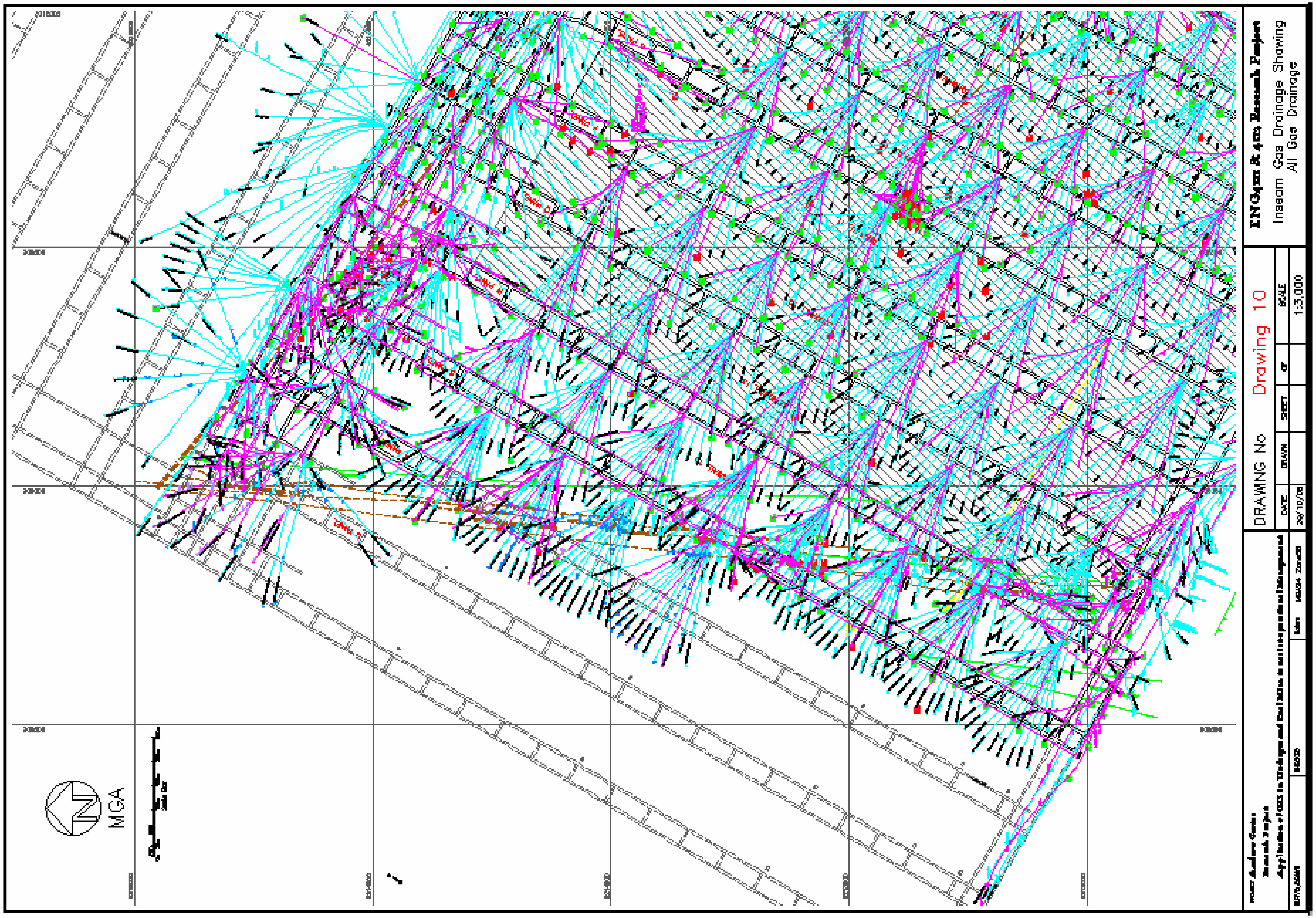

Inseam Gas Drainage Showing
Gas Drainage Across LW Block
& Ahead of Development
DRAWING No
Drawing 8
Inseam Gas Drainage
Inseam Gas Drainage Hole
Inseam Core Sample Hole
Seam Drainage around Holes
MGA

Appendix M:
Drawing 9 – Inseam Gas Drainage Inseam Holes that
Intersected Structures,
Drained Zones and Seam Core Sample Results


