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GIS and visualising the palaeoenvironment

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11.1 Introduction

Understanding the distribution of archaeological remains within a landscape is a difficult process. This is made even more challenging when the topography has undergone dramatic changes due to complex erosional and depositional processes. The fen edges of England are one such environment, much of it now a flat, alluviated landscape, revealing little of a well preserved relic landscape beneath.

These areas are not only of interest to archaeologists, they are also the target of mineral extractors due to the economic potential of associated sand and gravels. A large site north of the villages of Willingham and Over, Cambridgeshire, England, has been the focus of attention of one such company, ARC Central, who are to mine here for the next twenty years.

Using a set of over 1100 borehole samples collected by the company, it has been possible to use the depths of the alluvium, peat, sand, and gravels to model a series of relic landscapes, most notably a Bronze Age horizon. Using a Geographical Information System (GIS), the Digital Elevation Model (DEM) has undergone a series of techniques to aid the visualisation of the hidden landscape, helping to reveal some very interesting features which correspond well with its contemporary archaeology.

This paper shall discuss the processes involved in taking a raw data set and using the standard functions of a GIS to provide us with not only a rare look beneath the surface but also a base model upon which to create an effective prospection and management tool.

11.2 Visualisation and visual prediction

> Visualisation is a method of computing. It transforms the symbolic into the geometric, enabling researchers to observe their simulations and computations. Visualisation offers a method for seeing the unseen. It enriches the process of scientific discovery and fosters profound and unexpected insights. (McCormick *et al.* 1987)

So states a report which filled an entire issue of the periodical *Computer Graphics*. The above quote forms part of the opening statement defining what has now become a well used and accepted term, *Visualisation in Scientific Computing*.

GIS and its introduction to archaeology has meant that not only can databases and maps be held together in the same integrated system, but that complex data can be presented in a way in which we can visualise it on screen and so 'see the unseen'. In many cases, it is surface modelling which has been the main use of this methodology, the software enabling simple x, y and z data to be viewed in many different formats and perspectives. This is carried out with the intention of gaining further insight into the data, be it a representation of a cost surface or a terrain model.

Digital modelling is perhaps the most common form of data visualisation performed by a GIS. These models can be used to calculate parameters such as slope and aspect which can then be used in a deterministic manner to investigate and attempt to explain the distribution of sites. Another approach is to use a visual approach to understanding the archaeology within a landscape. By entering into a landscape through the use of perspective views it is argued that we will perhaps gain an insight into the perceived landscape of a time and place.

Whatever methodologies are thought beneficial, we are almost always restricted to the representation of a modern landscape when attempting to further our understanding of one that is not. The archaeology within any environment is to a large extent the product of interaction between inhabitants and this environment. Therefore it follows that a greater understanding will be gained through the investigation of past surfaces, landscapes which are contemporary with the societies which helped to form them.

However, the major problem in this methodology is a lack of data with which to model. Fortunately mining companies collect such information in the form of horizon depths while investigating the potential of a site. An expensive exercise, borehole information can now be used again, not only to help archaeologists look at hidden landscapes, but also as as aid to mining companies in fulfilling their obligation as regards protecting the archaeology within a mining site.

The principal aim of the modelling and data visualisation undertaken in this study has been to investigate the way in which models of relic surfaces can be used to determine where ARC Central and archaeologists should be concentrating resources.

11.3 The site, the setting and the situation

Before discussing modelling and prediction, a little about the project area itself, with the aim of suggesting why this technique of creating views of hidden surfaces is both so important, and especially rewarding in wetland landscapes.

The site itself is unique in its size, 8.3 km^2, being the largest sand and gravel extraction site of its type in the United Kingdom. Situated approximately nine miles north west of Cambridge, England, it is characterised by low lying, floodplain and lies within two important landscapes, a lower valley interface zone, and what has been defined as the fen edge (French & Pryor 1992).

The fen edge is a zone where the drained wetland of the Fens to the north meet with the relatively higher, drier gravels and clays to the south. This environment has achieved a complex history due to both marine transgression and regression, and also a dynamic network of river channels, producing large variations in erosion and deposition over the centuries.

