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VOLUME I

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Digging deep: GIS in the city

1 Introduction

Over the past few years, CAA conferences have been bombarded by session after session on GIS applications. The conference proceedings for each year since the mid-eighties bear testament to the spreading adoption of GIS within the discipline, either through a rash of paper titles worded around 'GIS' or through allusions to a great new technology/awful new bandwagon within the text.

2 The evolution of GIS usage...

A cursory inspection of this literature is enough to suggest that the relationship between user and tool is a complex one, but it seems possible to simplify matters in order to describe an evolution in the way GIS is used and perceived by the profession. The simple analogy presented below serves to outline my view of the way in which we relate with this tool, and perhaps presents some timely warnings to those about to embark upon GIS-based research (or marriage!).

2.1 Stage One – Infatuation

The first stage would appear to be something approaching euphoria, as user and new toy court each other. The manual is incomprehensible, and the computer keeps insisting that it would really quite like 100Mb of RAM for the operating system, and with what you have given it you can forget running GIS too, but these problems are all surmountable. Given all that free time for research during the summer vacation, you can soon have a fully featured GIS that will solve all the problems ever faced by your subject.

I went through this phase. I even said 'In short, this project will answer questions of deposit creation and survival..., and will look at how these deposits reflect past human activity within the city' (Miller 1995: 153). The implication was that my GIS and I could 'solve' York.

2.2 Stage Two – True Love

After a while spent experimenting, the lucky GIS user gets a break, and courtship is replaced by love. Ideas of solving the problems of your specialism are soon replaced by megalomaniac tendencies — you and your GIS can solve *everything*. In my case, the lucky break was getting ARC/INFO's topology working well enough to select the city walls from a map of York, *and* colour them in.
A happy few days were spent painting the city walls using every colour in ARC/INFO's palette; no one else was impressed.

2.3 Stage Three – The threat of divorce...

Then the crash comes. In a fit of pique, your GIS starts *doing* things to your data. Previously closed polygon coverages spring leaks, and your nice database begins to look decidedly unwell. You seriously consider divorcing the GIS to run off with that nice drafting pen you met at a party. In conference presentations, this period expresses itself in the 'GIS is just a bandwagon. It cannot help archaeology' type of paper. These papers are as common — and as damaging — as the more positive papers advertising GIS as the answer to all problems.

2.4 Stage Four – Middle Aged contentment

For those stupid or stubborn enough to persevere past this threat of divorce, you then enter the last phase, where user has developed a healthy respect for GIS. Your use of the system is now tinged by a suspicion that it might be lying to you, which is probably a good thing. Your awareness of the limitations of system and data is now at its height, but you are also optimistic enough to recognise where potential does exist for useful research. In many cases, the presentations are less pretty and less impressive than in earlier stages, but they work, and your techniques are durable enough to withstand the battering of daily use.

I'm not sure what comes next in this analogy, as I can't really see me and my GIS staying in at night to drink cocoa in 40 years' time...

An advantage of having reached such maturity within your relationship is that a number of papers have been published (Chartrand/Miller 1994; Miller 1994, 1995; Miller/Oxley 1994) which cover the background to your work, meaning that little time needs to be spent introducing issues. Straining this analogy towards breaking point, you could say that all your friends have by this time met your new partner...

Figure 1. Deposit thickness across York city centre. Map shows computed thickness of deposition *c.* AD 70 - 1990.

3 Background

York has been an urban centre for some 2000 years (Addyman 1994), ranging from its apparent foundation as a Roman legionary fortress (Ottaway 1993) through Anglian *wic* and ecclesiastical centre to the famous Viking Jorvik (Hall 1994) and on into the Middle Ages as archdiocese and market centre.

Due to favourable conditions, deposits from this past have been well preserved across the city, and in some areas highly stratified anaerobic remains extend more than 10 metres below the modern street level. This research aims to examine the nature of deposits beneath York, and has been using them to answer questions about the city throughout its past.

