GSR_2
School of Mathematical and Geospatial Sciences,
RMIT University
Monday 10 to Wednesday 12 December 2012

# Historical GIS – Examples from the Creswick Goldfields.

Jodi Turnbull
LaTrobe University
J.Turnbull@latrobe.edu.au

Jodi is a senior research assistant at LaTrobe University, Archaeology department and has established the GIS databases for several historical GIS projects, all of which have a strong emphasis on the examination of geo-referenced historical maps to inform archaeological research. She also manages the GIS at a Melbourne heritage consultancy and is integrating IPAD technology into archaeologists work flow. She is a member of the newly formed DADA (Digital Archaeological Data Archive) group which seeks to establish an archaeological spatial data archive and explore the potential of GIS for archaeology and cultural heritage management in Victoria.

## ABSTRACT

This paper presents an overview of Geographical Information System (GIS) applications currently being utilized in an historical archaeology research project supported by La Trobe University. This work is the first stage of a broader study titled "Cultural Landscapes of Colonial Water Management in Victoria's Central Highlands", funded by the Australian Research Council (DP110100437). The current area of focus is immediately south east of Creswick. The project incorporates a variety of GIS applications in order to understand the spatial and temporal relationships between water management features such as water races, dams and reservoirs utilized on the 19th century Creswick goldfields. MapInfo software has been utilized to integrate various GIS applications and technologies, such as geo-referenced historical maps, 3D visualization, temporal mapping and integration with Google Earth, Google Maps, and IPAD. This paper introduces the reader to Historical GIS and discusses some limitations encountered thus far concluding that GIS has been integral to understanding this complex historical landscape and the complex relationships between water users.

Keywords: Historical GIS, TGIS, Creswick, Goldfields, Archaeology

## Introduction

This paper presents a case study of the archaeology of water management on the Creswick alluvial goldfield in central Victoria. It illustrates how archaeological[1] and documentary evidence has been integrated in GIS databases to facilitate the investigation of key questions around the adaptation of technology in new environments and industries, changes in water management strategies through time, and the environmental effects of different kinds and scales of water technology. The analysis of historical archaeological evidence of capturing, storing, transporting and using water and the associated environmental degradation will produce understandings of changes to land use, landscape and environment at a local and regional level providing historical context for modern debates about water sustainability and climate change. The Cultural Landscapes of Colonial Water Management in Victoria's Central Highlands project is ARC funded research led by Susan Lawrence and Peter Davies. It commenced in 2011 and is ongoing until 2014 (see Lawrence & Davis 2011, 2012), thus this paper presents the GIS component of this work to date.

## Cultural Landscapes of Colonial Water Management

Water was vital to almost every aspect of gold mining in the colonial period, but many areas of Central Victoria such as Creswick, had limited access to reliable water supplies. Creswick has a small catchment area, creeks rather than rivers and no large natural water bodies (see Figure 1). Miners responded by building substantial reservoirs and lengthy races to capture, store and distribute water to mining claims. During the 1850s and 1860s, miners at Creswick constructed numerous dams and, according to documentary evidence, several hundred kilometres of races, many of which are well preserved on the goldfield today. The remains indicate the ways in which miners came to terms with environmental limits and created landscapes of water management (Lawrence & Davies 201I, 2012). Australia-wide there have been few comparable detailed archaeological studies of water management systems on goldfields, Michael Tracey (1997) being one exception. Two central Victorian studies have examined hydrology systems on a broader scale providing historical context for this project (Nathan 2007, Russell 2009)

[1] In this paper, archaeological evidence includes surface features such as water races and dams.


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5
Melbourne: Geospatial Sciences, RMIT 2012

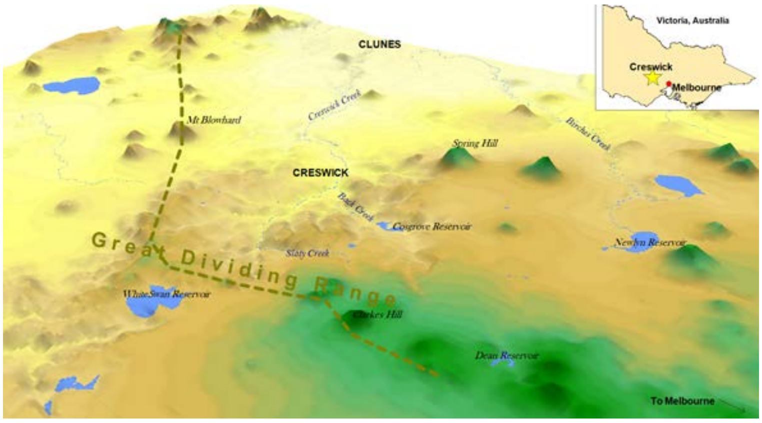

Figure 1: The study area, Creswick.

The project aimed to map the major races and reservoirs at Creswick using field survey and historical resources, particularly maps. However the project has exceeded expectations and has mapped over 170km of major and minor races and dozens of dams in the study area, representing a significant portion of the historical water network supplying the Creswick goldfield. Many of these features have subsequently been associated with lease and/or water right licenses and rich historical references assisted in associating individuals and families to many of the features thus making a major contribution to the history of the Creswick goldfields (Davies, Lawrence & Turnbull 2012)

## Historical GIS – What is it?

Historical GIS is the application of GIS to study the past and describes well the convergence of history and geography; geography being the study of spatial differentiation and history being the study of temporal differentiation (Knowles 2002). GIS is able to assist in deconstructing temporally rich and complex landscapes such as mining landscapes and provides new ways to visualize and analyse change over space and time. Historical GIS therefore has a strong historical or temporal component and relies on the integration of historical documents, geo-referenced historical maps and 3D modeling to assist interpretation. Archaeologists have developed methodologies for GIS over the last 20 years, particularly for spatial analysis and visualization of site distributions (McCoy & Ladefoged 2009) and GIS is now firmly entrenched in the cultural heritage industry for assisting the management and stewardship of archaeological sites. The use of GIS to analyse temporal (differentiated from spatial) changes has gained momentum over the last ten years particularly within historical and landscape archaeology. However, over the past 15 years many have argued that GIS was a method in search of a theory and had yet to fulfill its potential (Johnson 1999, Knowles 2002, Ebert 2004) and although GIS is now being applied far more rigorously and judiciously, some of these arguments are still being echoed today. In particular, GIS is falling short of achieving full spatio-temporal analysis and problems of how to deal with 'fuzzy' archaeological time and space in a GIS system persist (Green 2008, Johnson 2008). Chronology is a corner stone of archaeological research and is measured in a bewildering variety of ways, both absolute and relative. e.g. clock time, years, decades, date ranges, periods, stages, phases, radiocarbon dates, typologies, and seriation to name a few. Many of these measurements of time are imprecise, variable and overlapping and pose difficulties in a GIS database. As a result much historical analysis using GIS is stuck in a basic model that maps time slices or snapshots of time. Some have even argued that GIS is atemporal (Castleford 1992 cited in Ebert 2004 p334) and that a truly temporal GIS (TGIS) requires an axis of continuous time, in the same way the x, y, & z are continual axis of location and elevation (Lock & Harris 2000 p 5). The development of TGIS software is a current area of development.

Many archaeologists struggling with representing time in GIS have few helpful methodologies to follow. Many GIS project methodologies are too project specific and not readily applied to other projects or lack informative, explicit methodologies. In addressing this, González-Tennant (2009) has been explicit in his methodology for structuring GIS data for a historical GIS project on the New Zealand goldfields using ArcGIS, however this also seems to suffer from project and software specific detail. A promising approach for more general temporal mapping is Ian Johnson's TimeMap™project (Johnson1999, 2008, Johnson & Williams 2003). Johnson focused on three issues:(1) a methodology for recording time-based cultural features, (2) an interface for displaying time-based maps, and (3) the generation of map-based animations to display time-depth. While Timemap™ appears to be producing fruitful results in areas such as public display, education, interaction, and map animation, there is a regrettable move away from the more archaeological concerns of fuzzy time from where the project initially started. To counter Johnson's move away from archaeological time, Green (2008) developed a TGIS methodology for archaeologists to use within ArcGIS. Although Green advocates the development of TGIS specific software, he thoughtfully argues that a better approach is to start with applications that archaeologists are already familiar with. This project looks promising and appears to have true TGIS capabilities enabling probability mapping and scenario testing. Similarly Lock & Harris (1997) present some useful ideas for developing a temporal database that has probability and scenario testing capabilities. The interested reader is directed to Green's (2008) PhD. thesis for an excellent detailed introduction TGIS and the problems of representing fuzzy time.


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5
Melbourne: Geospatial Sciences, RMIT 2012

Returning to the project at hand, work is just commencing on the temporal analysis and presentation of the historical data. A considerable amount of spatial data has been assembled in the GIS and thoughts have turned to how to best utilize the capabilities of GIS for understanding the temporal relationships between mapped features and other significant events such as drought, floods and mining/water legislation. A basic temporal analysis based on a time slice model is envisaged in order to show change over time. A time slice model involves a series of maps displaying features from different periods. In addition, some colour-coded maps have been utilized to indicate the timing of events. However even this initial foray into temporal mapping has posed challenges and will be discussed in more detail later.

Fuzzy time aside, the issue of fuzzy space is also problematic. Another commonly faced issue in historical GIS is how to quantify measure and present the accuracy of historical data. Historical maps and documentary evidence provide the basis for the historical GIS database however the nature of this data is often imprecise, vague and inaccurate. One is always aware when mapping historical features using a GIS that there is a danger of implied accuracy or spurious authority given to the data. This project involved the mapping of many historical features derived from historical texts and map, the accuracy of which is at times questionable. Secondary errors are also introduced in the process of geo-referencing historical maps. While the GIS operator may be aware of these issues, expressing or publishing the inaccuracies for the reader can be difficult. For example one part of a geo-referenced map may be accurate to +/- 2 m while other parts of the map may be less accurate. There appears to be very little literature on methodologies for calculating and publishing error in historical data other than to be explicit in the metadata, text, legends, and disclaimers. Is it time to develop some accepted symbolization for fuzzy boundaries and locations?

