THE UNIVERSITY OF HULL

Comparative and introspective GIS: an analysis of cell-based GIS methods and their applications within landscape archaeology.

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by

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Abstract

Comparative and introspective GIS: an assessment of cell-based GIS methods and their applications within landscape archaeology

by Henry P. Chapman

This thesis presents an assessment of cell-based GIS techniques and their applications within landscape archaeology. It highlights and addresses four main limitations within previous archaeological GIS research. Firstly, studies have traditionally been restricted to areas of high topographic variability. Secondly, there have been few truly comparative GIS studies within archaeology and so the value of methods remains uncertain. Thirdly, issues of resolution and its effects on the process and results of analyses require further assessment. Finally, the DEM is rarely considered as representing an archaeological feature itself, but rather as a surface over which archaeology is draped.

In response to these identified limitations two contrasting landscapes were studied, each using input-data obtained at both low and high resolutions from Ordnance Survey contours and high resolution GPS survey respectively. The first landscape was chosen for its topographic variability. It was centred on the Neolithic cursuses around the village of Rudston on the Yorkshire Wolds, East Yorkshire. For the second landscape a flatter, wetland area was chosen. This was focused upon the pair of Iron Age lowland enclosures on Sutton Common in the Humberhead Levels near the town of Askern, South Yorkshire. Each area measured 10 x 10 km, although the extents of the higher resolution surveys were much smaller, focusing on the specific archaeological monuments.

A range of GIS methods was applied systematically to each of the landscapes so that the results could be usefully compared. These methods included techniques of surface generation, surface representation, surface analysis and multiple surface analysis. The results were discussed comparatively and assessed introspectively within the themes of GIS methods and the applications of GIS within landscape archaeology. The latter was further subdivided between its principal themes of landscape interpretation and cultural resource management to provide a realistic assessment of the overall value of GIS tools to landscape archaeology.

The conclusions of this research highlight the wide range of possibilities that GIS provides to landscape archaeology. From a methodological perspective, the advantages and limitations of the various methods have been presented, particularly demonstrating how flatter landscapes may be studied successfully so long as surface data are collected at an appropriate resolution. Further, it has been demonstrated that both input-data and GIS techniques are transferable, enabling a wider range of potential results to be of use within archaeology than might at first be assumed.

Other conclusions have been made in terms of landscape archaeology. This thesis has demonstrated the great heuristic value of GIS and this has been expanded to incorporate narrative approaches from the social sciences, applying them to the abstract landscapes that GIS creates. It has also demonstrated the wide potential of GIS for identifying sites, for assessing their preservation, both above and below ground, and for the long-term monitoring of the buried environment.

This thesis has provided an assessment of cell-based GIS methods and has recommended ways in which their applications may be enhanced for the benefit of landscape archaeology.

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In memory of Phyllis Chapman

Part 1: Introduction

Chapter 1

Introduction

1.1 Introduction

Geographic Information System (GIS) software with the capability of generating and manipulating digital elevation models (DEMs) is becoming increasingly available and its use is growing within archaeology. This has occurred mostly within the broad sphere of activity that may be termed 'cultural resource management' (CRM), but the software is also being used as a platform and tool for interpreting archaeological landscapes. The uptake of GIS use within archaeology, however, has been piecemeal and unstructured. To date there have been no comprehensive analyses of the applicability of the various techniques and tools available within the software for creating, assessing, modelling and analysing virtual topographic surfaces to suit the needs of archaeology.

There have been a number of limitations in the application of cell-based GIS to the extent that many themes and concepts have yet to be explored in detail. In particular, four of these concepts can be highlighted. Firstly, studies have focused on upland areas with high topographic variability, often to the neglect of flatter lowland landscapes. Secondly, there has been little comparative study of the applicability of GIS methods to contrasting archaeological scenarios. As such, new techniques have often been evaluated in relation to a single example, thereby limiting the robustness of the methodology. Thirdly, previous investigations into resolution of both the data sample and the digital surface have been limited. Finally, previous assessments of landscape have not investigated the relationship between archaeology and surface, frequently considering the two separately, with the former at best superimposed on the latter. This is an oversight, particularly in terms of earthworks, for example, as they may be considered as both the surface and the archaeology.

The aim of this thesis is to examine the suitability of various GIS surface generation, representation and modelling tools for various archaeological requirements, and particularly to provide an assessment of, and response to, the four main issues outlined above. Thus a comparative approach has been taken, using and assessing a suite of GIS tools on both a topographically variable upland site (on the Yorkshire Wolds) and a flatter lowland site (within the Humberhead Levels). Further comparison in relation to

resolution has also been made by obtaining contrasting data sets for each landscape, using both low-resolution contour data, and high-resolution survey data.

The analysis of the results of GIS studies is notoriously difficult to quantify due to the lack of a baseline standard against which they can be evaluated. In this study the results were assessed by comparing those from each of the different surfaces. In this respect the study was introspective, investigating the applicability of GIS tools in relation to themselves rather than in relation to an artificial baseline.

The results of this research were assessed in relation to their archaeological application. Conclusions were drawn from them within the two contexts. Firstly, each of the tool groups was analysed in relation to their applicability to archaeological requirements. This was then expanded upon and analysed in relation to the two main themes within landscape archaeology mentioned above: CRM and landscape interpretation. This provided a realistic and useful baseline by which to assess the value of different GIS methods and tools.

This chapter begins with an outline and review of the development of GIS and its influence upon different themes within landscape archaeology. It continues by explaining the rationale underlying the thesis, in the context of what may be perceived as four limitations of past research. Within this context an overview of the approach is given, followed by an outline of the structure of the thesis. Further review of the literature relating to GIS is undertaken within the methods section (part 2, chapters 3 & 4) with particular reference to input-data and GIS tools and approaches.

1.2 Geographic information systems and their historical development

1.2.1 Definition

> "An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information."
>
> ESRI 1995 (glossary).

> "A GIS is a sophisticated database management system designed for the acquisition, manipulation, visualisation, management and display of spatially referenced (or geographic) data."
>
> Aldenderfer 1996: 4.

The name 'geographic information system' (GIS) describes a range of software packages displaying the common abilities to store, manage, manipulate, analyse and display spatially referenced information. Traditionally GIS software packages have been divided into two types on the basis of data management, and these are known as vector and raster systems. The former stores data in relation to points (or nodes), lines (or arcs) and closed polygons. The storage of such data reflects the mathematical discipline of topology, whereby the relationship between points is important rather than their true positions. The latter considers space in terms of cells, dividing a digital surface into regular blocks that can each be given a value or attribute that describes it (Figure 1.1). For example, cells may be labelled with information attributing to colour or shade, as is often used for two-dimensional images or maps, or by numerical values, such as heights, to provide a third dimension. Within more advanced GIS packages the representation of height in addition to Cartesian data means that topographic maps may be created. The nature of data storage, however, means that the third dimension is stored as an attribute representing height, unlike the continuous scales in the other two dimensions. As a result such models are considered as 2.5 dimensional (2.5D). The value of cell-based modelling of this kind is that different types of surfaces may be generated and compared mathematically in order to create new models.

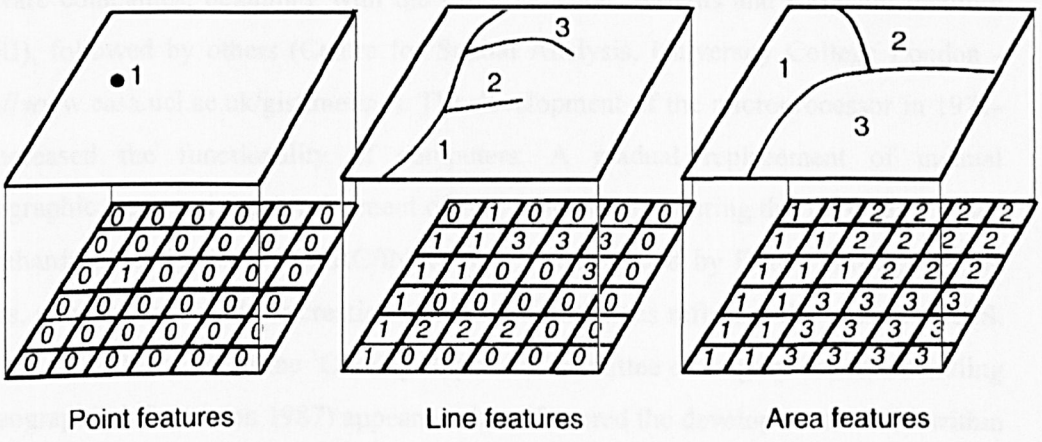


Figure 1.1 Cell-based GIS (after ESRI 1995 glossary) showing the representation of topographical features. Values may also represent elevation within a Digital Elevation Model (DEM)

In application, the differences between raster and vector GIS are not always so clearly defined, with models typically containing data of both types. Both types of data management provide the potential for generating, manipulating and analysing DEMs, with the main limitation being the complexity of the software itself. Further, they both

have the potential for being overlain with other multiple layers of data of different types. However, raster data structures require greater computer memory, although they have the advantage of being more flexible for further analysis. It is possible to convert data between the two data types, although the potential for generating error within such procedures has been highlighted (e.g. Van der Knapp 1992). For the present study the more flexible raster, or cell-based system has been used.

1.2.2 Inception

Digital mapping was first introduced by Waldo Tobler with the 'map in map out' (MIMO) model that first applied computers to cartography (Centre for Spatial Analysis, University College London - http://www.casa.ucl.ac.uk/gistimeline). The first true GIS was created in 1962 in Canada and was called the Canadian Geographic Information System (CGIS). It was developed in response to two factors - the growth in electronic computer technology, and the increased complexities of life that needed to be considered within the framework of public and private sector decision-making. Two years later a similar system was created in the USA called MIDAS that began processing data on natural resources. At this time the focus of GIS was to manage developments and infrastructure expansion, and to aid in the planning process (Bernhardsen 1992). By the end of the 1960s the development of GIS had led to the creation of commercially-based software companies, beginning with the Environmental Systems and Research Institute (ESRI), followed by others (Centre for Spatial Analysis, University College London - http://www.casa.ucl.ac.uk/gistimeline). The development of the microprocessor in 1971-2 increased the functionality of computers. A gradual replacement of manual cartographic work and the development of GIS followed this during the 1970s and 1980s (Bernhardsen 1992). In 1981 ARC/INFO was first launched by ESRI. Throughout the 1980s, new products and the creation of research initiatives reflected the growth in GIS. In 1987 the publication of the 'Chorley Report' (Committee of enquiry into the handling of geographic information 1987) appears to have fostered the development of GIS within the UK, although it never led to the establishment of a national initiative as in the USA. Rather, it led to a series of regional research programmes funded by the Economic and Social Research Council (ESRC) (Centre for Spatial Analysis, University College London - http://www.casa.ucl.ac.uk/gistimeline). It was in the same year that the *International Journal of Geographical Information Systems* (Taylor and Francis) was first published.

1.3 The development of archaeological GIS

Harris and Lock (1990) provide a documentary of the development of GIS within archaeology, upon which the following is largely based. The first use of GIS within an archaeological context was in the 1980s in North America where it was used to predict archaeological site location within a management context (Kohler and Parker 1986, *cf.* Gillings and Wise 1990). Interest in GIS and its potential within archaeology appears to have emerged in 1985 at conferences organised by the Society for American Archaeology. The first included papers relating to the analysis of intra-site distribution using GIS (presented by Gill and Howes), and the use of GIS for regional archaeological research (presented by Kvamme). The second conference saw papers on methods and principles. The following year a third conference, *the National Workshop on Microcomputers in Archaeology*, saw papers on the potential of GIS for archaeological research and data management (presented by Kvamme) and on the availability of appropriate software (one presented by Ferguson and another by Miller) (reported on in Harris and Lock 1990).

Within the UK the genesis of interest in GIS appears to have occurred at the same time as in the USA, but the uptake was faster within geographical than archaeological study. The initial interest in relation to archaeology was in the mid-1980s and was focused upon the computerisation of spatial data at a regional level for archiving, education and research, and to aid decision-making in the planning process (Harris 1986). By the later 1980s the potential of GIS within UK archaeology had been broadened to include 2.5D modelling with archaeological data draped over digital terrain models (Harris 1988). The development of GIS continued into different archaeological applications over the succeeding years (Harris and Lock 1990). More recently, such developments have merged the distinctions between computer-aided design (CAD) and GIS, and the wider issues of general data management, compatibility and storage (e.g. Gillings and Wise 1999) have come to the fore. The use of GIS within archaeology has become widespread at all levels and within all disciplines, particularly with the emergence of desktop software (*cf.* Elshaw Thrall and Thrall 1999). This has been reflected over the past few years, for example, by the growth of the GISARCH e-mail discussion list. It has also been reflected in an expansion of archaeological GIS into other computer disciplines (*cf.* Gillings and Goodrick 1996).

1.4 The archaeological applications of GIS

Archaeological research may be split into three main areas: methods, interpretation and management. These have been used to identify the main three themes of research into GIS within the archaeological context, even through many projects combine different aims together (e.g. Chartrand *et al.*1993). A further theme of *spatial statistics* has also been developed that has been closely linked to management, but dominated to a greater extent by predictive modelling, particularly of site location (Harris and Lock 1995).

1.4.1 GIS procedure

The first research theme, relating to methods, is often referred to as GIS procedure (e.g. Savage 1990), and is primarily concerned with the accuracy of results from studies using GIS, often at an algorithmic level (e.g. Kvamme 1990). The sphere of GIS procedure is relatively indistinct in relation to archaeology, as it extends into other analyses using GIS. For example, studies examining the potential error within GIS algorithms will apply to archaeology and other disciplines, providing a wider literature base. Themes of research have included methods of raw data sampling in relation to accurate surface generation (Fletcher and Spicer 1988), processes of surface generation from various data sources and using different algorithms and measuring accuracy (e.g. Kvamme 1990, Haigh 1993, Carrara *et al.* 1997, Gao 1997, Lopez 1997, Voigtmann *et al.* 1997), and the error within the algorithms used for further analyses, and ways of approaching it (e.g. Fisher 1993, De Floriani and Magillo 1994, De Floriani *et al.* 1994, Puppo and Marzano 1997). Other work has been more ambiguous, falling within the spheres of GIS procedure and other themes such as interpretation (e.g. Gillings and Wheatley forthcoming). Many such papers present a new method, using an example to present the method. For example, Lake *et al.* (1998) outlined a GIS procedure that tailored the basic software in order to speed up analyses. While this may be considered to fall within the sub-heading of GIS procedure, the process was developed and presented as a way of quantifying archaeological landscape interpretation. It seems that the boundaries, particularly between procedure and the other two main spheres of GIS work outlined below, are extremely blurred. These themes will be expanded upon within the methodology (chapters 3 and 4).

1.4.2 Landscape interpretation

> "... GIS is increasingly being seen as much as a place to think as a simple data management and mapping tool"
>
> Gillings and Goodrick 1996.

The need to obtain meaning from data is fundamental to the study of archaeology, and so a level of interpretation is always required. Approaches to understanding archaeological landscapes may be considered in relation to three main trends, loosely reflecting historical developments in theory. The first of these may be termed *normative*; essentially classifying data according to common patterns; creating 'cultures' that reflect 'normal' behaviour (e.g. Piggott 1968). Within landscape studies the principal traditional tool for this has been the distribution map, used to describe and interpret spatial patterns of similar artefacts or assemblages, and how they change through time. Interpretation from such sources is typically by creating theories to explain the boundaries of these 'cultures' in order to understand changes seen in the archaeological record (e.g. Piggott 1968). This approach may be criticised for being descriptive and deterministic (e.g. Binford 1964), especially as the classification of the 'cultures' forms essentially false boundaries between them, limited to the chosen parameters, without consideration of anomalous features. The creation of false boundaries typically determines interpretations of change based upon either a migration of population or diffusion of ideas, rather than upon other theories such as evolution. Consequently, conclusions typically take the form of descriptions.

The second generalising theme in landscape interpretation relates to some of the developments of the *New Archaeology*, and is often referred to as *processual* (*cf.* Clarke 1978). Themes include the requirement to become 'scientific' in approach, to construct models to explain the archaeological record rather than to describe it, and to add other levels of data including those from anthropological analogies and environmental work. Borrowing from the other social sciences, popular approaches stem from the creation and testing of theories to construct robust conclusions. Much of this work has grown from positivist reasoning - testing hypotheses to create new ones on the basis of generalisation. Within landscape archaeology, the main developments have been in relation to environmental factors and the integration of 'scientific' methods of palaeoecological reconstruction such as palynology. This type of approach may be criticised for a number of reasons, primarily that the problem of inferring interpretation from archaeological data still required a jump from the results to generalisation (*cf.* Popper 1972). Similarly, the parameters that could be studied were still a construct of their survival and were therefore not real. Many critics of this type of approach indicate that the systems created are deterministic, particularly environmentally in relation to archaeological landscapes (e.g. Bradley 1984).

The third theme is commonly referred to as 'theoretical', in contrast to 'scientific'. It harks back towards a more humanistic view of the archaeological record. This has been applied to landscape archaeology in such a way that it has developed into a discipline in its own right (e.g. Tilley 1994). Central to this has been the presumption that landscapes are imbued with meaning (*cf.* Cosgrove 1989), and that this meaning transcends economics and filters into all activities. As such, landscapes are seen as more than merely a surface that archaeology rests upon (or within), but rather as interactive platforms for human experience. The landscape is constantly re-created through physical and metaphysical constructions that constantly alter the relationship between it and those people who engage in activities within it. The physical constructions may be measured, at least in part, through archaeological investigation, and it is on the basis of these features that meaning is sought. However, it has been argued that the same landscape can be perceived in different ways by different people or from different perspectives (Meinig 1979, Tuan 1979, Bender 1992).

Landscapes have been classified in a number of ways. Fundamental to many of these has been Tuan's (1977) distinction between place (where activity occurs) and space (the area between places where paths reside). The central themes within landscape theory are underpinned by the definition of landscape (*cf.* Olwig 1993). Tilley (1996) summarised the relationship between archaeology and landscape in four ways: (1) as "... a set of relationships between named locales" (p 161); (2) to be "... experienced and known through the movement of the human body in space and through time" (p 162); (3) as "... a primary medium of socialisation" (p 162); and (4) creating "self-identity" by controlling knowledge and thereby influencing power structures (p 162). The key principle is that of experience, and thus studies of archaeological landscapes have been based upon attempting to replicate the experience of "Being-in-the-world" while trying to reconstruct the dialectic of the existential "Being" (Tilley 1994: 12). The primary method of measuring experience (if measuring is a suitable word) is through analysing visibility patterns. For example, Thomas (1993) investigated the visual impact of monuments, particularly around Avebury, suggesting themes of inclusion and exclusion (similar to Tilley's fourth point, mentioned above). Devereux (1991) analysed the spatial relationships between monuments and topography at Avebury by investigating their visual relationships. Similarly, Tilley (1994) investigated three archaeological landscapes through a narrative and photographic essay and by recording patterns of intervisibility between monuments.

Work involving the interpretation of past landscapes revolves around what may be defined as the two areas of perception and cognition (van Leusen 1999). Perception can be defined in terms of landscape awareness and includes feelings of being within the landscape. Cognition within landscape archaeology can be defined as knowledge of the landscape that influences perception (Zubrow 1994). For example, cultural or social implications of a certain place may influence its significance within a landscape and may form a completely different perception of the environment - the imbuing of meaning upon landscape and from it.

GIS provides a forum that enables multiple disciplinary study and can therefore assist in interpretation (e.g. Potts *et al.* 1996). The potential for reconstructing past landscapes within a digital framework allows for the possibility of stripping back the temporal layers to provide a basis for quantifiable analysis. However, the specific application of GIS to landscape archaeology lacks the historical development of the archaeological discipline, being a relatively new technique – "in GIS the concept of theory is less mature" (Zubrow 1990a: 69). Perhaps as a consequence of this, the divisions between approaches are less pronounced and studies tend to span two or more of the paradigms described above. Interpretation within GIS may, however, be divided in terms of levels of sophistication.

The least sophisticated interpretative models act in a similar way to the distribution plots seen within work characterised as normative archaeology. However, the advantage of GIS is its capability to display multiple layers of data together such that correlation with other forms of data is often used as a tool for understanding (e.g. Middleton and Winstanley 1993, Van de Noort & Ellis 1995, 1997, 1998, 1999, 2000). More sophisticated models use algorithms to provide information about the topographic surface, thereby allowing the GIS to generate data rather than merely to correlate external datasets. For example, distance to resources may be calculated in order to understand relationships between different data sources (e.g. van Leusen 1993), or sites may be examined in relation to elements such as aspect or slope angle. Such analyses are often descriptive rather than directly interpretative, forming a common basis for locational predictive modelling (mentioned above), but also acting as a foundation for other methods of interpretation.

More sophisticated approaches tend to be based around two main elements: visual analysis and cost-surface analysis. The most common approach is through the creation of viewsheds, and the analysis of what is visible from a given position in much the same

way as is done by Tilley (1994) and others on the ground. Part of the reason for this is the potential for GIS to quantify visibility (*cf.* Wheatley 1995, Lock and Harris 1996, Fisher *et al.* 1997, Lake *et al.* 1998, van Leusen 1999, see chapter 4, section 4.5.3). Some approaches combine the viewsheds from several positions in order to analyse distributions of monuments. For example, Lock and Harris (1996) argued that Neolithic long barrows in the Danebury area represented highly visible territorial markers because their calculated viewsheds did not overlap. Cumulative viewshed analysis has grown as a sub-context of visual analysis and this was characterised by Wheatley (1995). This is a technique that combines the viewsheds from several monuments, investigating recurrence of visible areas in order to assess visual qualities of monuments from a statistical perspective. This type of approach has been expanded to assess the validity of empirical interpretations by the introduction of random points from which to generate viewsheds (Fisher *et al.* 1997). In this way interpretations based on monument positions (chosen *places*) may be compared to those from other areas (random *space*). This approach was extended by Lake *et al.* (1998) who achieved such an analysis by 'tailoring' a GIS software package to enable automate analyses. This process allowed for the comparative quantitative investigation of viewsheds from a large sample of cells within the model, in order to assess whether an archaeological site might have been located due to its significantly higher visibility.

A second approach towards providing insight into the interpretation of past landscape from a cognitive perspective is the creation and analysis of 'cost-surfaces' (Wheatley 1993, Stead 1995, Gaffney *et al.* 1996, Maschner 1996, van Leusen 1999, Bell and Lock forthcoming, De Silva and Pizziolo forthcoming). This technique is based upon the possibility of measuring the effort it takes to cross an area of the DEM. For example, an area of flat land would be easier to cross than a steep area. A cost-surface generates different values for each of the cells making up the surface based on whichever parameters are chosen; though commonly slope is a significant factor. A cost-surface can then be used to find the path between two points on the surface that encounters the least effort. Such approaches have been used to investigate how past landscapes may have been perceived (e.g. Wheatley 1993, Stead 1995), and to define and explain routes, such as the Ridgeway extending across the southern chalklands of England (Bell and Lock forthcoming).

A combination of both visual and cost-surface analyses has been used on a number of occasions to provide a broader basis for interpretation (e.g. Gaffney *et al.* 1996, Lock and

Harris 1996). Each of these methods outlined here in relation to themes of GIS and landscape interpretation is expanded upon in the methodology (chapter 4, section 4.6).

A disadvantage of past and current approaches to interpretative landscape archaeology is that there is a general desire to produce testable models and theories (e.g. Zubrow 1990b, Lake *et al.* 1998). Although repeatable and testable experiments are useful in terms of positivist theory (e.g. Bell 1994), the fundamental reasoning of post-processual interpretation lies beyond the need for them, with criticisms levelled towards such processes. For example, past populations could not analyse a landscape to find the most suitable position in terms of visibility and so there may have been better, unknown sites. Further, such theories exclude the influence of cultural factors that may equally determine the positioning of a site. GIS has also been criticised for its abstract nature, in terms of being environmentally deterministic (*cf.* Gaffney and van Leusen 1995). It works by assessing measurable aspects such as slope, aspect and distance, and so it may be argued that this capability will determine interpretative processes. However, as Llobera (1995) noted, such a criticism may lie in the semantic confusion of the words 'environmental' and 'deterministic', and may therefore be over-simplifying the role of the user. Rather, Llobera argued that GIS should be seen as a heuristic for exploring the possibilities of social theory, with the abstract social theories 'translated' into GIS approaches. This conforms to trends within non-archaeological GIS approaches elsewhere that aim for increased conceptual sophistication by adding a social perspective to models, including the subjectivity of the observer (Couclelis 1999).

1.4.3 Cultural resource management

CRM is also referred to as archaeological resource management (van Leusen 1995) and has is commonly associated with site location modelling (Savage 1990). CRM covers the majority of professional applications of GIS and is often publicly funded. The many processes and activities encountered within this broad title may be categorised into three main areas: recording, protection and management.

Recording encompasses both the classification of sites and landscapes and their archiving. In relation to GIS, this theme includes aspects of database design, creation and management (e.g. Stine and Lanter 1990), site categorisation and the digital archive (Williams *et al.* 1990, *cf.* Gillings and Wise 1999). Such work is typically focused on the values and caveats of using GIS as a data curation, management and display tool (e.g. Guillot and Leroy 1995). Trends within this area of CRM highlight the various ways of

approaching the listed themes, and note the common value of GIS for the management of large quantities of data.

The second area of CRM, protection, is a broader concept encompassing mitigation strategies for threatened archaeology such as preservation by record, preservation *in situ*, and rescue excavation, and is governed largely by documents such as PPG16 (Department of the Environment 1990). This aspect of CRM involves the decision-making processes by which a threatened site is managed. GIS studies addressing this aspect of CRM often involve more complex modelling techniques, typically exploiting the their ability to model possible outcomes, such as site distributions, in one area based upon trends identified from empirical observations in other areas. The most common aspect of this type of CRM analysis involves the predictive modelling of site location. This technique has been commonly used in areas where the management of the archaeological resource is limited by either a poorly documented record, or limited information regarding the location of sites. This type of deductive approach is often centred around observed correlation between the distribution of archaeological material and a range of environmental factors such as slope, aspect, elevation and proximity (*cf.* Kuna and Adelsbergerová 1995). There have been a number of outlines (e.g. Marozas and Zack 1990, Warren 1990a) and case studies (e.g. Hasenstab and Resnick 1990, Warren 1990b) that have approached these issues in this way. Altchul (1990) offered a philosophical alternative when presenting a critique of this approach, arguing that such models were capable only of revealing what was already known. Instead, he argued that an approach based upon 'red-flagging' was preferable. Rather than just providing 'accurate' distributions extrapolated patterns of data already recognised, the GIS could be used to highlight (or 'red-flag') areas where increased archaeology may be encountered by a developer and where mitigation may be more costly. Further, he wished to expand the technique to highlight anomalies of significance, rather than merely to show patterns.

The basis for this type of modelling lies in the protection of the unknown archaeological resource through its statistical identification. The value of this technique is clear in relation to the activities of developers and the need for archaeological mitigation strategies. However, a number of more fundamental criticisms have arisen over this technique. Firstly the results from it are essentially difficult to test without high expenditure, and so the results will lack robustness. Secondly, the prevailing requirement to model archaeological patterns in relation to environmental factors may be considered

to be deterministic (see Gaffney and van Leusen 1995 for conflicting views). As such, the technique remains as a large discipline in itself, with its own conflicting paradigms and discourse.

The third issue relating to CRM is management. This concerns archaeology as a known resource within the landscape, with its own considerations, but as one of many other landscape interests. Management issues typically involve financial and political decision-making in addition to directing research aims. Such approaches to GIS have been particularly prevalent within areas where wide ranging interests, each with large datasets, lie together, such as within National Parks. For example, the GIS for Exmoor National Park consists of data covering archaeology and many other environmental themes (V. Heal *pers comm.*). In relation to GIS, applications relating to management extend from basic data storage and display to more complex issues.

1.5 Main issues and problems

So far, this chapter has outlined the main developments within cell-based GIS research, and has been extremely general in its approach, highlighting the applications of GIS within three broad archaeological disciplines: procedure, interpretation and resource management. The main developments within each have been outlined.

A number of criticisms of past GIS approaches have already been mentioned, lying both within the areas of landscape interpretation and CRM, and permeating through both of them (e.g. the criticism that GIS applications are essentially environmentally deterministic and therefore the tool is fundamentally normative and reductionist). Many archaeological applications using GIS may be criticised for using the tool because it is available rather than using it to assist with archaeological requirements. Lock and Harris noted this potential problem, that GIS may be used as a "high-tech 'fishing trip'" (1996: 239), and thus advised that approaches should therefore be theory-driven. As such, it has been noted that a theoretical underpinning of applications of GIS has been lacking (Gillings and Goodrick 1996). It is therefore important to assess the quality of the different GIS tools in relation to method and within the context of the various archaeological requirements that may be subdivided between interpretational and managerial (i.e. CRM) archaeology.

A number of gaps and limitations exist within the past and current corpus of work using cell-based GIS within archaeology. The multiple functions of some single GIS tools for

various archaeological requirements strengthen Gillings and Goodrick's (1996) mentioned above, and highlight the need for a structured assessment of the applicability of the currently available GIS tools for archaeological uses. This is made ever more crucial as software becomes increasingly user-friendly and widely used. As argued in relation to computer visualisation (Miller and Richards 1995), developments in sophistication of computer techniques highlight the need to assess methods in greater detail in order to avoid misuse. Without a firm understanding of the applicability, potential and limitations of different techniques from a systematic study, there will remain a limited theoretical underpinning of the subject. Four limitations within past GIS research may be identified that contribute towards this.

1. Within cell-based GIS studies involving archaeological landscapes, there has been a trend towards studying those areas that display high topographic variability. For example, van Leusen (1993) mentioned that the choice of study area within the Netherlands for this type of GIS work was restricted to the south since it was the only area displaying sufficient topographic variability (*cf.* Martlew 1996). Such a bias in the areas studied limits the understanding of the applicability of the various GIS tools used for this and other archaeological research.

2. Archaeological GIS studies have rarely been truly comparative, even though comparison would enable a more complete understanding of the applicability of the various tools. There have been a number of studies analysing procedure, that have compared the effects of different tools and algorithms to different types of raw data and landscape unit types, and on the display of different landscape features (e.g. see chapter 4, section 4.3), but these have been generic rather than archaeological. Some archaeological studies have highlighted more than one landscape within a study (e.g. Gaffney *et al.* 1996), but these have not been entirely comparative of different landscape types in relation to the archaeology and their relationship with the GIS tools being applied. This is perhaps surprising within archaeology where trends, particularly within resource management, have attempted to classify different archaeological landscape types. They have often been categorised into polarised couplets, depending upon their environmental features or their potential for preservation of different types of archaeology. Opposites including wetland/dryland or upland/lowland have been identified (*cf.* Darvill 1987a), though this trend has not been reflected within archaeological studies involving GIS. Such a lack of truly

comparative studies means that there can be no meaningful understanding of the usefulness of different GIS tools in fulfilling archaeological requirements.

3. The issue of resolution has not been explored in any significant detail, other than through correlation of different types of data (e.g. Richards 1996). As with the effect of algorithms on various landscape types (see point 2 above), issues of resolution have been addressed from a non-archaeological standpoint, investigating the relationships between the resolution of raw data and the resolution and accuracy of resulting DEMs (see chapter 4, section 4.3). Further, higher resolution data have been shown to indicate greater potential for analysis, such as through the inclusion of anthropogenic earthwork features within the interpolated DEM (*cf.* Bell and Lock forthcoming). Studies relating to archaeology have seldom focused upon issues of resolution, rather justifying the surface resolution chosen in relation to the accuracy of the raw data, or memory requirements, though the latter view is decreasing in significance (van Leusen 1993). Otherwise, they focus upon the requirements of raw data resolution and variability (e.g. Fletcher and Spicer 1988). The value of different resolutions of surface data in relation to archaeological questions and requirements has not been investigated significantly, despite traditional survey work by groups such as the Royal Commission on the Historical Monuments for England (now part of English Heritage). Such past work has investigated sites and landscapes with traditional graphical survey techniques at different resolutions in order to answer different archaeological questions (*cf.* Bowden 1999).

4. The majority of current GIS research affecting archaeology has made a distinction between the surface, as represented by the DEM, and the archaeology, which is seen to lie upon it, or be draped across it. This indirect relationship is misleading for two reasons. Firstly, the evidence of earthworks demonstrates that, dependent on resolution (see point 3 above), the surface can be seen as archaeological itself, and not separate and abstract. Secondly, the processes that conceal or reveal a site will also affect the relationship between the archaeology and the land surface. For example, alluviation can flatten a landscape, concealing detail of archaeological features. The majority of previous GIS studies have not considered this physical relationship between the landscape surface and the archaeology, and so such issues have not been explored.

1.6 Main thesis research aims

In response to the issues highlighted above (section 1.5), it may be considered that a systematic assessment of GIS methods and their application within landscape archaeology is required to complement the expanding uses of the tool within the subject. Therefore the aim of this thesis is to provide an assessment of the main tools available within current GIS packages, and their application within landscape archaeology (within the two main themes of interpretation and CRM). Further, it is aimed at being a comparative study in response to the four limitations outlined above that provide its framework (*vis* the focus upon topographically variable landscapes, a lack of comparative archaeological research, the effect of resolution and the psychological distinction between surface and archaeology). Each of these four points may be considered in terms of a research design.

1. The lack of previous DEM-based research into topographically flatter landscapes forms the basis of the choice of landscapes for study. As a consequence a low-lying, relatively flat landscape was chosen for the analysis (see chapter 2).

2. The lack of comparative GIS research suggests that a second landscape should be chosen – one that shows a sharp contrast to the chosen flat, lowland landscape. Therefore, a topographically variable landscape was also chosen (see chapter 2). Comparisons of the various GIS methods and tools could then be made in relation to the topographically variable/flat and the dryland/wetland zones (*cf.* Darvill 1987a). In this way the effectiveness and applicability of the GIS tools could be compared in relation to the requirements of the contrasting archaeological landscapes, each with their different types of archaeology, particular interpretation difficulties and requirements, and contrasting CRM issues. To provide direct comparability between landscapes it was important that the two were of an equal size, but of contrasting topography. Further, in order to focus study towards the archaeological requirements, they should each be centred on a particular monument with a limited temporal range in order to limit variables. It is also important that the nature of the archaeology and landscapes is not fully understood in order to limit preconceptions of both interpretation and CRM.

3. The impact of variable resolution surface sampling for the creation of DEMs has been partly investigated previously through an abstract approach (Fletcher and Spicer 1988). However, the issue of resolution is broader, reflecting that of both the raw

input-data sample and the resultant DEM. Further, the effect of interpolation algorithms upon the ratio of 'sample density to surface resolution' makes the issue even less straightforward. The effect of resolution in relation to archaeology may only be understood through comparative research using contrasting data resolutions and through generating DEMs of contrasting resolutions. Consequently, an area of each of the two landscapes was chosen for higher resolution survey and analysis. The decision over which area to study was based upon the principal monuments being studied and areas that had been surveyed previously to enable comparison.

4. The issue of whether a DEM surface provides an abstract backdrop to the archaeology, or represents the archaeology itself may be approached through higher resolution investigations in areas of known archaeology. By sampling a surface at variable resolutions with contrasting sets of raw data the surface will be generalised within the DEM in different ways. A comparison between the surfaces resulting from the different sampling techniques can be used to examine the possibility that the surface may be perceived as both backdrop and archaeology. Further, through such an examination, the possibilities and limitations of each GIS approach, in relation to landscape archaeology may be understood more clearly.

1.7 Thesis structure and philosophy

Philosophical approach is always important for any study. Within archaeological GIS studies, approaches have been accused of being driven by a strict positivist approach, and as such have been criticised for being environmentally deterministic. There have been criticisms that GIS studies can be technology-led (*cf.* Lock and Harris 1996) and there have been calls for a theory-led approach (e.g. van Leusen 1995) and an overall cognitive shift to reflect the new technology (e.g. Zubrow 1990). Others have highlighted the importance of studies being data-led rather than technologically led (Gaffney *et al.* 1996). Gillings and Gaffney (1996) highlighted that GIS was developing into a "place to think" and more recent research has demonstrated that the tool is not so philosophically limited (e.g. Llobera 1995).

A potential paradox exists when applying a 'scientific' method to a discipline that aims to study past human action which is essentially subjective. Empirical data and positivist approaches can help in the understanding of the past, but can be extremely subjective and misapplied. For example, cell-based analyses investigating archaeological distribution may be criticised for creating a hierarchical distinction between cells such that certain

cells are defined as archaeological (places) and others are considered as part of the surface (spaces). This distinction may be considered to be determining results - approaches may be data-led from the positions of archaeology, but it is known that the archaeological record is incomplete. Further, studies merely concentrating upon cells containing archaeology may be considered to be unsystematic, and therefore of limited value. A response to this issue was provided by Lake *et al.* (1998) who presented a study that investigated the significance of viewsheds from the positions of Mesolithic sites to assess the assumption that they had been positioned to maximise the viewpoint. An automated programme was developed that calculated the numbers of cells visible from a random sample of cells within the study area to compare the results for significance. While this approach seems sufficient in response to the issues highlighted, such testing of a hypothesis relies on an assumption that may be considered to be incorrect or incomplete. Within the example cited, many other issues will influence the location of an archaeological site, including both physical factors such as local vegetation (Chapman and Gearey 2000) and cognitive factors such as choice or belief systems.

The aim of this thesis is to better understand GIS methods and their application within the two main areas of landscape archaeology - interpretation and CRM. The chosen method for this was to apply a range of GIS tools to contrasting archaeological and environmental situations and to record observations based on their usefulness in relation to the spheres of landscape interpretation and CRM. Such an approach lies within the third theme of GIS procedure. The approach employs a fundamentally positivist structure - identifying problems (the four highlighted in section 1.5) and applying methods to address them (chapter 4) to obtain results and generalisations. However, although the overall structure fits into this broad paradigm, the approaches within the methods themselves are more complex, calling upon various methods of examination, including both hypothesis-testing and narrative description, to obtain understanding. The thesis is therefore polyfocal: whilst its aims are to assess the applicability of method, this can only be achieved in relation to those theories that underlie the separate spheres of archaeology (i.e. landscape interpretation and CRM). The focus is therefore one of applied rather than pure science.

In response to these aims, this thesis is structured around the suite of commonly available cell-based GIS techniques. These are applied to each of the landscapes in turn in a systematic way in order to assess their applicability in each case. The results from these analyses are then compared in order to understand the relative usefulness of different

techniques for each and at variable resolutions. This work is aimed at providing a basis for a better understanding of the various GIS tools, to highlight some applications that may not have previously been considered and to mention others that are less than useful.

Although many issues within the current framework of archaeological GIS have been approached within this study, others have not. For example, the subject of predictive modelling of site location using GIS has not been approached. This is for three main reasons. Firstly, this application may be considered to be a separate discipline in itself and is thus imbued with its own philosophy and approaches, relying on a its own particular assumptions. Secondly, predictive modelling commonly deals with larger landscapes and samples of data in order to maintain statistical robusticity, and so is less compatible with the themes being approached here. Thirdly, the results from predictive modelling require a greater amount of ground-truthing, thereby falling outside of the framework of introspective analysis used for the present study.

1.8 Summary of chapter 1 and outline of the thesis

In this chapter, a framework of previous and current cell-based GIS research has been presented, focusing on the developments and trends within archaeological landscape research. Also, some of its main shortcomings have been outlined. These have been focused upon the need for a more structured analysis of the possibilities of the GIS toolbox, and its applicability within the themes of interpretation and CRM within landscape archaeology. The need to examine the potential of cell-based GIS to a range of physical environments, each with particular archaeological characteristics and needs has also been demonstrated. It has been highlighted that this may be best achieved through a comparative study of both the different types of landscape and the contrasting resolutions of input-data. It has also been suggested that the most appropriate approach for testing the applicability of the different tools to the different scenarios is through a comparison using an introspective analysis. For example, the sampling of landscape data is not absolute and cannot be accurately assessed in terms of error.

In chapter 2 the selection of the two study areas is presented, outlining details of their environment, archaeology and previous research, highlighting particular issues for each relating to both landscape interpretation and CRM. In chapters 3 and 4, the input-data and the suite of GIS methods are outlined, including further review of previous applications. Chapters 5 and 6 list and describe the results from each of the two study areas, and are structured around the methods outlined in chapter 4 to maintain a

systematic approach. The following two chapters discuss these results in relation to the usefulness of GIS methods (chapter 7) and their applications within landscape archaeology (chapter 8), the latter assessing the results in relation to the archaeological themes of landscape interpretation and CRM. Each of these two chapters begins with an assessment of the results in relation to the questions particular to each of the two landscapes, and continues by comparing the usefulness of the different GIS techniques for the different types of landscape and different resolutions of input-data and DEM. The final chapter (chapter 9) presents the conclusions from the study, assessing cell-based GIS methods and their applications within landscape archaeology.

Chapter 2

The study areas and significant issues to be addressed

2.1 Introduction

In the previous chapter the objectives of this thesis were outlined in relation to four shortcomings of earlier research. It was concluded that two contrasting landscapes needed to be chosen to provide a basis for a comparison of the value of different parts of the GIS toolbox to remedy the present bias in GIS studies in that it has been focused upon areas with greater topographic variability. It was noted that, for comparison, each of the two landscapes needed to be focused upon a primary archaeological site. It was also concluded that the two study areas should be of the same size to enable meaningful comparison. An area of 10 x 10 km was considered appropriate for the study, providing a balance between a wide distribution of archaeological features, without detracting from the central monuments in each case.

The choice of topographically variable landscape was the Yorkshire Wolds, focused upon the complex of cursus monuments that concentrate around the village of Rudston (UK National Grid TA095675 - Figure 2.1). This complex lies within a bend in the Great Wold Valley and the Gypsey Race that runs along it and into the North Sea nine kilometres to the east at Bridlington. The site displays typical topographic variability of a chalk landscape, and a cluster of unique archaeological monuments. A cluster of cursus monuments is centred on the massive Rudston Monolith of Millstone Grit, apparently dating to the late Neolithic period (*c.* 2000 BC). Following the valley, the area displays great topographic variability and a range of broadly contemporary monuments.

The flatter landscape chosen for study lies on the western edge of the Humberhead Levels. This is an area of lowland, containing many wetland areas, that lies to the west of the Lincoln Edge and to the east of the Pennine foothills and the Sherwood Sandstone outcrops upon which Doncaster lies. The study area is focused around the archaeological site of Sutton Common (UK National Grid SE563122 - Figure 2.1) that lies on the eastern side of the A19 to the south of Askern. On the Common two early Iron Age enclosures lie on opposing sides of the palaeochannel of the Hampole Beck, surrounded by past wetlands. The enclosures lie less than two kilometres from the nearest higher land and so the study area has been positioned so that they are contained within its

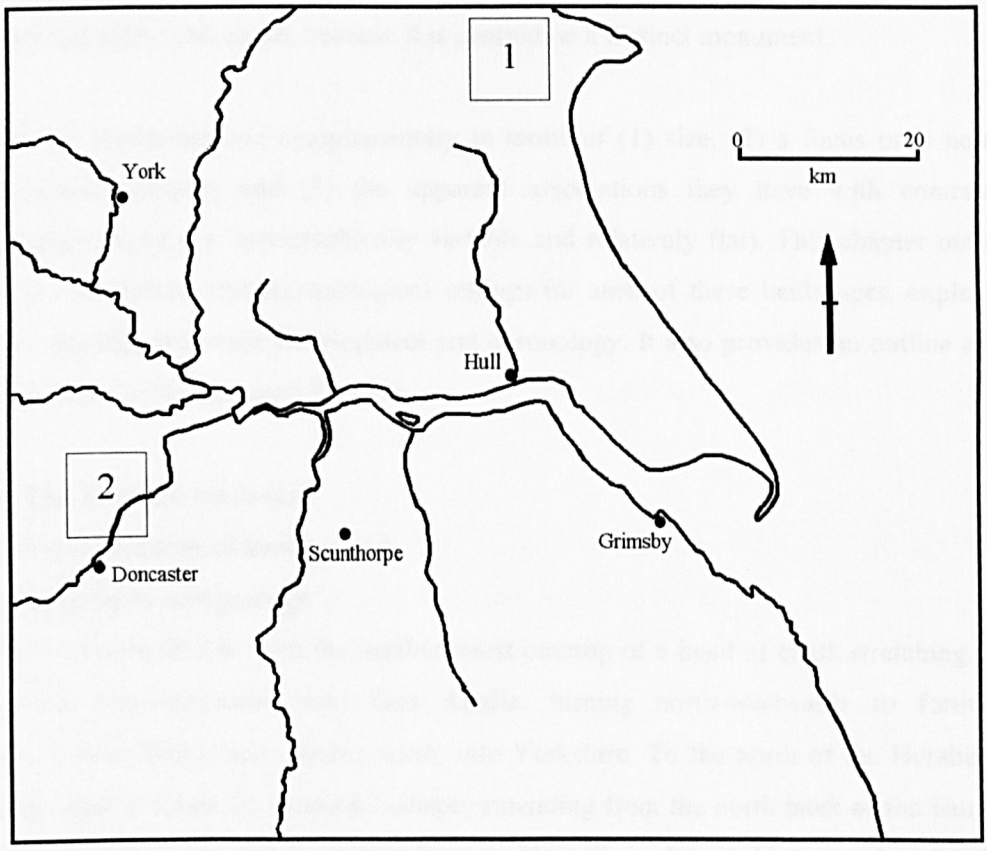


Figure 2.1 Location of the two study areas.
1. The Rudston landscape, 2. The Sutton Common landscape

northwestern quarter. This area was chosen to contrast the upland landscape topographically and, again, because it is centred on a distinct monument.

The two landscapes are complementary in terms of (1) size, (2) a focus on a notable monument complex and (3) the apparent associations they have with contrasting landscape types (i.e. topographically variable and relatively flat). This chapter outlines the environmental and archaeological settings for each of these landscapes, explaining past research, landscape development and chronology. It also provides an outline of the main issues to be addressed for each.

2.2 The Rudston landscape

2.2.1 Environmental background

a. Topography and geology

The Yorkshire Wolds form the northernmost outcrop of a band of chalk stretching from Wessex north-eastwards into East Anglia, turning north-westwards to form the Lincolnshire Wolds and, further north, into Yorkshire. To the north of the Humber the chalk outcrop forms an inverted L-shape, extending from the north bank of the Humber, and continuing northwest to Wilton Beacon. Here, it reaches its highest point of 243 m, before curving to the east, meeting the North Sea at Flamborough Head. This shape was formed by the folding of the Cretaceous Chalk block during the Tertiary period that formed a syncline with a northwest-southeast axis, plunging to the southeast and forming a scarp on its inland side (Catt 1990). Overlying the lower dip slope to the southeast are the Quaternary deposits that form the Hull valley and Holderness. On the western side of the scarp are the deposits of the Vale of York, which are dominated by glacial lacustrine sediments derived from Lake Humber overlying Triassic Mercia Mudstone. On the northern side of the Wolds the Vale of Pickering divides the chalk from the Tabular Hills. The Vale of Pickering also consists of Quaternary deposits dominated by the glacial lacustrine sediments of Lake Pickering.

The Quaternary geology of the Yorkshire Wolds is dominated by the deposition of loess that overlies the chalk sometimes in excess of a metre depth. Loess soils are recognised as silts that are uniform in both particle size and spatial distribution, and this characteristic reflects their derivation. Loess on the Yorkshire Wolds was deposited by aeolian action eroding the glacial out-wash plains of the North Sea. This deposition has been dated to the later Devensian (i.e. after approximately 25,000 years BP - Catt 1994). Stratigraphically, the loess deposits on the Yorkshire Wolds pre-date the deposition of

Devensian till. The likely source of the latter is the North Sea basin that must have been dry or braiding at this time. The loess must therefore have been deposited prior to the arrival of the ice sheet at Dimlington that occurred shortly after 18,500 BP (Catt *et al.* 1974, Catt 1978, Catt 1990). Frost shattering of the chalk during the later Devensian led to a mixing of the chalk and silty loess material, known as Chalky Grut. While this was eroded from steeper slopes, in more stable areas, such as the dry valleys, this material was weathered to form a brown silty clay (Catt 1990). The high clay content of these deposits, higher than normally expected within loess soils, may be due to the dissolution and decalcification of the chalk coupled with the disaggregation of the aeolian deposits, leaving a clay-rich residue (Catt *et al.* 1974, Ellis and Newsome 1991).

The overall topography of the Wolds is characterised by gently rolling hills and this is largely a product of periglacial processes. During colder periods the chalk became frozen and consequently impervious. The temporary thawing of the more superficial layers therefore freed up water that could not drain and so the unstable frost shattered material and Chalky Grut was carried away by the slow downslope movement of material *en masse* over a subsurface frozen layer. Conversely, during warmer periods, such as the Holocene, the chalk was no longer frozen and therefore became permeable, increasing subterranean drainage, and so erosion of this kind was less likely (Catt *et al.* 1978). However, mass movement of a lesser extent has been witnessed and recorded on the Yorkshire Wolds in the nineteenth century by the Reverend E. Maude Cole (Cole 1887) and more recently following a rapid melt of snow (Anon 1904). Gullying in arable fields has also been recognised following storms and the saturation of the soil (Foster 1978). The main valleys within the Yorkshire Wolds are the Great Wold Valley that runs across the northern area, meeting the North Sea at Bridlington, the Market Weighton Gap and the slacks along the western scarp.

The permeable chalk overlies impermeable Upper Jurassic clays, producing a spring line at the base of the chalk. The shape of the ground water table broadly follows the surface topography, forming an aquifer dependent on the distribution of faults and open joints in the chalk (Hayfield and Wagner 1995). A second source of water is generated by the subterranean drainage within the areas of colluvium (slope deposits) in the deeper valley bottoms. This water occasionally rises as springs, referred to locally as gypseys, during wetter seasons when ground water levels rise. The largest of these springs on the Wolds is the Gypsey Race that forms a surface stream along the floor of the Great Wold Valley throughout most of the year. This joins with other smaller gypseys, rising near the

western escarpment of the Wolds near Wharram, and flows into the North Sea at Bridlington Quay (Dakyns and Fox-Strangeways 1886). The surface-flowing water of the Great Wold Valley, relative to the dry nature of the permeable chalk Wolds, has been noted as one of the main reasons for the distribution and nature of settlement in this area (Waites 1970, Allison 1974, Hayfield and Wagner 1995). However, recent research within the high Wolds has produced evidence of a pair of hollows that retain water due to a glacial or karstic clay lining. The density of lithics from around the site, dating from the Mesolithic, Neolithic and Bronze Age, suggests that these ponds formed a separate water source (Hayfield *et al.* 1995, Hayfield and Wagner 1995).

b. Vegetation history and landuse

It has been noted that chalklands present several problems for studying palaeoecology (Moore 1987, Flenley 1990; observed by Chapman and Ellis 1997). Firstly the porosity of the chalk substrata restricts the development of lakes and peat deposits so areas of relative wetland are often subject to periodic drying and aeration. However, their calcareous soils do preserve gastropods that can provide localised information. Consequently the history of vegetation change on the Yorkshire Wolds is restricted to a number of variable sources. It is fortunate that towards the centre of the study area, at Willow Garth, a detailed palaeoecological study of both microfossils and macrofossils has been conducted (Bush 1986, Bush and Flenley 1987, Bush 1988). Otherwise the evidence for the vegetation development of the area comes from analyses of the surrounding lowlands (e.g. Beckett 1981). Willow Garth is located within the Great Wold Valley 2.5 km to the east of Rudston (at TA126676). It lies at 18 m OD and is a wetland site consisting of several hollows within the valley floor. The stratigraphy at this site shows 0.7 m of moss and wood peat overlain by 0.5 m of gyttja. The base of the peat here has been radiocarbon dated to *c.* 8950 - 8250 cal BC (9460 BP uncalibrated) with the base of the gyttja dated to *c.* 370 - 30 cal BC (2120 BP uncalibrated). The top of the gyttja dates to approximately 110 BP. The palynological evidence from the site showed a full sequence, except for a hiatus between *c.* 7000 cal BP (8000 BP uncalibrated) and *c.* 3000 cal BC (4300 BP uncalibrated) when there was a break in deposition.

The overall history of the development of vegetation within the larger area can be found elsewhere (*cf.* Flenley 1990) and need not be repeated here. Instead a localised development of vegetation during the middle to late Holocene will be given to provide an overview of changes on the Wolds during the periods represented by the archaeology (see section 2.2.3 below). Prior to the hiatus in deposition at Willow Garth, *c.* 7000 BC,

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an open grassland landscape appears to have persisted on the Wolds in this area and it has been suggested that this was encouraged and maintained anthropogenically (Bush 1986, Bush and Flenley 1987, Bush and Ellis 1987, Bush 1988). Evidence from other sources has shown that a relatively open Wolds landscape existed during the early Neolithic period (Manby 1963, 1976, 1988). Evidence of a pastoral landscape was found beneath the Willerby Wold long barrow. The earliest date from the long barrow construction was obtained from the facade trench pit and produced a determination of 3010±150 BC (BM-189) that calibrated to 4250-3350 cal BC (Manby 1988), indicating that a grassland landscape existed at this location prior to this date. However, molluscan evidence showed that woodland existed nearby (Manby 1963). Similarly at Kilham, evidence of cultivation, regeneration and further cultivation, with developed woodland nearby, was obtained from beneath the long barrow (Manby 1976). The earliest date from the structure of the Kilham long barrow, from the plank packing of the mortuary enclosure, was 2880±125 BC (BM-293) which calibrates to 2950 - 3300 cal BC (Manby 1988). By the time the Willow Garth record resumes, around 3000 - 2900 cal BC, the palynological evidence shows a mixed agricultural practice with abundant pastoral weeds, such as the plantain *Plantago lanceolata*, and some cereal pollen, coupled with increased forest clearance (Bush 1986). This mixed agriculture continues throughout the Bronze Age and Iron Age with a continued decline in forest cover (Bush 1986). The development of a gyttja deposit at Willow Garth at *c.* 370 - 30 cal BC (2120±50 BP uncalibrated) has been interpreted as relating to slope wash, or colluviation, as a response to arable cultivation (Bush and Ellis 1987). The pollen evidence shows that cultivation commenced much earlier than this and it seems likely that this deposit reflects an intensification of arable farming (such as opening up more land), or else a change in approach (such as deeper ploughing or ploughing up the slope). This activity is perhaps reflected in the elaboration of the Wolds dyke system which probably originated earlier during the later Bronze Age (Manby 1980a, Dent 1984, Bevan 1997) and the development of field systems, especially around Rudston, which continued to be used in the Roman period (Stoertz 1997). Excavations have demonstrated further evidence of agriculture from this time. Within the area between the two ditches of cursus A (see below) evidence of hand-cultivated 'lazy beds' was found with pottery dating to the late third to mid fourth centuries within the furrows (Abramson 1997). Later landuse appears to have been dominated by a similar mixed agricultural regime, with a development of a Medieval open field system of strip cultivation and sheep walks until the enclosure award in 1777 that forms the modern road and field pattern (Waites 1970, Manby 1977). Over the following hundred years arable farming intensified and it is estimated that by as early

as the 1830s approximately seventy percent of agricultural land in the area consisted of arable land. By 1848 very little old grassland persisted and this diminished with increased ploughing during the first and second World Wars (Harris 1996). Table 2.1 provides a summary of the development of the landscape of the Yorkshire Wolds and how landuse has changed.

Table 2.1 *Landscape development and landuse on the Yorkshire Wolds*

Calibrated dates	Event	Reference
AD 1777	Enclosure award - modern road and field system established	Manby 1977
pre-AD 1777	Open field strip cultivation and sheep walks	Manby 1977
c. AD 275-350	Pottery found in lazy bed furrows	Abramson 1997
370-30 BC	Soil erosion suggests increase in arable cultivation	Bush 1986
pre-3785 BC	Grassland near woodland at Willerby Wold	Manby 1963, 1988
pre-3950 BC	Arable cultivation beneath the Kilham long barrow	Manby 1976, 1988
8590-8250 BC	Base of peat formation at Willow Garth	Bush 1986

2.2.2 Archaeological background

Interest in the archaeology of the Yorkshire Wolds began largely in the early nineteenth century. It followed the final agricultural enclosures that were accompanied by a widespread expansion of arable farming that destroyed many archaeological earthworks (Manby 1988: 35). This activity, however, released much archaeological material into the ploughsoil, which was collected by farm workers throughout the nineteenth century and sold to help satisfy the demands of dealers, collectors and museums within the region. From the 1840s barrow digging became extremely popular within the region with the work on the Wolds mostly carried out by T. Bateman (Bateman 1861), Canon William Greenwell (Greenwell 1877, 1890) and J.R. Mortimer (Mortimer 1905). However, the significance of what had been found was not recognised until the 1920s when advances in the classifications of the Neolithic were made (Manby 1988) and more specific studies were made of the artefact record (e.g. Newbiggin 1937).

By the 1940s the techniques and approaches of modern archaeology were developing. The recognition of the vast quantities of material from East Yorkshire, coupled with the high threat to this resource from arable agriculture, led to an increase in aerial photographic work to identify sites. It also led to a programme of rescue excavation

concentrated on the ploughed barrows that had been investigated previously through the work of the antiquarians. The latter was led by T.C.M. Brewster under the auspices of the East Riding Archaeological Research Committee for the Ministry of Works, later to become the Department of the Environment (Manby 1988). Following this initial input, much archaeological work has been conducted on the Yorkshire Wolds, including commercial work (e.g. Abramson 1996a) and a high proportion of research-based work. This work has included the excavation of cursuses (Dymond 1966, Kinnes 1982, Abramson 1996b, 1997) long barrows (Manby 1963, 1976), henges (McInnes 1964), round barrows (Petersen 1969, Manby 1970, Pacitto 1972, Manby 1980b) and Neolithic occupation sites (Manby 1975). Aerial photographic work has also been prevalent within the region (Riley 1980a, 1988, Stoertz 1997). Similarly, studies have been conducted on the distribution of small finds, including pottery (Manby 1956) and flint (Manby 1979, Durden 1995). Later features have also been intensively investigated within the study area, including Iron Age features (Stead 1991, Dent 1998) and the numerous Roman features in the landscape such as Rudston Roman villa (Stead 1980).

2.2.3 Monument classes

For the present study, those monuments dating to the Neolithic period provide the focus centring on the ritual/ceremonial monuments that cluster within it (Figure 2.2). There are no monuments (only lithic scatters) within the area dating to any earlier periods, and those from later periods are only considered in relation to their spatial association with the distribution of earlier features. The study is also concentrated upon those monuments that would have been upstanding and visible in the landscape, thereby influencing the continual and ongoing recreation of the landscape. The positions of settlement sites dating to the Neolithic (after Manby 1975) have been noted in terms of their date, based on their artefact records, and their position within the landscape. This provides a link to where activity had taken place, albeit with limited evidence, to provide a focus from which the landscape of that period may have been perceived.

a. Long barrows

Long barrows are usually rectangular or trapezoidal mounds constructed of stone, of earth or of both. Their length normally twice exceeds their greatest width, between 25 m and 120 m on average, usually with parallel quarry ditches either side of them. Sometimes the mound is revetted with either timber or stone that can form an elaborate facade at the higher or wider end of the monument. Often one part of the mound contains

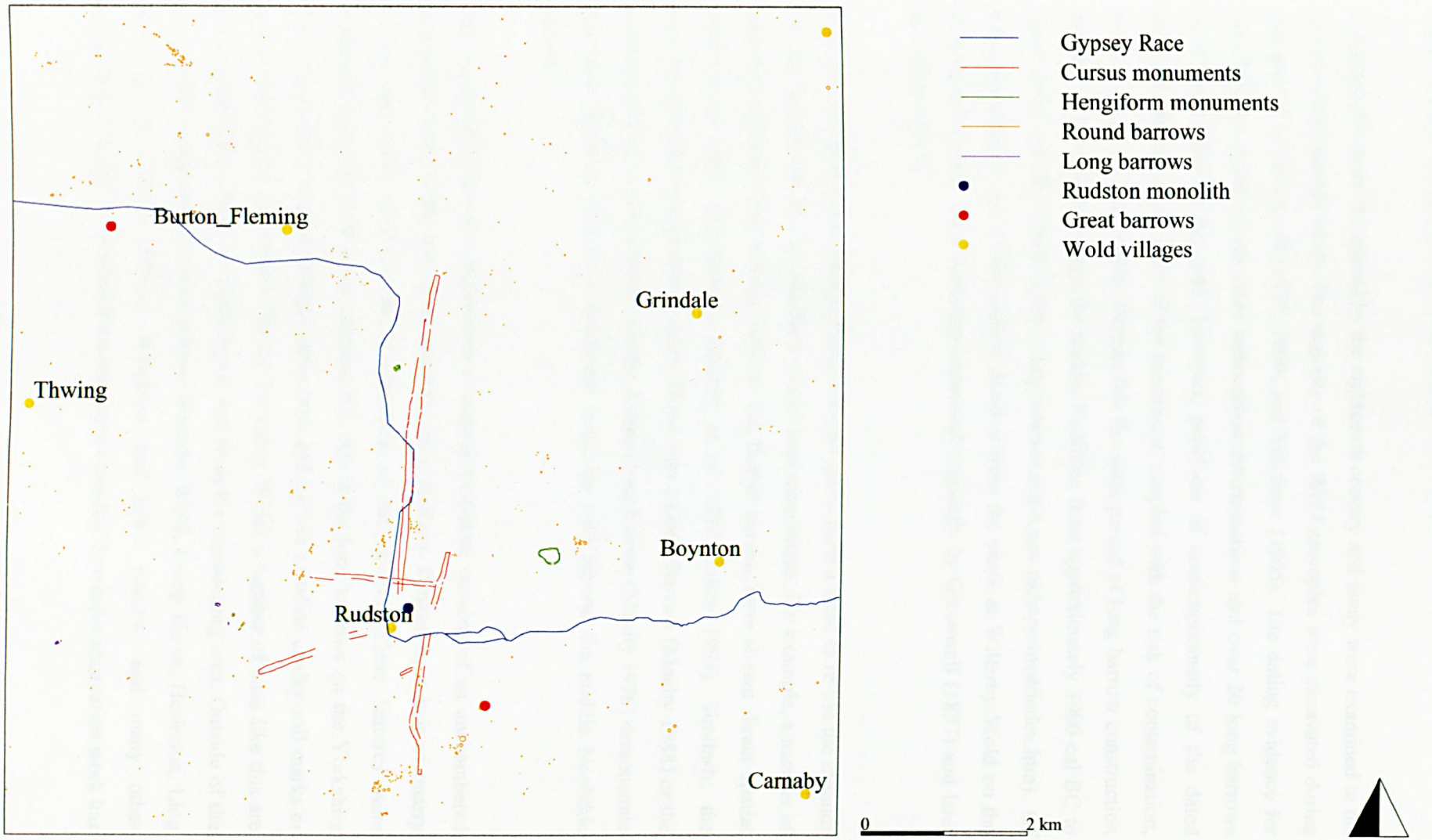


Figure 2.2 The Rudston landscape showing the distribution of archaeological features.

a stone or wooden burial chamber (MPP 1998 - http:///www.eng-h.gov.uk/mpp/mcd/index.htm, Lynch 1997).

Long barrows were recognised by the eighteenth century and many were examined in the course of antiquarian study. The majority of the Wold examples were excavated during this period by Greenwell (1877, 1890) and Mortimer (1905). The dating evidence for long barrows comes mostly from radiocarbon determinations and over 20 long barrows have been dated in this way. However, problems of contemporaneity of the dated material and the construction of the monument, coupled with the risk of contamination, make such dating less certain. Despite this the main period of long barrow construction appears to have been through the middle Neolithic from approximately 3000 cal BC to about 2400 cal BC (MPP 1998 - http:///www.eng-h.gov.uk/mpp/mcd/index.htm). Of these monuments, one of the earliest dated is from the chalk at Willerby Wold on the Yorkshire Wolds in East Yorkshire excavated originally by Greenwell (1877) and later by Manby (1963).

A notable problem in the dating of long barrows stems from a trend to re-use the mounds for later burial or to incorporate them within later monuments. For example, a number of cursus monuments (see below), such as the Dorset cursus, have shown direct spatial relationships with long barrows (Barrett *et al.* 1990, Tilley 1994). Similarly, the conversion of the long barrow at Kemp Howe into a Great Barrow (Manby 1988) or the constructions of a round barrow over the Kilham long barrow (Manby 1976) demonstrate that these features enjoyed a functional longevity well beyond the middle Neolithic period.

The typical long barrow construction in eastern Yorkshire consists of an unchambered mound of chalk rubble and earth, standing on a platform flanked by a pair of quarry ditches that were used for the construction of the mound. These features were constructed during the third millennium BC. All of the long barrows on the Yorkshire Wolds have been levelled through agriculture and survive as white chalky soil marks or as crop marks over the ditches. On the Yorkshire Wolds a number of sites like this are known both from within the study region and from the surrounding area. Outside of the study region, examples are known from Willerby Wold, Kemp Howe, Heslerton, Ling Howe, Cross Thorns, Market Weighton and Esh's Barrow, and many other morphologically similar features have also been recorded. Extensive excavation work has

been carried out on some of these sites, most notably at Willerby Wold (Manby 1963), though there was much antiquarian work also (*cf.* Greenwell 1877).