Along with a group of others (Chartrand this volume; Mytum this volume; Richards this volume), this paper is part of a wider examination of the use of GIS at scales from the individual site (Mytum this volume; Richards this volume) through urban entity to the wider landscape (Richards this volume, Chartrand this volume). The urban assessment work in York described here fits in near the bottom end of the scale, examining everything from individual excavations through to a chunk of the urban entity some 3000 hectares in area. Even in this work, where the range of working scales from individual site to city core is relatively small, a variety of techniques need to be applied in any modelling of deposits. The research has shown the difficulty of applying standard techniques to problems at a variety of scales, and has illustrated the ways in which display and analysis techniques must be tailored towards specific problems.

4 Micro-scale applications

Although the examination of site-level dynamics within the city might appear less complex than the study of whole landscapes, added complexity is introduced by the significant deposition to be found in urban centres such as York, where ten metres or more of deposition are not unusual (fig. 1). Combined with the dense nature of settlement and the often anaerobic conditions, this makes York a vitally important archaeological resource, on a par with the Walbrook valley in London, the river front in Dublin and the centre of Ribe in Denmark.

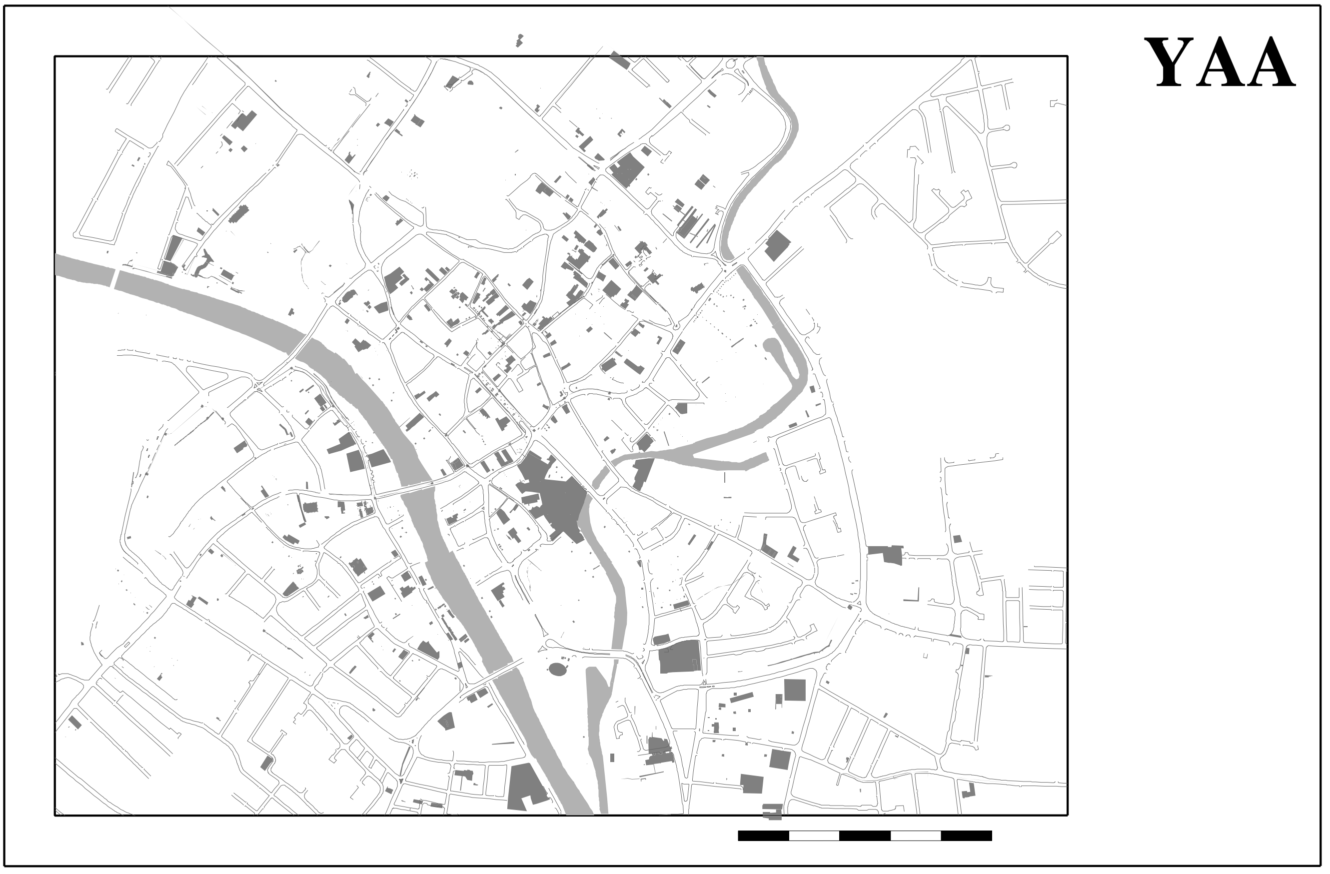

Figure 2. Excavations carried out by York Archaeological Trust, 1972-1992.

In a city such as York, there has been extensive archaeological work over the past few centuries which today provides a rich archive describing everything from antiquarian observations to state of the art excavations. A database of these contacts with the archaeology has been compiled (Miller 1994; Ove Arup 1991), ranging from observations of a Roman cemetery in 1681 through to York Archaeological Trust excavations at the end of 1992. The excavations of York Archaeological Trust over the past 20 years (fig. 2) have greatly enriched this archive, and two of their sites have been selected for examination in order to assess the usefulness of their archives to deposit related questions (fig. 3) at the micro level of the individual excavation.

4.1 City Garage, Blake Street

City Garage, 9 Blake Street, was excavated in 1975, and the extant archive reflects the age of this site. At the time, planning was by means of large composite plans, rather than today's single context system. The lack of a level III report and some apparent inconsistencies within the archive made the site difficult to study, and the final results were less than satisfactory for deposit modelling purposes.