MGA
Gas Plan 9
Map Base
Seam Core Influence
Inseam Drainage
Inseam Gas Drainage Showing
Holes that Intersected Structures
Drained Zones & Seam Cores
DRAWING No
Drawing 9
SCALE
1:3,000

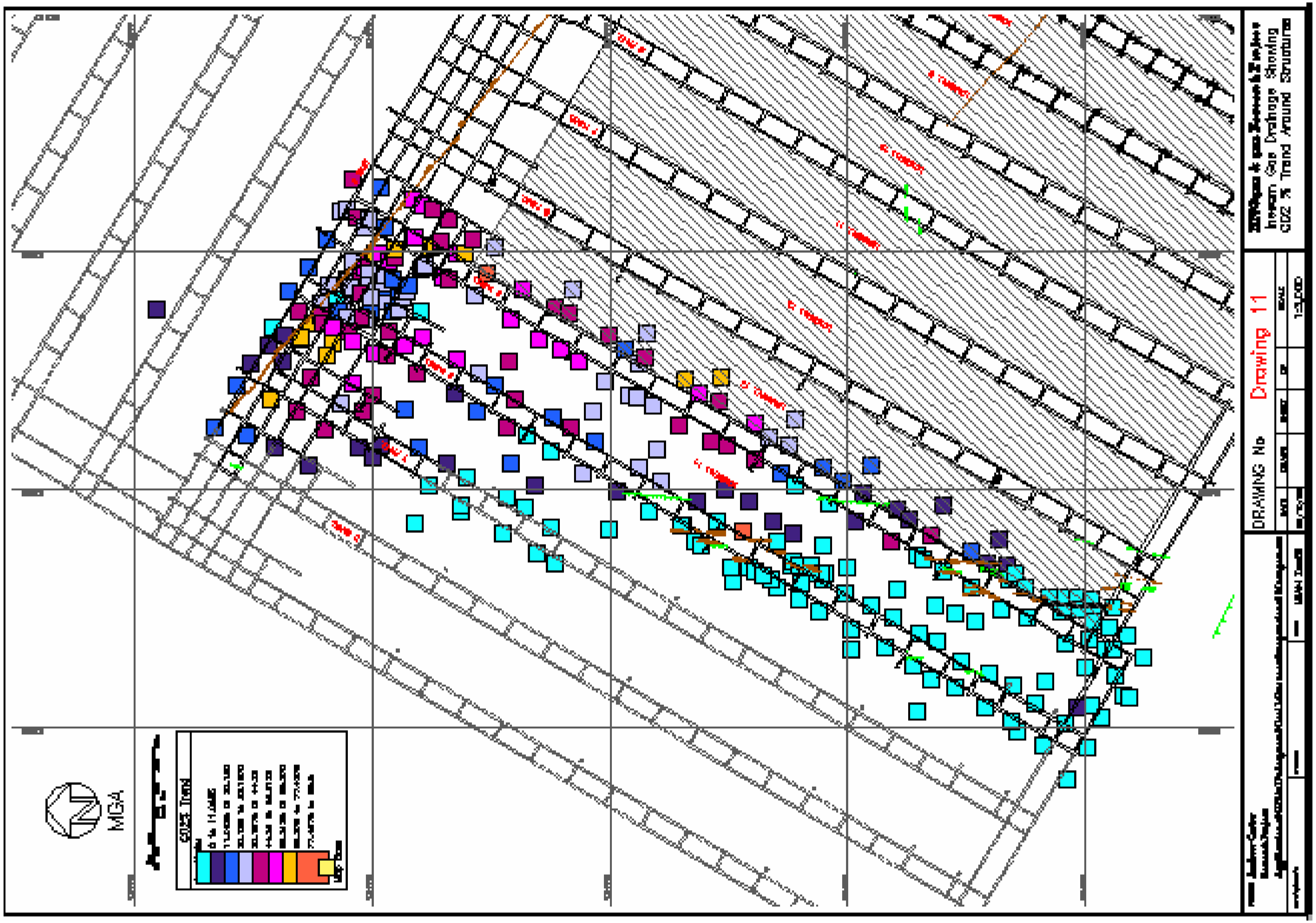
Appendix N:
Drawing 10 – Inseam Gas Drainage

All Displayed at Once


MGA
Inseam Gas Drainage Showing
All Gas Drainage
DRAWING No
Drawing 10
SCALE
1:3,000