Kilham Long Barrow, Kilham (TA05606732)

National Monuments Record (NMR) No. TA06NE3

Sites and Monuments Record (SMR) No. Humberside 4016

The Kilham long barrow (Figure 2.3) lies to the west-southwest of Rudston village towards the edge of the study area. It survives today only as a soil mark and crop mark. In plan this consists of broad parallel ditches *c.* 13 m apart aligned northeast to southwest for a distance of *c.* 65 m. 20 m to the northeast are the cropmark remains of a ring ditch. This site was first excavated by the Rev. Canon Greenwell in the autumn of 1868 (barrow number CCXXXIV) when it lay within the Londesborough estate (Greenwell 1877: 553-6) after it had been noted that several human bones had been unearthed with the removal of tree roots from the site. In 1868 the site was 170' (51.8 m) long and 60' (18.3 m) wide and 4' (1.2 m) high at its northeastern end and 45' (13.7 m) wide and 3' (0.9 m) high at its southwestern end. Within the barrow were found several human bones, including some burnt, and a number of inhumations, including those of infants. Pottery from the site included some fragments of a "plain vessel" and, accompanying two later inhumations, food vessels were found. At the western end of the barrow a rise was interpreted as an added round barrow which contained an inhumation of a girl of about sixteen accompanied by another food vessel. A number of holes, or pits, were discovered beneath the chalk bank (Greenwell 1877: 553-6).

The site was again excavated between 1965 and 1969 and a ring ditch facing its northeastern end was investigated in 1971 (Manby 1976). These excavations established the full dimensions of the site and located the positions of Greenwell's earlier work. It also identified a number of phases of activity. The first phase is characterised by scatters of flint and a number of hearths and pits dating to the Mesolithic period. This was followed at some point by a period of cultivation recognised from the soil profile and the palynological evidence. Molluscan evidence also demonstrated that well developed trees grew nearby, similar to at the Willerby Wold long barrow that was built within grassland near to a wood (Manby 1963). The primary phase of barrow construction, phase I, consisted of parallel quarry ditches which were dug in sections and which presumably provided upcast for the construction of a narrow mound. No associated burial was found to complement this phase, although the later phases on the site and Greenwell's investigations may have removed the evidence. The ditches from this phase were then



Figure 2.3 Aerial photograph showing the cropmark remains of the Kilham long barrow (Riley 1988: 203)

allowed to silt up for a significant period of time, perhaps more than a century, since a new soil formed and vegetation grew within the ditches, thereby slowing the silting process. The second phase of long barrow construction, phase II, may be divided into two sub-phases. Firstly, a timber mortuary enclosure and avenue were constructed and infilled, leaving only the northeastern end with its burial chamber open. At a later date this timber structure was burnt and the northeastern end was completed and infilled. A number of later developments also took place on the site, the evidence from the northeastern end displaying a continued usage. Within the northeastern ends of the quarry ditches sherds of Grimston ware pottery were found along with flints and animal bones. Pottery remains from this area continue through to the later Neolithic period as 'all-over-corded' beaker fragments have been found. Early Bronze Age material was also discovered including the remains of food vessels and collared urns. During the early Bronze Age a number of other inhumations were added to the mound, as noted by Greenwell, associated with food vessels. The ring ditch to the northeast of the site was found to contain a small collared urn and fragments of a food vessel. It is perhaps significant that this feature was constructed over the line of the posted avenue in a similar position to that at Willerby Wold, though the recognition of the posts at this time, following burning and biological decay is unlikely (Manby 1976). A single radiocarbon date of 2880±125 BC (BM-293), which calibrates to 3950-3300 cal BC, was obtained from the planking packing the mortuary enclosure (Manby 1976, 1988).

Rudston Long Barrow, Rudston (TA075677)

NMR TA06NE23

SMR Humberside 4145

The Rudston long barrow lies nearly 200 m to the east of the Kilham long barrow. It is probably the barrow excavated by the Rev. Canon Greenwell (Greenwell 1877: 497), though this feature could also relate to the Denby long barrow (Riley 1988 – see below). Aerial photographs were taken of it in 1970 which were backed up by ground survey which revealed the feature to be 3' (0.9 m) high (Ramm 1971). The feature at this location consists of a pair of parallel quarry ditches *c.* 80 m long and up to *c.* 8 m wide. The area between the ditches is up to 20 m wide and can be seen as a chalky soil mark on aerial photographs (Stoertz 1997: 23). The feature is aligned west-northwest by east-southeast with a widening towards the eastern end where a small ditch runs between the two ditch terminals.

Denby Long Barrow, Rudston (TA077675)

The Denby long barrow is the most easterly long barrow within the study area. It lies to the northeast of the Rudston long barrow (see above) and appears to have been first photographed in 1974. Later flying and recording resulted in the conclusion that the crop marks represented a long barrow (Riley 1988). This feature, catalogued during the National Mapping Programme (NMP) of the Yorkshire Wolds as a possible long barrow, consists of short parallel ditches 18 m long and 25 m apart, located just 200 m to the south of the Rudston long barrow (Stoertz 1997). In 1970 it was noted that this feature had been incorporated into a dyke (Ramm 1971).

b. Cursus monuments

Cursus monuments have always been enigmatic since their initial recognition in 1723 (Chippendale 1996). There are a number of different monument forms that can be included within the cursus classification. Principally, a cursus may be defined as a pair of long, parallel banks, usually with external ditches. Cursus terminals are often sealed with the bank forming an elongated rectangle when viewed in plan. In length they have been recorded as between 45 m and 5640 m, although in Dorset two cursuses, the Gussage (5640 m) and Pentridge (4290 m) monuments, adjoin one another in a line forming a monument nearly 10 km long. In terms of width cursuses have been recorded between 12 m (Llandegai, Gwynd) and over 100 m (Amesbury, Wiltshire) across, although the ratio between length and width varies less (Loveday 1985).

Cursuses (using the anglicised plural form), as a class of prehistoric monument, were first recognised in 1723 when the great antiquarian, William Stukeley, described the Greater Cursus at Stonehenge. From this date until the 1930s, the main emphasis within the scant references to cursuses was on their function. This was dominated by the desire to understand how they were used and how they related to the other monuments within their immediate landscape and this is revealed through contemporary drawings and sketches (Stukeley 1740, Colt Hoare 1812, Crawford 1935, Chippendale 1996). However, the absence of a rigid relative chronology meant that the phasing of landscapes, such as that at Stonehenge, was misunderstood. A total of four examples of cursus monuments had been identified by the year 1934. In the succeeding years the emphasis shifted towards a clearer understanding of morphology and a quest to define rules within which the class of cursus could be classified. Focus was placed upon two morphological characteristics. Firstly, the terminals of the cursuses were studied for their presence or absence, their shape (rounded or square), and whether they were regular or

irregular. Secondly, the alignments of cursuses were described in terms being straight, curved or irregular (*cf.* Stone 1947, Atkinson 1960, Loveday 1985). Also a typological examination began with a search for similar monuments (e.g. Allen 1938, Riley 1944, St. Joseph 1956) - a reaction perhaps largely due to the development of aerial photography as a method for finding new sites. By 1947 Stone had recorded eight sites, though this included the bank barrow on Maiden Castle in Dorset (Stone 1947).

By the 1950s interest in cursuses increased and the first significant excavations took place (e.g. Leeds 1934a, Atkinson *et al.* 1951, Piggot 1954, Thomas 1955, Alexander 1958, Selkirk 1967, Atkinson 1960, Dymond 1966, Atkinson 1986) which followed a desire to date monuments. Considerations of function were still secondary to the science of archaeology and themes were typified by the examination of the chronological relationship between cursuses and henges (*cf.* Stone 1947, Thomas 1955, Alexander 1958) and the building of the monuments (e.g. Atkinson 1955, 9). The culmination of the work during this period came in 1960 with the publication of a definition of cursus monuments and a listing of known sites at the time - 15 in total (RCHM 1960). By the 1970s the trend in cursus research remained with the identification of new sites but an increased level of interest in function began. Penny and Wood (1973) typified this with the application of astronomical theories to the Dorset Cursus. However, interpretation and theory were to remain subsidiary to dating more previously known sites and locating new ones.

The 1980s saw a resurgence of interest in the interpretation of the role of sites within society and particularly how they functioned within social and economic systems. This trend extended into cursus research and a number of landmark papers exist as testament to where cursuses were considered as parts of wider studies of prehistory (e.g. Pierpoint 1980). It was at this time that the first definitive work on cursuses was published presenting the results of the excavation of the Springfield Cursus and placing them in relation to what was termed as the "cursus problem" (Hedges & Buckley 1981). At this time some 48 cursus monuments were known and this research listed the main theories for the function of these sites (Hedges & Buckley 1981, 19-20). Roy Loveday followed the work at Springfield, Essex four years later by the submission of a thesis (Loveday 1985). This catalogued and critically assessed all previous work in the field and produced a gazetteer of sites including dating evidence and theories regarding their function, role, spatial distribution, morphology and apparent association with river valleys.

Following Loveday's work, research into cursuses moved largely to the question of their function and role within society (e.g. Bradley 1984, Barrett 1994, Tilley 1994), although further excavations and empirical research continued (e.g. Richards 1990, Guilbert 1996). The disciplines of ethnography, anthropology, human geography and developmental psychology have been called upon to provide new ways of looking at the archaeology of landscapes and to provide new theories for the representations of culture within the prehistoric landscape.

The dating of cursuses has been extremely enigmatic. Evidence from Thornborough (Thomas 1955) and Maxey (Pryor and French 1985: 59, 232) demonstrates that they generally pre-date henges, on the basis of direct stratigraphic relationships. Loveday (1985) approached the issue of date from a typological stance by producing a classification of cursuses on the basis of the plan of their terminuses, class A displaying convex ends in plan, and class B displaying squared ends. These categories were subdivided on the basis of more subtle changes in their form including the regularity of their shapes (table 2.2).

Table 2.2 *Categorisation of cursuses on terminus shape (after Loveday 1985)*

Class	Terminus shape	Example
AI	Rounded	Thornborough, N. Yorkshire
AII (convex)	Partially flat	Dorchester, Oxfordshire
BI	Precisely squared	Springfield, Essex
BII	Irregularly squared	Rudston A, E. Yorkshire
BIII	1 corner with obtuse angle	Pentridge, Dorset

A further classification was made on the basis of the length and aspect ratio of cursuses. Those measuring less than 140 m long were assumed to be long mortuary enclosures. *Minor* cursuses were typically those between 180 m and 420 m long and between 25 m and 50 m wide, including the lesser cursus at Stonehenge (Wiltshire). *Major* cursuses were those typically greater than 800 m long and over 40 m wide such as Rudston B, C and D (Loveday 1985). This categorisation was found to reflect the dating evidence from the excavation of these sites and horizontal monument stratigraphy, and it was argued that the different classifications were more frequent during different periods. In this classification, AI cursuses represented by the examples at Thornborough (North

Yorkshire) and, probably of this class, Maxey (Cambridgeshire) were presumably quite early with a relatively short life just after *c.* 3200 cal BC. AII cursuses as at Dorchester (Oxfordshire) and Fornham All Saints (Suffolk) have also been dated to approximately 3200 cal BC. The B class cursuses, on the other hand, have produced generally later dates than the 'A class' monuments. BI monuments, as at Springfield (Essex), Barford (Warwickshire), Aston (Derbyshire), Drayton A (Oxfordshire) and Scorton (North Yorkshire), produced artefactual material which generally post-dated 3200 cal BC, with the examples at Springfield and Aston dating to *c.* 2550 cal BC and later. Similarly, BII examples, including Offerton (Tyne and Wear), Amesbury (Wiltshire) and Rudston A (East Yorkshire) produced a range of material dating from between 3200 cal BC and up to c. 1850 cal BC, Rudston A being the latest example containing mid to late Beaker sherds. However, more recent excavations at Rudston revealed middle to late Neolithic pottery within a re-cut of the cursus ditch (*cf.* Abramson 1997, 1998). This evidence was more in keeping with the Offerton and Amesbury examples placing the group within the 3200 - 2550 cal BC bracket, although with certain re-use during the beaker period. It is perhaps likely that contamination of the remains at the southern terminus of this monument was due to the addition of a possible round barrow and secondary burials (Greenwell, 1877, Dymond 1966). Finally, group BIII, such as the Gussage (Dorset) cursus which contained material ranging from plain Neolithic wares to Mortlake, Fengate and middle Beaker pottery, provided a range of dates ranging from c. 3200 cal BC to after 2550 cal BC. Despite the generally limited evidence, a temporal division was concluded. Those monuments displaying 'A class' terminals were of an earlier date, grouping around 3200 cal BC, and that those displaying 'B class' terminals were generally later, dating from 3200 cal BC to possibly as late at 1850 cal BC during their functional life (Loveday 1985).

Within the study area is a cluster of four cursuses, with a possible fifth example (Figure 2.4). The pattern of cursuses in this area has developed over a number of years. Their presence in this area was first recognised in the 1950s with the work of Messrs C. and E. Grantham (Dymond 1966). This recognition was verified through the aerial photographic work of J.K. St. Joseph in 1961 that determined the pattern of three cursus monuments published in 1966 highlighting a complex of three cursuses (*ibid.*). Further investigation into the past collections of aerial photographs from the area lurking within the Cambridge University Committee for Aerial Photography (CUCAP) and the National Monument Record (NMR) collections revealed a much more complex archaeological landscape (Riley 1988). This newer transcription established that the northern section of

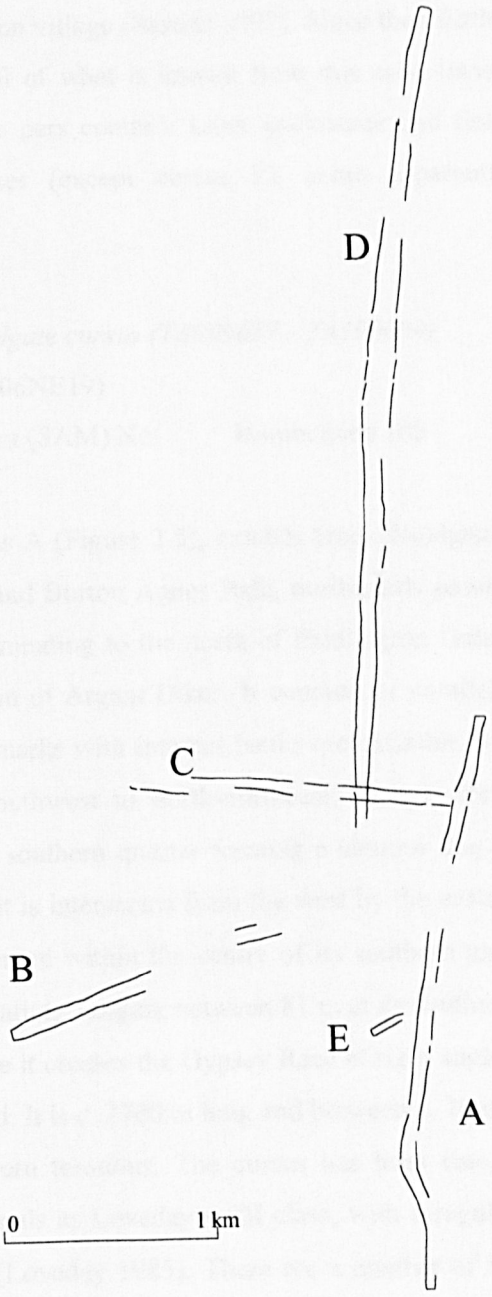


Figure 2.4 The Rudston cursus group (after Stoertz 1997).
North is to the top of the page.

cursus A was part of the same monument as the southern section and added the northern terminus, as well as adding detail to each of the other features. A fourth cursus, cursus D, was also added to the plot extending to the north from the village with a visible terminus at its northern end (Riley 1988). The National Mapping Programme (NMP) of the archaeology of the Yorkshire Wolds by the Royal Commission on the Historical Monuments of England (RCHME) added further detail and a possible fifth cursus directly to the south of Rudston village (Stoertz 1997). Since then further reconnaissance work has increased the detail of what is known from this area (Jane Stone, York Air Photo Unit, English Heritage pers comm.). Later enclosures and field system features overlie each of the cursuses (except cursus E), some apparently respecting the monuments.

Cursus A, Rudston - the Woldgate cursus (TA099657 - TA103684)

NMR TA06NE22 (and TA06NE19)

Scheduled Ancient Monument (SAM) No. Humberside 105

SMR Humberside 4124

The Woldgate cursus, cursus A (Figure 2.5), extends from Woldgate at the junction of the Woldgate Roman road and Burton Agnes Balk, northwards passing Rudston village on its western side and terminating to the north of Bridlington Gate where its western bank is extended in the form of Argam Dikes. It consists of parallel ditches visible on aerial photographs as crop marks with internal banks recognisable as chalky soil marks. These are aligned south-southwest to north-northeast, straight for its northern three quarters, but curved for its southern quarter forming a sinuous dog-legged plan. 400 m from its northern terminus it is intersected from the west by the eastern end of cursus C. A ring ditch has been recorded within the centre of its southern end (Stoertz 1997). It runs down the slope at elevations ranging between 81 m at its southern end to 3 m OD to 27 m OD at the point where it crosses the Gypsey Race at right angles and then rising to 53 m OD at its northern end. It is *c.* 2700 m long and between *c.* 70 m and 40 m in width, tapering towards its southern terminus. The cursus has been categorised on the non-symmetrical squared terminals as Loveday's BII class, with a regular western ditch but an irregular eastern ditch (Loveday 1985). There are a number of breaks in the ditches transcribed but these are due mostly to the Rudston village lying over a northern central area of both ditches and the positions of current roads, the latter particularly truncating the eastern ditch towards the southern terminus. Two other causeways are visible which cannot be otherwise explained. The first lies across the western ditch just to the north of the dogleg. The second lies across the eastern ditch at the northern end of the cursus, just



Figure 2.5 Aerial photograph showing the cropmark remains of cursus A looking north towards Rudston (Cambridge University Committee for Aerial Photography collection)

south of the plantation. Cursus A has been recorded in a number of gazetteers from the area (Loughlin and Miller 1979).

Cursus A was first excavated in 1869 by the Rev. Canon Greenwell when he considered the earthworks of the southern terminus to be the remains of three conjoining large mounds – barrow LXVI/Rudstone VII-IX (Greenwell 1877: 253-7). In his report he mentioned a main mound to be oriented east-west, 137' (41.7 m) long, 40' (12.2 m) wide and approximately 5.5' (1.7 m) and 4.5' (1.4 m) high at the eastern and western ends respectively, but less in between. His excavations revealed what appeared to be a round barrow raised upon the surface of the western end of the long mound. Within this round mound, and above the surface of the western end of the principle mound, was an inhumation burial containing the remains of an adult and a child with an associated beaker. Within the same grave was another inhumation with an associated beaker, which had itself disturbed the remains of an earlier burial. Three other inhumations were also found within the long mound 76' (23.2 m) to the east of the grave (Greenwell 1877: 253-7).

The southern terminus was excavated a second time between 1957 and 1958 when Messrs C. and E. Grantham dug a section across the western ditch. At this time the bank still survived up to between 1' (0.3 m) and 2' (0.6 m) higher than the interior and up to 4' (1.2 m) higher than the exterior surface. The southern bank was also approximately 170' (51.2 m) long and spread to between 60' (18.3 m) and 80' (24.4 m). The eastern and western banks were highest at the corners where they joined the southern bank, but declined to the north. From the excavation and a contour survey undertaken at the time it was concluded that the eastern and western banks of the feature extended further to the north then had been appreciated by Greenwell (Dymond 1966). The excavations in the western ditch revealed four beaker sherds at the bottom of the primary silting (Dymond 1966). The conclusion that these features represented the terminus of a cursus was verified in 1961 with J.K. St. Joseph's aerial photography that established the monument continuing to the north. The earthwork excavated so thoroughly by Greenwell was shown to be the southern terminal (Dymond 1966). The site was visited again on the 27th May 1975 on behalf of the RCHME by Sainsbury who described the southern terminus as "visible as a slight ground swelling only" (NMR TA06NE19). By the 1980s the bank of the southern terminus had a maximum height of 1.2 m which was spread by ploughing over 18 m (Loveday 1985).

Further excavation of cursus A was conducted at Pits Plantation, further to the north towards Rudston, in October and November 1995 by Northern Archaeological Associates (NAA) in advance of the construction of a gas drillsite and access road (Abramson 1996b, 1997). This excavation revealed the parallel cursus ditches, defined as soil-filled features cutting into the natural chalk, lying 70 m apart on either side of a wide palaeochannel feature. 5.5 m of the western ditch was excavated and it proved to be 4.3 m wide and *c.* 1 m deep with steep sides and a broad U-shaped profile. Probable evidence for the natural weathering of the chalk sides of the ditch was discovered. Towards the top of the section a Medieval furrow cut through the ditch fill to a depth of 0.1 m and a possible worn bronze coin was found at this level. No evidence of any bank was found. The eastern ditch was excavated to a length of nearly 5 m and proved to be 4.6 m wide and 1.16 m deep with steep sides and a flat base; the sides formed from apparently unweathered stable bedded chalk blocks. A primary fill, perhaps derived from erosion of the bank, had been cut through in the base by a v-shaped ditch with a narrow base 0.2 m wide. The second fill of this ditch was more uniform, similar to that filling the western ditch. A pit 0.25 m deep and 0.75 m in diameter had been cut into the secondary fill and contained a single ogival flint arrowhead. The re-cut of the eastern ditch contained residual Mesolithic flint and other material dating to the middle to later Neolithic period.

Cursus B, Rudston - Rudston House cursus (TA081669 - TA094675)

Rudston House cursus, cursus B, is aligned broadly southwest to northeast. It lies to the north of Kilham Lane, running at a height of *c.* 48 m OD at its southwestern end and *c.* 27 m OD at its northeastern end. It spans a total length of *c.* 1,550 m, ranging between *c.* 45 m and 80 m wide. Only the southwestern terminus remains, the end extending beneath the village of Rudston. The terminus at its southwestern end is irregular and unsquared falling into Loveday's category BIII (Loveday 1985: 389). There is a large break in both ditches towards its northeastern end, though the general absence of other crop marks in this area suggests that this break is due to a methodological limitation of aerial photography and is perhaps not a real break in the monument's length. There are no visible causeways within the length of the monument.

This feature was identified by the 1960s (Dymond 1966) and reported on in the 1970s following examination of CUAC and NMR oblique aerial photography (Loughlin and Miller 1979: 124). However, it was not seen on aerial photographs taken in the 1980s (Riley 1988: 91, Stoertz 1997: 25-8). Loughlin and Miller (1979: 67) recorded this monument within the list of Neolithic and Bronze Age monuments in the area.

Cursus C, Rudston - High Street cursus (TA088682 - TA102680)

High Street cursus, cursus C, is aligned west-northwest to east-southeast and extends over 1480 m, ranging between *c.* 50 m and 60 m wide. It crosses the Gypsey Race at right angles and passes the monolith on its southern side. At its western end it reaches a height of *c.* 53 m OD, falling to *c.* 27 m OD as it crosses the Gypsey Race and rising to *c.* 49 m OD to the east. The recorded ditches of cursus C are more fragmentary compared to those of the other cursuses, but there is no evidence to suggest a causeway across any of the visible ditches. Neither terminus remains of this feature, although its eastern end abuts the western ditch of cursus A. Cursus C appears to have been built at a later date than cursus A because of three reasons. Firstly there is a lack of evidence for a terminus at this end, secondly cursus C stops as it meets cursus A, and thirdly there is a lack of overlapping phasing suggesting that cursus A was upstanding when cursus C was constructed.

Cursus C intersects the southern end of cursus D. Two trenches were excavated across the junction between the two cursuses in 1978 by Kinnes (Kinnes 1982, Loveday 1985, Abramson 1997). The trenches produced no artefactual evidence although the association between the two monuments was demonstrated. At the point of intersection a break in the ditch of cursus D was found through which ditch of cursus C continued. This indicated that cursus C pre-dated cursus D. This is also exemplified by its relationship with cursus A. It therefore seems that cursus C post-dates cursus A, and pre-dates cursus D.

Cursus D, Rudston - Gypsey Race cursus (TA097678 - TA102719)

Cursus D, the Gypsey Race cursus, is aligned north-south and runs the full length of the similarly aligned stretch of the Gypsey Race (*c.* 4000 m) ranging in height between *c.* 56 m OD at its northern end to *c.* 27 m OD nearer to Rudston. It varies in width between *c.* 50 m (at its terminus) and 90 m. Its northern end stops in line with the northern bend in the Gypsey Race and its southern end stops at Rudston in the crook of its southern bend. A terminus is visible at the northern end of the cursus, though its southern end appears to lie beneath Rudston village, the visible remains stopping just to the north. The entire length of the cursus lies at the foot of the eastern slope of the Great Wold Valley, on the eastern side of the Gypsey Race, although a canalisation of the channel has formed a bend that cuts through both ditches before turning back to its southerly course. It seems likely the elevated position of the cursus would have meant that the Gypsey Race did not previously cut it. Its northern terminus is squared but very irregular - of the BII classification (Loveday 1985). The plan of the cursus is relatively straight, curving

slightly to the north-northeast within its northernmost quarter. Although there are several breaks in the transcribed plan of the monument (Stoertz 1997) there are no clear causeways across either of the feature's ditches. At its southern end it intersects the eastern end of cursus C.

One of Kinnes' trenches excavated in 1978 cut through cursus D. Although it produced no artefact evidence, it demonstrated a relative chronological association between it and cursus C. A break in the ditch of cursus D at this point demonstrated that it post-dated cursus C, but by an unknown margin (see cursus C above, Kinnes 1982, Loveday 1985, Abramson 1997).

Cursus E, Rudston (TA097669)

A fifth possible cursus feature was identified during the recent National Mapping Programme (NMP) of the Yorkshire Wolds by the RCHME (Stoertz 1997). The feature is represented by an elongated rectilinear feature with parallel sides, aligned west-southwest by east-northeast and measuring 160 m long and 30 m wide. A terminus that defines its western end is regular and squared with rounded corners. At this end is a ring ditch which may be compared with the clusters of ring ditches which occupy the terminuses of the other cursuses in the study area (Stoertz 1997: 27). Its eastern end is not distinct.

c. Henges

Henges are prehistoric monuments, classified as being roughly circular or oval in plan, over 20 m in diameter and normally formed by a ditch with an external bank. The earthworks usually have one, two or four causeways which are often opposed (MPP 1989: http://www.eng-h.gov.uk/mpp/mcd/index.htm). The dating of henges has been based upon the evidence from a number of excavations. At Thornborough, North Yorkshire a henge had been constructed over the silted up remains of a cursus. This suggested that a certain length of time had existed between the discontinued use of the cursus prior to the construction of the henge, and there is no suggestion of the possibility of deliberate back filling (Thomas 1955). A similar scenario was encountered at Maxey (Pryor and French 1985).

The name 'henge' was first coined by T.D. Kendrick in 1932 with reference to Stonehenge when a possible etymological interpretation of the word suggesting that 'henge' referred to the earthworks surrounding the monument (Kendrick and Hawkes

1932, Harding and Lee 1987). The second major work regarding henges was produced four years later (Clark 1936). In 1939 the henge classification was sub-divided into two groups. Class I had one entrance, and class II had two diametrically opposed entrances (Piggott and Piggott 1939). These were further subdivided on the basis of the existence and nature of the ditch (Atkinson, Piggott and Sandars 1951: 82). The groupings of henges were further analysed both morphologically and regionally (Burl 1969), and radiocarbon dating evidence was applied (Wainwright 1969). More recently, diversity within henge design locally has led to calls that further classification of these monuments is required and that henges generally are a much more complex feature with more complex roles and origins (Catherall 1971). A later catalogue of henges and hengi-form monuments was produced in the 1980s (Harding and Lee 1987).

The function of henges has always been uncertain. When Stukeley described the earthworks of Robin Hood's Ball in the eighteenth century he noted that the internal ditch precluded defence and concluded that a theatrical role was most suited in the nature of the Roman amphitheatre (Chippendale 1996). This interpretation is interesting since some henges appear to have been re-used in this manor such as at Maumbury Rings (Burl 1991). During the 20th century they became to be understood as prehistoric features with non-utilitarian functions. In the late 1920s it was suggested that such features represented large tombs and certainly maintained a sepulchral function (Crawford and Keiller 1928: 213), though later it was suggested that they represented sacred temples or meeting places (*cf.* Kendrick and Hawkes 1932). Clark agreed with the latter conclusion but added further detail. He demonstrated that they were not constructed to commemorate the dead due to the general infrequency of burials and, when present, their nature and location. He noted that at Woodhenge, for example, the location of an infant's grave was across an alignment with the midsummer sunrise. Further, the infant had a cleft skull perhaps suggesting a sacrifice. The conclusion was that burials within henges probably served to consecrate the 'sanctuary' rather than the henge being constructed as a memorial (Clark 1936, 25-7). He also noted that the occasional association with avenues suggested that any ceremonial activity carried out at these sites would probably have included processions (Clark 1936, 26). Excavations of henges throughout Britain have produced variable evidence of stone or timber settings/circles (e.g. Stonehenge, Avebury, Durrington Walls, Wiltshire), burials, cremations (e.g. Llandegai, Gwynedd), possible roofed timber structure (e.g. Durrington Walls, Wiltshire) and cairns (e.g. Dun Ruadh), and artefactual evidence such as axes (e.g. Llandegai A, Gwynedd). Other conclusions on the function of henges have included ritual centres, community focal points (following

the role of long barrows), and a focus for trade, particularly in stone axes (Burl 1991). It is most likely that these monuments changed function through time (Darvill 1987b). Some examples display later uses including the Roman amphitheatre/military training ground and later Civil War gun battery and 18th century gallows at Maumbury Rings, Dorchester (Burl 1991) and the supposed re-use of Maiden's Grave, East Yorkshire as a windbreak during the Romano-British period (McInnes 1964).

In 1939, it was suggested that these features were unlikely to date to earlier than the early Bronze Age and that they probably remained in use until the middle, and possibly the later, Bronze Age (Piggott and Piggott 1939: 141-2). It was not long, however, until a realisation that they stemmed back to the later Neolithic period was made (*cf.* Wainwright 1969, Catherall 1971) and it was suggested that class I henges may predate class II henges (*ibid.*). This temporal distinction between the two may also be added to since class I henges are also generally smaller, less regular and less circular than class II henges (Clare 1986). There is a selection of radiocarbon determinations associated with henges, although the main problem with such evidence is that this has usually been attached to internal features that may not be wholly contemporary with the main henge structure. Relative chronological relationships, such as the cursus and henges at Thornborough, North Yorkshire indicate that henges post-dated the construction of cursuses, possibly by a considerable length of time (Thomas 1955). In terms of absolute dating, a summary of previous work was carried out by Catherall (1971: 150). The dates ranged from the earliest at Durrington Walls, Wiltshire with a determination of 2450 ± 150 BC (NPL-191), to the latest at Stonehenge, Wiltshire with a determination of 1240 ± 105 BC (I-2445). These dates calibrate to between 3550 - 2600 cal BC and 1750 - 1150 cal BC. This provides a date range extending into the Bronze Age (Catherall 1971: 150), but with a watershed in the later Neolithic. The continued placing of barrows and funerary monuments within the vicinity of long barrows into the early Bronze Age demonstrates their continued importance.

Within the study area there is only one henge, though there are a number of other features which may be classed as hengi-form structures identified and classified from aerial photography (*cf.* Stoertz 1997). Only one of these features has been excavated and the evidence for the others is limited. No firm evidence of internal structures has been found from any of the sites and so the main dating and functional foundations for these sites lie with their morphological similarities to those that are better understood and investigated.

On the Yorkshire Wolds, however, there are a number of other possible henge sites. At Paddock Hill, Thwing, to the east of the study area, a possible class II henge was found beneath the fortified settlement following excavation (Stoertz 1997: 30). The other main possible henge site surrounds the Great Barrow of Duggleby Howe, also to the west of the study area within the base of the Great Wold Valley (Riley 1980a, 1988). This feature is extremely large, being *c.* 350 m in diameter. Although this feature shares certain morphological characteristics with causewayed enclosures, it has been suggested on the basis of its lowland position that it may belong to a class of hengiform monuments of the style found at Durrington Walls and Avebury in Wiltshire (Stoertz 1997: 30). A final possible hengiform monument has been located at Walkington with opposed entrances in its northwestern and southeastern sides (Stoertz 1997).

Maiden's Grave, Burton Fleming (TA09667064)

NMR TA07SE8

SAM Humberside 24

SMR Humberside 731

Maiden's Grave henge (Figure 2.6) was first discovered as a crop mark when J.K. St. Joseph photographed it in 1962. The site was visited in January 1964 when it had been deep ploughed revealing the chalk banks as soil marks visible on the ground. The features revealed the monument to be an oval-shaped class II henge - the first of its kind to be reported in the East Riding of Yorkshire - with its opposed entrances aligned northwest by southeast. It has been noted elsewhere that this alignment of entrances is a common pattern for class II henges across the country (Burl 1969). It was excavated by members of the East Riding Archaeological Society (ERAS) and Hymers College between March and May 1964 (McInnes 1964, Harding and Lee 1987: 168). The henge has a diameter of 95 m and the aerial photographs show evidence of an external chalk bank (*cf.* Stoertz 1997). The excavations on the site revealed the bank to be 37' (11.3 m) wide but only 2" (0.6 m) high due to ploughing, although it was noted that within this section of the monument the bank was lower than elsewhere (McInnes 1964). Despite investigations, no external ditch was found though a greater depth of soil was found outside (2' - 0.6 m) compared to inside (9" - 0.4 m) the monument indicating hill wash in conjunction to the ploughing regime which must have previously avoided the monument (McInnes 1964). The internal ditch proved to have a steep v-shaped profile, 38' (11.6 m) wide and 13' 3" (4.1 m) deep with no berm. Initial silting from the bank was recognised, followed by three periods of silting. These were interrupted by two more rapid infilling phases, which were interpreted as reflecting disturbance. The primary silts produced no

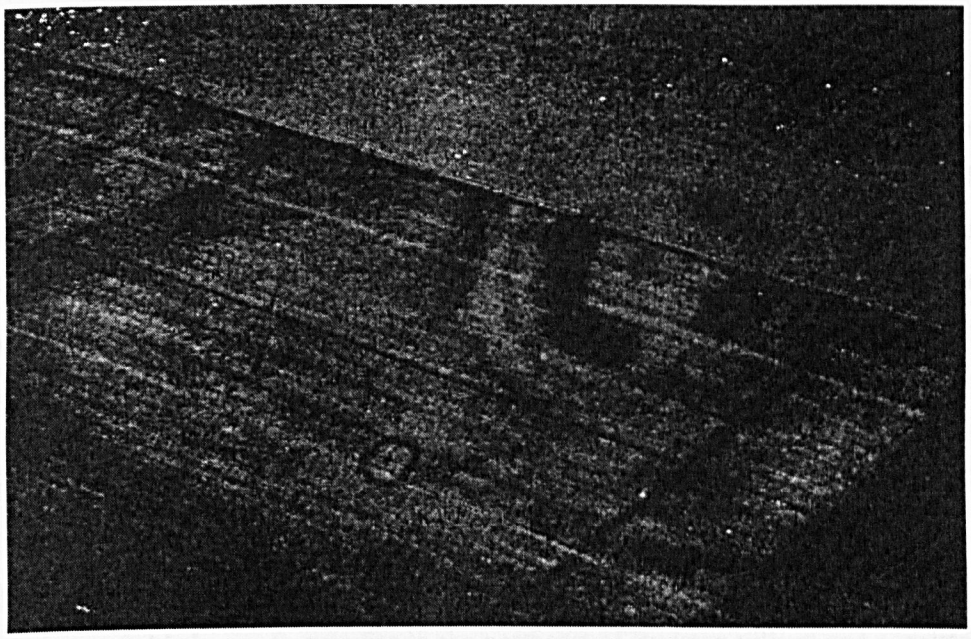


Figure 2.6 Aerial photograph of Maiden's Grave henge (McInnes 1964)

cultural material though the secondary silts revealed Beaker and Peterborough Ware pottery. At this level a hearth was found against the slope which was probably placed using the bank as a windbreak (McInnes 1964). The tertiary silts produced Romano-British pottery, above which a Medieval sherd was found in the ploughsoil. Investigations across the southeast entrance showed it to be 50' (15.2 m) wide, the ditches displaying steeply sloping and squared ends. In the centre of the henge limited excavations revealed four postholes in a line, two of which produced beaker sherds (McInnes 1964).

Greenlands (TA115683)

NMR TA16NW40

SMR Humberside 7297

Another possible henge feature lies to the northeast of Rudston village and consists of an irregular curvilinear enclosure measuring 240 x 200 m with two entrances; one in its eastern side, the second in its southern side. This feature has been categorised as a possible henge/interrupted ditch enclosure (Stoertz 1997: 30) and as a possible defended settlement, perhaps relating to the later Bronze Age (Stoertz 1997: 49). The conclusion from this work is that the feature shares more similarities with the latter period (*ibid.*). Challis and Harding (1975: 122), however, suggested that this feature relates to the Iron Age and that it is most likely to represent the remains of a hill-fort.

The Rudston Group (TA077676, TA078675 and TA078674)

Three possible hengiform monuments lie within the southwestern quarter of the region within the vicinity of the cursus group. They exist only as crop marks representing single ditches and have been transcribed as part of the NMP of the Yorkshire Wolds. The first (A) is centred at TA077676 and measures 32 x 28 m. It is irregular in plan and has a single gap in its western side. The second (B) is centred at TA078675 and measures 30 x 22 m, is more regular in plan despite being oval and has opposing causeways in its northwestern and southeastern sides (as is more common in class II henges - see above). The third site (C) lies to the southwest of site B, and is centred at TA078674. It measures 20 x 18 m and has a single causeway in is southwestern side (Stoertz 1997: 30-1). These three features are surrounded by linear and non-linear crop marks, although none cross them so temporality cannot be established. However, there does not appear to be any spatial associations and so they are probably not contemporary with these features which are presumably later on the basis of their morphology. Similarities between these features

and henges as at Coneybury, Wiltshire, have been noted (Stoertz 1997) and it is possible that these features do represent hengiform monuments.

Rudston Beacon (TA095656)

Dymond (1966) alluded to another possible henge within the study area in the area of Rudston Beacon. The same feature was also mentioned in Harding and Lee's work (1987: 173) although they concluded that the evidence was too weak to suggest that the feature was real. The recent work by the RCHME has transcribed a vast cluster of ring ditches within this area, but no features which fall within the morphological categories to suggest a henge and it is therefore most likely that this feature is real and is probably just an interrupted ring ditch.

d. Great barrows

A further class of monument found within the study area has been termed *great barrows* (Manby 1988). Excavation has suggested that several long barrows were converted into round barrows at some later time, such as the Kemp Howe long barrow which was depicted as a round mound by the Ordnance Survey in 1958 (Stoertz 1997: 23). Excavation at this site by Brewster revealed evidence of an earlier long barrow (Manby 1988) which was verified through subsequent aerial photography which displayed a crescent-shaped mark of the probable mortuary enclosure (Stoertz 1997: 24). Four Great Barrows are recorded from outside of the study region on the Yorkshire Wolds (Manby 1988). These are Duggleby Howe (SE880669) (Kinnes *et al.* 1983), Garton Slack barrow 79 (SE979577), Prior Moor (TA025759) and Wold Newton barrow 284 (TA048726). Of these, the Wold Newton example lies only *c.* 160 m to the west of the study area within the floor of the Great Wold Valley. It appears that the development of great barrows marked a zenith in the development of round barrows during the later Neolithic period.

Within the study area lie two great barrows on the western edge and within the area to the south of Rudston, both overlooking the Great Wold Valley.

Southside Mount, Rudston (TA10736657)

NMR TA16NW11

SAM Humberside 69

SMR Humberside 4156

The Southside Mount great barrow lies on Woldgate, to the south of the Gypsey Race, in a position within sight of the Rudston Monolith and the cursus complex (Pierpoint 1980:

271). When this site was first excavated by Greenwell (Rudston 67) it had already been ploughed over but still measured 100' (30 m) in diameter and 9' (2.7 m) high. It consisted of an earthen inner mound with a capping of heavy chalk rubble, though the dimensions of the inner mound were never recorded (Greenwell 1877: 257-62, Manby 1988: 85). Cultural material from within the mound consisted of earlier Neolithic domestic debris and an overall indication of an earlier occupation on the site, predating the construction of the mound. The primary burial within the mound contained the inhumed remains of a child and part of a woman within a wood-lined cist (Greenwell 1877: 257-62, Petersen 1969: 263), but no associated grave goods were recovered. Manby (1988: 64) noted that the inclusion of only a selection of the bones of the woman reflects earlier Neolithic burial practices. Other burials within the mound were secondary; the earliest accompanied by an AOC Beaker, the latest by a Food Vessel.

Willie Howe, Thwing (TA06157235)

NMR TA07SE1

SAM Humberside 21190

SMR Humberside 3931

Willie Howe lies within the base of the Great Wold Valley. It was first excavated by Albert, 1st Baron Londesborough in 1857 from which the remains of a massive unfilled trench crossing the mound is still visible. This excavation located a central shaft, but little detail was recorded (Manby 1988, 85). It was again excavated by Greenwell when it survived as a monument measuring 140' (43m) in diameter (measured NW-SE) by 120' (37 m, measured NE-SW) with a ring ditch measuring 40-45' (12-14 m) in width (Greenwell 1890: 22-4, Kinnes 1984: 36). This makes it the largest of the great barrows on the Yorkshire Wolds. The mound has never been ploughed over, but was planted with trees in the mid-19th century.

e. Monoliths

The dating of standing stones as a monument class is not clear due to a lack of material to provide radiocarbon dates. Very occasional finds of associated pottery have been found, but these are often in association with other monuments of later Neolithic to middle Bronze Age date. It is normally assumed that such features served a non-utilitarian function as symbols and elements of the ritual or ceremonial landscape (MPP document: http://www.eng-h.gov.uk/mpp/mcd/index.htm - 3.3.90).

Two standing stones have been identified from within the Rudston landscape. The first is extremely imposing, being the largest monument of its kind in Great Britain. The second measures approximately 3' (0.9 m) high lies in the northeastern corner of the churchyard, but this was apparently moved from its original position which lay just to the east of the monolith (Purdy 1972).

Rudston Monolith (TA09806774)

NMR TA06NE13

SAM Humberside 26515

The Rudston Monolith (Figure 2.7) is made of Jurassic grit with a source near Cayton Bay, between Filey and Scarborough, 16 km to the north (Manby 1988: 65). It has been measured at 25'9" (10.1 m) high, though Kinnes records it at 7.7 m high (Kinnes 1984: 37), and a maximum of 5'10" (1.5 m) on its eastern face by 3' (0.9 m) on its northern face. The top was protected temporarily from further weather erosion in 1773 by a lead sheet and it has been suggested that the monument may have previously been higher. An experiment in the late 18th century by Sir William Strickland suggested that it extended deep into the ground (Purdy 1972). The monolith remains undated but its location within a box defined by the cursuses, particularly cursuses A, C and D, has led to the suggestion that it marks the topographic and ritual focus for the complex (Dymond 1966, Kinnes 1984). It has been noted that there is no reason to suggest that the Rudston monolith be not in its original position (Dymond 1966: 90).

A study by Pierpoint extended the theory that the cursuses and the monolith were associated, when noting that, not only did the monolith act as the focus for the complex of cursus monuments, but also it lay at the centre of the distribution of 'elaborate artefacts', with eighty percent of all Grooved Ware sites on the Wolds lying within 5 km (Pierpoint 1980: 271-5). It also was demonstrated to lie at the centre of distributions of polished flint knives, stone maceheads and two forms of flint adze, with a fall of in numbers of each with increased distance from the monolith (*ibid.*). Not only does this demonstrate the importance of the site during prehistory, but also indicates a *terminus post quem* for the site (if not the monolith itself) in the later Neolithic.

f. Occupation sites

The seminal work by Manby (1975) on the Neolithic settlement on the Yorkshire Wolds forms the basis for the following data. The main form of evidence for settlement consists of pits, hollows and hearths with associated artefactual remains to provide a date, though

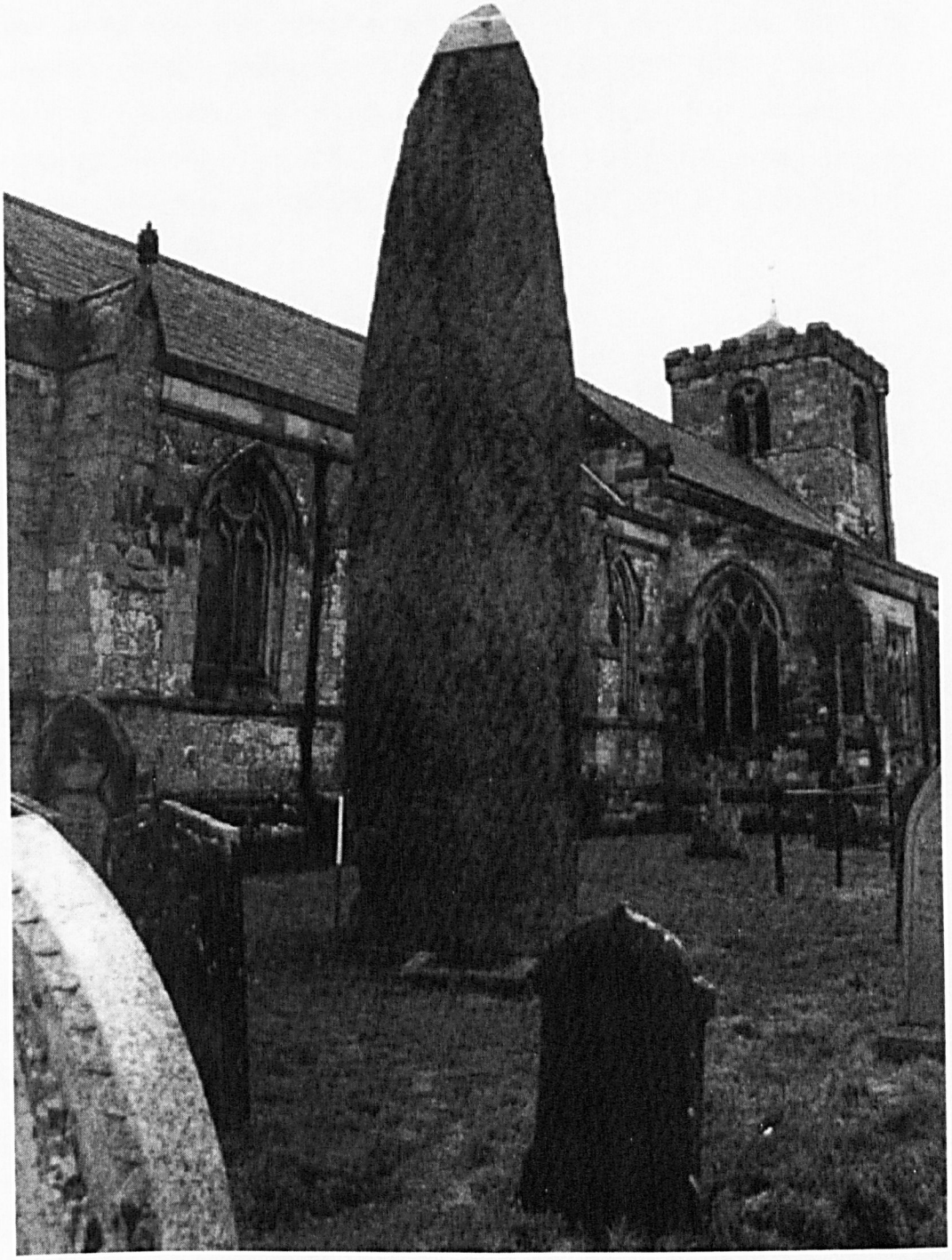


Figure 2.7 The Rudston monolith.

the interpretation of such features as occupation sites has recently been questioned (*cf.* Evans *et al.* 1999). These features have been found mostly on Woldgate, the ridge overlooking Rudston from the south, though similar remains have been found beneath several monuments where the evidence is concentrated upon the pit sites. The distributions of these settlements, while being far from comprehensive, provide a backdrop or focus from which the landscape was perceived at some time during the Neolithic period. In this section the divisions of the sites dependent upon their ceramic associations (*cf.* Newbigin 1937, Manby 1958) have been kept since this provides a dating framework (table 2.3).

Grimston Ware sites

Grimston Ware is a plain pottery style associated with the long barrows including those at Willerby Wold (Manby 1963) and Kilham (Manby 1976). Associated radiocarbon dating has produced dates of 3474±117BC (BM-679), which calibrates to 3500 - 2700 cal BC, to 2217±78 (BM-755), which calibrates to 2920 - 2510 cal BC (Manby 1975, 50).

Towthorpe Ware sites

Towthorpe Ware ceramics in East Yorkshire have been dated to the middle Neolithic period on the basis of vertical stratigraphy at sites at Flamborough (Manby 1975: 50). Towthorpe pottery was found on the palaeo-surface and within the mound at Greenwell's Barrow 62 when it was re-excavated in the 1960s (Pacitto 1972). Only one occupation site within the study area was found containing Towthorpe Ware ceramics.

Peterborough Ware sites

Peterborough Ware is the general name given to the Fengate, Mortlake and Ebbsfleet styles, as well as the Rudston style, of ceramic production. This pottery dates from the later Neolithic and its use continues into the early Bronze Age. Occupation sites displaying Peterborough Ware pottery were more frequent than sites displaying either of the other two pottery styles (table 2.3).

Table 2.3 *Occupation sites and ceramic associations (after Manby 1975)*

Ceramic tradition	Site name (after Manby 1975)	NGR
Grimston	Rudston Wold, Corner Field, Site 6	TA09776579
	Rudston Wold, Corner Field, Site 8	TA09696572
	Rudston Wold, Corner Field, Site 11	TA09976595
	Boynton, North Carnaby Temple, Site 11	TA13586710
Towthorpe	Boynton, Carnaby Top, Site 14	TA12316688
Peterborough	Rudston Wold, Corner Field, Site 2	TA09806580
	Rudston Wold, Corner Field, Site 7	TA09766577
	Rudston Wold, West Reservoir Field, Site 5	TA10806620
	Rudston Wold, 2nd Field West of the Reservoir	TA10406620
	Rudston Wold, East Reservoir Field, Site 8	TA11276645
	Boynton, Carnaby Top, Site 11	TA12776671
	Boynton, Carnaby Top, Site 19	TA12736675
	Boynton, North Carnaby Temple, Field 3, Site 5	TA13566697
	Boynton, North Carnaby Temple, Field 3, Site 6	TA13576703

g. Round barrows/ring ditches

Ring ditches are the most common prehistoric features on the Wolds and a figure of approximately 1,300 have been recorded in total (Dent 1998). Many of these features have been excavated in the past particularly by the antiquarians Lord Londesborough (whose estate covered a large area of the Wolds), Bateman (1861), the Rev. Canon W. Greenwell (Greenwell 1877, 1890) and J.R. Mortimer (Mortimer 1905). Those features excavated have provided evidence of primary deposits relating to the later Neolithic or early Bronze Age periods. Many of these features typically contain Peterborough Ware and Beaker style pottery and other finds including ornamentation (Manby 1988). However, it is far from uncommon for these mounds to have been used for secondary interments, sometimes as late as the early Medieval period.

The majority of archaeological attention on the Wolds has been afforded to the round barrows that were excavated in huge numbers by Bateman (1861), Greenwell (1877, 1890) and Mortimer (1905). However, the overwhelming majority of these features have been levelled for agriculture. Much of this damage had already occurred by the 19th century, as indicated by antiquarian's reports that many of the barrows were already damaged (*cf.* Greenwell 1877). Of these features, the vast majority have been dated to the early Bronze Age, mostly through artefact typologies, though some through more absolute dating methods (Manby 1980a). The number of known round barrows known from the area has been greatly increased through aerial photography that reveals the remains of ploughed features often as circular ring ditches. However, the morphological characteristics of these features are shared with other archaeological features such as hut circles, mills, ponds and searchlight emplacements, and some of the smaller circles may relate to Iron Age barrows (Stoertz 1997: 33). The majority of these features lie on the western angle of the high Wolds, although a dense cluster surrounds the Great Wold valley, both on the higher ground around the Gypsey Race and on the valley floor.

Within the study area the antiquarian activity was limited to Greenwell (1877, 1890) and, in part, by Tyndall (1870). Later activity has been concentrated upon the re-excavation and examination of his barrows (e.g. Pacitto 1972), and a generalisation of these is given in table 2.4.

Other evidence of round barrows is available from the transcriptions of circular ditches (NMP Yorkshire Wolds project - Stoertz 1997).

Table 2.4 *Excavated round barrows within the study area*

Name	NGR	References
Greenwell 60	TA0572	Greenwell 1877: 226-8, Kinnes and Longworth 1985: 59
Greenwell 61 (Rudstone I)	TA098658	Greenwell 1877: 229-32, Kinnes and Longworth 1985: 59-61
Greenwell 62 (Rudstone IV)	TA098658	Greenwell 1877: 234-45, Tyndall 1870, Pacitto 1972, Kinnes and Longworth 1985: 61-8
Greenwell 63 (Rudstone V)	TA098658	Greenwell 1877: 245-51, Tyndall 1870, Kinnes and Longworth 1985: 69-71
Greenwell 64 (Rudstone VI)	TA094855	Greenwell 1877: 252, Kinnes and Longworth 1985: 71
Greenwell 65 (Rudstone X)	TA0965	Greenwell 1877: 252-3, Kinnes and Longworth 1985: 71-2
Greenwell 67 (Cranswick I)	TA107666	Greenwell 1877: 257-62, Kinnes and Longworth 1985: 74-6
Greenwell 68 (Cranswick II)	TA0865	Greenwell 1877: 262-9, Kinnes and Longworth 1985: 76-7
Greenwell 69 (Jordan)	TA1165	Greenwell 1877: 269-71, Kinnes and Longworth 1985: 77-8
Greenwell 244 (Folkton I)	TA050736	Greenwell 1890: 13-4, Kinnes and Longworth 1985: 115-9
Greenwell 250 (Folkton VIII)	TA075742	Greenwell 1890: 18-21, Kinnes and Longworth 1985: 119-20
Greenwell unnumbered 103:1	TA0971	Kinnes and Longworth 1985: 146

2.2.4 Local chronology

The evidence from the past research into the Neolithic and early Bronze Age archaeology of the Yorkshire Wolds has defined a chronology for the region. Manby developed the main local chronology on the basis of a range of data, using both relative and absolute dating evidence (Manby 1988). This classification used the traditional period labels (after Piggott 1954, and developed by Smith 1974) with the Neolithic divided into earlier and later phases on the basis of cultural development. The earlier Neolithic period was divided between what was termed the *pioneer period* (*c.* pre-4300 - 3900 cal BC) and the *mature period* (*c.* 3900 - 3000 cal BC), which saw the development of ritual/mortuary structure, a trade in stone axes and a development in pottery styles. The later Neolithic period was divided between the *Meldon Bridge period* (*c.* 3000 - 2750 cal BC), which followed the Duggleby horizon, and the *Mount Pleasant period* (*c.* 2750 - 2000 cal BC) which saw the evolution of Beakers.

Despite the lack of radiocarbon dates from within the study area, the stratigraphic relationships displayed both within the region and nearby means that a relative monumentality can be constructed, calibrated in part by the available absolute dates.

a. Early Neolithic

The first monuments to be constructed within the study area appear to have been the long barrows at Kilham, Denby and Rudston. Kilham provides a date for its phase IIa of c. 3950 - 3300 cal BC placing its construction within Manby's *Mature period* of the early Neolithic (Manby 1988). Evidence from Kemp Howe, outside of the study area, but on the Wolds, suggests that the construction of the Great Barrows followed that of the long barrows since it was constructed through a remodelling of an earlier long barrow (Manby 1988, Stoertz 1997). While indicating that these features post-date long barrows, it appears that the area still features dating from the earlier Neolithic due to the primary burials at Duggleby containing a selection of inhumed bones in the manner of burials of that period (Manby 1988).

b. Later Neolithic

The development of cursuses appears to have occurred during the later Neolithic on the Yorkshire Wolds, although a relative chronology between the five possible examples can be shown. Dates from cursuses elsewhere suggest that they were being constructed mainly between approximately 3200 cal BC and 2550 cal BC. Loveday (1985) suggested that class A cursuses (including Rudston cursuses C and E) predated class B cursuses

(including Rudston cursuses A, B and D). However, this appears not to be the case on the Yorkshire Wolds and it seems that further excavation evidence which provided an earlier date for Rudston cursus A is the main cause in this change. Relative chronology is apparent between cursuses A, C and D, although cursuses B and E, assuming E to be a cursus, provide no stratigraphic relationship and therefore must be considered more generally. Chronologically, cursus A appears to be the earliest as cursus C runs up to it and stops against its western ditch. Although it is possible that cursus A was built on an alignment to follow the end of cursus C, the extension of cursus A to the north suggests that it was probably in place beforehand. Cursus C was constructed secondly - excavation at the junction between it and cursus D revealed a break in the ditch of cursus D at the junction. However, while the chronology of the three monuments is reasonably understood, the time lag between each construction is not understood and it has been suggested that they were largely contemporaneous (Kinnes 1984).

The construction of the cursuses appears to have been followed at some later date by the construction of Maiden's Grave henge. Although there is no direct relationship between the two classes of monument, and the fact that Maiden's Grave produced very little cultural material, stratigraphic evidence from elsewhere (e.g. Thomas 1955) suggests that it post-dated the construction of the cursuses. If current understanding of monoliths is correct (e.g. MPP document: http://www.eng-h.gov.uk/mpp/mcd/index.htm - 3.3.90), the construction of the Rudston monolith is likely to have taken place at this time or later. However, the inferred relationship between the cursuses and the monolith has led some to believe that the cursuses were constructed around it as a focus (e.g. Dymond 1966, Kinnes 1984).

The division of pottery styles within this period is unclear, although associations suggest that Towthorpe styles dominated the middle Neolithic whilst Peterborough styles dominated the later Neolithic. The evidence of Grimson pottery styles, with associated dates between 3500 - 2510 cal BC (see above) suggests that it spanned a greater part of the period, though the association with the long barrows suggests that they may generally predate the Peterborough styles.

c. Early Bronze Age

The transition of the Neolithic into the Bronze Age is seen with the construction of the round barrows that cover large parts of the Yorkshire Wolds.

d. Later periods

Further relationships with later monuments are also clear from the display suggesting the longevity of monuments. The western bank of cursus A appears to have been extended to the north during the later Bronze Age with the construction of Argam Dikes, a type of feature which continued to be used and elaborated into the Iron Age (Dent 1984, Bevan 1997). Similarly, the Romano-British field system pattern extending between cursus B and cursus C shows a fan-like plan, using the alignments of each. This suggests a fossilisation of the earlier monuments in the same manor as is seen elsewhere such as on Dartmoor, where the Bronze Age land divisions have become fossilised beneath Medieval and Post Medieval stone walling (Fleming 1978, 1988).

2.2.5 Interpretation issues to be addressed

a. The function of the cursuses

Cursuses form one of the more enigmatic classes of monument. This is because no satisfactory answer has been provided for their morphology. Since their recognition on the 6th August 1723 by William Stukeley (Stukeley 1740: 41) many different interpretations regarding their function have been forwarded. However, the overall lack of artefacts and internal features resulting from excavations has meant that their function has remained a mystery. In this section the main theories and themes are examined.

Most of the theories relating to the function of cursuses are linked, and so a split classification may be inappropriate and unrealistic. However, such classification provides a focus and useful generalisation of the data. Overlaps between the different theories highlight the limitations of the empirical evidence, meaning that it can be applied to multiple theories. The main example of this is the question of whether or not they were designed for movement along them (see below). Ideas both for and against the suggestion will have a profound influence on later theories. Therefore, in this section, the groupings of past theories are segmented into a list of theories and suggestions.

Procession avenues

The fundamental issue regarding the function of cursuses is whether they acted as processional ways or avenues - essentially, did people walk along them? There are a number of different arguments both for and against this. From the original interpretation of these features as racetracks based upon Homerian analogy (see below), it has often been assumed that they defined areas to be travelled along. Their morphological similarity to avenues also lends weight to this argument. The fundamental reasons for the

interpretation that these features were designed for movement appears to be based upon their long, thin plans which imply travel in the same way as a circle might suggest a meeting place (*cf.* Fleming 1972).

The first suggestions that this class of monuments acted as foci for processional activities were made by Atkinson (Atkinson *et al.* 1951, Atkinson 1955: 9, 1986). When describing the arrangement of monuments at Stonehenge, he noted the position of the Amesbury Cursus was aligned on a long barrow to the east, "obviously aligned deliberately" (Atkinson 1986: 150). This, he argued, linked the two, which in turn linked the site to "a cult of the dead" suggesting an "obviously religious or ceremonial" function, but acknowledged that the purpose of these monuments was unknown (Atkinson 1986: 151). The evidence supporting Atkinson's assumption that these monuments served a processual role is linked to an appreciation of avenues such as at Stonehenge, with an underlying implication of focus such that the avenue maintains a purpose only as part of a larger monument or landscape. Thus the early concepts of procession apparently degenerated the cursus or avenue to a subsidiary feature of the larger monument. This interpretation of cursuses fulfilling a processual function was augmented by the work of Hedges and Buckley on the Springfield Cursus in Essex (Hedges and Buckley 1981: 19). Evidence of a timber setting and numerous pits at its eastern end was seen to provide a focus; one that was interpreted as ritual rather than secular since there was also plentiful evidence of burning and there were finds of cremated animal bone in the pits.

Processional theories have developed more recently suggesting that the routes may have crossed various elements of the natural and past landscape generating a process of 'stage managed' experience for one walking along it, encountering features in a prescribed order (Bradley 1993: 51, Tilley 1994). This may have been accentuated with elements of linking past and present, linking death with life (with alignments on earlier mortuary structures) and providing elements of inclusion or exclusion (see below).

The alternate view, that cursuses did not provide a focus for processual activity was first presented by Webster and Hobley (1964) who, on examination of a cursus in the Avon valley in Warwickshire, suggested that cursuses may have been unsuitable as processual ways (or race tracks) due to topographic factors.

Ancillary structures to other monuments

If it were assumed that cursuses were processual monuments, it may been argued that they followed a similar role to avenues in being ancillary to other monuments. Coincidence of alignment with other monuments has been used to suggest that these features satisfied a similar function to avenues (e.g. Stone 1948, Hedges and Buckley 1981). However, this interpretation is an ambiguous one. For example, Atkinson's remark that the Amesbury was deliberately aligned on a long barrow was used to suggest that the two were linked (Atkinson *et al.* 1951, Atkinson 1986). Similarly, Tilley suggested that the cursus was designed such that movement along it would have provided an experiential route revealing a changing landscape of monuments to one passing along it (Tilley 1994). The inference is that cursuses may be linked to other monuments, but not as ancillary monuments. Rather they provided a reconstruction of the landscape based upon other, earlier monuments. Further, the evidence of closed terminals strikes a sharp contrast with the traditional role of avenues and so it appears that cursuses could not have followed the same function, but that they may have satisfied a similar one, as an avenue to many structures rather than to a single one.

Cursuses as racetracks

Early interpretations of cursuses were based upon analogies from classical literature. The descriptions of native charioteering skill described by Caesar appear to have held the backdrop and, without further dating evidence, this image was applied to cursuses. It was therefore assumed that the Amesbury cursus, first published on 6th August 1740 represented a racecourse for Celtic chariots. The various other earthwork features in the area were linked to the associated activities of judging and spectating: a forum for displaying skills focused on funerary games (Stukeley 1740: 41). On the basis of this interpretation the name *cursus* - a Latin work meaning 'race track' - was applied. Upon the recognition of this monument Stukeley was able to add other similar features to the class including sites at Rawdykes (Leicester), Dyke Hills (Dorchester), on the River Lowther (Penrith) and at Royston (Stukeley 1740: 43). This interpretation of these features as racecourses was upheld in 1812 when Sir Richard Colt Hoare wrote of the Winterbourne Stoke lesser cursus (Colt Hoare 1812: 158). He later added to this class the cursuses at Gussage and Pentridge in Dorset discovered by William Cunnington. In 1934 features recorded from the aerial photography of Major G.W. Allen were published by E.T. Leeds (Leeds 1934b: 266). A reply to this article the following year by O.G.S. Crawford suggested that this feature belonged to the class of 'cursuses', anglicising the Latin word for the first time (Crawford 1935: 77-8). Within this note Crawford noted that

Stukeley's suggestion that these features functioned as racetracks was "quite a reasonable one", though maintained that such an interpretation "must remain purely a matter of guess work" (Crawford 1935: 78). In support of the postulation that such races were part of funerary games he added that Homer and other ancient authorities record such games, also linking the possibility of similar barrow burial rites. However, he did note that the interpretation of the sites simply for sports seemed contradictory to the discoveries of burials inside of the enclosures. This resurgence of interest in this class of feature prompted Allen to publish surveys of a number of cursuses (Allen 1938: 169-70).