The processes of water entering into, and out of, the landscape has created a present surface, unrecognisable from that of 3500 years ago. Previously more undulating, marine and river systems have since deposited silt and alluvium, eroded surfaces, created still water allowing peat formation, and produced what can superficially be described as a flat, featureless landscape. This 'blanket alluviation' has essentially levelled off the land giving us few clues as to both its previous shape, and also the extent and distribution of any archaeology.

Assessment by field walking and photographic evidence has however pointed to the presence of up to 15 round barrows (Evans 1992), though many of these are noted as 'possible', and all are heavily obscured. French & Wait (1988) interpret one of the sites as definitely Mesolithic, stressing its extreme rarity in the fenland and helping them to conclude that the site is of national and European importance.

The presence of alluvium creates both frustration and excitement. The obstruction it causes in attempting to interpret former landscapes and their archaeology causes some frustration, especially when judgements on the allocation of resources and distribution of sampling are to be made. However, what is exciting is the likelihood that any archaeology that does lie within the area is well preserved by this same alluvium. Firstly, the deposits seal off earlier landscapes, protecting subsoil features from surface activities which have taken place since that time and secondly, the alluvium helps to 'cap' archaeological features which are at present waterlogged but under threat from alterations to the water table.

It is therefore evident therefore that any attempt to model the present surface is pointless, as the terrain is both lacking any distinct topology, and unrelated to any form of archaeological distribution. To model a surface which is roughly contemporary with its archaeology seems a much more obvious and profitable exercise and through the use of interpreted borehole data this is possible.

11.4 Data preparation

When modelling surfaces beneath the ground in order to examine the distribution of contemporary archaeological evidence it is important to be able to answer the questions: Which horizons are going to be modelled?, and what periods of activity do they correspond to?

Figure 11.1 is an example of the recording format for a borehole sample. The diagram describes in detail the depths and composition of each horizon whereas the table beneath is in a digital format, providing the x, y and z locations with an associated code corresponding to material composition.

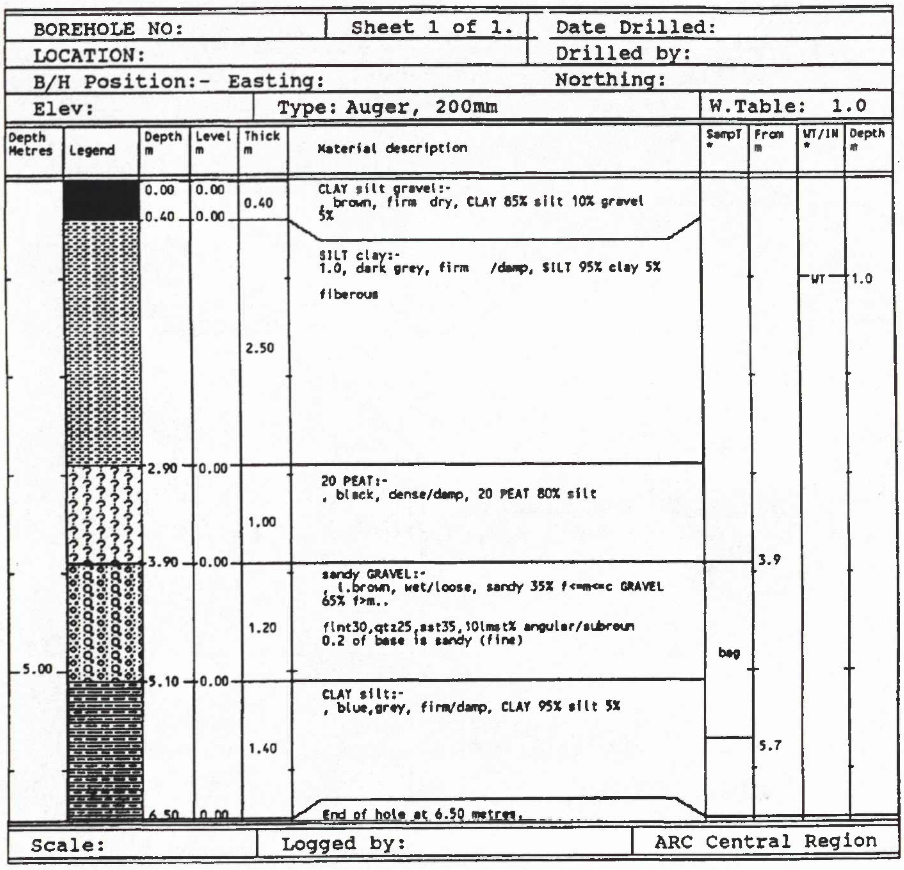
The first aim of the modelling process is to select horizons which are both recognisable and whose extent across the site is discernable. This then allows models to be created for only those areas within which the horizon is present, rather than for the entire site. Due to the data structure within the GIS package, only one z value is allowed for each individual point therefore requiring that each selected horizon must be placed in a separate file and modelled individually.

