Edward González-Tennant

Using Geodatabases to Generate "Living Documents" for Archaeology: A Case Study from the Otago Goldfields, New Zealand

ABSTRACT

Geographic Information Systems (GIS) are still growing in relation to historical archaeology, and the related literature contains little on the actual methods for structuring such data. The author draws on fieldwork at four sites in the Otago Region of New Zealand to present a sample data model as well as various uses for GIS in historical archaeology—from initial data collection to public presentation. Methodology developed here was used to map surface remains with GPS at four gold mining sites. Because unforeseen problems can arise when transitioning field data into digital formats, the process developed as part of the author's work to translate, organize, and disseminate data is presented in clear steps. The benefits for public consumption of archaeological material is discussed as well as the potential for GIS to address simple phenemonelogical questions about past decisions in regards to site placement.

Introduction

The combination of increasingly accurate global positioning system (GPS) receivers and improvements in the intuitiveness of geographical information systems (GIS) software provides historical archaeologists with a unique means for both conducting research and, particularly, presenting information to the public. The benefits of combining these technologies include the rapid recording and dissemination of accurate data, creation of publicly accessible and user-friendly presentations, and assisting with future research. Setting up and using GPS units to collect accurate and precise data requires specific but by no means complex planning to achieve solid returns and to insure continued usability. Unfortunately for beginning and intermediate users of GIS, the archaeological literature that deals with creating GIS rarely features usable training models. This regrettable circumstance forces new users of GIS to create their own models. Such situations, as many project leaders can attest, often create future problems for projects that require time-intensive solutions.

Role of GIS in Archaeology

Maps are perhaps one of the most fundamental tools of archaeology. These two-dimensional representations of the world often divulge complex patterns and relationships, from early distribution maps of flake scatters to international networks of villages and forts (Williams 1992). The introduction of GIS into the archaeologist's toolkit means complex, contextual geographical relationships can be more readily quantified than in the past; GIS facilitates the rapid integration and analysis of spatial information. Advances in both data-acquisition techniques (such as the introduction of GPS) and computational power mean that work, which took weeks to complete just one generation ago, can be completed in a matter of hours today.

Mark Aldenderfer (1992) divides the uses of GIS into three classes, and this classification system remains an effective way to discuss the archaeological uses of GIS. The first class calls upon GIS to be used for its traditional purpose, mainly to create maps, becoming "little more than a two-dimensional (2D) cartographic presentation tool" (Kvamme 1999:164). Initially, many archaeologists predicted that GIS would eventually stagnate and do little more than reproduce the uses of CAD programs (Lock 1993:1). GIS software includes, however, a number of sophisticated features not available in CAD. The ability to link with database management systems allows the user to access information from a visual interface rather than a text-driven one (Chartrand et al. 1993; Miller 1995, 1996). GIS structures allow for the incorporation of ancillary data (Romano and Tolba 1995) and can display continuous data (rainfall patterns, artifact densities, annual temperatures, etc.) in relation to a spatially defined area (Biswell et al. 1995).

Historical Archaeology, 2009, 43(3):20–37.

Aldenderfer’s second class begins to draw upon these more advanced uses of GIS to complete complex analysis, rarely undertaken. Examples of this type include the predictive modeling of archaeological sites (Allen 1996; Hasenstab 1996), which involves bringing together large amounts of data, such as slope and soil type, and examining the relationships that exist among known sites and these resources. Kenneth Kvamme (1999:169) compares the uses of chi-squares and GIS to make this point: if 70% of sites are located on a slope of 20%, this is still not significant if 70% of the overall areas are situated on a slope of 20%. The time required to calculate this by hand (with a calculator and terrain maps, for example) is high, but GIS software can make such computations rapidly, which allows archaeologists to develop more sophisticated statistical and geographical models.

The third class of GIS uses defined by Aldenderfer looks at new and unique methods of analysis. These techniques include two wholly new concepts, both born out of GIS developments. The first is termed cost surface analysis (CSA) and assigns weights to individual physical locations. Looking at slope, for example, steep slopes might be assigned a high weight in the uphill direction because they involve more energy to traverse. Numerous CSA datasets (re-created vegetation maps, terrain, prehistoric waterways) were used to predict possible pathways of the first Americans (Steele et al. 1996). This technique was termed “optimum corridor analysis” (Madry and Rakos 1996). The second new technique is termed viewshed analysis and has become one of the most common analytical uses of GIS in archaeological studies of landscape. Viewshed analysis has been used to address the social statements associated with assigned meanings of visible locations (Gaffney and van Leusen 1995; Lock and Harris 1996). It has also been used to examine the placement of barrows near Stonehenge, where David Wheatley (1996) found that intervisibility was statistically significant, suggesting a conscious decision was made to place sites within the landscape in a manner that would make them visible from other, similar, sites.

Peter Fisher (1999) uses a different scheme to classify GIS uses. His approach stresses using the material produced by GIS as a means of classification. The first use Fisher terms “inventory.” This corresponds with Aldenderfer’s first class of GIS: continuing to do what archaeologists have commonly done in the past. Fisher (1999:8) is a proponent of using GIS for map making, stating that this ability “should be regarded as a strengthening of the survey method.” He believes that using GIS to record and map archaeological resources on the landscape, without any analysis, is still a valid use of the technology and should not be ignored or treated as useless. The second use outlined by Fisher focuses on spatial analysis and corresponds closely with the second and third classes outlined by Aldenderfer. Spatial analysis has been explored above, but Fisher offers an additional important insight through the work of Scott Madry and Carol Crumley (1990), which looked at the visible areas from a series of hill forts in the south of France to verify that each fort was located in view of nearby roads. Fisher (1999:8) termed this study—completed without the use of statistical proofs—as a “contextual study.” The third use outlined by Fisher is for publication, referring to the use of GIS for publishing the results of archaeological data. Unique ways of presenting data are possible by employing a visual GIS interface. For example, a site plan in GIS format, accessed through a GIS interface (such as ArcReader), can contain links to text, graphics, statistics, and other elements—allowing an author to share a large amount of information with interested parties in a highly efficient manner and allowing a researcher to select information for viewing according to specific needs.

Unfortunately, while many historical archaeologists recognize the potential benefits of GIS, one of the greatest difficulties faced in the use of new technology is the lack of educational materials that speak directly to the archaeological discipline. In relation to GIS, a number of resources have sought to remedy this situation since 1990 (Allen et al. 1990; Lock and Stancic 1995; Aldenderfer and Maschner 1996; Maschner 1996; Johnson and North 1997; Lock 2000; Westcott and Brandon 2000; Wheatley and Gillings 2002; Conolly and Lake 2006). Generally, these authors center on various forms of analysis (viewshed analysis, least cost pathway analysis, etc.) and do not discuss actual schemes used to organize the data itself. The prevailing attitude of these authors in relation to sample database designs is summed up in the recent volume, where James Conolly and Mark Lake (2006:33) state, "It is not our intention to discuss … the appropriate structure of a spatial database for managing the archaeological record, as these decisions are most appropriately made by government bodies and the archaeologists charged with the tasks of recording and managing the archaeological resource." The unfortunate result of this approach is an absence of model organizational schemes available for archaeologists engaged in data translation and organization. To help fill this literature gap, the methodology used for GIS mapping at four Otago goldfields sites is described, from regional history and site descriptions through to public presentation of data.

Industrial History of Otago

The four sites selected for GIS mapping are all located in the Otago region of New Zealand's South Island (Figure 1). Gold was discovered in the region in May 1861, sparking a rush that affected all of Australasia (Salmon 1963:11). The initial rushes lasted less than two years. During this time, the Otago city of Dunedin, temporarily New Zealand's most prosperous town, was briefly considered as a candidate for the capital of the country and became home to the Bank of New Zealand (Bristow 1994:9). The gold rushes were directly responsible for development of roads and infrastructure throughout the Otago region, including a stagecoach, well-maintained roads, and power generators. By 1865, however, the number of gold miners had already dropped from the high mark of 10,000 in 1864 and to 6,000 by 1867 (Ritchie 1986:17–20). In the late 1860s and early 1870s, a majority of the miners left for the west coast (Pyke 1962:90–92) where the gold rush was less intense but longer lived.

The Otago goldfields also featured a significant Chinese population. The fear that Otago's gold rush days were over following the 1865 exodus to the west paved the way for an invitation to Chinese miners later that same year. This development was generally greeted with condemnation by European miners. The owners of flagging businesses and provincial leaders believed, however, that the invitation might alleviate poor gold returns and sagging economies. The first Chinese arrived in 1866, initially from Australia and then later directly from China after the provincial treasurer guaranteed protection (Ritchie 1986:14–15). The population of Chinese miners grew almost as quickly as did the European, although never reaching quite the same numbers.

There were five major goldfields in Otago (Figure 2). The first was Gabriel's Gully, where, according to contemporary sources, 150 miners had arrived by July 1861. This number swelled to an estimated 6,000 miners by year's end (Salmon 1963:57). The next field was Waitahuna, where nearly 4,000 men were working by the end of 1861 (New Zealand House of Representatives 1861:3). The Carrick, Old Man, and Dunstan ranges, considered a single field, were discovered as miners spread into the interior of Otago. Maori Jack discovered the Arrow and Shotover rivers in 1862 (Pyke 1962:84–85), a particularly profitable field (Pyke 1962:88; Salmon 1963:87). The Mount Ida field was discovered in May 1863, where a small number of miners initially worked in relative secrecy for several months (New Zealand House of Representatives 1863:6), but 2,000 miners soon arrived to work the area (Salmon 1963:97).