The main arguments in favour of this theory revolve around the long narrow morphology of these features. Many arguments have been levelled against the racetrack interpretation, despite the ever-growing corpus of examples of cursuses displays an increasing range of peculiarities presenting a range of forms that would seem unlikely to have such a common function. Similarly, the range of environmental scenarios in which they have been found suggests that cursuses could not have been raced along. For example, those cursuses that cut across river or stream courses such as Rudston A would inhibit racing potential. Similarly, Stukeley's suggestion that some of the earthworks would have facilitated spectators is less likely since growing evidence has demonstrated that intervisibility within cursuses is often restricted and controlled by the structure of the features themselves (e.g. Tilley 1994).

Funerary/sepulchral functions

Stukeley (1740), Colt Hoare (1812), Leeds (1934), Crawford (1935) and, inadvertently, Greenwell (1877), all acknowledged the association of cursuses and apparently funerary monuments, postulating in most cases that the monuments served a non-secular function and may have been associated with death. A cult of the death was also postulated by Atkinson (Atkinson *et al.* 1956, Atkinson 1986) who noted that the Amesbury cursus was *deliberately* aligned upon a long barrow to the east and noted that the two must have been linked, perhaps in function as well as monumentality (see above). The possible genesis of cursuses from bank barrows has also been used to suggest that these monuments implied an elaboration of mortuary rites (Bradley 1984: 32).

Ceremonial functions

The interpretation of cursuses as monuments involved in ceremonies is linked closely with their apparent association with the dead, and also with the theories suggesting that their function involved movement, perhaps in the form of a procession.

Social functions

The role of cursuses within the landscape will inevitably have had an influence on society, and its has been suggested that such monuments were constructed in such a way as to define and reinforce social roles and behaviour. The physical scale of these and other contemporary monuments indicates that their construction would have required a large workforce. It has been argued that this suggests a degree of control by an individual over a community, although this may have been increased or decreased by the length of time available for the total construction and consequently the workforce requirement (Hedges and Buckley 1981). Similarly, the infrequent causeways into the areas enclosed by the cursus earthworks, pits or palisades may suggest that access to the interior was restricted and exclusive, like an inner sanctum. Further, the thin nature of the structure would have meant that certain members of a group would need to go ahead with others following (Bradley 1993: 55). Thirdly, it has been argued that cursuses formed a social role in defining the transition to adulthood. Tilley (1994) suggested that cursuses may have formed a symbolic pathway or journey - a mysterious, exiting and frightening place, a walk along which would have presented a story told through the changing landscape and monuments encountered as it was moved along. Bradley (1984: 32) has argued that the possible genesis of cursuses from bank barrows suggests an elaboration of mortuary rites (see above). He suggested that some cursuses might have been built following prolonged social competition that became manifest in an ever-increasing elaboration of monuments and settlement, in this case expressed through funerary ritual. Bradley also suggested that the distinctive layout of cursuses might relate to a need for traditional practice (Bradley 1984: 44).

Temenos - sacred places

Another key interpretation of the function of cursuses is that they defined a sacred area, serving as a *temenos*. Evidence for such a theory has been limited to classical analogy but is argued through the absence of other likely theories (Loveday 1985). Other authors have reflected this theory suggesting that the area of land enclosed within them were sacred places (e.g. Brophy 1999). Perhaps linked to the concept of cursuses defining sacred areas is Johnston's suggestion that cursuses defined areas where human processions previously took place, but where they had stopped (Johnston 1999).

Link to natural processes

Brophy (1999) suggested that cursuses might have been constructed as a reaction to paradoxes in nature. He noted the frequent association of cursuses with streams or rivers

and, upon reflection, noted also that rivers were both life giving (providing water, food and transport), but were also dangerous (they can drown and flood). He suggested that cursuses were build as a response to this "paradox of nature" (Brophy 1999: 7).

Astral and geometrical responses

A number of papers have suggested that the form of cursuses, and other monuments, has centred upon geometric determinations, and alignments or associations with astral or solar cosmic events. Stukeley noted that alignments at Stonehenge pointed towards the sunrise of the Summer solstice (Stukeley 1740). Such interpretations are often closely linked to interpretations of a religious function in which the monuments formed celestial calendars for recording, forecasting and influencing events. Such interpretations are often steeped in ceremonial activities taking place on these sites. Work at Stonehenge suggested that the monument could be used to predict eclipses and it was argued that the monuments were constructed to such a grand design for a higher accuracy and sustainability to make it invulnerable (Hoyle 1966). Similarly, Thom's work also suggested that stone circles were built to a structured, accurate mathematical design (Thom 1966). Atkinson also followed this premise and noted that Stonehenge was positioned for astronomical reasons, down to its latitudinal position, and that it was possible to predict lunar events that would not be actually visible from the monument (Atkinson 1966).

Against the theory that megalithic monuments were constructed upon astronomical alignments is Heggie's argument of practicality (Heggie 1972). Heggie notes that, to plan such a monument would require such close observation of celestial activity that would be impossible through basic hindrances such as cloud cover. Similarly, he makes the point that alignments are based upon sight lines that require an observation point and a foresight: a point that is looked through as a sight. The large scale of megalithic monuments suggests that any foresight would be difficult to define. Similarly, if a foresight were a natural feature on the horizon it would be equally difficult to define it and to therefore measure its accuracy in terms of alignments. Fundamentally, the scale of the monuments and landscape precludes accurate measurement.

The above theories have been concerned mostly with Stonehenge and other megalithic monuments. However, some work has been done particularly concerning cursuses. It has been noted that many cursuses are aligned east - west, but that this is not consistent (*cf.* Hedges and Buckley 1981), though it has been argued that this trend reflects a

'monumentalisation' of astronomical events, such as midwinter sunrise (Devereux 1991: 894). The Dorset cursus has also been investigated in terms of astronomical alignments, where it has been argued that the double banks of chalk acted like a sighting tool to point towards the approximate direction in which to look for a distant astronomical object. They were not wholly aligned on particular celestial events, but rather joined a series of viewing positions together (Penny and Wood 1973). This was interpreted as having the dual function of being both a way of providing a wholeness to these areas, and perhaps providing a bounded area that needed to kept free of vegetation.

Trade

Finally, trade may be considered as a reason for the construction of large monuments such as cursuses. At a number of monumental centres, including Avebury, Stonehenge and Dorchester, distributions of contemporary items of high quality lithics have been recovered from the general area. Similarly, at Rudston, the surrounding area has produced many polished stone axes and other flintwork (Manby 1979, Durden 1995). It has been argued that such concentrations of material may indicate centres of trade (Pierpoint 1980: 253) and so the monuments may have been associated with such activities, though this may equally apply to the monolith in the case of Rudston.

Summary

Many of the theories involving the function of cursuses reflect the philosophical standpoint of the particular author. Interpretations of the reasons for their construction and the influence that they had on the community are largely based upon more fundamental theories such as the conflicts between environment, society and religion, and how each one influenced the others. For example, an environmentally determined attitude may imply that they were reactions to a hostile environment that needed to be controlled. A religiously determined interpretation may imply that these constructions formed a process of appeasement. Conversely, a socially determined response may suggest, for example, that all of the above were true, but were determined and manipulated by leaders in a quest for power or justification. Each of the theories reflects the overlapping archaeological processes of observation and explanation. The former refers to ideas that stem from direct empirical recording and experience of the monuments through archaeological fieldwork. The division of space is explored and relationships between the monument being discussed and the surrounding landscape and other monuments are considered and described. This is taken further to suggest how the form of the monument indicates how it may have been used and theories suggesting

movement or static observation are postulated. The second term, explanation, extends the point to interpret the function and role of these monuments within the society and strives to gain insight into the society behind the monuments. The latter approach is clearly more subjective but is the only way of furthering the research into this area. Observational theories have been found to often be restricted and not universal. Only by presenting interpretations can these be tested with any usefulness. Overall, problems lie in the general difficulties of providing evidence to support the different functions - they cannot be qualified or quantified and analysed statistically. These theories are questioned in the light of this in chapters 4 and 7.

b. Landscape chronology

The second major issue concerning the prehistoric Wolds landscape surrounding Rudston is that of chronology. Although much data is available for the area, there are a number of issues regarding chronology that have yet to be understood.

The date of the monolith

As noted above, the dating of monolith features is extremely limited and only a broad assumption of date can be made. The Rudston monolith's key positioning within the Neolithic and early Bronze Age landscape suggests that it was important within it, though it is not clear at which date it was put in place. The distribution of elaborate finds (polished knives and maceheads) and pottery (Grooved Ware) that decreases in density with distance from the monolith may indicate a later Neolithic date for the site (Pierpoint 1980). However, there is no clear distinction between the possible focal role of the cursuses or the monolith, or indeed the site of the monolith and the monolith itself, both of which would affect its date. Further, the distribution of finds would only place it into a broadly late Neolithic time slot that is also occupied by monuments including both the cursuses and the henges, without temporal subtlety. An analysis of the spatial relationships between the different monuments may provide a key as to the relative chronological development of the landscape and may also provide an understanding of how the monolith fitted into this.

The chronological relationship of the cursuses

The second chronological enigma of the archaeology of the Wolds landscape is the relative chronology of the cursuses. Although evidence exists for the relative chronology between cursuses A, C and D, the timing of cursuses B and E is not clear. They display a consistent alignment (west-southwest by east-northeast) which differs from the primary

north-south or east-west alignments of cursuses C and D, and the pattern of cursus A is again different. Again, an analysis of the spatial positioning of each monument in relation to the others may provide some insight into this problem.

The influence of earlier monuments upon the placing of later monuments

Finally, the issue of the longevity of monuments and the time between the completion of one monument and the construction of another appears to be significant. For example, it is not known how long each cursus stood or was maintained before another was built. Similarly, although it is assumed that the construction of Maiden's Grave henge post-dated cursus construction, evidence from Thornborough indicates that the cursus had silted up by the time the henge was constructed over it (Thomas 1955). This would suggest that cursuses had gone out of functional use by the time henges were constructed.

Summary

Issues concerning landscape chronology can be hinted at through an analysis of monument positioning and how this was affected by the locations of earlier monuments or how the new constructions effected the overall landscape. By analysing these relationships the relative chronology can be hinted at and theories as to the time delay between constructions and the influence of earlier monuments on later ones may be postulated.

2.2.6 Cultural resource management issues to be addressed

a. Agricultural erosion of monuments

As noted earlier in this chapter, the Wolds are especially prone to soil erosion and thin soils. This has far reaching implications for the survival of archaeological features, particularly since the vast majority of the landscape is under arable cultivation. The rate of such erosion however is not known. Continuous and recent approaches aimed at protecting the monuments through scheduling may be considered to be ill informed since they do not outline requirements of monitoring the erosion and damage to archaeological sites in any way.

b. Archaeological visibility of monuments

The publication of the results from the National Mapping Programme of the Yorkshire Wolds (Stoertz 1997) demonstrated the huge volume of archaeology within this landscape, but also highlighted that the vast majority was known of only through its cropmark and soilmark remains. However, since the publication of this work it has been

noted that a significant number of new features have been discovered within the area, including extensions of those features already noted (Jane Stone *pers comm.* mentioned above). Recent work towards protecting elements of the landscape (for example, through scheduling) may therefore be limited. However, this process is currently inflexible and unreflexive. Consequently, there is a need to be able to predict areas where the main basis of evidence (i.e. crop marks) may be restricted. Further, this issue does not appear to be one of geology and so the basis of correlation between archaeological distribution and geological units (*cf.* Riley 1983) does not seem appropriate due to the relatively simple geological variation of the area. It is therefore likely to be influenced by various depths of masking deposits.

2.3 The Sutton Common landscape

2.3.1 Environmental background

a. Topography and geology

The second study area lies on the western edge of the Humberhead Levels, the flat, low-lying area to the southwest of the upper reaches of the Humber estuary. Its limits are defined by the Rivers Aire and Ouse to the north, the Isle of Axholme and the River Trent to the east and the Pennine margins to the west (Ellis 1997: 7). The nature of the landscape of this region is largely defined by its Late-glacial/early Holocene development.

The study area is split east-west about its solid geology. On the western edge, Upper Magnesian Limestone occurs. This is overlain by Triassic Sherwood Sandstone that covers the eastern two thirds of the region (Ellis 1997). These deposits outcrop on the western edge of the area at Askern and Bentley where Upper Permian Marl is also present underlying meandering river gravel deposits. Across the southeastern part of the region areas of older river gravel and glacial sand and gravel outcrop, particularly around Edenthorpe (Geological Survey of Great Britain 1969, 1971). Late Quaternary deposits and the landscape evolution of the region are described by Gaunt (1994) and by Dinnin (1997a) upon which the following is based. Six key phases of landscape development have been identified from the Humberhead Levels that cover the majority of the lowland area.

The initial phase of the Holocene development of the study area stems from a legacy of the Dimlington Stadial of the Devensian, *c.* 18,000 - 13,000 BP (uncalibrated). During this time an ice sheet blocked the Humber gap, leaving meltwater and runoff to form

Lake Humber which began to fill with inwashed sediment. Following the melting of the ice sheet at approximately 13,000 BP, the blocking of the Humber gap was maintained by glacial deposits. Sediment continued to accumulate until it raised above the level of the Humber gap. This episode has been dated to 11,100±200 BP (N-810), though this may have happened earlier in parts of the Humberhead Levels. The resulting lacustrine plain sloped across the region from approximately +8 m OD near Selby to +5 m OD east of Doncaster (Dinnin 1997a).

The formation of lacustrine deposits was followed by a braided river phase, probably due to the Humber Gap not having been breached since contemporary sea-level was very low at this time. This phase lasted between approximately 11,100±200 BP (N-810) and 10,469±60 BP (SRR-870) and is marked by the deposition of sandy levée deposits along the river courses which are noted from the eastern half of the study area around West Moor. These sandy levées were subsequently re-worked through aeolian action that partially eroded the low sandy ridges and formed a number of sandy dune systems. This phase extended into the early Holocene during a cold arctic climate.

The early Holocene is marked by channel incision, probably due to the break in the Humber gap. Contemporary sea-level appears to have been lower than -20 m OD and the drainage of the Humberhead Levels began to flow into the proto-River Humber. The unconsolidated and waterlogged lacustrine deposits of Lake Humber were deeply incised by the rivers as they cut down towards base-levels. This formed an early Holocene landscape defined by deep, relatively straight valleys. This phase continued until some time before 5740 - 5410 cal BC (6681±100 BP: Q-401) by which time sea-level had begun to rise (Dinnin 1997a).

Continued sea-level rise had two main consequences within the Humberhead Levels. Firstly, it impeded freshwater runoff, and secondly, the lower parts of the catchment were influenced by marine water, which ponded further upstream. The result of this was a deposition of sediment and the river channels began to infill partially with alluvium and peat. This episode has been dated by a series of radiocarbon determinations providing a global date for the region of *c.* 3350 - 2510 cal BC (Dinnin 1997a). However, evidence of sea-level change has suggested that by *c.* 3800 cal BC sea-level was within a few metres of OD (Dinnin and Lillie 1995). This rise in sea-level continued, and by *c.* 1800 cal BC had reached a height near to OD (Dinnin and Lillie 1995). Since this date sea-level, together with other factors such as channel infilling, impeded runoff and perhaps the

forest clearance, led to the development of a wetter landscape with rising groundwater levels and paludification (Dinnin 1997a). This appears to have been a rapid process, as demonstrated by the waterlogging and preservation of areas of buried woodland at the base of peat deposits. The development of peat at this time is demonstrated at West Moor (Dinnin 1997b). The infilling of channels and impeded runoff also led to over-bank flooding of the contemporary rivers causing floodplain aggredation, the deposition of alluvium and the development of floodplain peat (Dinnin 1997b). This is marked along the course of the River Don within the study area (*cf.* Lillie 1997).

Geologically, the study area is split about the floodplain of the River Don that crosses the region from the southwest to the northeast. To the northwest of this line the area is characterised by early Holocene clay-silt deposits derived from Lake Humber. Along the western edge, outcrops of earlier deposits including Upper Magnesian Limestone exist as occupied by the site of Askern. To the south, around Bentley, First Terrace Gravels outcrop. The palaeochannel of the Hampole Beck runs northwards past Askern extending towards the River Went further north. Elsewhere across the large plain of clay-silts a number of small sandy islands exist, near Fenwick and Fosterhouses. To the southeast of the River Don the landscape is very different. Here the geology comprises Older River Gravels and Triassic Sherwood Sandstone, the latter lining the edge of the River Don's alluvial floodplain. These deposits are locally interspersed by deposits of glacial till, further clay-silts and glacial sand and gravel, the latter lining the southern perimeter of the region. Within the southeastern corner is the circular peat-filled hollow of West Moor (Geological Survey of Great Britain 1969, 1971). The geomorphology and general development of the River Don, the Hampole Beck and West Moor have been investigated within the study region on a number of occasions (see Dinnin 1997c for the River Don further downstream, Buckland 1987 and Lillie 1997 for the Hampole Beck, and Dinnin 1997b for West Moor).

b. Vegetation history and landuse

The vegetation history of the region is much better known than that of the Rudston landscape (see 2.2.1 above) due to the proliference of wet-preserved deposits that have yielded much palaeoenvironmental data. As with the Rudston landscape, a number of palaeoenvironmental investigations have been conducted. The primary palaeoenvironmental resource lies within the catchment of the Hampole Beck palaeochannel near to Askern. At the southern end of this system is a series of peat-filled faults such as Shirley Pool (Buckland 1987). This area has formed the basis of many of

the palaeoecological investigations in the area (e.g. Skidmore and Howe 1987, Dinnin 1994) other than those from Thorne and Hatfield Moors (e.g. Smith 1985).

Palaeoecological investigations within the Humberhead Levels have been dominated by Thorne and Hatfield Moors (*cf.* Smith 1985) with further details extrapolated from work within the surrounding area. The postulated vegetation development has been documented elsewhere (*cf.* Dinnin 1997a) and will only be briefly outlined here (table 2.5).

Table 2.5 *Holocene vegetation development (after Dinnin 1997a)*

Date	Vegetation development
post *c.* AD 1000	Increased drainage with peat cutting on the moors.
c. AD 440-1000	Decline in herbs and increase in arboreal and shrub taxa. Some woodland regeneration, possible post-Roman agricultural decline and later Anglo-Saxon expansion. Increased flooding with raised base levels. Settlement nucleation.
c. 480 cal BC - AD 440	Development of raised mire vegetation on Thorne and Hatfield Moors. Increased agricultural clearance with a mixed farming economy, emphasising pastoralism. Subsequently increased soil erosion and flooding leading to increased alluviation.
c. 1930-480 cal BC	Initially a drop in *Pinus, Tilia, Ulmus* and *Quercus*. Small scale mid-Bronze Age clearance seen through agricultural weeds coupled with dense woodland. Possible increased clearance towards the end of the Bronze Age with a regeneration of woodland on abandoned agricultural land.
c. 2920-1930 cal BC	Some dense *Quercus-Alnus-Corylus* forest with some *Pinus* and *Tilia*. Perhaps a modified mixed forest due to anthropogenic activity.
c. 4040-790 cal BC	*Ulmus* decline with increase in agricultural indicators such as *Plantago lanceolata* and *Plantago major*. Peat growth commences on Hatfield Moors. Localised clearance and forest regeneration.
c. 5320-3990 cal BC	Increased *Alnus* and *Tilia*. Some *Quercus-Tilia* forest and *Corylus* and *Betula*.
c. 8050-5230 cal BC	Increased differentiation, including some mixed *Corylus-Quercus-Ulmus* forest - possible evidence of anthropogenic fire clearance
c. 9500-9000 BP (uncal.)	Increase in *Corylus*, *Pinus* and *Ulmus*
c. 10,200-9500 BP (uncal.)	*Betula* dominated woodland with some *Pinus* and *Salix*

Data from the study area itself display a more detailed understanding of the local landscape development, particularly throughout the Iron Age, contemporary with the monuments being studied (see section 2.3.3 below). Work by Buckland (1987), Hale (1987), Lillie (1997), Bunting and Schofield (in Van de Noort and Chapman 1999) at various areas across Sutton Common has shown a palaeoecological development spanning potentially from *c.* 7500 BP (uncalibrated) to the present. Work by Schofield at Shirley pool identified six characteristic periods within the palynological evidence (Van de Noort and Chapman 1999). The basal phase, SUTT1, was characterised by a *Tilia-Alnus* dominated assemblage that was suggested to date from the later Mesolithic or early Neolithic period, post-dating the *Alnus* rise, but pre-dating the *Ulmus* decline. SUTT2 was characterised by a decline in *Tilia* and *Pinus* and suggested a dense fen woodland, with *Alnus*, *Quercus* and *Corylus* forming a relatively closed canopy. A sharp decline in *Ulmus* was identified towards the end of this phase, probably relating to either early Neolithic anthropogenic influence, or more probably to increased paludification. SUTT3 was characterised by a rise in *Betula* and a reduction in *Alnus, Quercus* and *Corylus*, indicating a birch carr with wetter stands of *Alnus* and *Salix*, with occasional *Quercus* and *Corylus*. The fourth phase, SUTT4, saw a successional reversal to an increasingly wet environment not dissimilar to SUTT2, but with a more open canopy identified through an increase in herbaceous taxa. This was represented predominantly through an alder carr. SUTT5 provided some evidence of human activity with an increase in herbaceous taxa including the agricultural indicator *Plantago lanceolata*, with a decline in dryland trees. An increase in inorganic sediments implies greater runoff, typically signifying clearance (*cf.* Buckland 1987, Lillie 1997: 73). SUTT6, the final phase identified from Shirley Wood, began with evidence for deforestation with some cereal pollen, which was followed by a decline in *Alnus*.

Evidence from the Hampole Beck is more limited palaeoecologically, although a number of inferences have been made from other sources of evidence (*cf.* Buckland 1987, Lillie 1997). The channel is *c.* 70 m wide and up to *c.* 4.8 m deep between the enclosures which occupy reworked islands derived from Lake Humber, and has been mapped as alluvium (Geological Survey of Great Britain 1971). The basal peat within the channel has been dated palynologically by Weir to after the later Bronze Age, but before the Roman period (Lillie 1997: 69-70), and this conclusion is echoed by the inferred relationship with rising base levels seen at Thorne Moor (Buckland 1987).

Palaeoecological work has been conducted on the Iron Age earthworks at Sutton Common (see below). Hale (1987) investigated the palynological remains beneath the bank of enclosure B. The basal unit of this, taken from a probable buried soil horizon, contained very little pollen but did produce evidence of *Ulmus* and *Quercus*, suggesting an overall relatively open, mixed woodland with open dry areas containing herbs and ferns. Bunting's work (in Van de Noort and Chapman 1999) investigated the pollen from within the ditches of the two enclosures. While the study aimed to investigate the preservation of pollen, conclusions were made from the assemblages, with two main zones identified. The lower zone was dominated by arboreal pollen, particularly *Alnus*. This was succeeded by a transitional phase characterised by increased *Plantago lanceolata*, perhaps suggesting livestock grazing, followed by the second zone which consisted of grasses, sedges and herbs, perhaps reflecting arable cultivation. This pattern reflected previous investigations of the deposits from the ditch of enclosure B (trench F) that revealed a wooded landscape with areas of wetland and limited grassland towards the base (Parker Pearson and Sydes 1997). The higher fill reflected increasingly open grassland with a decline in woodland and an increase in wetness, and the deposition of spelt in the ditch.

In summary, human activity has been inferred from a mixture of palynological evidence and clastic sedimentation resulting from slope runoff. This suggests that forest clearance began at approximately 4000 BC, with restricted regeneration that may be associated with environmental change characterised by rising base levels and paludification. Towards the end of the Bronze Age there appears to have been an increase in forest clearance, which continues to the end of the Roman period. Initially, this appears to have been dominated by pastoralism, but later by increased arable cultivation, though it must be considered that the balance between the two was not a linear progression, but rather an interrupted change. This activity is reflected within the archaeological record in the region by the discovery of carbonised spelt seeds from the ditch of enclosure B at Sutton Common (Parker Pearson and Sydes 1997: 229), and also by the large field systems which cover much of the drier areas of the study region (Riley 1980b, see below). The more densely forested areas were probably the heavier clays, which were cleared towards the end of this period. Following the Roman period came an initial regeneration of woodland, but this reverted yet again to further clearance towards the end of the early Medieval period. The Post Medieval period is characterised by peat cutting and increased drainage, particularly in the seventeenth century by Vermuyden (Dinnin 1997d).

The area around Sutton Common remained as common land much later and was only first subject to drainage operations in approximately 1859 (Whiting 1936: 57), although the effect upon the wetland in that area appears to have been limited. In 1868 the Rev. Scott F. Surtees described the area as a morass untouched by drain or plough (Surtees 1868) and as late as 1908 the area was described as wet and swampy (Allcroft 1908: 246-7). In 1936 Whiting (1936: 57) noted that wet weather soon rendered the lower-lying ground waterlogged. In 1982 the Ministry for Agriculture initiated a drainage scheme which was implemented through 1983 and 1984 (Sydes and Symonds 1987: 53-4, see below). In 1990 English Heritage commissioned a report into the de-watering of the site which concluded that off site water abstraction was having a negative impact on its hydrology (Geomorphological Services Ltd. 1990). Two years later, in 1992, a visit to the site by English Heritage commissioners heightened concern that the site was continuing to dry out (Parker Pearson and Sydes 1997).

2.3.2 Archaeological background

The Sutton Common landscape (Figure 2.8) is less rich in archaeological remains and heritage as the upland landscape of the Yorkshire Wolds due to a number of possible factors. Firstly, the primary evidence of features on the Yorkshire Wolds is from crop marks visible on aerial photographs. Other than on the Sherwood Sandstone where the natural drainage is very good, the lowlands provide a high water table. This restricts differential moisture retention and thereby inhibits the growth of crop marks (*cf.* Riley 1944, Jones and Evans 1975, Riley 1982, 1983). Secondly, the accreting nature of wetland landscapes means that some sites will become buried deeply, and will therefore be invisible to aerial photography or to ground reconnaissance. In contrast, the thin soils of the Yorkshire Wolds are prone to erosion (Stoertz 1997, D. Macleod pers. comm.). Thirdly, factors such as the practicalities of conducting different activities in the past within wetland landscapes become important, particularly in relation to sea level change. However, the difference in distribution, density and nature of the archaeological resource within this type of region is counted by differences in the potential of the archaeology in terms of organic preservation.

Previous archaeological investigations within the Humberhead Levels have been widespread (*cf.* Van de Noort and Fenwick 1997: 222-6). Much of the area has been covered by the aerial photographic work of Riley (e.g. Riley 1980b) and also by the RCHME. These have been followed by a widespread ground survey between 1995 and 1996 (Van de Noort and Ellis 1997). Particular work relating to the later prehistoric

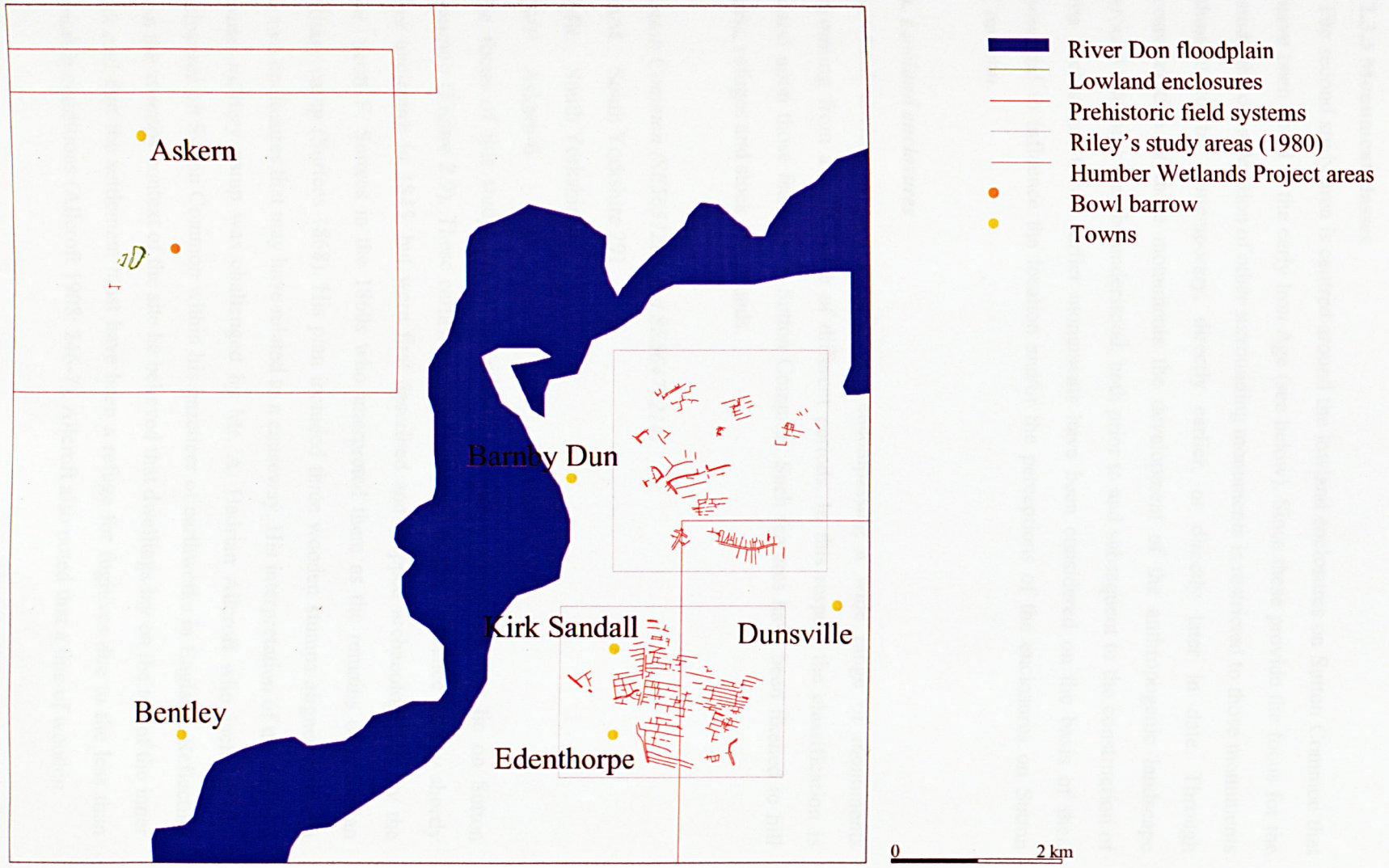


Figure 2.8 The Sutton Common landscape showing the distribution of archaeological features.

period has been concentrated at Sutton Common and on the cropmark field systems of the Sherwood Sandstone within the southeastern part of the region (see section 2.3.3 below).

2.3.3 Monument classes

The second study area is centred around the lowland enclosures on Sutton Common that have been dated to the early Iron Age (see below). Since these provide the focus for the study the consideration of other surrounding monuments is restricted to those monuments thought to be contemporary, directly earlier, or directly later in date. Through consideration of these monuments the development of the anthropogenic landscape around that time may be understood, both prior to and subsequent to the construction of the enclosures. Other earlier monuments have been considered on the basis of their potential to influence the location and/or the perceptions of the enclosures on Sutton Common.

a. Lowland enclosures

Lowland enclosures is a generic term encompassing a wide range of monuments stemming from a wide range of different periods. In this respect the classification is based upon those features on Sutton Common. Such features have been likened to hill forts, refuges and stock compounds.

Sutton Common (SE5651205 and SE56471214)

SAM South Yorkshire 291

SMR South Yorkshire 3

HWP Askern-6

The focus of this study area is the pair of earthwork enclosures that lie on Sutton Common (Figure 2.9). These earthworks were mapped by the Ordnance Survey shortly after enclosure in 1845, but were first described and mapped archaeologically by the Rev. Scott F. Surtees in the 1860s who interpreted them as the remains of a Roman military camp (Surtees 1868). His plan included three wooden stumps aligned between the two enclosures that may have related to a causeway. His interpretation of the site as a Roman military camp was challenged by Mr. A. Hadrian Allcroft who included the enclosures on Sutton Common within his gazetteer of earthworks in England. Reflecting upon the swampy context of the site he believed that dwellings lay on the top of the inner bank and that the settlement must have been a refuge for fugitives due to the less than habitable conditions (Allcroft 1908: 246-7). Allcroft also noted that a line of wooden

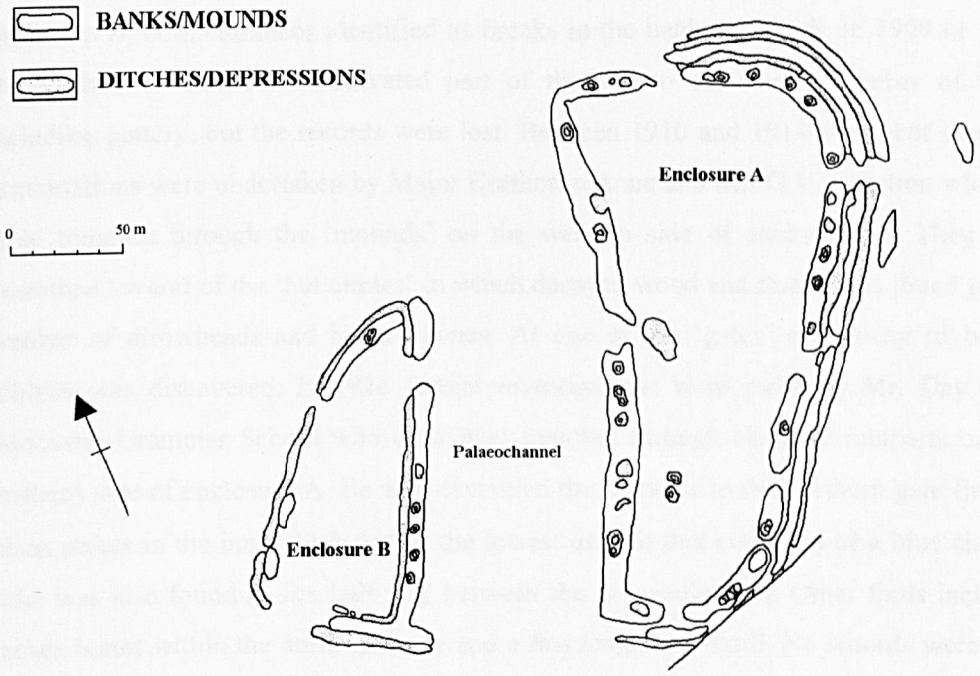


Figure 2.9 The enclosures on Sutton Common as surveyed by Bennett and Hill (Whiting 1936), re-drawn with relative positioning used by Parker Pearson and Merrony (1993)

stakes ran between the western entrance to enclosure A and the eastern entrance to enclosure B, both entrances identified as breaks in the bank and ditch. In 1909 or 1910 Dr. Corbett of Doncaster excavated part of the site to discover a number of finds including pottery, but the records were lost. Between 1910 and 1914 a number of other examinations were undertaken by Major Crathorne Anne and Mr. G.V. Charlton who cut three trenches through the 'mounds' on the western side of enclosure A. They also examined several of the 'hut circles' in which decayed wood and thatch was found plus a number of arrowheads and human bones. At one of the 'gates' a pathway of brown pebbles was discovered. In 1926 further investigations were made by Mr. Day from Doncaster Grammar School who excavated trenches through all three ramparts on the northern side of enclosure A. He also examined the entrance to the northern gate finding fallen stakes in the inner ditch within the lowest deposit that consisted of a blue clay. A stake was also found *in situ* half way between the two enclosures. Other finds included human bones within the north gateway and a *Bos longifrons* skull. No records were kept of this work either and the finds were lost (Whiting 1936: 58).

In the late summers of 1933, 1934 and 1935 further investigations were made under the direction of Emeritus Professor Whiting and the findings were published in the *Yorkshire Archaeological Journal* after he excavated many trenches across both enclosures (Whiting 1936). His work was mostly restricted to sectioning the main earthworks and investigating features visible on the tops of the banks and so most trenches either followed their alignment or were excavated at right angles to them. Two of the perpendicular trenches were extended further. Trench I, cut across the centre of the earthworks on the eastern side of enclosure B was extended half way across the interior of the enclosure and the same distance into the palaeochannel. Trench IIc was excavated further to the north and was extended from the bank a further *c.* 40 m into the channel. His findings included carbonised wheat, a baked clay ball, a possible net sinker, Romano-British pottery, an oak plank, a circular oak slab (interpreted as a wheel), a possible dug-out, several flint implements and waste and a number of bones including human, ox, sheep and goat and some *Bos lonifrons* horns. He concluded that there were at least two phases to the site. The first phase was represented by the wooden palisade or stockade that was found surrounding the northern section of enclosure A and was seen in part elsewhere including under the bank at the northern end of enclosure B. The second phase was at "probably a much later date" (Whiting 1936: 79) when the two 'sandbanks' were occupied by the people who erected the ramparts. A stone revetment of poor quality construction including pieces of wood faced these. Whiting was certain that these

occupants were generally, if at all, unaffected by Roman culture and therefore suggested that the site was prehistoric. This conclusion was supported by the fact that the Romano-British pottery had been discovered high up within the ditch on the western side of enclosure B. He recognised the unusual nature of the site - not a lake village because there were no piles to suggest that any part of the site stood on water; and unusual in terms of contour camp. He did not consider it to be a fortress either due to the relatively low ramparts and therefore suggested that it was a site of refuge, perhaps with banks constructed to keep out the water on all sides. Occupation had been short lived, suggested by the small number of finds, and it was concluded that the first phase had been at some time during the Bronze Age. Whiting argued that the earthworks had been constructed at a later date by a poor and primitive people before the end of the second century AD, and perhaps even before the Roman period. In 1937 the site was afforded protection in the form of scheduling (SAM 291) on the basis of Whiting's work. At this time a detailed plan was made of both of the enclosures by Bennett and Hill, these published within Whiting's work (see Figure 2.9).

The site received little attention until 1979-80 when enclosure A was bulldozed for arable agriculture by the tenant farmer, Mr C. Lodge (see Figure 2.10a & b). The bulldozing of the smaller enclosure was halted by staff of Doncaster Museum, but only after it had destroyed the southeastern corner where originally an easterly extension of the southern side ran towards the Hampole Beck palaeochannel. 'Before and after' aerial photographs were taken of the site by Derrick Riley (1982: 20) and the soil marks on the later photographs demonstrate the amount of damage that was done (Figure 2.10). At the time of bulldozing large quantities of wood and stone walling were seen and a few fragments of quernstone were recovered (Parker Pearson and Merrony 1993). In 1982 the Ministry for Agriculture initiated a scheme of drainage whose deep dikes dropped local water levels on the Common by *c.* 2 m (Parker Pearson and Sydes 1997: 223).

By the late 1980s concern about the preservation of the site had become acute due to added drainage and the loss of the site as a wetland and so English Heritage funded three separate research assessment projects to be undertaken by the South Yorkshire Archaeology Unit. The first took place in 1987 (Sydes and Symonds 1987) when two trenches were excavated within enclosure B: A/C over one of Whiting's trench to enable comparative work, and B. The following year, in 1988, a second assessment led to the excavation of two further trenches (D and E), this time within enclosure A, to assess the preservation of organic material within the ditches (Adams *et al.* 1988). Further



Figure 2.10a Aerial photograph of Sutton Common looking south before bulldozing (DNR877 SE5612/8/36 – 7.7.1976) NMRC © Crown Copyright



Figure 2.10b Aerial photograph taken shortly after bulldozing and ploughing (DNR1586 SE5612/26/7 – 13.9.1979) NMRC © Crown Copyright

investigations were carried out in 1992 when one of the 1987 trenches was reopened for comparative study (Sydes 1992). In 1993 a further study was carried out under the auspices of Sheffield University Department of Archaeology and Prehistory, South Yorkshire Archaeological Services and Doncaster Museum. This assessment reopened the earlier trenches and also opened a new trench - trench F - on the eastern side of enclosure B (Parker Pearson and Merrony 1993). This work also investigated the huts originally identified by Whiting and concluded that a lack of beam slots and other features could suggest no more than ambiguous posted structures. On top of one of the banks however, within trench E, a four-post structure was found which was considered by the excavators to be part of a granary rather than a box rampart. This conclusion, however, could not be further substantiated due to the narrow widths of trenches. Further work including environmental assessments (including Buckland 1987 and Hale 1987) were published with the results from much of this earlier work in 1997 (Parker Pearson and Sydes 1997).

In 1996 the site and landscape was assessed by the Humber Wetlands Project based in Hull University. Field walking and aerial photographic analysis were used to understand the landscape better. Previously scatters of worked lithics had been found on two raised 'islands' (SUT1 and SUT2 - Sydes and Symonds 1987) to the northwest of the enclosures adjacent to the Hampole Beck, although a third island (SUT3) to the northeast, currently occupied by a pylon, revealed no worked material. A row of stakes was also recorded in the drain section between SUT1 and SUT2 (recorded as SUT3 - *ibid.*). Fieldwalking by the Humber Wetlands Survey also produced worked flint from this area, particularly from the area of SUT2 (Askern-7) which produced an assemblage of 122 pieces ranging in date from between the later Mesolithic to the early Bronze Age (Head *et al.* 1997: 233 and 236-8). This suggested that the palaeochannel was flowing during this earlier period (*cf.* Lillie 1997: 73), and also demonstrated the continued use of this landscape.

Dating of the site has not been totally clear. The excavations at the site have revealed several different phases that have been grouped in a number of different ways. Whiting (1936: 78-9) identified two separate phases of occupation relating to the enclosures. The first was marked by the erection of a timber stockade/palisade around enclosure A. The second phase, which was suggested to have been at a much later date by Whiting, was characterised by the construction of the ramparts, either destroying the stockade/palisade, or at a time after it had already been destroyed. He suggested that this later phase was

'backward' on the basis that the stonewalling was of a poor quality incorporating wood in the construction. While Whiting noted that phase 1 contained prehistoric material, he only marked that the earthworks were constructed at some time before the end of the second century AD due to the position of Romano British pottery having been found above the walling.

Parker Pearson and Sydes' (1997) summary of the work by the South Yorkshire Archaeology Unit and Sheffield University throughout the later 1980s and early 1990s also identified a number of phases. Phase 1 was characterised by late Neolithic occupation on the area covered by enclosure A. Phase 2 dated to the mid-Bronze Age seen by the discovery of a dirk blade. Phase 3 marked the first construction of the enclosures characterised by the erection of the timber alignment across the palaeochannel, perhaps coinciding with the construction of the timber palisade around enclosure A (Whiting's phase 1). This phase was radiocarbon dated to approximately the early Iron Age (2370±50 BP: GU-5524 and 2360±50 BP: GY-5525 which calibrate to 760-390 cal BC and 760-380 cal BC respectively). Phase 4 saw the construction of the earthworks of enclosure B and probably those of enclosure A, and this was also dated to the early Iron Age on the basis of the discovery of a shale bead. Phase 5 saw the growth of peat in the enclosure ditches. Burnt spelt was also deposited at this time in the ditch of enclosure B and has been dated to between 550 cal BC and 200 cal BC on the basis of a range of radiocarbon dates (Parker Pearson and Sydes 1997: 229). Phase 6 saw limited use of the site during the Roman period noted from finds of pottery and metalwork. It was suggested that peat continued to form in the ditches at this time. Continued activity into the Medieval period was also recognised. With reflection to the environmental data collected during this work, the majority related to phases 4 and 5, suggesting a clear landscape with woodland regeneration prior to the construction of the earthworks. Following the construction of the earthworks, as shown by remains in the ditches, woodland appears to have been in decline. Parker Pearson and Sydes (Parker Pearson and Sydes 1997: 252-3) suggested that the function of the enclosures may have been to hold stock, but only briefly. It was argued that the site was probably not used for human activity at this time. Deposits and artefactual evidence from the ditches of the enclosures probably reflected either abandonment or less intensive use.

The results from the work by the Centre for Wetland Archaeology at the University of Hull that continued in 1998 and 1999 concentrated purely on the enclosures (Figure 2.11) and identified four phases (Van de Noort and Chapman 1999, 2000). Phase 1 was

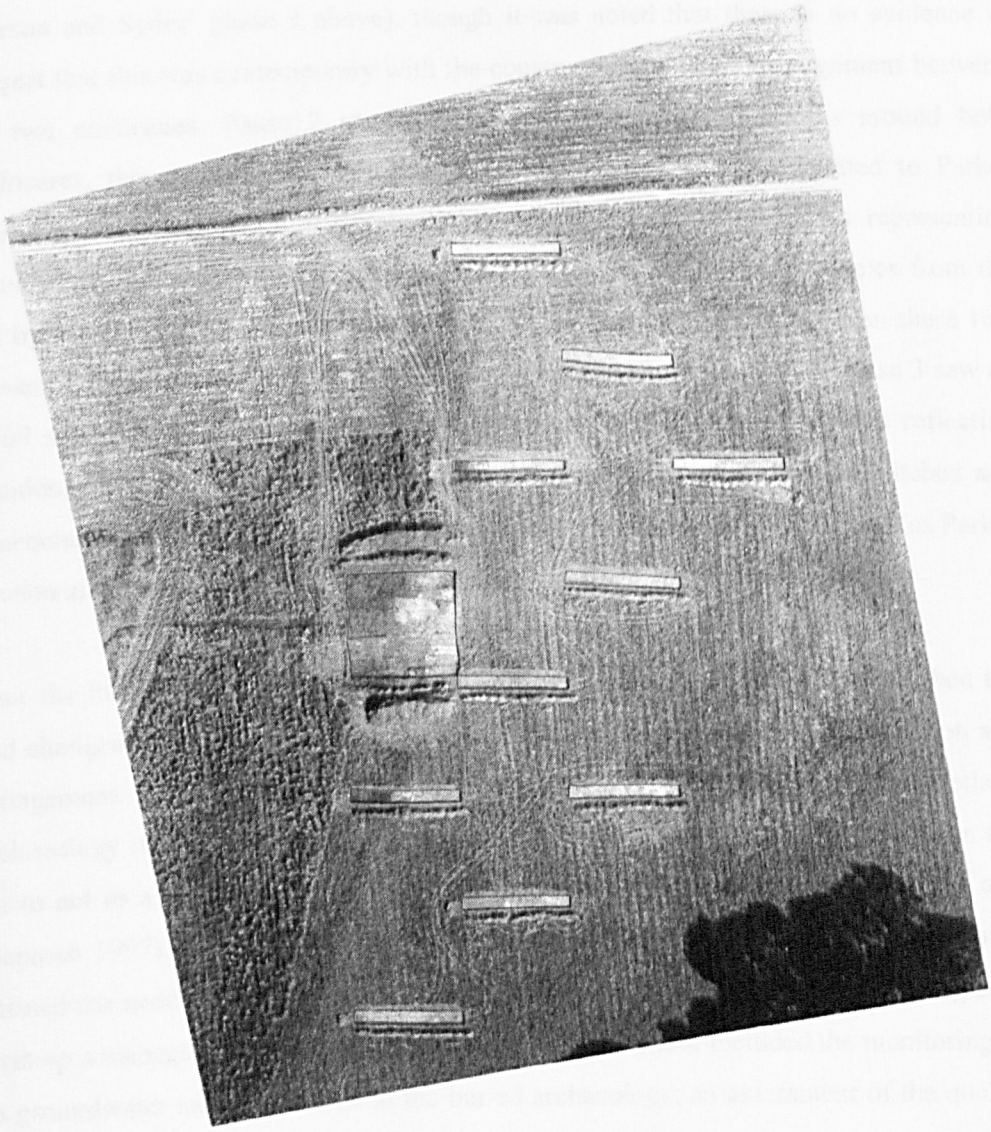


Figure 2.11 Aerial photograph taken of Sutton Common during the excavations in Autumn 1999. North is to the top of the image and each of the narrow trenches is 30 m long (Neil Mitchell-Air Photo Services UK, rectified by J.G.C. Tovey).

characterised by the construction of the timber palisade around enclosure A (as Parker Pearson and Sydes' phase 3 above), though it was noted that there is no evidence to suggest that this was contemporary with the construction of a timber alignment between the two enclosures. Phase 2 saw the construction of the earthworks around both enclosures, though the contemporaneity was unproved. This phase related to Parker Pearson and Sydes' phase 4 above. Phases 1 and 2 were identified as representing primary activity at the site. Subsequent dendrochronological work on samples from the site by Nigel Nayling (Lampeter University) suggested a difference between these two phases of between 3 and 39 years (in Van de Noort and Chapman 2000). Phase 3 saw an initial slumping of banks causing a primary silting in the ditches, perhaps reflecting abandonment - secondary activity. Phase 4 saw peat development in the ditches and palaeochannel (as Parker Pearson and Sydes' phase 4) with later use of the site (as Parker Pearson and Sydes' phase 5). This was labelled as tertiary activity on the site.

Since the bulldozing in 1979/80, the site continued to be ploughed until 1997 when the land changed ownership to the Carstairs Countryside Trust (CCT) for its protection and management. Following this purchase of the land, the CCT and the Centre for Wetland Archaeology (CWA) joint funded a high resolution GPS survey to be conducted on the site to act as a tool to assist in the future management of the site (Van de Noort and Chapman 1997). This was followed by a further proposal (Van de Noort 1998) which outlined the need for a number of monitoring and research measures prior to being able to set up a management plan for the site and landscape. These included the monitoring of the groundwater table in relation to the buried archaeology, an assessment of the quality of organic microfossils and macrofossils on the site and its overall state of preservation. An investigation into earlier postulated theories was also undertaken including the examination of a possible causeway running between the two enclosures. This was followed by a project design (Chapman and Van de Noort 1998) which outlined the proposed aims and methods. Groundwater levels were to be monitored using a grid of piezometers and would be modelled using GIS. Palynological investigations would be conducted from all around the site and landscape and a number of trenches would be excavated to obtain macro fossils including wood for preservation analysis and to investigate the possibility of a causeway. In order to assess the differential preservation of organic archaeology across the whole site, trenches were proposed to be spread out. Trenches were also usefully positioned to ground truth features which had been revealed through the GPS survey and subsequent GIS modelling.

Piezometers were installed at the site during September 1998 in a regular 50 m grid (see chapter 3, figure 3.7) and were monitored as soon as water levels within them had settled. These continued to be read until the end of January 1999. Excavations began in late September and continued through most of October when five trenches were excavated. Trench 1 was excavated across the proposed entrance on the eastern side of enclosure B; trench 2 across the causeway between the enclosures; trench 3 across the western entrance to enclosure A; trench 4 across the eastern entrance to enclosure A and trench 5 across the southern break in the bank of enclosure A near to the modern drain.

The piezometer monitoring revealed high water levels throughout the winter but a high level of fluctuation throughout the year with a much lower groundwater table throughout other times of the year. Assessment of the preservation of pollen proved it to be good in all but the highest levels, whereas the preservation of the wood was more variable across the site.

b. Prehistoric field systems

Large expanses of prehistoric field systems are recognised from across the country, although a particularly good example are the Bronze Age reaves on Dartmoor which survive largely as earthworks and low stone walls (Fleming 1978, 1988). Elsewhere other earthwork remains of possible early field systems have been found such as at Allerton in the Vale of York where features were discovered during the National Mapping Programme of the area by English Heritage (formerly the RCHME - Peter Horne pers comm.), although Roman pottery has also been found from this area. However, the majority of field systems which have been found exist only as crop marks or soil marks. Within the northeast, many areas of possible later prehistoric field systems have been identified within larger studies (e.g. Riley 1973, 1976, 1980b, Jones 1987, 1988, Chapman 1997: 398-400, Stoertz 1997, Chapman 1998a: 252, Winton 1998, Chapman 1999a: 245). In all of these cases, however, a common limitation lies in dating evidence. Firstly, morphological similarities with later sites mean that early field systems are not exclusively diagnostic. Secondly, when artefactual evidence is sought, it is often found that earlier pottery does not survive as well. Thirdly, the possibility that these sites continued to be occupied into the Roman period, with times of maintenance and ditch cleaning means that the potential for finding earlier artefactual evidence is more limited. It has also been argued that other factors may have limited the understanding of earlier periods including inappropriate sampling techniques (Cumberpatch 1993c), the potential for the incorrect dating of pottery, and the possibility that South Yorkshire could have

experienced a largely aceramic Iron Age (Chadwick 1997). A clear example of this problem is the extreme rarity of Iron Age pottery from South Yorkshire (Cumberpatch 1993a, Merrony 1993).

Excavations on sections of field systems within Yorkshire and Nottinghamshire have revealed a number of interesting results. The majority of sites have revealed evidence of Roman activity (e.g. Magilton 1978, Samuels and May 1980, Cumberpatch 1993a, Atkinson 1994, Chadwick and Cumberpatch 1995). Evidence for late Iron Age activity was discovered from Pickburn Leys, near Doncaster (Cumberpatch 1993a), but otherwise prehistoric material has always been rare. However, increasing numbers of excavations across these sites, often restricted to developer-funded work, are beginning to demonstrate that these sites appear to have had a complex history of reworking and maintenance. This indicates a certain longevity which suggests that these sites may have been in use from an even earlier date and that this material is more likely to have been destroyed by later activity (Chadwick and Cumberpatch 1995, see below). Similarly, this points to a degree of continuity of settlement and approach to the landscape throughout the later prehistoric and Roman periods.

Other than questioning the dating of these field systems, past and current research has moved towards questioning the function of these sites. Three main types of field system have been identified on the basis of morphology; nucleated, irregular and brickwork (Riley 1980b). Of these the greatest interest has been with the brickwork patterns. These have been interpreted as being too large for ploughing (Riley 1980b: 26) and this, coupled with the limited amount of pottery from fieldwalking, has led to a conclusion that they represent pastoral activity (Branigan 1989: 166). However, other reasons for the limitations in ceramic evidence have been outlined above. More recent research has been concerned with the iconoclastic deconstruction of interpretations of landscape which are based upon structuralist understandings and ways of thinking (e.g. Chadwick and Cumberpatch 1995, Chadwick 1997, Robbins 1998, *cf.* Tilley 1994). Instead, a concern with the economic function of these sites has been replaced with discussions of their social function; the role of boundaries, the control of access, perceived wealth, complex belief systems and systems of renewal (*ibid.*). It has been understood from fieldwork that these landscapes are more complex than they appear from the cropmark evidence alone, and that they would have altered over time. These changes may have reflected both economic and social changes. Finally, it has been stressed that these changes came about within a society which was otherwise preoccupied with their everyday practices, and so

such changes may have held a greater social significance than is generally understood today (Robbins 1998).

Within the study area there is a large area of field systems concentrated upon the areas of Sherwood Sandstone and older river gravels within its southeastern quarter. These areas have been studied in increasing detail and the results from this work is outlined below with reference to each landscape group. The distinct relationship between these features and the local geology has been investigated in some detail, including an analysis of derived soils (e.g. Riley 1980b, 1983, Chapman 1997). It has been concluded that these features lie on the more permeable soils which allow for greater potential for creating crop marks (see Riley 1944, and Jones and Evans 1975 for an outline on those factors which influence the formation of crop marks). However, these studies have also remarked that the freer draining soils that are often occupied by crop marks are likely to be more attractive for occupation, clearance and general agricultural practices. Therefore it is not certain whether those areas covered by crop marks are a true representation of past activity or whether past activity is just not seen in other areas due to methodological constraints. It seems perhaps most likely that different environmental areas would have fulfilled different economic functions and that, therefore, the former is mostly true, but with a buffer area that is not seen. This buffer region is indicated at a number of sites including those within the study region. The site at Edenthorpe extends towards the peaty areas of West Moor but stops at the point of geological change. Here the soils become less responsive to cropmark formation, but the morphology of the site suggests that it may have continued into this area (Van de Noort *et al.* 1997: 373-4, see below).

Edenthorpe (SE630070)

SMR South Yorkshire 46, 51, 65, 1247, 1826, 1867, 2692, 2694, 2695, 2696, 3356, 3357, 3358, 4212

Humber Wetlands Project (HWP - Head et al. 1997): Dunsville-3 (and Dunsville-1 and -2)

APs 872/25a, 26, 26a, 27, 27a, 28, 28a, 29, 29a, 30, 30a, 31 (3.7.76); 1035/10 (9.7.78); 1083/2-12 (26.7.77); 1093/9-12 (31.7.77); 1042/29 (20.6.78); 1031/15-19 (28.6.78); 1035/11-12 (9.7.78); 1042/18-28 (20.7.78); 1294/14-17 (6.7.79); 2358/0-5 (7.7.84); 2413/10-11, 24-25, 29-31 (11.7.89) D.N. Riley collection, South Yorkshire SMR. AP94, AP102, AP103 (1975); AP140, AP141, AP143, AP144 (1974) Doncaster Museum. SE6306/33-34 (2.7.74); SE6207/9/12 (31.7.77); SE6306/13 (28.6.78) NMRC Air Photographs, Swindon

Between the villages of Edenthorpe and Dunsville, and the peatlands of West Moor, are the crop mark remains of a large regular brickwork-pattern field system on an area of older river gravels overlying Sherwood Sandstone (Figure 2.12). It bridges the 10 m topographical contour surrounding the staggered road junction between Thorne Road (the A18), Armthorpe Lane and Hatfield Lane. It consists of a central area of classic brickwork pattern fields following a west-northwest to east-southeast alignment of parallel ditches, delineated on their western side by a double-ditched feature (aligned north to south), approximately 25 m wide. The parallel ditches are approximately 80 m apart, with the individual fields formed by divisions at right angles within these parallel ditches. The length of the fields is very variable, although an average of 170 m is suggested. A square enclosure (40 x 40 m) lies within the field system at SE627068, with a smaller enclosure lying approximately 500 m to the north.

To the east of the central area the fields become longer and narrower, and to the south they become more irregular and amorphous. To the west a north-south aligned double-ditched feature that appears to be contemporary to it delineates the central features. However, to the west of this double-ditched 'lane' the alignment of the fields is predominantly west-southwest to east-northeast. These features meet the double-ditched feature rather than cross it.

In terms of alignment and morphology, a number of phases seem to be present, despite there being very few occasions of overlapping features. The irregularity of the fields to the south contrast with the regular fields in the central area and this could be a result of a later expansion of the system. Similarly, the narrowing of the fields to the east may represent a separate phase, or rather addition, to the main site. Perhaps most interesting are the features to the west, separated from the central area by the north-south aligned double-ditched feature. The change in alignment at first appears to indicate a separate phase. However, the way in which crop marks on either side of the double-ditched feature run up to it and stop, respecting it, suggests that all of the features were in existence at the same time. Certainly, the 'lane' feature was in existence in some form prior to the construction of the other ditches which ran up to it. This would suggest that the changes in alignment might represent additions to and transformations of the main site. This would indicate a continued occupation through time.

These cropmark remains were first noticed during flying in 1971 and 1972, and were reported on the following year (Riley 1973). They were again published, but in greater

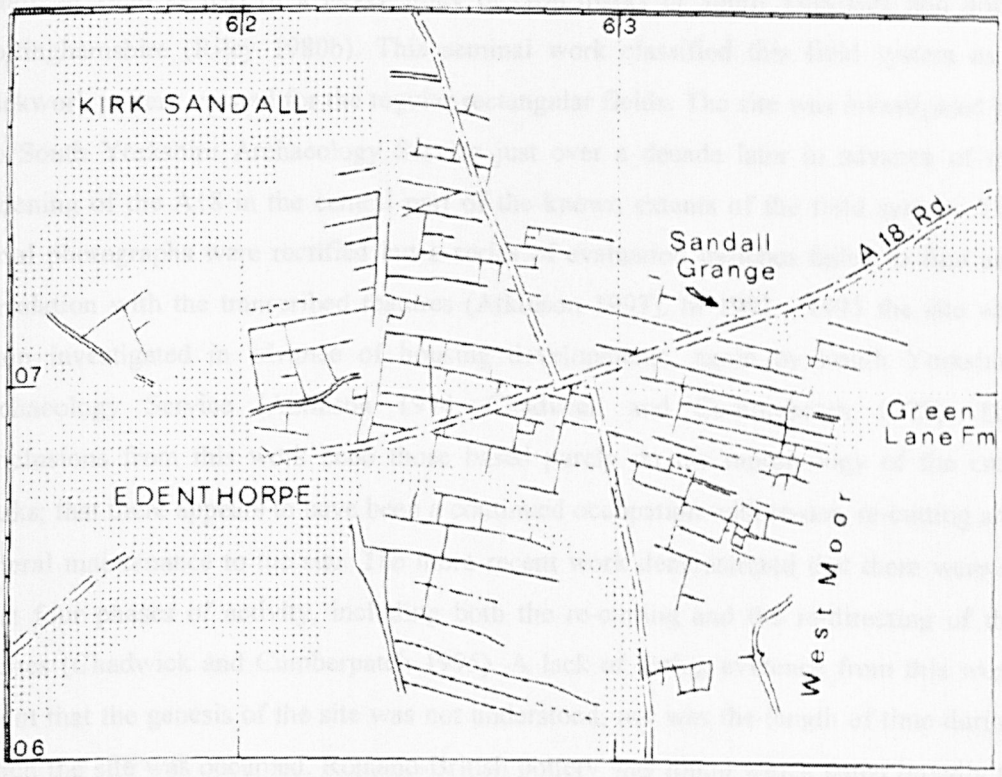


Figure 2.12 Transcribed crop marks of the Edenthorpe field system (Riley 1980: 90)

detail, in 1980 as part of a larger study of crop marks in South Yorkshire and north Nottinghamshire (Riley 1980b). This seminal work classified this field system as a brickwork pattern, named for the regular rectangular fields. The site was investigated by the South Yorkshire Archaeology Service just over a decade later in advance of the widening of the A18 in the central part of the known extents of the field system. The aerial photographs were rectified but a series of evaluation trenches failed to find any correlation with the transcribed features (Atkinson 1993). In 1993 - 1995 the site was again investigated in advance of housing developments, again by South Yorkshire Archaeology Service (Atkinson 1994, Chadwick and Cumberpatch 1995). The conclusions from this work echo those based purely on the morphology of the crop marks; that there appears to have been a continued occupation with re-use, re-cutting and general maintenance to the site. The more recent work demonstrated that there were at least four phases of activity, including both the re-cutting and the re-directing of the ditches (Chadwick and Cumberpatch 1995). A lack of dating evidence from this work meant that the genesis of the site was not understood, nor was the length of time during which the site was occupied. Romano-British pottery was found which dated broadly to the later second and early third centuries AD. A carinated bowl was also found which probably dated to the later first or early second century AD. However, this latter example was of a form that was derived from the later Iron Age.

Perhaps the most interesting aspect of this work was the discovery of such complex phasing within the ditches. While four phases were identified, it was acknowledged that more thorough cleaning of ditches would have rendered other phases as invisible, and that not all phases may have been identified (Chadwick and Cumberpatch 1995: 45). It was noted that most of the re-cutting had occurred after the earlier features had almost totally silted up. It was argued that such re-cutting reflected a careful maintenance of the ditches and overall field system.

The evidence of phasing also led to interpretations of the function of the site. The irregular re-cutting that allowed some ditches to silt up was argued to contravene functions such as livestock control or drainage. Indeed, the older river gravel and Sherwood Sandstone is generally very well drained producing extremely receptive soils for the formation of crop marks. It was noted that the ditches were very large, and would have been larger had they not been truncated by ploughing, and that this also suggested an excessive amount of work if they were required only to hold stock. What has been understood is that this impracticality of the monuments, coupled with the complex

phasing of the site, suggests that they were not constructed in the interests of increased efficiency (Chadwick and Cumberpatch 1995: 46). Following a more post-processual stand point, it was argued that the re-cutting of the ditches, and their re-direction, reflected boundaries and ownership, and how this might have changed or been reaffirmed over time was considered, with control of rights of access to different parcels of land. Further it was suggested that such re-cutting might have had a greater social role than any subsequent functional role that the ditches may have performed (Chadwick and Cumberpatch 1995: 47). In this respect the double-ditched features may have represented boundaries rather than the 'lanes' or 'droveways' that are usually assumed (Chadwick and Cumberpatch 1995: 46).

Chadwick and Cumberpatch (1995) also argued further phasing for the site. It was suggested that the 'lanes' were part of the first phase of the landscape. This was based upon the later emphasis of re-cutting at the ends of the ditches. A complex cutting and re-cutting of ditches followed this phase. While the pottery from the site demonstrates activity during the first and second centuries AD, it is likely from the evidence of re-cutting that these features were in use from a much earlier date. This would allow time for the cutting, near complete silting, and then a number of further phases of re-cutting. It is clear that the pattern on the ground is more complex than may be assumed from the cropmark plots, and this was further reflected by geophysical survey that only emphasised the last phases of the site (Chadwick and Cumberpatch 1995). Elsewhere in the Humberhead Levels other similar sites have been excavated that have produced just a single phase of activity (e.g. Samuels and May 1980). This suggests that the field system at Edenthorpe was different in terms of its economic and social function.

Warren Hill (SE635087)

SMR South Yorkshire 1248, 1249, 1252, 1253, 2516, 2535, 2700, 2701, 3355

HWP Dunsville-7

APs 753/27-29, 32 (5.7.75); 872/17a, 18, 18a, 19, 19a, 20, 20a, 21a, 22a, 23a, 24, 24a, 25 (3.7.76); 1568/14-15 (2.8.79); 1083/13-28 (26.7.77); 1294/13-15 (6.7.79); 1295/33-37 (9.7.79); 1296/3-13 (9.7.79); 1535/19-20 (12.7.79); 1568/16-18 (2.8.79); 1570/14-18 (6.8.79) D.N. Riley collection, South Yorkshire SMR. SE6308/20/8 (10.7.79) NMRC Air Photograph, Swindon

The second stretch of early field systems also lies on the older river gravel and Sherwood Sandstone, but to the north of Edenthorpe. This system covers more than 2 km² and again reflects a number of phases. It exists in a number of sections and so it is not certain

whether they all relate to the same system or whether they reflect a number of foci. To the east of Barnby Dun, the fields are regular and aligned west-southwest to east-northeast, with a number of enclosures and double-ditched features. The fields are smaller on the southeastern side. To the east of Ling house, a small section of fields is visible following the same alignment and presenting a similar morphology. However, to the west of Ling House the fields are more irregular, perhaps suggesting a different phase.