The separation of data into files through the identification of layers across the site was expected to be a simple task as the first fifty or so boreholes all have four identical horizons representing:

- the present day surface
- alluvium
- gravel
- basal clay

However, upon further investigation of the file a multitude of layers come and go, corresponding with descriptions such as silty-clays, clay-silts, sandy-gravels and gravelly-clays. The presence of peat was also discovered.

This is of course what should be expected in such a complex landscape and although initially unwelcome within the data set, the complexity can be seen as an advantage. This is because it forces us to stop and



ID#	EASTING	NORTHING	SURFACE (M)	FROM (M)	TO (M)	SOIL CODE	SOIL TYPE	HORIZON (M)
43	347988.9	273436.6	2.5	0	0.4	10	soil	2.5
43	347988.9	273436.6	2.5	0.4	2.9	23	silt	2.1
43	347988.9	273436.6	2.5	2.9	3.9	29	peat	-0.4
43	347988.9	273436.6	2.5	3.9	5.1	30	gravel	-1.4
43	347988.9	273436.6	2.5	5.1	6.5	40	clay	-2.6

Figure 11.1: Borehole data format.

think about the data which is going into the model. It is tempting to use visualisation techniques as the first means of data investigation, examining the data for features such as surface anomalies or gaps in the data. However, this lack of 'plug in and play' functionality of the data ensures a fuller investigation before modelling, creating much more confidence in any subsequent enhancement techniques.

The extent of three peat pockets have been discovered, as well as the realisation that the series of mainly Iron Age clay, silt and alluvium deposits are very complex (Pryor 1991) and have a variety of extents across the site, requiring some generalisation to be made. Five surfaces have been selected for interpolation with the intention of gaining the most information from the least number of models: today's surface, the top of the alluvium, areas of peat, the top of the gravel and the top of the basal clay.

11.5 The modelling process

All modelling and enhancement has been carried out using a SUN SPARC station 20 running a standard GIS package, ARC/INFO. Although there are both different interpolation methods and surface modelling techniques (see for example ESRI 1991 or Burrough 1986), kriging has been used as it allows a good investigation of the data and enables the best fit model to be built.

The accuracy of the resultant surfaces is partly dependent upon the distance between the sample points and is often a pay off between loss of accuracy, processing time and data redundancy. A 10m resolution has been chosen which although initially processor intensive has advantages when shading or contouring surfaces as there is no need for resampling to improve the resolution. Once the five resultant lattices are created, enhancement techniques are used in order to gain as much new information from the data as possible.