Individual Site Histories

The author investigated four sites as part of this project (Figure 3). The fist site, Nenthorn, was home to one of Otago's last gold rushes and saw rapid rise and fall (Figure 4). First surveyed and inhabited in 1889, it was completely abandoned less than five years later. The possibility of a new gold mining town this late in the history of Otago gold mining brought many settlers to the area, and Nenthorn was even prosperous enough to have its own newspaper (Thompson 1949).

A brief archaeological survey of the site was undertaken in 1984 (Jacomb and Easdale 1984), centering on identification of historic features found on an aerial photograph, with sites selectively visited if they appeared threatened by pastoral development of the area. The information collected for the author's project resulted in the recording of nearly 20 structures and several dozen features, none of which had been accurately mapped previously. The information collected by the author at this site was shared with the Institute of Geological

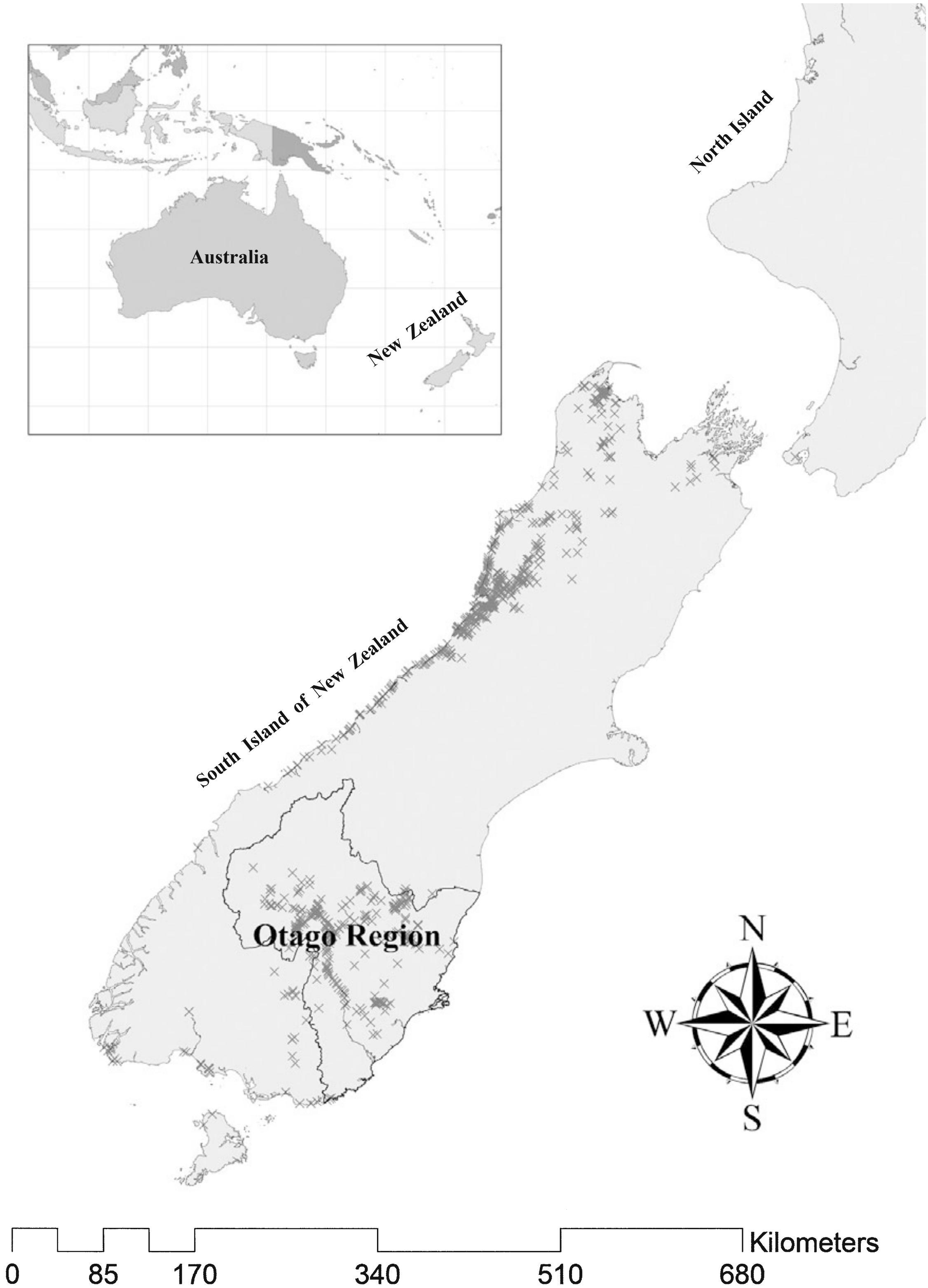

FIGURE 1. Otago region in New Zealand. (Map by author, 2004.)

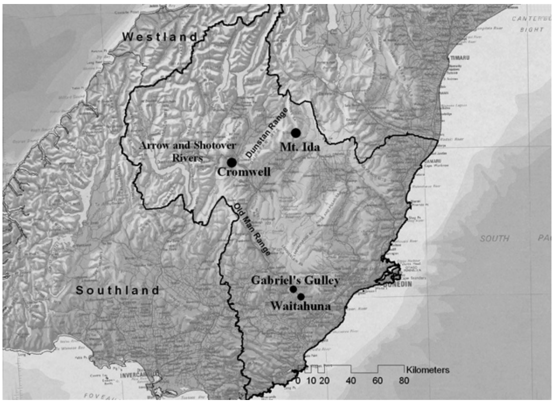

FIGURE 2. Gold mining areas and sites mentioned in text. (Map by author, 2004.)

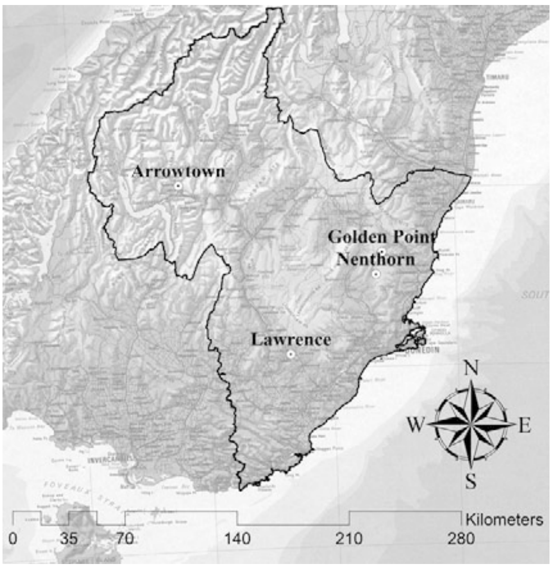

FIGURE 3. Location of sites investigated by author. (Map by author, 2004.)

and Nuclear Sciences in Dunedin to help protect heritage resources during future mineral prospecting operations (Tennant and Bristow 2004:208–209).

The second site investigated, formed in 1866, was the Lawrence Chinese Camp. This camp served as the gateway for miners, Chinese and non-Chinese, heading for the goldfields in western Otago (Figure 5). This was a prosperous settlement with three restaurants and probably more than one gambling establishment. Historic photographs show many distinctively Chinese buildings, such as a Joss House (Figure 6), Chinese stores, and gambling houses. Prior to the addition of rudimentary water facilities in 1882 by the Tuapeka County Council, it can be assumed that wells were dug and water boiled, "a factor which was recognized to have kept down the disease rate of the camps" as well as the "Cantonese preference, almost a fetish, for having their food as fresh as possible" (Ng 1993:251). A multiseason fieldwork project at the Lawrence Chinese camp is underway as of this writing. These investigations are the result of cooperative efforts between James Ng of Dunedin, the New Zealand Department of Conservation and Historic Places Trust, and the Anthropology Department at the University of Otago. The author's GIS mapping of this site was undertaken as part of the preparation for the excavation.

The Golden Point Historic District reserve currently consists of approximately 1 sq km of protected land managed by the Department of Conservation and is home to the third case study (Figure 7). The hills and mountains surrounding the site are home to New Zealand's largest mining operation, the Macraes Mining Project (currently known as Gold and Resource Developments N.L.). Procurement of gold began here with the arrival of Chinese miners in 1869, and initially consisted of small-scale alluvial gold extraction. Hard-rock mining began soon after, with the building of the first ore-crushing complex in the early 1870s. Hard-rock mining continued well into the 20th century, when scheelite became the primary ore sought at Golden Point, for use in the construction of munitions casings for WWI (Williams 1974:55). The area contained five different hard-rock mining operations; one still operable stamping battery is curated by the New Zealand Department of Conservation. GIS mapping was undertaken by the author at the Historic Reserve to assist the New Zealand Department of Conservation with monitoring the onsite heritage resources.