## Methodology

The project aimed to map the major races and reservoirs at Creswick using field survey and historical resources, particularly maps. Base data was assembled from Victorian Government VicMap data,
Department of Primary Industries and MapInfo. Field data was collected sporadically over an 18th month period using real time RTK differential GPS units and non differential GPS devices. A significant input of spatial data for water races was obtained 15 months into the project from a source at Melbourne University (Creswick) and while this was an invaluable contribution it was challenging incorporating this data. Managing the database effectively was a key consideration as data was continually added and modified. Historical and local maps were geo-referenced and relevant features were digitized. These methods are discussed in more detail below. The culmination of research to date for this stage of the project is presented in Davies et.al (2012).

## Assembling the spatial database.

The GIS software utilized for this project is MapInfo v 11. Basedata for this project was supplied by VicMap data: the authoritative spatial data supplier for the State of Victoria and the foundation of Victoria's primary mapping and geographic information systems. Spatial data obtained from Vicmap for the Creswick area included cadastral property, vegetation cover, transport and hydrology datasets. The Department of Primary Industries provided shallow workings, mine shafts and mines datasets. In addition some MapInfo'Street Pro Display' basedata was used. This spatial base data provided the background layers on which the historical databases were added.

It is essential to be aware of the accuracy of base data and it can be informative to understand how the dataset was created. Metadata supplied with most spatial data should describe these attributes. For example VicMap's Property layer positional accuracy is classified as "BB" accuracy. That is, 90% of well-defined features are within 1mm (at plot scale) of their true position, e.g. 1:500 equates to +/- 0.5metre and 1:25,000 equates to +/- 25 metres. VicMap's Property layer is derived from what were originally two logically and physically separated databases. Melbourne Water created a digital data set covering the Melbourne Metropolitan area and Survey and Mapping Victoria created a similar data set covering rural Victoria. Both data sets consisted of "spaghetti" line work (that is, unintelligent data). Neither data set was suited to GIS applications, as neither was "clean" in terms of line work, topologically-structured or held any significant degree of "intelligence". Considerable effort was required by VicMap to prepare the data for GIS (2012. Metadata,*VicMap Data*). This metadata is informative and also introduces the terms "spaghetti line work" and "intelligent data"; Spaghetti line work means disjointed and overlapping lines, and intelligence refers to how well the fields and attribute content has been structured in order to query the data purposefully.

Knowledge of the accuracy of acquired spatial data was an important consideration when mapping historical features and geo-referencing[2] historical maps. Experience has shown that many roads, major and minor and rivers and streams especially in non-urban areas are inaccurately mapped in both VicMap and Street Pro data (the accuracy of Street Pro transport layer for non-urban areas is described as the same as 1:25000 topological maps) and this can cause issues if used as control points for adding historical data or geo-referencing maps.

[2] Geo-referencing and registering are terms used interchangeably in this paper. This is discussed in more detail later.


ISBN: 978-0-9872527-1-5

GIS can be thought of as a spatially referenced database (Maschner 1996 p 2). In establishing the historical spatial database careful thought was given to the structure of the database. The attribute fields provide the "intelligence" from which the data can be sorted and queried. Migrating data from base data assisted in establishing some datasets that were then customized for the project's individual needs. For example a database titled "Creswick Dams" was established using VicMap's hydrology data. Existing dams from the Creswick region were selected and historical dam locations were then added and a new field titled 'Status' added to distinguish between Pre 1900 dams, historical dam in current use and modern dam features (see Figure 2).

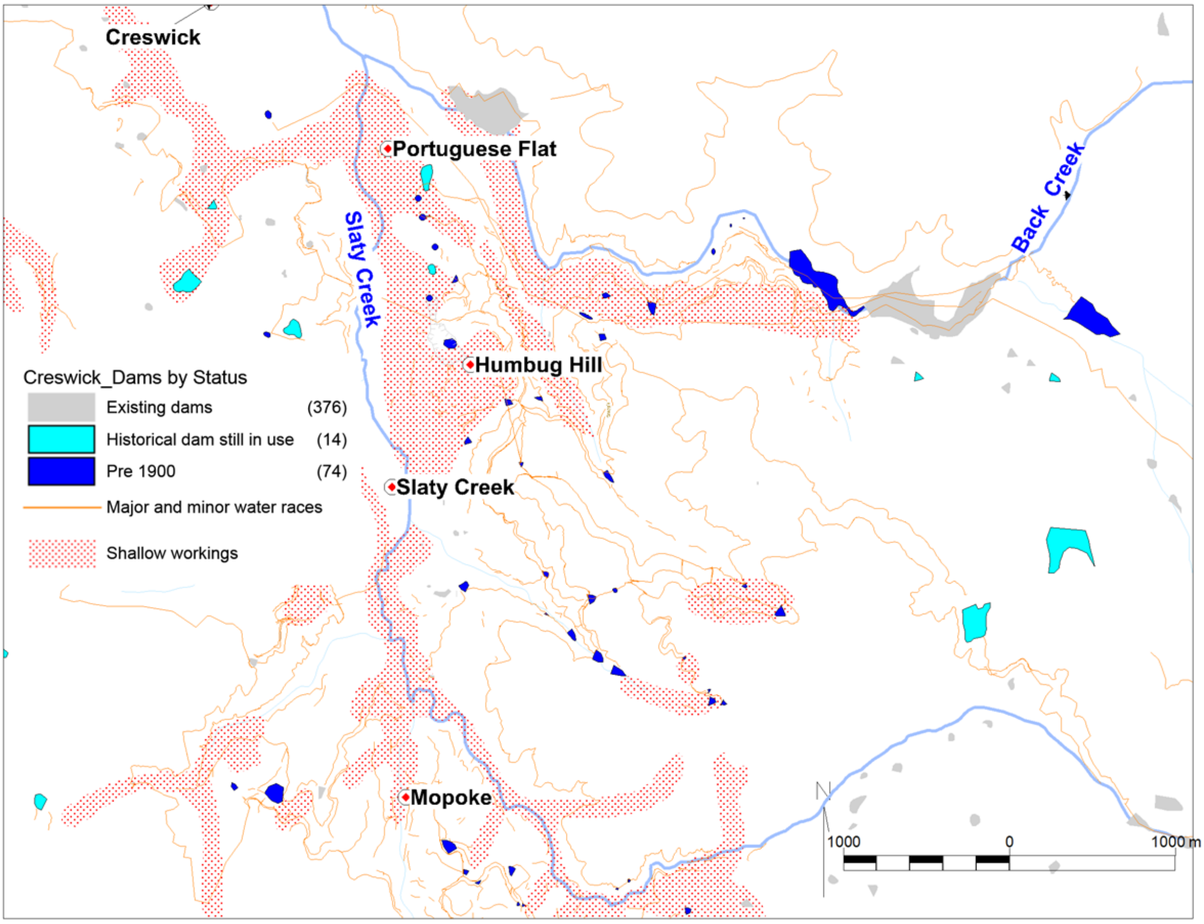


Figure 2: Colour coded map by the 'Status' field to illustrate historical and current dams.

Temporal questions relating to phases of mining and possible correlation with climate events and spatial questions concerning the relationship between features were important considerations when defining attribute fields. Using MapInfo's SQL (structure query language) ability the database could be queried to establish relationships. For example, a simple use of the GIS data in this project might be to *see water races in relation to historical dams*. This is in effect a query that in GIS terminology could be worded as "select and display water races and dams from the 19th century". To take this one step further, a query entered into the GIS could be structured as follows: Select records from 'Water Races'& 'Hydrology' tables where Date <1900 & Status = historical dam & historical dam in current use. This type of question can also be displayed in a similar way by using the thematic overlay function in MapInfo (see the above figure) which colour codes according to attributes. As the project progressed attributes and fields were often modified to answer new questions.

In order to query the database for temporal information, the data included attributes with temporal markers. As previously mentioned, measurements of time in history and archaeology are more often than not, imprecise, however historical archaeology is relatively comfortable with attributing features, sites and artefacts to historical periods and phases. The initial database included two fields that allowed temporal querying: Date and Period of Use (See Table 1). What is immediately evident from this table is that the date column proved ineffectual for querying due to lack of dates and essentially the 'Period of Use' column was established to overcome this limitation.


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5
Melbourne: Geospatial Sciences, RMIT 2012

| ID | FEATURE | DESCRIPTIION | FEAT_NAME | Date | Period of Use | REFS | NOTE_SUBJ |
|---|---|---|---|---|---|---|---|
| 5 | Chinese Site | Previous Chinese camp resumed by State Forest Gov Gas 57.1759 | Chinese Camp | | 1860-1870 | Creswick 1 Parish Plan | |
| 2 | Chinese Site | Chinese village | Chinese Village | | 1850-1860 | Krause map/Council Minutes | |
| 32 | Puddler | Puddler in good condition at near Eatons Dam. Map location needs GPS co-ord as only eyeballed in at present. | Puddler | | 1850-1860 | Barnham 2000 | Verified |
| 28 | Puddler | Puddler in good condition at near Eatons Dam. Map location needs GPS co-ord as only | Puddler | | 1850-1860 | Barnham 2000 | Verified |
| 29 | Puddler | Potential Puddler location- not verified. | Puddler | | 1850-1870 | Barnham 2000 | Location not verified |
| 30 | Puddler | Potential Puddler location- not verified. | Puddler | | 1850-1870 | Barnham 2000 | Location not verified |
| 31 | Puddler | Potential Puddler location- not verified. | Puddler | | 1850-1870 | Barnham 2000 | Location not verified |
| 6 | Circular Feature | Circular features of unknown function. | Circular Features | | 1850-1870 | Field Work | Uncovered after bush fires. See newspaper refs. HI registered. |
| 42 | Ruins | Historical cottage- location not verified. | Townsend Cottage | 1856 | 1850-1860 | LEGL Plan 93/40 | Noted on LEGL Plan 93/40 |
| 35 | Ruins | Woofe's Hill Hotel site | Woofe's Hotel | | 1860-1870 | Goldsmith 2000:2 | Approximate location. "There is nothing now to show what was there". |
| 3 | Chinese Site | Chinese Graveyard | Chinese Graveyard | | 1860-1870 | Goldsmith 2000:6 | References to a location called the Chinese Gravyards. |
| 36 | Ruins | House Ruins | Ruins | | 1860-1870 | Goldsmith 2000:7 | Goldsmiths father and uncles houses. |

Table 1: Example from Historical Features database.