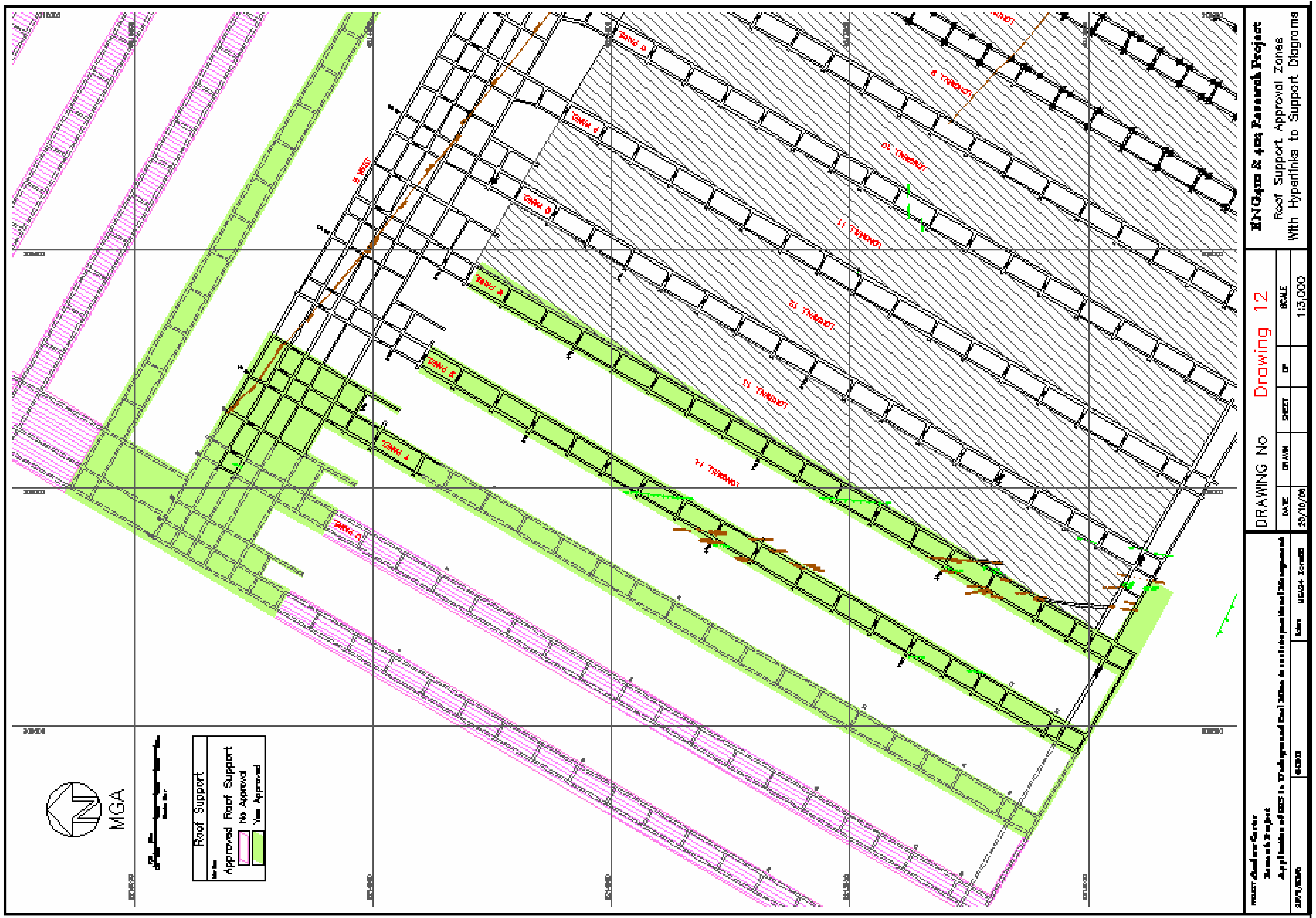
Appendix O

Drawing 11 – CO_2% Trend Around Structures