The fourth site is located along the Arrow River where gold was discovered in 1862 (Figure 8). The first Chinese miners arrived here in 1866, and in 1870 a row of 20 huts was recorded in the Arrowtown Chinese settlement. Local anti-Chinese sentiment and the availability of vacant Crown land probably influenced the Chinese to settle outside of Arrowtown proper. The Arrowtown Chinese settlement is one of about 10 Chinese camps or settlements that

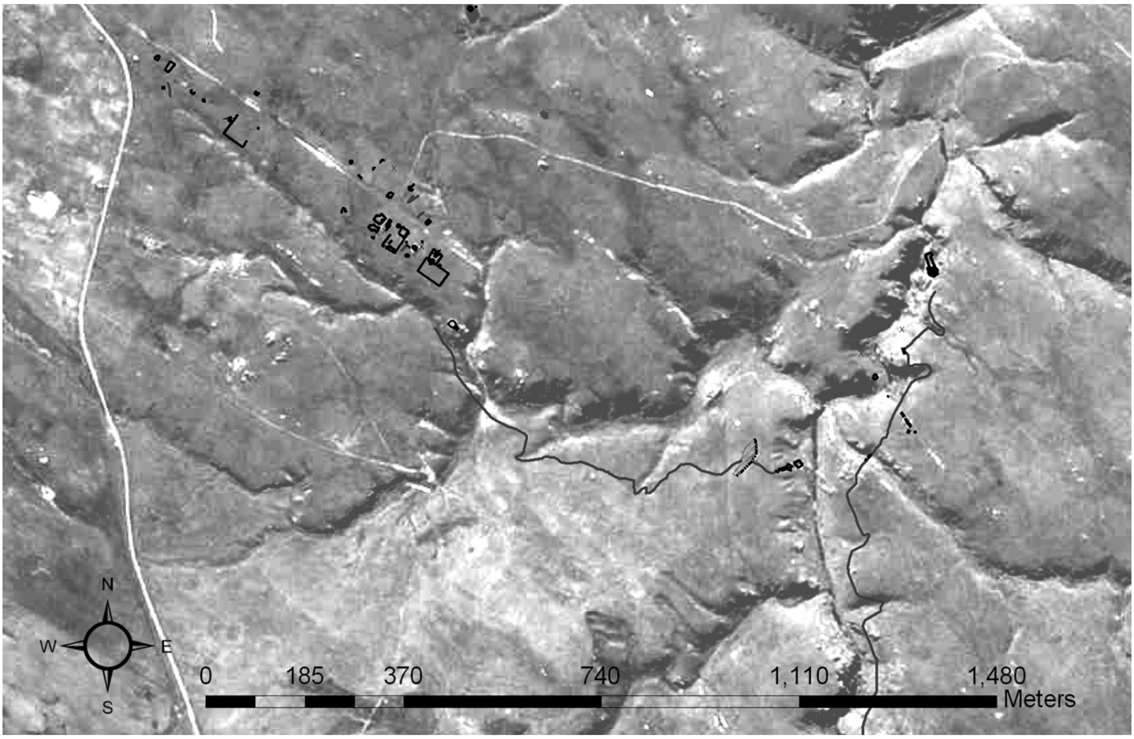

FIGURE 4. Nenthorn, showing surface and water features. (Map by author, 2004.)

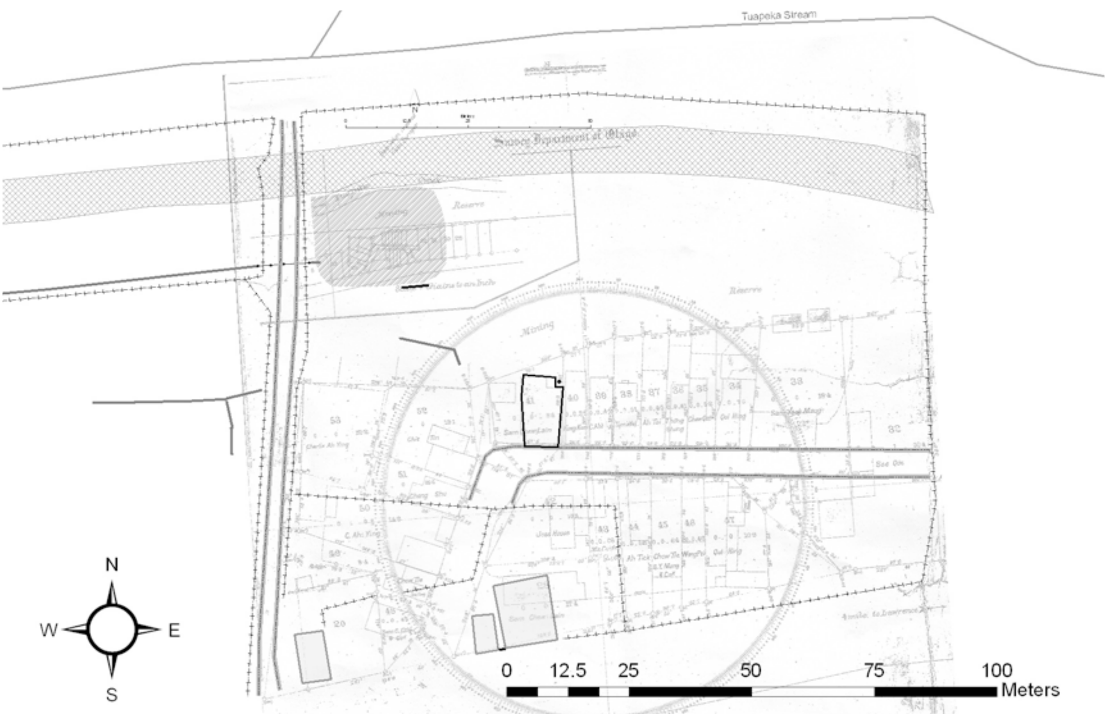

FIGURE 5. Lawrence, showing surface and water features and 1882 historic survey. (Map by author, 2004.)

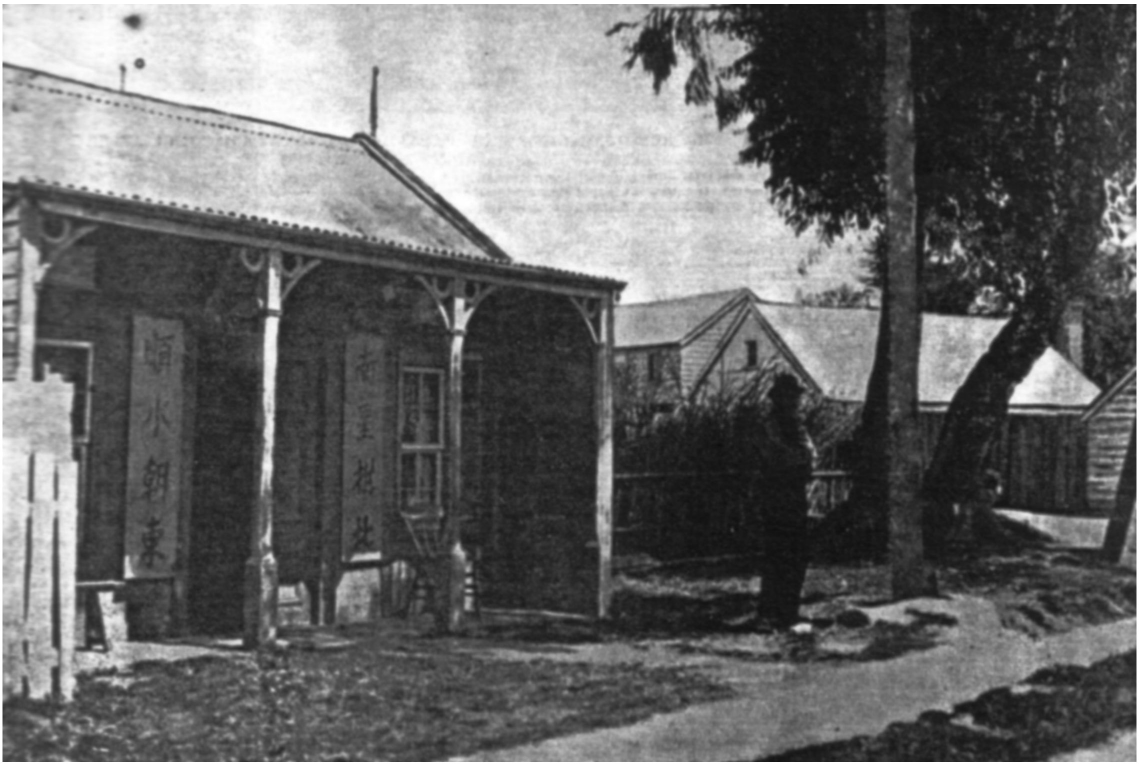

FIGURE 6. Joss house at Lawrence Chinese camp, ca. 1890. (Alexander Turnbull Library, New Zealand.)

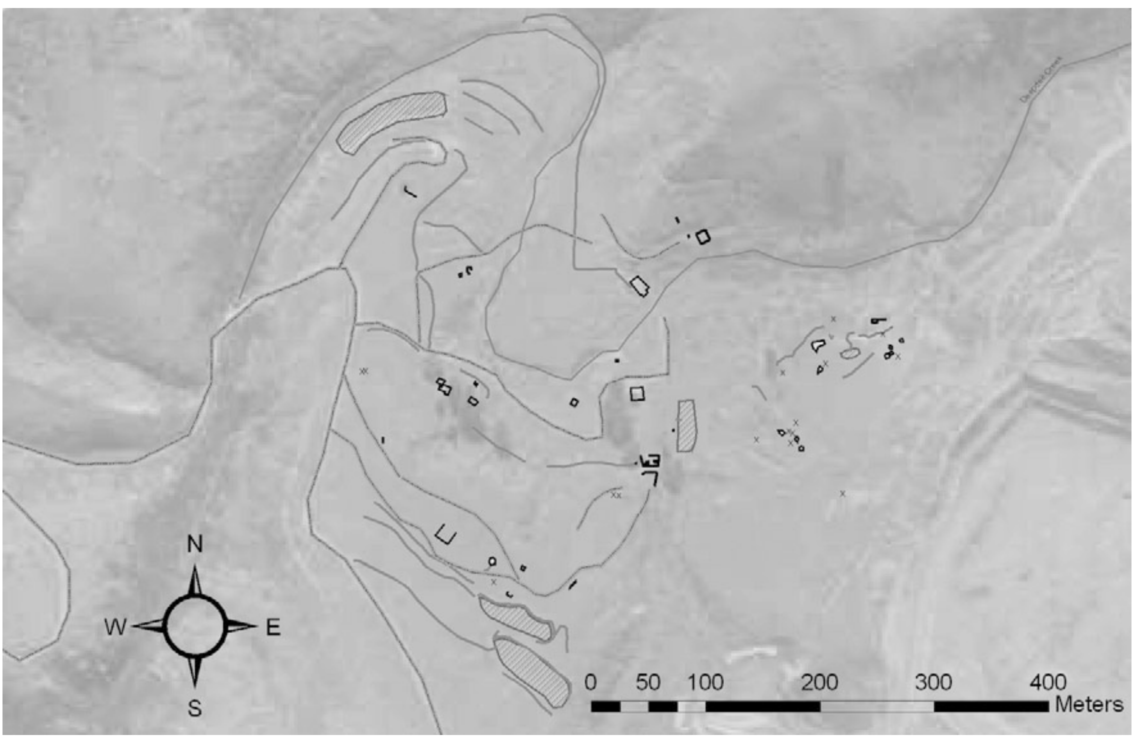

FIGURE 7. Golden Point, showing surface and water features. (Map by author, 2004.)