A basic historical feature typology was developed progressively as new data was added and comprised a wide variety of different types of historical features, with the knowledge that this could be refined and divided into separate databases if required. Feature typology attributes included race, dam, mine, ruin, puddler, sluicing feature, property, etc. This database soon become unwieldy and was separated into Historical Features, Water Races and Creswick Dam databases. Additional databases were added as the project progressed including Mining Leases, Prior Waterways, and Historical Locations.

Water race data came from varied sources such as historical sources (e.g. 19th century maps which often indicated races), geo-referenced modern maps and various field surveys. A major source of information was obtained from detailed modern orienteering maps[3]. Due to the size of the study area it was never intended to map all of the races, however very early in the project, the discovery of unpublished orienteering maps, which showed many races in great detail, meant that once geo-referenced, a vast majority of races in the study area were digitized early in the project. This diverted priorities from the need for extensive fieldwork to more background research to understand the mapped races. In addition we acquired comprehensive spatial data for most of the major races in our study area, collected over the past few years by Dr Kevin Tolhurst, using a non differential GPS unit. Combined, these two datasets covered a large proportion of the extant and non extant races in the Creswick Regional Park (see Figure 3).

[3] Unpublished maps provided courtesy of Eureka Orienteering Club, Ballarat.


ISBN: 978-0-9872527-1-5
Melbourne: Geospatial Sciences, RMIT 2012

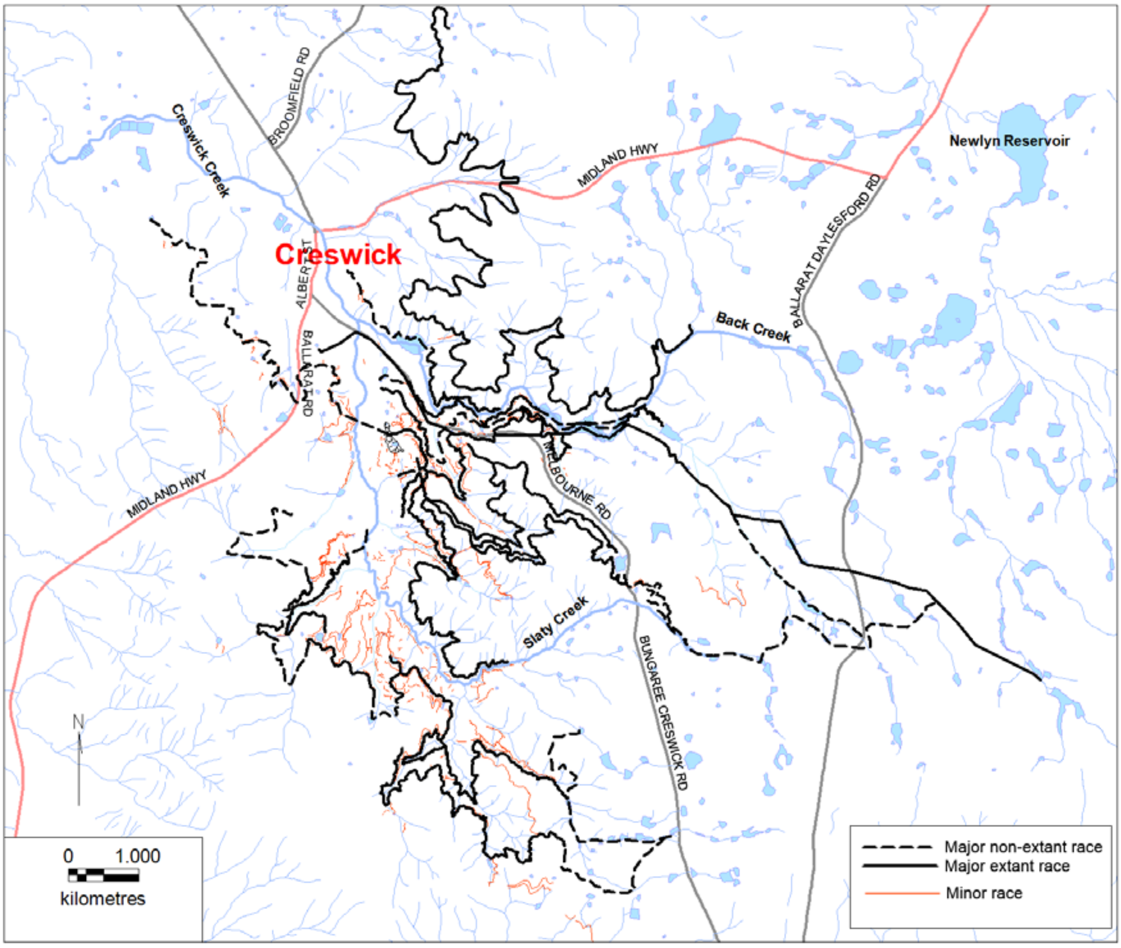

Figure 3: Water races mapped at Creswick.

Races were classified as major supply races, or minor races such as branch, head or tail races. As the project progressed and increasing quantities of data from varying sources were added it became apparent that the Water Races layer was presenting data management challenges, with the potential to become ‘unintelligent spaghetti’.

## Managing the database.

A major aspect of working with the GIS databases was simply keeping it ‘clean’, for if the data becomes ‘messy’ or disaggregates into ‘unintelligent spaghetti’ the data becomes difficult to query and generate clean map legends. Consolidating and cleaning data was time consuming and unrewarding but necessary. Spatial data can quickly become disorganized due to the nature of the database being ‘behind the scenes’. Linear data such as roads, waterways and races can be particularly complex as they can be made of up of many segments. For example the longest race at Creswick is made up of 1114 combined line segments which if disaggregated would add 1114 separate rows to the database.

Much of the field survey data comprised disjointed fragments. The generation of statistical data such as measurements of extant and non extant portions, and major and minor races required very clean data. Careful data management to remove overlaps, combine disjointed segments and select which data to retain was required. From this clean set of data three separate water race datasets were established; (1) Major Historical Races, (2) Extant and Non-extant Major Races and (3) Extant Races which includes minor and major races(see figure 3).While these layers may seem very similar, the need to separate them is partly linked to the way the GIS automatically generates map legends from the data and while this automatic function is generally most helpful and efficient, it can at times produce map legends with unwanted symbols. The intricacies of map production are beyond the scope of this paper, however suffice to say that it was often simpler to create separate databases for specific map outputs and for some statistical calculations.

The regular input of new data from varied sources also presented a challenge. Some races had varying data from many different sources such as historical maps, DGPS (+/-1m accuracy) survey, standard GPS (+/-5m accuracy) survey, and orienteering maps (+\- 5m). To complicate matters further some races were mapped historically by different surveyors, each with minor variations


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5

and similarly some races had field survey data from different GPS units, each with slightly different data. The most accurate set of field survey data was obviously retained and then matched against the already digitized data. Surprisingly most of the digitized historical data matched unambiguously with the field collected data allowing some digitized historical race spatial data to be removed, with the geo-referenced maps still able to provide the historically mapped race alignment for reference (see Figure 4). The relatively good match between the many of early historical race surveys and the existing races is a remarkable testament to the accuracy of the early surveyors for what must have been difficult features to map in difficult terrain.

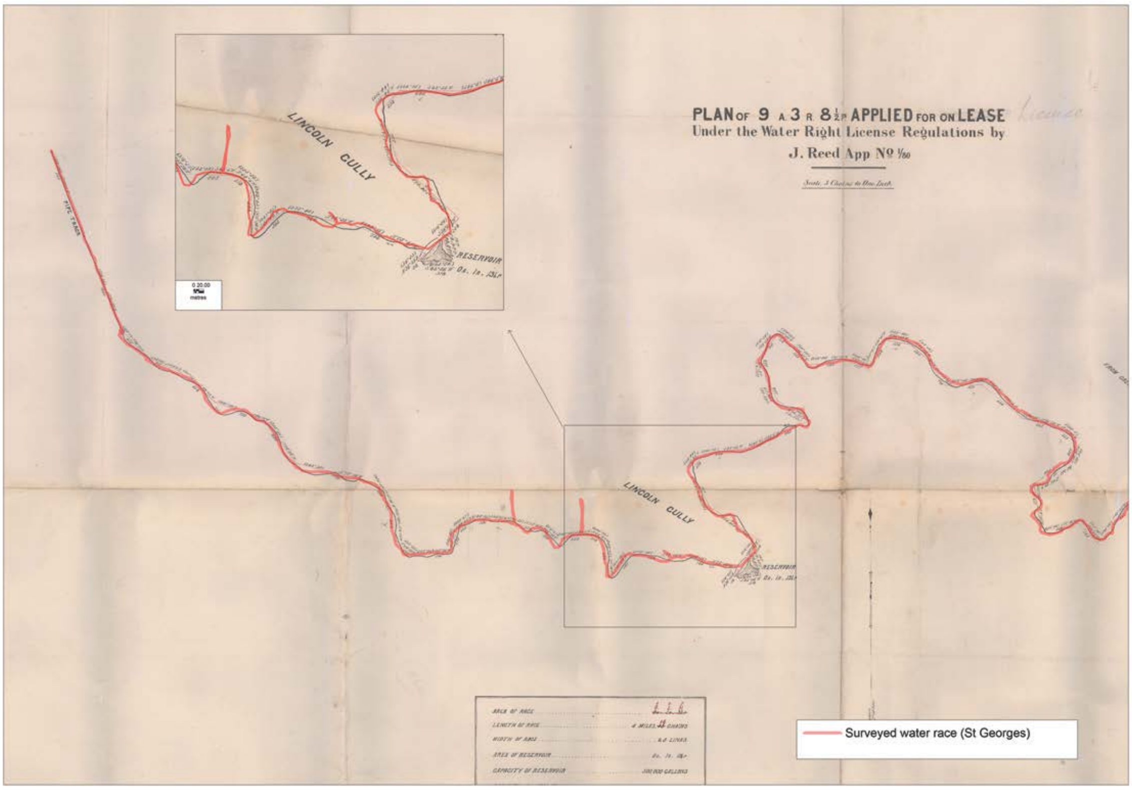


Figure 4: Example of a good correlation between an existing race and historical survey plan for Water Right No 421(Public Records Office of Victoria 06784-P0004-000001).