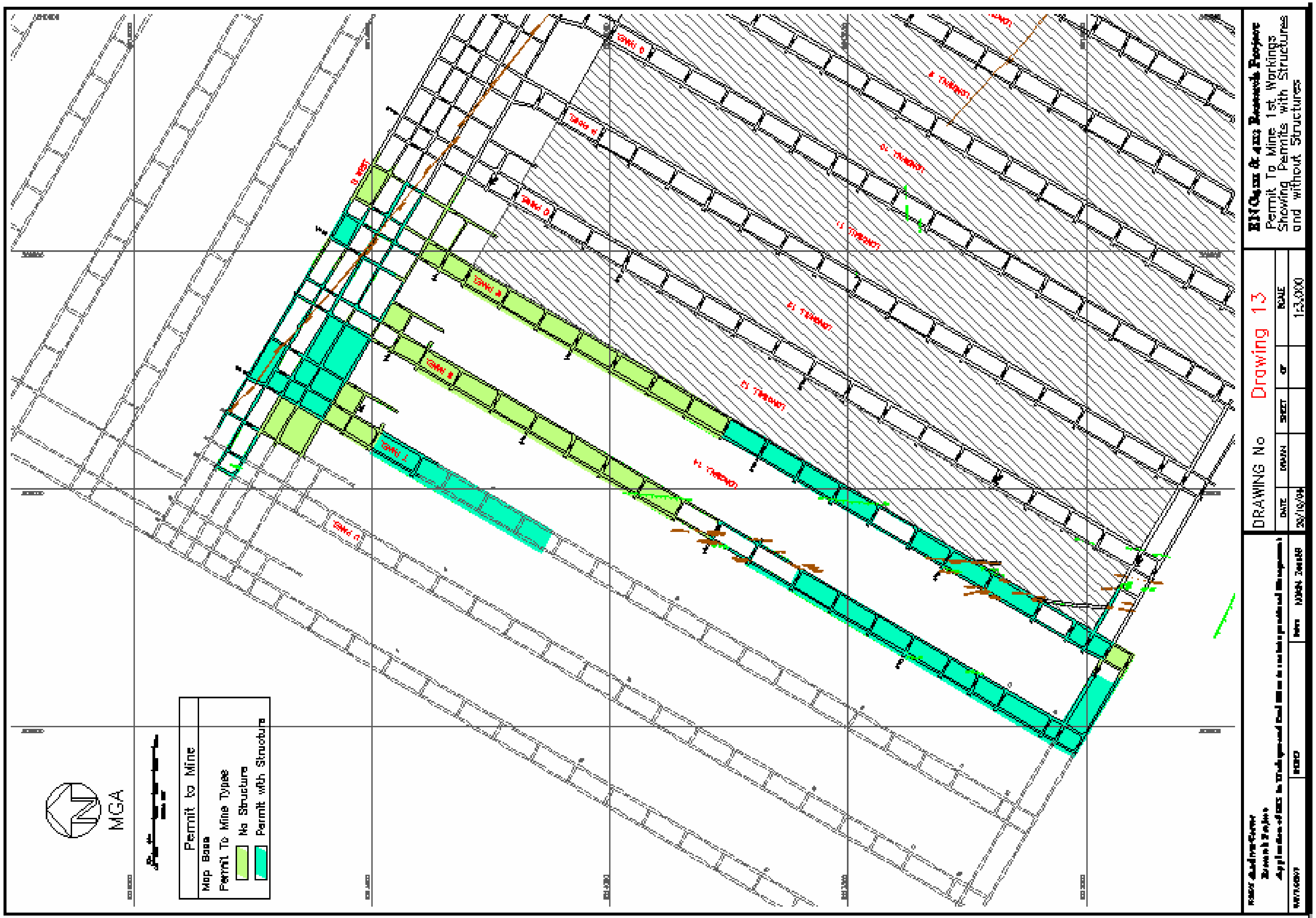


Inseam Gas Drainage Showing
GOZ % Trend Around Structures
DRAWING No
Drawing 11
1:3,000
MGA