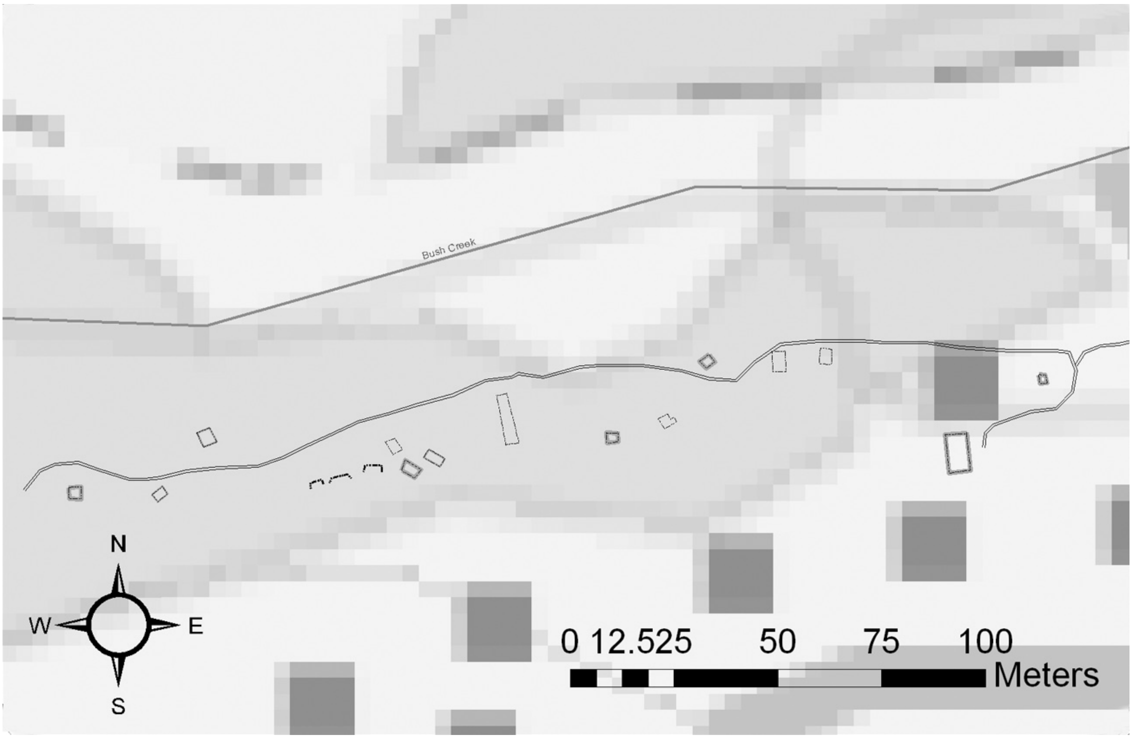

FIGURE 8. Arrowtown with topographic underlay. (Map by author, 2004.)

developed adjacent to Otago goldfields towns and is part of the Otago Goldfields Park, which contains 21 sites throughout the region, each site highlighting an aspect of goldfields history. The Arrowtown Chinese settlement is the only all-Chinese site in Otago that has not been substantially obscured by later development. The settlement was excavated in the 1980s and partially restored. Following the national government's 2002 public apology for the treatment of Chinese during the 19th and early-20th centuries, restoration work was again undertaken in 2003, using monies granted to help preserve and interpret aspects of the Chinese experience in Otago. The Arrowtown Chinese camp was mapped by the author to provide base information for the construction of a virtual tour site aimed at site visitors <http://www.little-yeti.com/nzarch/arrowtown/arrowtown.html>.

Fieldwork in the Otago Goldfields

The majority of fieldwork consisted of mapping surface features with GPS receivers. The unit used for recording measurements was the Trimble GeoExplorer CE XT, which has replaced more cumbersome units (such as the Trimble Pro-XR backpack units used by Smith, Clement, and Wise [2003] to map Civil War battlefield features) since it was introduced in 2002. The main difference between earlier units and the GeoExplorer is accuracy. The new unit can provide measurements to sub-meter accuracy in the field prior to postprocessing, which improves overall accuracy to approximately 25 cm or less. This increased accuracy allowed for the recording of fine features such as structure foundations and artifact mapping across the four sites.

As a test for measuring GPS accuracy, readings from the same staked position (one for each site) were taken each day during fieldwork to check the "drift" in accuracy of the units. These daily positions were compared, and the differences were used to gauge accuracy. This test confirmed an accuracy (or level of error) of approximately 25 cm for each site.

Including a preproject planning stage for the initiation of GPS surveys is a vital step in ensuring data integrity. In order to gain the greatest return from a GPS survey, the use of an almanac file is necessary. Almanac files, which are automatically collected by Trimble GPS units, record the positions of each satellite for the following month, allowing the user to create a timetable (also known as a plan) of excellent, good, and poor satellite service. Almanac files must be updated every 30 days to account for a GPS satellite's drift.

GPS units come with a built-in ability to predict the amount of error present from moment to moment. This capacity is referred to as dilution of precision (DOP), which measures the amount of error (uncertainty) at the moment GPS measurements are recorded. There are two main types of DOP values: the horizontal dilution of precision (HDOP) and the position dilution of precision (PDOP). HDOP gauges accuracy in two dimensions (horizontally) and relates to the x, y coordinate measurements. The more common PDOP gauges accuracy in three dimensions, and relates to x, y, z coordinate measurements. As a rule, the lower the PDOP, the more accurate the measurement, and a PDOP of 4 or less is ideal. The large spikes at 13:00 and 17:00 hours in Figure 9 demonstrate PDOP values that are too high for accurate recording. A more complete review of practical GPS field methods can be found in *Global Positioning Systems (GPS) in the Field: A Practical Guide to the Theory and Application of GPS Technologies* (Tennant and Rescot 2005).

The newer models of GPS units allow for real-time comparison of collected measurements with a map function. The experienced GPS user will make heavy use of this utility to guarantee that the collected data closely conform to the features mapped. As with many new technologies, ultimately the best way to develop expertise in GPS use is simple practice.

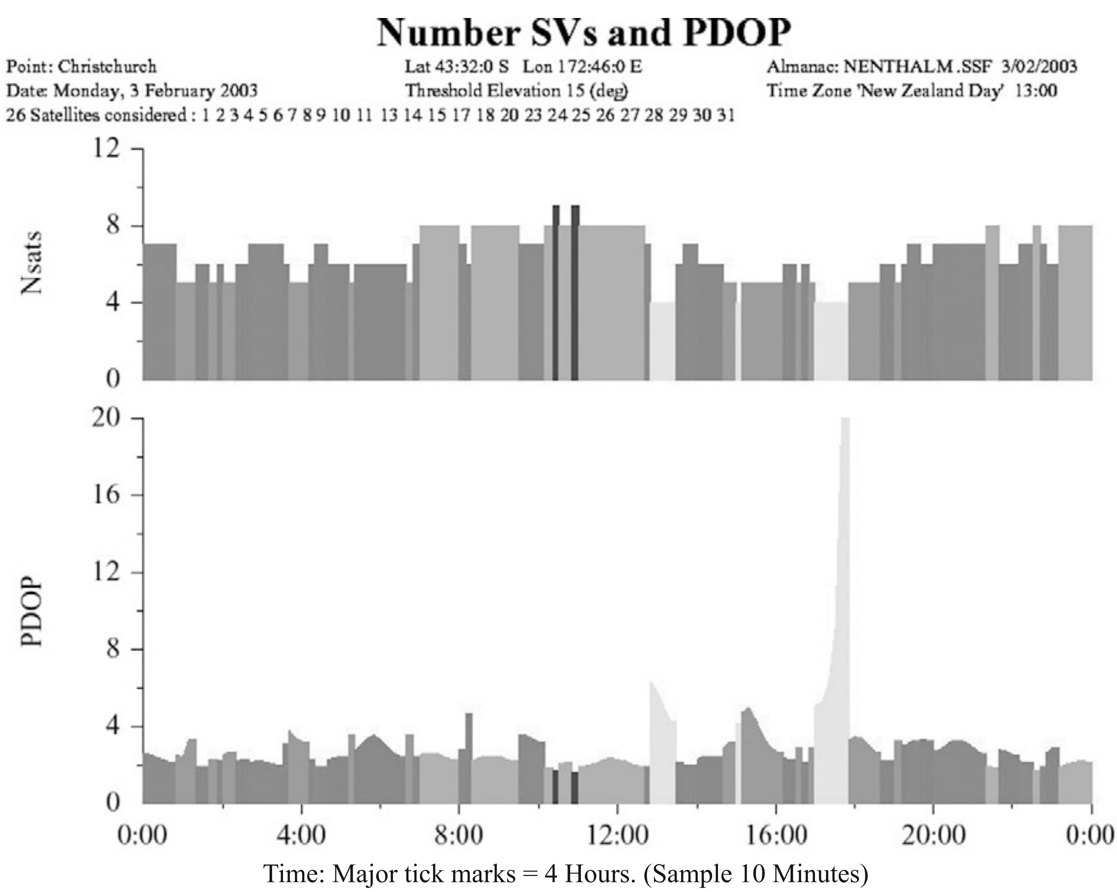

FIGURE 9. Sample plan from Nenthorn survey. (Graph by author, 2004.)