To the southeast, at Warren Hill, the principle crop marks comprise a double-ditched feature, over 700 m long, aligned east to west and measuring between 15 m and 20 m wide, forming a concave curve to the south (Riley 1980b). The field system associated with this feature is formed by a series of ditches extending perpendicularly from this feature to both the north and the south. These are positioned between 25 m and 60 m apart and are visible until they meet the modern road to the north and the Common Drain to the south. Adjacent to the northern side of the double-ditched feature, towards its western end, is a ditch enclosing an area of approximately 0.3 ha.

Just to the west of the Warren Hill complex is a crossing of double-ditched features surrounded by other ditches that may be associated with it. Here a small enclosure, 25 x 30 m, is incorporated into a bend in one of these ancillary ditches which may represent part of a field. This pattern is not dissimilar to those features on Warren Hill, but are very different in form to the other features in this area. This may suggest that they represent a separate phase, though the lack of excavation of these sites precludes further understanding.

Black Sike, Owston (SE561117)

HWP Askern-3

APs 2413/15, 22 (11.7.89) D.N. Riley collection, South Yorkshire SMR

To the south of Sutton Common, adjacent to a drain named Black Sike on Ordnance Survey mapping, a small fragment of a possible field system has been recorded from crop marks visible on aerial photographs (Head *et al.* 1997: 233). Here, a single linear ditch extends from east to west with at least two other ditches crossing it at right angles indicating fields. The date of this feature is not known and, despite fieldwalking, no artefactual evidence has been found from this area (*ibid.*). However, this feature is not dissimilar to some of the other features mentioned above and is therefore included here.

c. Earlier prehistoric features

Sutton Common bowl barrow, Owston (SE56871218)

SAM 13254

HWP Askern-8

A possible bowl barrow has been scheduled to the east of Sutton Common. The feature consists of a 2-3 m high, hemispherical mound of earth measuring approximately 17 x 13 m (Head *et al.* 1997: 238). An earlier observation noticed a 3-4 m wide band of softer soil on the southern side of the mound which was described as a possible construction ditch and the feature was interpreted as a barrow or probable late Neolithic or Bronze Age date (Sydes and Symonds 1988). It has been noted that this feature may not be a barrow since there are no other references to it and that the evidence on the ground is limited without further independent research (Head *et al.* 1997: 238). However, other probable barrows are known from the vicinity at Campsall Quarry on the Magnesian Limestone to the west of Askern (*ibid.*: 232).

2.3.4 Local chronology

The local chronology of study area two is more straightforward than that for the Rudston landscape. Principally, the earliest phase is demonstrated by the construction of the bowl barrow in Owston parish, presumably at some stage during the early Bronze Age, and three possible barrows on the higher land at Campsall, just beyond the western margin of the study area (HWP-Askern-2 - Head *et al.* 1997). Activity has been recorded on Sutton Common during the Bronze Age as attested by the discovery of the bronze dirk (mentioned above), but the extent of this is unknown. Other Bronze Age finds include a number of scatters of lithic material (HWP-Askern-1, -4 and -10 - Head *et al.* 1997). Larger scale activity within the enclosures began at some stage during the early Iron Age, although there is currently no evidence to accurately indicate the full length of time during which they were occupied. However dendrochronological analysis (see above) suggests a relatively short occupation period of the first phase at least. Probably after the main abandonment of the enclosures on Sutton Common, activity to the southeast appears to have expanded with the construction of the field systems on the Sherwood Sandstone and older river gravels. While it is almost certain that these were occupied and used during the later Iron Age into the Roman period, it is likely that their initial use predated this, dating to an earlier period and may well have been contemporary with the enclosures on Sutton Common. What appears to be certain is that their use outlived that of the enclosures on the Common.

2.3.5 Interpretation issues to be addressed

a. Location of monuments and the development of the archaeological landscape

The development of any landscape is influenced by the earlier landscape, and consequently will influence the future landscape (*cf.* Bradley 1993, Thomas 1993, Tilley 1994). In terms of the archaeological landscape, this development through the Bronze Age and into the late Iron Age is significant in terms of economics and society. There has been no study of the relative positions of the different sites in relation to the topographic landscape and so possible spatial relationships have not been explored. Further, this has restricted the potential understanding of chronology and longevity of the various features, most of which have not been absolutely dated. Similarly, the possibility of whether the bowl barrow to the east of Sutton Common represents a true archaeological feature remains unanswered. Without approaching such issues it is not possible to obtain a more comprehensive appreciation of the chronological landscape.

b. Location of monuments in relation to the environmental landscape

The archaeological value of the Sutton Common landscape is complemented by the potential for palaeoenvironmental reconstruction due to the well-preserved wetland resource of palaeoecological deposits. This has provided a better overall understanding of the natural landscape, how it has changed through time, and the possible anthropogenic influences in this development. The environment can influence past choices and, equally, past choices can influence the landscape. Therefore, a consideration of the developing landscape with regard to the changing environment is important. Further, such considerations will influence the spatial interaction between peoples in different areas and between sites. This is particularly significant since topographic factors are likely to be of less significance in terms of landscape phenomenology due to the relative flatness of the area.

c. Function

The function of the various monuments within the landscape remains in question, following closely from the two above questions. Elements of the landscape such as the field systems have been explored in terms of function (e.g. Chadwick 1997), though the more holistic understanding of the function of the various monuments and their interaction within the landscape has yet to be explored. This highlights both the relative archaeological site distributions and the relationships with the contemporary environment.

d. Further understanding of the Sutton Common landscape

On a more focused level, the issue of the role of Sutton Common within the Iron Age landscape needs to be approached. Firstly, questions of whether or not the site was settled remain unanswered, highlighting the question of function. Secondly, the interaction between the enclosures and the local environment, and the nature of phasing remains poorly understood.

A fundamental issue relating to both of these issues is the spatial relationship between the two islands occupied by the two enclosures. The nature of the relict palaeochannel of the Hampole Beck at a time contemporary with the enclosures is not known. Differing conclusions on this issue alone will have dramatic implications for the understanding of the relationship between the two enclosures and therefore their role and function within the landscape.

2.3.6 Cultural resource management issues to be addressed

a. Nature of the preservation and identification of enclosure A following bulldozing and ploughing over 17 years

The two most dramatic events relating to the Sutton Common landscape were the bulldozing of enclosure A for arable agriculture and the installation of land drains. This, followed by 17 years of annual ploughing, including at least one year of deep ploughing for potatoes, has been reflected in the literature as having had a very destructive effect on the archaeology. The only record of the enclosure prior to this is the 1930s survey published by Whiting (1936), and the investigations into the preservation of the archaeology following de-watering have been extremely limited and negative. The damage from these events has not been fully understood, but rather assumed. The overall condition of the site has not been assessed and is not understood.

b. Potential for the* in-situ *preservation of archaeological and palaeoenvironmental source material on Sutton Common

The de-watering of Sutton Common through agricultural drainage, mentioned above, has had a damaging effect on the archaeology. The actual damage has been assessed in an extremely piecemeal way that has assumed that conditions across the site may be inferred from small trial trenching. This work has shown that the wet archaeology has been deteriorating, but no scientific approach has previously been made to monitor the site in a quantifiable way in order to advise on its future management. This is a primary concern

for this site, and further, for other sites like it where preservation *in situ* is challenged by the influence of environmental factors.

2.4 Summary

This chapter has outlined the reasons for choosing the two study areas. It has also provided a synthesis of the landscape development of each, and the history of past archaeological work in relation to both the landscapes as a whole and to the principal monuments. For each landscape an outline of the main issues to be addressed have been outlined in terms of both landscape interpretation and CRM. This focuses the requirements of each landscape and, in doing so, makes it ultimately possible to assess the effectiveness, and thereby the value, of the GIS techniques being applied in relation to each landscape's perceived needs.

In summary, the Rudston landscape may be considered as (relatively) topographically variable. The study area lies on the Yorkshire Wolds and is focused on the Neolithic cultural landscape characterised by the cluster of cursus monuments, plus both earlier and later archaeological monuments. During the Neolithic there is a gap in the available palynological evidence for the past landscape, although it appears that the landscape would most likely have been relatively open. In more recent years the landscape has been predominately arable and this has had an effect upon the survival of monuments and their visibility on the ground making the landscape difficult to interpret. These problems are further highlighted by the enigmatic nature of cursus monuments.

The Sutton Common landscape is much flatter than the Rudston landscape, lying within an area of past and present lowland wetland. The focus of the study area is a pair of enclosures dating to the Iron Age. The palaeoenvironmental evidence from the area suggests that the landscape would have been relatively wooded with alder carr during the Iron Age. As with the cursuses, the morphology and location of the enclosures has made them difficult to interpret despite a number of investigative excavations. A large part of the site was bulldozed two decades ago and the area was ploughed until recently. This was accompanied by agricultural drainage that has lowered groundwater levels threatening the buried organic archaeology. The site is therefore difficult to understand on the ground, and has presented challenges in terms of preservation.

The aims of the present study are to assess GIS tools in relation to contrasting archaeological landscapes (see chapter 1, section 1.6). Accordingly, the two landscapes

are very different in terms of their topography. The Rudston landscape on the Wolds is topographically variable displaying valleys and hills that are characteristic of most digital elevation model based studies (see chapter 1, section 1.5). In contrast, the Sutton Common landscape is much flatter. In order to be able to assess the GIS methods in relation to archaeological requirements, both landscapes are centred on a particular archaeological monument. In the case of the Rudston landscape, this consists of the complex of Neolithic cursus features. At Sutton Common, the site consists of the pair of enclosures within the wetland. In each case these monuments lie within a landscape that also contains other archaeological monuments. Questions relating to archaeological interpretation and management issues have been highlighted with each of the two landscapes. This provides a platform for the assessment of the success of the GIS tools applied to the landscapes (see chapter 8, section 8.3 and chapter 9, section 9.3).

The following chapter outlines and expands upon this, presenting the procurement of the various sources of data obtained for the analysis of these landscapes.

Part 2: Methodology

Chapter 3

Input-data procurement

3.1 Introduction

The previous chapter described the two landscapes chosen for the present study, presenting information about the environment (including the palaeoenvironment) and the archaeology for each. In this chapter this 'input-data' is rationalised in terms of that used within the GIS. Here, the process of translating the detail presented in chapter 2 into its geographical information system (GIS) format is presented. The sources of the input-data are shown, as are the methods by which both surface data and archaeological data were obtained, and incorporated into the GIS.

GIS are usually defined as systems designed for the "storage, management, retrieval, display and of *creation* of geographically referenced data" (Savage 1990, 23 - his emphasis). This implies that they represent more than just spatial databases, such that the database is curated within a problem-solving environment (*cf.* Cowen 1988). This also means that they incorporate input-data, and from this create new data (e.g. section 3, chapters 5 & 6). The importance of the data that are contained within them therefore defines their effectiveness and, consequently, their usefulness and value to archaeological landscape research and CRM. The range of data that can be held within a GIS is multi-faceted influencing both the creation of surfaces and information regarding the locations of sites and other features that lie within the landscape.

The input-data for this study have been divided into two categories: surface data and feature data. While the two types are mentioned separately here, it must be remembered that through conversions and analysis the distinctions between the two are less well defined. Within this chapter the two types of input-data will be categorised in terms of their procurement, prior to further analysis and data conversions. It must also be noted that, while this definition allows for a clearer outlining of the data, it must also be understood that the surfaces themselves can be classified as features. This point forms one of the main issues outlined in chapter 1 (section 1.6) and will be expanded upon within the succeeding chapters.

3.2 Surface input-data

A 2.5D DEM consists of cells of a standard size. Each cell represents Cartesian co-ordinate data (in x and y) with an attribute attached to it. In the case of topographic surface models this

attribute contains data regarding the height of the cell defined by the Cartesian attribute. The input-data format for generating such DEMs consists of georeferenced data either as three-dimensional points (x, y and z), for example in ASCII format, or otherwise in a line format (contours) with each line represent a z-value, for example as a .DXF. The latter type of data structure may be imported into the GIS such that the lines (or arcs) are each stored with a unique label. An attribute table is then attached consisting of the list of unique labels and the relevant values for each (e.g. the z-value - height). The data for the generation of DEMs for this study were obtained from two different sources dependent upon the desired output resolution of the DEM. The larger, lower resolution landscapes were based upon contour data obtained from the Ordnance Survey. The smaller, higher resolution sampled areas were based upon point data obtained from differential Global Positioning System (GPS) transect surveys.

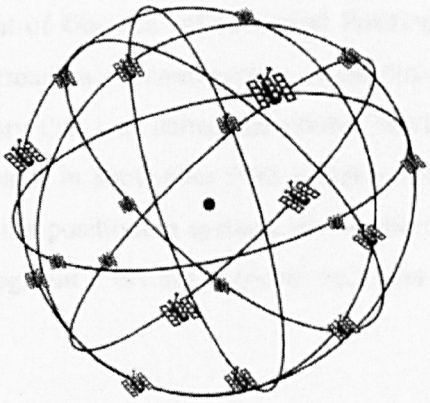
3.2.1 Commercially available data

The contour data for the large-scale, lower resolution DEMs was the Ordnance Survey 1:50,000 scale land-form PANORAMA. These data were supplied as digitised contours with associated lookup table entries containing metadata including height values. This type of data is not the most accurate available from the Ordnance Survey. Land-form PROFILE is scaled at 1:10,000 with a contour height accuracy of ±1.5 m. PANORAMA format, on the other hand, has a vertical accuracy of ±3.0 m (Ordnance Survey 1999) with contours set at intervals of 10 m, derived from the higher resolution data (João 1998). The digital terrain model data that is also available from the Ordnance Survey provides a 50 m grid.

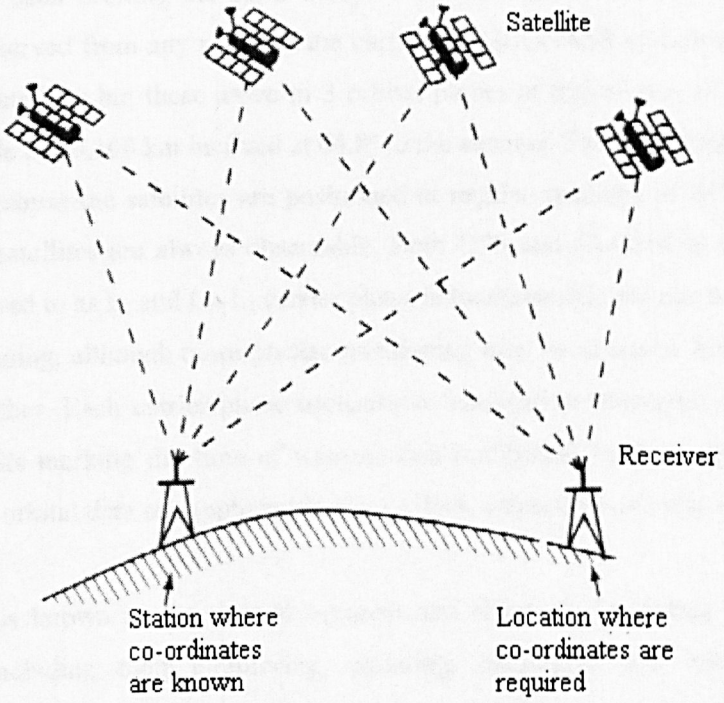
The data were converted from Neutral Transfer Format (NTF) using an ESRI NTF file format converter on a UNIX platform to a format readable by ARC/INFO. These files then formed the basis for conversion into DEMs.

3.2.2 Field-based data collection

The point data for the higher resolution models were obtained in the field using systematic surveying methods. Spectra Precision's *Geotracer© System 2000 L1 - RTK* differential Global Positioning System (GPS) equipment was used for the surveys. This equipment uses satellites to provide high accuracy positions in three-dimensions relative to a base station (Figure 3.1). The earliest use of satellites for providing positioning information grew from the application of the Doppler effect whereby the position of the receiver was recorded in relation to signal wavelength from a satellite of known orbit (Bannister *et al.* 1998). Problems with this method were that it was both very slow and expensive. It required many satellite passes and several receivers tracking the same satellite in order to get a fixed position. Even



The constellation of GPS satellites.



Differential positioning.

Figure 3.1 Global positioning system technology (after Bannister *et al.* 1998).

then, the accuracy achieved from the system was limited. An alternative method was developed by the US Department of Defence called Global Positioning System (GPS) and was operational by 1993. Concurrently a different system of satellite positioning system was developed by the Russian military that was called the Global Navigation Satellite System (GLONASS) which was first useable in September 1993 and declared operational in January 1996. Most texts outlining satellite positioning systems divide the operational process into three stages comprising 'space segment', 'control segment' and 'user segment' (*cf.* Bannister *et al.* 1998, Dana 1998).

The 'space segment' of satellite positioning systems refers to the satellites themselves. Within GPS there is a constellation of 28 satellites of which 24 are continuously operational. They orbit the globe at an altitude of 20,200 km, placed within six orbital planes inclined at 55° to the equator, each orbiting the earth every 12 hours. This means that at least four satellites can be observed from any point on the earth. The GLONASS system also consists of 24 operational satellites but these move in 3 orbital planes at trajectories of 120° to one another at an altitude of 19,100 km inclined at 64.8° to the equator. Their orbit takes 11 hours and 15 minutes. Because the satellites are positioned at regular spacings of 45° around the orbit, at least five satellites are always observable. Both GPS and GLONASS transmit two carrier signals referred to as L_1 and L_2. L_1 carrier phase is fundamental, and can be used alone for standard positioning, although more precise positioning may be obtained from L_1 and L_2 carrier phases together. Each carrier phase transmits a 'Navigation Message' consisting of time-tagged data bits marking the time of transmission (calibrated by the onboard atomic clock) with precise orbital data sets (ephemeris data). Clock corrections are also transmitted.

The second stage is known as the control segment and refers to the management of the satellite system including their monitoring, updating, calibrating and restricting use. Concerning the latter point, without any correction, it is possible to use a receiver to provide global accuracy to within 10 m on the surface of the earth. Due to the national and international threat that such accuracy can provide, a process called 'selective availability' (SA) is applied to the data transmitted from the GPS satellites (until it was switched off on 1st May 2000, after the surveys had been completed). This is done in two stages. The first is called *SA-dither*, which places some of the satellite clocks out of phase. The second is called *SA-epsilon*, which makes satellites provide data giving the wrong position for themselves.

The final stage, the user segment, refers to the equipment used to obtain position data from the constellation of satellites. The equipment consists of an antenna that receives the signals,

and a receiver that processes them with the assistance of a computer. Surface measurements made by satellite positioning systems are calculated using a unidirectional distance measurement. Positions are therefore dependent upon accurate time measurements and precise synchronisation of the clocks in both the satellite and the receiver so that the known speed of signal can be measured in terms of time dither. However, the clocks within the receiver are not atomic and so highly accurate positions can be generated by processing the data in one of two ways. The first is referred to as 'pseudo-range' and uses the continuous signals transmitted by the satellites to establish a pattern that can then be copied by delaying it until the two are in phase. The subsequent shift in time can be converted into a distance by multiplying by the speed of light. Simultaneous distances from at least four satellites that are spread evenly (i.e. not clustered together) and within at least two orbital paths can be used to compute location through trilateration. The highest accuracy possible using this technique is 0.3 m.

The second method of measurement is known as 'carrier phase measurement'. This method uses paired antenna/receiver units and is often referred to as *differencing*. This is a more complex process that takes simultaneous readings on two satellites and by observation onto a single satellite from two antenna/receiver stations. Through a process known as *squaring* the carrier frequency is effectively doubled, thereby halving the wavelength and allowing millimetre accuracy. However, this process reduces the accuracy of satellite location and so such accuracy can only be measured relatively on the ground and not absolutely without control.

The co-ordinate system used by satellite positioning systems is divorced from normal projections. GPS use a system called WGS84 (World Geodetic System of 1984) and GLONASS uses PZ-90. Both of these are earth-centred spherical Cartesian co-ordinate systems in three dimensions (*cf.* Seeger 1999, Ordnance Survey 2000) and need to be transformed into more useful co-ordinate systems such as National Grid for comparative archaeological requirements.

Other errors exist within the system due to the way that radio waves travel, including the delay generated through the movement of the signal through the troposphere and ionosphere. Another main cause of error is 'multi-path' caused by the reflection of signals off buildings and other structures that alters the length of the signal. Other errors are generated by refraction and noise of the signal during its travel through the ionosphere and troposphere. Further, many unseen errors exist due to the statistical nature of calculating position (*cf.* van

Diggelen 1998, Lange and Gilbert 1999). Many of these errors can be countered by using *differential positioning* whereby two receivers are used. The base station has an established known point and a rover station is positioned at the point that needs to be fixed. A relative position is gained at a high accuracy since discrepancies between the known point and the computed point can be recognised, assumed to be errors, and calibrated for the rover. Leick (1995) has demonstrated this increase in accuracy (table 3.1).

Table 3.1 *Potential accuracy of single and differential GPS (after Leick 1995).*

	Single (m)	Differential (m)
Horizontal accuracy	50	0.01
Vertical accuracy	78	0.02
3-D accuracy	93	0.02

The accuracy of Spectra Precision's *Geotracer© System 2000 L1 - RTK* differential Global Positioning System (GPS) equipment was investigated in relation to two pegs. These were labelled point A and point B. They were both surveyed during five separate surveys at Sutton Common in October to November 1997 and corrected to a known point. The readings for point B show a maximum range of 0.054 m for the x-coordinate, 0.056 m for the y-coordinate and 0.029 m for the z-coordinate. The differences in standard deviation between these points do not hold equal accuracy weighting - calculating a mean of these values is therefore not appropriate to check the overall standard deviation of the equipment in practice. Rather, the most accurate values are likely to be those with the lowest standard deviation recorded in the original point calculation. However, because of the landscape scale of the surveys an overall potential error range of between 0.029 m and 0.056 m was considered acceptable (table 3.2).

Table 3.2 *Readings to point B from repeated surveys and standard deviations keeping point A as constant (all measurements given in metres).*

	x-coordinate	y-coordinate	z-coordinate	σ
1	456519.813	412215.452	4.815	0.010
2	456519.830	412215.470	4.798	0.007
3	456519.842	412215.472	4.804	0.014
4	456519.791	412215.416	4.786	0.008
5	456519.789	412215.468	4.759	0.007

Each of the sites was surveyed in transects using either the ploughing direction or ranging rods to provide straight sighting lines along which to walk. The resolution of the surveys was different in each case, balancing between the need for being systematic and the need to react to archaeological features and topographic variability as it was encountered. Topographic and other hindrances to both the surveyor and the equipment were also taken into account. The relative values of gridded and non-gridded survey data acquisition have been explored by Fletcher and Spicer (1988) who applied contrasting sampling methods to a virtual surface in a simulation study. By recreating the surface from the sampled data the two different approaches were considered (objective and subjective). The conclusions from their study echo the approach used for the current investigation whereby a mixed strategy was deemed the most efficient in relation to accuracy. The approach used for each site is described below.

The survey at Rudston was carried out on 14th January 1999, with permission from the farmer, Mr Graham Thompson, following the ploughing of the field prior to sowing (Figure 3.2). A total of 772 points was surveyed covering an area of approximately 11,378 m^2 providing a mean density of 0.07 points per m^2 (678 points per hectare - Figure 3.3). Points were again recorded by pacing along transects. This time a resolution was used of between 3 m and 5 m intervals consistently across the entire area owing to the full arable nature of the landscape without discernible archaeological features visible.

The survey at Sutton Common was conducted between 28th October and 5th November 1997 (Figure 3.4) following the last cropping of the fields after the transfer of the ownership of the site to the Carstairs Countryside Trust (CCT). The field conditions therefore were predominantly stubble with grass at the eastern end running up to the edge of Shirley Wood. The survey was jointly funded by the Centre for Wetland Archaeology (CWA) at the University of Hull and the CCT (Van de Noort and Chapman 1997). A total of 5,290 points was surveyed covering an area of approximately 286,754 m^2 providing a mean density of 0.02 points per m^2 (184 points per hectare - Figure 3.5). Points were recorded at between 3 m and 8 m intervals along transects. On areas of high topographic variation, such as across the earthworks defining enclosure B, the survey resolution was increased to provide greater detail (see above).

3.2.3 Other surface data

Further surface data for input into the GIS were available for the high-resolution area at Rudston (southern terminus of cursus A). This data was published in 1966 as a plan with displaying contours set at 3" (0.076 m) intervals (Dymond 1966 - Figure 3.6). These contours

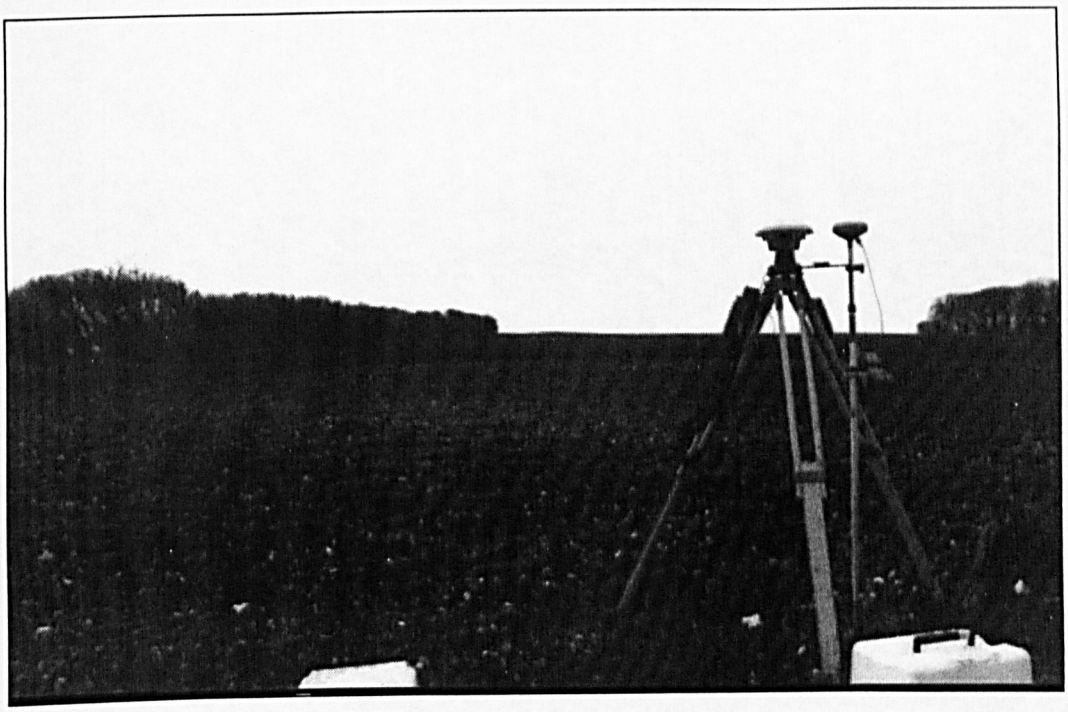


Figure 3.2 GPS survey under way at Rudston.

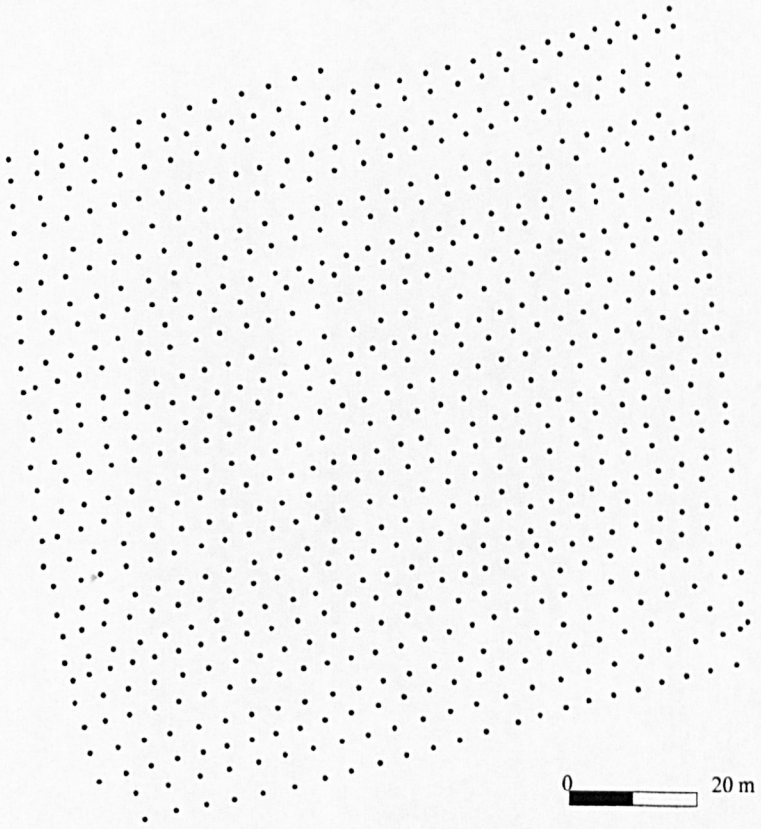


Figure 3.3 Survey points at Rudston.



Figure 3.4 GPS survey under way at Sutton Common.

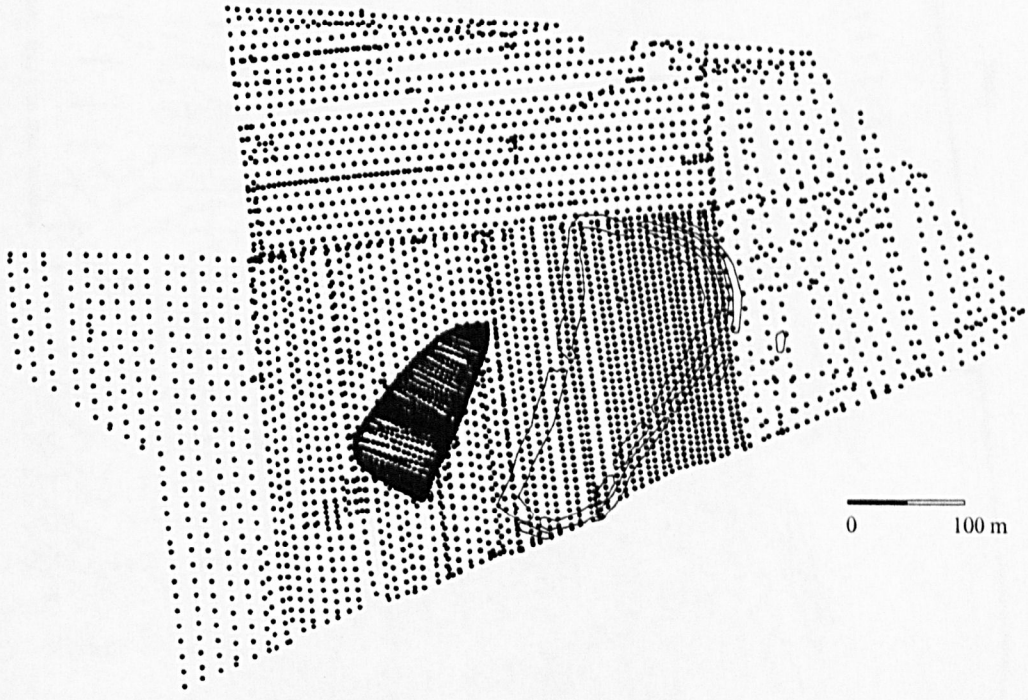


Figure 3.5 Survey points at Sutton Common
(with the location of the larger enclosure).

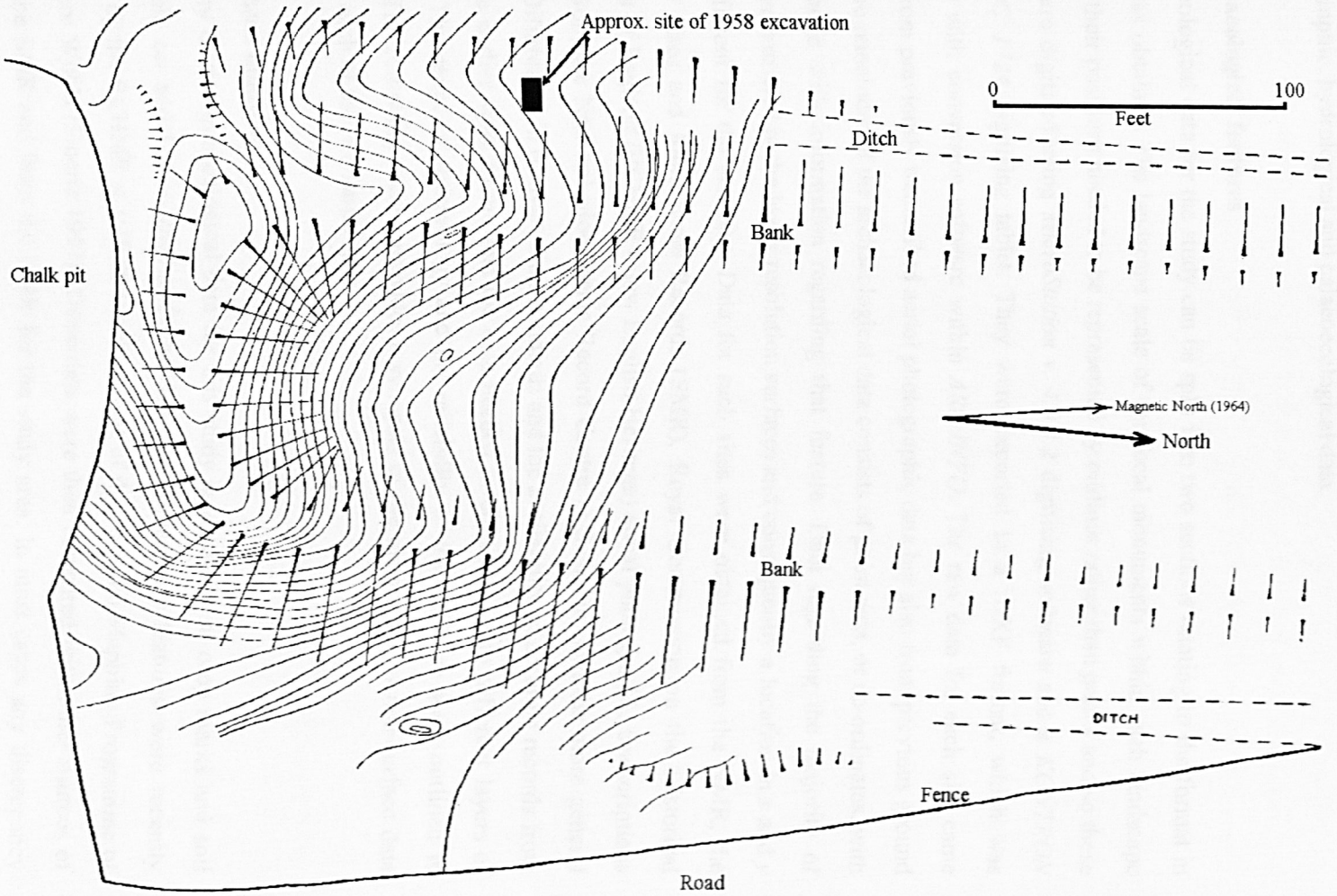


Figure 3.6 Results from the contour survey undertaken in 1964 (after Dymond 1966: 87).

were digitised and transformed to form a surface using methods described in chapter 4 (section 4.3.1).

3.3 Feature data

The majority of the feature data obtained for the study related to the distribution of archaeological sites. However other data were collected relating to environmental elements of the landscape, obtained from a number of different sources (see chapter 2). The latter include both topographic, hydrological and palaeoecological data.

3.3.1 Archaeological features

The archaeological data for the study can be split into two sections relating to the format in which it was obtained. The landscape scale of the focal monuments within each landscape meant that their positions needed to be represented by outlines rather than points and so these features were digitised using *MicroStation v. 4.0.3.2* digitising software and a *KONTRON Digicad DC 1724* digitising tablet. They were exported in a .DXF format, which was compatible with conversion software within *ARC/INFO*. The raw data for each site came primarily from previously transcribed aerial photographic data but also from previous ground surveys. The remainder of the archaeological data consists of point data, or co-ordinates, with a lookup table with information regarding that feature. Data regarding the majority of features was restricted to the lower resolution surfaces and consequently a location in x and y proved sufficient for the analyses. Data for such sites were obtained from the NMR, the appropriate Sites and Monuments Records (SMR), Royal Commission on the Historical Monuments of England (RCHME - now English Heritage) aerial photographic transcriptions (obtained from the National Monuments Record Centre in Swindon) and the more general literature. Differences in the recording standards and the availability of accurate records from some of the earlier work meant that the data needed to be divided into different layers of reliability. The range of archaeology and the reliability of the evidence were outlined in chapter 2. The following section provides a synopsis of the main areas of non-surface data sources for each of the two landscapes.

a. The Rudston landscape

The majority of the archaeological data for this study area consist of crop marks and soil marks visible on aerial photographs. Fortunately the represented features were recently transcribed by the RCHME at 1:10,000 scale as part of the National Mapping Programme of the Yorkshire Wolds (Stoertz 1997). These data were then compared with other sources of data from the SMR and from the NMR for the study area. In most cases any discrepancy

between data sources could be understood and calibrated, particularly in the cases of sites with an excavation archive. Very few sites have been destroyed entirely prior to being photographed and recorded through aerial archaeology. Sites that were not recorded, such as the Neolithic settlement sites, were processed by NGR obtained from the appropriate publications.

b. The Sutton Common landscape

Study area two had not received the same level of standardised survey as study area one, but had been covered well by previous work. The cropmark evidence across parts of the area had been recorded and transcribed at 1:10,000 scale by South Yorkshire Sites and Monuments Record and published elsewhere (Riley 1980b, Chapman 1997). Ground survey data also existed from within the Sutton Common landscape. The outlines of the banks and ditches of the Sutton Common enclosures were surveyed by Bennett and Hill in the 1930s (Whiting 1936) and a contour survey had been carried out in the 1990s by Sheffield University (Parker Pearson and Sydes 1997). The former could be scaled and digitised for inclusion within the GIS - the latter was used for comparative purposes.

3.3.2 Non-archaeological features

Non-archaeological features within the two study areas were largely confined to topographic data obtained from the Ordnance Survey and through survey, though other data included the digitised areas of mapped alluvium and present watercourses. High resolution hydrological data was obtained in relation to the Sutton Common landscape as piezometer readings. The tops of the piezometers were surveyed using GPS using the method outlined above and these were corrected to OD (Figure 3.7). The piezometers were measured every two weeks over a period of four months (in conjunction with further work being carried out by the CWA funded by English Heritage - see chapter 2, section 2.3.3) and the depths to the water table was subtracted from the OD value to give an absolute height of the water table at that point. Areas between the piezometers were interpolated using the same methods used from the point data from topographical survey of this site.

3.4 Summary

This chapter has developed the information presented in the previous chapter for each of the two landscapes in the present study to be compatible within the GIS. This has included the capture of input-data for the creation of digital elevation models (DEMs) and for the archaeological features. The following chapter expands this data, presenting the range of GIS methods being used and assessed within the present study.

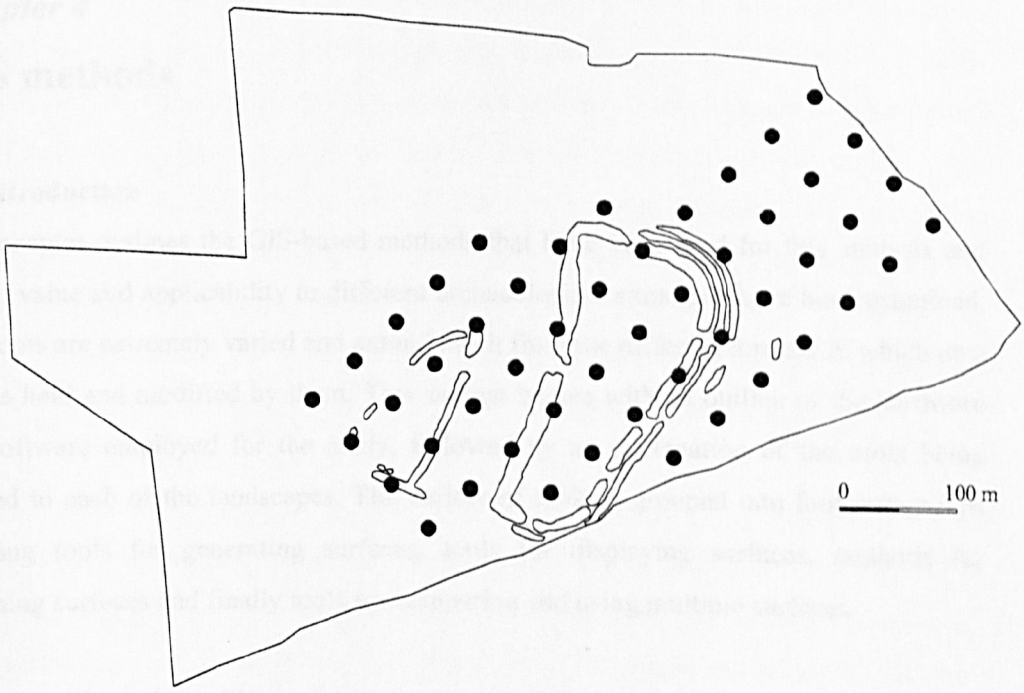


Figure 3.7 Location of the piezometer grid at Sutton Common (north is to the top of the image).

Chapter 4

GIS methods

4.1 Introduction

This chapter outlines the GIS-based methods that have been used for this analysis and whose value and applicability to different archaeological situations have been examined. GIS tools are extremely varied and extend much from the different formats in which data can be held and modified by them. This section begins with an outline of the hardware and software employed for the study, followed by an explanation of the tools being applied to each of the landscapes. The variety of tools is grouped into four sub-groups covering tools for generating surfaces, tools for displaying surfaces, methods for analysing surfaces and finally tools for comparing and using multiple surfaces.

The results from these GIS analyses are presented in chapter 5, regarding the Rudston landscape, and chapter 6, regarding the Sutton Common landscape. Each chapter is structured around the GIS tools being analysed although the data is analysed in terms of the specific problems relating to that landscape (see chapter 2). Each section of these results is explained in terms of the larger scale landscapes and the smaller scale landscapes separately. Chapters 7 and 8 then consider these results together within the frameworks of GIS methods and the themes of landscape archaeology respectively in order to assess the usefulness and value of each group of methods.

4.2 Peripherals - hardware and software

The principle software employed for the study was *ARC/INFO version 7.2.1*, developed by the Environmental Systems Research Institute (ESRI) and run on a UNIX operating system. This software was run through both a *SUN* workstation terminal and a UNIX emulator (Hummingbird Exceed version 6.0) run through a networked PC. Other general software operations were conducted on PC. These included GPS data conversion software (*GPS data editor version 2.0* created by R. Middleton) and *Microsoft Excel version 7.0* for mathematical calculations of the raw data.

The choice of *ARC/INFO* was based on three main factors. Firstly, its huge flexibility allowed for the analysis of data in multiple formats enabling the comparison of results and surfaces within the same system. Secondly, the relative transparency of operations through the UNIX interface meant that fewer calculations were taken for granted. The

requirement to perform more steps of each operation rather than the computer generating its own invisible macros meant that clearer conclusions could be drawn. Thirdly, *ARC/INFO* is a well established, standard GIS package used throughout industry and within the archaeological community. Unlike other studies (e.g. Carrara *et al.* 1997) that have compared the differences in operation results between different GIS packages to measure inaccuracies, within this study just one package was used. This was to enable continuous introspective comparison in keeping with the study objectives that were to measure the effectiveness of different tools rather than the relative accuracy of the same types of tools within different packages with different computational algorithms.

Since the onset of this work there have been a number of developments in GIS which require some mention here. Of primary importance is the impact of the development of PC hardware and subsequent memory capabilities and processing speeds that have meant that the software which used to only be run through computer networks and operating systems such as UNIX has since become available through PC. In relation to *ARC/INFO*, the development particularly of ESRI *ARC/VIEW* has allowed many of the computations previously only possible within its UNIX-run counterpart to be available on PC with an MS Windows interface. This interface allows for faster analyses and has become employed widely within the public sector. However, the ease by which many computations can be conducted, and the invisibility of the control interface means that it is possible that they may lack theoretical underpinning and technical understanding.

The tools selected for use within the present study can be divided into four main areas: surface generation, surface representation, surface analysis and multiple surface analysis. These areas have been used to provide a convenient division of the results, and an outline of the main methods for each is given below.

4.3 GIS surface generation tools

Of principal importance to GIS cell-based modelling is the DEM and a number of studies have investigated the applications, values and limitations of different raw data sources, ways of creating the DEM and ways of measuring errors within the DEM (e.g. Burrough 1996, Hutchinson and Gallant 1999). A number of studies have addressed the accuracy of resulting models from different types of data and through different approaches. This section outlines the main interpolation techniques being used for the present study, followed by a consideration of resolution and a view of how error may be recognised within the resulting model.

4.3.1 Interpolation methods

Different GIS software provide different options for the interpolation of DEMs, although the range may be classified into three main categories - *linear interpolation* (drawing straight lines through data points), *Cubic Spline* (drawing a curve through the data points) and *statistical interpolation* (Gillings and Wise 1999: 35-6). An outline of these various methods is provided in chapter 8 of Burrough (1986). This text describes the mathematical framework of the various techniques, and some of the effects of the various methods that may be used in their application.

One aim of the present study is to assess the effects of the interpolation methods as they might be used within archaeological studies, and so the default methods have been chosen in each case for the comparison, rather than expanding into the various permutations (*cf.* Burrough 1986). It is felt that this will provide a foundation for understanding the techniques in this comparative and applied way. The range of interpolation techniques begins with some of the fundamental methods, and these are followed by methods more specific to *ARC/INFO*. Finally, the use of triangulated irregular networks (TINs) and their conversion to cell-based surfaces is considered.

a. Trend

Trend describes "gradual long-range variations" of the z-value of a model (Burrough 1986: 149). It uses polynomial regression to generalise the surface from a statistical approach to the raw point data. As such the surface rarely passes through the survey points, but rather provides a model of trend. The default for *ARC/INFO* uses a linear trend, although options for non-linear surfaces using quadratic and cubic regression are possible. The effects of these are outlined in Burrough (1986).

The trend method of surface interpolation is therefore different to the other in that it does not attempt to re-create a landscape, but rather it generalises the data. The usefulness of trend surfaces lies in possibility of measuring deviation from the general trend. It is therefore not normally considered as an interpolation method (Burrough 1986). Within the present study, trend has been included as a baseline for generalising the dataset and a basis for comparisons with other data.

b. Spline

Spline interpolation creates a surface from point data by fulfilling two criteria. Firstly the surface must pass exactly through all data points rather than generalising them. This

means that the resulting DEM will retain the more subtle features unlike with the trend function (Burrough 1986). Secondly, the surface must display minimum curvature, creating a continuous and smooth surface (ESRI 1995). An advantage of this technique is that calculations do not require high processing power. Two options for spline interpolation are offered by *ARC/INFO*, though in all cases the default *regularised spline* has been used.

c. Inverse distance weighting

Inverse distance weighting (IDW) is a method of interpolating a DEM by calculating the averages of the data around each input-data point. With IDW, this averaging is weighted inversely with distance. For each cell in the DEM, those input-data points closer to the cell are given greater influence on its value than those further away. The effectiveness of this function is dependent upon the size of influence for each cell (Burrough 1986). In other words, changes in the radius used will have a direct effect upon the influence on the value of each cell point as more or less data is considered. Greater radii will also increase the need for computing effort. The default within *ARC/INFO* uses the nearest twelve points to the cell for the calculation, with a maximum radius of five map units. The use of the twelve nearest neighbours is also the default within *ARC/VIEW*. For the present study, the default for IDW interpolation was not changed.

d. Kriging

Kriging (or 'optimal interpolation') is an interpolation method that uses spatial covariance to create a statistical surface from point data, based upon factors more complex than the single function of distance demonstrated by spline (Burrough 1986). The technique is most useful when interpolating surfaces from data that is less anomalous (Burrough 1986) for the creation of the DEM. Kriging assumes that regional spatial variation is statistically reflected by the rest of the data and is thus not appropriate for datasets displaying vast local vertical variations, as the surface will be treated as uniform. This is the most advanced interpolation method, relying on multiple factors rather than just distance.

The default function of kriging uses a spherical semi-variogram model that describes the shape of the graph used to calculate this. For the present study the default settings for the interpolation of the DEMs were used for each study area.

e. TOPOGRID

According to ESRI (*ARC/INFO help version 7.2.1*) the TOPOGRID function generates a "hydrologically correct grid of elevation from point, line, and polygon coverages". This function works by using a weighted median of the surrounding points from a given known elevation point, whereby closer points are given the greatest weight. Each cell of the generated grid is given a value based upon the elevations of the surrounding cells. The function works globally, generating a coarse grid that is then refined to the user-defined resolution. The advantages of this technique lie in its ability to generate more realistic landscapes through an understanding of ridges and streams such that the generation of interpolation artefacts such as sinks (local minimums) and peaks (local maximums) is reduced. TOPOGRID also enables a clearer interpolation of contour data, which is one of the more common topographical data storage formats. Contour data is read in and generalised to point data so that a hydrologically accurate and visually realistic surface is created.

f. CREATETIN/TINLATTICE

The CREATETIN/TINLATTICE combined function is a two-staged process which first generates a framework that is then used as reference from which a second, cell-based, surface can be interpolated. A TIN, or Triangulated Irregular Network, (also referred to as a Polyhedral Irregular Network) is a vector-based surface interpolation. It calculates elevation of a plane passed through the closest data points of known value by joining them with their nearest neighbours by arcs to form polygons. With TINs these polygons are always trianglular. TINs have an advantage insofar as they can generate surfaces from multiple data sources that can include breaklines (which define sudden changes in height). TIN models can be generated directly from either regularly or irregularly spaced input-data, so that greater detail may be obtained from one part of a surveyed site than another.

A TIN's accuracy is dependent upon the process of triangulation that is employed to form a continuous surface. *ARC/INFO* uses an interpolation method known as Delaunay Triangulation, which follows a criterion that a circle drawn through the three nodes of each triangle will contain no other data points, thereby requiring smaller triangles in areas of greater point density (*cf.* Voigtmann *et al.* 1997).

Other than the ability to generate surfaces from regularly and irregularly spaced data and from multiple sources (including both contours and points), there are three main benefits

to using TINs in the generation of surfaces from point-based data (Goucher 1997, 249-50). Firstly, the Delaunay Triangulation process means that the triangles formed are as equiangular as possible, providing a better geometry than if the angles were able to become more acute. This means that the surfaces are potentially more accurate which is helpful for further analyses. Secondly, the Delaunay process ensures that every interpolated area is a near as possible to a triangle node so a minimum of interpolation is required. Finally, this process gives each survey point equal priority so that the order in which the points are processed will not affect the resulting surface (Goucher 1997: 249). However, although TIN generators have become increasingly popular over the past decade due to their apparent efficiency and flexibility, they are more reliable when the data source consists of irregularly distributed spot heights. When contour data is used they are less reliable forming a less realistic landscape representation. Further, they can generate errors when modelling valley bottom morphology, requiring subjective breaklines to be added, although some research has been conducted to overcome such errors (e.g. Voigtmann *et al.* 1997). It was also noted that the potential of surface smoothing provided a further paradox insofar as it can reduce artefacts of the interpolation process but will also lose some micro-relief information (Voigtmann *et al.* 1997).

Once the TIN has been created using the CREATETIN function, it is converted to a cell-based surface, or lattice, by using the TINLATTICE function. This is a conversion that interpolates a continuous grid using the TIN as a reference from which gridded elevations are calculated. The function places a grid of cells at a pre-determined density across the area covered by the TIN which are referenced in terms of x and y coordinates. A height attribute for each cell is then interpolated from the TIN. *ARC/INFO* allows for a number of different ways of converting a TIN to a lattice using this function, the primary two being linear and quintic interpolation. Linear interpolation treats the TIN's arcs between nodes as straight lines that are reflected directly in the heights of the cells across it. The areas enclosed by the TIN's triangles are then treated as flat plates. Surfaces constructed using linear interpolation often look faceted and unnatural, though the potential for interpolation inaccuracies is reduced. The second main TINLATTICE method, quintic interpolation, applies smoothing to the areas inside of the TIN triangles. This method appreciates that the surface being represented is smooth without the harsh breaks in slope represented through linear interpolation. Instead a continuous smooth surface is created which runs through the nodes and forms a smooth interpolation

through the areas between. The resultant surface is not only more aesthetically realistic, but has the potential for being more accurate with a curved rather than faceted surface.

4.3.2 DEM resolution

The relationship between the data source and the DEM extends further than the choice of interpolation/generation method to be used. DEM resolution is crucially important and may be defined as the size of each cell in x and y. Principally, the DEM resolution directly influences the degree to which it is suitable for a specific application (Veregin 1999). The value of each method of interpolation is dependent on the input-data source and the desired cell size of the resulting grid. It has been shown however that general trends exist. For example, a paradox exists within grid interpolation techniques such that computer processing power and data storage can be a problem if a large area is analysed at high resolution (i.e. small cell-size). If a lower resolution is chosen then the DEM can become inaccurate and over-generalised (Carrara *et al.* 1997), and may negatively affect analyses (Madry and Rakos 1996).

Studies have also highlighted the effect of the relative resolution of the data source (*cf.* João 1998) and the desired cell-size within cell-based DEMs. Gao (1997) chose three landscapes displaying the different topographic characteristics of a valley, a peak and a ridge and generated DEMs from digitised contours interpolated into a grid through kriging. The relationship between the accuracy of each DEM (compared with the real landscape being represented) and the input contour density was compared in relation to different DEM cell resolutions, concentrating particularly on the effect on gradient measurements. The results of this research demonstrated the minimal effects of resolution on gradient and provided a method for achieving optimal surface resolution from a given contour density.

The present study has used a variety of DEM resolutions. For the lower resolution landscapes the contour data have been interpolated to surfaces at two resolutions. Firstly, a 50 m cell size was used as this is the size recommended by the Ordnance Survey for the supply of their data (Ordnance Survey 1999, see chapter 3, section 3.2.1). The data were also interpolated to a 25 m grid following recommendations from previous work that suggested that such a higher resolution was appropriate for this type of data (*cf.* van Leusen 1993).

4.3.3 Measuring error

A distinguishing feature of GIS is its ability to create new data from input-data, achieved by applying algorithms to the data. For example, a DEM may be created from raw variable resolution input data and the resulting DEM will form the basis for further computations and analyses. Therefore, the accuracy of results from all later levels of analysis is dependent upon the accuracy of the creation of the DEM in the first instance. The possibilities of error may become compound as further levels of analysis are conducted. It is for this reason that the accuracy of the original data, the *intrinsic* data, is as high as possible. It is also important to scrutinise the validity of the algorithms and processes that are used to generate the new data. This may be referred to as *operational* error (see Marozas and Zack 1990 for error definitions, *cf.* Heuvelink 1999). Finally, it is important to be able to assess the potential that any errors have been encountered, particularly within the operational process, since these can be corrected. While the abstraction of the landscape into GIS models is advantageous, allowing analyses to be performed which would be impossible on the ground, this same principle means that they cannot be accurately compared to it in order to check for error. Therefore other methods have been proposed by different researchers to establish ways of checking the accuracy of DEMs and analytical processes, and thereby their reliability within further analyses. For example, a method using progressive thinning of the input-data was applied to assess changes in the DEM in relation to both surface area (compared to its simple two-dimensional planimetric area) and volume (Brasington *et al.* 2000).

It is important to understand where errors occur within a DEM due to the surface's fundamental influence on the results of further analyses (Kvamme 1990). Fisher (1999) highlighted the range of errors that may occur within GIS, classifying *error*, *vagueness* and *ambiguity*, relating error with *uncertainty*. This work demonstrated the need for users to be aware of these issues in order to provide confidence in decision-making.

The main problems in such analysis lie in the lack of benchmarks by which to compare abstract data models. The first obstacle is that a model can only be as good as the raw data, and therefore can only be compared with it. Such a comparison has been attempted statistically (e.g. Li 1994) and visually (e.g. Wood and Fisher 1993). The overall quality of the resulting DEM has been examined in a number of ways. Gao (1997), for example, measured the accuracy of 200 randomly chosen points from a given terrain to enter into a statistical equation to calculate root-mean-square-error. Haigh (1993) analysed his resulting DEMs in relation to reliability, robustness and realism. Reliability was

measured through the application of the technique to a number of different sites. Robustness was seen in relation to the required job of the model, in his case the rectification of aerial photographs, and realism was measured by a comparison between the model and the perceived surface it represented. He also noted that large changes could be noted when surfaces were interpolated from contours depending upon the number of points used to digitise them, and through the addition of extra data points. Amongst other methods, Carrara *et al.* (1997) analysed a DEM by comparing the contours that formed the source data for the model and the contours generated from it. In this study five categories were identified for analysis. Firstly, cells near to contours should be of similar height; secondly, between contours all cells should be within the vertical range displayed by them; thirdly, in these areas heights should vary linearly between elevations; fourthly, in areas of low relief variability the cell values should reflect a '*realistic* morphology'; and lastly, the distribution of interpolation artefacts should be small (*ibid.*: 453). Similarly, a further dimension to assessing DEM accuracy was provided by López (1997) who demonstrated that two types of errors were present within DEMs: systematic, resulting from the method used to generate the DEM, and random (*cf.* Beard & Buttenfield 1999). This research presented a new methodology for identifying random errors by using Principal Component Analysis that was tested by analysing user-generated random errors. More recently, a statistical approach to measuring the probability of error across a DEM has been suggested (Kyriadis *et al.* 1999). This method produced alternative representations of other possible outcomes for areas not covered by what was referred to as 'hard' data, or input-data.

Assuming the accuracy of the raw data is robust, acceptable error elsewhere can only be achieved in terms of tolerances. For the purposes of this study, the appropriateness of GIS techniques was analysed. In this respect the intention was to identify the most appropriate technique of interpolation for each landscape type at each resolution. This can be defined in relation to two main areas that may be termed introspective analyses and externalised analyses. Each of these methods of analysis was applied to each of the sets of data and surfaces were interpolated at a variety of surface resolutions. For the larger geographical areas obtained from the Ordnance Survey as contour data two surface resolutions were attempted providing 50 m and 25 m grids. The range of point density for those areas surveyed using GPS means that the range of surface interpolation accuracy is outlined in the relevant results section. This work highlights the need to assess the quality of a DEM.

a. Introspective analysis

For the present study, introspective analysis involved the comparison of the surface with the raw data from which it was derived, and was therefore quantitative. It should be possible to understand the extent to which an interpolation method creates artefacts or reflects the ranges of the original measurements. The limitation of this method of analysis is that it is unable to reflect upon the quality of the survey data and that its conclusions will inevitably be abstracted, testing against a relative rather than an absolute benchmark.

It may be assumed that a more accurate DEM will reflect the maximum, minimum and mean values of the raw data used to create it. It should be expected that interpolation will generate a minimum value slightly lower than that of the raw data and a maximum slightly higher because the raw data cannot be fully expected to have covered all of the highest and lowest points of the surface. Conversely, a minimum value vertically higher than that of the raw data, or a maximum value that is lower than that of the raw data will indicate error. However, variations should not be massive compared to the raw data. In terms of mean values, a closer value to the mean should indicate a greater degree of accuracy, particularly with regards to surfaces derived from point data where this may be measured accurately.

A second method of introspective analysis of surfaces is through the direct comparison of one surface to another through mathematical operators. By subtracting one surface from another, the values represented in the resulting surface will highlight areas of greatest difference. Through an analysis of these differences it is possible to highlight areas which require further investigation.

b. Externalised analysis

Externalised analysis, on the other hand, assesses the accuracy of the digital surfaces in relation to aesthetics and the real world, and is thereby qualitative. This is very difficult to define since a digital elevation model generalises the landscape that it represents and therefore is not an exact replication. Also, it is not possible to check data against the real world without a second process of survey and abstraction that will inevitably result in the same limitations. This limits such analyses to the visual assessment of the surface to assess the impact of surface artefacts. This analysis was approached in two ways.

The first method analyses the digital surface in relation to another digital generalisation of that same surface but derived from different data. In this way the relative values of the survey-derived models can be considered with those models derived from Ordnance Survey contour data. By subtracting one model from the other it is possible to see how they differ and subsequently to reflect upon those differences. This process also acts as a form of 'ground-truthing' for the surfaces derived from the Ordnance Survey data.

The second method of externalised analysis is more subjective, less quantifiable, but with equal value to the first. It involves aesthetics - through a visual appreciation of the surface it is possible to assess the accuracy of the surface. Such an approach formed the basis for the analysis of the effects of standardised and non-standardised survey methods by Fletcher and Spicer (1988) who compared the results from them in relation to the 'real' digital surface. Artefacts generated through different interpolation processes can be noticed in relation to other surfaces, aerial photographs and other visual data sources.

4.3.4 Summary of surface generation tools

Each of the available surface generation techniques was applied to each of the various datasets, using the greater number of techniques available for point data. In most cases options existed for tailoring the tools, but, unless otherwise stated, the default options were maintained to provide a manageable number of options and to make the processes more easily repeatable. This also had the added advantage of keeping analyses to the more likely types of GIS approaches used by archaeologists. The tools were also each applied to generate DEM surfaces at a range of different resolutions. Each of these surfaces was analysed in relation to introspective and externalised assessment, highlighting the elements of quantifiable accuracy and visual quality. They were also analysed in relation to resolution and, specifically, the comparative resolution of the input data and the output cell-size. In each case the most appropriate method of interpolation was chosen. The resulting surface was then used exclusively for the later analyses.

4.4 Surface representation tools

The representation of digital surfaces can provide information regarding the nature of the landscape and has the potential to provide information about micro-topography that may reflect archaeological and non-archaeological activity. Surfaces can be represented in two ways, centred on whether or not elevation is displayed.

4.4.1 Elevation-based surfaces

Elevation-based surfaces display models such that their vertical scale is represented. Typical methods of display include contours and contour bands whereby ranges in vertical drop are generalised by a given symbol. The advantage of such methods is that they display features that highlight vertical drops such as river valleys and assist in the understanding of the landscape.

On a basic level, elevation surfaces may be represented as contour lines or bands. Contour lines are usually positioned at given intervals in order to provide a linear representation of height. Contour bands can fulfil the same job, but can also be scaled mathematically from the data. Archaeological features are normally identified as being anomalous compared with the surrounding landscape. Linear contour bands generalise a landscape, and therefore limit the visibility of surface detail. Within landscapes where archaeology lies upon a relatively flat plane, it is possible that features will lie within a single contour band and will therefore not be visible. Therefore, a second method of contour banding was also applied based upon percentiles of the frequency of different cell values.

4.4.2 Non-elevation-based surfaces

Non-elevation surface representations display detail of topographic change, highlighting subtleties of the surface itself, rather than in changes in elevation. It has the added advantage of representing details that may be missed lying between contour values, for example. There are several methods of non-elevation-based surface representation. The first illuminates the surface from a given lighting position (an analytical function, though considered here under the heading of representation, but which could equally be considered within surface analysis). Hillshading (as it is referred to in *ARC/INFO*) is a method of improving the visual quality of a map. It calculates areas of light and shade by determining reflectance of the source based upon elements of aspect and slope (see below, Burrough 1986). The result of such analysis is a surface that is similar aesthetically to aerial photographs, highlighting earthworks, for example. By altering the position of the light source it is possible to highlight alternative features.

The second main method included within the theme of non-elevation surface representation is perspective modelling, using elements such as elevation exaggeration and draping of vector and raster features or a wire-frame mesh. Principally, this is achieved through identifying a DEM as the surface (see 3.3.2 above), multiplying the

values of each cell by a given exaggeration value and draping a mesh (or other data) over it. This is represented from a given angle, with an observer position and a target position, providing an oblique perspective image. The advantage of this representation method is that the less pronounced features will be highlighted with the altered ratio between the Cartesian co-ordinates and the height values. Further, the perspective model provides a backdrop for draping other archaeological features, providing a clearer visual understanding of the relationship between topography and archaeology.

4.4.3 Summary of surface representation tools

For the present study each of the methods of surface representation were applied to each of the models. These were then analysed in relation to their potential for understanding the topography of the area and for providing further information about the archaeology from a visual basis and to explore the implications of this on the interpretation and management of the landscape. Each of the display methods was also compared with the distribution of data from other sources, such as draped archaeology layers, in order that comparisons could be made and correlations observed.