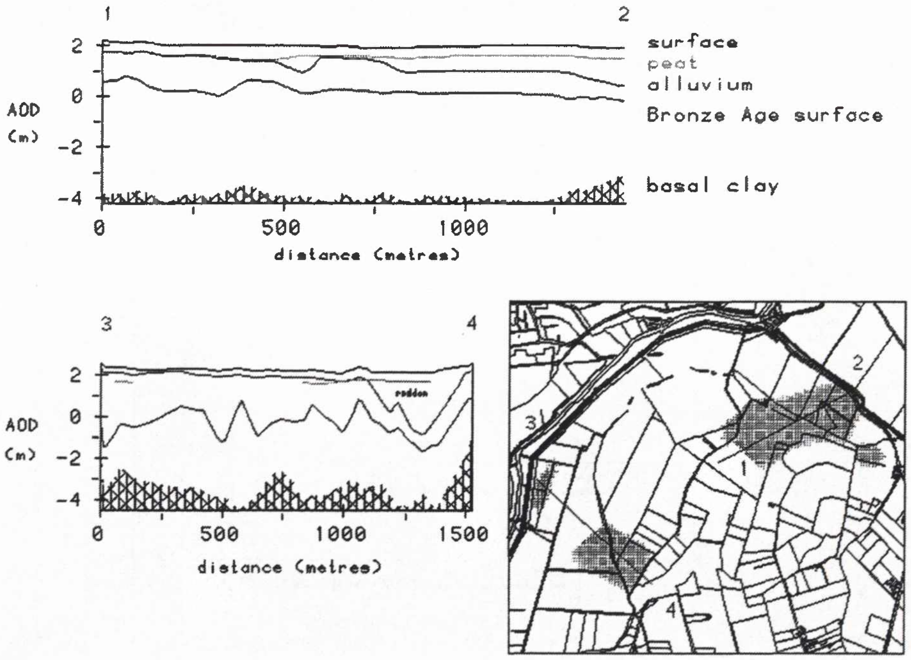


Figure 11.2: Cross-section profiles of generated surfaces.

11.6 Model display and enhancement

Although five models have been created, the nature of the software's two dimensional data structure means that viewing multiple surfaces simultaneously is problematical. However, it is possible for cross-sections to be calculated and viewed in profile (Figure 11.2). This is a very effective technique as it allows quick interrogation of the data, showing the shape and extent of the subsurface topography. This has immediately helped to place the peat pockets within the sequence of layers and also identify the presence of a relic channel.

It is time now to return to the second of the two modelling questions mentioned in section 11.4, that is: what periods of activity do these surfaces correspond to? Although it is difficult to decipher the complicated series of later alluvium deposits, it is a little easier to distinguish the stable underlying gravel surface, and also determine its age. French *et al.* (1992) tell us that encroaching reed swamp due to an increasing sea-level rise led to the abandonment and burial of fen settlement and field systems during the late Bronze Age. This indicates that the surface preceding the series of alluvium deposits dates from around this time and is contemporary with much of the recorded archaeology within the site.

Working solely on what has now been termed the Bronze Age surface, various techniques have been used to visualise it through enhancements enabled by the software. A number of shading and display techniques are available, helping to define and highlight features and enable us to gain a clearer idea about the processes taking place within the landscape at that time.

The first technique is perhaps the most important and is essential for all subsequent manipulation. This is the ability to alter the scale in the z direction. Rather than displaying height values in the same unit of measurement as the z and y dimensions, they can be exaggerated so that the topography is amplified for viewing more easily (see Thelin & Pike 1991). In the case of a relatively flat site, in which the difference in surface height is about 5m compared to a range of around 2500m on the x axis, this technique is essential if the viewer is to see anything at all.

Once the z scale is exaggerated there is enough variability in this dimension for subsequent surface shading techniques to be effective. Figures 11.3 and 11.4 show the results of the two main shading algorithms, altitude shading and hill-shading. Figure 11.3 represents higher areas with lighter shading and aides interpretation by the addition of contours at 0.5m intervals. Hill-shading (Figure 11.4) helps to give a more realistic view of the surface calculating pixel values on the basis of slope, aspect and the effects of shadowing using a light source from the northwest.

However, just as it is difficult to understand the complexities of a terrain from the seat of an aeroplane, so it is to fully understand these images. It is clear that much more information can be gained from the two models if we are able to experience more than just a planimetric view.

The ability to create perspective displays is a valuable feature allowing the viewer more interaction with the landscape and therefore the data itself. Figure 11.5, a fishnet drape, shows that even without the use of surface shading, a perspective image immediately offers a very different view picking up the more subtle topography. Figures 11.6–11.7 help to visualise this topography more easily, with the addition of a vector base-map helping to locate surface features within the modern landscape of roads and field boundaries.