In some cases the correlation was less accurate, yet still unambiguous (see Figure 5). Given this map is not a survey map, but a working map to indicate the location of mining leases, this inaccuracy was not unexpected.


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5

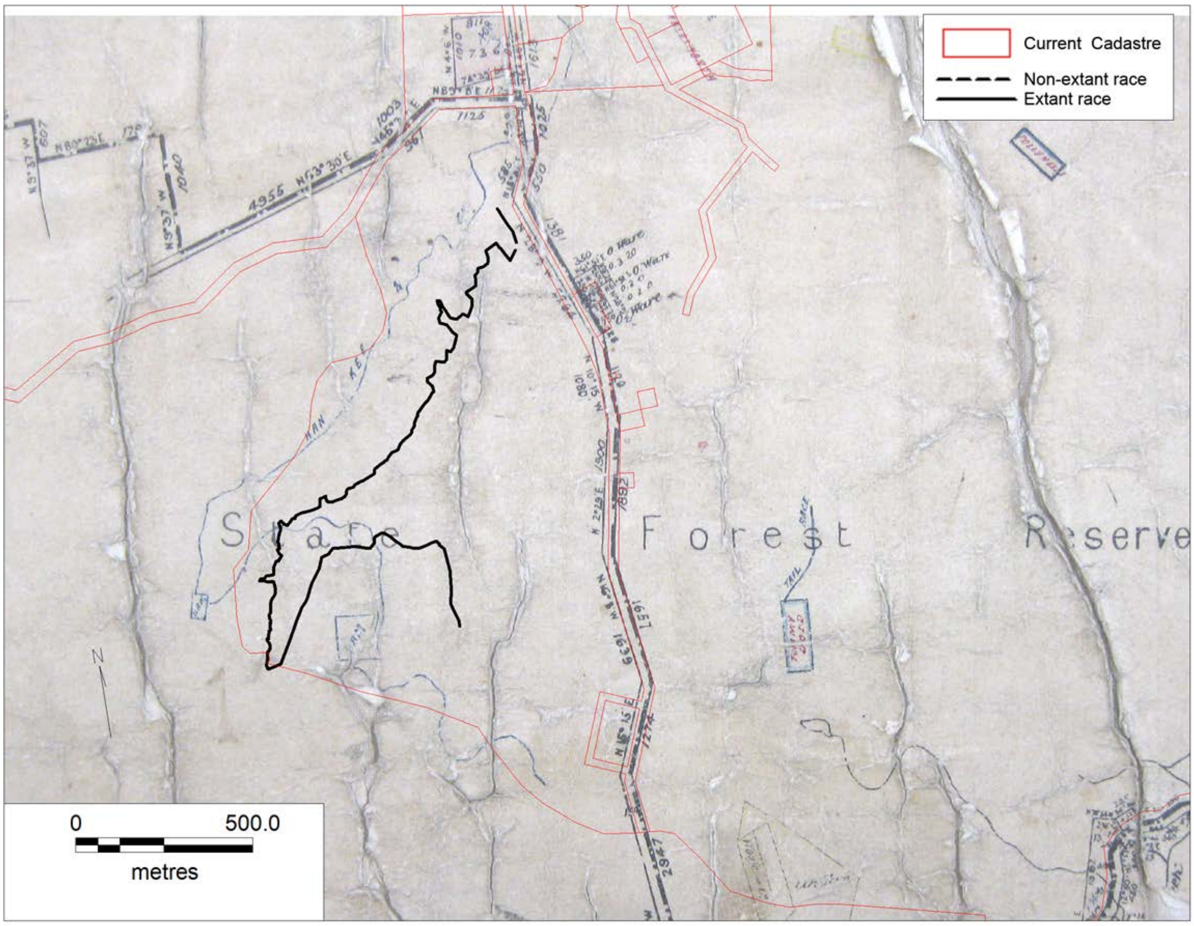


Figure 5: Inaccurate yet still unambiguous correlation between an extant race and the historical survey map. The original map shows the race (in blue) 200m to the west of the field surveyed race. The cadastre is matched to +/- 10 m suggesting that the location of this race on the historical map is incorrect(Part of undated lease map held at Public Records Office of Victoria 7842-0002-41).

This paper has only touched on the complexities of establishing and management of the databases. As Gonzalez-Tennant (2009) has pointed out, methodologies for GIS database creation and management are often lacking in research papers but I believe this is partly because of the individual and complex nature of the spatial databases required for individual projects. With the increasing role of GIS in archaeology, the need to develop standardized methods to facilitate data sharing, yet maintain project specificity will be challenging. Moves toward some standardization of archaeological spatial databases are currently underway by the newly formed Digital Archaeology Data Archive (DADA) group in Victoria.

## Geo-referencing historical maps.

Historical GIS relies heavily on the use of geo-referenced historical maps. Once geo-referenced, features can be digitized, maps overlaid and changes over time that may be difficult to perceive using paper maps become more apparent. Many of the earliest historical references for Creswick water races came from historical maps such as 19th century parish, geological survey, town survey, mining lease maps and water right survey maps. A number of more modern forestry maps and orienteering maps were also geo-referenced; over 30 maps in total. Geo-referenced maps can be draped over elevation data for a more intuitive perspective (see Figure 6).


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5
Melbourne: Geospatial Sciences, RMIT 2012

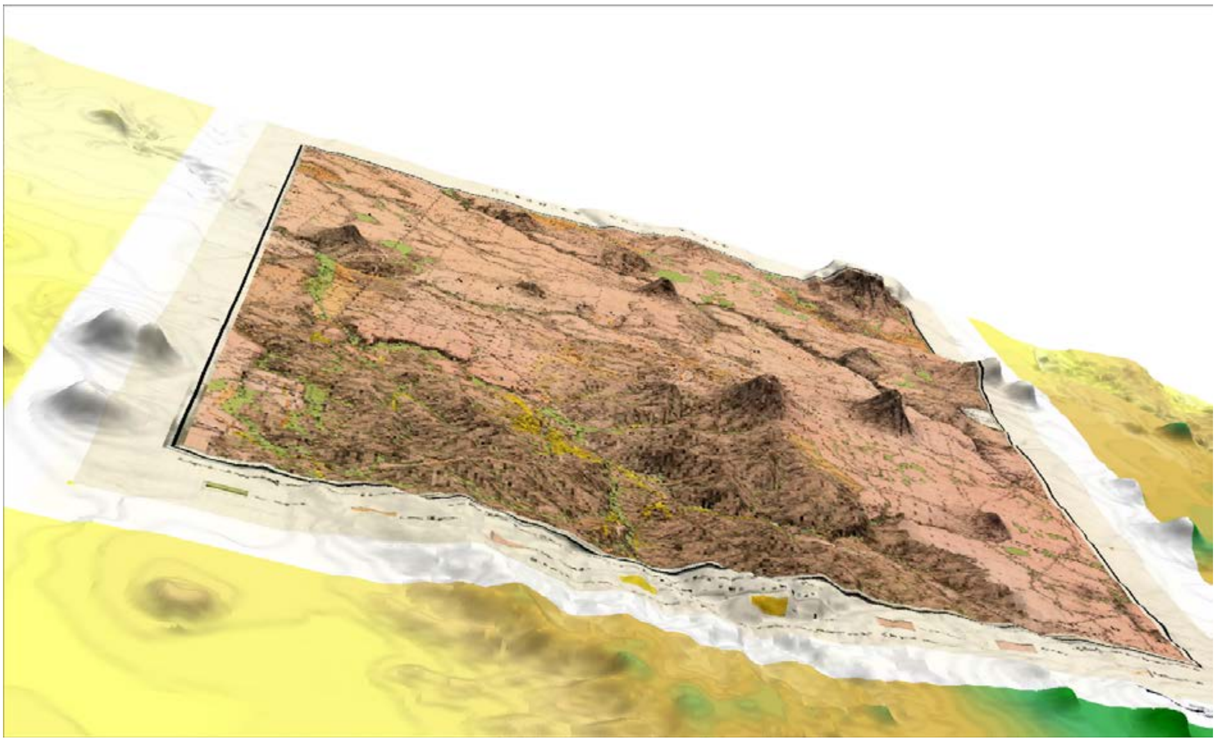

Figure 6: Geo-referenced and draped historical map of Creswick goldfields (Geological Survey Map 1880, Surveyed by F. M. Krause).

Historical maps were generally sourced from Public Records Office or the Department of Primary Industries. The process of geo-referencing requires digitizing the hard copy map at the best resolution affordable (600 dpi is desirable but 300 dpi is usually sufficient and most of the maps for this project averaged a manageable <10 MB in size.). Digitizing was done either by taking photographs or scans. Photographing maps requires care not to introduce distortions from using a too wide zoom or by taking the photo on a slightly oblique angle. Geo-referencing or registering the digital image is the process whereby control points on the digital map must be aligned with their actual geographical location, whether by assigning geographical co-ordinates to each point (if known)or by linking each point to its equivalent position on the digital basemap layers. In this case, cadastral boundaries, roads and field surveyed races were most often used to assign control points. Once the control points are in place the original map is warped to fit the chosen map projection as best as possible. Often the first fit is not accurate and further adjustments are done by adding more control points or modifying existing control points (Rumsey & Williams 2002). Choosing a map projection that is similar to that used by the original map is preferable. If a projection that is not similar to the scanned map is used, then often, no matter how many control points are added the map will only fit well in very limited areas.