4.5 Surface analysis tools

A DEM surface can be analysed in a number of ways before any other layers of data are added to it, but also in relation to other layers of data (such as archaeological distributions). Surfaces can be generalised, by calculating slope or aspect, or more complex analyses of visibility can be used. The former types of analysis can form a basis for understanding the surface, particularly in relation to overlain archaeological features. The latter types of analysis using visibility are often used for the interpretation of archaeological landscapes, but have also been used in relation to assessing the impact of development. Analyses involving surface analyses are common, particularly within studies using multiple techniques to understand terrain form in relation to archaeological distribution (e.g. Kvamme 1992).

4.5.1 Slope

Slope has been defined as the combination of both gradient (the maximum rate of change in altitude) and aspect (compass direction of gradient) (*cf.* Burrough 1986: 50). For the present study slope is being used as a gradient model, labelled following the *ARC/INFO* command used to generate it. The calculation of slope creates a new DEM with values relating to the gradient for each cell. The output grid is defined either in terms of percentage or degree and is calculated from the greatest change in height between the cell

in question and the eight cells immediately surrounding it. Slope, along with elements of elevation, has been used to investigate location preference in past occupation distributions (e.g. Kuna and Adelsbergerová 1995), providing both CRM and interpretative results. Calculations of slope have been a principle aspect of multiple surface analyses, particularly those involving predictive modelling (e.g. Kohler and Parker 1986, Carmichael 1990, Marozas and Zack 1990, Kuna and Adelsbergerová 1995 - not expanded upon within this thesis) and interpretative cost-surface analyses (*cf.* van Leusen 1999, Bell and Lock forthcoming, De Silva and Pizziolo forthcoming, see below).

4.5.2 Aspect

The calculation of aspect within a DEM identifies the direction of the maximum rate of change in values of each cell. Ascribed cell values are given in positive degrees from north. Archaeologically, it may been argued that elements such as south-facing slopes within the northern hemisphere may be preferentially settled or farmed due to increased solar exposure. Therefore an exploration of correlation between aspect and site distribution may present interesting results in relation to this hypothesis. An example of the use of aspect modelling was provided by Llobera (1996) who generated an aspect model of the Wessex chalklands and compared it to the distribution of linear ditches. This, coupled with other analyses identifying hillcrests, was used to explore the relationship between anthropogenic and natural boundaries. It was noted that there was a positive correlation between changes in aspect and turn in the ditches.

As with slope analysis, the generation of aspect models has been used as one of several layers of data within multiple surface analyses of CRM predictive modelling (e.g. Altschul 1990, Kvamme 1992).

4.5.3 Visibility

Visual analysis on a DEM can be conducted in two ways. Lines of sight (LOS) can be calculated in the binary sense, investigating whether two points are inter-visible, or complete directional or non-directional viewsheds can be calculated from a given position. The former measures whether obstructions lie between two given points, and the latter calculate all cells that have a clear line of sight from the observation point. The GIS calculates a viewshed for a given position from which rays are sent out to all cells of the DEM. The output of the process is a binary map showing which cells are obstructed, and which are visible.

GIS viewshed analysis has been criticised in a number of ways, including assessments of the nature of accuracy at an algorithmic level (e.g. De Floriani and Magillo 1999). Otherwise, the main focus of criticism has been with the unrealistic binary output that does not reflect the complexities of reality (e.g. Fisher 1992, 1993). In response to this problem, other methods have been applied in order to provide a more realistic understanding of visibility, particularly in relation to visual impact assessments for new developments. For example, Nackaerts *et al.* (1999) demonstrated an approach that combined the DEM with a second surface that represented error within it to provide a more realistic probabilistic calculation of the likely visibility from each cell.

The application of visibility analysis within landscape archaeology is well founded (e.g. Devereux 1991, Thomas 1993, Tilley 1994, see chapter 1, section 1.4.2). The principles upon which visual analyses of this type rest are those of existence and perception. Within contemporary studies in the social sciences, it has been suggested that visibility is the principal way in which humans relate to and interpret their landscapes (e.g. Punter 1982). Equally, it has been argued that such interpretations are only possible with a prior understanding of the landscape so that the signs may be interpreted (*cf.* Meinig 1979, Tuan 1979, Cosgrove 1989). Archaeologically, visibility has been an element that may be investigated and understood (e.g. Bender *et al.* 1997) and has been used frequently within interpretative approaches.

Within archaeological studies using GIS, visibility has also been used as a function to provide a basis for interpretation of past landscapes. For example, Lock and Harris (1996) demonstrated that viewsheds could be used to demonstrate socio-political units in a more useful way than Thiessen polygons for the distribution of Neolithic long barrows within the Danebury landscape and the images demonstrate very little overlap. Within this study, viewsheds were also shown to demonstrate the defensive prospect of hillforts within the region, but it was noted that they were more importantly positioned to maximise visual dominance over valleys and other smaller settlements. Similarly, visual relationships formed the basis of conclusions made by Gaffney and Stančič (1991) about the siting of Roman towers. A slightly more complex approach by Fisher *et al.* (1997) demonstrated how viewshed techniques could be enhanced by statistical analyses of the results. In a study of Bronze Age cairns on Mull it was shown that it was possible to use viewshed analysis within a hypothesis-testing environment to provide a question-led approach. However, the widespread use of visibility analysis within landscape interpretation has been criticised. Lake *et al.* (1998), for example, noted that

intervisibility between two locations may not be considered to be a determining reason for the location of one of the two points without analysis of other areas that may also provide the same results. Similarly, Wheatley (1996) highlighted that the results from any single analysis, such as LOS, may only be significant relative to themselves, and that other variables from other analyses may also be 'causal factors'.

Gillings and Wheatley (forthcoming) summarised many of the criticisms of visibility analysis. This work highlighted the main limitations and critiques of the approach using three categories: pragmatic, procedural and theoretical critiques. Pragmatic critiques covered issues such as environmental factors (see section 4.6.3), eyesight, mobility, simplification and causation. These critiques covered the practical problems and oversights that underlie visual analysis. Procedural critiques reflected Marozas and Zack's *operational* error (1990), reflecting upon those problems encountered through the method. Listed items included problems with the DEM, viewshed algorithms, the binary nature of viewsheds and overall robustness. They also added the concept of the 'edge effect' highlighting the problem of viewsheds that often extend beyond the edges of the DEM, or the influence of viewsheds from outside of the DEM that have the potential to extend onto it. Finally, theoretical critiques highlighted further problems. These included elements such as the 'unquestioned primacy' placed upon vision above other sensory factors, and the abstracting nature of technological determinism and particularly the way in which viewsheds are generally presented in plan.

The need for a qualitative approach to viewshed analysis was argued in response to these limitations. Gillings and Wheatley (forthcoming) proposed an approach to viewsheds using an 'Higuchi' model. This classified three depths of vision, along with a range of other physical and social characteristics. It was argued that short, middle and long distance views would be relevant for different perceptual experiences and may therefore be more useful in interpretative studies.

For the purposes of this study a height of 1.7 m was chosen for the height of the observer when performing visual analyses. This height was obtained from skeletal studies from within the northeast of England from the Yorkshire Wolds. Here a number of prehistoric cemeteries have been excavated providing a large population sample, particularly for the early Iron Age (e.g. Stead 1991). A statistical analysis of these skeletal remains was presented by Leese (1991) who has compared the results from this region to broadly contemporary sites elsewhere in the country. In the Yorkshire region mean heights of

1.71 m and 1.58 m for males and females respectively have been given from populations of 68 and 48 individuals respectively. This figure is slightly high compared to the other sites of Wetwang on the Wolds which produced figures of 1.67 m and 1.56 m from populations of 122 and 168 individuals, and Maiden Castle which produced figures of 1.65 m and 1.52 m from populations of 19 and 9 individuals. The rounded figure of 1.7 m has taken from the data for male heights as a standard in keeping with other GIS-based studies that have used visibility (Mark Gillings pers comm.) in order to maintain potential for comparison of results. Clearly other influencing factors including clothing and vegetation will influence the accuracy of level of sight, and so a more accurate determination is not appropriate.

Within this study the application of visual analyses using GIS has been based upon the assessment of the basic methods for either interpretation or resource management. Consequently, the visual approaches that have been used are of a basic nature. However, comments and conclusions from these analyses have been made within the background of such previous work.

4.5.4 Summary of surface analysis tools

Each of the DEMs was analysed using each of the tools outlined above and observations were made in relation to both the surfaces alone and the surfaces compared with the distribution of the overlain archaeological features. Many other methods of surface analysis exist within most three-dimensional GIS frameworks, including buffer zonation, site catchment analysis and Thiessen polygons. The focus of the present 'surface analyses' classification concerns the more fundamental processes of analysing a surface itself and comparing the results to the distribution of archaeological features.

4.6 Multiple surface analysis

Bringing a number of surfaces or DEMs together can increase the potential of understanding a landscape more deeply and usefully. The majority of site-specific studies have used a combination of techniques together in order to fulfil its requirements (e.g. Kvamme 1992, Lock and Harris 1996). The sub-heading, multiple surface analysis, refers to the use of multiple grids rather than the overlaying of vector-format data over grids as mentioned within the sections outlined above.

The number of approaches that may use multiple surfaces is vast and so any systematic approach cannot be possible. Rather, multiple surface approaches will be determined to a

greater extent by the landscape being studied. However, traditional approaches using multiple surfaces have been typified in a number of key areas. These include the creation and analysis of 'cost' surfaces, the analysis of multiple viewsheds, and the generation of predictive models. The first two are explored within the present study, with a third approach aimed at exploring environmental factors of landscape. The issue of predictive modelling has not been explored for reasons outlined in chapter 1.

4.6.1 Cost surface analysis

Cost surface analysis is a process involving several stages that generates a surface displaying 'cost' on the basis of pre-determined parameters. Costs are usually ascribed on the basis of movement through the landscape so that elements such as steep slopes would provide a higher cost to pass than a flat area. Once a cost surface has been created it is possible to measure the 'cost' of travelling along a specified route. The sum of the values of those cells travelled over provides a cost for travelling the route. Assuming the principle of least effort, it is then possible to use the GIS to display the route of least cost between two points.

An example of cost-surface application within an early Neolithic monumental landscape was used to investigate the hypothesis of 'central places', arguing that physical centrality within the contemporary environment was not significant, being present with only a selection of the causewayed enclosures studied (Wheatley 1996). Another example of cost-surface analysis was presented by Bell and Lock (forthcoming) who generated a cost surface across the ridgeway in Wiltshire based upon slope with an exponential increase in cost (effort) with increase in slope (percentage). This was an extension to Stead's observation that the relationship between slope and effort (measured in calories) was an exponential function (Stead 1995). It was also added that perceptual elements also had an effect on the definition of a cost surface. A detour may be made to avoid the excessive though short-lived effort up a slope, although the alternative takes longer at an ultimately higher calorific cost. It has been noted that it is important to take into consideration a whole complex of variables that form the interaction between humans and the process of movement (De Silva and Pizziolo forthcoming). Further elements could be added to add costs for more subjective options that could influence choice (e.g. Wheatley 1993). Van Leusen (1999) also investigated the effect of social factors within a cost surface by incorporating viewshed analysis, suggesting that factors other than physical cost will influence a route.

Criticisms of cost-surface analysis include both practical and theoretical considerations. The former has been demonstrated by the need to calibrate effort in relation to slope. Clearly, a slope of 90° will increase effort by more than 25 % in relation to a level surface. The relationship between the two is not a linear one, but has been found to be exponential, highlighting the need for such a calibration (e.g. van Leusen 1999, Bell and Lock 2000). From a theoretical perspective, cost-surface analysis is currently dependent upon factors relating to the measurable, physical environment, while, as Tilley (1994) has pointed out, many other metaphysical and psychological factors may also have a profound influence on the understanding of so-called 'cost'.

4.6.2 Cumulative viewshed analysis

The application of inter-visibility and viewshed analyses, and the processes involved, has been outlined above. However, despite this expression of value it has been argued that this provides gaps in the method. Although it may be demonstrated that the location of a site commands a particular view, the value of this location over others may not be addressed. A method of cumulative viewshed analysis was first introduced by Wheatley (1995) to investigate inter-visibility in a more robust way, particularly in the light of unknown environmental factors that could influence and restrict visibility. By generating a binary grid representing each viewshed and adding these together for each of the long barrows within his study area, it was possible to understand whether their locations displayed exceptional inter-visibility. A similar study by Lock and Harris (1996) explored the relationship between different monuments within the Danebury landscape. This study demonstrated a lack of overlap from multiple viewsheds derived from the positions of long barrows in the area that was interpreted to indicate that they acted as highly visible markers defining territories. Ruggles *et al.* (1993) used a method of cumulative viewsheds in conjunction with other tools as a basis for generating deterministic and predictive models in relation to the locations of stone rows in northern Mull, Scotland, to identify significant visual foci (in terms particularly of astronomical alignments) and to highlight areas where other stone rows may be found respectively.

Cumulative viewshed analysis has been used further. The significance of a viewshed from a given point has been interpreted to suggest that the location of a site is significant due to the viewshed that it commands (e.g. Thomas 1993, Tilley 1994). Llobera (1996) applied these theoretical concepts to archaeological GIS studies, suggesting that GIS was not a limited, normative and reductionist tool, but rather had the potential to act as a heuristic tool; exploratory rather than dualistic. Multiple viewsheds were generated from

the lines of the linear ditches on the Wessex chalklands to see if a similar area could be seen from either side. It was indicated by the analysis that the viewsheds were singly-directional, supporting the view that they were territorial markers. A further level of cumulative viewshed analysis was then achieved through the creation of a *gradient view*. This used a cumulative viewshed formed by the combination of views of different distances (set at 50 m intervals). For example, areas closer to the observer would be seen within each viewshed, whereas greater distances would be seen fewer times. The conclusions from this research suggested that the function of the linear ditches were to mark territories, but that these were not in the enclosed, inward-looking sense but rather as markers.

GIS has also been used as a tool to test hypotheses relating to visual significance of the type suggested by Thomas (1993) and Tilley (1994). The traditional (non-GIS) approach has been criticised by suggesting that the significance of a location for visual factors can only be qualified if this location is the only one that displays these features. This criticism was approached by the statistical generation of non-sites within a given area and the quantification of viewsheds from each (Fisher *et al.* 1997). The quantified viewsheds demonstrated that there was a significance of certain repeated views from cairns that were not statistically repeated by the random sample, and that dominance of viewsheds over the sea within the studied landscape could be demonstrated. Another study approached the question of Mesolithic site distribution, investigating the hypothesis that they were located in positions that commanded better views by which to watch game (Lake *et al.* 1998). This study took an intensive assessment of every cell within the study area to compare the viewsheds from sites and non-sites to assess this hypothesis by tailoring the software. The results demonstrated that the hypothesis was not robust.

Such approaches have been expanded upon considerably in a recent study by Llobera (forthcoming: a). This developed the use of cumulative viewshed models to provide a different perceptual surface for such analysis as proximity analysis, with the aim of providing an alternative GIS method for the investigation of archaeological landscapes using some of the more abstract theoretical concepts of the landscape archaeologists. For the present study, multiple viewsheds have been calculated from combinations of like monuments within the Rudston landscape where such evidence exists.

4.6.3 Environmental modelling

An environment consists of many factors including topography, soils, geology, hydrology and flora, and this is understood in relation to time (Goodchild *et al.* 1993). However, a DEM represents only certain elements of this, based mostly around topography, although possibly extending to the buried topography (e.g. Richards 1991, Miller 1996). Some studies have used a range of environmental factors when building up models combining several DEMs for their analyses. For example, predictive modelling often uses DEM derived and other features to build up analyses of location (e.g. Maschner 1996). Non-topographic features have been at least partially neglected within archaeological GIS approaches to landscapes. Principally, elements such as vegetation have been neglected from analyses, primarily due to limitations in the resolution local floral record. Vector-GIS has recently been used as a basis for mapping global vegetation types across the north of England on assumptions made about temporal successions of different plants, and the determining factors of geology, soils and elevation (Spikins 2000). Again, however, it was argued that palynological data was generally insufficient for a detailed reconstruction, and that a model was the most appropriate solution. With cell-based approaches a similar conclusion was made by Fisher *et al.* (1997: 587) who argued that it was "not possible to reconstruct vegetation with sufficient detail for visibility analysis" despite the palaeobotanic record for the area. However, the significance of vegetation in its ability to obstruct viewsheds, for example, cannot be overstated (Chapman and Gearey 2000). This has been noted by advocates of object-orientated approaches that may enable elements such as variable and changing vegetation coverage to be modelled (*cf.* Raper and Livingstone 1995, Raczkowski *et al.* forthcoming).

In addition to the influence of vegetation within archaeological GIS modelling, a second theme of hydrology may be considered. Previous studies have highlighted some of the potential of modelling hydrology to different degrees. For example, Gillings (1995) re-established the pre-canalisation drainage network in the Upper Tisza valley in Hungary to understand previous flood dynamics, using this to understand areas of flooding risk during the middle Neolithic, enabling site locations to be grouped within the context of this distribution. Similarly, Boaz and Uleberg (forthcoming) investigated the effect of changing sea level to interpret changes in the perception of landscape during the Scandinavian Mesolithic. This was conducted by blocking out areas below given absolute heights using a flat water level and analysing the distribution of contemporary sites. This was then compared with the same distribution but with current sea levels

shown, highlighting the potential for incorrect conclusions, without some type of environmental reconstruction prior to interpretation.

The usefulness of attempting to model environmental factors is demonstrated by these two elements alone - vegetation and hydrology - although the application is to some extent dependent upon the landscape being studied. The focus of the present study is not to develop techniques to remedy the difficulties in environmental modelling (for example, with vegetation). Rather the focus is upon applying the available techniques to the two landscapes. In terms of vegetation, the palaeobotanical record for each of the study areas has been outlined (see chapter 2, sections 2.2.1 & 2.3.1). This evidence has indicated that, during the periods being studied, the Rudston landscape was relatively open, and so the influence of vegetation has not been assessed. The Sutton Common landscape, however, has previously shown evidence of an alder carr vegetation across the wetland landscape. The area of wetland has been mapped previously (Lillie 1997) and so the likely height of vegetation could be added to the heights of the DEM cells for this area. This process is expanded upon in chapter 5 (section 5.5.3).

The role of hydrological factors was applied to both of the study areas. Within the Rudston landscape the porous substrate and the complex system of gypsey springs mean that accurate modelling would require extremely high-resolution data (see chapter 2, section 2.2.1). However, surface hydrology could be modelled and compared with the distribution of archaeological features (*cf.* Verhagen 1996). Within wetland landscapes, such as Sutton Common, a high water table is characteristic of any understanding of the archaeology and of its preservation (*cf.* Miller 1996). Again, such modelling would only be appropriate at a high-resolution, and this data was available for the higher resolution landscape from a network of piezometers (see chapter 3, section 3.3.2). The specifics of the approaches to environmental modelling are given within the appropriate sections of the following two chapters.

4.6.4 Summary of multiple surface analysis

Other established complex techniques of study have not been included within this section. Of particular significance is the technique of predictive modelling, one of the earlier uses of archaeological GIS mentioned in chapter 1, that has been used intensively to provide answers to questions regarding CRM particularly (e.g. Altschul 1990, Carmichael 1990, Hasenstab and Resnick 1990, Warren 1990a, 1990b, Zubrow 1990). This has not been included for the reasons of limited testability - the results cannot be

tested within the framework of this study - and theoretical constraints. To make such results useful requires an accurate knowledge of the raw data and its applicability to other regions. For this reason too, the study areas may be considered too small for such an application to be useful.

Unlike the earlier GIS tools and techniques, analyses using multiple surfaces cannot be applied to contrasting landscapes in such a systematic manner. The techniques are too varied and extend towards the applications and requirements of each of the landscapes at each of the resolutions (see chapter 2). Therefore an investigatory approach has been used and reflected upon. This approach is a more common practice when analysing certain landscapes rather than specific techniques, providing a reactionary framework rather than a hypothetico-deductive approach.

4.7 Summary

In this chapter the methods used for this study have been outlined. The actual processes have been described and the overall advantages and disadvantages of each have been explained on the basis of previous research. Each tool group has been outlined separately, this forming the format for the following two chapters. In the case of the more complex approaches, such as multiple surface analysis, the precise application of the tools are outlined where appropriate within the results sections. This outline divides the study into two separate approaches. Firstly, the different landscapes and resolutions are compared through the application of standardised techniques in a systematic, technique-led manner. Secondly, the multiple surface analysis is applied to the various landscapes as appropriate, changing the focus to a more question-led approach.

In relation to the research aims outlined in chapter 1 (to assess the applicability of cell-based GIS tools to archaeological research) four themes were outlined: the limiting focus upon topographically variable landscapes, the need for comparative archaeological study, the need to assess the impact of resolution and the need to investigate the concept of 'surface as archaeology'. The methods outlined above reflect these needs. The application of the same tools to a variety of landscapes displaying different resolutions of input data and contrasting topography, generating DEMs at a variety of resolutions, provide a basis for approaching each of these issues. Overall, the systematic approach to applying GIS tools to the contrasting landscapes provides a basis for understanding the applications of cell-based GIS to archaeology.

As outlined in the appropriate sections, other tools exist within GIS but have not been used here (for example, predictive modelling - see chapter 1, section 1.7). Similarly, other archaeological applications have been used that have not been studied. This has been to maintain the focus of the study. Otherwise, the reasons for this have been given. The following two chapters present the results from these analyses and are planned around the four tool groups outlined in this chapter.

Part 3: Results

Chapter 5

Results from the Rudston landscape

5.1 Introduction

This chapter presents the results from the application of the methods, described in chapters 3 and 4, to the Rudston landscape, described in chapter 2. It is split into two sections. The first explores the application of the different GIS tools outlined in chapter 4 to the lower resolution landscape based upon the Ordnance Survey data. The second explores the same groups of tools applied to the higher resolution landscape surveyed by GPS, focused upon the southern terminus of cursus A.

5.2 Surface generation of the lower resolution landscape

DEM surfaces were generated from the raw, commercially available Ordnance Survey contour data using the appropriate techniques described in chapter 4 and at two resolutions - 25 m and 50 m - in order to find the most applicable technique.

5.2.1 Quantifiable results

The accuracy of a surface can only be measured in relation to the raw data from which it was created. In this respect one would assume the maximum and minimum values to be similar if the surface was accurate and *vice versa*. However, the contours supplied by the Ordnance Survey are provided at 10 m vertical resolution such that each contour is given as a whole number. The surface of the landscape will clearly not be confined to whole numbers and so it is reasonable to assume that elevations will extend below and above the minimum and maximum heights respectively.

Some fundamental conclusions may be drawn from the data (table 5.1). Chapter 3 outlined the difficulties in measuring error and greatest accuracy of DEMs. Despite this a number of key elements may be seen as indicators of the more accurate surfaces relative to the raw data input into them on the basis of their minimum, maximum and mean measurements. Also further results are notable from this in relation to the different levels of surface resolution.

Table 5.1 *Surface interpolation results using Ordnance Survey*

	Min. height (m)	Max. height (m)	Mean height (m)
Ordnance Survey contour file	10.000	130.000	-
TOPOGRID - 25 m resolution	9.621	130.555	66.175
TOPOGRID - 50 m resolution	9.329	130.717	66.188
TIN	10.000	130.000	-
TINLATTICE - linear - 25 m resolution	10.000	130.000	66.177
TINLATTICE - linear - 50 m resolution	10.000	130.000	66.218
TINLATTICE - quintic - 25 m resolution	9.997	133.423	66.229
TINLATTICE - quintic - 50 m resolution	10.002	133.087	66.273

The data show that the accuracy of the TIN was the same as that for the raw data, since the TIN merely applies a vectorised surface structure to the raw data (2.5 dimensional - *cf.* Voigtmann *et al.* 1997) and does not actually interpolate those areas that are not represented within the dataset. Also interesting is that the linear TINLATTICE interpolations each maintain identical results in terms of minimum and maximum values - a mean value cannot be compared as none exists for the raw data.

For the minimum values, the lowest contour of the raw data was at 10 m OD. Of the interpolated surfaces the closest value to this was displayed by the TINLATTICE quintic function at 50 m resolution. However, this value was actually higher than the raw database indicating that this part of the raw data had not been included in the analysis. The next closest value was displayed by the TINLATTICE quintic function at 25 m resolution that provided results 0.003 m lower than the basal contour. The TOPOGRID functions both provided minimum values much lower than this by 0.379 m at 25 m resolution and by 0.671 m at 50 m resolution.

In relation to the maximum values all of the interpolation methods (other than the linear TINLATTICE function) produced surfaces with a higher value than displayed by the contour data. The TOPOGRID function provided the closest values, being 0.555 m and 0.717 m higher for the 25 m and 50 m resolution surfaces respectively. The surfaces generated using the TINLATTICE quintic function displayed values even higher, at 3.423 m and 3.087 m for the 25 m and 50 m resolution surfaces respectively.

The mean values are less useful since the contours do not provide a useful mean value to act as a benchmark for comparison. The total range in values between each method was 0.098 m with no remarkable changes that may highlight one method. Not surprisingly, those interpolation techniques that had generated a higher maximum value were reflected by a higher mean value. The overall similarities of mean values indicate that there were no excessive artificial artefacts generated during interpolation.

In summary of the basic values, those surfaces generated using the TOPOGRID function produced values that were closer to the raw data. The higher resolution (25 m) of the two surfaces was also shown to be closer to the raw data - this was not reflected by the TINLATTICE quintic functions.

To analyse the relative accuracy of the surfaces generated from the Ordnance Survey contour data further the individual surfaces were subtracted from one another to highlight areas of difference. The minimum, maximum and mean values were recorded from the resulting surfaces (table 5.2). Here the values have been listed such that the surface with the overall lower value was subtracted from that with the overall highest value in each case to maintain a positive value for the mean to enable comparisons.

Table 5.2 *Results from the subtraction of surfaces from each other (TL = TINLATTICE, TOPO = TOPOGRID).*

	Min. value (m)	Max. value (m)	Mean (m)
TL quintic – TL linear (25 m resolution)	-12.855	12.517	0.052
TOPO - TL linear (25 m resolution)	-7.094	8.510	0.021
TL quintic – TOPO (25 m resolution)	-8.735	12.900	0.031
TL quintic – TL linear (50 m resolution)	-12.220	10.584	0.055
TL linear – TOPO (50 m resolution)	-14.058	9.842	0.004
TL quintic – TOPO (50 m resolution)	-15.252	11.335	0.059

The maximum difference displayed between the minimum and maximum values was 26.587 m (TINLATTICE quintic surface minus TOPOGRID surface at 50 m resolution). The minimum difference was 15.194 m (TOPOGRID surface minus the linear TINLATTICE surface at 25 m resolution). The next lowest difference was 21.635 m

(quintic TINLATTICE surface minus the TOPOGRID surface at 25 m resolution. All other results lay quite evenly spread between this figure and the highest value.

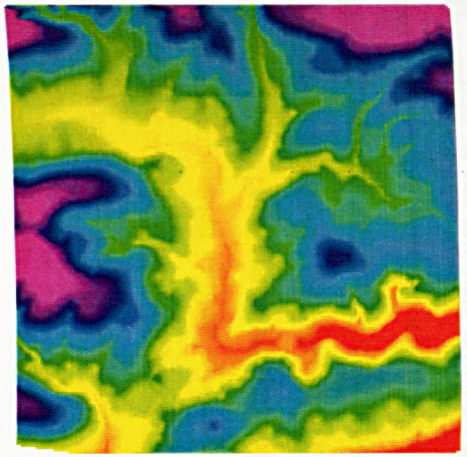
Comparing the effect of resolution on the resulting surfaces suggests very few changes other than between the linear TINLATTICE surfaces and the TOPOGRID surfaces. With these the difference between 25 m and 50 m resolution resulted in 15.194 m and 23.9 m differences in minimum/maximum values: an overall difference of 8.706 m. This high value relative to the other surfaces is not reflected by the basic data for the two shown in table 4.1.

The results from the mean values indicate that the effects of minimum and maximum values is restricted and does not appear to affect the overall model. This indicates that the accuracy of all of the models is within acceptable tolerance limits. It appears that overall the most accurate surfaces for present requirements were generated using the TOPOGRID function.

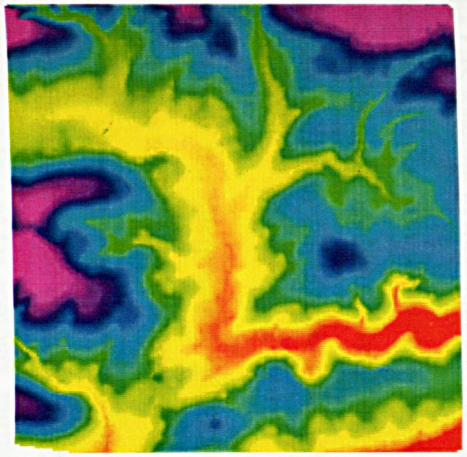
5.2.2 Visual results

A view of the resulting models provided further information regarding accuracy (Figure 5.1). Each surface was examined visually independently and in relation to the raw contour data which was overlain and, finally, profiles were calculated through the surfaces. Observations were based upon aesthetic realism and deviation from trends within the raw data. The subjective nature of this analysis has been observed (chapter 4, section 4.3.3).

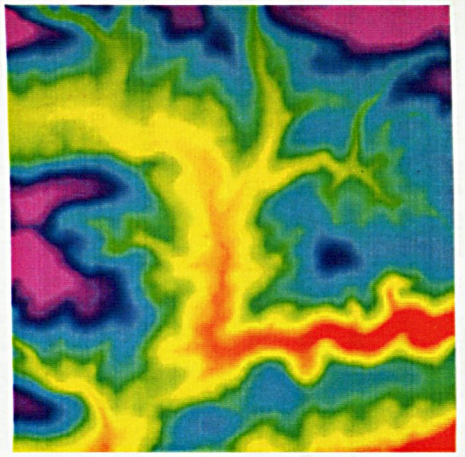
Each of the techniques provided a smooth surface with no glaring interpolation artefacts as suggested by the introspective analyses. In all cases the higher resolution provided a slightly clearer landscape. Differences identified through comparison showed that the linear TINLATTICE function generated a slightly angular landscape, whereas the same function with quintic smoothing generated the most rounded appearance. However, with both of these the interpolation only went to the edge of the data rather than to the edge of the region. For most parts of the landscape this was not a problem because of the density of contours. Within the southern corners, however, areas were found missing from the model. This was particularly highlighted within the southwestern corner of the site. This raises the question of the validity of data supply when it is in the form of contours since it is purchased in quarter sheets (5 x 5 km blocks). Although this is advantageous in one way - there is no interpolation where there is no data - it is restrictive in terms of



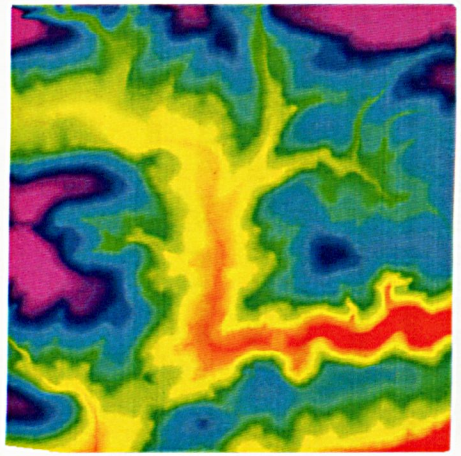
tinlattice linear at 50 m resolution



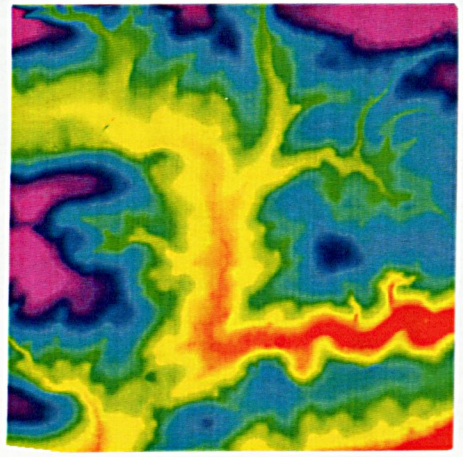
tinlattice quintic at 50 m resolution



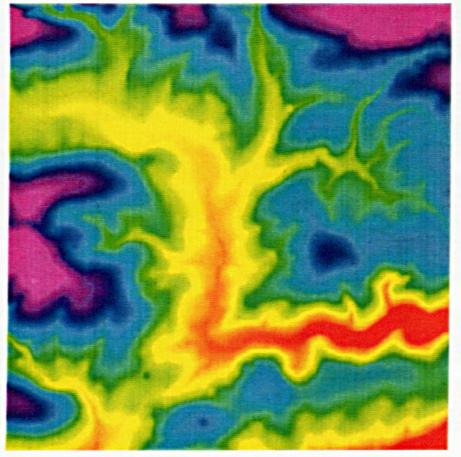
topogrid at 50 m resolution



tinlattice linear at 25 m resolution



tinlattice quintic at 25 m resolution



topogrid at 25 m resolution

Figure 5.1 Results from various interpolation methods at different resolutions. Displayed using a default linear colour-scaling based upon the frequency of cell values. Each area measures 10 x 10 km, with north to the top of the images.

practicalities. A more effective technique would be to interpolate a larger area and to then cut out the area of interest, although this incurs further expenses. With each interpolation method, the surfaces produced conformed well to the positions of the original contours derived from the Ordnance Survey with no clear errors or artefacts. A brief analysis of the type outlined in Carrara *et al.* (1997) revealed no problems indicating inaccuracy in relation to the raw data.

5.2.3 Summary of surface generation

The generation of DEMs from contour data has been outlined previously (Carrara *et al.* 1997) but there are a number of factors that may be added. Firstly, the influence of resolution upon this landscape appears to have been minimal in relation to the raw data. The one risk that may be identified is within those areas of very high contour density where the DEM resolution must remain at a higher resolution to avoid the potential problems of under-interpolation (i.e. too much data for each cell). This would result in the GIS needing to re-sample the raw data thereby generating further possible errors. The converse is also true because contours are presented in equal vertical spacings. If the DEM resolution needs to be very high to address very close contouring, the possibility of over interpolation within other areas with fewer contours is higher.

In terms of the interpolation technique, the TOPOGRID function appears to be more appropriate to the technique applied to the upland landscape with raw data in the form of contours. This technique provided minimum and maximum z values closest to the raw data and spatially filled the entire study area, interpolating to the boundary edges rather than to the edges of the contours. Further, it produced a more realistic surface.

5.3 Surface representation of the lower resolution landscape

5.3.1 Elevation-based surfaces

The nature of the raw data provided an elevation-based generalisation of the landscape and so elevation-based modelling may be considered to be less valuable than for surfaces derived from other forms of data. The application of elevation-based representations to the upland landscape highlighted well the nature and shape of the geomorphology (*cf.* Lewin 1969), particularly highlighting the position of the Great Wold valley and its seasonal tributaries (Figure 5.2). Particular features included the position of the Woldgate crossing the southeastern edge. Variable mapping of the vertical range provided no clearer information about the surface.

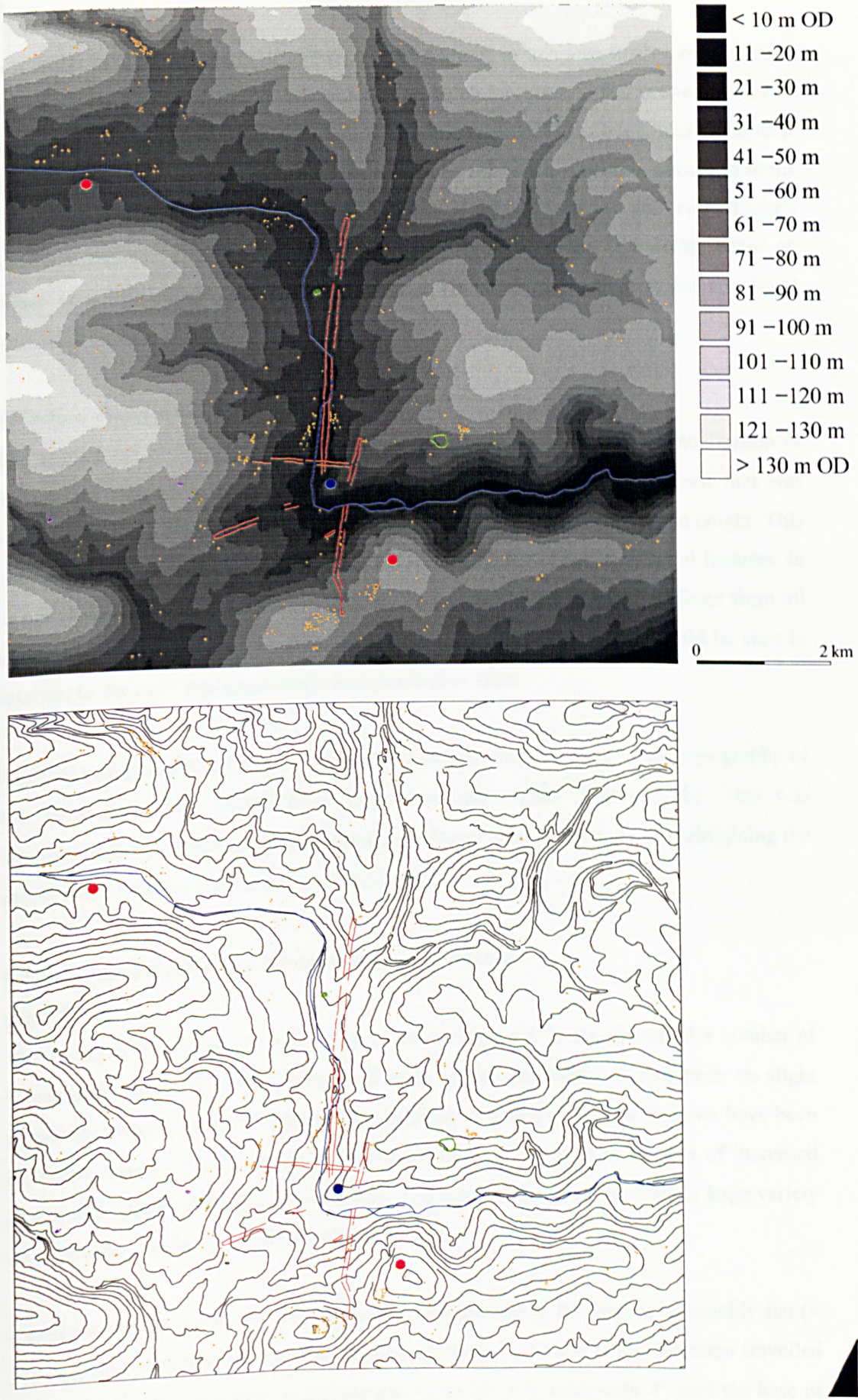


Figure 5.2 Elevation-based surface representations.

In relation to the distribution of archaeological features in this area further observations can be made. The locations of the cursuses can be clearly seen to run between areas of higher ground (except for cursus D) but running into areas of lower lying land along their lengths. Other than the cursuses there appears to be very little elevation choice in terms of the Neolithic monuments. The distribution of round barrows and ring ditches, however, presents a different picture. The largest concentrations of barrows occur on ridges or within valleys, but rarely in between. However, the pattern is not consistent across the study area.

5.3.2 Non-elevation-based surfaces

The application of light sources to the model presented a more realistic visualisation of the surface (Figure 5.3a). An advantage of this lay in the reduced contrast that was visible within the elevation height banded models due to the large changes in height. This 'smoother' surface was more appropriate for the overlaying of archaeological features. In terms of understanding the surface, this method of modelling allowed surfaces from all elevations to be compared equally and so the more level valley bottom could be seen in relation to the more topographically complex higher areas.

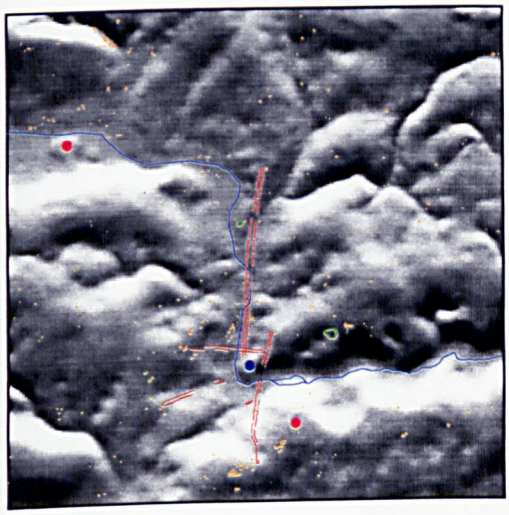
Vertical exaggeration (up to x 10) provided a clearer understanding of the topography of the landscape when viewed from various oblique angles (Figure 5.3b). This was augmented when archaeological features were draped across the surface, highlighting the relationship between the cursuses and topography.

5.4 Surface analysis of the lower resolution landscape

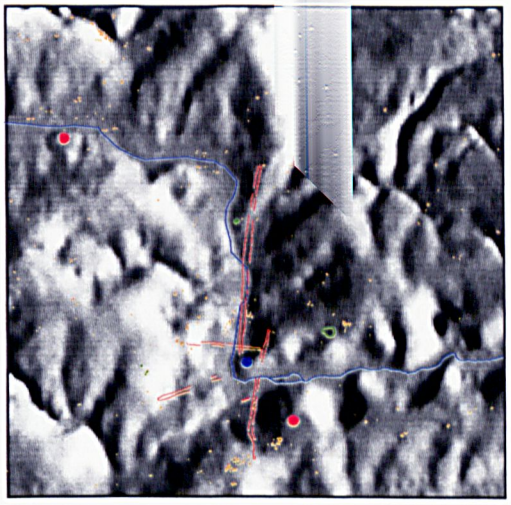
5.4.1 Slope

The location of monuments in relation to slope (Figure 5.4) has identified a number of trends chronologically. The positions of each of the long barrows have been on slight slopes (between 1° and 2°) whereas the positions of both of the great barrows have been on flatter land (< 1°). However, in both cases they lie just near to an area of increased slope, indicating a directional positioning. The areas of the cursuses cover a large variety of slopes but can be measured in relation to each.

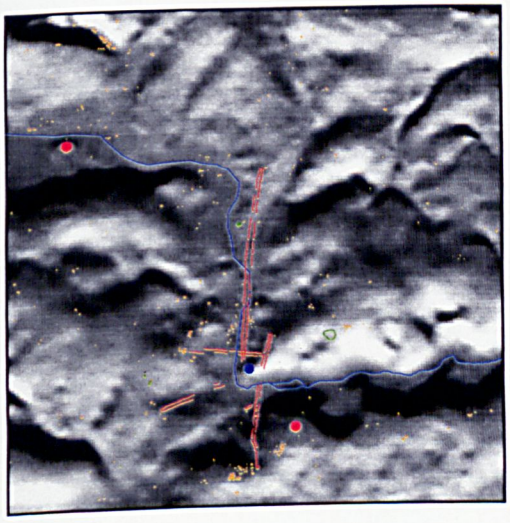
Cursus A (south-north) - At the southern end of the feature the land is reasonably flat (< 3°) and this continues through the dog-leg. However, as soon as the direction travelled becomes straight again there is an increase in the slope to more than 4° until the base of the valley is reached and the land levels off to less than 3° again. Once this area is



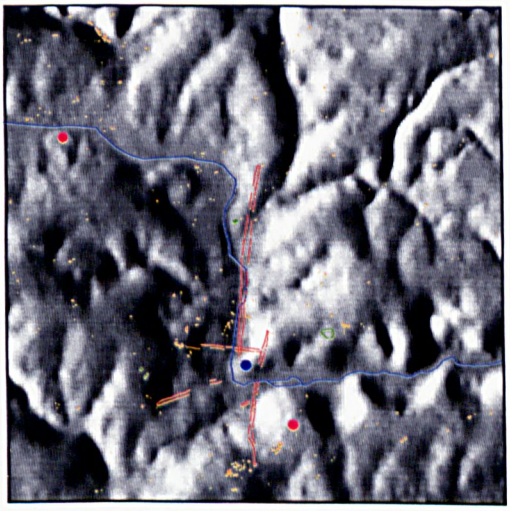
Lit from the north



Lit from the east



Lit from the south



Lit from the west

Figure 5.3a Hillshade models with light source in different positions. Each area measures 10 x 10 km, with north to the top of the images.

Figure 5.3b 100 m interval lattice and archaeological features draped over the surface model using a x 10 surface exaggeration (looking northeast).

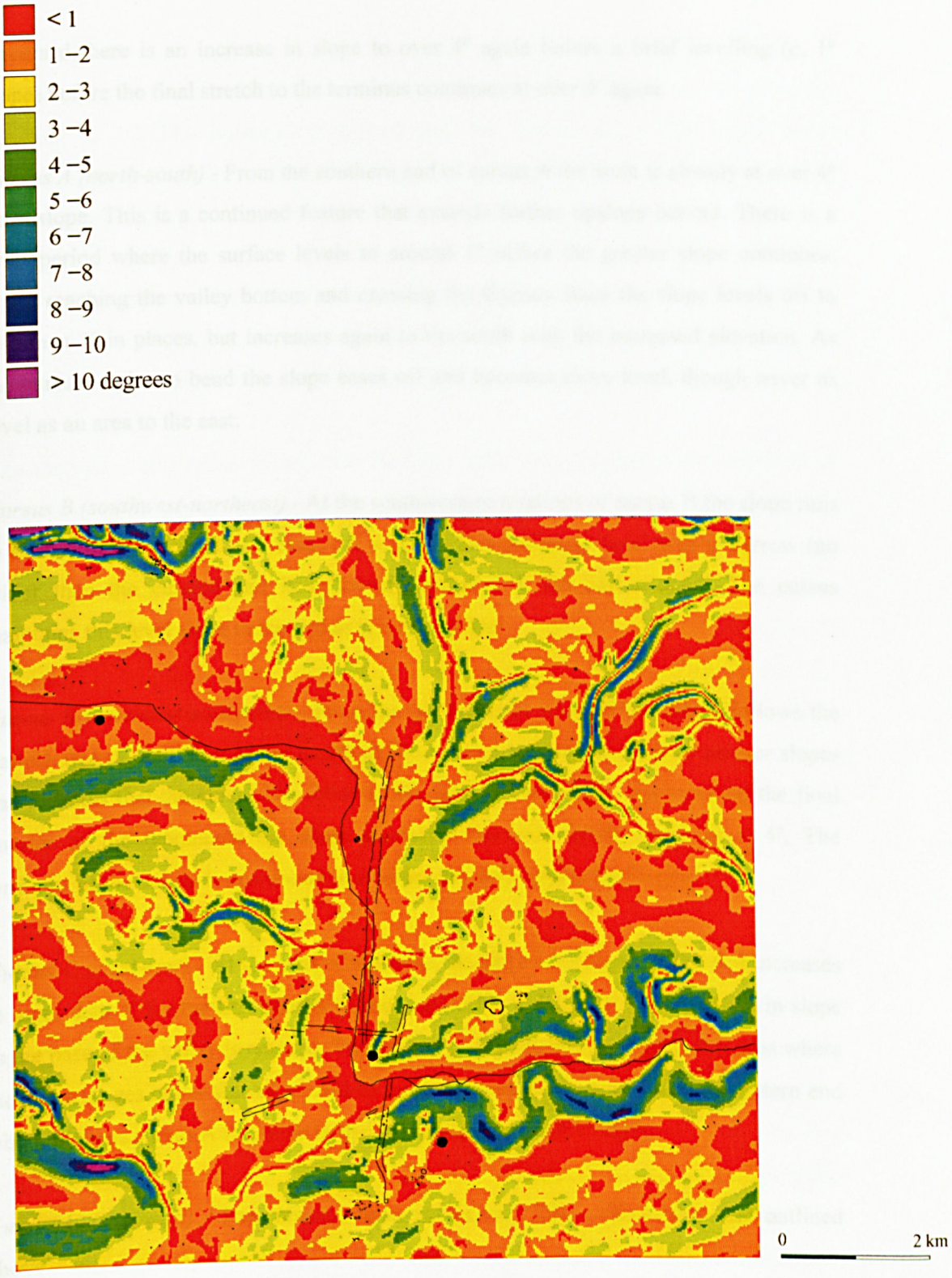


Figure 5.4 Slope model derived from the DEM.

traversed there is an increase in slope to over 4° again before a brief levelling (*c.* 1° slope) before the final stretch to the terminus continues at over 4° again.

Cursus A (north-south) - From the southern end of cursus A the walk is already at over 4° downslope. This is a continued feature that extends further upslope behind. There is a brief period where the surface levels to around 1° before the greater slope continues. Upon reaching the valley bottom and crossing the Gypsey Race the slope levels off to less than 1° in places, but increases again to the south with the increased elevation. As the cursus begins to bend the slope eases off and becomes more level, though never as level as an area to the east.

Cursus B (southwest-northeast) - At the southwestern terminus of cursus B the slope runs in excess of 4° but gradually eases off to *c.* 1°. This relatively level area is narrow (no wider than the cursus) and is followed precisely by the cursus itself. The cursus maintains this level slope to the end as it is transcribed.

Cursus B (northeast-southwest) - From the northeast the route of the cursus follows the flattest area of land. Part of the length of the cursus lies between areas of steeper slopes and it seems that the cursus has followed the path of least slope. Approaching the final quarter of the monument the slope gradually increases finally reaching < 4°. The terminus of the cursus is positioned just before the slope gradually flattens.

Cursus C (west-east) - At the start of the route the slope is of about 2° but this increases to more than 4° for the first quarter of the route. This is followed by a decrease in slope as the base of the valley is reached. The majority of the cursus lies within this area where the slope ranges either side of 1°, before increasing rapidly to over 4°. At its eastern end where it meets cursus A the slope is slightly reduced to about 2° again.

Cursus C (east-west) - The converse route shows very little difference to that outlined above.

Cursus D (north-south) - At the northern end of cursus D the terminus lies on a relatively flat surface (*c.* 1°). This increases briefly to just over 3°, but the slight bend in the plan of the northern half appears to largely avoid this. The rest of the cursus lies at between 0° and 2°, following the centre of this slope for the northern half of the monument, but then keeping on the eastern edge of this area in its southern half.

Cursus D (south-north) - The southern end of cursus D lies within an area of relatively flat land (*c.* 1°). This remains constant up until the final section as the cursus bends slightly. At this point the slope briefly increases to around 3°, but soon returns to less than 2° up to and beyond the northern terminus.

The monolith lies at a slope of about 3.5°, although it is placed upon a rise in land that is perhaps too localised for such analysis. Maiden's Grave henge lies on the relatively flat land within the valley floor.

The analysis of slope demonstrates that there is a difference of approach within the group of cursuses. The most remarkable difference is the position of cursus D that maintains a relatively flat slope for its entire route, compared to the other cursuses that follow a range of slopes as they run down the valley sides rather than along them. Also apparent is the way that cursus B precisely follows a narrow path of flatter land compared with the surrounding landscape. Cursus A is interesting since its dog-leg at its southern end appears to have been constructed to avoid increased slope. A further observation is that the junction between cursuses A and C is on an area of flat land in relation to the directly surrounding landscape, though it is interesting that the route of cursus A continued to the north onto increased slopes.

5.4.2 Aspect

Aspect modelling reinforced what could be seen from the application of a light source (Figure 5.5). In relation to the archaeology very little could be observed. Aspect does not appear to have been an influential feature in the laying out of the cursuses, unlike the linear ditches on the Wessex chalklands (*cf.* Llobera 1995). All but cursus B traverse a range of cardinal aspects. The monolith lies in a southwest-facing area, which is interesting in relation to cursus B that appears to be sighted towards it from this direction (see below). The positions of the long barrows demonstrates that all three observe a southerly or westerly aspect. The Kilham and Denby long barrows occupy areas along the boundaries of the aspect areas (assuming cardinal classifications), whereas the Rudston long barrow lies firmly within an area of southerly aspect. The implications of this suggest that, if a territorial function is to be assumed (*cf.* Lock and Harris 1996), then the territories of each would be more likely to point towards the south and west. However, such an analysis of only the cardinal aspects is limiting for interpretation

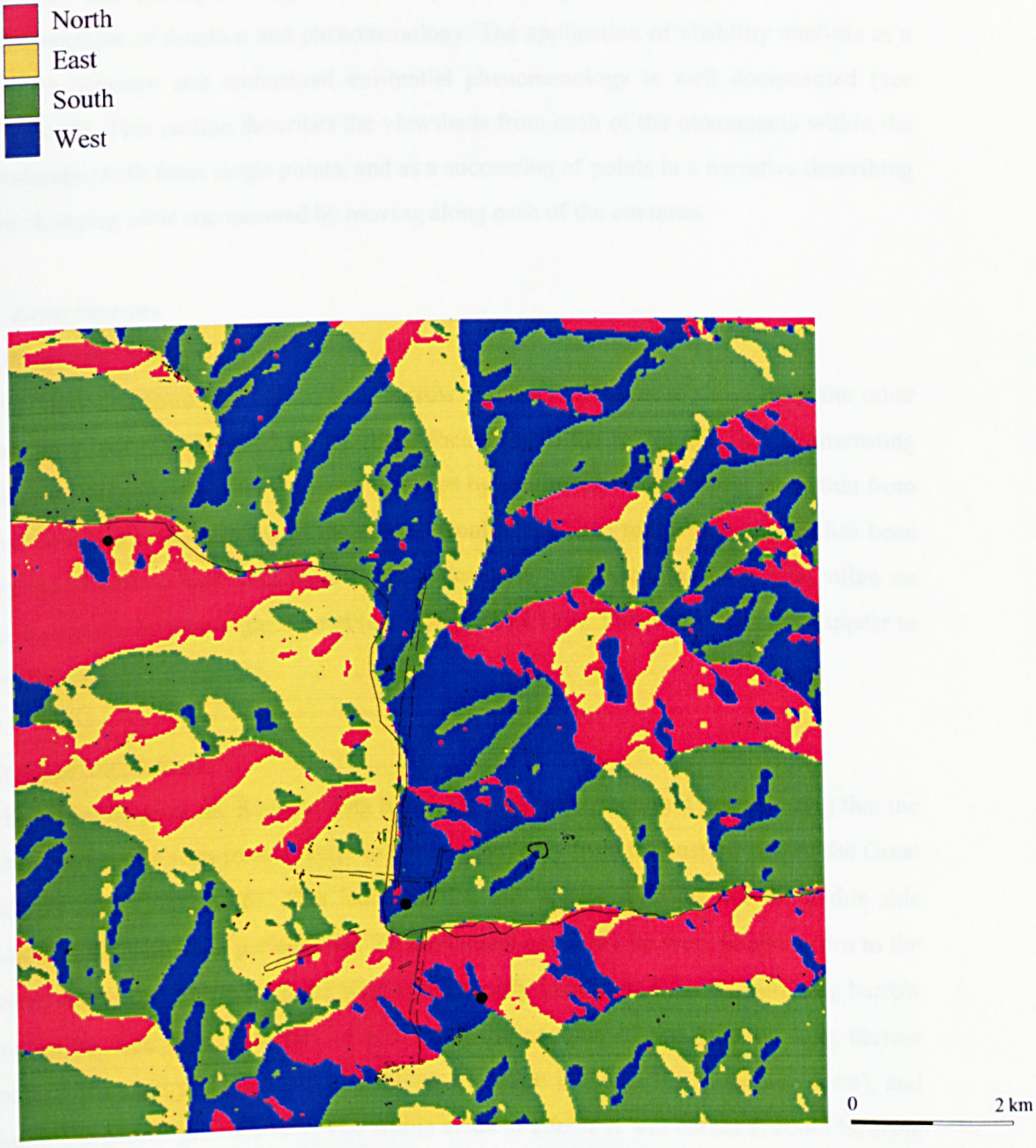


Figure 5.5 Aspect model derived from the DEM.

purposes since it creates false boundaries. Therefore further consideration may only be taken in relation to other forms of analysis.

5.4.3 Visibility

One of the principal study features of archaeological landscapes has been the interpretation of function and phenomenology. The application of visibility analysis as a tool to *measure* and understand existential phenomenology is well documented (see chapter 3). This section describes the viewsheds from each of the monuments within the landscape, both from single points, and as a succession of points in a narrative describing the changing view encountered by moving along each of the cursuses.

a. Long barrows

Kilham long barrow

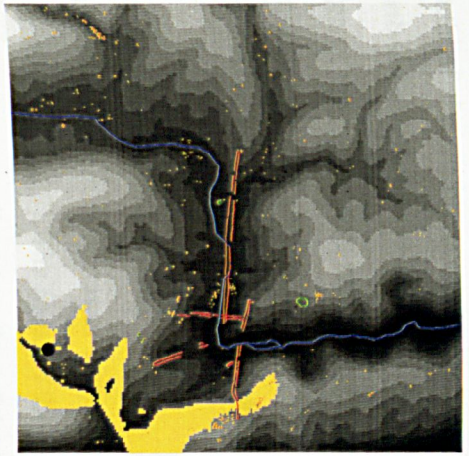
The viewshed from the Kilham long barrow was very different to those from the other two long barrows (Figure 5.6). Its visual focus was to the southeast. This is interesting since the alignment of the ditches is northeast by southwest, which would mean that from the viewshed area, the view of the barrow would have been to the side of it. It has been argued elsewhere that long barrows were designed to be seen from the side, often on false crests below the highest point (e.g. Tilley 1994:159). This would certainly appear to be the case for this feature.

Rudston long barrow

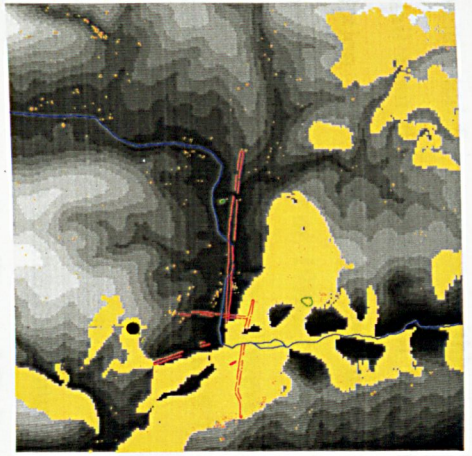
The visual focus of the Rudston long barrow is to the east, though it is interesting that the site could not be seen from directly to the east, but only from the eastern side of the Great Wold valley (Figure 5.6). This indicates that any approach to the site from this side would have included a period when the monument could not be seen, unless a turn to the south was made. The area to the west is not clearly visible, and the Kilham long barrow cannot be seen. Sites that can be seen from the position of the Rudston long barrow include the Denby long barrow (on the near horizon immediately to the southeast), and Southside Mount great barrow. The whole areas of cursus A and cursus E could be seen, but very little of the other cursuses. The visual focus of the site cannot be as well defined as for the Denby long barrow (see below).

Denby long barrow

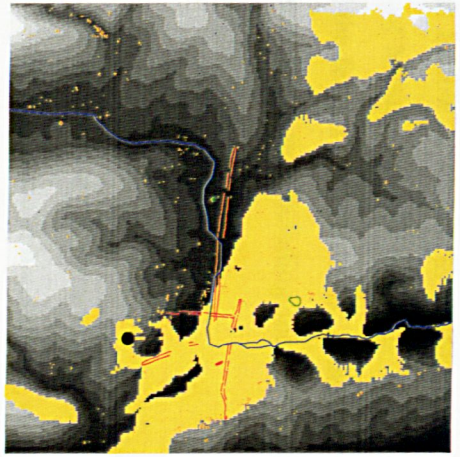
The visual focus of the Denby long barrow is eastwards, along the southern section of the Great Wold valley aligned west-east, although focused particularly on the bend in the



Viewshed from the Kilham long barrow



Viewshed from the Rudston long barrow



Viewshed from the Denby long barrow

visible areas

Figure 5.6 Visibility calculations from the long barrows.
Each area measures 10 x 10 km.

valley around the modern village of Rudston (Figure 5.6). To the west very little can be seen. Visible monuments within the area include the Southside Mount great barrow (lying near the horizon and possibly visible in profile). To the northwest the nearby Rudston long barrow can also be seen on the horizon, although the Kilham long barrow cannot be seen. The monolith is entirely visible from this position as are the majority of the cursus monuments. In terms of chronological understanding, the most important features within this viewshed are the distribution of the other two long barrows, and the fact that one is visible on the horizon, as this may have influence the location of the Denby long barrow. Also significant is the visual focus upon the area of Rudston – an area that became central to many other features shortly afterwards.

b. Cursus monuments

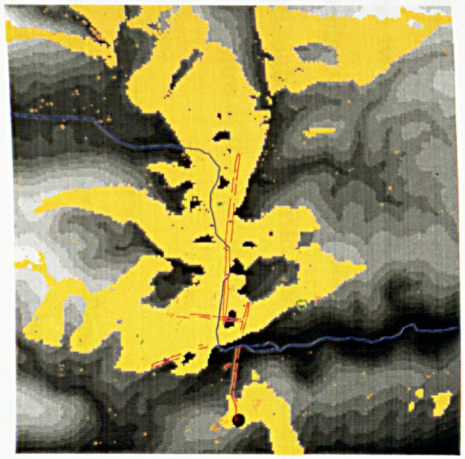
Studies have also been directly focused upon cursuses using visibility (Tilley 1994). Cursus landscapes may be tailored to visibility analysis since they provide "routes" through the landscape. Although it has been argued that cursuses may not have been constructed for movement within them, they provide a linear focus that provides more detail than the single-focus of barrows. Consequently the analysis of positioning in relation to the landscape need not be investigated from a statistical background (as opposed to Lake *et al.* 1998). Not all of the terminals have been located from the aerial photography in the region. However, the views from those terminals that have been located can provide insight (Figure 5.7).

Cursus A (southern terminus)

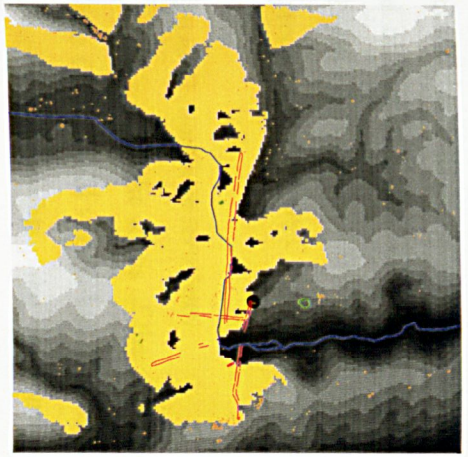
The view from the southern terminus is focused along the north-south aligned section of the Great Wold valley (Figure 5.7). From this point it is possible to see the positions of the Rudston and Denby long barrows, although the Kilham long barrow lies just to the south of the visible area. Southside Mount great barrow is visible in profile to the northeast on the horizon. The hengiform structure of Maiden's Grave is visible, and the edge of the visible area runs through the centre of the feature at Greenlands. Almost the whole of each of the other cursuses is visible from this point including the northern terminus of cursus A, although its central area cannot be seen.

Cursus A (northern terminus)

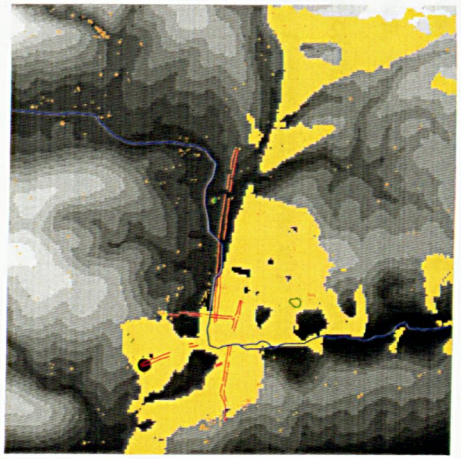
From the northern terminus of cursus A it is possible to see many other archaeological features (Figure 5.7). The focus of the viewshed is to the west, though highlighting most of the north-south aligned section of the Great Wold valley. From this point it is possible



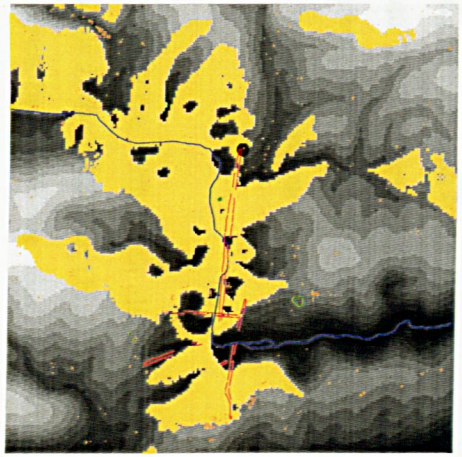
South terminus of cursus A



North terminus of cursus A



South-west terminus of cursus B



North terminus of cursus D

visible areas

Figure 5.7 Visibility calculations from the cursus terminals.
Each area measures 10 x 10 km, with north to the top of the images.

to see virtually the full lengths of all of the other cursuses but not the central section of cursus A, though its southern terminus is visible on the southern horizon. On the southeastern horizon Southside Mount is visible on the horizon and, to the west the area occupied by the Rudston and Denby long barrows is also visible on the horizon. The edge of the viewshed runs between the two, indicating that they may both have been visible in profile given the increased elevation of the earthworks and a more accurate data model.

Cursus B (southwestern terminus)

From the southwestern end of cursus B the visible area is focused towards the northeast, in the direction of the cursus (Figure 5.7). The rest of cursus B runs down the centre of the viewshed from this point and lies central to a narrowing of the viewshed. This viewshed focuses towards the monolith and along the cursus itself. It seems possible therefore that the cursus was laid out on the basis of visibility from this point. The whole of the feature (as transcribed) can be seen from this point. Other features that can be seen include the Rudston long barrow and the Denby long barrow, both lying on the horizon to the northwest. Also, to the east Southside Mount great barrow lies on the horizon. Almost all of cursus A is visible from this point except part of the southern terminus. The eastern half of cursus C is visible, but the northern two thirds of cursus D cannot be seen.