Data Processing

The ArcGIS suite of programs developed by the ESRI firm was the fundamental tool used for GPS data compilation in the Otago fieldwork. ArcGIS, as opposed to a CAD program, was used to manipulate the data for two important reasons: first, to develop a document that could assist and coexist with future archaeological research in Otago; second, to explore applications of ArcGIS that extend beyond simple map making.

Importing GPS data into ArcGIS is convenient for a number of reasons. The Trimble GeoExplorer units were designed to work with Trimble's Pathfinder Office software. The GPS receivers can be connected to a computer via a serial or USB cable, and the program then transfers the files, which contain mapping vector data already in point, line, and polygon shapes. This allows data collected with Trimble GPS receivers to be quickly integrated into ArcGIS documents. There are two possible approaches to organizing this data, which exist as "shapefiles" or "feature classes" within ArcGIS. The first approach is to create a series of individual shapefiles that correspond to the different features the user wishes to represent. In the case of archaeology, this approach can create a bewildering number of shapefiles and system files. For example, the creation of artifact files in GIS with this method requires at least three shapefiles representing points, lines, and polygons. Since each shapefile actually consists of several system files (anywhere from 3 to 12, depending on the type of file), this means that 3 shapefiles may require up to 36 different system files. It is not difficult to imagine an archaeological database achieving truly epic numbers of system files, especially for a large project. A GIS program accessing several dozen individual shapefiles (literally hundreds of system files) requires significant system resources.

The second approach is to structure data in ArcGIS through a geodatabase, as was done with the work at Otago. This format option was introduced by ESRI in the ArcGIS 8.1 release in 2000 and was subsequently improved with ArcGIS 9.0 (2004) and 9.1 (2005). Using the geodatabase structure has numerous advantages. An immediate benefit is the much lower number of system files created. A GIS accessing a few dozen separate shapefiles is, in actuality, accessing several hundred system files simultaneously. This action creates an enormous drag on system resources and results in unsteady performance, even crashing some computers (the author's included). The geodatabase, instead, is one system file, and the GIS software, no matter what is asked of it, only has to access this one file, freeing up system resources.

Tim Ormsby and colleagues (2001) outline three further advantages to using a geodatabase. These advantages deal with the structure of GIS data. As already mentioned, vector data (points, lines, and polygons) are stored in shapefiles, otherwise known as feature classes and defined as "a group of points, lines, or polygons representing similar" geographically related objects (Ormsby et al. 2001:351). A geodatabase allows for the creation of feature datasets. The creation of a feature dataset enables coordinated relationships between feature classes instead of using individual shapefiles. If a feature class representing artifact points is moved, the subsequent artifact polygon and line feature classes are also moved, ensuring their continued relationship.

Another advantage of the geodatabase structure is that it allows for the creation of domains. A domain assigns valid values or ranges for the attribute table that forms part of the information contained within a feature class. This feature reduces errors in data entry by eliminating invalid entries and reducing data-entry time through the creation of a series of drop-down menus. The construction of a geodatabase also has advantages for future research, specifically work that uses GPS receivers. The structure of a geodatabase, with its domain settings in place, mirrors the data dictionary structure used in GPS units. Data collected with a GPS unit records data, using a data dictionary derived from the geodatabase, in a format that is immediately translatable into a usable GIS file. These GIS files can be quickly incorporated into the geodatabase for updating purposes, fulfilling the requirement that an information system remain updatable.

The actual formatting of a geodatabase is, in reality, not very complicated. The possible structural elements number less than a dozen. The most basic element is the feature class or shapefile. Vector data (points, lines, and polygons) have attribute tables as part of their basic structure. At the same fundamental level are raster feature classes, which consist of continuous data such as aerial photographs, scanned images, or continuous elevation data. Feature classes are grouped together to form feature datasets. Datasets can hold an unlimited number of feature classes.

Domains are set up in the properties of the geodatabase itself (Figure 10). They involve setting limits on possible inputs in the attribute tables of the feature classes (shapefiles). In essence, domains create drop-down menus in these tables that, as noted above, help decrease data entry error. Relationship classes connect fields in one feature-class attribute table to fields in another feature-class attribute table. One possible use of this would be an address table that is used for feature classes that contain different types of features at one address, such as polygons representing houses, points representing telephone poles, lines representing underground pipes, and so forth. A major benefit of using relationship classes is the time saved by eliminating the need to enter repetitive data in multiple feature classes.

As the feature classes created from the Otago goldfields field data were prepared, examples of data structuring from three additional sources were examined in order to decide what type of data to attach to the GIS files. The first example was from New Zealand: *Archaeological Site Recording in New Zealand* (New Zealand Archaeological Association 1999). The other two examples were American: *Arkansas Archaeological Survey's Automated Management of Archeological Site Data in Arkansas* (Hilliard and Riggs 2000) and the Florida Department of State Division of Historical Resources' *Smart-Form II* information system. This comparison was undertaken to provide an idea of standard types of data routinely attached to archaeological data within database and GIS projects.

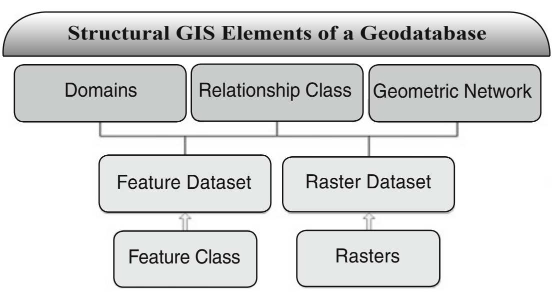

FIGURE 10. Diagram of geodatabase elements discussed in the text. (Drawing by author.)

A series of data fields was then constructed within each feature dataset using common attributes from the comparisons above. Six datasets were created, each containing a number of feature classes:

Arch-Tools	Information about archaeological organization of the work
Boundaries	Simple polygons labeled to outline work areas in the study
Structures	Information about standing or ruined structures, past or present
Artifacts	Information about individual artifacts or scatters of artifacts
Environment	Characteristics of the physical environment (natural or manmade)
Transportation	Information about transportation facilities, past or present

This data structure should not be construed as a call for standardizing structures according to these criteria. This organization is offered simply as a starting point for the archaeologist new to GIS (Figure 11). Basic attribute tables will often require additional data fields as work progresses. Additionally, some sites may have features that do not neatly fit into defined divisions such as artifact, structures, environment, and transportation. The basic concept of creating feature classes under broader feature datasets, however, allows users to create a "clean" dataset that can be added to in a timely and efficient manner.

Use of GIS Data at the Otago Goldfields

The simplest use of the data generated and organized as part of this project was the creation of site inventories for each of the four sites. The most practical way to access these data is through a series of paper maps or a visual interface. ESRI has eliminated the need to purchase the ArcMap program if a user is only interested in looking at, searching through,

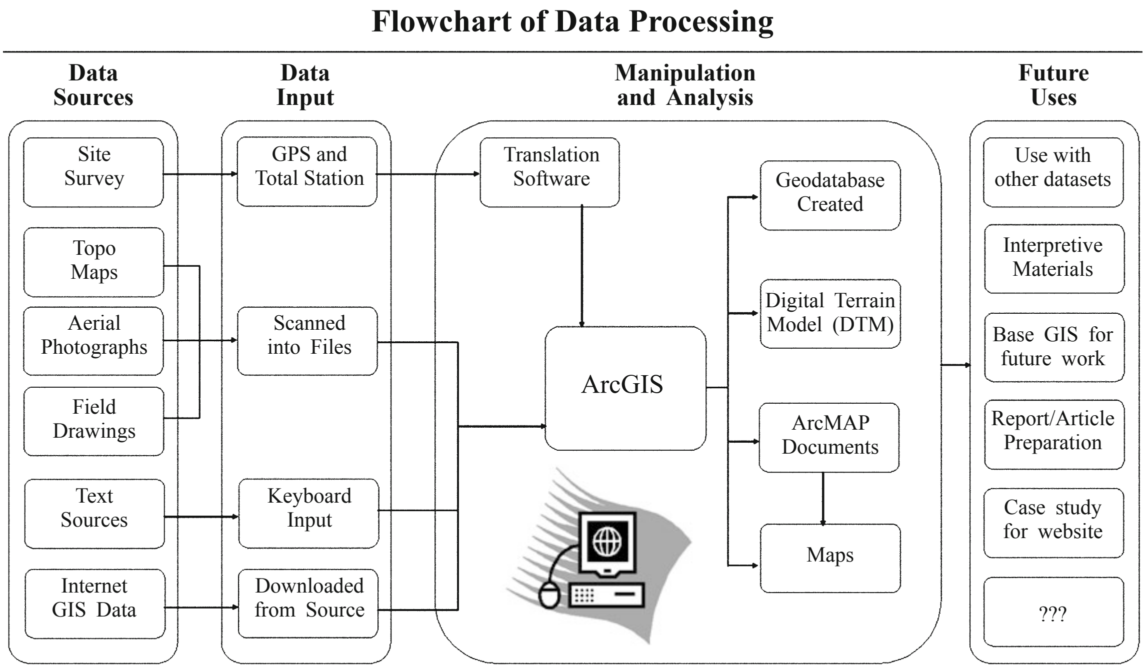

FIGURE 11. Flowchart of data processing. (Drawing by author.)

and printing maps of GIS data. The free ArcReader program is available for download from the ESRI website and can be used to view published map documents created by ArcMap. This enables anyone with a computer to view GIS data free.