Several hundred points were collected for six identified periods of occupation from the early first century AD through to the post-Medieval. Points were gathered in order to define the land surface at the beginning of each period, and were derived from all available site plans either as physically surveyed levels or as interpolated points manually generated in order to effectively render topography as described by hachures and breaks of slope on paper plans.

The distribution of points was far from even, and several points in one period even appear outside the accepted edge of excavation. Given the nature of the data, the available points produced very disappointing surfaces, and it is unlikely that any new information about the site may be gained from the exercise; the resulting elevation models would appear to bear no relation to the actual topography. In one case, only two points were available for the whole period across the site, rendering that particular phase unmodellable.

Figure 3. Locations of 9 Blake Street and 12-18 Swinegate, plus other YAT excavations.

4.2 12-18 Swinegate

The second site, 12-18 Swinegate, was excavated in 1989, by which time single context planning was in use. Helpfully, this site was one of those earmarked for experimentation with computer based techniques and, as such, all site plans were entered into Brian Alvey's Hindsite system (discussed at the 1989 CAA conference in York, but unpublished) during or soon after the excavation. Context information was also input into York Archaeological Trust's Context Recording System (CRS) database on site.

The nature of data storage made it a relatively simple task to identify those contexts on the 'bottom' of each period, and to extract them from the archive. These were then combined to create period surfaces, complete with breaklines defining the shape of cut features on the site. The resulting surfaces are far more realistic, contain far more data, and were constructed more rapidly than those for Blake Street.

Although only based on a sample of two sites, the results of this study would appear to highlight some of the dangers inherent in assumptions made about the value of data so painstakingly recorded. Without the presence of breaklines, even the increased density of points from Swinegate produces an unrecognisable and unsightly representation of the surface, and even the best results from Blake Street are dismally poor. Given the increased interest in building models such as these for excavations and larger areas, there is a need for greater care to be taken in recording, analysing and representing the data from which they are built. It seems that while prepared to accept some data without question, we are equally prepared to spend extended periods of time debating the smallest elements of other data sets in the name of academic integrity. A little more consistency might not be a bad thing.