Cursus D (northern terminus)

From this point the focus of the viewshed is again along the north-south aligned section of the Great Wold valley, but with an extension towards the northwest (Figure 5.7). On the horizon from this point are Southside Mount great barrow to the south and Willie Howe great barrow to the west, although none of the long barrows within the region were visible. The position of the monolith lies outside of the viewshed and the visibility to other cursuses is not clear. Most of cursus D is visible, but fragmented by blank areas. The two ends of cursus C (as seen) could be seen, but not the central section, and a similar scenario was present for cursus A. Most of cursus B lay outside of the viewshed, although its northeastern end was visible. Maiden's Grave henge was also visible within the centre of the viewshed.

Walking the cursuses

Cursus A (south to north –Figure 5.8*)* - Walking along the first section of the cursus up to the bend there is a contrast between the distant view, which remains quite constant, and the closer view, which increases to the west as the hill is passed. The plan of cursus

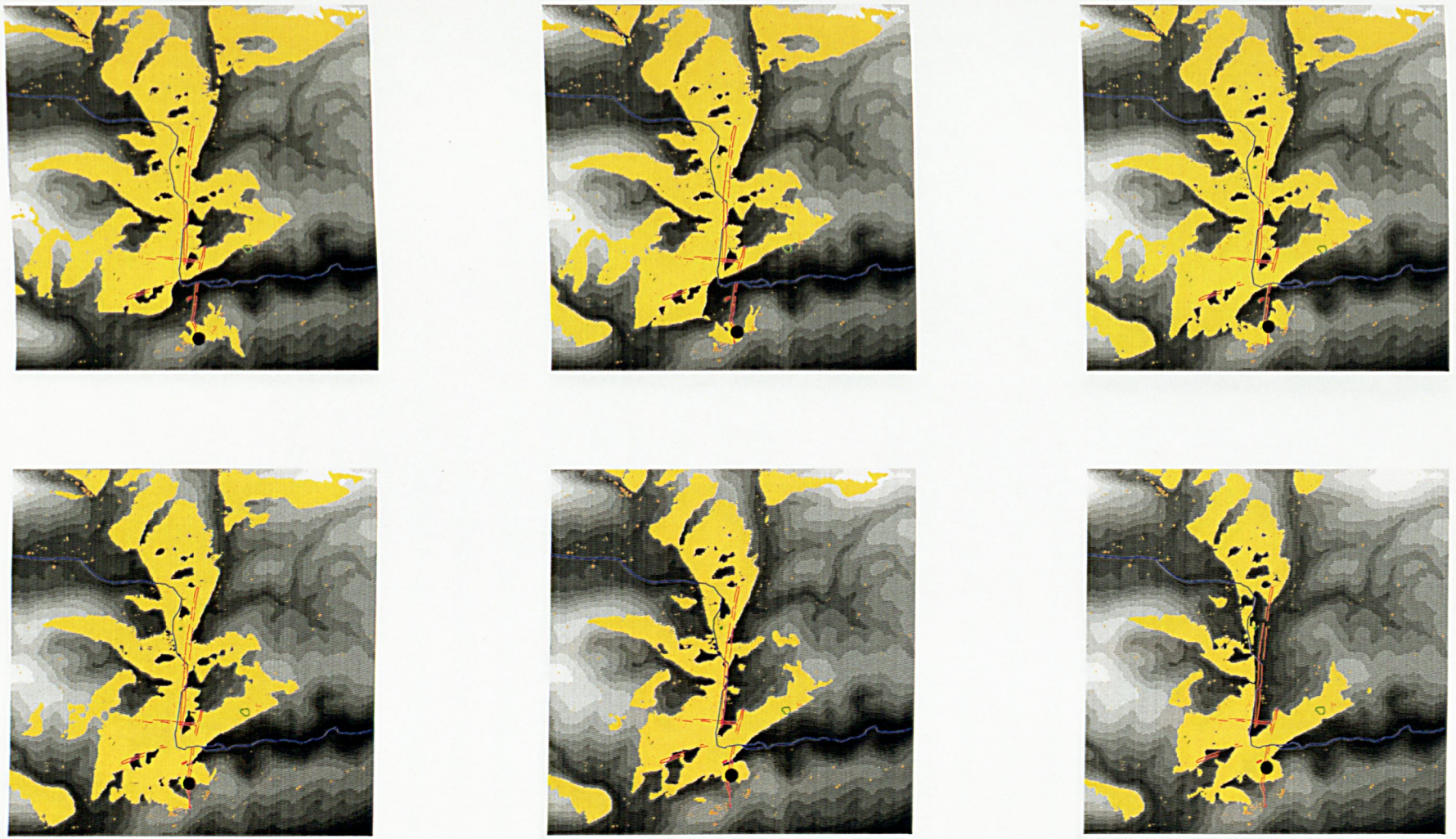


Figure 5.8 Visibility calculations walking along cursus A from south to north.
Each area measures 10 x 10 km.

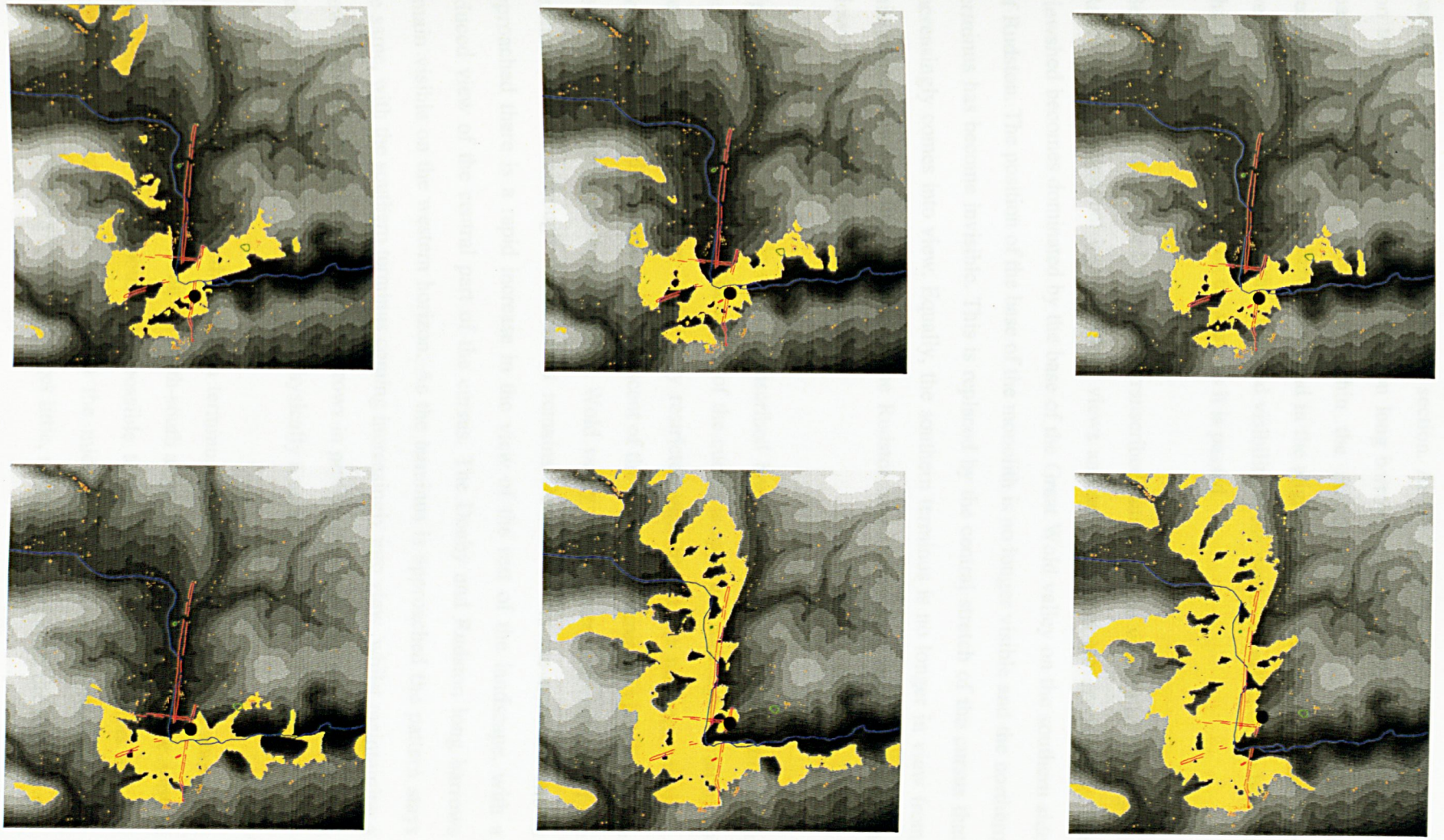


Figure 5.8 cont. Visibility calculations walking along cursus A from south to north.
Each area measures 10 x 10 km.

A with its sinuous form highlights point of change. The view from the southern terminus is outlined above, and shows views of most of the other cursuses, including the northern terminus of cursus A but not its central section. At this point the northern terminus lies on the horizon. The Denby and Rudston long barrows and the Southside Mount great barrow appear to be prominent within the middle distance and close distance respectively. At the point before the bend in the alignment, the view is still similar with very little change except for the increased visibility to the west. The effect of the bend in this feature is very limited on the view as it is passed.

Between the bend and the break in the transcribed cursus (in the vicinity of the Gypsey Race) there is a gradual loss of distant views and an increase in closer visibility. The viewshed becomes dominated by the base of the Great Wold valley on the southern side of Rudston. The position of the base of the monolith is no longer visible and the northern terminus has become invisible. This is replaced by the central stretch of the cursus that increasingly comes into view. Equally, the southern terminus is no longer in view from this point. However, the positions of the Rudston and Denby long barrows remain in view on the western horizon.

Upon reaching the far side of the transcribed break, the pattern is still similar. An increased visibility of the southern half of the cursus is apparent, although the terminus can still not be seen. There is still very restricted visibility of the northern terminus. However this rapidly changes with the ascent of the slope with increased visibility of the north-south aligned section of the Great Wold valley and an increased visibility of the northern section, although the terminus remains from view. As the northern end is approached there is a rapid increase in the view of the rest of the landscape, with a reduced view of the central part of the cursus. The Denby and Rudston long barrows remain visible on the western horizon. As the terminus is approached the pattern stays the same, with the southern terminus coming increasingly into view, whilst maintaining a view of the Denby and Rudston long barrows in profile. However, the northern terminus remains beyond the viewshed until it is physically reached.

Cursus A (north-south) - At the northern terminus of the cursus, as outlined above, the view is focused to the west along the north-south aligned valley. The view to the north is very restricted, but to the south it is possible to see the southern terminus and the southern section of cursus A, although the middle section is out of the viewshed. Walking southwards, the viewshed changes little, maintaining a view of the Rudston and

Denby long barrow area on the western horizon. The view changes rapidly with the drop in elevation with a reduction in the visibility of the north-south aligned section of the valley.

At the break in the transcribed cursus, across the Gypsey Race, the view is focused on the central part of the cursus, with the area ahead more visible than the area behind, although the southern terminus is no longer visible. The Denby and Rudston long barrow area is still visible. As the slope is ascended the viewshed expands behind within the north-south aligned valley again and the northern terminus becomes visible, also behind. The area ahead is increasingly visible, although the slope itself obscures the immediate foreground. This pattern remains as the bend is passed. Unlike the approach to the northern terminal (on the south-north direction route) the southern terminus is visible at an increased number of stages on the route. With the rising path it is also possible to see Southside Mount in profile on the southeastern horizon and the Denby and Rudston long barrows remain in view.

Cursus B (southwest-northeast – Figure 5.9*)* - As outlined above, the view from the southwestern terminus of cursus B covers the whole of the monument, and much of the central area of the cursus cluster. The position of the monolith is visible, and Southside Mount great barrow and the Rudston and Denby long barrows lie on the southeastern and northwestern horizons respectively. The focus of the view is towards the northwest and the area of the monolith. The view remains very much the same until about a third of the way along the first transcribed section of the two. At this point the central area of the cursus is lost from view, in the area almost precisely defined by the break in the transcribed monument. With increased movement down the slope even less is visible and at about half way along the first section of the cursus the northeastern section falls from view. The viewshed is present again from the position of the monolith and behind it. However, as the end of the first section is approached, the area becomes visible again with a viewshed very similar to that from the southwestern terminus. Here the Rudston long barrow has been lost from view, although the positions of the Denby long barrow and the great barrow of Southside Mount remain visible on the horizon.

At the beginning of the second section of the transcribed cursus the view is more disjointed. The southwestern terminus can be seen, but much of the central area is out of view. The Denby long barrow lies on the horizon as does the Southside Mount great barrow, though pushed just beyond the edge. The view to the monolith is no longer clear

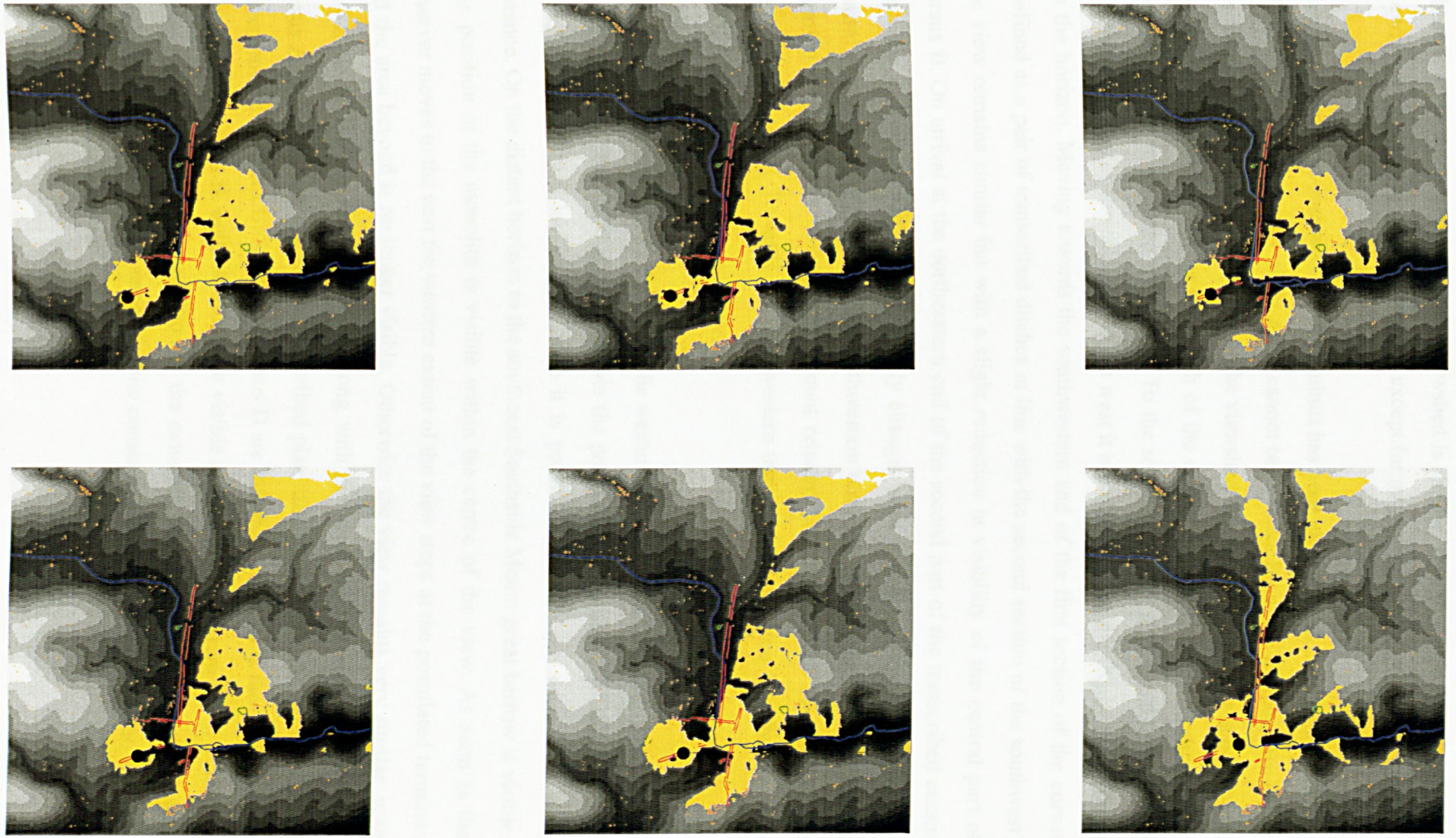


Figure 5.9 Visibility calculations walking along cursus B from southwest to northeast.
Each area measures 10 x 10 km.

although the area around it can still be seen. From here the edges of the viewshed are defined by both terminuses of cursus A. At the northeast end of the transcribed features (there is no terminus at this end) the viewshed is similar, though with a more open local view, with visibility of most of cursus B except for its centre.

Cursus B (northeast-southwest) - No terminus has been identified on the northeastern end of cursus B and so the start of the route cannot be defined. From the northeastern end of the transcribed features the majority of the viewshed lies behind. In front it is possible to see the southwestern terminus and much of the central area of the cursus, although an area in front of it is hidden from view. To the south-southwest it is possible to see the southern terminus of cursus A, and to the west it is possible to see the Denby long barrow on the horizon. Moving towards the southwestern end of the first section of the cursus (defined as a pair of transcribed ditches in line with the second section of the southwest) the view remains similar but with a slight reduction in visibility of the central part of cursus B. On arrival at the northeastern end of the second part of the transcribed cursus the view in front remains similar. It only changes with an increase in visibility of the central area once it is reached. The southwestern terminus remains in full view for the duration. The visibility of Southside Mount remains constant as does the view of the Denby long barrow. Towards the southwestern terminus the Rudston long barrow also comes into view.

Cursus C (west-east – Figure 5.10*)* - At the western end of cursus C there is a slight kink in the cropmark remains that may indicate the position of a terminus. At this point the viewshed is eastward looking, although it is possible to see to the west for a short distance. On the distant horizon to the southeast Southside Mount great barrow is visible. The position of the monolith is visible within the centre of the view. As soon as the observer moves to the east the western extent of the view stops at the postulated terminus and the area beyond is no longer visible. Otherwise the view remains very similar, with the whole of the cursus within view along with the southern and northern halves of cursus A (with only the gap in the transcribed plan missing from view). With the initial movement the northern two thirds of cursus D are lost from view, as is the southwestern two thirds of cursus B, both of which are visible at the terminus. From about a third of the way along the cursus the position of the monolith becomes visible near the eastern horizon. The view to the east remains quite constant, although the view behind expands with the increased elevation.

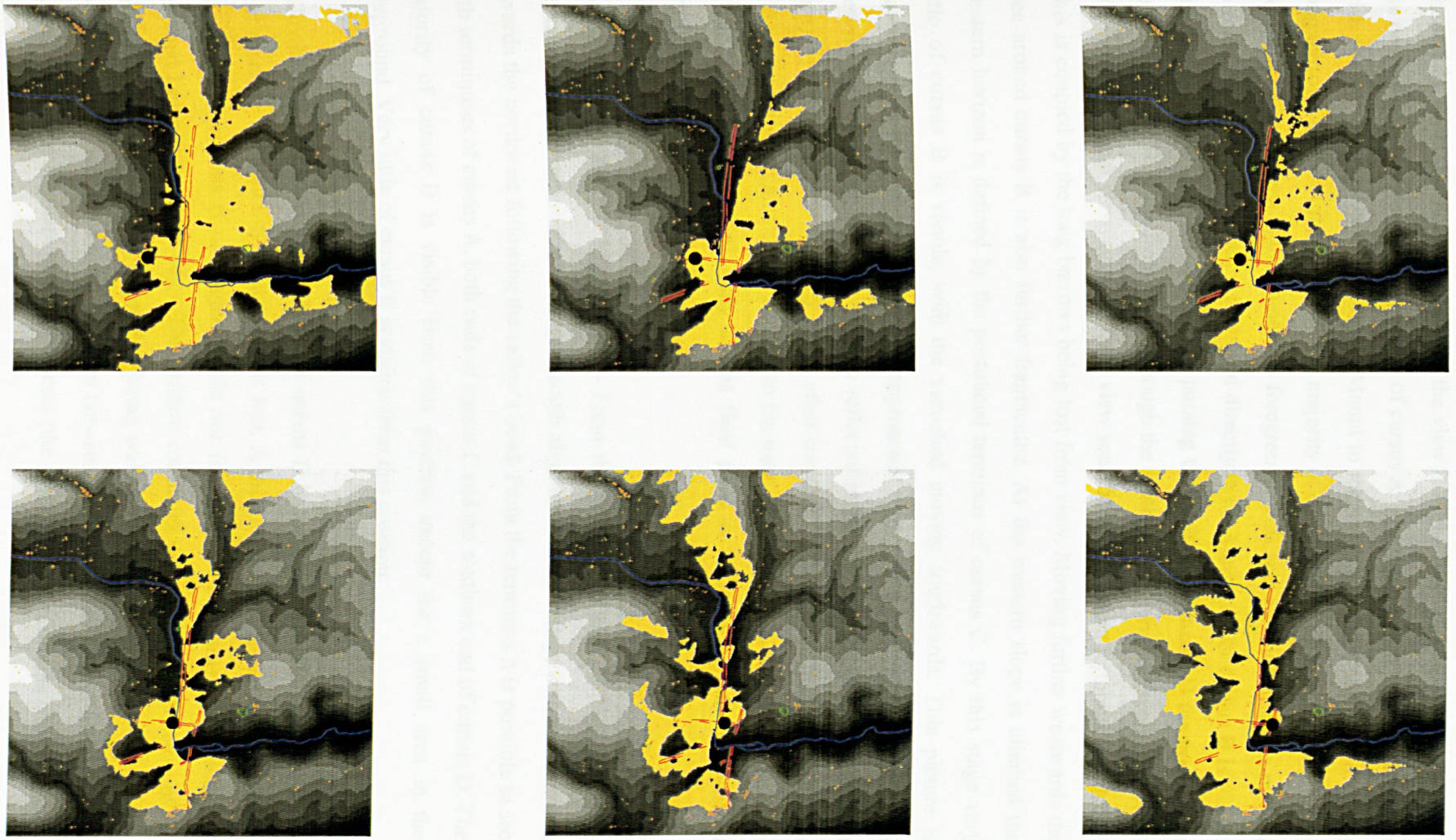


Figure 5.10 Visibility calculations walking along cursus C from west to east.
Each area measures 10 x 10 km.

Cursus C (east-west) - The eastern end of cursus C appears to be defined by the junction with cursus A which has been used to suggest that cursus A is the older of the two (see chapter 2). From this point the focus of the view is to the west with very little visible to the east other than the northern terminus of cursus A. The distant view is quite extensive, with the horizon marked by Southside Mount to the south and the Rudston and Denby long barrows to the west-southwest. The majority of cursus C is visible from this position except for a small area in the immediate foreground. This area remains invisible moving in this direction except when it is walked directly over. Almost all of cursus B is visible as are most of cursuses B and D. Upon passing the position of cursus D the area of the centre of cursus B is lost from view, although the southwestern terminus remains visible. With the movement westwards the large view seen from the eastern terminus is reduced. This is coupled by the long barrows being lost from view. Moving further westwards the area around cursus B is also further fragmented. As the western slope is climbed the western horizon is defined by the postulated terminus of cursus C. By this stage very little of cursus B is visible, with the viewshed moving southwards. This picture is maintained as the western terminus is approached, but with a general increase in the viewshed as elevation increases. This is reflected mostly behind the observer (to their right) with the increased visibility of the other cursuses, including the majority of cursus D. The terminus remains on the horizon to the west. The visibility of cursus D increases as the terminus is reached. Only at this final point is the area beyond the western terminus of cursus C visible.

Cursus D (north-south – Figure 5.11*)* - From the northern terminus of cursus D the viewshed is broad and follows the north-south alignment of the valley, with an extension towards the northwest following the valley's bend. From the terminus it is possible to see both terminuses of cursus A, both ends of cursus C and the southern end of cursus D. The majority of cursus D is visible from this position except for a small area in the foreground. Very little of cursus B is visible from this position.

Following the route southwards, more of cursus D becomes visible. However, within a short distance the visibility of cursus C is lost. A third of the way along the monument the northern terminus is no longer visible nor is most of the southern half, with the viewshed lining its western edge. This pattern continues with a fragmented view of all parts of cursus D other than the stretch being walked along. The visibility of the other cursuses remains restricted to the junction between cursuses C and D, and the terminals of cursus A. At the southern end of the cursus (the position of the terminus has not been

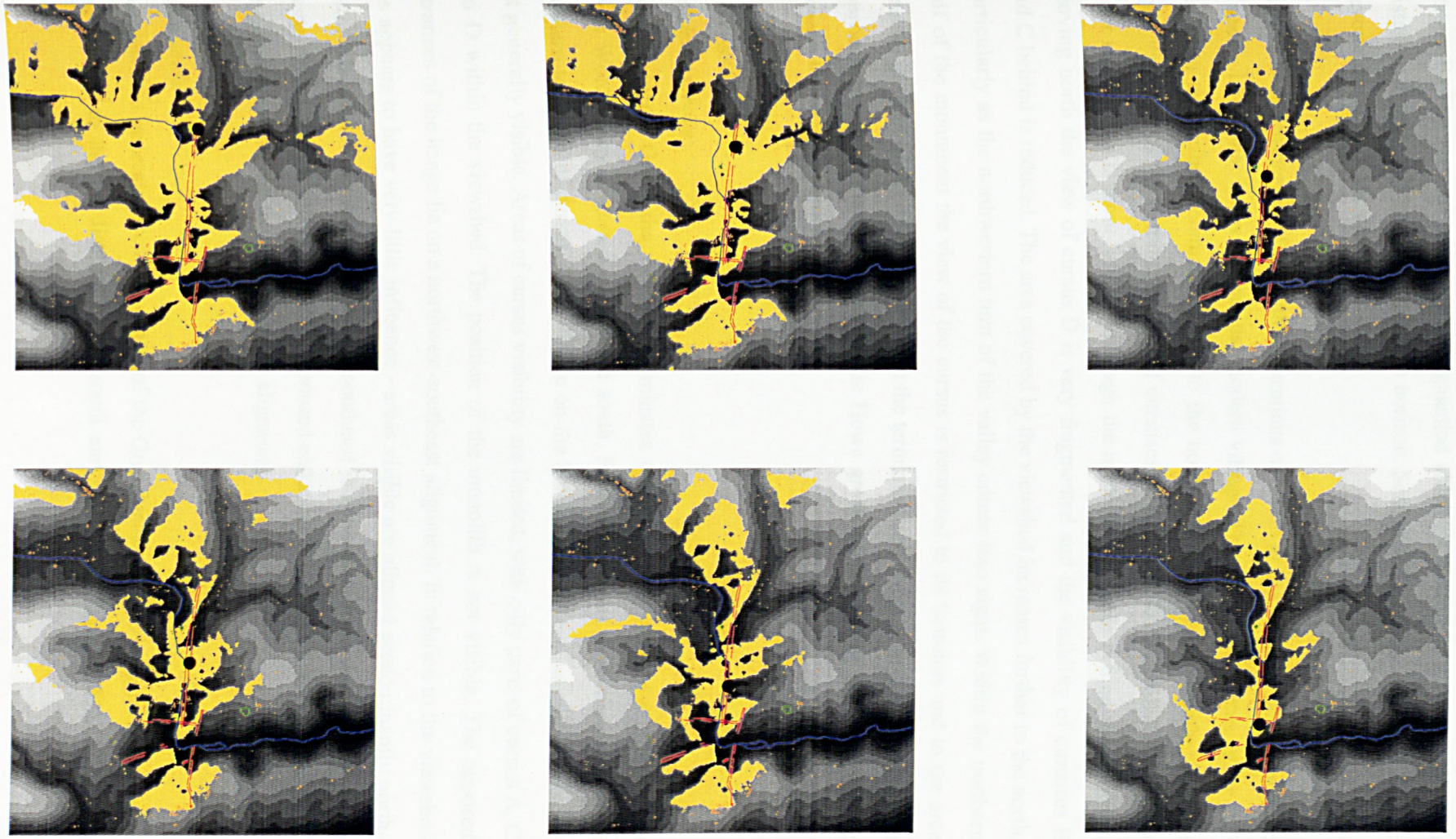


Figure 5.11 Visibility calculations walking along cursus D from north to south.
Each area measures 10 x 10 km.

determined) the view is more restricted than at the northern terminus. Parts of the northern and southern ends of cursus A are visible, as is the southwestern terminus of cursus B. The view of cursus D is fragmented although the terminus is visible in the distance, though only on an intermediate horizon. Southside Mount great barrow lies just beyond the edge of the view.

Cursus D (south-north) - The southern terminus of cursus D has not been determined and it seems likely that it lies beneath the modern village. The end of the cursus as far as it has been transcribed commands views to the north and south predominantly. There is good visibility of the terminuses/ends of cursuses A, B, C and D. The relationship with other monuments is more limited, although the monolith is visible behind the observer. Moving north the view of cursus D is very fragmented and the visibility of cursuses B and C behind is reduced. The area covered by the viewshed increases further to the north, particularly as the northwestern turn of the valley comes into sight. Within the northern half of the monument the view of the cursus is restricted to its terminus and to the area directly in front of the observer, although the terminus itself fades in and out of view. On approach to the northern terminus Willie Howe great barrow comes into view on the horizon to the west-northwest.

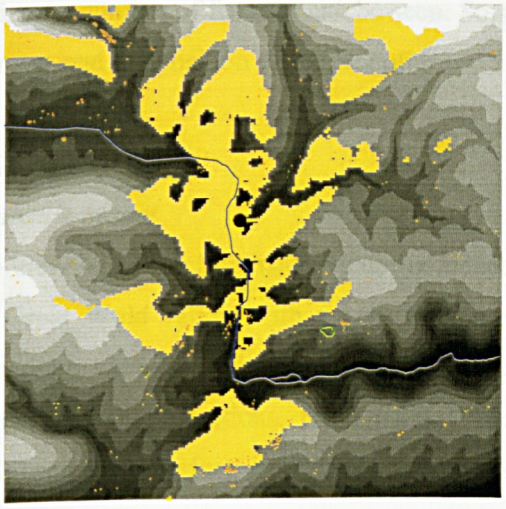
c. Henges

Maiden's Grave

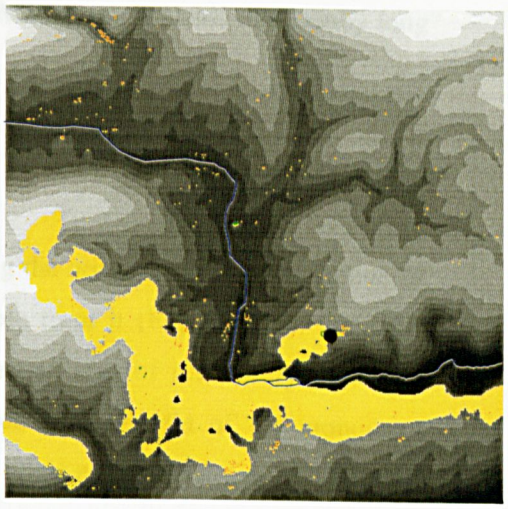
From Maiden's Grave the viewshed dominates the north-south aligned section of the Great Wold valley (Figure 5.12). To the south, Southside Mount great barrow and the southern terminus of cursus A are visible on the horizon, but otherwise monuments are not generally visible. Areas of cursus visibility are limited, with only parts of cursus A, C and D within the viewshed. The position of the monolith is not visible. The opposed entrances of the henge lie on a northwest-southeast alignment. In relation to the viewshed this appears to have very little influence - areas visible are aligned predominantly north-south. Also, the area immediately to the southeast is not visible from the position of the henge. It appears that this alignment of opposed entrances is not determined by visibility, but rather is in contrast to the north-south alignment.

Greenlands

The viewshed generated from the centre of the Greenlands possible hengiform feature is concentrated to the far distance to the south and southwest (Figure 5.12). Along the



Viewshed from Maiden's Grave henge



Viewshed from Greenlands hengiform feature

Figure 5.12 Visibility calculations from the henges.
Each area measures 10 x 10 km, with north to the top of the images.

horizon a number of features can be seen: Southside Mount, the Rudston and Denby long barrows and the position of the monolith.

d. Great barrows

Southside Mount

The viewshed from Southside Mount is focused along the north-south aligned section of the Great Wold valley, with a very large area visible from it (Figure 5.13). Only the immediate vicinity of the monument is visible before an area of invisibility of over a kilometre in all directions. Even without reconstructing the height of the monument itself, and keeping just the 1.7 m offset, a range of other monuments can be seen. All three of the long barrows can be seen, with the Kilham long barrow lying on the visual horizon. Similarly Maiden's Grave henge and Greenlands can be seen. Willie Howe cannot be seen however.

Willie Howe

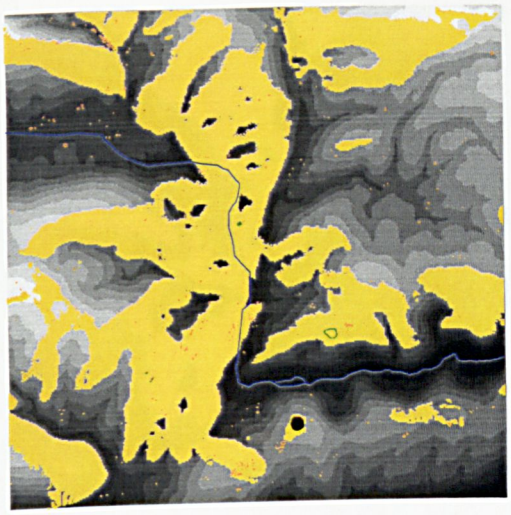
The viewshed from Willie Howe is focused upon the valley within the northwestern area of the region, extending to the west (Figure 5.13). No other monuments except for the northern terminus of cursus D are visible within the viewshed. This and the viewshed from Southside Mount are quite different, perhaps indicating territoriality (*cf.* Lock and Harris 1996). Further, it is notable that the viewshed from Willie Howe includes the area directly adjacent to the monument unlike that from Southside Mount.

e. The monolith

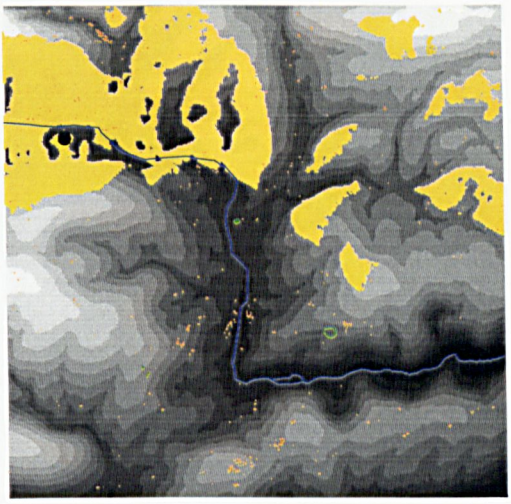
A second issue relating to visibility, also outlined in chapter 2, is the location of the Rudston Monolith. Visibility to the monolith is slightly different since visibility can only run in one way - it is not possible to stand on the monolith. Therefore an offset was given for the monolith's position relating to its height (7.7 m after Kinnes 1984 - see chapter 2) and a second observed offset was given (1.7 m) for the height of the individual observing. A viewshed calculated from the position of the monolith using these offsets provides a picture of areas from which the top of the monolith could be seen (Figure 5.14).

The results from this analysis can be categorised into a number of key areas:

- Using the current offsets it is possible to see the top of the monolith (at 7.7 m) for the full length of all five of the possible cursuses.

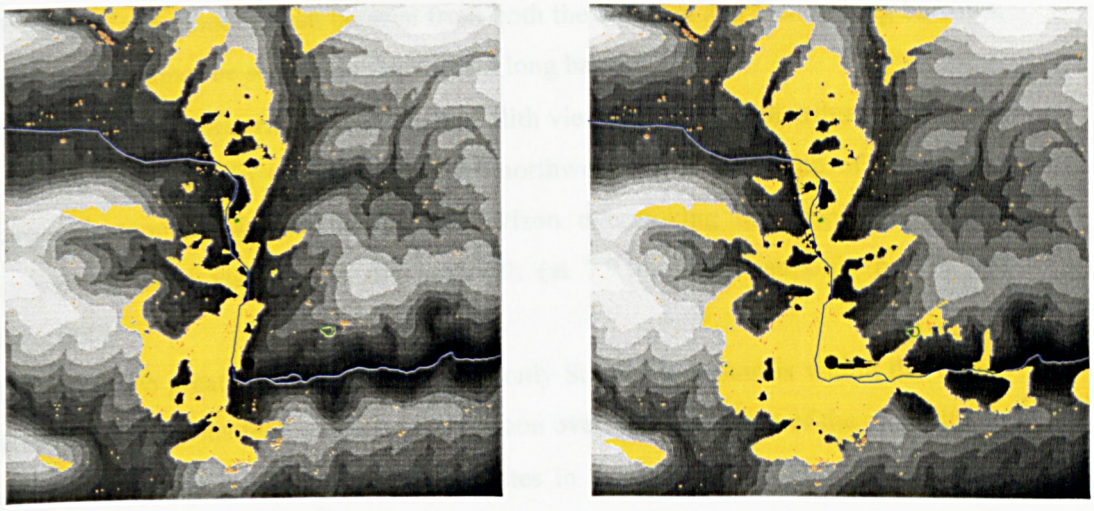


Viewshed from Southside Mount



Viewshed from Willie Howe

Figure 5.13 Visibility calculations from the great barrows.
Each area measures 10 x 10 km, with north to the top of the images.



Viewshed from the base of Rudston monolith

Viewshed from the top of Rudston monolith

Figure 5.14 Visibility calculations from the monolith.
Each area measures 10 x 10 km, with north to the top of the images.

- The top of the monolith can be seen from both the Rudston and Denby long barrows, although it cannot be seen from the Kilham long barrow.
- There is no clear pattern between the monolith viewshed and the distribution of round barrows. However, in two places (in the northwest and in the south of the region) large clusters of barrows lie on the horizon overlooking the monolith. This is interesting since visibility to the monolith (at 7.7 m high) can only run in one direction.
- From the two great barrows in the region, only Southside Mount is within the visible area and, again, this feature lies on the horizon overlooking the top of the monolith.
- From the limited number of occupation sites in the area, all of the Grimston Ware sites, and the Towthorpe Ware site are within the visible area. However, some of the Peterborough Ware sites lies outside of the viewshed. Peterborough Ware sites are likely to be later in date than the other two (see chapter 2). The number of settlements recorded are insufficient to provide clear evidence of change, though it may be hypothesised that the later settlements were located with less of a focus towards the monolith.
- When compared to the viewshed from the position of the monolith, but at an observer height of 1.7 m, very few differences can be discerned. The visibility from the Rudston and Denby long barrows is sustained, as is the visibility of the cursuses. The only difference lies in the area directly west of the monolith extending further down the Great Wold valley. This area is not visible without the added elevation of the monolith.

f. Summary of visibility analyses

In terms of method, the upland landscape is a useful example. A valley lies in the centre of the landscape and therefore very few viewsheds extend beyond its limits, reducing the problems of edge effect (*cf.* Gillings and Wheatley 2000). Long barrows have been interpreted as territorial markers through previous GIS studies elsewhere (Lock and Harris 1996). The present study is deficient in the population of long barrows, although there are two visual foci. The first is westerly looking with the viewshed from the Kilham long barrow, and the second is easterly looking from the Rudston and Denby long barrows (if the latter two are considered as a group). The viewsheds do not overlap significantly, in keeping with the territorial theory. If current thinking is correct, and the development of great barrows post-dated the construction of long barrows, then the positioning of the Southside Mount monument appears to ignore this division and rather bridges the two territories. Further, a comparison between the viewsheds of Southside

Mount and Willie Howe indicate quite a different focus with restricted overlapping. It is possible that this reflects a re-definition of territoriality after the long barrow phase.

Following the territoriality theme, the development of the cursuses alter this pattern yet again. From the northern terminus it is possible to see both of the great barrows on the horizon at the same time, thereby linking the two territories. Further from the southwestern terminus of cursus B, Southside Mount and the Rudston and Denby long barrows could be seen on opposing horizons. It seems possible that the laying out of the cursuses drew territories together in a different way so that the great barrows may be interpreted as re-defining territories.

The cursus-walking exercises also demonstrated a number of key issues in relation to the changes in the viewshed. With cursus A it appears that the relationship with features on the middle-distance horizon is very significant, with close attention paid to the Denby and Rudston long barrows to the west and, to a lesser extent, the Southside Mount great barrow. The relationship with the long barrows is apparently constant to the extent that it may have played a role in the route of the cursus, although a more detailed study would be needed for certainty. On the basis of parallel interpretation of landscape using *anticipation/arrival* or *space/place* concepts to understand directional movement (*cf.* Tilley 1994), it appears that the cursus was travelled from south to north, if a procession is assumed (see chapter 2). Following this direction the far terminus is visible at the start, but soon becomes hidden. It is then only seen at the very end of the route when it is reached physically. The converse direction, from north to south does not display this pattern, with the southern terminus visible on a number of occasions during the route, and therefore does not conform to the *anticipation/arrival* theory.

The pattern from cursus B is not as clear, perhaps due to the lack of a northeastern terminus. There appears to be a visual relationship with the Rudston and Denby long barrows and the Southside Mount great barrow, although the view of the Rudston long barrow is only clear towards the southwestern end of the feature. Again, horizons appear to be important in these positionings. The narrowing of the viewshed from the southwestern terminus includes the whole monument and it therefore appears that the location of the feature is defined by this phenomenon. The focus upon the monolith also seems significant in the placing of either the cursus or this feature. Regardless of the relative chronology of the two, it seems significant that the two were recognisable on the ground at the same time, and each held certain significance.

The route along cursus C is quite inconclusive. It appears that the postulated western terminus is in the correct position as indicated by the viewsheds. The eastern end is more ambiguous, but the relationship with cursus A indicates a more complex chronological and morphological picture. The significance of Southside Mount as some kind of landmark is reflected again, although the constant relationship with the long barrows is not reflected. The way that the western terminus defines the western horizon when moving from the east indicates that this may have been the direction of travel, but the confusion with the eastern end precludes any more than speculative comment. The pattern from cursus D appears to be less determined by visibility and it has been the least productive of the cursuses for providing answers. An interesting point is the visual relationship with Willie Howe.

5.5 Multiple surface analysis of the lower resolution landscape

5.5.1 Cost surfaces

Cost surfaces have been used in the past to explore the relationship between real space and perceived space on the ground (e.g. Wheatley 1993, Gaffney *et al.* 1996). Cost surfaces were generated to show the least-cost route between the terminuses of the cursuses in order to examine the interpretation of these features as routes. Each cost-path was used in relation to slope. This was done for two reasons. Firstly, there is much debate and work in relation to the influence of slope on increased effort (calories) generated by movement, indicating that the relationship between slope increase and effort is exponential. Further, the direction of movement through a landscape has been seen as a possible influential factor (*cf.* van Leusen 1999, Bell and Lock forthcoming, De Silva and Pizziolo forthcoming). However, in this example slope is only slight and therefore may be considered to have a limited effect upon movement. Secondly, the function of the cursuses has never been considered as efficient in terms of movement. Therefore, a consideration in relation to the least cost in terms of slope is beneficial to test the basic narrative comparisons between the routes and basic slope outlined in the preceding section (Figure 5.15).

a. Cursus A

The least-cost route (in relation to slope) deviates far from the route of the cursus (Figure 5.15). The southern end is however reflected. The shape of the southern dog-leg is echoed by this feature, indicating the same route around the hilltop. However, as the cursus straightens and runs down hill, the pattern is not reflected. The least-cost path

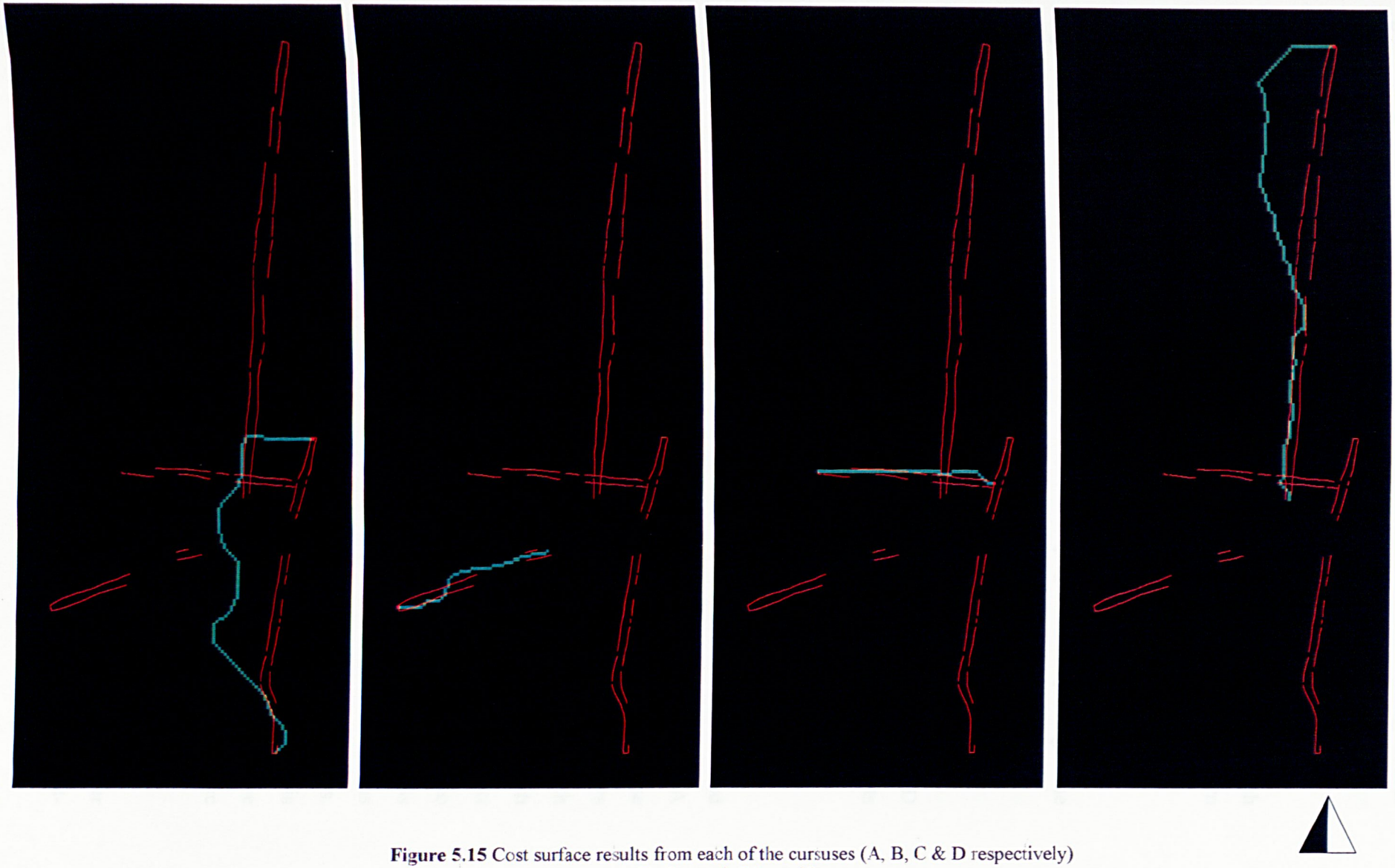


Figure 5.15 Cost surface results from each of the cursuses (A, B, C & D respectively)
Each area is 3 km wide.

goes further to the west and past the western side of the monolith before turning towards the northern end directly from the west.

b. Cursus B

The route of cursus B follows a very similar path to that of the least-cost route, which keeps adjacent to the southern side of it at its southwestern end, moving to the northern side and then to the centre at the northeastern end (Figure 5.15).

c. Cursus C

Again the least-cost route between the ends of cursus C display a relatively straight line following the path of the cursus (Figure 5.15).

d. Cursus D

Curiously the least-cost route between the terminus and the southern end of cursus D follows the path of the Gypsey Race almost exactly, deviating south-westwards from its northern terminus directly towards the river (Figure 5.15).

e. Summary and expansion of least-cost path analysis using slope

Of the four routes, the least-cost route of cursus A deviates most from the route defined by the crop marks, followed by the northern end of cursus D. The deviation of cursus A may be explained by the greater importance of the visual relationship between it and the Rudston and Denby long barrows highlighted earlier in this chapter. However, it appears that in these two cases where the routes deviate most is along the longer cursuses with more complex plans in terms of morphology. The routes following the most direct path downslope, in order to reach the widest area of level ground before climbing the next slope perpendicularly, highlight the deviation. In each of these two cases the cursuses do not naturally run down the steepest parts of the slope unlike cursuses B and C. This phenomena has been highlighted elsewhere (Bell and Lock forthcoming), where it was interpreted as a reaction to a limited method of just using slope to define cost surfaces. This also highlights that cost-surfacing is perhaps an inappropriate method for analysis for features such as the smaller cursuses since the short length of the route cannot be reflected well in terms of effort, as for cursuses B and C where the route follows the straight route of the cursuses.

Fundamentally elements such as landscape cognition (*cf.* van Leusen 1999) and other cultural influences will effect a route such that it cannot be reduced to pure cost-

effectiveness. This is particularly the case with monuments that may be interpreted as ceremonial such as the cursuses that may have much deeper reasons for their route rather than the quickest or easiest route between two points.

An experiment in relation to this problem was attempted in order to understand the relationship of slope to the route, by providing greater weighting to slope in order to investigate the relationship in terms of scale. A basic weighting formula was used:

$$\text{Weighted grid} = (\text{slope grid})^2$$

This provided exponential weighting so that any increase in slope will be squared providing increased preference towards flatter areas. The results from this in relation to cursus A displayed a very similar route with very slight extensions making the route further in terms of Euclidean distance but reduced in terms of cost-distance. In terms of a realistic understanding of cost surfaces in relation to slope, a slight increase in slope will not result in a large increase in effort until a threshold is reached.

In conclusion, slope has previously been demonstrated to be just one of a large number of physical, perceived and cognitive factors influencing the concept of cost surfaces and the generation of least-cost path through archaeological landscapes. Despite this, the application of the method based upon this single element has highlighted a number of points. Firstly, the relationship between slope and effort using multiple surface analyses has provided differing results, particularly in relation to cursus D. Secondly, the problems of just using slope as a factor have been demonstrated, particularly in relation to an apparently ceremonial landscape. Thirdly, the distance factor has been highlighted, with cursuses B and C not providing adequate morphological or topographic data for an analysis of least-cost routes.

5.5.2 Cumulative viewsheds

a. Long barrows

The cumulative viewshed from the three long barrows highlighted the results made during the earlier visual analyses (Figure 5.16). By recreating the viewsheds as binary grids and adding them together it was possible to see the total values of cells visible from each and which cells were visible from more than one of the features. The results showed that no cells were visible from all three. The majority of the visible cells were seen twice. The viewsheds corresponding to this area related to the Rudston and Denby long

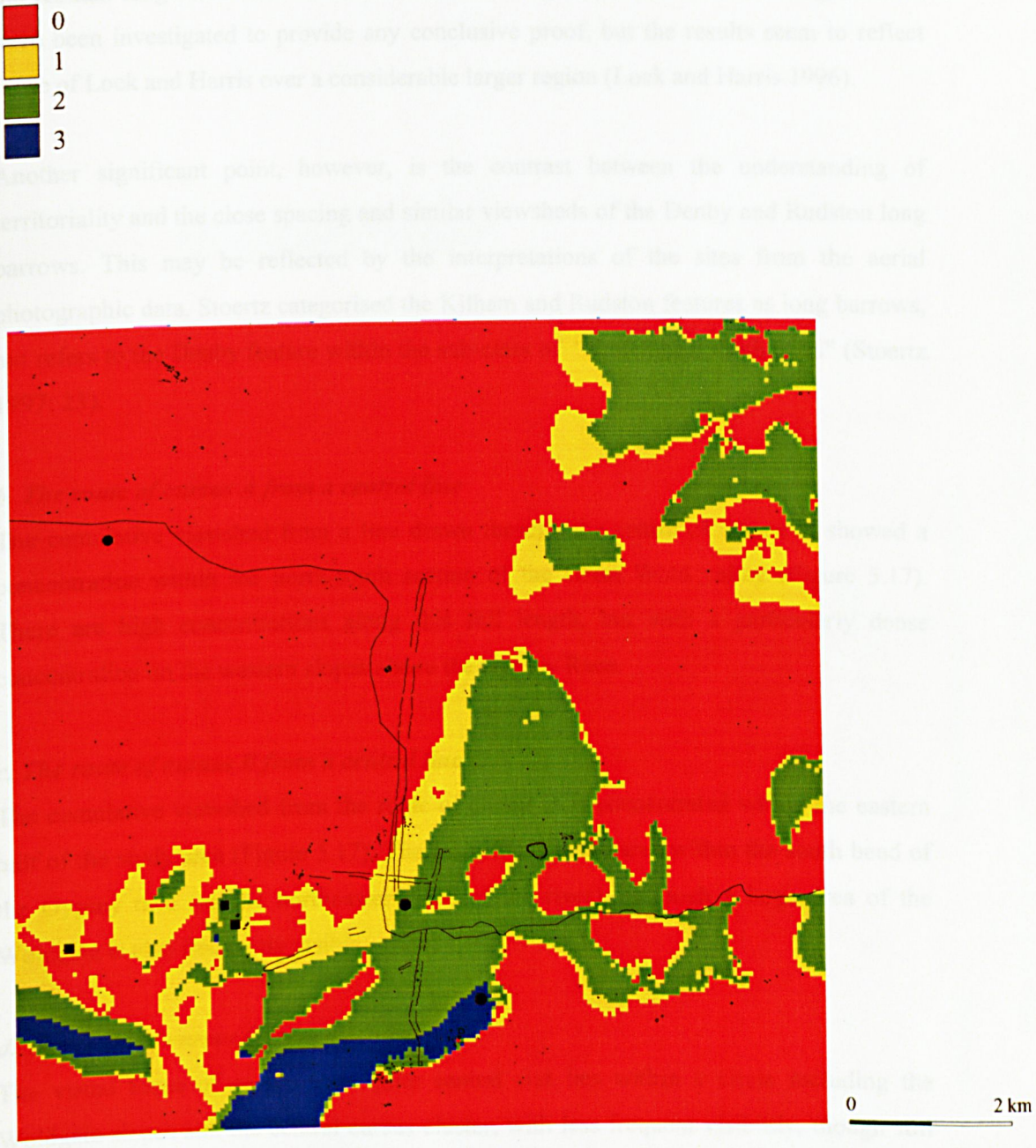


Figure 5.16 Cummulative viewsheds from the long barrows.
Long barrows are depicted by squares.

barrows. The implication that the Kilham long barrow represented a separate viewshed territory to the others was confirmed by separate cumulative viewshed calculations between the three separate long barrows. The results showed very similar viewsheds for the Rudston and Denby long barrows but very different results between each of these and the Kilham long barrow. In each case cells were only seen once. Too few long barrows have been investigated to provide any conclusive proof, but the results seem to reflect those of Lock and Harris over a considerable larger region (Lock and Harris 1996).

Another significant point, however, is the contrast between the understanding of territoriality and the close spacing and similar viewsheds of the Denby and Rudston long barrows. This may be reflected by the interpretations of the sites from the aerial photographic data. Stoertz categorised the Kilham and Rudston features as long barrows, but refers to the Denby feature within the sub-class of "short linear ditch pairs" (Stoertz 1997: 23).

b. The route of cursus A from a central line

The cumulative viewshed from a line drawn through the centre of cursus A showed a concentration within the north-south section of the Great Wold valley (Figure 5.17). There are high concentrations along this full length, but with a particularly dense concentration on the western slopes above the Gypsey Race.

c. The route of cursus B from a central line

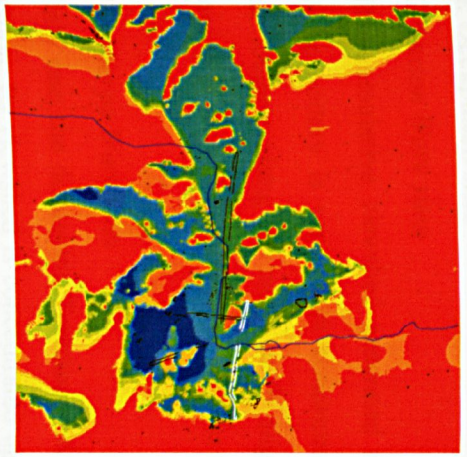
The cumulative viewshed from the route of cursus B is concentrated within the eastern half of the study area (Figure 5.17). The main focus is the area within the south bend of the Gypsey race (on the northeastern side of the river), although a large area of the Woldgate is also frequently visible.

d. The route of cursus C from a central line

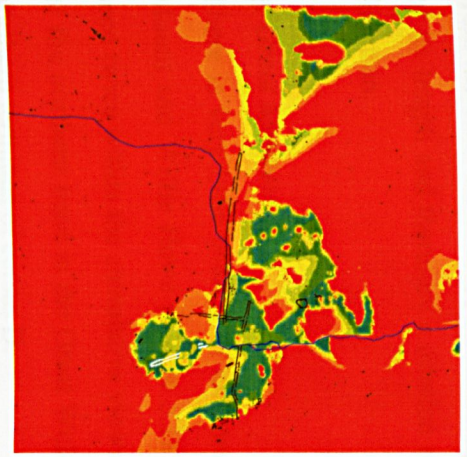
The visual focus of cursus C is quite central and lies within a circle including the Woldgate slopes and the central cursus cluster, with less frequent visibility, though still high, to the north (Figure 5.17).

e. The route of cursus D from a central line

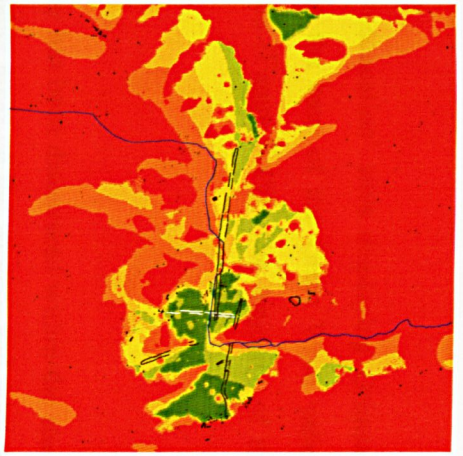
The cumulative viewshed from cursus D is more northerly focused than those resulting from the other cursuses (Figure 5.17). It also has less of a focus, indicating a very general priority for the route it takes, with frequent visibility of the Woldgate, but otherwise less



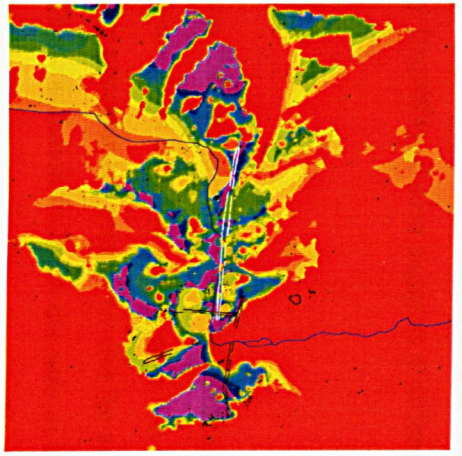
Cursus A cumulative viewshed



Cursus B cumulative viewshed



Cursus C cumulative viewshed



Cursus D cumulative viewshed





Figure 5.17 Cummulative viewsheds from the cursuses. Relevant cursus is depicted in white.

specific. This may be due to its increased length that will result in more areas being visible but for a shorter time.

f. Comparisons of the cursus cumulative viewsheds

All of the cursuses except for cursus D define relatively focused cumulative viewsheds. There also seems to be a distinct relationship in terms of frequency with archaeological features. The Rudston/Denby long barrow complex lies on the cumulative horizon of one of the most frequently visible areas from the route of cursus A. With cursuses B and C the position of these long barrows also lies on the edge of the viewshed, but beyond the high frequency. This indicates that, for cursus A at least, the visual relationship with the Rudston and Denby long barrows was significant in its positioning.

Cursus D has displayed a cumulative viewshed model that indicates a different focus from the other three. It appears to be more fragmented and, while this could be a product of its length and therefore a dilution of visibility frequency, it also suggests a different function.

g. Great barrows

There is very little overlap of the viewsheds from the two great barrows of Southside Mount and Willie Howe (Figure 5.18). Where there is an overlap, where cells can be seen twice within the cumulative viewshed, they are concentrated mostly around the area of the northern bend in the Great Wold valley. This correlation includes the area of the northern terminus of cursus D.

h. Occupation sites

Grimston Ware sites

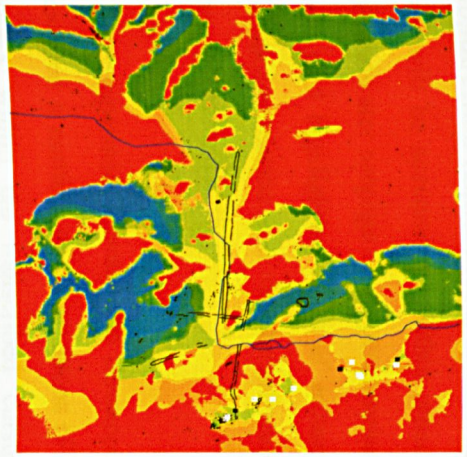
The cumulative viewshed generated from the 'occupation' sites displaying Grimston Ware pottery is very much concentrated within the base of the Great Wold valley, particularly along the north-south aligned section (Figure 5.19). The majority of this region is seen from three or four of the four sites.

Towthorpe Ware sites

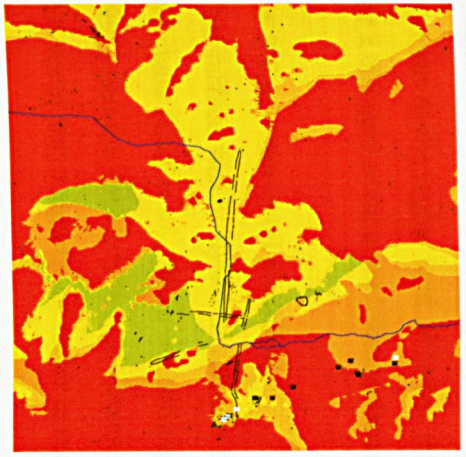
Only one site displaying Towthorpe Ware pottery has been discovered within the study region. Its viewshed is concentrated upon the higher areas on the western and northern parts of the study area, and on the northern side of the Gypsey Race within the southeastern quarter.



Figure 5.18 Cummulative viewsheds from the two great barrows. Willie Howe is to the northwest and Southside Mount is to the south.



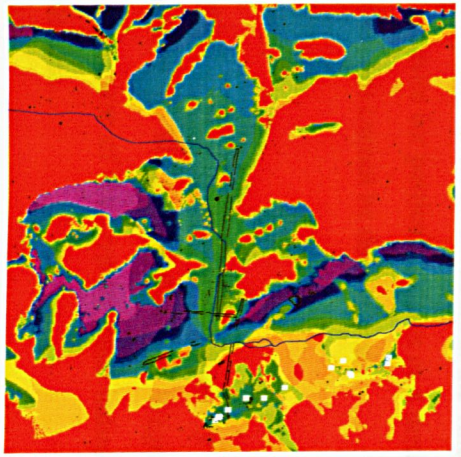
Peterborough ware sites



Grimston ware sites



Towthorpe ware site



Cumulative viewshed from all occupation sites



Figure 5.19 Cummulative viewsheds from the occupation sites.
Relevant sites are depicted in white.

Peterborough Ware sites

The cumulative viewshed derived from the nine sites revealing Peterborough Ware pottery highlights concentrations of visibility on the higher areas (Figure 5.19). The areas of greatest cumulative visibility, with values of seven or above, follow a very similar pattern to that displayed by the Towthorpe occupation site. They cover the higher areas, particularly on the western side of Gypsey Race, and also within the extreme north and to the north of the Gypsey Race within the southeastern quarter of the study area.

Comparison of cumulative viewsheds from occupation sites

There appears to be a temporal change reflected by the cumulative viewsheds from occupation sites (Figure 5.19). The sample for the Towthorpe Ware site is too limited with just the one site and so the comparison is best made, though still limited, between the Grimston Ware (four sites) and the Peterborough Ware (nine sites) occupation locations. With these there appears to be a significant shift is visual focus from the valley bottoms to the higher land. Whether this reflects a desire for particular views or a desire for a changed occupation location focus for other reasons cannot be determined.

5.5.3 Environmental modelling

The surface was analysed in relation to hydrological flow. The natural permeability of the chalk (Catt *et al.* 1978), the consequent dryness of the Wolds (Hayfield and Wagner 1995) and the concentration of cursuses around the course of the Gypsey Race indicate that water was a significant factor in activity in this area.

Flowaccumulation grids provide data on the accumulation of water from the *flowdirection* function for each cell. Therefore, a deposition of a given volume per each cell will be accumulated within other cells due to surface run off (other elements of groundwater seepage or evapotranspiration are not calculated for), therefore providing a new grid highlighting areas of accumulation. Assuming water to be erosive then the flowaccumulation grid may be inferred as broadly relating to accumulation of sediment through colluviation.