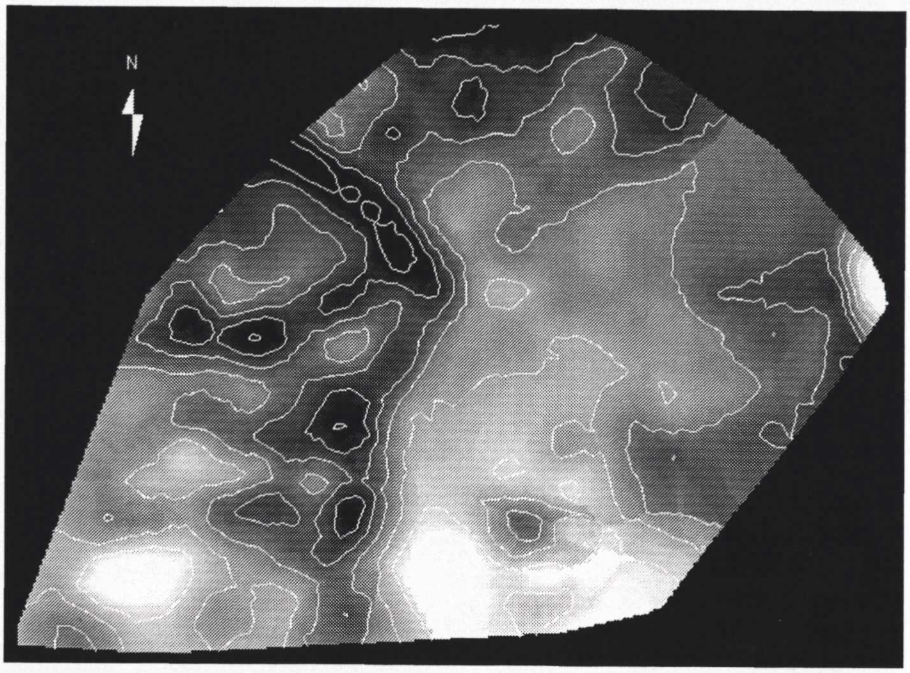


Figure 11.3: Altitude shading with contours at 0.5m intervals.

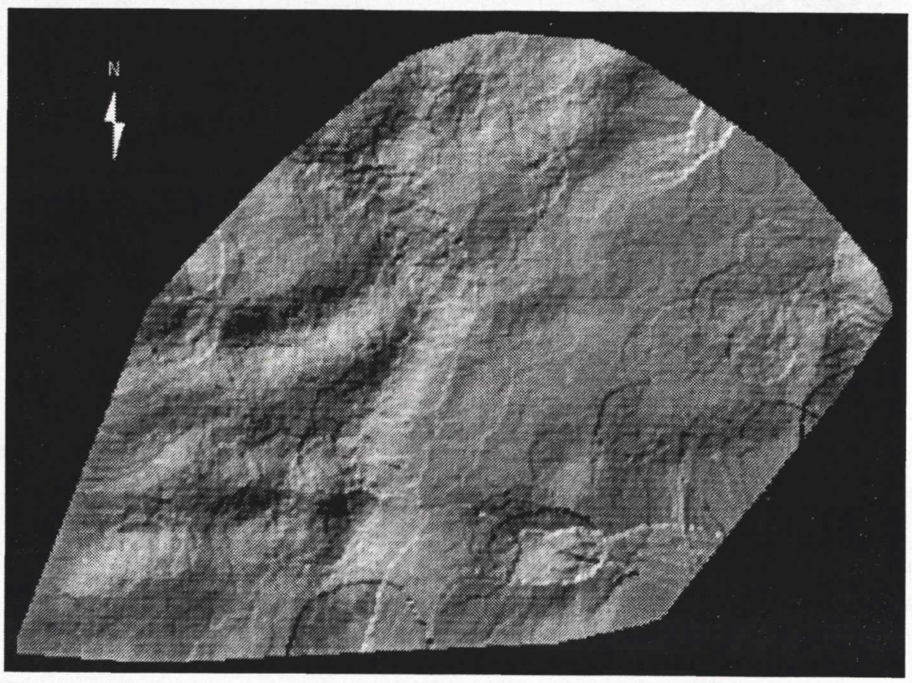


Figure 11.4: Hillshaded surface.

From this imagery, there are now a number of new landscape features which have been revealed. The main area of activity is in the western side of the site where there are a number of channels which surround a series of three higher islands of land.

Thus it seems clear that to visualise a hidden landscape is both quite possible, and very effective in providing new information. But what of using this information to help preserve the archaeology within an area of land which is soon to be systematically disturbed or destroyed? Can we make any predictions as to where we should be looking?

11.7 Prediction and prospection

It must be stressed that this predictive process is not statistical in nature. That is, it is not an attempt to, for example, predict the probability of the existence of sites based on the existence of known sites using variables such as soil type, aspect or slope. The site does not lend itself readily to this process for a number of reasons.