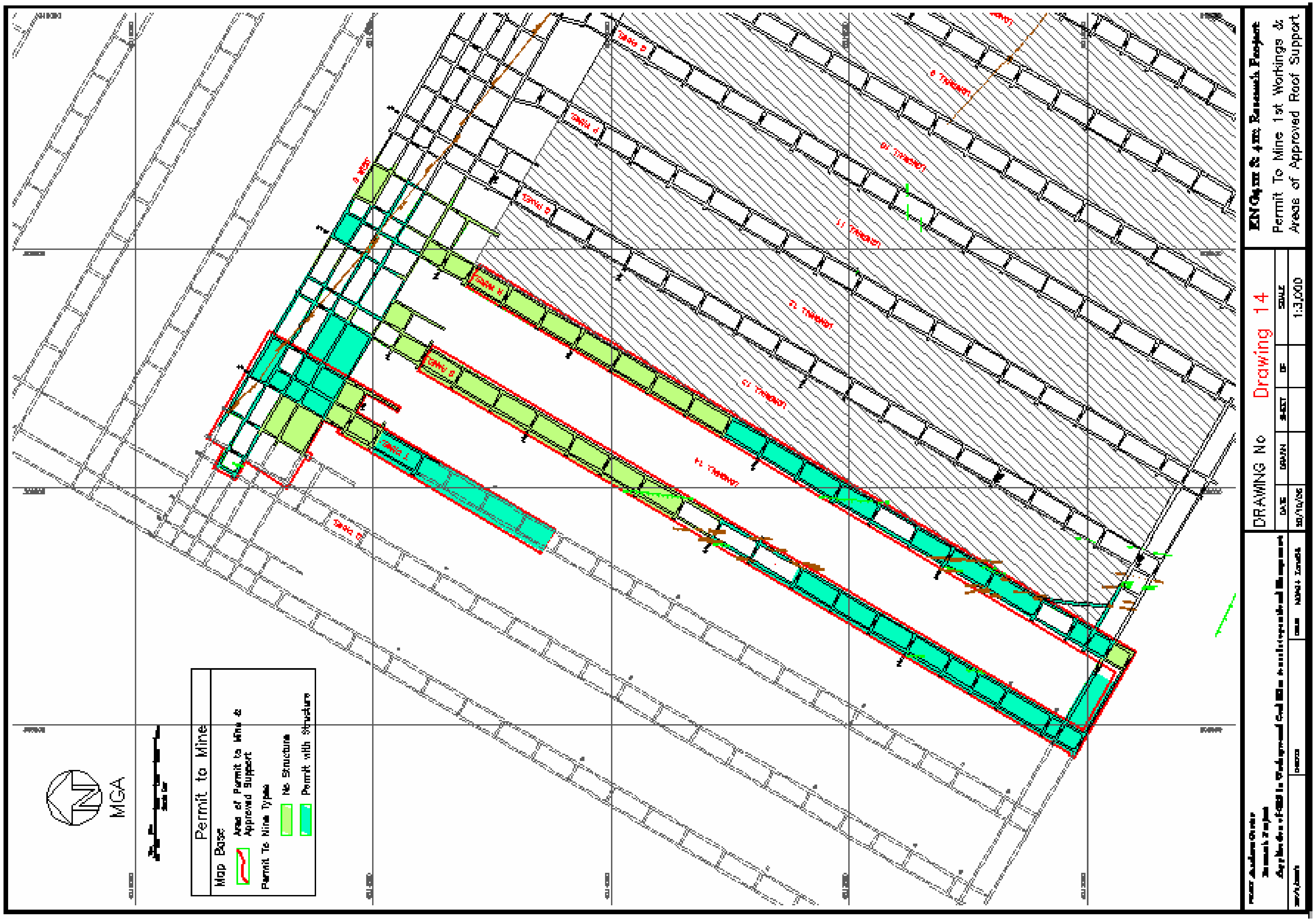
Appendix P:
Drawing 12 – Roof Support Approval Zones with
Hyperlink to Support Diagrams


Roof Support Approval Zones
With Hyperlinks to Support Diagrams
DRAWING No
Drawing 12
SCALE
MGA
Roof Support
Approved Roof Support
No Approval
Yes Approved

Appendix Q:
Drawing 13 – Permit to Mine 1st Workings Showing
Permits With Structures & Without Structures