The comparison between the flowaccumulation grid and the positions of the cursuses revealed a number of observations (Figure 5.20). For example, in a number of cases, breaks within the transcribed cursus features correlate with areas of increased flowaccumulation. While this correlation is not one hundred percent, the correlations may indicate reasons for the invisibility of these features.

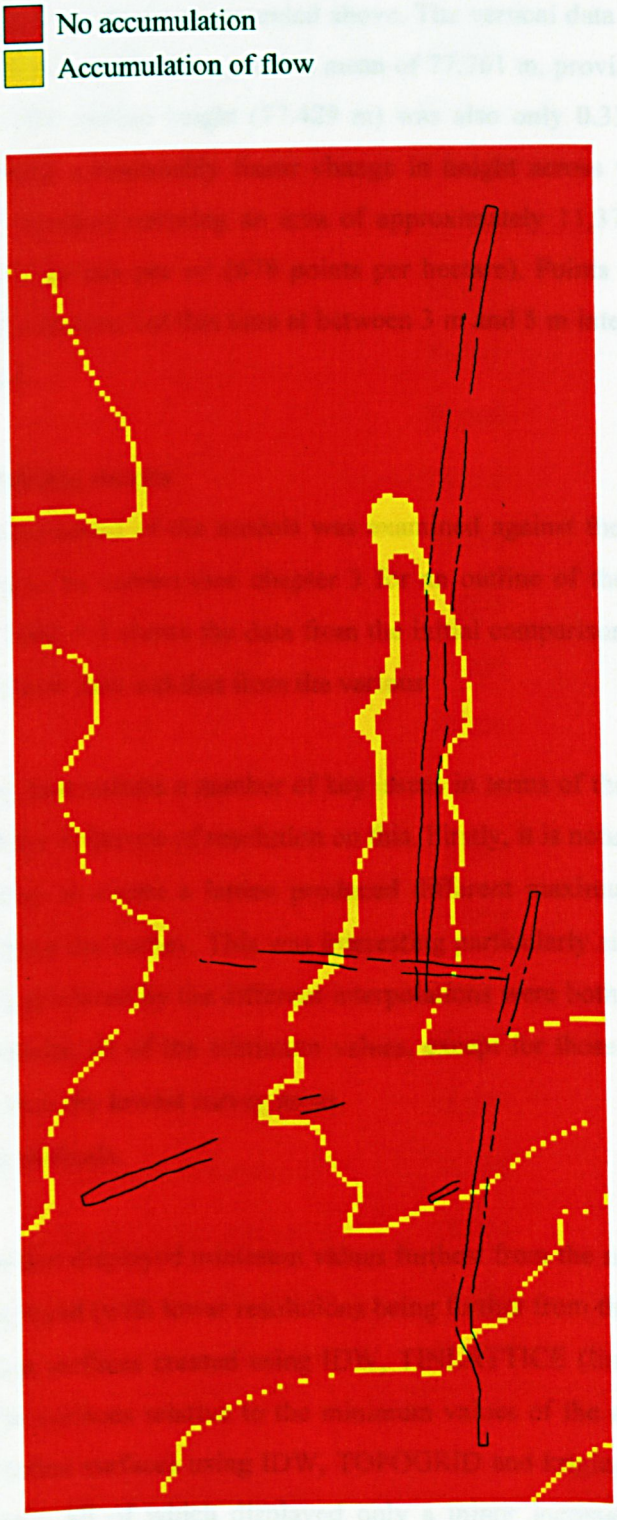


Figure 5.20 Flow-accumulation and the distribution of cursuses. The area is 3 km wide.

5.6 Surface generation of the higher resolution landscape

A surface was generated from the GPS survey data using the available methods outlined in chapter 3. A greater number of interpolation techniques were available for point data rather than for the contour as presented above. The vertical data range of the survey was between 75.00 m and 79.858 m, with a mean of 77.761 m, providing an overall variation of 4.858 m. The median height (77.429 m) was also only 0.332 m different from the mean suggesting a reasonably linear change in height across the site. A total of 772 points were surveyed covering an area of approximately 11,378 m^2 providing a mean density of 0.07 points per m^2 (678 points per hectare). Points were again recorded by pacing along transects, but this time at between 3 m and 5 m intervals consistently across the entire area.

5.6.1 Quantifiable results

The initial assessment of the models was examined against the raw survey data which was assumed to be correct (see chapter 3 for an outline of the survey method and its reliability). Table 5.3 shows the data from the initial comparisons between the statistical ranges of this raw data and that from the various

These results demonstrate a number of key issues in terms of the rigidity of the different methods and the influence of resolution on this. Firstly, it is noteworthy that each method of interpolation to create a lattice produced different maximum and minimum height values than from the survey. This was interesting particularly since, while the maximum height values produced by the different interpolations were both greater and smaller than the survey results, all of the minimum values, except for those generating using spline, were higher than the lowest survey areas.
interpolation methods.

The surfaces that displayed minimum values furthest from the minimum GPS value were created using trend (with lower resolutions being further from the value), followed by the 3 m resolution surfaces created using IDW, TINLATTICE (linear) and KRIGING. The most accurate surfaces relative to the minimum values of the raw survey data were the highest resolution surfaces using IDW, TOPOGRID and kriging, and the 1 m resolution kriging surface, all of which displayed only a minor increase of 5 mm. These were followed closely by the 1 m TOPOGRID surface and the 0.5 m resolution TINLATTICE surface generated using quintic interpolation, which were both less than 10 mm more than the survey values.

Table 5.3 *Surface interpolation results - GPS survey data*

	Min height (m)	Max height (m)	Mean height (m)
GPS survey	75.000	79.858	77.761
Trend - 0.5 m resolution	75.224	80.195	77.780
Trend - 1 m resolution	75.224	80.185	77.779
Trend - 3 m resolution	75.343	80.185	77.781
Spline - 0.5 m resolution	74.990	79.857	77.778
Spline - 1 m resolution	74.991	79.856	77.777
Spline - 3 m resolution	75.097	79.821	77.779
IDW - 0.5 m resolution	75.005	79.854	77.779
IDW - 1 m resolution	75.005	79.848	77.779
IDW - 3 m resolution	75.118	79.809	77.780
Kriging - 0.5 m resolution	75.005	79.849	77.778
Kriging - 1.0 m resolution	75.005	79.849	77.778
Kriging - 3.0 m resolution	75.100	79.822	77.779
TOPOGRID - 0.5 m resolution	75.005	79.856	77.773
TOPOGRID - 1.0 m resolution	75.007	79.850	77.775
TOPOGRID - 3.0 m resolution	75.090	79.827	77.767
TIN	75.000	79.858	77.761
TINLATTICE – linear - 0.5 m resolution	75.012	79.853	77.776
TINLATTICE – linear - 1.0 m resolution	75.027	79.850	77.776
TINLATTICE – linear - 3.0 m resolution	75.102	79.828	77.776
TINLATTICE – quintic - 0.5 m resolution	75.009	79.863	77.776
TINLATTICE – quintic - 1.0 m resolution	75.024	79.854	77.775
TINLATTICE – quintic - 3.0 m resolution	75.097	79.824	77.775

The values furthest from the maximum values were from the trend surfaces that displayed values well above the maximum height of the raw data. These were followed by the surfaces generated at 3 m resolution using kriging, followed by the TINLATTICE surface with quintic interpolation, the TOPOGRID surface and the TINLATTICE surface generated using the linear interpolator. The closest value in relation to the maximum surface heights was that generated using spline at 0.5 m resolution, followed by the TOPOGRID at 0.5 m resolution and spline at 1 m resolution. This was followed closely by the 1 m resolution TINLATTICE surface generated using the quintic interpolator, the 0.5 m resolution TINLATTICE surface with linear interpolation and the 0.5 m resolution TINLATTICE surface with quintic interpolation. The latter was the only surface that produced a value higher than the maximum value, perhaps due to the smoothing process.

From these values what is immediately clear is that in each case surfaces generated at the coarser 3 m resolution proved to be the least accurate by a long way, in terms of both the maximum and minimum values. trend was found to be the least accurate interpolation method. Surfaces from each of the IDW, spline, kriging, TOPOGRID and both TINLATTICE interpolation methods provided accurate surfaces at the higher resolutions.

Every interpolated surface also produced a mean height that was higher than that produced from the raw survey data, reflecting the general heightening of the minimum and maximum values. The 3 m resolution TOPOGRID surface produced a mean closest to that of the raw data, being only 6 mm higher. All other surfaces produced increases of over 1 cm. The greatest differences in mean (17 mm to 18 mm higher than the raw data mean) were from the three surfaces generated using the KRIGING function. However, the value of the mean is more limited. Although the survey was relatively systematic, gridding the site, the results are not directly comparable to the surface results. However, an assessment of the overall results from the interpolation methods provides a range of 0.014 m and a mean of 77.777 m. None of the results from the various interpolation methods has been highlighted from an analysis of their mean values.

5.6.2 Visual results

Despite the overall statistical accuracy of the surfaces generated using the different interpolation techniques, a number of visual observations were made in terms of realism and overall visual accuracy (Figures 5.21a – c). With each of the interpolation methods attempted, the higher resolution surfaces appeared to be more aesthetic and realistic. The surfaces generated using the TOPOGRID function, particularly those of higher

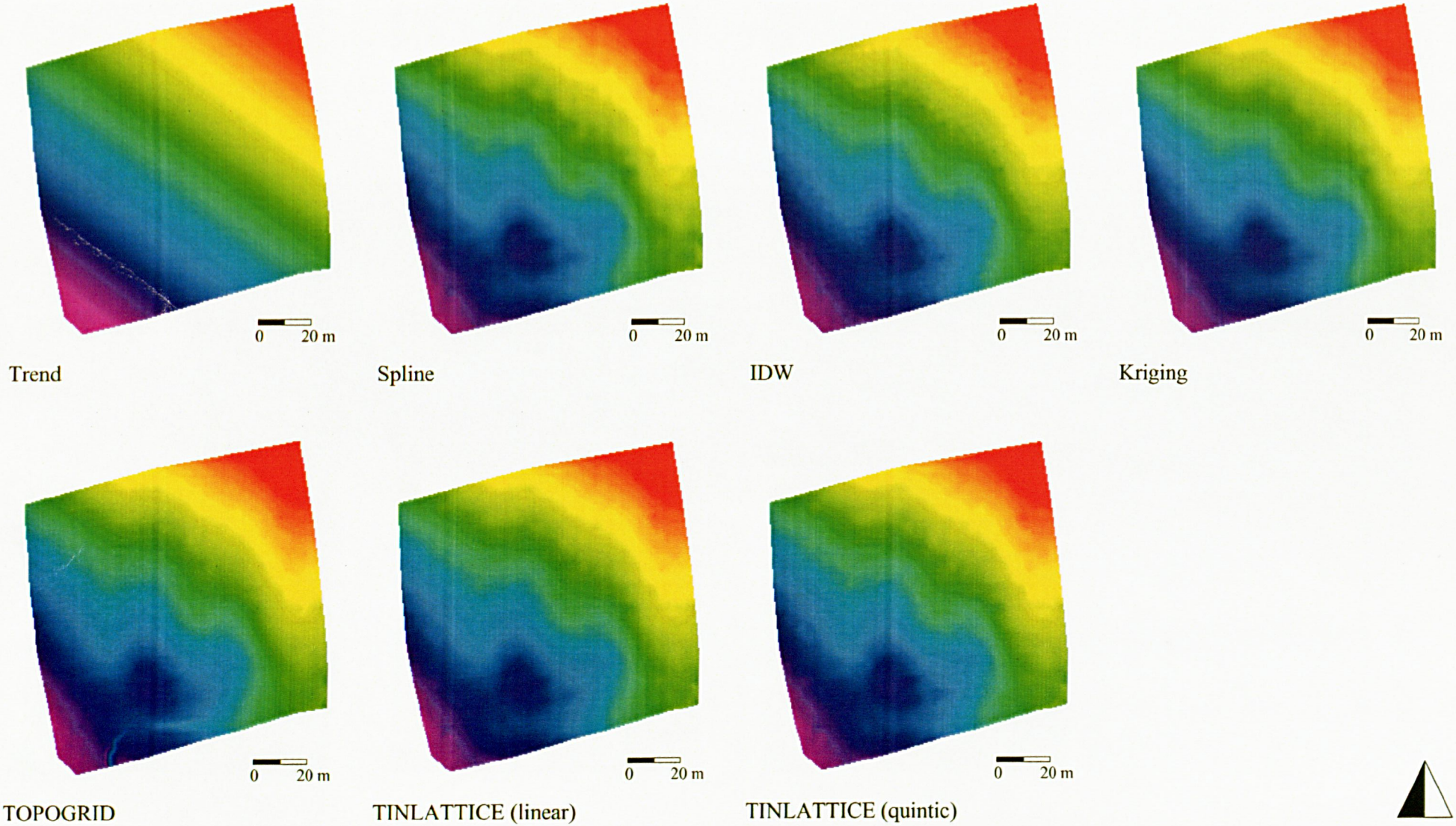


Figure 5.21a Results from the application of the various interpolation methods to the high resolution survey data of the cursus terminus
Displayed using a default linear colour-scaling based upon the frequency of cell values. Cell resolution at 0.5 m

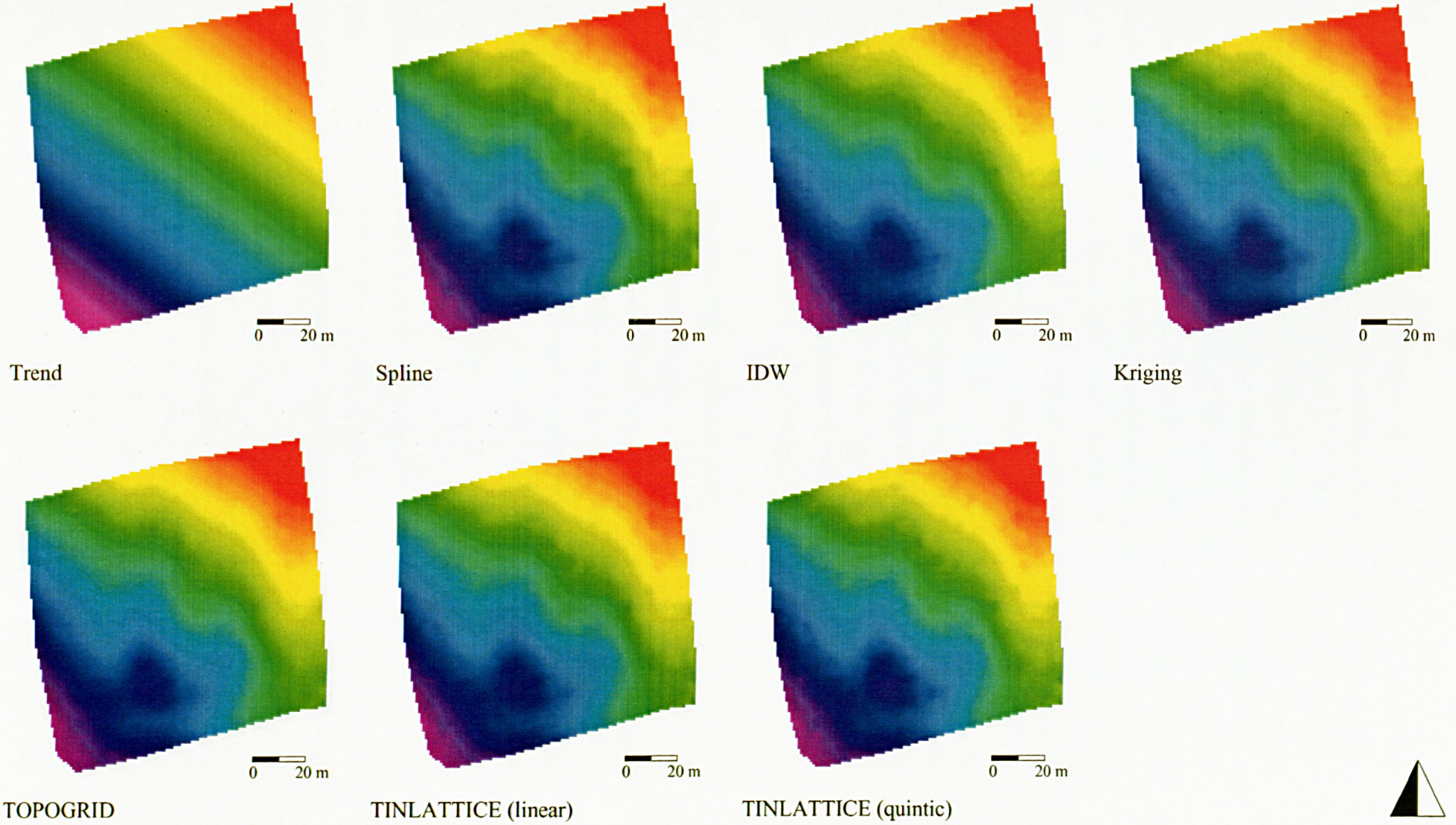


Figure 5.21b Results from the application of the various interpolation methods to the high resolution survey data of the cursus terminus Displayed using a default linear colour-scaling based upon the frequency of cell values. Cell resolution at 1.0 m.

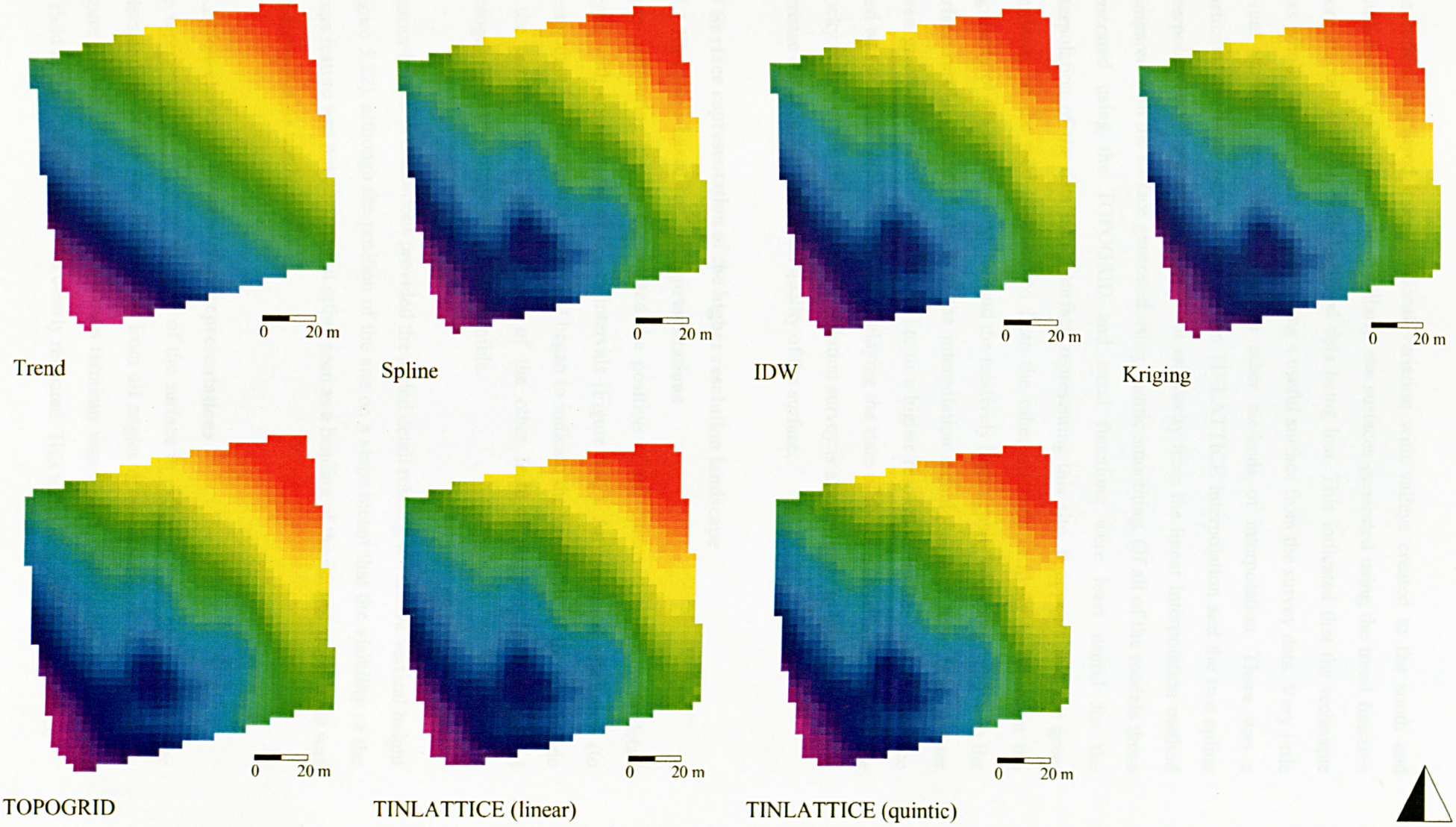


Figure 5.21c Results from the application of the various interpolation methods to the high resolution survey data of the cursus terminus Displayed using a default linear colour-scaling based upon the frequency of cell values. Cell resolution at 3.0 m.

resolution, displayed increased local variation with valleys created to the south and southeast of the main mound. Similarly, the surfaces generated using the trend function were smooth and flat, with localised data being lost. This indicated that the technique was wholly inappropriate for generating a useful surface from the survey data. Very little visual variation was found from the other methods of interpolation. There was a particular similarity between the quintic TINLATTICE interpolation and the two spline interpolations. There was no significant angularity from the linear interpolation method compared with the surface generated using quintic smoothing. Of all of the models those generated using the TOPOGRID and trend functions were least useful for the interpolation of the data into a surface representing this site. It appears that the great similarity of the models generated from the other methods is likely to represent the regularity of the survey sampling, and the relatively high density of points relative to the surface resolution. Artefacts from the interpolation techniques may have been greater given greater levels of interpolation (i.e. to a higher resolution surface) but the surface used was adequate archaeology for displaying the state of the cursus terminus. Given the blocky nature of the field, a higher resolution survey is also unlikely to have been able to increase the accuracy and visual quality of the surface.

5.7 Surface representation of the higher resolution landscape

5.7.1 Elevation-based surface representations

Basic contouring clearly highlighted the position of the cursus terminus, with detail shown with contours set at 0.1 m intervals (Figure 5.22). An increased resolution (to greater than 0.05 m contour intervals) began to indicate the variability of the area inside of the cursus, though the positions of the other features mapped from the aerial photographs in this area were not discernible.

Contour band representations provided the added detail relating to relative vertical height (Figure 5.22), although the position of the site on a slope meant that the visibility of the cursus feature was not distinct, but rather seen as a bending of the natural slope. This was less distinct at its northern end.

5.7.2 Non-elevation-based surface representations

The representation and generalisation of the surface in different ways provided further understanding of the site. Hillshading from all angles displayed a very uneven surface (Figure 5.23a). The outline of the cursus terminus was visible, but the blocky nature of the field at the time of survey was clearly reflected. This technique enabled the surface

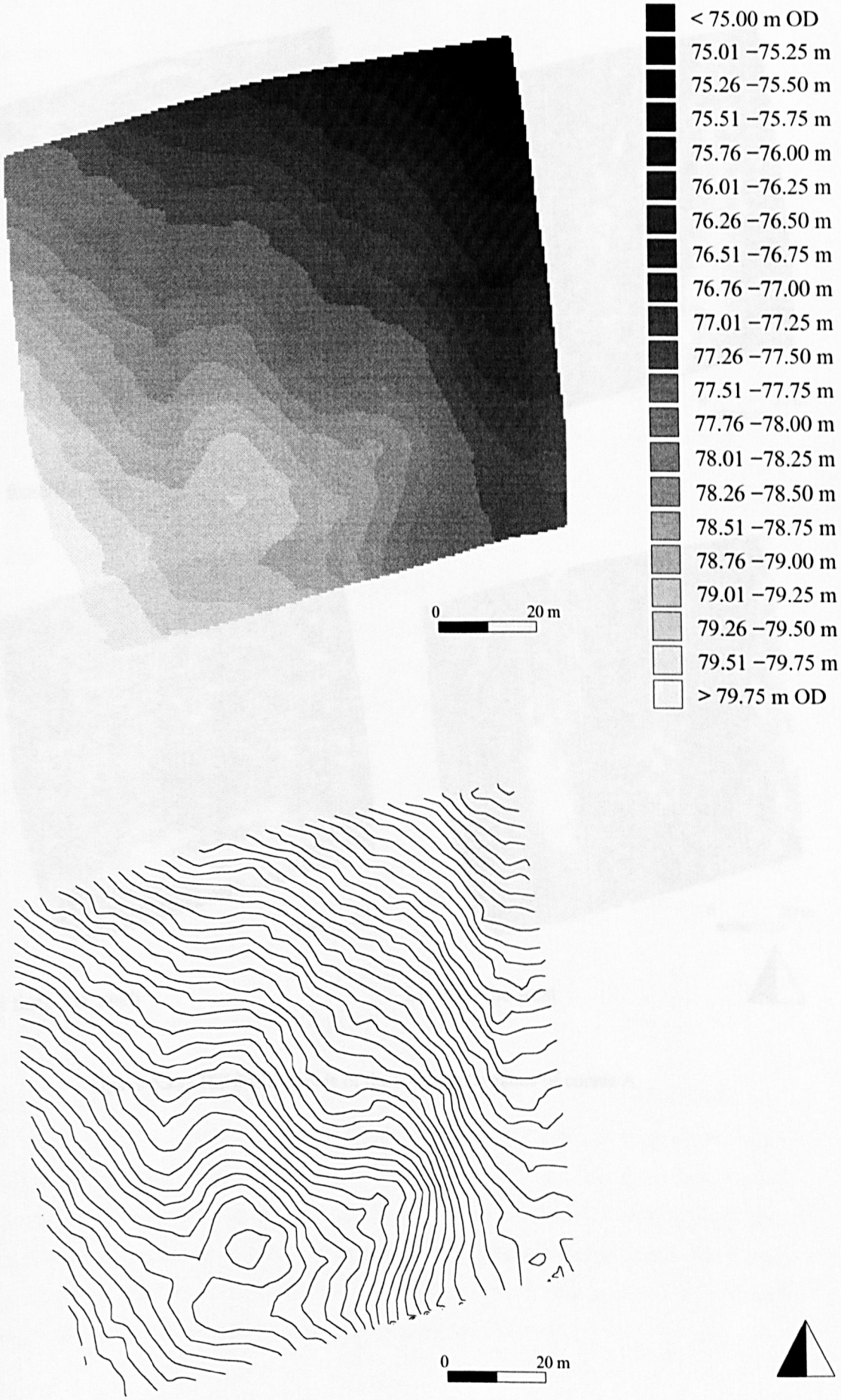
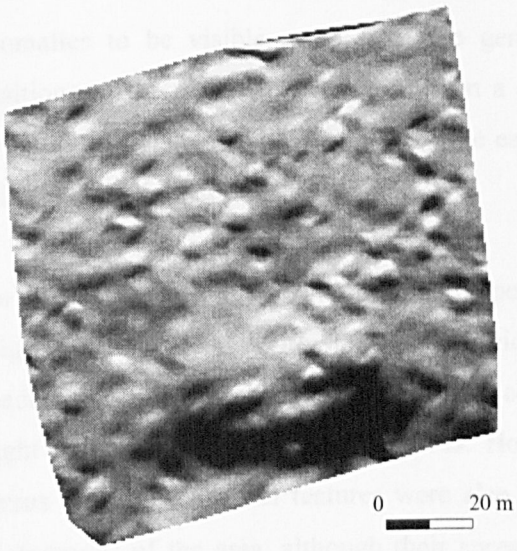
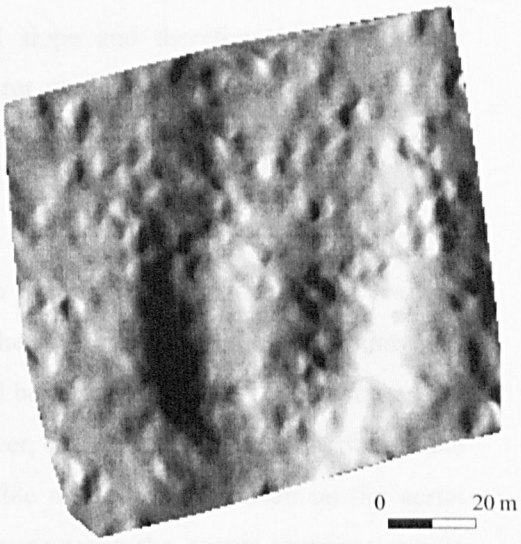


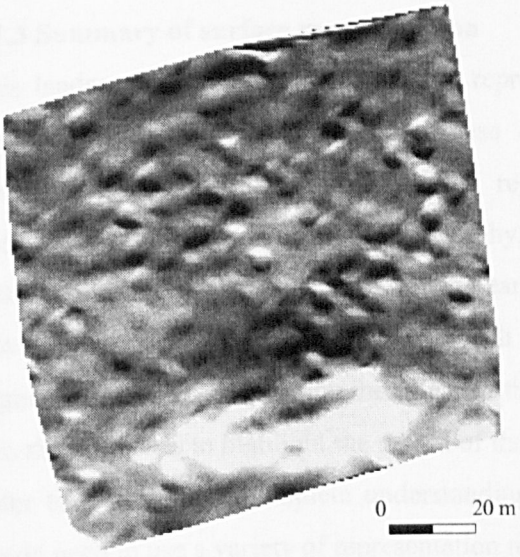
Figure 5.22 Elevation representations including contours at 0.1 m intervals.



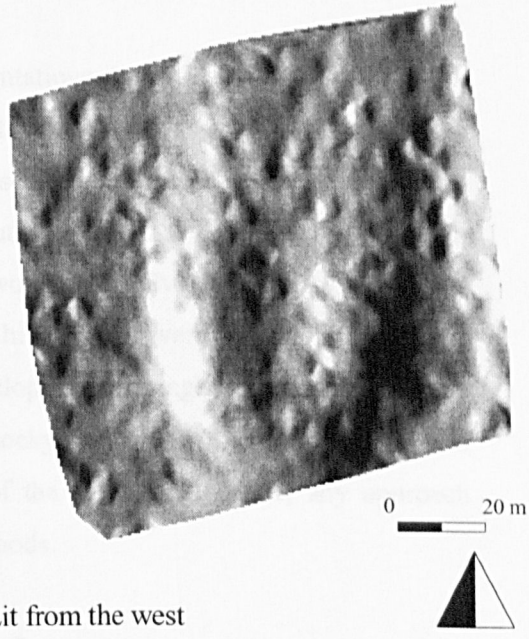
Lit from the north



Lit from the east



Lit from the south



Lit from the west

Figure 5.23a Hillshade models of the southern terminus of cursus A.

anomalies to be visible aside from the general slope and therefore highlighted the positions of the archaeological features in a clearer way. The U-shape of the southern terminus was visible and, when lit from the east, the subtle external ditch on the western side was highlighted.

Surface exaggeration and draping also helped to highlight the archaeological features (Figure 5.23b). Despite the slope upon which the site lies, a large exaggeration was needed (x 10) before archaeological features could be clearly seen. This demonstrated the slight nature of these ploughed features. However, the resulting model displayed the cursus distinctly. Internal features were also visible reflecting those seen on the aerial photographs of the area, although their spread forms made the cursus terminus appear less distinct.

5.7.3 Summary of surface representation

This landscape is interesting in terms of representations due to it being visible as low earthworks, but particularly because these earthworks extend down a slope. As a consequence the elevation-based surface representations are necessary in order to understand the nature of the slope topography, but this limits the amount of information that can be gained about the nature of the earthworks themselves. Conversely, the non-elevation-based surface representations, such as hillshading, were able to highlight the slight earthworks by cancelling the effect of the slope. Interestingly, these methods were also the only ones to highlight the nature of the blocky field. Fundamentally, therefore, in order to gain a more complete understanding of the nature of the site, any approach would need to use a variety of representation methods.

5.8 Surface analysis of the higher resolution landscape

5.8.1 Slope

The slope model showed a variable surface highlighting the blocky nature of the field, also noted from the hillshaded model (Figure 5.24). Larger areas of high slope were found following the position of the terminus, particularly its raised corners, again reflecting areas anomalous to the general landscape pattern. Another area of increased slope was found within the central part of the cursus, being more distinct than the slope at its southern end. It seems likely that this increase reflects the positions of interior features also noted from surface exaggeration (mentioned above).

Figure 5.23b Southern terminus of cursus A looking northeast.
Lattice (at 10 m intervals) draped over a DEM with a x 10 exaggeration

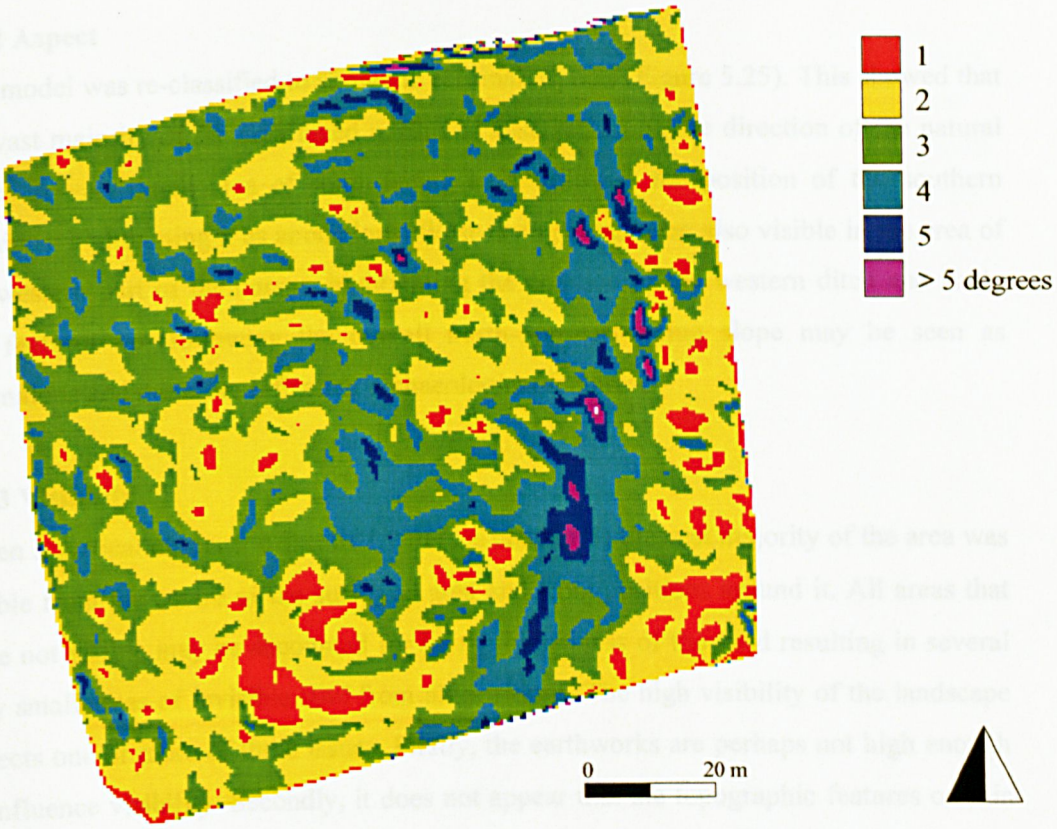


Figure 5.24 Slope model of the southern terminus of cursus A.

5.8.2 Aspect

The model was re-classified to show the cardinal aspects (Figure 5.25). This showed that the vast majority of the area faced north and east, reflecting the direction of the natural slope. A very small area of south-facing land followed the position of the southern terminus, highlighting it as anomalous. West-facing areas were also visible in the area of the western part of the cursus, highlighting the position of the western ditch and bank. All features not following the overall north- or east-facing slope may be seen as anomalous and therefore reflecting archaeological features.

5.8.3 Visibility

Given a vertical observer offset of 1.7 m (see chapter 3) the vast majority of the area was visible from the centre of the surveyed area and from positions around it. All areas that were not visible may be accounted for by the blockiness of the field resulting in several very small areas of invisible land from all positions. The high visibility of the landscape reflects one or more of three issues. Firstly, the earthworks are perhaps not high enough to influence visibility. Secondly, it does not appear that the topographic features on this local scale were sufficient to influence visibility so that the earthworks were not merely positioned to augment a natural phenomenon. Thirdly, and perhaps most significantly, the area surveyed was not large enough for a practical assessment of visibility.

5.9 Multiple surface analysis of the higher resolution landscape

The data for the positions of the cursus earthworks (from the aerial photographs) was insufficient to enable any reconstruction to take place. The area of the landscape was considered too small for the analysis of multiple viewsheds (see above) or for generating cost paths. However, a contour model of the site existed at the time of survey (Dymond 1966: 87) and was influential on the choice of site for higher resolution study (see chapter 2). It was therefore important to compare the results from the two surveys. The published representation of the survey displayed the image as a contour plan with contour lines set at vertical intervals of 3" (0.076 m). The survey was presumably conducted in 1964, judging by the labelling of magnetic north (*ibid.*).

A fundamental problem was encountered when dealing with this data. No datum height was provided on the 1964 survey so that accurate comparisons could not be made in terms of height between the two models, although the pattern of the surveyed modern roads was enough to locate the two in terms of x and y co-ordinates. This meant that a

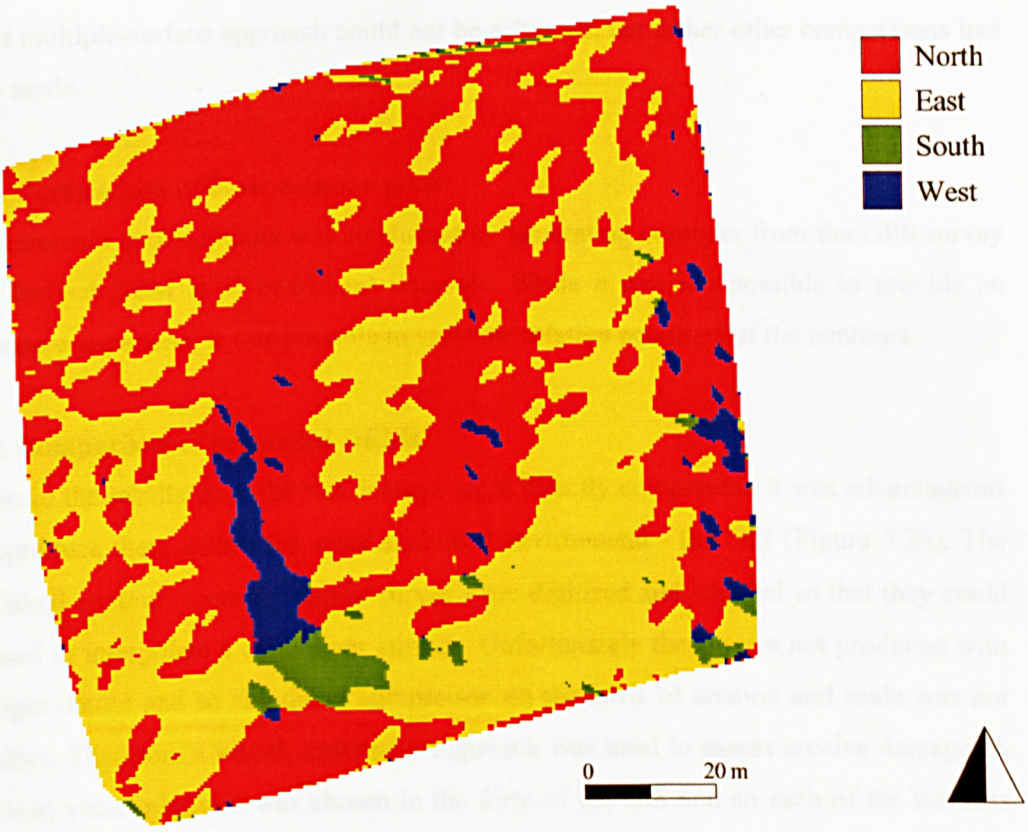


Figure 5.25 Aspect model of the southern terminus of cursus A.

direct multiple-surface approach could not be achieved, but rather other comparisons had to be made.

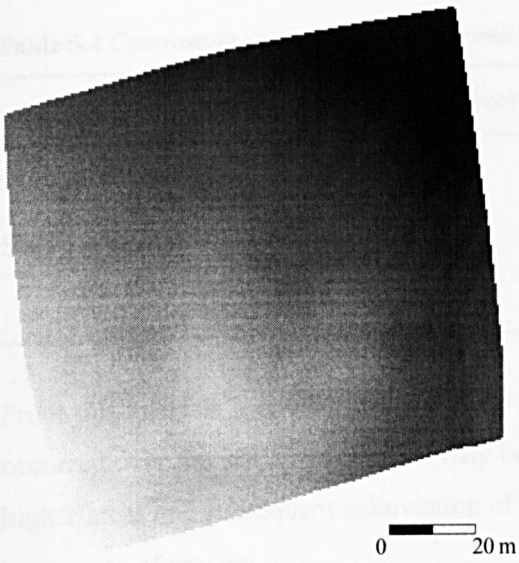
5.9.1 Comparison of basic contour plots

The comparison of contours was conducted by generating contours from the GPS survey data derived DEM at 3" (0.076 m) intervals. While it was not possible to provide an accurate comparison, it was possible to view the relative positions of the contours.

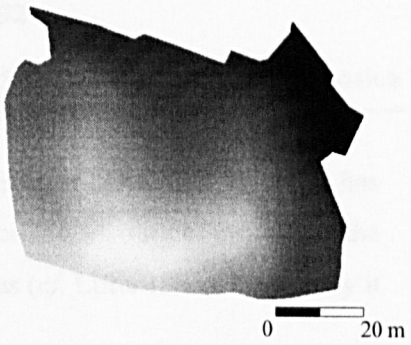
5.9.2 Comparison of generated DEMs

To make the results from the two surveys more directly comparable it was advantageous to reproduce them within the same analytical environment - the GIS (Figure 5.26). The published contours from the earlier survey were digitised and labelled so that they could be used to interpolate a continuous surface. Unfortunately these were not produced with a height datum and so any direct comparison on the basis of erosion and scale was not possible. Therefore a visual, qualitative approach was used to assess erosive damage. A common visual platform was chosen in the form of the GIS and so each of the surfaces resulting from the two surveys was generalised into comparable contour diagrams with vertical intervals of 0.1 m. The results from this comparison demonstrate how the overall shape has remained the same although detail has been lost. The shape of the terminus has become 'generalised' and less distinct, though this is hard to quantify. It is possible however to display the area of full contours as shown on the earlier survey from the highest point and compare the area covered by the change in height.

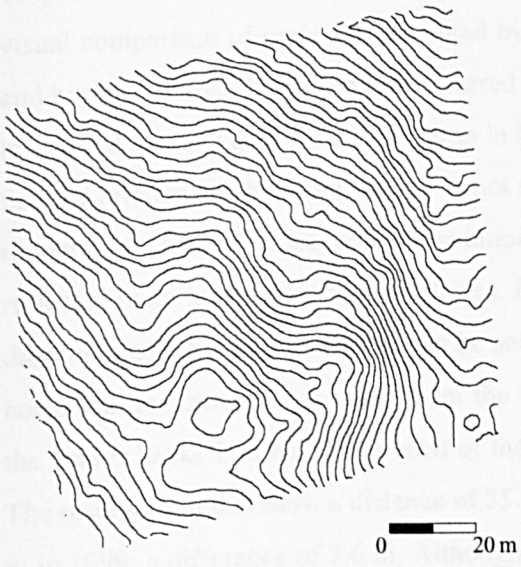
The 1964 survey contours were digitised and each provided with a height value relative to the lowest contour that was given the datum value of 1 m. Smaller contours which provided no information on whether they indicated rises or falls in ground level were ignored, although there were only very few of these. The resulting surface was generated using both the TOPOGRID function and the TINLATTICE (quintic) function to a surface resolution of 0.5 m to enable direct comparisons to be made with the GPS derived models. Unlike the comparison between the GPS survey and OS data derived models, it was not possible to compare the surfaces resulting from the two data sources by subtracting one from the other due to the lack of a datum. Instead two points of fixed x and y coordinate were investigated for each and compared. These were taken from the highest and lowest areas of the 1964 surface (as it was smaller) and the differences between the two for each model were compared. The results from this are provided in table 5.4 below.



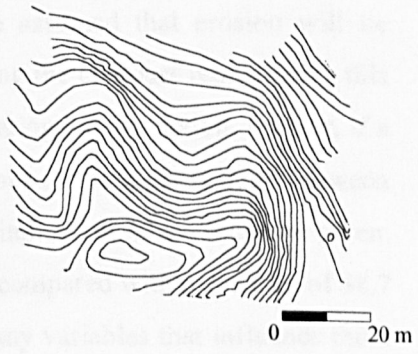
DEM interpolated from GPS data



DEM interpolated from 1964 data



0.1 m interval contours from GPS data



Interpolated contours from 1964 survey

Figure 5.26 A comparison of the DEM and contour plots of the southern terminal of cursus A with those derived from the previous survey (after Dymond, 1966).
North is to the top of the images.

Table 5.4 *Contrasting z-values for the 1964 and 1998 surveys*

	1964 survey (relative)	1998 survey (GPS)	
510004 465807 - A	3.911 m	78.991 m	
509965 465754 - B	1.100 m	76.892 m	
	2.811 m difference	2.099 m difference	= 0.702 m erosion

From this analysis it is clear that a change of 0.702 m between the same two points has occurred over the last 35 years. This may be accounted for as a mixture of erosion of the higher areas and subsequent colluviation of the lower areas (*cf.* Lillie 1995). Ultimately it is measure of erosion.

To provide a more quantifiable measurement of erosion between the two contour plots a visual comparison of scale was accented by displaying the ratio between vertical height and horizontal area. If erosion has occurred in the time between the two surveys then the horizontal area covered for a given drop in height will be greater. While it must be noted that the relationship between the two is not a linear one, due to the influences of irregular topography, natural slope and colluviation, it may be assumed that erosion will be reflected in an increase in horizontal area. By highlighting the contours representing this drop in height, the expanded area can be seen, demonstrating erosive action. Further, if a horizontal measurement is taken from the highest contour to the highest point between the cursus banks 2 m below for each of the surveys an indication of scale can be given. The results from this show a distance of 35.1 m in 1964 compared with a distance of 38.7 m in 1999; a difference of 3.6 m. Although there are many variables that influence these measurements, the differences between the two indicate that a considerable amount of erosion has occurred, which would seem to confirm the visual assessment.

5.10 Summary

This chapter has presented the results from the application of the GIS methods outlined in chapter 4 to the Rudston landscape described in chapter 2 (section 2.2). The implications of these results are discussed in chapters 7 and 8, in relation to GIS method and themes of landscape archaeology respectively. The following chapter describes the results from the application of GIS tools to the Sutton Common landscape.

Chapter 6

Results from the Sutton Common landscape

6.1 Introduction

This chapter outlines the results from the application of the methods described in chapter 4 to the Sutton Common lowland/wetland landscape within the Humberhead Levels described in chapter 2. This chapter, like chapter 5, is split into two sections on the basis of input-data resolution. The first explores the application of the different GIS tools outlined in chapter 3 to the whole 10 x 10 km Sutton Common landscape based upon the Ordnance Survey data. The second explores the same tools applied to the smaller section of landscape surveyed by GPS focused upon the two enclosures on Sutton Common.

6.2 Surface generation of the lower resolution landscape

DEM surfaces were generated from the raw, commercially available Ordnance Survey contour data using a number of techniques and at two resolutions - 25 m and 50 m. Immediately recognisable from the raw data is that the density of contours is very limited, given the 10 m vertical interval of them over a relatively flat terrain with variation of only 20 m.

6.2.1 Quantifiable results

As outlined in chapter 4, the measurement of accuracy within DEMs generated using different methods is troublesome. Table 6.1 outlines the main statistical results from this analysis.

A number of key conclusions may be drawn from these results. Firstly, they demonstrate which of the interpolation techniques kept closest to the raw data and which can therefore be classed as most accurate within this study. Secondly, they show how changes in the output resolution can alter the accuracy of the model relative to the raw data.

The values show that the accuracy of the TIN was the same as the raw data, as was noted in chapter 4, since the TIN merely applies a surface structure to the raw data and does not actually interpolate those areas which are not represented within the dataset. Also of interest is that the *linear* TINLATTICE interpolations maintain one hundred percent accuracy compared to the raw data in terms of their minimum and maximum height

values. Their mean values were also very similar, with a variation of just 0.012 m between them. While the more accurate of these cannot be assessed because of the lack of comparative data, it is notable that, by changing the resolution of the resulting surface, the overall statistics can be changed despite keeping the maximum and minimum values. In this respect, the overall model is different on a micro scale, although the linear interpolation that does not follow the curve of the landscape to beyond the original values maintains the same maximum and minimum values. Interestingly the TINLATTICE function using quintic smoothing also produced two surfaces that displayed identical minimum and maximum values to one another with only a small (0.010 m) variation in their mean values, indicating that the effect of resolution was minimal. The surfaces generated using TOPOGRID did not conform to this pattern in the same way.

Table 6.1 *Surface interpolation results - Ordnance Survey data*

	Min height (m)	Max height (m)	Mean height (m)
Ordnance Survey contour file	0.000	20.000	-
TOPOGRID – 25 m resolution	-0.481	21.960	6.039
TOPOGRID – 50 m resolution	-0.337	21.747	6.030
TIN	0.000	20.000	-
TINLATTICE – linear - 25 m resolution	0.000	20.000	6.171
TINLATTICE – linear - 50 m resolution	0.000	20.000	6.183
TINLATTICE - quintic - 25 m resolution	-0.600	20.600	5.438
TINLATTICE - quintic - 50 m resolution	-0.600	20.600	5.428

In terms of the minimum value, other than the TINLATTICE linear interpolations, the other four interpolation methods produced a range of results, deviating from the raw data (0.000 m) with both surfaces generated using TOPOGRID keeping closer to this value than the TINLATTICE approaches using quintic smoothing. Both maintained lowest values below that of the lowest contour provided by the raw data. The maximum values from the various interpolations from these two interpolation methods were each above the value of the raw data. The TINLATTICE quintic function provided surfaces with an equal balance of 0.600 m above the highest contour and below the lowest contour. Unlike the minimum values the TOPOGRID function provided maximum values furthest out of

the two, with an excess of nearly 2 m in each case, with greater deviation with the higher resolution surface.

Overall, mean values were all quite similar with a mean of 5.8815 m and a maximum range of 0.755 m, suggesting that no single method could be singled out as anomalous. This suggests that the generation of surface artefacts, sinks and peaks is likely to be minimal in each case.

In summary, it is expected that a surface interpolated from a dataset of contours set at vertical intervals of 10 m will produce a minimum value lower than the lowest contour value, but not as low as the next lowest contour interval. It will also produce a maximum value greater than the highest contour value, but not as high as the next interval. For this surface the contour density was 10 m with a minimum value of 0 m and a maximum value of 20 m OD. Because these contour values were present in the dataset, any accurate interpolated surface must contain them. Therefore, any surface presenting values that are within a range of < 0 m but >-10 m and > 20 m but < 30 m OD may be considered accurate in relation to the data unless any visible surface artefacts have been created. In the present study, it appears that the surfaces generated using the TINLATTICE (linear) interpolation technique are likely to be the least accurate, although they do conform closely to the data itself. In terms of resolution, there appears to have been little effect generally within these surfaces. The TOPOGRID generated surfaces presented the greatest variation with increased resolution reflecting greater deviation from the range of the raw data.

To further analyse the relative accuracy of the surfaces generated from the Ordnance Survey data the individual surfaces were subtracted from one another and the minimum, maximum and mean values from the resulting surfaces were recorded and are listed in Table 6.2.

The most notable feature of these results is differences present from the different interpolation techniques in relation to one another. While the minimum and maximum values from these resulting surfaces present reasonable variation, the ranges in each case are similar. The mean of the ranges is calculated to 16.090 m with an overall range of 4.001 m between the highest and lowest ranges (14.516 - 18.517 m). Resolution appears to have had a limited effect upon these results. There is a slight reduction in the ranges of

the lower resolution data indicating that the surfaces generated using the different techniques were less variable.

Table 6.2 *Results from the subtraction of surfaces from each other (TL = TINLATTICE)*

	Min value (m)	Max value (m)	Mean (m)
TL linear - TL quintic (25 m resolution)	-7.917	10.600	0.733
TL linear – TOPOGRID (25 m resolution)	-10.141	4.987	0.148
TOPOGRID - TL quintic (25 m resolution)	-5.957	10.181	0.584
TL linear - TL quintic (50 m resolution)	-5.761	9.912	0.725
TL linear - TOPOGRID (50 m resolution)	-8.378	6.138	0.187
TL quintic - TOPOGRID (50 m resolution)	-6.860	9.709	0.539

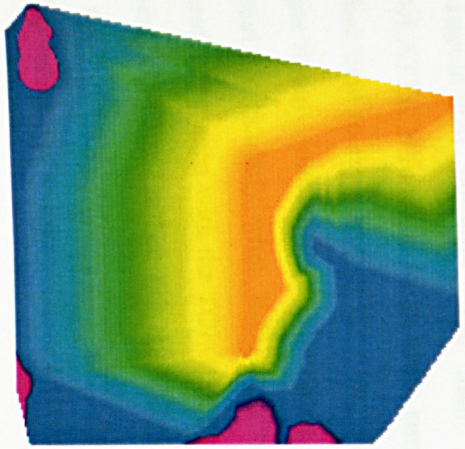
Overall, it is not possible to state which method of interpolation is the most accurate, although it does seem that the lower resolution surfaces were closer to the original data with less variation than the higher resolution surfaces, although only very slightly. The linear TINLATTICE interpolations probably create the least accurate surfaces in relation to the landscapes they represent even though they maintain a close relationship to the raw data.

6.2.2 Visual results

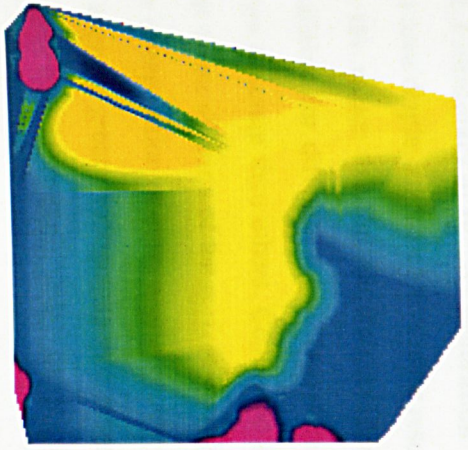
A view of the resulting models provided further information regarding accuracy (Figure 6.1). Each surface was visually examined independently and in relation to the raw contour data that was overlain and, finally, profiles were calculated through the surfaces. Observations based upon aesthetic realism and deviation from trends within the raw data. The subjective nature of this analysis is outlined in chapter 4 (section 4.3.3).

The linear TINLATTICE derived surfaces kept closely to the contours, grading between them evenly without apparent surface artefacts. The visual impact was very angular and the area covered by the model only extended as far as the contours and therefore did not fill the required area of the study region. Surface resolution had minimal effect upon the surfaces.

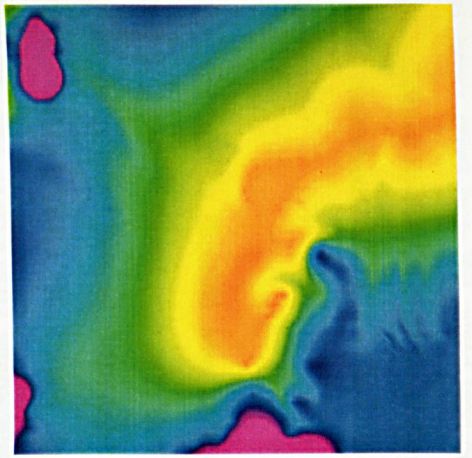
The TINLATTICE function using quintic smoothing produced surfaces that were quite different to those resulting from linear interpolation. The area within the northwestern



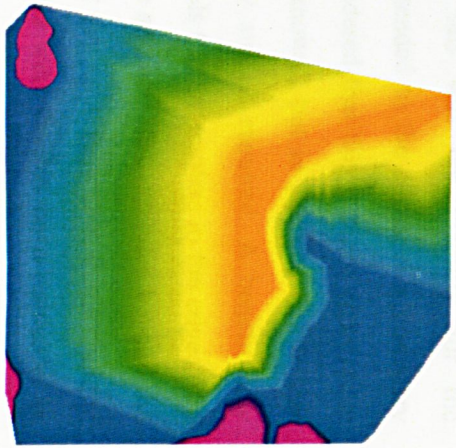
tinlattice linear at 50 m resolution



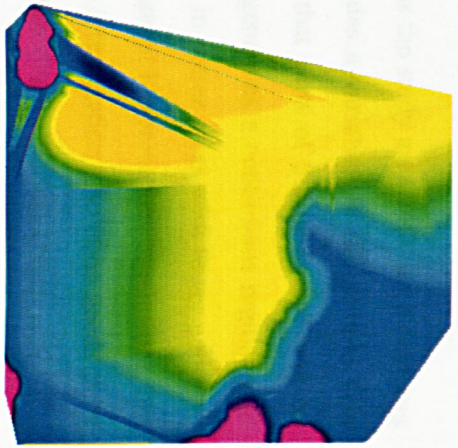
tinlattice quintic at 50 m resolution



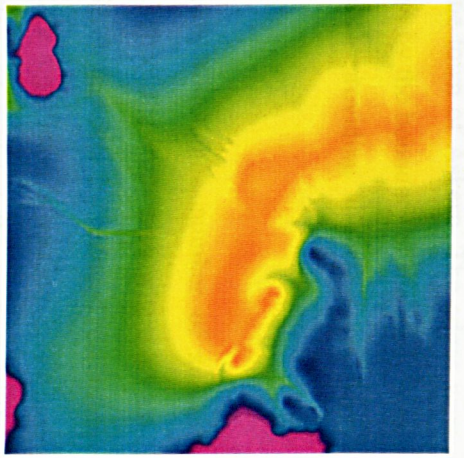
topogrid at 50 m resolution



tinlattice linear at 25 m resolution



tinlattice quintic at 25 m resolution



topogrid at 25 m resolution

Figure 6.1 Results from various interpolation methods at different resolutions.
Displayed using a default linear colour-scaling based upon the frequency of cell values. Each area measures 10 x 10 km, with north to the top of the images.

corner of the study area was extremely angular with difficulties in interpolating across the lower areas from the raised land occupied by the town of Askern. The edges were again defined by the limits of the contours rather than by the boundary of the study area. Again resolution had little effect other than through providing slightly more fuzzy aesthetics.

The TOPOGRID function also kept to the contours although a number of surface artefacts were produced such as within the western half of the study area where a west-northwest by east-southeast aligned valley was visible. In this case the reduced resolution (50 m) had a positive effect upon the surface with a significant reduction in surface artefacts. The TOPOGRID interpolation method also extrapolated the surface to the edges of the study area without the creation of any highly visible artefacts that did not conform to the limited pattern presented by the contours.

6.2.3 Summary of surface generation

An area displaying variable contour resolution such as the study area with more contours on the ridges than on the main lowland area provides a variation in the sample data available for different areas. Therefore, it is likely that parts of the landscape will be more accurate than others. Cell-based interpolation generates a continuous regular grid that treats all parts of the surface equally. Therefore, in flatter areas with fewer contours the interpolation of areas near contours will be accurate at lower surface resolutions, but in areas of greater topography with more contours the interpolation resolution needs to be greater in order to avoid under-interpolation and the resulting quantizing errors.

In terms of the numerical analysis, there appears to have been little variation to suggest that one surface interpolation technique was superior. However, the visual results provided some more useful results in relation to the generation of a surface for archaeological purposes. The main factor with this was the inability for the TINLATTICE function to generate surfaces that extended to the edges of a boundary rather than to the edges of the data. It may be considered that this is more appropriate since it only interpolates to the edges of what is 'known', but in practice this is less useful, particularly when a DEM of a given study area is required. A benefit may therefore be seen with the TOPOGRID derived models that interpolate to the edges of a given boundary. Further, this method did not produce artefacts that extended beyond the 10 m standard deviation provided by the contours for that area. However, this technique did produce some interpolation artefacts though these were limited by a reduction in

surface resolution. For the Sutton Common landscape it appears that overall the lower resolution surface generated using TOPOGRID was the most appropriate.

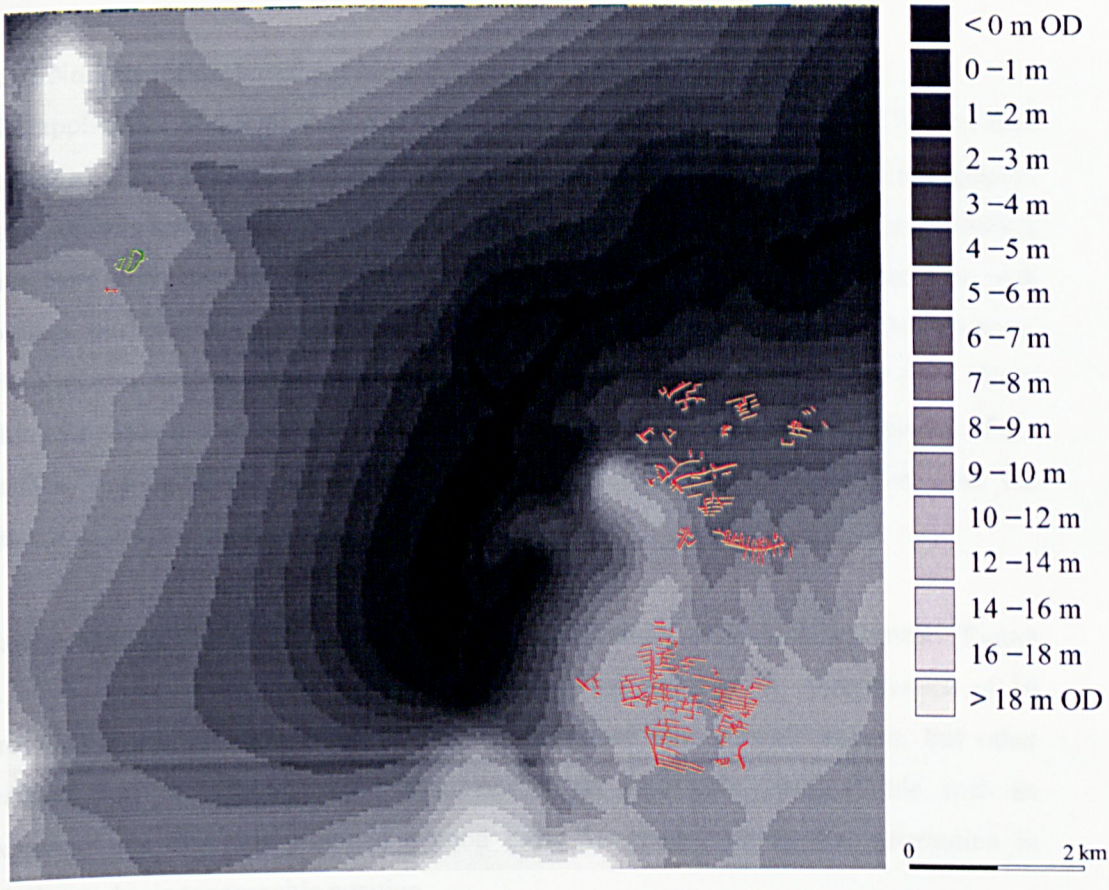
6.3 Surface representation of the lower resolution landscape

6.3.1 Elevation-based surfaces

The application of elevation-based surface generalisations was partially restricted for this site since the raw data consisted of contours (Figure 6.2). Therefore, any increased interpolation of those areas between the contours could not provide additional information about the surface. DEM modelling using contour bands was more useful since the generation of a continuous surface brought a greater understanding of the landscape.

Notable features visible from the DEM were highlighted by the raw data. The distinct palaeochannel was remarkable as were the areas of raised land on the western side of the study area (the Magnesian Limestone edge) and within the southeastern corner (the Sherwood Sandstone and older river gravels). There was no indication of the organic-filled hollow of West Moor in the southeastern corner of the region.

The overlaying of the principle archaeological features in the area suggested no particular pattern, although a number of general observations could be made. Firstly, the main distribution of the crop marks lay on the higher land within the southeastern corner above the scarp overlooking the River Don. However, this area has been studied in detail in relation to the geology and soils (Riley 1980, 1983). This work demonstrated that the crop marks overlie an area of greater natural drainage relative to those areas devoid of crop marks. This increased drainage enables the visibility of the buried features through the differential moisture retention of ditch fills relative to the surrounding soils which is reflected by differential crop growth, particularly on thinner soils where such a reaction will be more rapid (Jones and Evans 1975). Geologically there are similar areas locally which do not contain crop marks despite similar land use. However, Riley (1980, 1983) demonstrated that the vast majority of crop marks from within this area were isolated to the Newport series of soils, with some also visible on the Stockbridge series. The heavier soils, such as those of the Foggathorpe series, were absent from features though it is interesting that many of the features east of Edenthorpe run up to and stop at the edge of the heavy and organic soils of West Moor. This indicates that the features originally continued into this area, at least partially, but are not visible due to drainage conditions here.