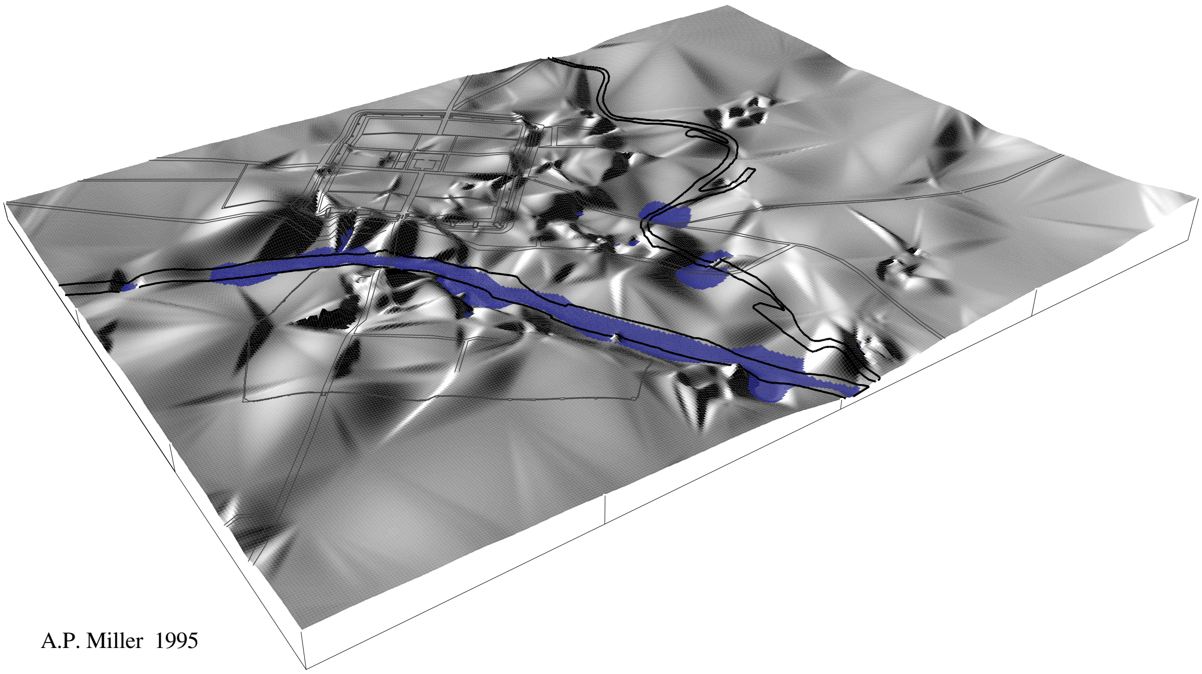

Figure 4. Digital Elevation Model (DEM) depicting the Roman topography of central York. Scale interval 500 m.

5 Macro-scale applications

Utilising a database of over 2,000 archaeological contacts, it becomes possible to produce surfaces depicting the topography across York at various periods in the past; and to examine the volumes represented by the boundaries of these surfaces. Due to the nature of the data, the best of these are the surfaces depicting the modern and Roman topographies, where alternative sources of elevation data add significantly to the distribution of data points from archaeology.

5.1 Topographic modelling

Modern topography has been constructed primarily from 1412 manhole cover heights provided by Yorkshire Water and York City Council. Other sources of data were investigated including stereo photogrammetry, the City Engineers and survey by Global Positioning System. Sadly, stereo photogrammetry of sufficient resolution proved prohibitively expensive, the City Engineers appear not to store height information over the long term, and cities such as York represent particular problems to GPS-based survey as it is really difficult to see enough sky for one satellite, let alone the three or more required for accurate locational information.