Firstly, the area, although large enough in terms of borehole coverage, is considered small when attempting to look at variables such as soil type. The present land surface is very homogeneous with very few differences in soil type or distances to water, and there

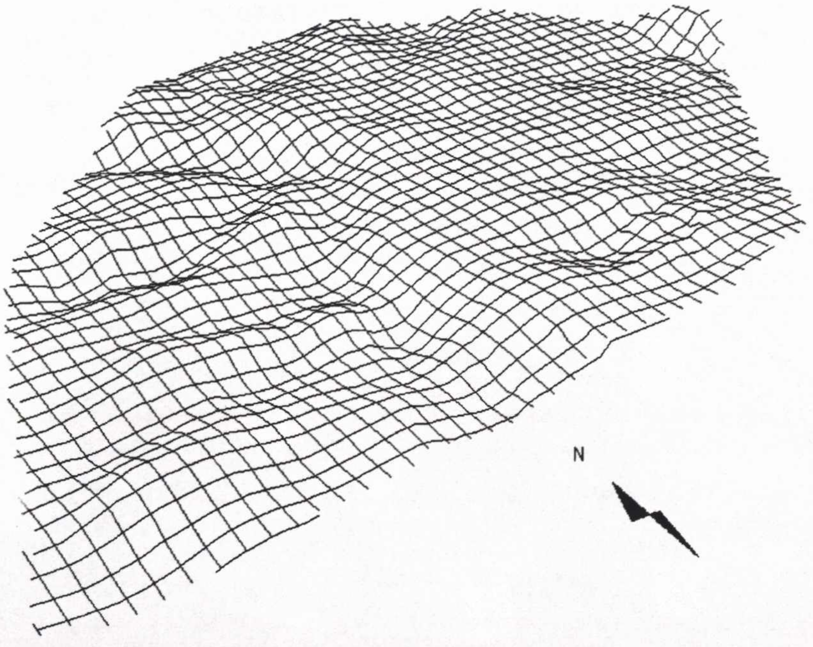


Figure 11.5: Perspective view with a fishnet drape.

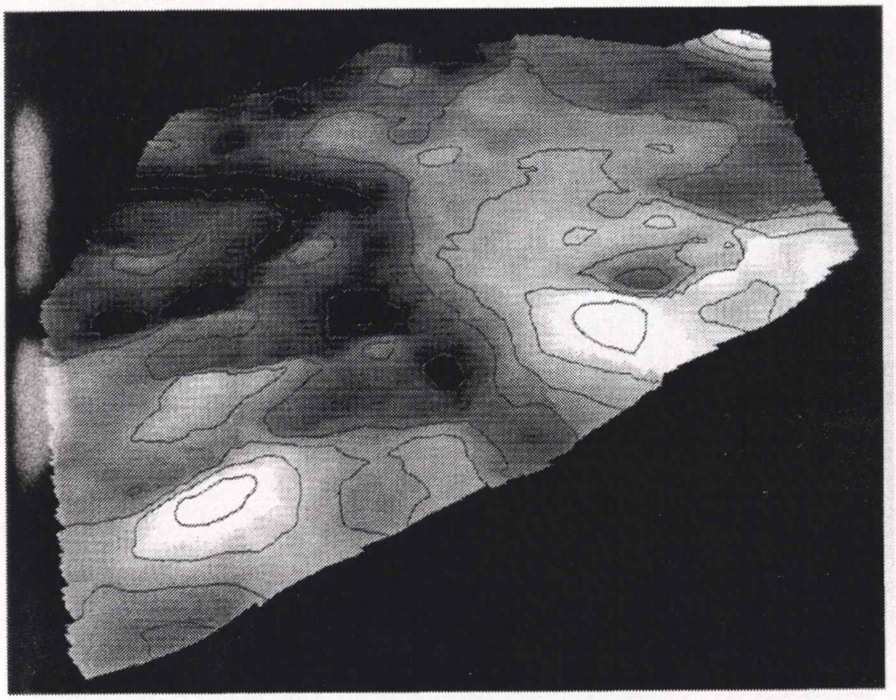


Figure 11.6: Perspective view with altitude shading and contours.

are certainly no slopes or aspects of note. Even when using the Bronze Age surface which has certain undulations, these topographic features are still very subtle and of little use. The other major factor preventing this type of deterministic modelling is the very same reason we have a homogeneous landscape, that is the alluvium. Alluviation has meant that little is known about the amount and extent of archaeology within the area and too few definite sites exist for an effective study.