On a more analytical level, a study of viewsheds at the Nenthorn site provides a case study of the type of analysis possible once basic data are appropriately organized. The sites of Nenthorn and Golden Point both featured hardrock mining operations and their associated stamping batteries, which are often incredibly noisy when in operation. The late Peter Bristow of the New Zealand Department of Conservation believed that sound may have guided the placement of structures in relation to these loud machines. The possibility that the natural landscape may have been used by the workers in order to shield them from the noises of these mills was considered during GIS analysis; the base hypothesis in this specific case was that locations that provided geographical buffers from noise might have been intentionally sought out by local residents.

The town of Nenthorn was situated above and away from the stamp mills. The placement of stamp mills is partially one of economics, in response to factors such as the availability of water, location of mine entrances, and suitable land features for construction. Figure 12 shows the location of the two stamp mills and the town. The town is on a portion of land with a gentle slope. While other areas that are closer to the stamp mills offer the same kind of geography, the town and individual huts were not placed there. Figure 13 shows two other possible locations with a similar amount of gentle sloping areas, but no remains currently exist there.

Finally, phenomenological approaches are rare in historical archaeology, and the inability to reproduce phenomenological methods is one reason why. However, using GIS to compute soundscapes is one potentially reproducible method, something increasingly addressed in phenomenology (Hamilton and Whitehouse 2006). Using the viewshed to compute soundscapes from the two mills (Figures 14, 15) provided at least one possible reason why no habitation structures were placed in the other two possible locations. Figures 14 and 15 show how a line of sight from the stamp mills includes portions of the other possible habitation areas. Soundscapes do not directly correspond to lines of sight, but the viewshed analysis does

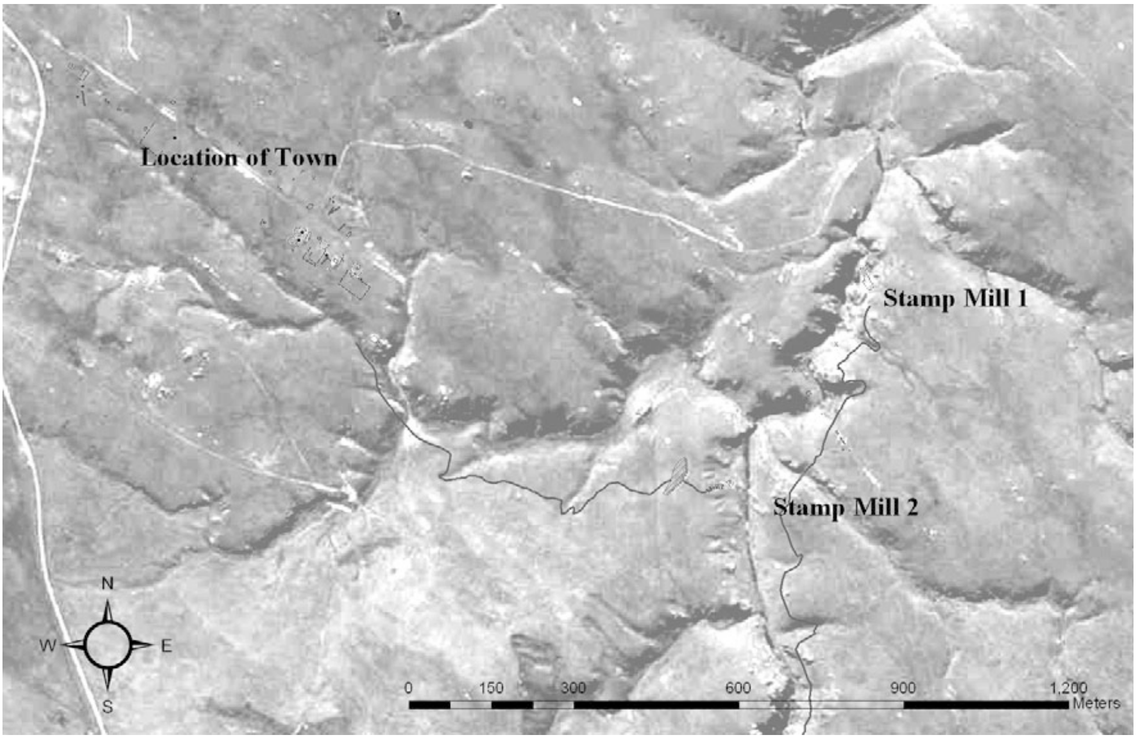

FIGURE 12. Location of stamp mills and Nenthorn township. (Map by author, 2004.)

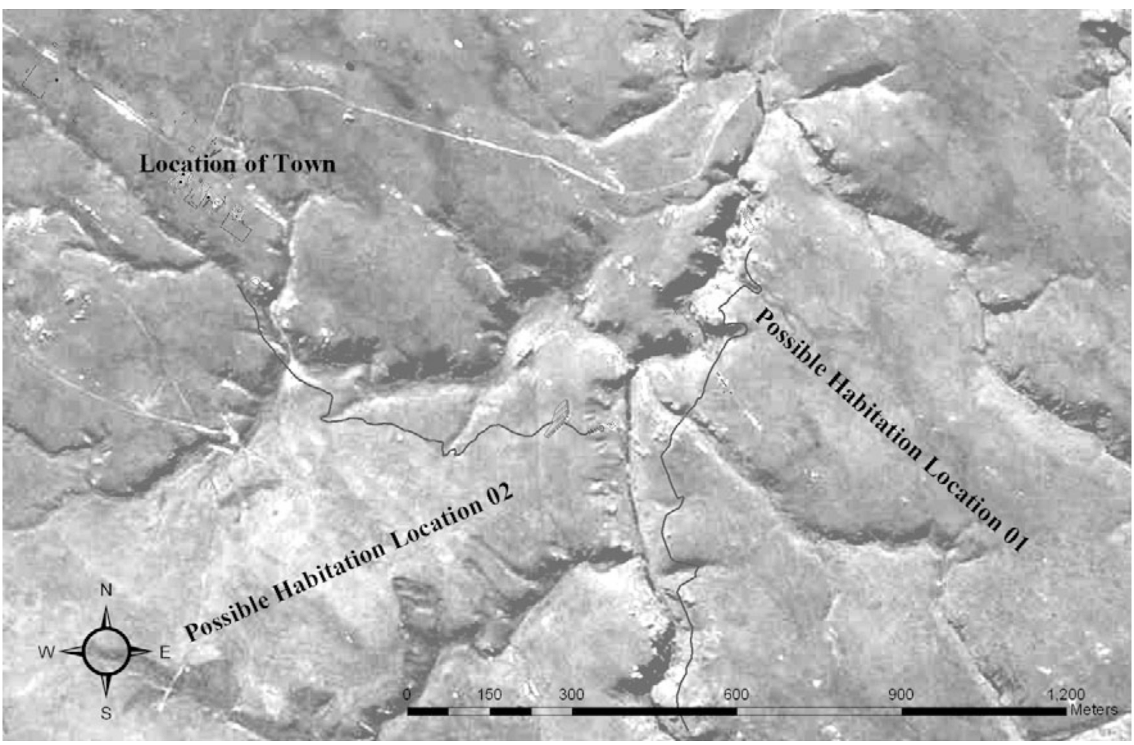

FIGURE 13. Possible habitation locations at Nenthorn. (Map by author, 2004.)

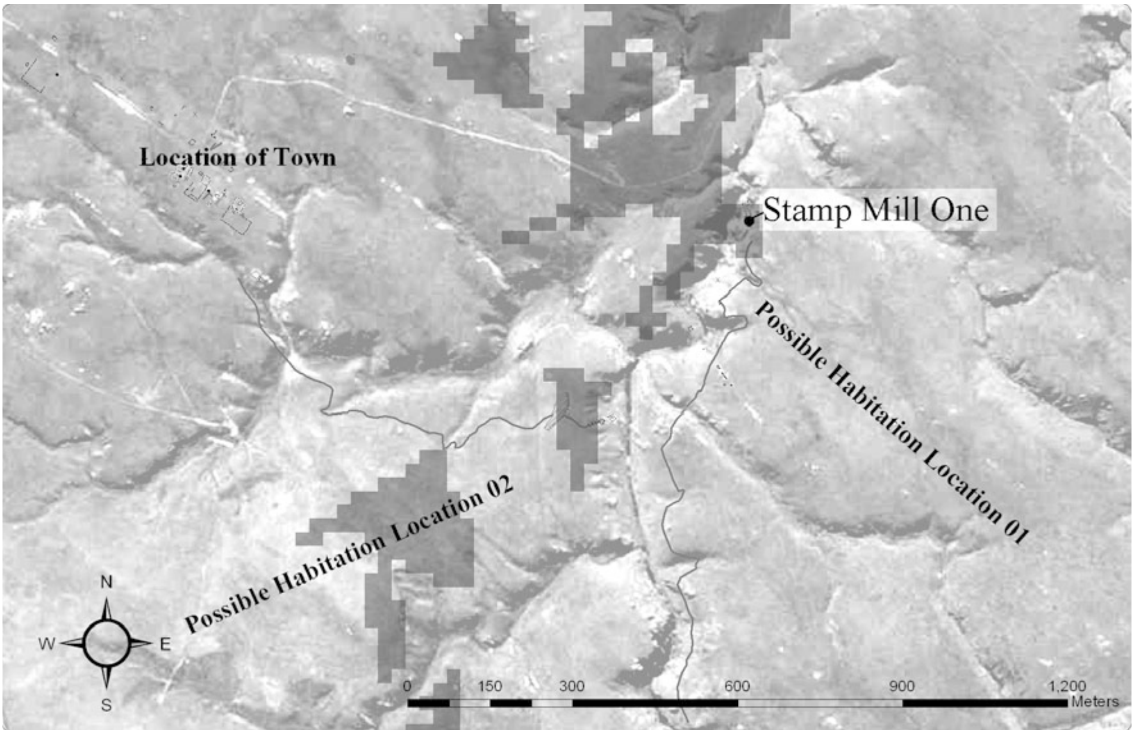

FIGURE 14. Viewshed from stamp mill one. (Map by author, 2004.)