The Roman topography is derived from borehole logs and excavated evidence (fig. 4). Whilst the modern surface shape was refined through the use of breaklines defining the *known* course and elevation of the river system, the Roman surface is generated solely from a series of elevation values. As such, the depicted river course is based upon computer estimates of mean water level rather than excavated evidence for the whole length of the river bank. Despite this, the majority of the modelled river system appears remarkably plausible.

Given data on surfaces at different points in the past, it becomes simple to generate a map of accumulated deposition across the city (fig. 1).

Figure 1, constructed simply by subtracting the Roman from the modern surface, clearly indicates the areas of significant deposition within the city. As would be expected, they lie primarily within the Coppergate/Ousegate focus between the rivers Ouse and Foss.

Areas of negative deposition are also apparent. These white areas mark elements of the terrain model where the Roman surface was found to be higher than the modern. Whilst some of these may represent anomalies, many of the negative areas are accurate depictions of recent civil

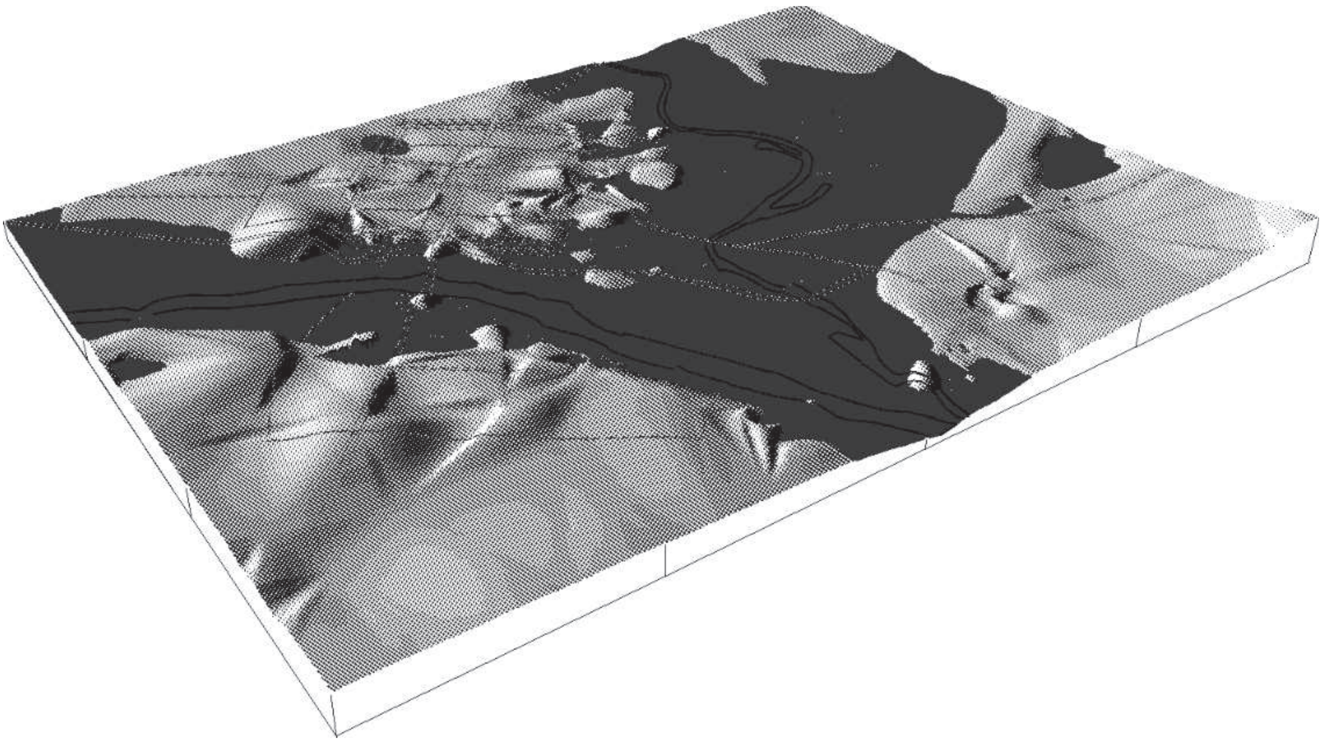

Figure 5. Result of flooding Roman elevation model to 10.66 m, as proposed by Herman Ramm. Scale interval 500 m.

engineering excesses, as with the British Rail headquarters complex, which today lies well below the surrounding ground in a readily apparent hole.