A more useful approach, and one which is enabled through data enhancement techniques is visual prediction. Using the visualisation of the Bronze Age surface and some understanding of settlement tendencies, judgements can be made as to where other features may be found within this site. Looking at figures 6 and 7 for example it is clear that there are distinct topographic features including a relic channel and a series of higher islands of land to the west of the site. From this it is possible to predict with more confidence where Bronze Age settlement could have and probably would not have taken place. For example, it is probable that the islands have been favoured rather than the bottom of the channels.

What is of great help at this stage is to undertake this visual interrogation with additional knowl-

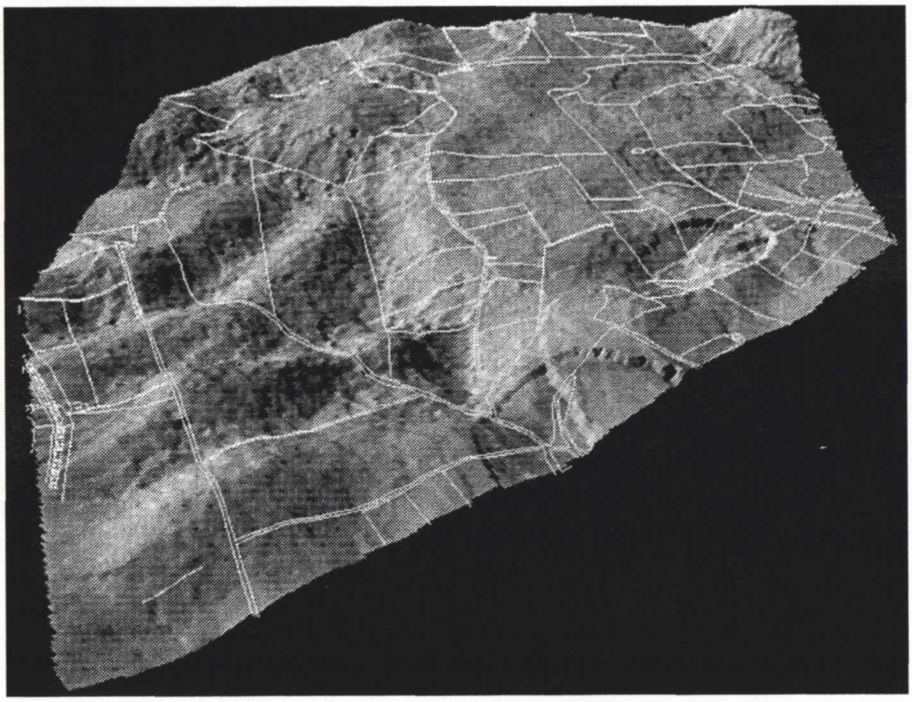


Figure 11.7: Perspective view with hill-shading and vector base-map overlay.

edge on the known archaeological distribution. During a recent comprehensive study of the whole of the Fens, aerial photographs from the past few decades have been brought together and examined for archaeological evidence (Hall & Coles 1994). Crop-marks and soil-marks from these photographs have then been transcribed onto a single map which, for the purposes of this study, have then been scanned and registered in the GIS. Once integrated this instantly becomes a useful data set as it not only shows the for the first time the position of the barrows in their own landscape (Figure 11.8), but it also helps create greater confidence on the usefulness and appropriateness of this technique. As can be seen, the barrows sit directly on top of the highest island of land within the site. It is now realistic to suggest that other areas which should be concentrated upon are the further two 'islands' to the north.

11.8 The next stage: comprehensive prospection data sets

With an accurate base model and the addition of data such as archaeological distribution and aerial photographs, a natural progression is to continue using the GIS to enhance the prospection process by integrating further sets of spatially referenced data. This integration creates what Kvamme (1995) has termed a 'comprehensive prospection data set'. Although others have suggested use of data from multiple sources (Scollar *et al.* 1990), Kvamme argues: '... why not go a step further? Incorporate into the database aerial photography (*e.g.*, crop marks), geochemical results, surface artefact distributions, and microtopography'.