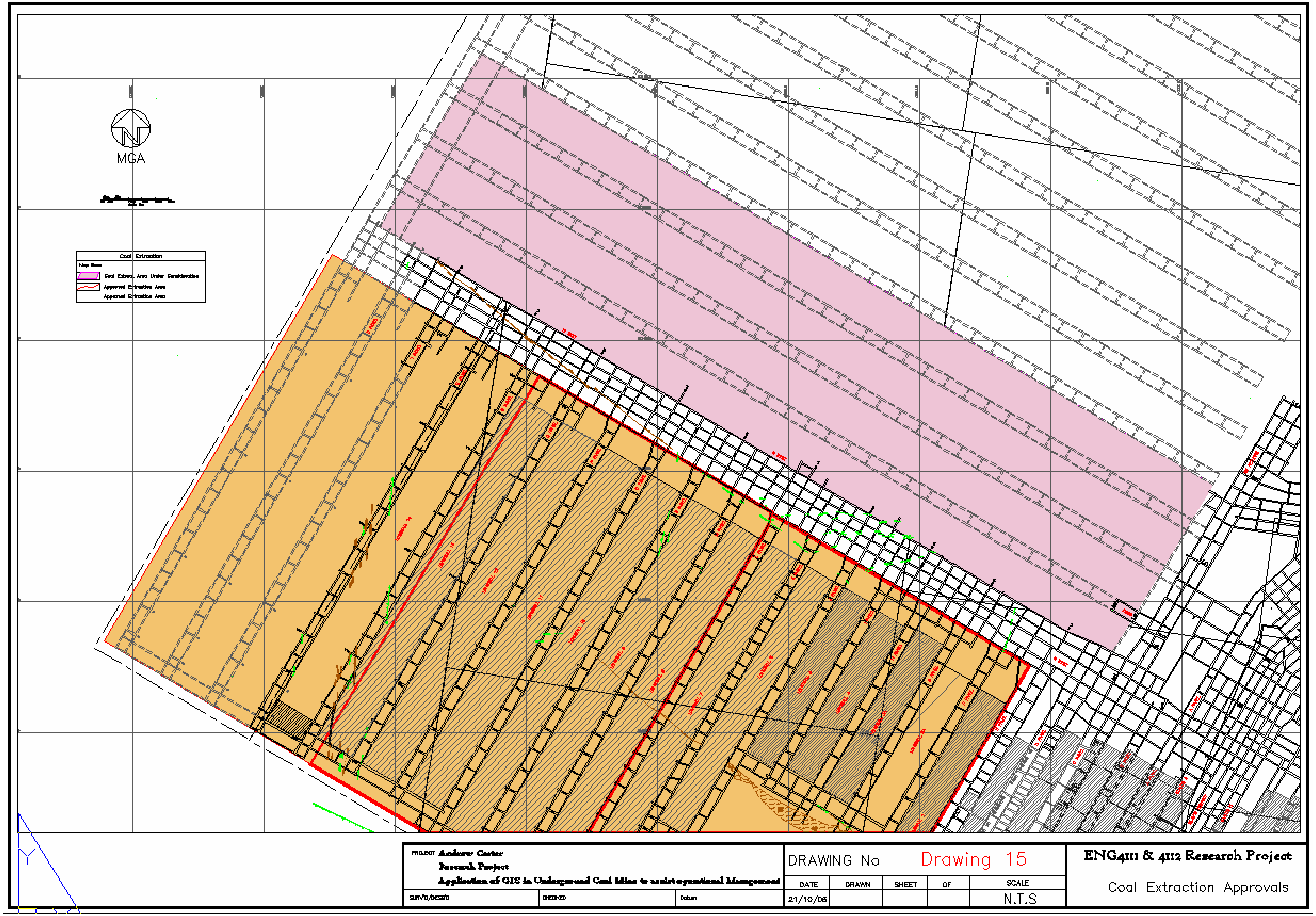

Permit to Mine
Map Base
Permit To Mine Types
No Structure
Permit with Structure
MGA
Permit To Mine 1st Workings
Showing Permits with Structures
and without Structures
DRAWING No
Drawing 13
DATE
DRAWN
SHEET
OF
SCALE

Appendix R:
Drawing 14 – Permit to Mine 1st Workings &
Areas of Approved Roof Support