When inaccuracies occur in the geo-referencing process it can be difficult to know where the source of error lies. Errors can lie in the basedata, historical map, digitizing or geo-referencing process. For example errors in the Street Pro basemap transport layer were only noted after an accurate (-/+ 1m) ground survey of races and some roads identified an error in one of the basedata road alignments, which then calls into question other roads in the immediate region. As roads were frequently used to register the historical maps (due to a lack of cadastre in the Creswick forest) this lead to some initial inaccurate geo-referencing. Another consideration is that the course of many historical roads, waterways and cadastre have been altered over time, so caution must be exercised when registering using these features. Once geo-referenced historical features identified on the maps were then digitized as point, line or area features and added to their respective database.

Parish maps were particularly useful for showing which early water races still retain cadastral boundaries (see Figure 7) and provided valuable property information which assisted in confirming the location of some races, for example when historical text associated races with particular properties.


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5
Melbourne: Geospatial Sciences, RMIT 2012

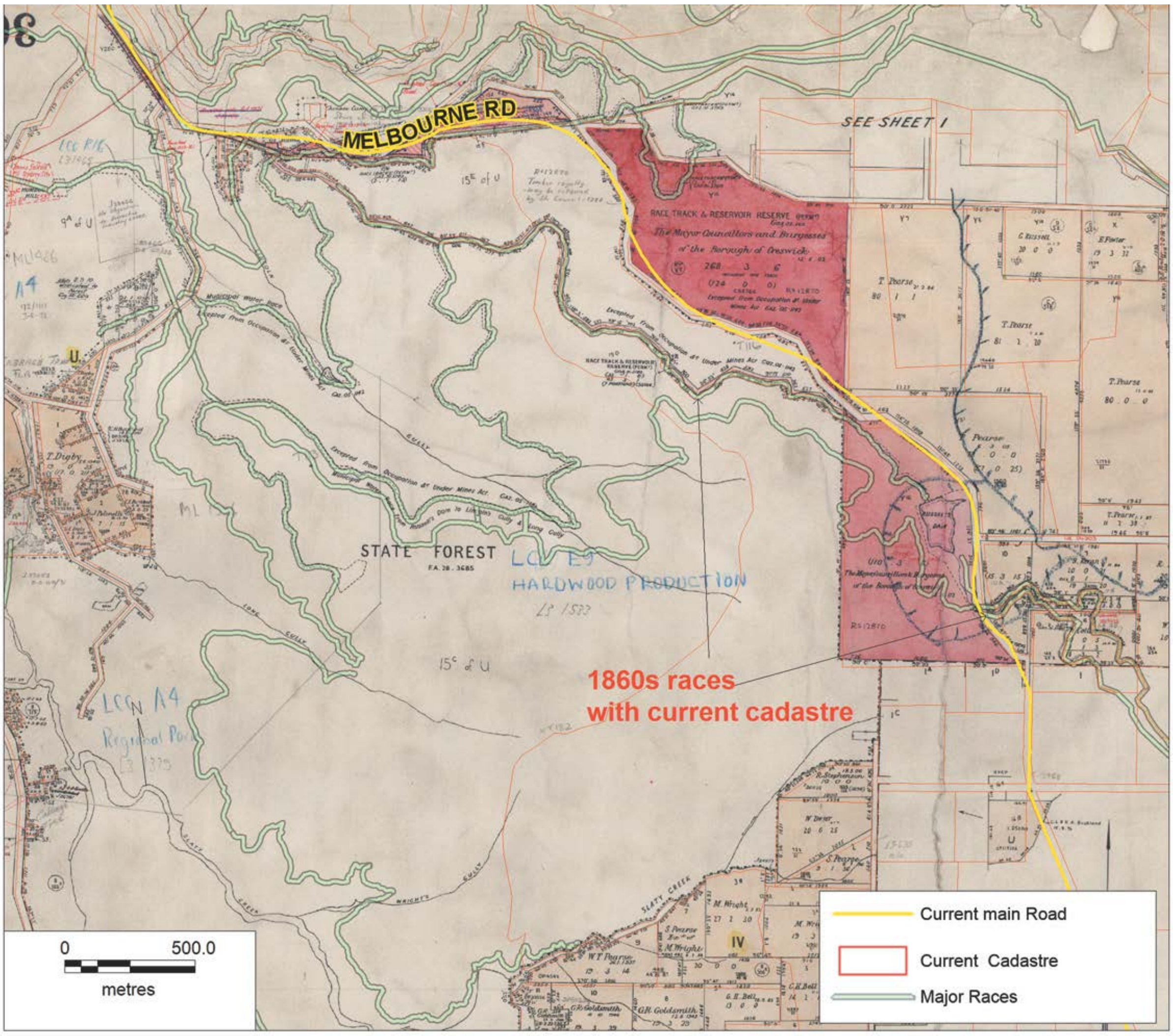


Figure 7: Parish map detail showing acceptable correlation between historical map, races and cadastre. Major races, main roads and current cadastre have been overlaid. The accuracy of the registration varies over this map and the margin of error is up to +/- 20m in places (MAP: Creswick -4 Parish Plan, 2464. Source -LandVic).

Krause's geological survey map (1880) is a good example of a less accurate correlation between an historical map and existing races (see Figure 8). Interestingly Krause chose to only represent Council owned races.



* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5

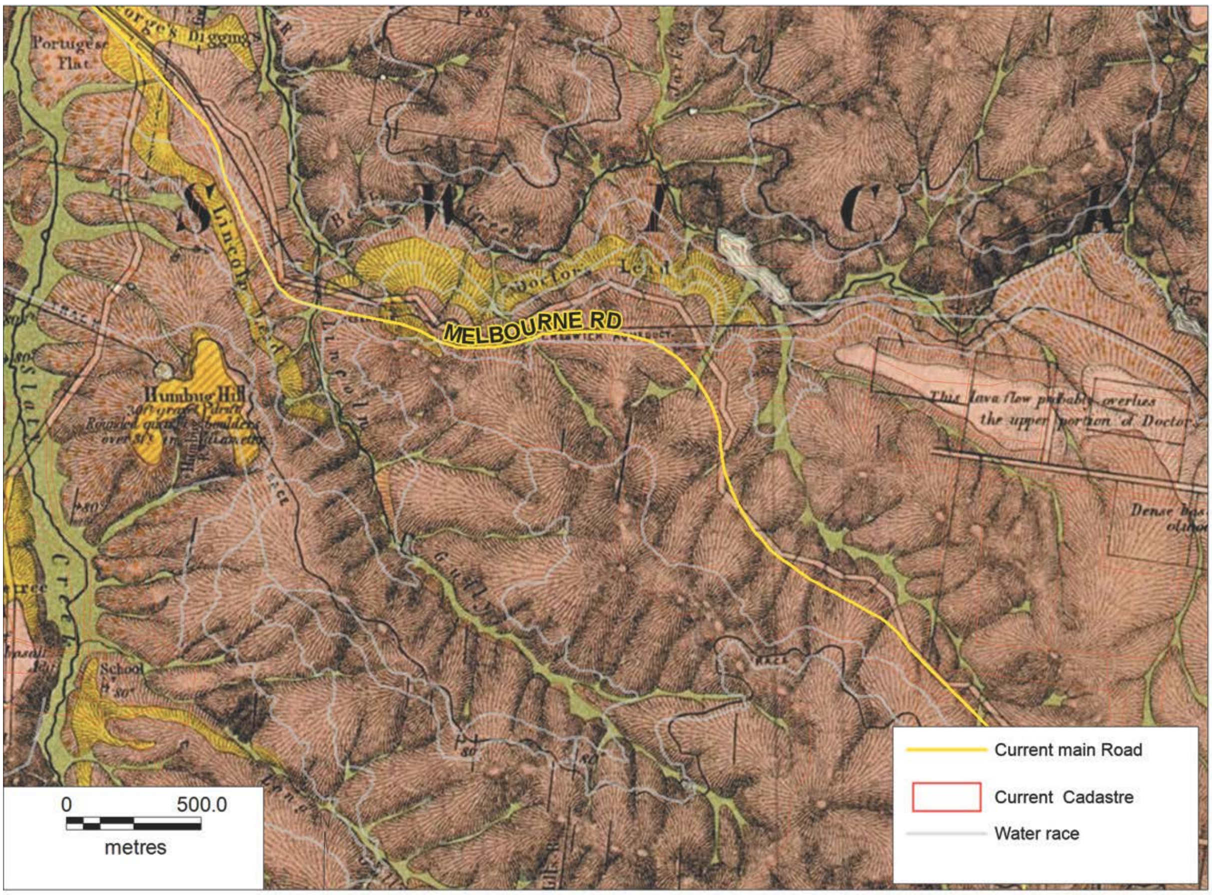


Figure 8: Detail from Krause (1880) showing less accurate correlation between the 1880's mapped races (black) and existing races (grey).

## Analysing the database.

One of the great strengths of GIS is the ability to query or analyze the data, although as previously mentioned this also is dependent on how well the database is constructed. One aim of this project is to develop spatial data that can be used to view and analyse the spatial and temporal relationship between historical features. Put simply a query might be "Show me the historical features that relate to a particular mining phase". In the complex mining landscape that is such a palimpsest of features from different phases, this initially seemed like a simple solution for simplifying and presenting such complexity. The issues with temporal mapping have already been alluded to and for this project abasic time-slice model was envisaged for temporal analysis. Initially a simple colour coded map showing the dates various gullies were opened was created (see Figure 9).