In any application of archaeological data, it is important to find ways in which the errors inherent within data collection, as well as analyses and displays, may be quantified and made explicit. The advent of tools such as GIS make it easier for users to produce impressive and visually stimulating results from often wholly inadequate data, and this trend increases the importance of developing error display techniques (Miller/Richards 1995). Within the York Archaeological Assessment, different ways of recording and representing error are being investigated, both in the form of metadata within the project database and in graphical displays of reliability.

5.2 Some basic archaeo-hydrological analyses

In the current debate raging over the possibility of preserving archaeology undamaged beneath modern buildings (Biddle 1994, 1995; Carver 1993, 1994; Ove Arup 1991), the most common suggestion has been that piles could be used to minimise disruption to the rich deposits beneath the ground (Ove Arup 1991: 49-52).

When deciding whether or not to employ piling it will be important to evaluate the effect groundwater has had on the preservation of any one site. Given that many of the most impressive sites in cities such as York are those sporting waterlogged deposits, it is likely that piling could have a disastrous impact upon preservation — the pile could act very efficiently to pierce the waterproof layer beneath the deposits, thus draining water from the site and potentially desiccating the deposits with disastrous consequences both for the archaeology and, possibly, for surface stability. Further work is required on the effects of piling, but it is unlikely that the technique will prove to be the perfect solution some expect it to be.

With information gathered from excavations and boreholes, it becomes possible to map the known extent of waterlogging, and to predict the unexplored areas also likely to contain waterlogged remains. It may well be that piling should be prohibited as a form of preservation in the mitigation strategies for those areas indicated as bearing waterlogged deposits.

A second area in which water has an effect upon York is the actions of the rivers during flood season. York still faces serious problems from flooding, despite the millions of pounds spent by the National Rivers Authority on flood alleviation. Given the effects of deforestation and dredging upon regional hydrology both now and in the past, it seems likely that the rivers were an important consideration throughout York's past.

In the early 1970's the late Herman Ramm (1971) proposed that 4th century Roman York was badly affected by the impact of rising river levels. He proposed that river levels rose to reach the 35' (10.66 m) contour, approximately 5 m above current mean water level and more than 7 m above computed mean Roman levels. This hypothesis was based upon limited evidence from a small number of excavations within the city, and was made in relation to the modern topography of the day.

For several reasons, the Ramm hypothesis was discredited, generating a backlash within York archaeology against the interpretation of alluvial deposits as being flood related. It is currently almost impossible to find serious references to flooding, despite evidence both of flooding today and of altering hydrology and sea levels in the past.

In figure 5 the Roman terrain model has been flooded to Ramm's 35' contour. The Roman fortress and the oldest parts of the *colonia* may both be clearly seen to sit above the flood zone. The lighter area is the computed area of the Roman river course when not flooding, which appears much narrower than has been suggested in the past (Ordnance Survey 1988). From this model, it is possible to plot the positions of known Roman excavations within the 'flood zone', and to investigate their archives in more detail in order to find means of refining the evidence for flooding. The current 10.66 m flood level proposed by Ramm may then be altered based upon this evidence in order to create more realistic views of river incursion in the late Fourth century.

6 Into the future ...?

When this project began, there was little existing expertise in the construction and interpretation of computer-generated deposit models for urban areas. Over the past couple of years, interest has grown and a number of organisations are now pursuing the possibilities offered by these techniques. Little work is being done, though, to judge the value or reality of the pictures produced. Hopefully, the research-driven nature of this particular project will allow it to produce both the pretty pictures and some guidelines for the ways in which they and others like them should be read.

Acknowledgements

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