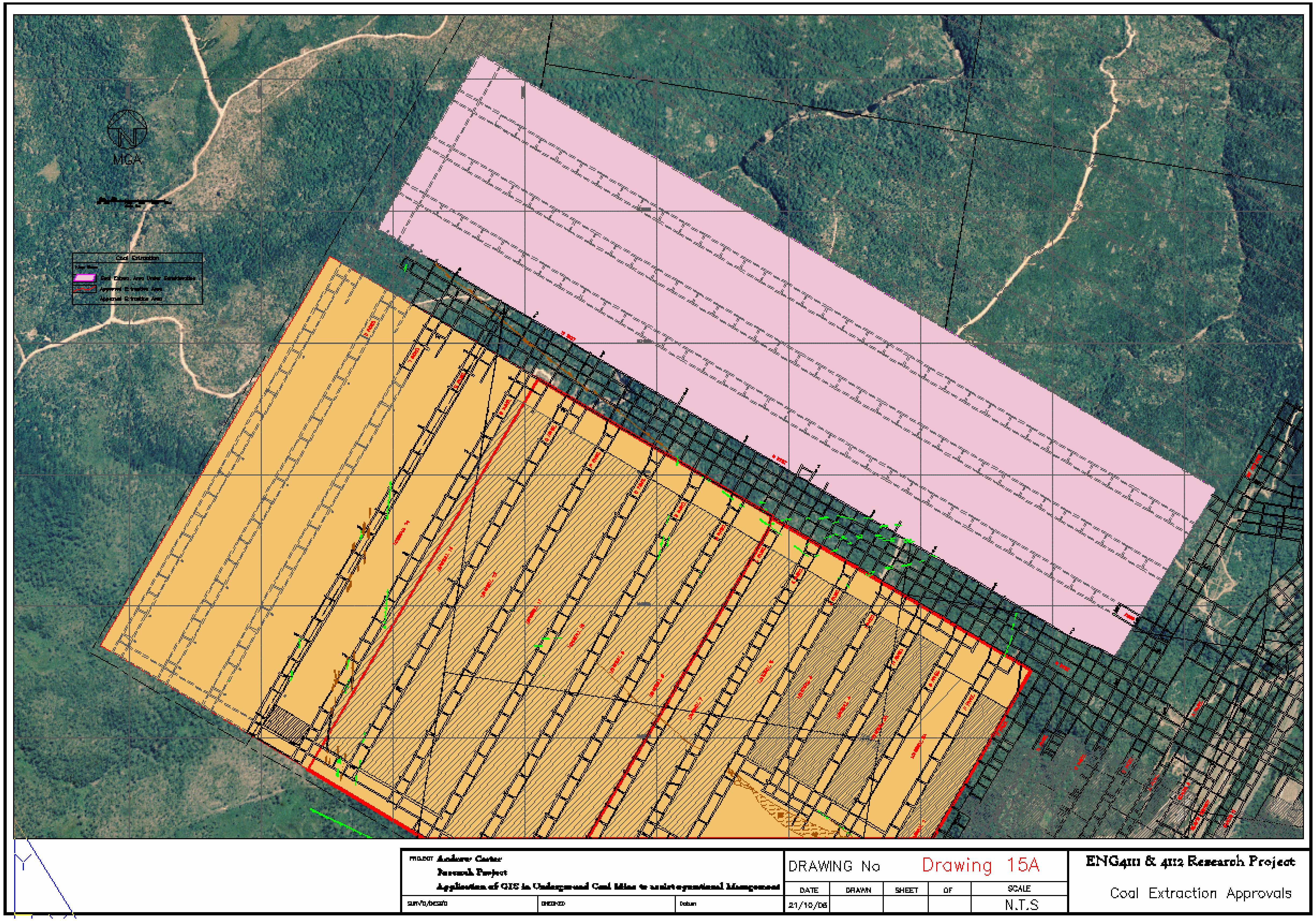


Permit To Mine 1st Workings & Areas of Approved Roof Support
DRAWING No
Drawing 14
DATE
DRAWN
SHEET
OF
SCALE
1:3,000
MGA
Permit to Mine
Map Base
Area of Permit to Mine & Approved Support
Permit To Mine Types
No Structure
Permit with Structure