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5

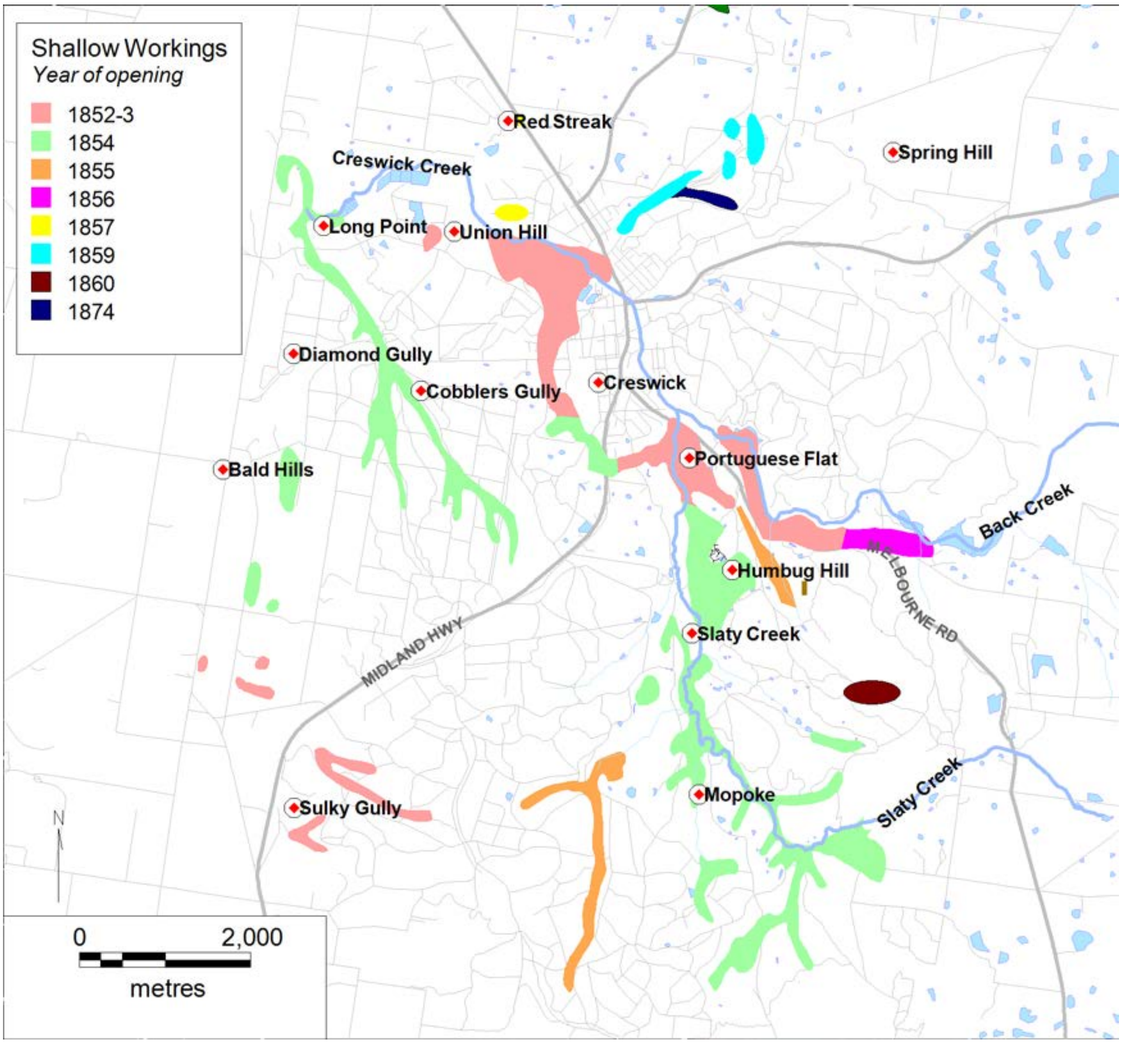


Figure 9. Shallow workings date of opening. An example of mapping using MapInfo's thematic layering tool for color coding by the 'Date' field.

However temporal mapping soon became more difficult. Many historical features were undateable at a single year resolution or even at the scale of decades. Attributing features to decades or phases seemed an obvious solution, however this too is proving problematic; the frustratingly basic problem is how to show features that span several years or decades of use, or more specifically how to structure the database to allow such queries.

Two fields allowed for basic temporal analysis of the historical data: Date (of construction) and Period of Use. Using the Date field a simple query could show features from a particular date or decade (i.e. "show all features from 185*"- asterix represents a wildcard- returns all features from the 1850s or "Show all features from the period >1858 and <1865" returns features that commenced within this date range). This however proved unsatisfactory due to lack of documentary evidence for some races and is limited to commencement date rather than showing all features extant during a particular period. The Period of Use attribute has limited analytical potential due to many undated features the fact that most of the races were established in the 1850-1860s anyway. As a result, using GIS to query this data adds little to our understanding and tends to only confirm what is already known. It was hoped that all mapped historical features could be dated to at least a broad date range or mining phases however this was optimistic and has not been possible.

However, work is still ongoing to explore the ability of GIS to analyse the data temporally and produce informative maps to show historical features relating to periods of interest or answer temporal questions that can explore the relationship between water management and drought such as "What features may have been constructed or abandoned as a response to particular drought periods?" or "What features were in operation during the 1865 drought?" Unfortunately the temporal resolution required to answer such questions is at a monthly or yearly resolution, for which we have the climate data, but few historical dates for features at this resolution. Our temporal analysis is currently (and likely to remain) limited to the most basic time slice models of presenting change through time, presented by a series of maps showing broad phases with the potential for animation by incorporating the time slice maps into a PowerPoint presentation. Cautions of being forced into an 'intractable compromise' or of


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5

simplifying one's questions to compensate for the limited ability of GIS to analyse the temporal data appear to ring true (Green 2008).

One of the strengths of GIS for this project has been the ability to problem solve by having an immediate interaction with the data. A vast amount of documentary evidence was examined, each being a small piece in a much larger puzzle, and in isolation such fragments were often difficult to interpret or map spatially. The historical documentary evidence relating to goldfields must be examined cautiously and critically to avoid misleading interpretations (Tracey 2007) and it can be tempting to match historical references with features located on the ground in order to provide some historical context. Painstaking corroboration of historical text with the spatially mapped data was undertaken. Some historical texts provided details that could be mapped or verified against already mapped features. While many mapped races correlated unambiguously with written descriptions, the area along Back Creek remains difficult to untangle due to disturbance and a plethora of confusing historical references. GIS was particularly useful in testing different scenarios for race alignments and ownership in this area. For example documentary evidence indicated water was diverted from Race 1 into Race 6, suggesting Race 6 is lower than Race 1. With this small piece of information the GIS data can be examined for races with this spatial relationship to assist in understanding the historical text. Verification of historical sources using GIS was particularly useful when historical references referred to measurements in miles or chains. The ability for the GIS system to project the data into earlier measurement systems was invaluable for verifying the correct identity and locations for many features based on measurements given in historical references and also provided visualization to help solve problems e.g. historical references referred to a race 14 miles (22 km) long starting high in the ranges (Wynn 1979). This was identified as St George's race, however, as currently only eight miles of race are mapped, this raised the question "Where in the ranges did the race originate"? The additional mileage places its commencement high on the Great Dividing Range around Dean, and suggests that many of the races thus far mapped may also be under-represented and may have been sourcing water from much further away in the catchment area than is currently mapped (see Figure 10). Unfortunately the remains of many races beyond the Creswick Regional Park have been destroyed by agricultural development.

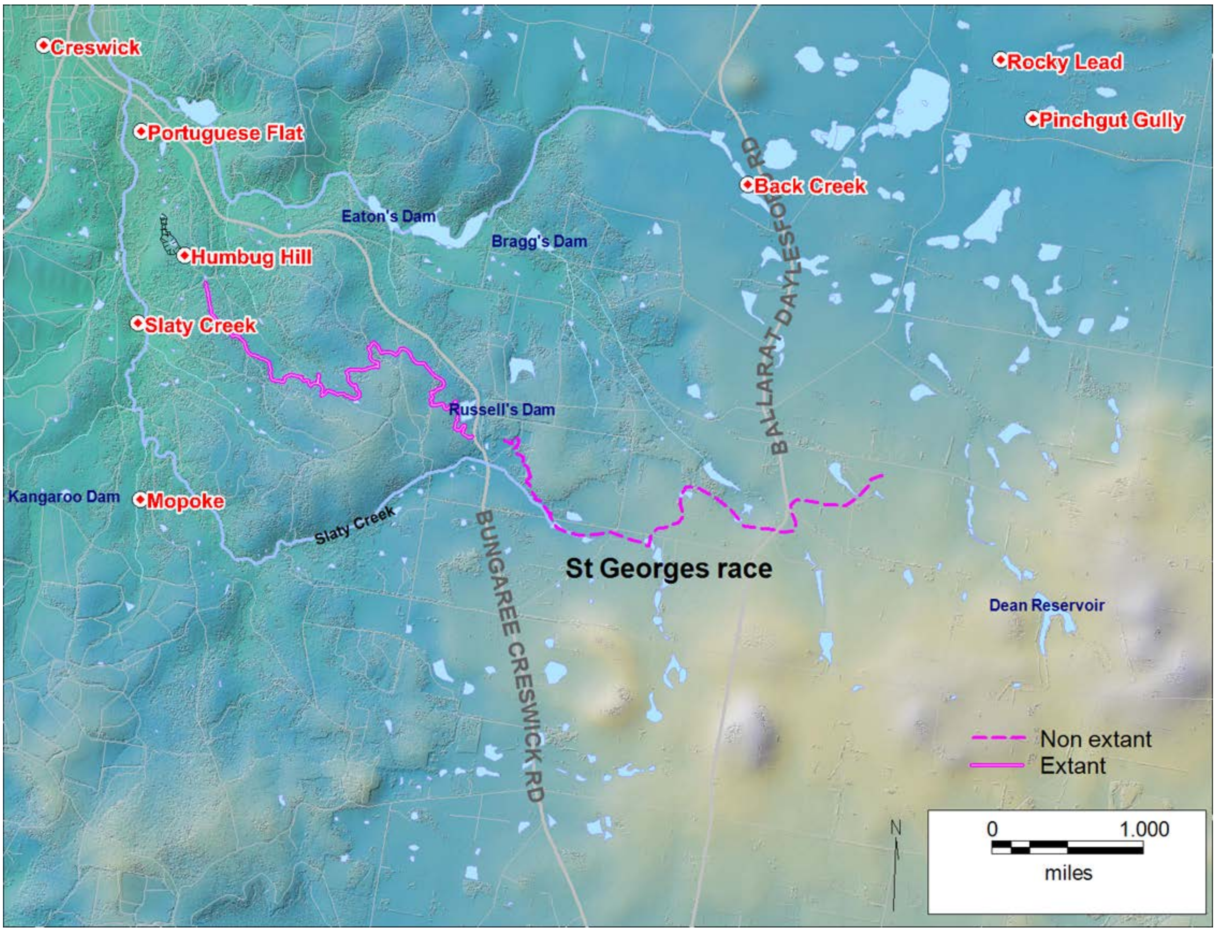


Figure 10: Eight miles of St George's race have been mapped, representing a little more than half of the distance referred to in historical texts, which raises the question, "Where did the race originate?"