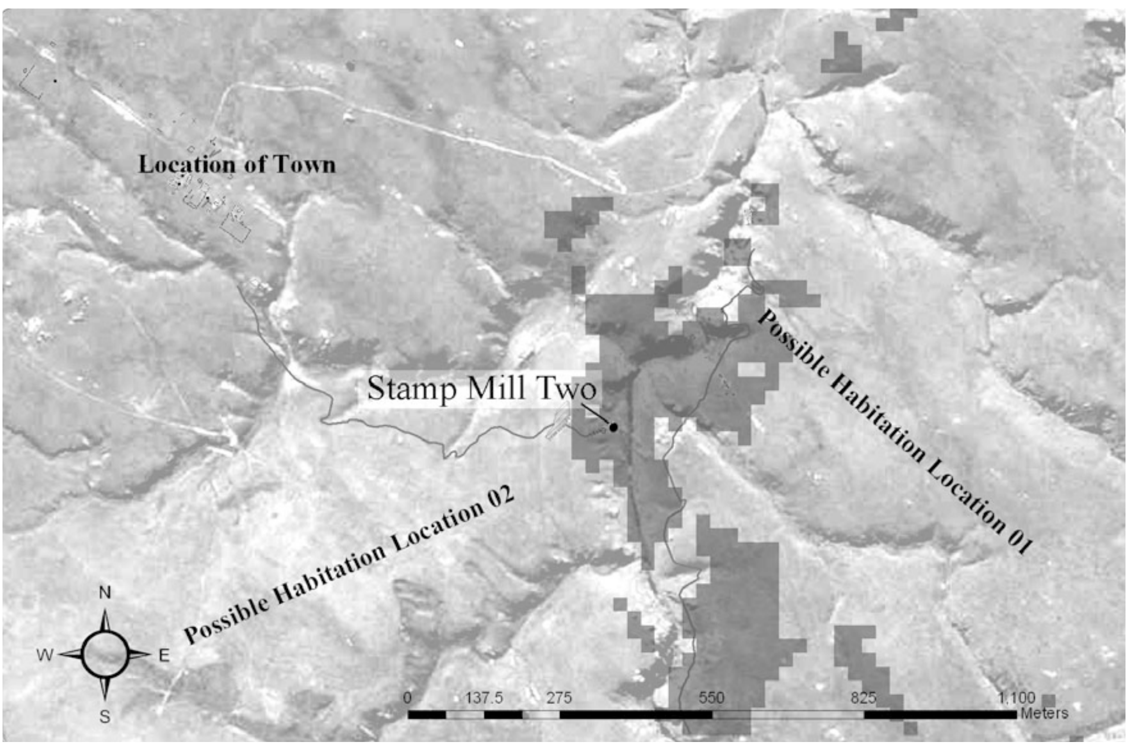

FIGURE 15. Viewshed from stamp mill two. (Map by author, 2004.)

confirm that sound might have been a determining factor in discouraging the placement of huts in these areas. While the placement of the town itself was possibly the result of other factors, there is no other apparent reason why miners would not have placed their own huts closer to their work sites.

Data Dissemination

As important as GIS analysis is to the archaeologist, it also provides an excellent tool for the public interpretation and dissemination of data, but the sharing of data is not limited to fellow professionals. Many archaeologists have walked the thin line between attracting the public to experience heritage areas while, at the same time, discouraging private citizens from going out and digging the sites themselves (Lerner and Hoffman 2000:231). The tension between involving the public and protecting sites is increasing, especially in places where tourism has become a major industry. One of the main methods for successfully navigating this type of situation is to control the amount and type of archaeological data released to the public. The use of GIS for storing archaeological data makes control of that data much more efficient (Wheatley and Gillings 2002:217).

Using the GPS data gathered, two forms of public presentation were designed for the Otago goldfields research. Archaeological maps were created using ArcMap. In addition, a website was created to host virtual tours of each site <http://www.little-yeti.com/nzarch>. These virtual tours include brief histories of the sites and hyperlinks to historic and modern photographs. This format allows users to navigate plan views of each site, with hyperlinks to pop-up windows of images, creating an interactive, self-guided virtual tour. Readers are encouraged to visit the web page to see the final outcome of the step-by-step GIS methodology previously described.

The use of web statistics software also allows website owners to monitor visitors to their sites on a page-by-page basis, thereby assessing how widely and efficiently data is disseminated. The statistics for a 12-month period demonstrate the effectiveness of using the Internet to disseminate this type of information to the public. The author's site uses AWStats software <http://awstats.sourceforge.net/> to monitor the number of visitor to the website and duration of the visit. While there is no way to determine how many hits are repeat visitors, the figures demonstrate that the Otago goldfields website was visited on nearly 25,000 separate occasions. Many of the visits each month come from search engines, and individuals may not remain at the site for a long period. Regardless, the web statistics still suggest that a large number of individuals have accessed the site over a 12-month period (Table 1).

Conclusion

Many archaeologists are familiar enough with the basics of GIS and GPS to appreciate the benefits that these technologies can bring to their research, but literature that guides the archaeologist in how to best organize GIS data for archaeological research was lacking. The use of GPS and GIS to map intrasite features is growing, mainly because as the prices of these units continue to drop, their accuracy improves dramatically, and the related software becomes increasingly intuitive. The uses of these technologies are becoming widely acknowledged, and increasing numbers of researchers are exploring their uses, demonstrated by the spread of courses at the undergraduate and graduate at

TABLE 1
MONTHLY VISITORS (NOV. 2005–OCT. 2006): ARCHAEOLOGY AND TECHNOLOGY ON THE OTAGO GOLDFIELDS <HTTP://WWW.LITTLE-YETI.COM/NZARCH>

Month/Year	No. Visitors
Nov. 2005	2,161
Dec. 2005	2,646
Jan. 2006	1,963
Feb. 2006	1,782
Mar. 2006	2,130
Apr. 2006	2,602
May 2006	2,175
Jun. 2006	2,999
Jul. 2006	1,597
Aug. 2006	1,767
Sep. 2006	3,018
Oct. 2006	3,045
Total	**24,840**

universities around the world. Use of the steps and methodological approaches outlined in this paper will greatly improve data collection, ease data handling, and create documentation strategies that can benefit both present and future research. This tight control and quick manipulation of spatial data inside a GIS is well suited for heritage management purposes. The use of 3-D site reconstructions on the Internet as a reputable vehicle for publication is a recent development. The acceptance of this medium is growing, evidence that many archaeologists want to share their work with each other and the lay public in a direct and immediate manner.

Acknowledgments

The Fulbright Scholarship funded this project for Study Abroad at the University of Arkansas. Peter Bristow at the New Zealand Department of Conservation was a constant source of inspiration and practical advice. I am eternally grateful for his guidance. While his unexpected passing in December 2004 was a source of great sadness and sorrow, his dedication and passion for archaeology will not be forgotten. The web version of the author's thesis on the growing use of GPS and GIS in archaeology is at <www.little-yeti.com/nzarch>. A website that provides practical information about using ArcGIS for archaeology, including a series of tutorials, is at <http://gis.little-yeti.com>.

References

ALDENDERFER, MARK
1992 The State of the Art: GIS and Anthropological Research. *Anthropology Newsletter* 33(5):14.

ALDENDERFER, MARK, AND HERBERT D. G. MASCHNER
1996 *Anthropology, Space, and Geographic Information Systems*. Spatial Information Series. Oxford University Press, New York, NY.

ALLEN, KATHLEEN M. S.
1996 Iroquoian Landscapes: People, Environments, and the GIS Context. In *New Methods, Old Problems: Geographic Information Systems in Modern Archaeological Research,* Herbert D. G. Maschner, editor, pp. 198–222. Occasional Paper No. 23. Southern Illinois University Center for Archaeological Investigations, Carbondale.

ALLEN, KATHLEEN M. S., STANTON W. GREEN, AND EZRA B. W. ZUBROW (EDITORS)
1990 *Interpreting Space: GIS and Archaeology, Applications of Geographic Information Systems.* Taylor and Francis, London, England, UK.

BISWELL, S., L. CROPPER, J. EVANS, V. GAFFNEY, AND P. LEACH
1995 GIS and Excavation: A Cautionary Tale from Shepton Mallet, Somerset, England. In *Archaeology and Geographical Information Systems: A European Perspective,* Gary Lock and Zoran Stancic, editors, pp. 269–286. Taylor and Francis, London, England, UK.

BRISTOW, PETER
1994 Archaeology and Ethnicity of the Remote Otago Goldfields. Master's thesis, Department of Anthropology, University of Otago, Dunedin, New Zealand.