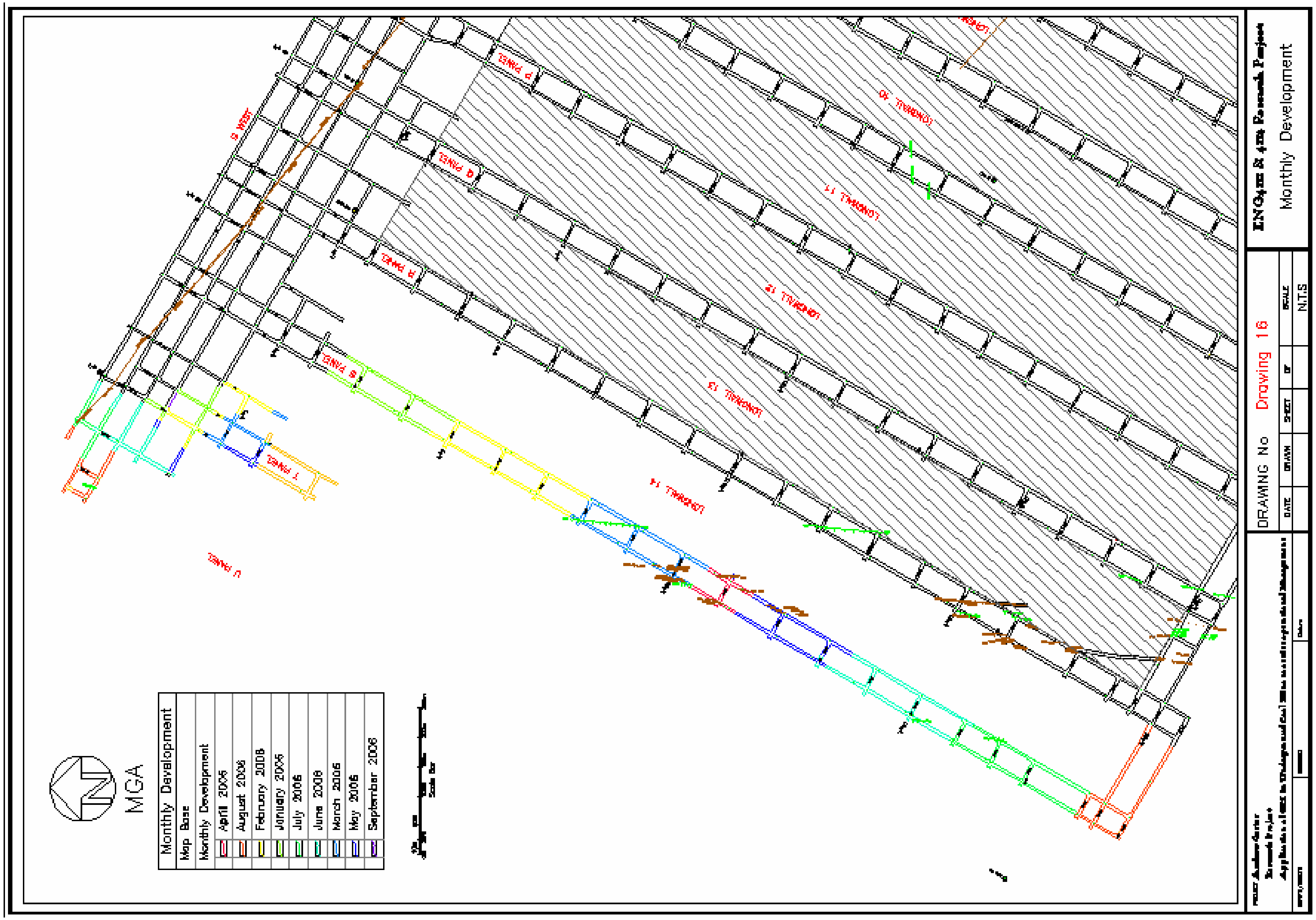
Appendix S:
Drawing 15 – Coal Extraction Approval


MGA
Coal Extraction
DRAWING No Drawing 15
DATE
DRAWN
SHEET
OF
SCALE
21/10/06
N.T.S
ENG4111 & 4112 Research Project
Coal Extraction Approvals

Appendix T:
Drawing 15A – Coal Extraction with Aerial Photography Underlay


MGA
Coal Extraction
PROJECT Andrew Carter
Research Project
Application of GIS in Underground Coal Mine to assist operational Management
DRAWING No Drawing 15A
DATE
DRAWN
SHEET
OF
SCALE
21/10/06
N.T.S
ENG4111 & 4112 Research Project
Coal Extraction Approvals

Appendix U:
Drawing 16 – Monthly Development 2006


MGA
Monthly Development
Map Base
Monthly Development
April 2006
August 2006
February 2006
January 2006
July 2006
June 2006
March 2006
May 2006
September 2006
Scale Bar
P PANEL
Q PANEL
R PANEL
S PANEL
T PANEL
U PANEL
LONGWALL 10
LONGWALL 11
LONGWALL 12
LONGWALL 13
LONGWALL 14
Monthly Development
DRAWING No Drawing 16
SCALE
N.T.S

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