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5
Melbourne: Geospatial Sciences, RMIT 2012

## Integrating spatial data with Google Earth and IPAD.

Various methods of integrating MapInfo generated spatial data with other applications were utilized; in particular Google Earth, Google Maps, &IPAD applications Galileo and Avenza PDF Maps[4]. This greatly facilitated data sharing and increased the efficiency and productivity of field survey.

Spatial data generated in MapInfo is easily convertible to other formats such as .kml, geo-referenced .tiffs and PDFs. The ease of this process greatly assists collaboration; for example .kmls can be emailed to colleagues and opened in Google Earth, thus providing a measure of GIS interactivity without sophisticated GIS software. Spatial data was also exported to a Google Maps account and from this program the data was imported easily to the Google Earth IPAD application thus providing yet another useful way of viewing MapInfo generated spatial data in the IPAD while in the field.

Two very useful IPADapplications for use in the field were Galileo and Avenza PDF. Galileo is a GPS application that tracks, marks waypoints and imports .kmls files and Avenza PDF maps imports geo-referenced maps and .kmls. Although this technology is not new the large IPAD screen greatly facilitated the field survey work. Galileo was trialed to test its capabilities as a back-up GPS unit with the results from Galileo comparing favorably with results from hand held DGPS and GPS units. Initial comparisons indicate that Galileo correlated well with DGPS data showing an average variation of 2-3 m. The furthest variation was no more than 6 m from the DGPS data (see Figure 11).

[4]Google Earth, Google Maps, & IPAD applications Galileo and Avenza PDF Maps are registered products.


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5
Melbourne: Geospatial Sciences, RMIT 2012

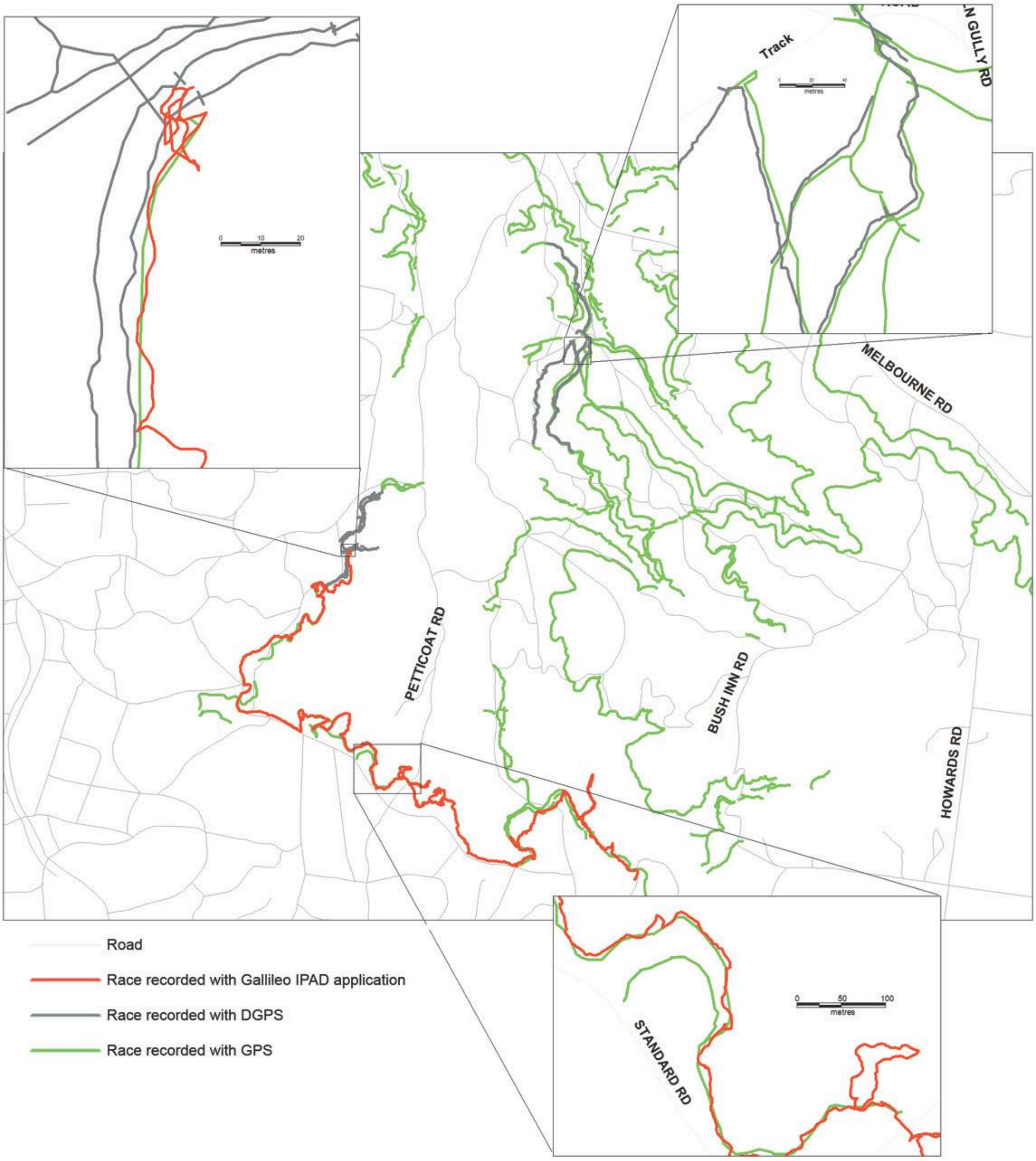


Figure 11: A comparison of races surveyed using DGPS, GalileoIPAD app and non differential GPS units.

In the complex landscape of tangled races and sluiced gullies the Avenza PDF Maps and Google Earth for IPAD were particularly useful for identifying one's location in relation to features, thus greatly assisting the ability to confidently identify and establish relationships between historical features while in the field. Avenza PDF Maps accepts geo-referenced maps including 1:30000 topographic series which can be purchased and downloaded already geo-referenced. A difficult area to interpret on the ground is the intersection of several races near Humbug Hill. This area has been utilized over many decades and is complicated to interpret. With historical geo-referenced and MapInfo generated maps in the IPAD, we were able to begin to unravel this complexity and start to establish temporal relationships in the field such as where earlier races has been diverted, cut or dammed to force water into more recent races. Very ephemeral features were indentified in this way. For example, the location of an 1860 pipeline indicated on Krause (1880) was easily located and minor traces of bitumen pipe and a faint ditch through the bush were identified with ease, saving time and effort in the field (see Figure 12).


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5
Melbourne: Geospatial Sciences, RMIT 2012

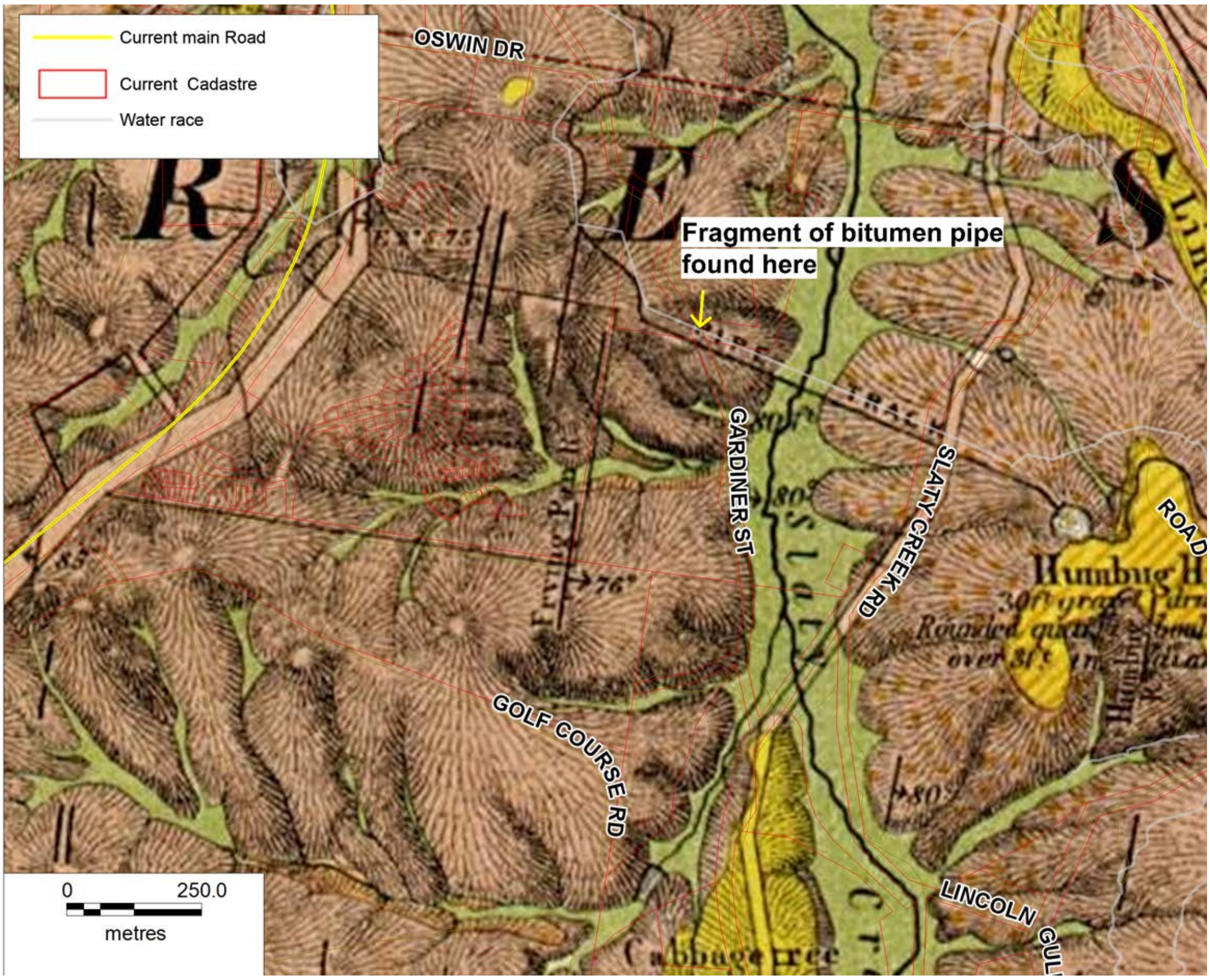


Figure 12: This geo-referenced map in Avenza PDF Maps for IPAD enabled the efficient identification of a small fragment of 1860s bitumen pipe saving time and effort in the field.