CHARTRAND, JEFFREY, JULIAN RICHARDS, AND BLAISE VYNER
1993 Bridging the Urban-Rural Gap: GIS and the York Environs Project. In *Computing the Past: Computer Applications and Quantitative Methods in Archaeology, CAA92,* Jens Andresen, Torsten Madsen, and Irwin Scollar, editors, pp. 159–166. Aarhus University Press, Aarhus, Denmark.

CONOLLY, JAMES, AND MARK LAKE
2006 *Geographical Information Systems in Archaeology*. University Press, Cambridge, England, UK.

FISHER, PETER F.
1999 Geographical Information Systems: Today and Tomorrow? In *Geographical Information Systems and Landscape Archaeology*, Mark Gillings, David Mattingly, and Jan van Dalen, editors, pp. 5–12. Oxbow Books, Oxford, England, UK.

GAFFNEY, V., AND P. M VAN LEUSEN
1995 Postscript: GIS, Environmental Determinism, and Archaeology. In *Archaeology and Geographical Information Systems: A European Perspective,* Gary Lock and Zoran Stancic, editors, pp. 367–382. Taylor and Francis, London, England, UK.

HAMILTON, SUE, AND RUTH WHITEHOUSE
2005 Phenomenology in Practice: Towards a Methodology for a 'Subjective' Approach. *European Journal of Archaeology* 9(1):31–71.

HASENSTAB, ROBERT J.
1996 Settlement as Adaptation: Variability in Iroquois Village Site Selection as Inferred through GIS. In *New Methods, Old Problems: Geographic Information Systems in Modern Archaeological Research,* Herbert D. G. Maschner, editor, pp. 223–241. Occasional Paper No. 23. Southern Illinois University Center for Archaeological Investigations, Carbondale.

HILLIARD, JERRY E., AND JOHN RIGGS
2000 *AMASDA Site Recording Manual*. Technical Paper No. 1. Arkansas Archeological Survey, Fayetteville, AR.

JACOMB, CHRIS, AND SCOTT EASDALE
1984 Nenthorn Interim Report. Manuscript, Department of Lands and Survey, Dunedin, New Zealand.

JOHNSON, IAN, AND M. NORTH (EDITORS)
1997 *Archaeological Applications of GIS: Proceedings of Colloquium II, UISPP XIIIth Congress, Forli, Italy, September* 1996. Archaeological Methods Series, No. 5. Sydney University, Sydney, Australia.

KVAMME, KENNETH L.
1999 Recent Direction and Development in Geographical Information Systems. *Journal of Archaeological Research* 7(2):153–202.

LERNER, SHEREEN, AND TERESA HOFFMAN
2000 Bringing Archaeology to the Public: Programs in the Southwestern United States. In *Cultural Resource Management in Contemporary Society: Perspectives on Managing and Presenting the Past*, Francis P. McManamon and Alf Hatton, editors, pp. 231–246. Routledge, New York, NY.

LOCK, GARY R.
1993 GIS or CAD: What's in a Name? *Archaeological Computing Newsletter* 37:1–2.
2000 *Beyond the Map: Archaeology and Spatial Technologies*, North Atlantic Treaty Organization, Science Series A: Life Sciences. IOS Press, Amsterdam, Netherlands.

LOCK, GARY R., AND T. M. HARRIS
1996 Danebury Revisited: An English Iron Age Hillfort in a Digital Landscape. In *Anthropology, Space, and Geographic Information Systems,* Mark Aldenderfer and Herbert D. G. Maschner, editors, pp. 214–240. Oxford University Press, New York, NY.

LOCK, GARY R., AND ZORAN STANCIC
1995 *Archaeology and Geographical Information Systems: A European Perspective.* Taylor and Francis, London, England, UK.

MADRY, SCOTT L. H., AND CAROLE L. CRUMLEY
1990 An Application of Remote Sensing and GIS in a Regional Archaeological Settlement Pattern Analysis: The Arroux River Valley, Burgundy, France. In *Interpreting Space: GIS and Archaeology*, Kathleen M. S. Allen, Stanton W. Green, and Ezra B. W. Zubrow, editors, pp. 364–80. Taylor and Francis, Bristol, PA.

MADRY, S. L. H., AND L. RAKOS
1996 Line-of-Sight and Cost-Surface Techniques for Regional Research in the Arroux River Valley. In *New Methods, Old Problems: Geographic Information Systems in Modern Archaeological Research,* Herbert D. G. Maschner, editor, pp. 103–126. Occasional Paper No. 23. Southern Illinois University Center for Archaeological Investigations, Carbondale.

MASCHNER, HERBERT D. G. (EDITOR)
1996 *New Methods, Old Problems: Geographic Information Systems in Modern Archaeological Research*. Occasional Paper No. 23. Southern Illinois University Center for Archaeological Investigations, Carbondale.

MILLER, A. PAUL
1995 How to Look Good and Influence People: Thoughts on the Design and Interpretation of an Archaeological GIS. In *Archaeology and Geographical Information Systems: A European Perspective,* Gary Lock and Zoran Stancic, editors, pp. 319–334. Taylor and Francis, London, England, UK.
1996 Digging Deep: GIS in the City. In *Interfacing the Past: Computer Applications and Quantitative Methods in Archaeology, CAA95,* Hans Kamermans and Kelly Fennema, editors, vol. 2, pp. 369–376. Analecta Praehistorica Leidensia, No. 28. University of Leiden, Leiden, Netherlands.

NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION
1999 *Archaeological Site Recording in New Zealand*. Monograph No. 23. New Zealand Archaeological Association, Department of Conservation, Wellington, New Zealand.

NEW ZEALAND HOUSE OF REPRESENTATIVES
1861 Goldfields Warden's Reports, Section D. In *Appendices to the Journal of the House of Representatives*. Department of Justice, Wellington, New Zealand.
1863 Goldfields Warden's Reports, Section D. In *Appendices to the Journal of the House of Representatives.* Department of Justice, Wellington, New Zealand.

NG, JAMES
1993 *Windows on a Chinese Past,* vol. 1. Otago Heritage Books, Dunedin, New Zealand.

ORMSBY, TIM, EILEEN NAPOLEN, ROBERT BURKE, CAROLYN GROESSL, AND LAURA FEASTER
2001 *Getting to Know ArcGIS Desktop: Basic of ArcView®, ArcEditor™, and ArcInfo™*. ESRI, Redlands, CA.

PYKE, VINCENT
1962 *History of the Early Gold Discoveries in Otago.* Otago Daily Times and Witness Newspapers Company, Dunedin, New Zealand.

RITCHIE, NEVILLE A.
1986 Archaeology and History of the Chinese in Southern New Zealand during the Nineteenth Century: A Study of Acculturation, Adaptation, and Change. Doctoral dissertation, University of Otago, Dunedin, New Zealand.

ROMANO, DAVID G., AND OSAMA TOLBA
1995 Remote Sensing, GIS, and Electronic Surveying: Reconstructing the City Plan and Landscape of Roman Corinth. In *Computer Applications and Quantitative*

Methods in Archaeology, 1994, J. Huggett and N. Ryan, editors, pp. 163–174. BAR International Series, No. 600. Tempus Reparatum, Oxford, England, UK.

Salmon, J. H. M.
1963 *A History of Gold-Mining in New Zealand*. R. E. Owen, Wellington, New Zealand.

Smith, Steven D., Christopher Ohm Clement, and Stephen R. Wise
2003 GPS, GIS, and the Civil War Battlefield Landscape: A South Carolina Low Country Example. *Historical Archaeology* 37(3):14–30.

Steele, J., T. J. Sluckin, D. R. Denholm, and C. S. Gamble
1996 Simulating Hunter-Gatherer Colonization of the Americas. In *Interfacing the Past: Computer Applications and Quantitative Methods in Archaeology, CAA95,* Hans Kamermans and Kelly Fennema, editors, vol. 2, pp. 223–227. Analecta Praehistorica Leidensia, No. 28. University of Leiden, Leiden, Netherlands.

Tennant, Edward W., and Peter Bristow
2004 Mapping Nenthorn: Taking Advantage of Emerging GPS and GIS Technologies. *Archaeology in New Zealand* 47(3):203–214.

Tennant, Edward W., and Robert A. Rescot
2005 *Global Positioning Systems (GPS) in the Field: A Practical Guide to the Theory and Application of GPS Technologies*. U.S. Department of Transportation, Eastern Roads Division, Sterling, VA.

Thompson, Helen M.
1949 *East of the Rock and Pillar: A History of the Strath Taiere and MacRaes Districts*. Otago Centennial Historical Publications, Dunedin, New Zealand.

Westcott, Konnie L., and R. Joe Brandon
2000 *Practical Applications of GIS for Archaeologists: A Predictive Modeling Kit*. Taylor and Francis, London, England, UK.

Wheatley, David
1996 Between the Lines: The Role of GIS-Based Predictive Modelling in the Interpretation of Extensive Survey Data. In *Interfacing the Past: Computer Applications and Quantitative Methods in Archaeology, CAA95,* Hans Kamermans and Kelly Fennema, editors, vol. 2, pp. 275–292. Analecta Praehistorica Leidensia, No. 28. University of Leiden, Leiden, Netherlands.

Wheatley, David, and Mark Gillings
2002 *Spatial Technology and Archaeology: The Archaeological Applications of GIS*. Taylor and Francis, London, England, UK.

Williams, Gordon J.
1974 *Economic Geology of New Zealand*. Monograph Series, No. 4. Australasian Institute of Mining and Metallurgy, Carlton, Australia.

Williams, Jack
1992 The Archaeology of Underdevelopment and the Military Frontier of Northern New Spain. *Historical Archaeology* 26(1):7–21.

Edward González-Tennant
Department of Anthropology
University of Otago
Dunedin, New Zealand