This site lends itself well to this technique as it has undergone intensive studies during past surveys and during the preparation of Impact Assessments and will continue to undergo surveillance over the next twenty year period. There are currently a number of data sets which can be integrated including: Infra Red Linescan imagery, barrow microtopography (French & Gdaniec 1994), resistivity, magnetic and ground sounding radar surveys, and hydrological monitoring data (Hunting Land and Environment Ltd. 1995).

Although it is imagery which is prevalent in the data mentioned so far, it is important not to forget the functionality offered by GIS. By, for example, linking the entries of an archaeological gazetteer of the site with the scanned image containing the recorded archaeology, an even more powerful tool emerges which not only deals with prospection but also the beginnings of site and landscape management.

11.9 Discussion

So from the initial steps of data processing and modelling has developed the potential to use such a system during the entire time a developer is involved in such a site, from the initial sub-surface visualisation through to recording and post excavation phases.

But what of the dangers of visualisation? An image conveys so much to the viewer (Spicer 1988) but has the power to speak its thousand words with some undue authority (Harley 1988; Miller & Richards 1993). Perhaps a study such as this is less prone to fall foul of this problem than projects which, for example reconstruct and render structures for which only foundations exist. Rather than produce a finished product,

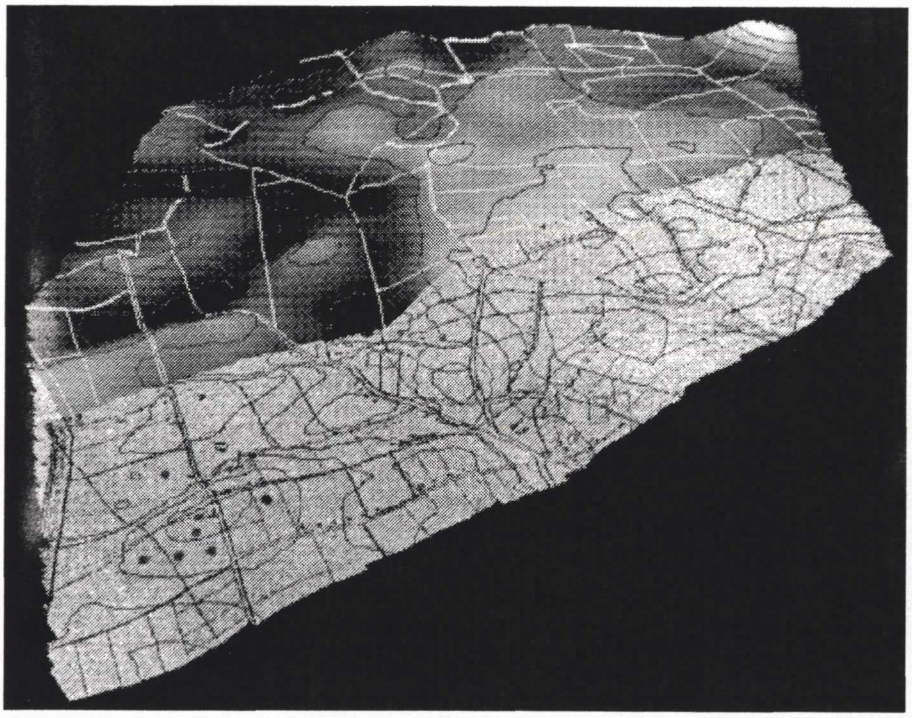


Figure 11.8: Draped Fenland Survey map showing the position of Bronze Age barrows (dark spots).

that being a definitive view of the Bronze Age environment, the models are being used as a starting point upon which to build upon. Once the current data is used to point to areas within the site which should be investigated, new data from these investigations can provide feedback and modification thereby creating a dynamic process.

GIS and its ability to model and visualise hidden landscapes offers archaeologists a rare look beneath the surface and creates ideal base models upon which to formulate the best method of assessing the site in a non-destructive way. It is perhaps naïve to suggest that these techniques are essential and must be used by all archaeological bodies working on a similar site, but do suggest that where the opportunity does arise it should be seized as it provides an unrivalled aid to archaeological prospective and management.

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