Similarly ephemeral features such as small holding dams (which today are eroded and difficult to discern) or flume commencement points were identified with the aid of historical maps in the IPAD. The IPAD also functioned well for taking geo-referenced photographs.

## Discussion and Conclusion

The initial focus of the project to date has been on the Creswick goldfield with the aim to use GIS to assist the understanding of temporal and spatial relationships between historical water management features. Goldfields present complex historical and archaeological sites, requiring skill to interpret them (Pearson & McGowan 2000), yet even experienced researchers can be challenged when presented with the palimpsest of features and disturbed landscapes that comprise many goldfields. The use of GIS maps has greatly facilitated the mapping of over 170km of historical water races, dams and reservoirs and mining leases and assisted in interpreting the spatial relationships between these features in the Creswick region. GIS greatly aided the historical research process and enabled many features to be confidently matched with historical texts, thus assisting greatly in adding the gold mining history of the region. The results of this stage of the project are presented in detail in Davies et. al (2012). The project has resulted in many water management features being registered on the heritage inventory maintained by Heritage Victoria.

It was envisaged that GIS could assist temporal analysis, particularly for correlating historical features with mining phases and events such as drought. However GIS has not greatly aided the understanding of temporal relationships due to both limitations of the software, and the limited resolution of known historical dates for many features. Furthermore, the presentation of temporal data was found to be difficult and has remained a basic snapshot model for this project. Many archaeologists have expressed similar frustrations at the limitations of current GIS for temporal analysis.

This paper highlights some of the methods and challenges for organizing and managing spatial data for a historical landscape archaeology project. GIS has contributed at all stages from mapping historical research, planning and executing fieldwork, analyzing and mapping results and finally to dissemination of information.

The project integrated spatial data and maps generated in MapInfo into various external applications such as Google Earth, Google Maps, &IPAD. This proved beneficial for sharing data and increased efficiency and productivity of field survey particularly for assisting in the identification and interpretation of features while in the field. Once the landscape features were interpreted with confidence, questions that look for correlations between these features and years of drought or wet, or the introduction of mining/water laws can be better understood and lead to a holistic understanding of water use on the goldfields. Historical GIS has provided a powerful tool for examining landscapes and land use.

GIS is far more than map production. One of the strengths of GIS is beyond the laboratory, particularly to reach a wider public audience which can then allow others to experience the interactivity of GIS generated data (Ebert 2004 p320).This project has demonstrated that spatial data generated in a GIS has varied uses outside the GIS and the ease of data transfer between colleagues and applications has made it a useful tool with much potential for public educational orientated delivery systems. The historical research and associated spatial data have the potential to make a significant contribution to Creswick's goldfield history. It is hoped that GIS data generated in this project can find an outlet that reaches the wider public in an interactive way.

The question has been asked whether GIS represents a change in how archaeologists formulate and solve problems or whether it is merely a new way of doing existing things (Lock & Harris 1997, Hu 2011, McCoy & Ladefoged 2009). Has GIS enabled archaeologists to become better practitioners, scholars and stewards? (McCoy & Ladefoged 2009, 263).This project has demonstrated that GIS enables many existing archaeological practices to be carried out efficiently such as by aiding fieldwork, assisting problem solving, recording sites for management and improving dissemination of information. Spatial data can be readily shared with heritage management and planning departments thus particularly benefiting the stewardship of historical sites. Without GIS the complex spatial relationship between many of the tangled races and storage dams would have been difficult to establish. Despite some limitations with temporal analysis GIS has been integral to understanding this complex historical landscape and the intricate relationships between water users.

Software: MapInfov11. Avenza PDF Maps app for IPAD, Galileo app for IPAD, Google Earth, Google Earth app for IPAD, Google Maps.
Hardware: Leica CS10 3.5G DGPS, Topcon GRS-1 DGPS, Garmin GPS, IPAD 2 & 3.

## Acknowledgements

The author would like to thank Ass. Prof. Susan Lawrence (La Trobe University), Dr Peter Davies (La Trobe University), Dr Kevin Tolhurst (Melbourne University, Creswick), Don Henderson (Hepburn Shire Council), Paul Kajewski (La Trobe University), Heather Bice (Ballarat), Eureka Orienteering Club, Evelyn Wright (Creswick and District Historical Society) and staff at Ballarat and Melbourne Public Records Office.

## References

2012. *VicMap Data* [Online]. LandVic.
http://services.land.vic.gov.au/landchannel/content/vicmapdata?productID=2 [Accessed 2012].

DAVIES, P., LAWRENCE. S & TURNBULL. J. 2012. Archaeology of Water Management on the Creswick Alluvial Goldfields.An unpublished report to Heritage Victoria.

EBERT, D. 2004.Applications of Archaeological GIS.*Canadian Journal of Archaeology,* 28**,** 319-341.

GONZÁLEZ-TENNANT, E. 2009. Generating 'Living Documents' with GPS & GIS for Archaeology: A Case Study from the Otago Goldfields, New Zealand. . *Historical Archaeology,* 43**,** 20-37.

GREEN, C. T. 2008.*Winding Dali's Clock: The construction of a fuzzy temporal-GIS for archaeology*.Doctor of Philosophy, University of Leicester.

HU, D. 2011. Advancing Theory? Landscape Archaeology and Geographical Information Systems. *Papers from the Institute of Archaeology.University College London,* 21.

JOHNSON, I. 1999. "Mapping the fourth dimension: The TimeMap™Project. *CAA97: Computer Applications in Archaeology.*

JOHNSON, I. & WILSON, A. 2003. The TimeMap™Project: Developing Time-based GIS Display for Cultural data. *Journal of GIS in Archaeology,* 1**,** 125-135.


* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5
Melbourne: Geospatial Sciences, RMIT 2012

JOHNSON, I. 2008. Mapping the fourth dimension. A Ten year retrospective. *Archeologia e Calcolatori*, 19**,** 31-43.

KNOWLES, A. K. 2002. Introducing historical GIS. *In:* KNOWLES, A. K. (ed.) *Past Time Past Place. GIS for History*. California: ESRI.

LAWRENCE, S. & DAVIES, P. 2011. Harvesting water on a Victorian colonial goldfield. *Australasian Historical Archaeology,* 29**,** 24-32.

LAWRENCE, S. & DAVIES, P. 2012. Learning about landscapes: archaeology of water management in colonial Victoria. *Australian Archaeology,* 74**,** 47-54.

LOCK, G. AND HARRIS, T. M. 1997 Analyzing change through time within a cultural landscape: conceptual and functional limitations of a GIS approach, in Sinclair, P. (ed.) *Urban origins in eastern Africa*, World Archaeological Congress, One World series.

MASCHNER. M 1996. Theory, Technology, and the Future of Geographic Information Systems in Archaeology.*In:* MASCHNER, M. (ed.) *New Methods, Old Problems: Geographic Information Systems in Modern Archaeological Research.* Occasional Paper 23.Carbondale: Center for Archaeological Investigations.

McCOY. D & LADEFOGED T. N. 2009.New Developments in the use of Spatial Technology in Archaeology.*Journal of Archaeological Research.* 17:263-295. (DOI 10.10007/s10814-009-9030-1).

NATHAN. E. 2007. Lost Waters: a history of a troubled catchment, Carlton, Victoria, Melbourne University Press.

PEARSON, M. & McGOWAN, B. 2000.*Mining heritage places assessment manual,* Canberra, Australian Council of National Trusts : Australian Heritage Commission.

RUMSEY, D. & WILLIAMS, M. 2002. Historical Maps in GIS in K. A. KNOWLES (ed) *Past Time and Place: GIS for History*. California: ESRI.

RUSSELL. G. 2009. *Water for gold! The fight to quench central Victoria's goldfields*.Melbourne, Australian Scholarly Publishing.

TRACEY. M. 1997. 'No Water - No Gold; Hydrological technology in nineteenth century gold mining - an archaeological examination'. *In:* KERR, R. & TRACEY, M. M. (eds.) *The Australian Historical mining Association - Conference Proceedings 1996.* Home Planet Design and Publishing, Canberra.

WYNN, G. 1979.*Life on the Goldfields: Fifteen Letters 1853-1861*.

MAPS
KRAUSE, F.M. 1880 Creswick Goldfield, Mining Department, Melbourne.

Creswick Parish Plan, Imperial measure 2464 Sheet 2, C 400 36a.

Undated lease map.Public Records Office Victoria VPRS 7842-0002-41.



* Review Paper – accepted after double-blind review.
ISBN: 978-0-9872527-1-5
Melbourne: Geospatial Sciences, RMIT 2012