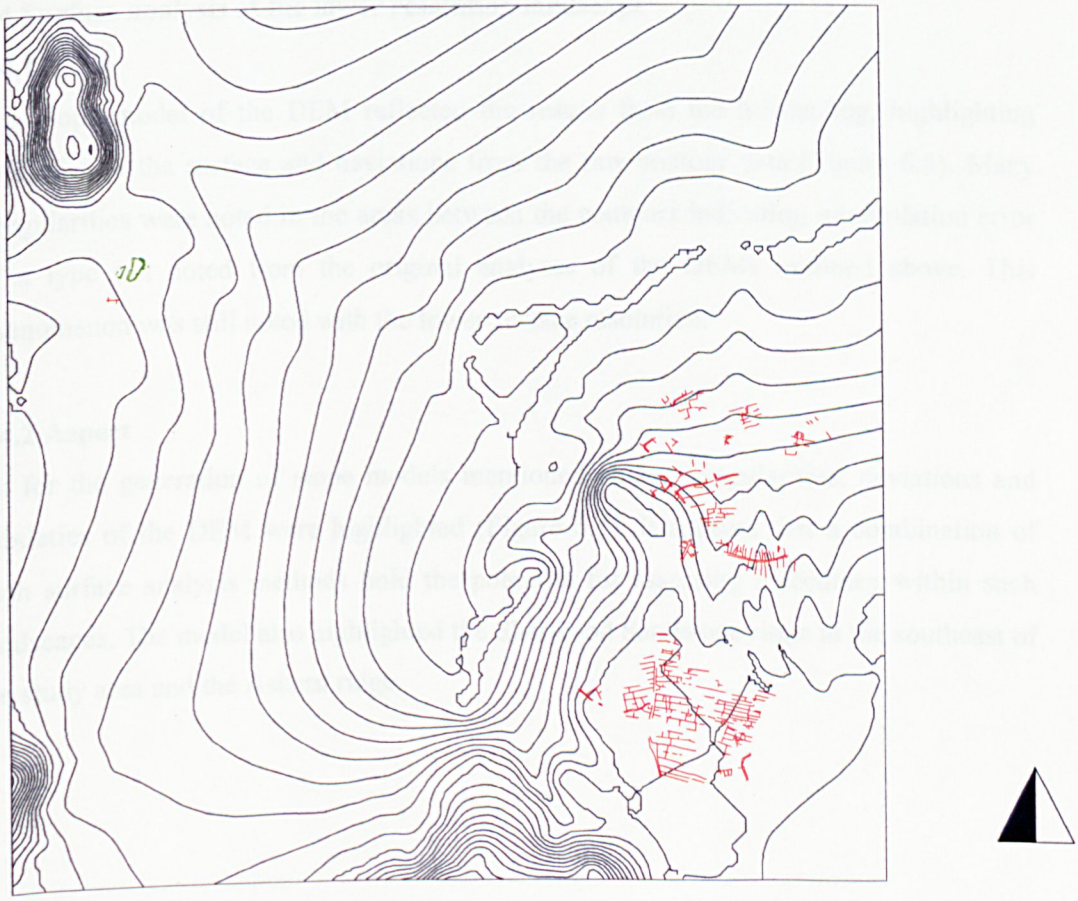


Figure 6.2 Elevation-based surface representations. Contours shown at 1 m intervals.

6.3.2 Non-elevation-based surfaces

The application of a light source to the surfaces derived from the Ordnance Survey data produced very plain and unrealistic results (Figure 6.3a). The lack of local topographic variation was reflected by the large areas represented by a single value producing models that were characterised by blocks of shades. It has been shown elsewhere that such lowland surfaces can produce good hill-shaded models on the larger scale, however, when an area such as this would be just a small part (*cf.* Van de Noort and Ellis 1997). This technique had an advantage in that it also highlighted some of the subtleties of the surface, highlighting areas where the interpolation technique had deviated from the pattern of the raw contour data.

Exaggeration of the surface made the topographic features easier to comprehend (Figure 6.3b). However, a large amount of exaggeration was required. A multiplication of 10 provided a draped surface that displayed the raised land around Askern, but other features such as the Sherwood Sandstone ridge were only made visible with an exggeration x 30. This provided a good basis for understanding site distribution in relation to basic topographic position.

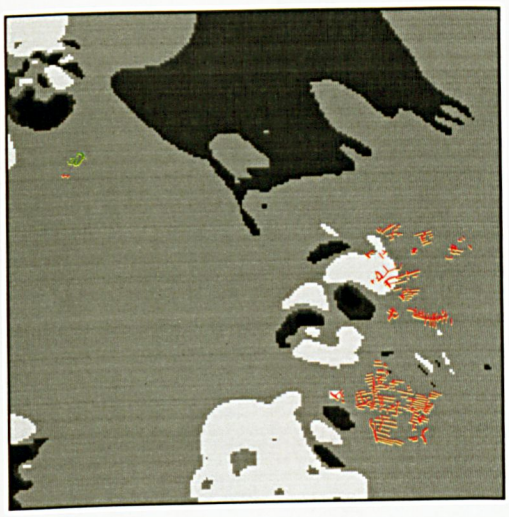
6.4 Surface analysis of the lower resolution landscape

6.4.1 Slope

The slope model of the DEM reflected the results from the hillshading, highlighting subtleties in the surface and deviations from the raw contour data (Figure 6.4). Many irregularities were noted in the areas between the contours indicating interpolation error of a type not noted from the original analyses of the DEMs outlined above. This phenomenon was still noted with the lower surface resolution.

6.4.2 Aspect

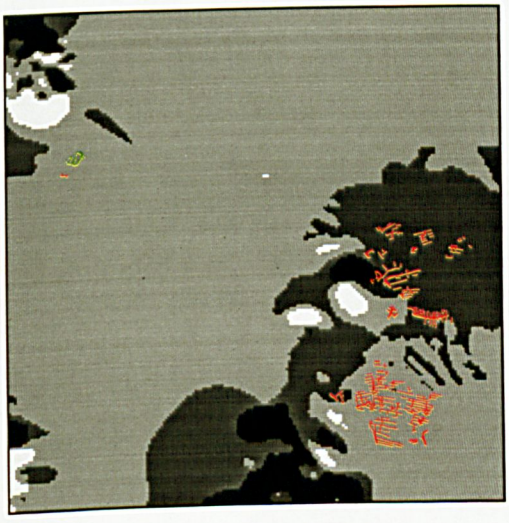
As for the generation of slope models mentioned above, irregularities, deviations and subtleties of the DEM were highlighted (Figure 6.5). It appears that a combination of such surface analysis methods hold the potential for assessing inaccuracy within such landscapes. The model also highlighted the Sherwood Sandstone ridge to the southeast of the study area and the Askern ridge.



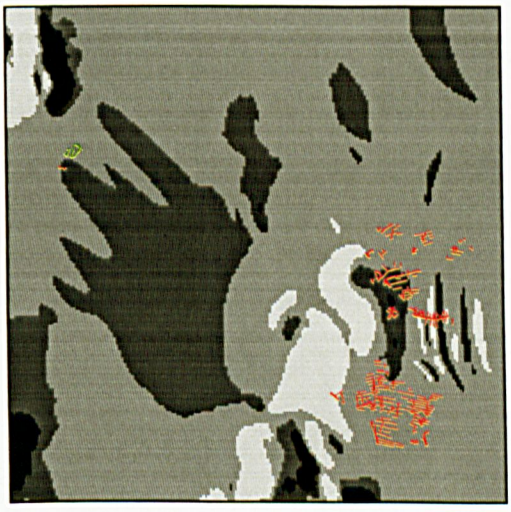
Lit from the north



Lit from the east



Lit from the south



Lit from the west



Figure 6.3a Hillshade models with light source in different positions.
Each area measures 10 x 10 km.

Figure 6.3b 100 m interval lattice and archaeological features draped over the surface model using a x 10 surface exaggeration (looking northeast).



Figure 6.4 Slope model derived from the DEM.

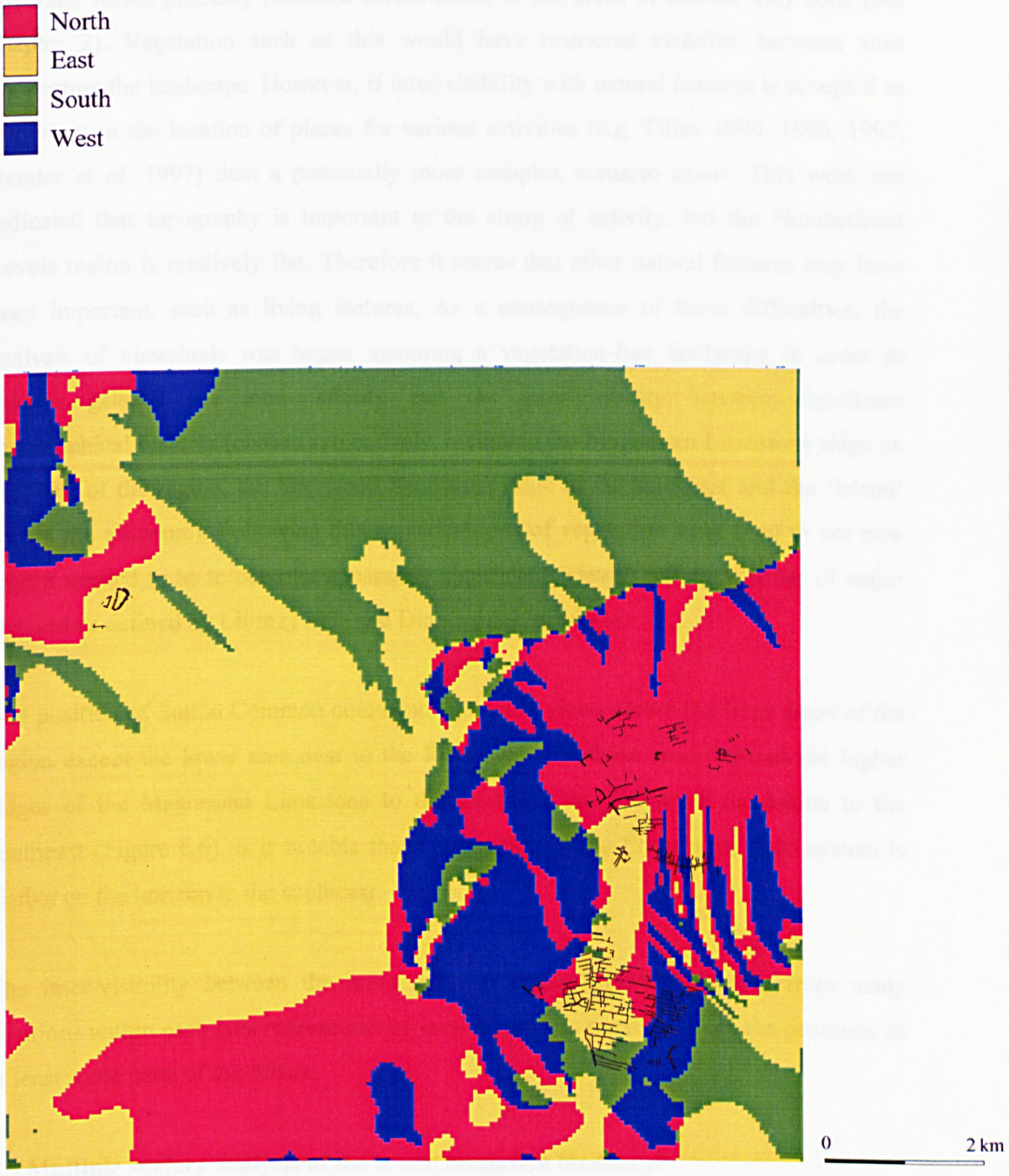


Figure 6.5 Aspect model derived from the DEM.

6.4.3 Visibility

Overall, inter-visibility may be considered as less important within an environment such as the Humberhead Levels during the later prehistoric period due to the thick vegetation coverage which probably persisted across much of the areas of heavier clay soils (see chapter 2). Vegetation such as this would have restricted visibility between sites connecting the landscape. However, if inter-visibility with natural features is accepted as important in the location of places for various activities (e.g. Tilley 1994, 1996, 1997, Bender *et al.* 1997) then a potentially more complex scenario exists. This work has indicated that topography is important to the siting of activity, but the Humberhead Levels region is relatively flat. Therefore it seems that other natural features may have been important, such as living features. As a consequence of these difficulties, the analysis of viewsheds was begun assuming a vegetation-free landscape in order to analyse general site inter-visibility and the inter-visibility between significant topographical features (chosen subjectively, including the Magnesian Limestone ridge on the west of the region, the Sherwood Sandstone ridge to the southeast and the 'island' within the alluvium). Following this considerations of vegetation were used to see how high it needed to be to obstruct apparently significant 'views' and along areas of major wetland as defined by Lillie (1997) and Dinnin (1997b, 1997c).

The position of Sutton Common commands potential views across the large areas of the region except the lower area near to the River Don and those areas beyond the higher ridges of the Magnesian Limestone to the west and the Sherwood Sandstone to the southeast (Figure 6.6). It is notable that the position of the Edenthorpe field system is visible on the horizon to the southeast.

The inter-visibility between the areas of field system demonstrate that from many positions within each area represented by crop marks it is possible to see the positions of at least some parts of the others.

6.5 Multiple surface analysis of the lower resolution landscape

The intervisibility between the Edenthorpe field systems and the enclosures on Sutton Common was mentioned above. How this reflects back on the early Iron Age landscape, contemporary with the enclosures, is dependent upon the contemporary environmental conditions that would inevitably restrict visibility. The direction of visibility to the southeast would require a clear line of sight through Shirley Wood and it is unlikely that during the early Iron Age this would have been clear. If an arbitrary figure of 10 m



Figure 6.6 Visibility calculation from the Sutton Common enclosures.

elevation is added to the area defined as wetland previously by Lillie (1997) it provides a visual barrier. Using this within the recalculation of the viewshed from the enclosure on Sutton Common provided a complete blockage of visibility (Figure 6.7). A reduction by half to 5 m vegetation restriction maintained this total block of the visibility to the east and southeast, even preventing all visibility of the Sherwood Sandstone ridge.

6.6 Surface generation of the higher resolution landscape

A surface was generated from the GPS survey data using the available methods outlined in chapter 3. The vertical data range from the survey was between 2.030 m and 5.771 m OD, with a mean of 4.471 m and a range of 3.74 m. The mean value suggests that the majority of points were taken from the higher levels.

6.6.1 Quantifiable results

The initial assessment of the models was examined against the raw survey data which was assumed to be correct (see chapter 3 for outline of survey method and reliability). The following table shows the data from the initial comparisons between the statistical ranges of this raw data and that from the various interpolation methods (Table 6.3).

An initial assessment of the results from this analysis demonstrate that the spline and trend surfaces stand out as different from both the raw GPS data and the surfaces generated using other means. In relation to the minimum values, that closest to the raw data was that generated using the IDW function at 3 m resolution (0.062 m above the lowest GPS value). The next closest was the surface derived from the TINLATTICE quintic (both 1 m and 3 m resolution) function (0.012 m lower than the lowest GPS value), followed by the same method using linear smoothing at 1 m resolution (0.119 m higher). The method producing a minimum value furthest from the raw data was the spline function that generated extremely low values indicative of interpolation artefacts. Interestingly, all values except for those generated using the TINLATTICE quintic function and the spline function generated minimum values higher than the lowest point of the raw data.

In relation to the maximum values the same pattern is true with just the TINLATTICE quintic and spline interpolation techniques generating surfaces with values higher than that of the raw data. The closest values were from the TOPOGRID function with the higher resolution displaying a closest value. The high-resolution IDW surface was also extremely close to the value (0.002 m lower). These were followed by the TINLATTICE

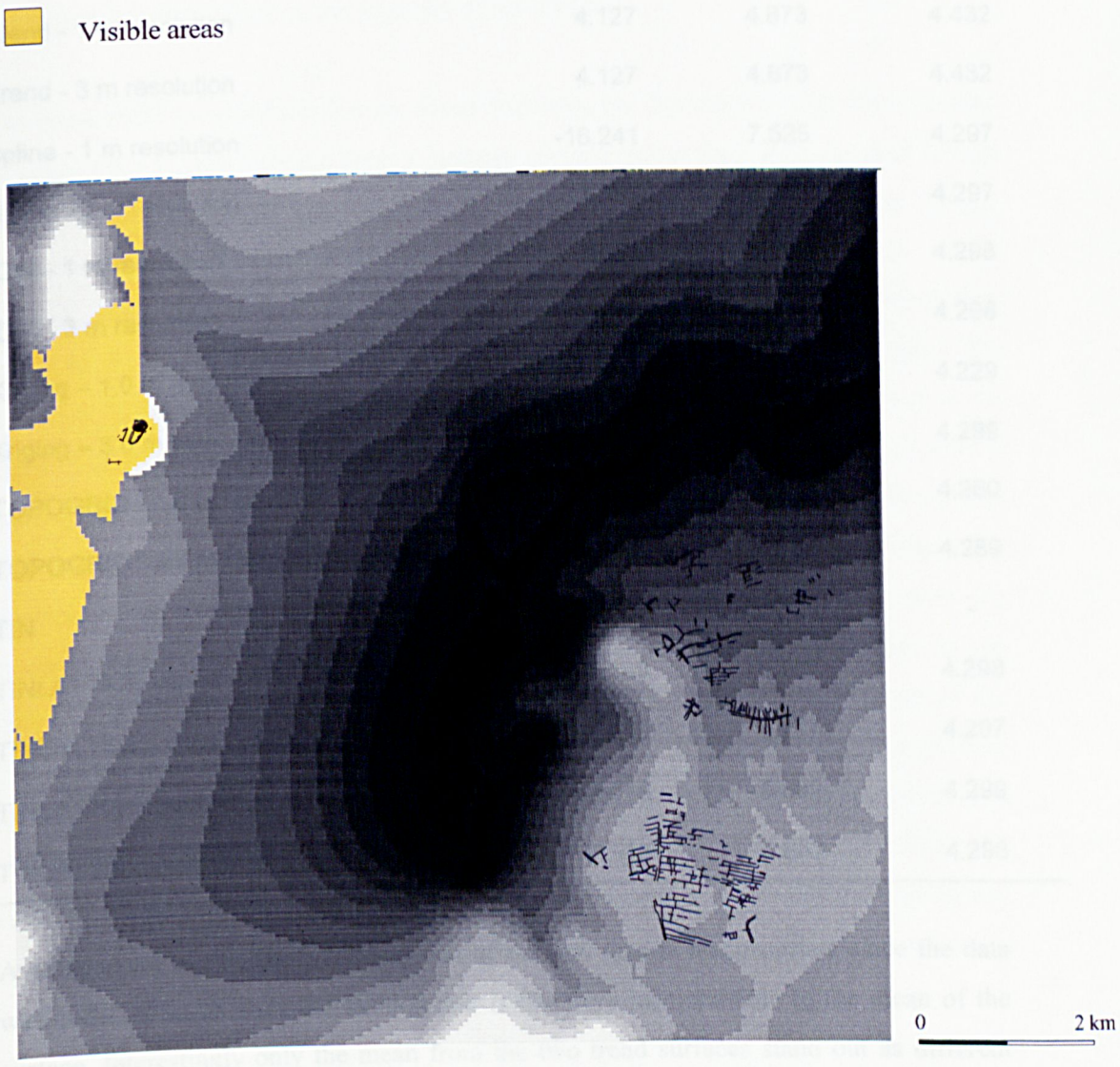


Figure 6.7 Visibility calculation from the Sutton Common enclosures incorporating a 10 m high vegetation barrier.

linear interpolation surfaces, again with closer values from the higher resolution survey. The method that deviated furthest from the raw data was again the spline interpolation technique.

Table 6.3 *Surface interpolation results - GPS survey data*

	Min height (m)	Max height (m)	Mean height (m)
GPS survey	2.030	5.771	4.471
Trend - 1 m resolution	4.127	4.873	4.432
Trend - 3 m resolution	4.127	4.873	4.432
Spline - 1 m resolution	-16.241	7.525	4.297
Spline - 3 m resolution	-11.753	8.340	4.297
IDW - 1 m resolution	2.092	5.769	4.298
IDW - 3 m resolution	2.092	5.736	4.298
Kriging – 1.0 m resolution	2.945	5.677	4.229
Kriging – 3.0 m resolution	2.948	5.677	4.299
TOPOGRID - 1.0 m resolution	2.160	5.770	4.260
TOPOGRID - 3.0 m resolution	2.442	5.768	4.289
TIN	2.030	5.771	-
TINLATTICE - linear - 1.0 m resolution	2.149	5.767	4.298
TINLATTICE - linear - 3.0 m resolution	2.189	5.747	4.297
TINLATTICE - quintic - 1.0 m resolution	1.918	5.882	4.299
TINLATTICE - quintic - 3.0 m resolution	1.918	5.882	4.298

A comparison of the mean value to that of the raw data is inappropriate since the data was collected in an irregular fashion and is therefore incomparable to the mean of the surface. Interestingly only the mean from the two trend surfaces stand out as different from the overall trend. Other than for the surfaces generated using spline and TOPOGRID, the effect of different resolutions on the data appear to have been minimal. This was particularly marked with the TINLATTICE quintic interpolated surfaces.

In summary, it appears that some techniques are better than others for the generation of surfaces appropriate for archaeological study. Firstly, the surfaces generated using spline

appear to be least useful since they appear to have generated a large number of surface artefacts judging by the wide range of values. Secondly, for a surface to be accurate in relation to the raw input data then one would assume that, as for the contour data outlined above, the minimum value of the surface would be lower than that of the raw data, and that the maximum value would be higher. Other than the spline surfaces where such values were excessive, this only happened when TINLATTICE was used with quintic smoothing. The lack of other variables from this data indicates that this technique is the most appropriate for dealing with this type of data. Further it appears that resolution has little effect on the accuracy of the surfaces.

The basic DEM provided much more detail than from the Ordnance Survey data (chapter 3, section 3.2.1), although the general balance was correct in each with the land falling away to the east with higher land to the west. However, the absolute height measurements from each were quite different in more ways than resolution would suggest. The Ordnance Survey derived surface was re-sampled from a surface resolution of 50 m to one of 1 m using a nearest neighbour assignment and clipped using the boundary (hull) created for the GPS survey area to allow for direct comparisons to be made. The processed surface provided a height range of 8.182 m to 9.169 m OD, with a mean value of 8.689 m OD, values which remained unchanged when the same surface was re-sampled to a 5 m surface resolution following the same process. The differences between these values and those of the surfaces generated from the GPS data are interesting particularly since they are based upon the same raw Ordnance Survey height data - the benchmark used to correct the GPS survey heights lay at the western end of the survey area upon a bridge. The overall lower level of the GPS model may be explained by subsidence which has been recorded from the mining industry in the area and, as a result of which, there is nothing solid within the area to check results against. However, both DEMs provide a mean value which is greater than half way between the highest and lowest values, demonstrating that each model shows the overall pattern of the relatively lower areas being present but less common across the area.

6.6.2 Visual results

Despite the overall statistical accuracy of the surfaces generated by different interpolators, a number of observations were made from the appearance of them (Figures 6.8a and b).

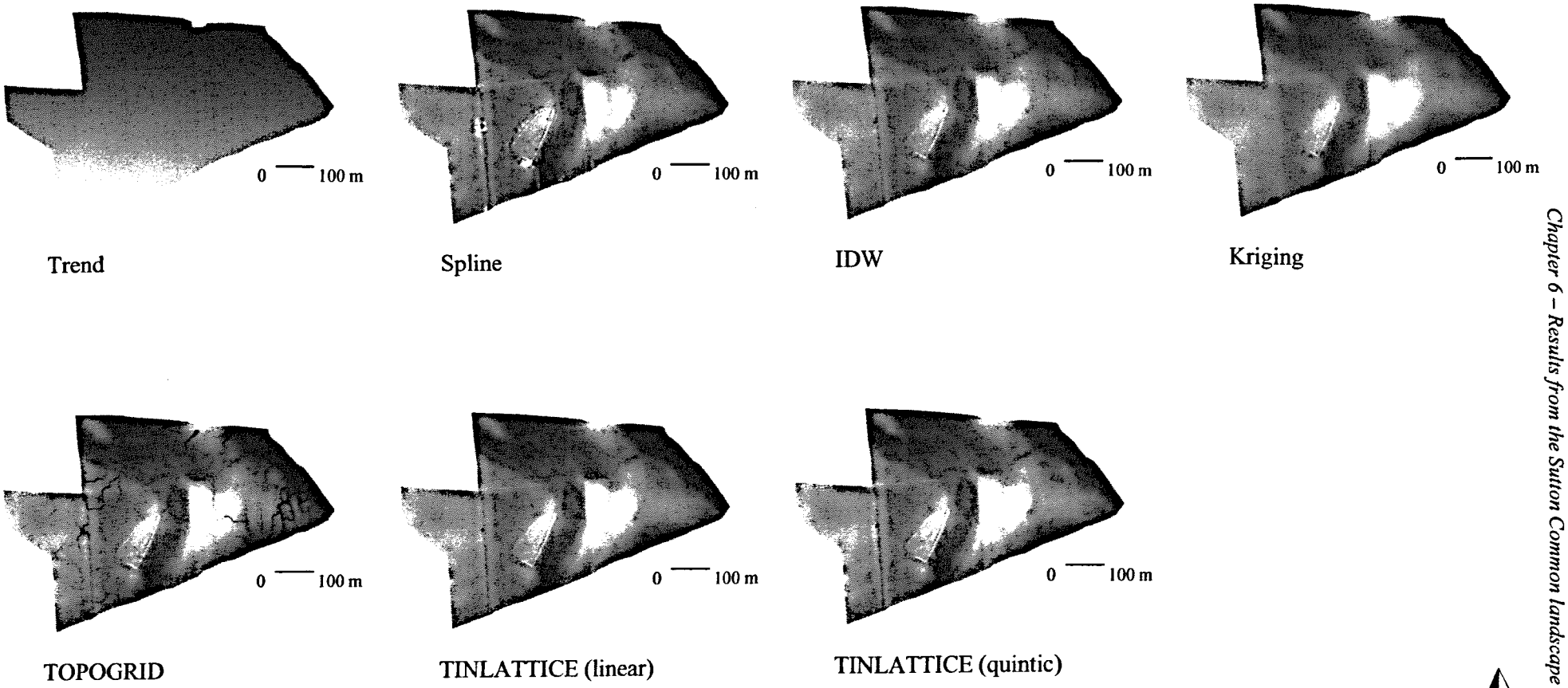
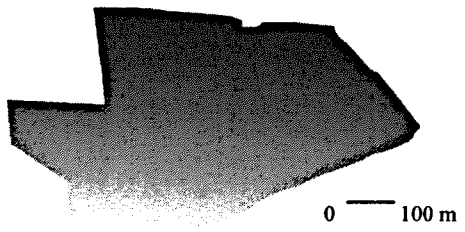
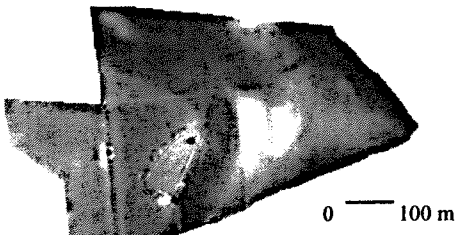


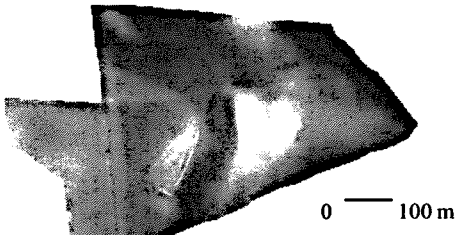
Figure 6.8a Results from the application of the various interpolation methods to the high resolution survey data of the Sutton Common enclosures. Displayed using a default linear grey-scaling based upon the frequency of cell values. Cell resolution at 1.0 m.



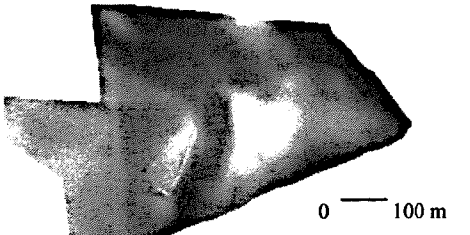
Trend



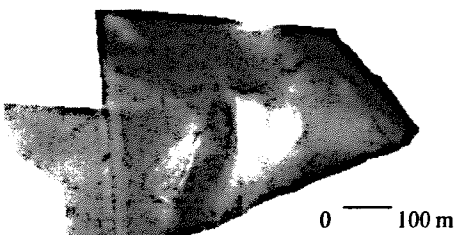
Spline



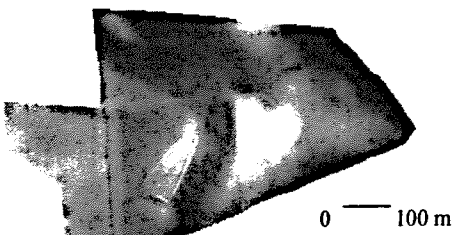
IDW



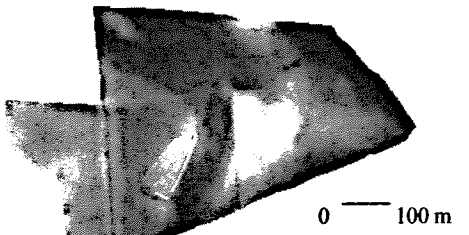
Kriging



TOPOGRID



TINLATTICE (linear)



TINLATTICE (quintic)

Figure 6.8b Results from the application of the various interpolation methods to the high resolution survey data of the Sutton Common enclosures. Displayed using a default linear grey-scaling based upon the frequency of cell values. Cell resolution at 3.0 m.

a. Trend

The surfaces generated using the trend function showed a linear value increase from north to south with constant values horizontally (Figures 6.8a-b). As such no archaeological features were highlighted and so the value of such a method can be seen to be extremely limited in terms of archaeology.

b. Spline

The surfaces generated using the spline technique produced a surface that displayed a number of excessively high areas such as to the south of enclosure B and low areas as in the southern part of the palaeochannel (Figures 6.8a-b). These features were visible at both resolutions highlighting the potential inaccuracy of this technique in application to this type of irregular data.

c. IDW

The 3 m resolution IDW interpolation method produced a surface that was smooth and regular with no visible artefacts generated (Figure 6.8b). The image was quite blurred although continuous features such as the banks of enclosure B were interpolated correctly providing a surface that reflected that of the ground well. The higher resolution surface was similar though less generalised (Figure 6.8a).

d. Kriging

The DEM surfaces generated using kriging were also very smooth, though the surface appeared to be more generalised than those created using the TINLATTICE function (see below). This was notable with the earthworks defining enclosure B that, although spatially accurate, were indistinct (Figure 6.8a-b). The application of a light source enforced this appearance of generalisation. The surfaces produced had a fuzzy, over-smoothed appearance and linear subtleties became localised to the area from which they were greatest. This was most apparent with the modern drain towards the western edge of the site. Different resolutions did little to enhance this. Lower resolution surfaces of the DEM and hill-shaded models appeared very coarse.

e. TOPOGRID

The DEM surfaces generated using TOPOGRID were marked by the generation of visible artefacts, especially with the higher resolution surfaces. The appearance of dendritic channels running across the site was produced despite the interpolation being set to avoid the creation of sinks. Equally, the earthworks of enclosure B were disjointed

with more breaks in the bank that were real. Again, the generation of artefacts between the points surveyed had created a surface that was unrealistic and misleading. Lower resolution surfaces produced fewer artefacts, but most were still present. Light source application produced excessively smooth surfaces for the majority of the site but enhanced these interpolation artefacts. Also, notable surface errors were noted in the same areas of the site as recorded from the TINLATTICE function, such as to the south of enclosure B where jagged steps represent overlap of different surveys. Though notable on this model, particularly the higher accuracy hill-shaded models, this effect was not as marked as on those surfaces generated using the TINLATTICE function.

f. TINLATTICE

The basic DEM formed by the linear interpolator was very similar in appearance to that constructed using the quintic interpolator. Each produced a smooth surface with very distinct edges to the earthworks of enclosure B. In each case the surfaces were visually better with the increased resolution and there was no generation of visual artefacts with such an increase. The applied light source across the surfaces produced more differing results. The quintic interpolator produced very smooth, realistic surfaces with highlighted distinct edges to upstanding earthworks. The linear interpolator, however, produced very much more angular, less realistic faceted surfaces. Again resolution played little role in the visual representations of each surface except that higher resolutions were less fuzzy and more realistic. Some error was notable, particularly on the hill-shaded models of higher resolution. To the south and north east of enclosure B (and to a lesser extent along its western edge) linear jagged features were noted. On further examination of the raw data points it was seen that these represent areas where different surveys overlapped since the site was surveyed in sections (see chapter 3, Figure 3.5). Extremely minor changes in elevation for points surveyed close to one another have generated this surface scarring which could only be remedied through the extraction of one half of the overlapping points along each of these lines.

g. Summary

The visual quality of the resulting surfaces from the different interpolation techniques may be classed in a number of ways. Firstly, the generation of artefacts by the interpolation process will inevitably produce inaccuracies in analysis and may lead to overall misunderstanding. In this respect the surfaces generated using the TOPOGRID function were worst by the creation of channel-like features and the mis-representation of the earthwork features of enclosure B. It is possible that the channel features could be

partially real through the exaggeration of surface trends between points, but this is not the case for all examples, particularly in the southeastern corner, and it is certain that these are ridiculously exaggerated. Secondly, the degree of smoothing may be commented upon. The surfaces generated using kriging and TOPOGRID were highly generalised and smooth, particularly the former which produced a surface that overly-generalised local changes in topography. Thirdly, the representation of the earthworks of enclosure A demonstrated that the TINLATTICE function was by far the best at distinct, accurate representations. Conversely, TOPOGRID generated artefacts within the earthworks and kriging over-smoothed them. Fourthly, the realism of the surface may be considered. The most visually realistic surface was generated using the TINLATTICE quintic generator which produced smooth surfaces but without over-generalisations and while keeping features distinct. The linear interpolator produced much more angular surfaces. Finally, resolution played a role in the visual accuracy of the surfaces. Higher resolution surfaces were more visually pleasing lacking the fuzziness and generalisations of those of lower resolution. In some cases the higher resolution exaggerated errors, as with the channel-like features generated by the TOPOGRID function. Despite the increased memory requirements for higher resolution surfaces, they were aesthetically more pleasing and in keeping with the higher resolution areas of the survey.

6.7 Surface representation of the higher resolution landscape

The basic GPS survey derived model added further topographic detail which was not possible from the Ordnance Survey model, due mostly to the resolution of the raw data and the physical scale of the topographic variation. The model was rendered through a variety of contour banding methods. This ranged from software-default linear scaling (which provides bands of colour or shading in a linear scale dependent upon the number of cells contained within the model that lie within a certain value bracket) to user-defined re-mapping of colours or shades to different value bands. A number of features were identifiable from this modelling technique despite the intensive agricultural regime of the previous seventeen years.

6.7.1 Elevation-based surface representations

Elevation-based surfaces revealed a number of very interesting details providing information about both natural and anthropogenic features, many of which were not visible on the ground during the survey (Figure 6.9).

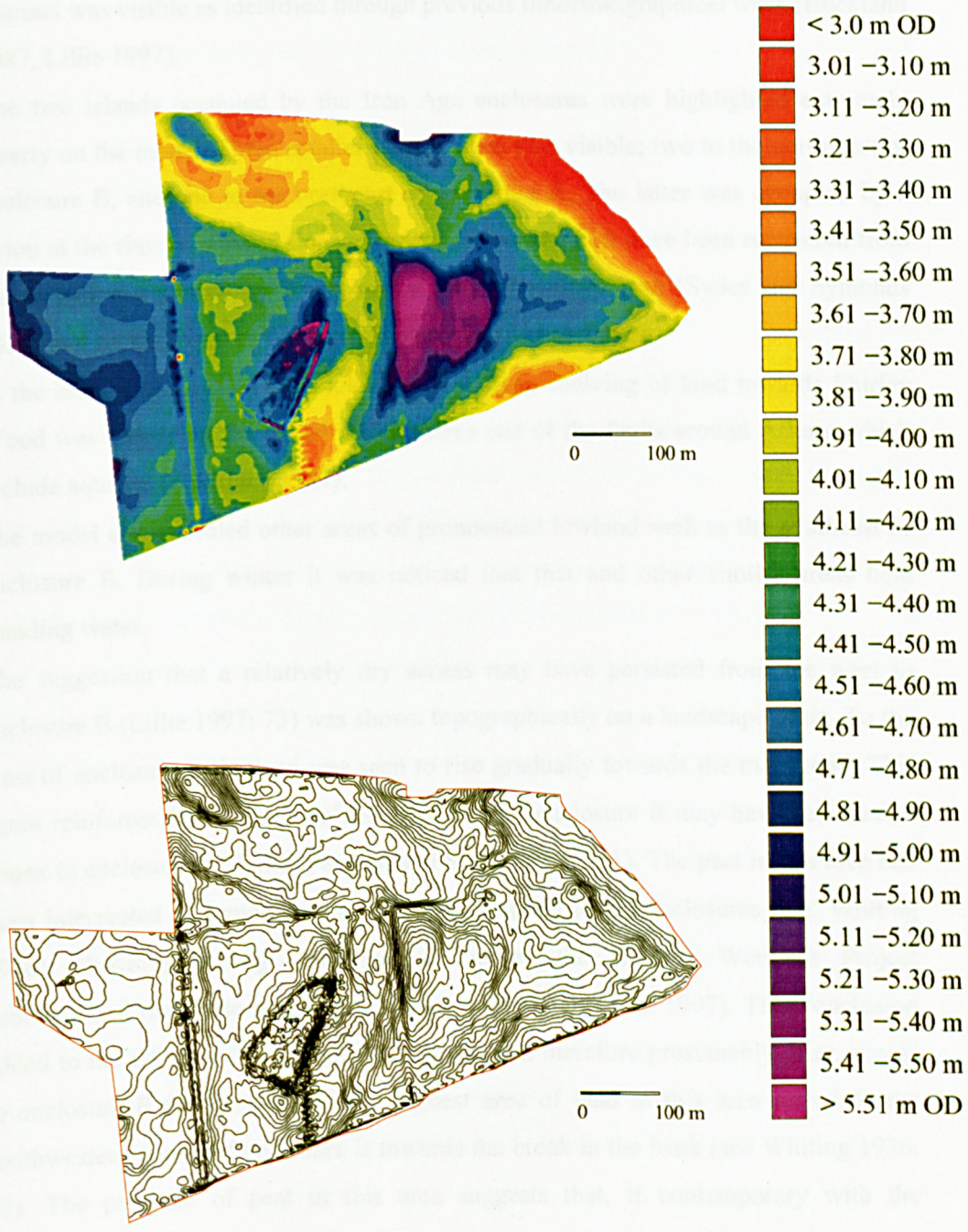


Figure 6.9 Elevation-based representations of Sutton Common (contour intervals at 0.1 m).

a. Contour-banded DEM

Natural features

- The most obvious feature was the relict Hampole Beck, which was visible in between the enclosures. Towards the northwestern part of the surveyed area, the braiding channel was visible as identified through previous lithostratigraphical work (Buckland 1987, Lillie 1997).
- The two islands occupied by the Iron Age enclosures were highlighted extremely clearly on the model. Three smaller islands were also visible; two to the northwest of enclosure B, and one to the northeast of enclosure A. The latter was occupied by a pylon at the time of survey. Concentrations of worked flint have been recovered from the former two islands by South Yorkshire Archaeology Unit (Sydes and Symonds 1988) and by the Humber Wetlands Project (Head et al. 1997).
- In the area to the east of the enclosures, the sharp shelving of land towards Shirley Wood was visible on the model which marks one of the faults around Askern which include aquifers (Buckland 1987).
- The model also revealed other areas of pronounced lowland such as the southeast of enclosure B. During winter it was noticed that this and other similar areas held standing water.
- The suggestion that a relatively dry access may have persisted from the west to enclosure B (Lillie 1997: 73) was shown topographically on a landscape scale. To the west of enclosure B the land was seen to rise gradually towards the main road. This again reinforces Parker Pearson's suggestion that enclosure B may have acted as an annex to enclosure A (Parker Pearson and Sydes 1997: 251). The peat in this area had been interpreted as providing a surrounding wetland to the enclosures (e.g. Whiting 1936). However, coring work carried out by the Humber Wetlands Project demonstrated that these peat deposits were superficial (Lillie 1997). This conclusion added to the DEM of the site shows a higher, and therefore presumably drier, access to enclosure B from the west. The highest area of land in this area runs into the southwestern corner of enclosure B towards the break in the bank (see Whiting 1936: 69). The presence of peat in this area suggests that, if contemporary with the enclosures, it forms the residue from a perceived 'wet' boundary between the relatively dry *island* tops occupied by enclosure B and the rising land to the west and the relative wetland between. This is in contrast to an actual physical boundary implying perceived defence rather than physical defence.
- When compared with the natural topography of the area it was notable that the western edge of enclosure A fell away sharply over the Hampole Beck palaeochannel.

However, on its eastern side the width of the enclosure was less than the width of the sandy island which dropped away gradually to the east up to the shelf near Shirley Wood. The positions of other low, wet areas around enclosure A's perimeter suggest that it cut off the end of a tongue of relatively dry land from the east. This may help to explain the increased earthwork rampart defences on this side of the enclosure since the extension of the dryer land to the east appears to join with a linear ridge aligned northwest by southeast.

Archaeological features

- The shape of the islands was highlighted by the outlines of the enclosures and this evidence suggests that their architectural plan was dictated, to a certain extent, by the shape of the islands. The triangular/kidney-shaped enclosures are reflected by triangular/kidney-shaped islands. This is particularly notable with enclosure A. The island extends further to the east than that occupied by the enclosure, but there is a notable elevation in height within the perimeter of the enclosure. Further, it appears from this evidence that this raise in height is not an artefact of past anthropogenic influence due to its distinct shape which is also continuous. Despite ploughing, it is unlikely that this could have been created through earth shifting.
- The earthworks of enclosure B are visible on the model, and the precise shape of it can be seen and understood.
- On the eastern side of enclosure B, a tongue of land was noticed extending eastwards from the eastern break in the earthworks. A possible causeway had been postulated in the past, but solid evidence of such a structure had never been found, although parts of a timber alignment had been seen in 1926 (Whiting 1936: 58, Parker Pearson and Sydes 1997: 251). The position of this spread, extending from a possible entrance to enclosure B, indicated the existence of such a structure. When this feature was investigated as part of the English Heritage commissioned investigations conducted by the Centre for Wetland Archaeology, the existence of a sandy causeway was discovered in this precise area (Van de Noort and Chapman 1999).

Modern features

- The drain running along the western edge of Sutton Common is clearly visible on the model.
- The track running east west along the northern edges of the enclosures is also visible as a slightly raised area. This is despite the fact that the track was purposely not surveyed, but rather the areas along its edges were picked up. The visibility of this

feature despite it not being surveyed demonstrates a certain level of potential destruction which may have been caused by the placing of this feature.

- The model revealed the position of a linear feature aligned approximately north south, cutting across the western edge of enclosure A. This alignment conformed to that obtained from the discovery of two modern fence stakes during excavation (*cf.* Van de Noort and Chapman 2000).

b. Basic contour models

A contour model of the site existed at the time of survey (Parker Pearson and Sydes 1997: 222) and so it was interesting to compare the results from this with those from the present survey (Figure 6.10). The published representation of this survey displayed contours at 0.1 m intervals relative to OD and covered an area greater than the present study region. Unfortunately the raw data for this survey was not easily available (Colin Merrony pers comm.) and so only a visual comparison may be made. Overall the two contour models were very similar over the areas which they both covered. All of the main themes and surface trends were reflected in each as were the overall elevation ranges. The palaeochannel and each of the islands were picked out on each, as were the various depressions and the shelving towards Shirley Wood. The shape and steepness of slopes were also similar in each. More detail however was seen within the present model that displayed higher detail particularly within and around enclosure A, although detail in the published survey may have lost detail during the reproduction process.

c. Profiling

Profiling of the site proved to be very useful in two ways. Firstly, through this method it was possible to examine the more minor details of the site. For example, the assessment of the earthworks was revealed in higher detail, particularly those on the western edge of enclosure A. By altering the relationship between the vertical and horizontal scales it was possible to examine the minor details of the levelled features. Secondly, profiling was used to assess the route into enclosure A which had been postulated and was commented upon above (*cf.* Parker Pearson and Sydes 1997, Figure 6.11). Through multiple profiles it was possible to see that a continuous area of higher ground extends towards the southwestern corner of enclosure B and it appears that the postulation made above from the contour-banded model was correct.

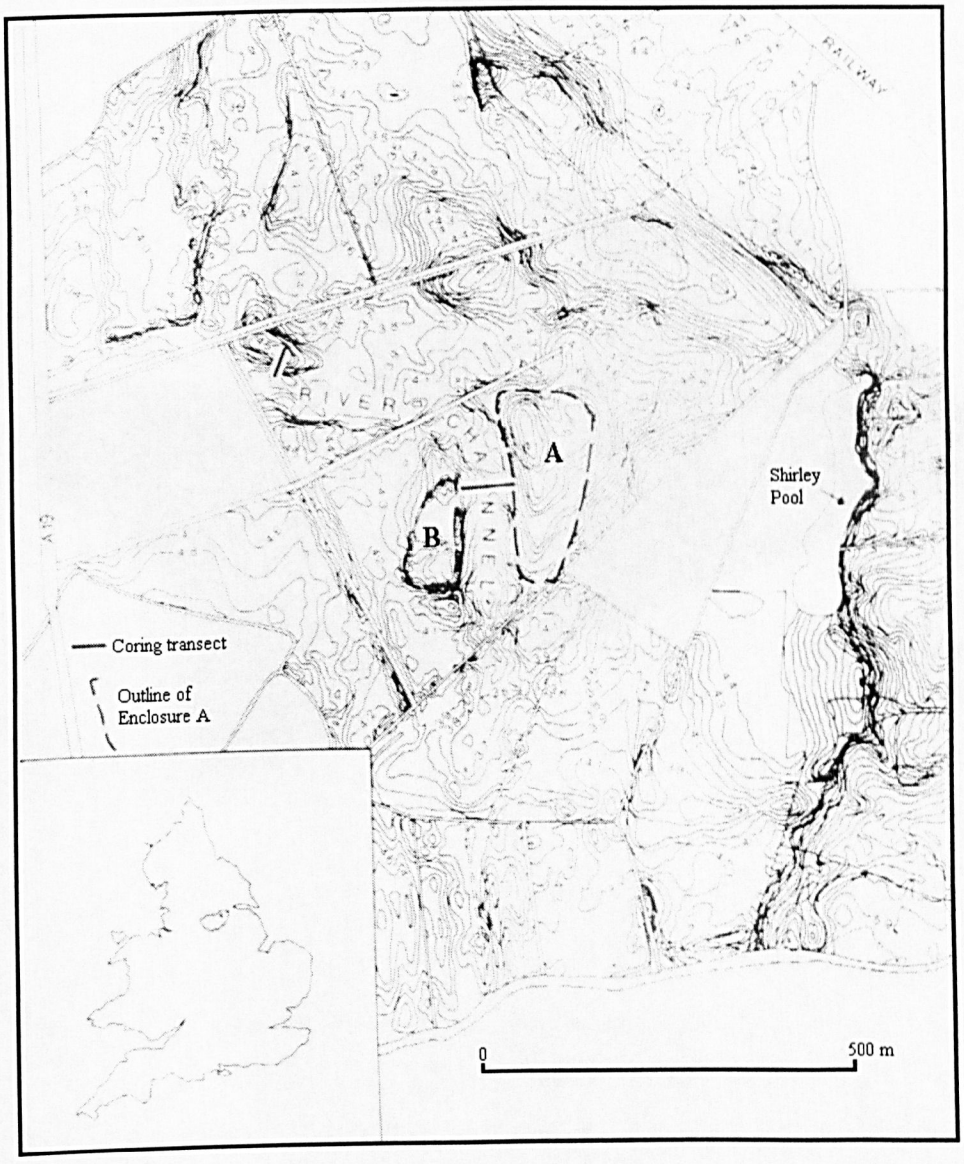


Figure 6.10 Previous contour survey of Sutton Common displayed at intervals of 0.1 m (after Parker Pearson & Sydes 1997: 222).

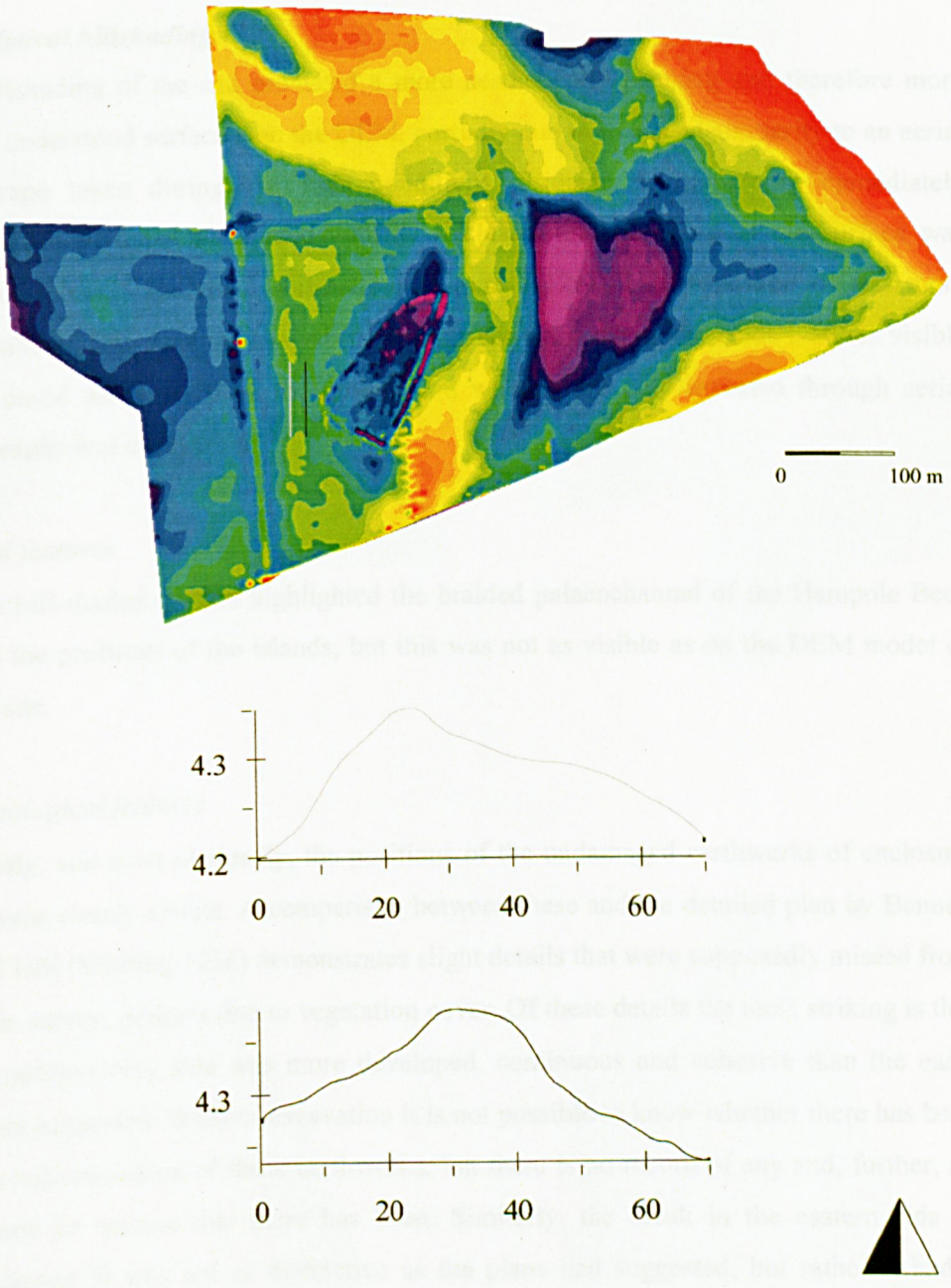


Figure 6.11 Profiles across the western approach to the smaller enclosures as postulated by Parker Pearson and Sydes (1997).

6.7.2 Non-elevation-based surface representations

The representation and generalisation of the surface in different ways provided further insights into the nature of the Sutton Common landscape and the features held within it.

a. Analytical hillshading

The hillshading of the site produced a more aesthetically pleasing and therefore more clearly understood surface than the DEM, partially due to its visual similarity to an aerial photograph taken during low light conditions. It made the site more immediately recognisable to those acquainted with it. A clearer understanding of the surface was obtained through analytical hillshading (Figure 6.12a). This was one of the more remarkable results from the analysis of this surface since the model made features visible which could not be seen on the ground and which were only revealed through aerial photography and excavation.

Natural features

- The hill-shaded models highlighted the braided palaeochannel of the Hampole Beck and the positions of the islands, but this was not as visible as on the DEM model of the site.

Archaeological features

- Firstly, and most obviously, the positions of the undamaged earthworks of enclosure B were clearly visible. A comparison between these and the detailed plan by Bennett and Hill (Whiting 1936) demonstrates slight details that were supposedly missed from their survey, perhaps due to vegetation cover. Of these details the most striking is that its northwestern side was more developed, continuous and cohesive than the early plans suggested. Without excavation it is not possible to know whether there has been any reconstruction of these earthworks, but there is no record of any and, further, no reason to assume that there has been. Similarly, the break in the eastern side of enclosure B was not as distinctive as the plans had suggested, but rather it had a gradual shape to it. Enclosure B was similarly highlighted by this analysis, though the difference between its representation as a basic DEM and as a shaded model was not as great as with the bulldozed and ploughed enclosure A. The outline was very clear and highlighted a number of details than had previously been identified from surveys of the site and, in conjunction with the evidence from the excavation, identified a new phase of activity.

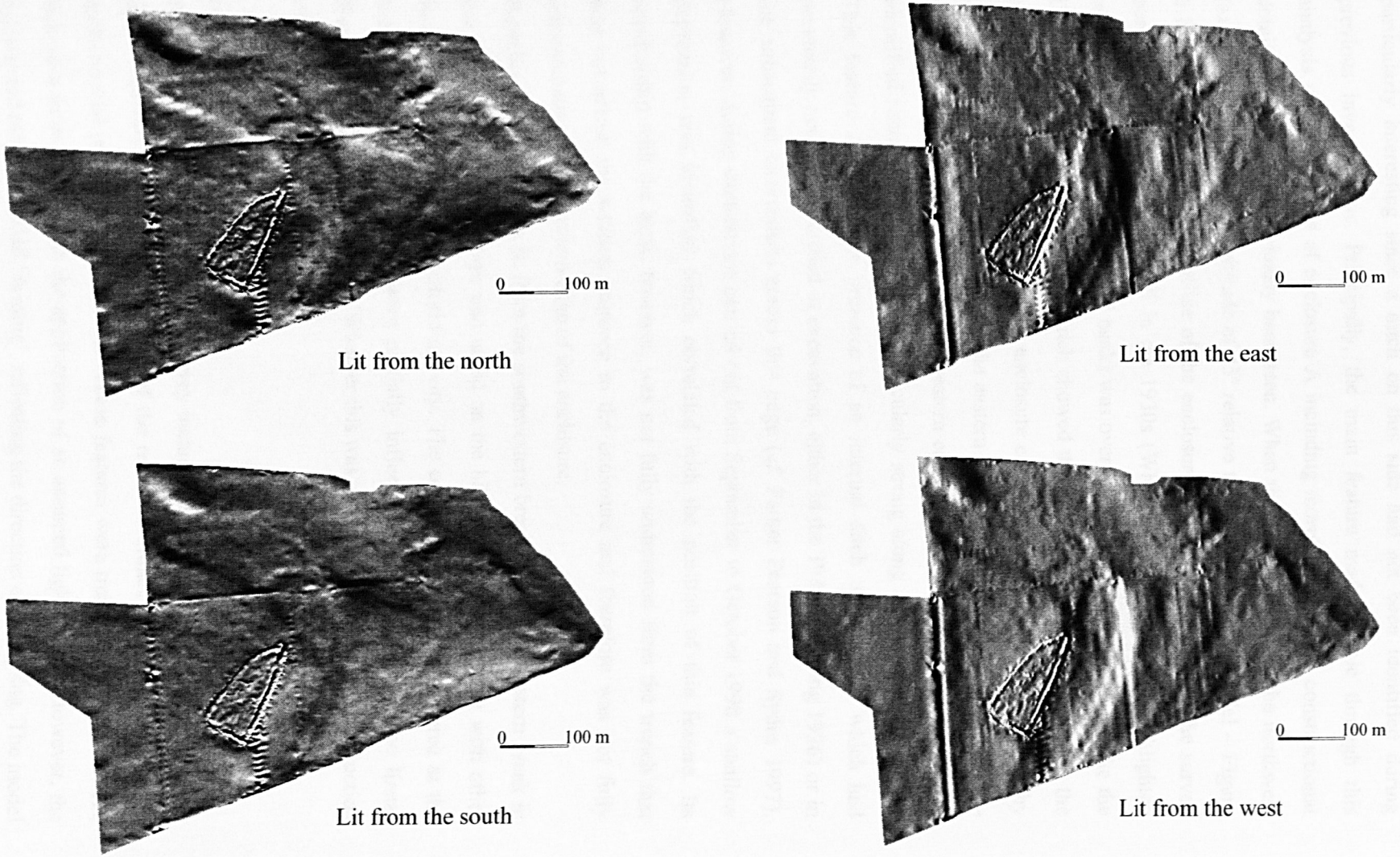


Figure 6.12a Results from hillshading with the light source at cardinal directions (45° altitude).

- The hill-shaded model identified greater detail of the outline of enclosure A including the position of what appeared to be a ditch on its western side. This feature was particularly interesting since a ditch on this side had not been identified during previous investigations. Principally, the main feature made visible through this analysis was the outline of enclosure A including morphological and constructional detail which had not previously been seen. When the site was lit from the northwest (azimuth of 270° with an altitude of 45° relative to the centre of the model – Figure 6.12b) it revealed the full outline of the enclosure which fitted well with the survey conducted by Bennett and Hill in the 1930s (Whiting 1936). This was highlighted when the outline of the surveyed banks was overlain as a vector coverage. Unlike the DEM outline mentioned above which showed the *island* extending some way to the east outside of the boundary of the enclosure earthworks, the outline highlighted by this model showed a scarp marking the eastern edge of the enclosure, away from the edge of the *island.* Similarly, on the western edge of enclosure A, a depression was identified running along its length, particularly strong along its southern two thirds. This feature suggested the presence of an internal ditch on this side which had previously not been identified in excavation, either in the 1930s (Whiting 1936) or in the subsequent excavations across this edge (*cf.* Parker Pearson and Sydes 1997). However, during excavations carried out from September to October 1998 a shallow depression was identified which correlated with the position of this feature. Its relationship with the bank, however, was not fully understood from the trench that was cut across the western entrance to the enclosure and therefore was not fully representative of the western edge of the enclosure.
- Running along enclosure B, from the southwestern break to the northeastern break in the bank, a linear depression was noted on the hill-shaded model, along with other lumps that may reflect prehistoric activity. The coarse vegetation in this area at the time of survey is likely to have partially influenced these results, but the linear features appear to be consistent. Whether this was contemporary with the construction of the banks or not is uncertain.

Modern features

- Recent features identified from the survey include the position of the track and drains and, surprisingly, the position of one of the removed drains, which was visible on earlier aerial photography of the site. These features were traceable on both models, but were more visible with the application of an assumed light source. However, the hill-shaded model revealed 'striping', reflecting the direction of ploughing. The model

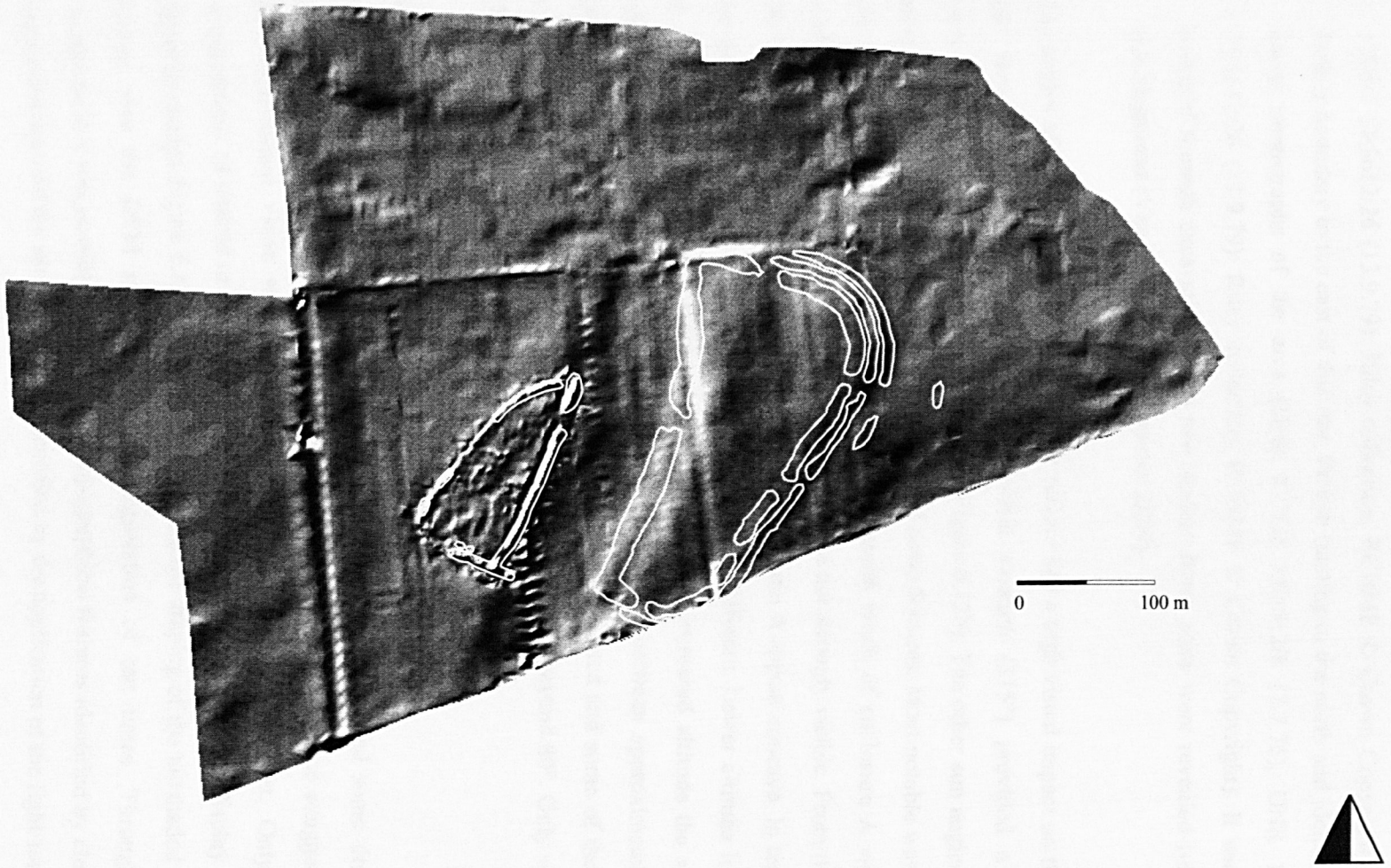


Figure 6.12b Default hillshade (315° azimuth, 45° altitude).overlain by the outlines of the banks from the previous survey of the site (after Whiting 1936).

also highlighted the position of a field division cutting across enclosure A. This division represented a fence visible on aerial photographs (*cf.* Aerial photograph DNR 1586/7 SE5612/26 (13.9.79): Riley collection, RCHME © Crown Copyright) and a further boundary to the east of this one, though running to the north and identified on aerial photographs of the area (DNR 877/36 SE5612/8 (7.7.76), DNR 1586/7 SE5612/26 (13.9.79): Riley collection, RCHME © Crown Copyright). It was also revealed through excavation where two modern fence posts were revealed lying on this alignment (Van de Noort and Chapman 2000).

The angles of the light source relative to the surface had a high visual impact on the site and how it could be understood. The default azimuth (315°) provided a good representation of all of the features identified (Figure 6.12b). The other sun angles were more notable therefore for the lack of visibility of some features. Most notable was if the site was lit from due south (180°). From this azimuth much of enclosure A was not visible and the southern end of the Hampole Beck was not strongly visible. From the east (90°) the reflection from the drain feature made enclosure A appear concave. In terms of the altitude of the light source, the effect was slightly different. Lower altitude lighting (*c.* 10°) produced a darker, more polarised image. With increased altitude the surface became generally lighter and greatest detail was achieved between approximately 30° and 60°. Above this value the surface became more generalised and some of the more minor features were lost, though the surface remained good to beyond 80°. Only with an altitude towards 90° did the major losses in surface detail come.

b. Surface exaggeration, wire framing and perspective modelling

Surface exaggeration and perspective displaying of the site produced some dramatic results with the Sutton Common landscape. Notably, without any surface exaggeration, three-dimensional views were extremely flat and difficult to interpret. Only with exaggerations of tenfold or more was a significant effect produced in the display of the flatter landscape Figure 6.12c shows the results from the draping of the hillshaded model draped over the DEM surface with an exaggeration of ten times. Through this exaggeration it was possible to see both the topographical features identified by elevation representations and the surface features identified by the application of the light source.

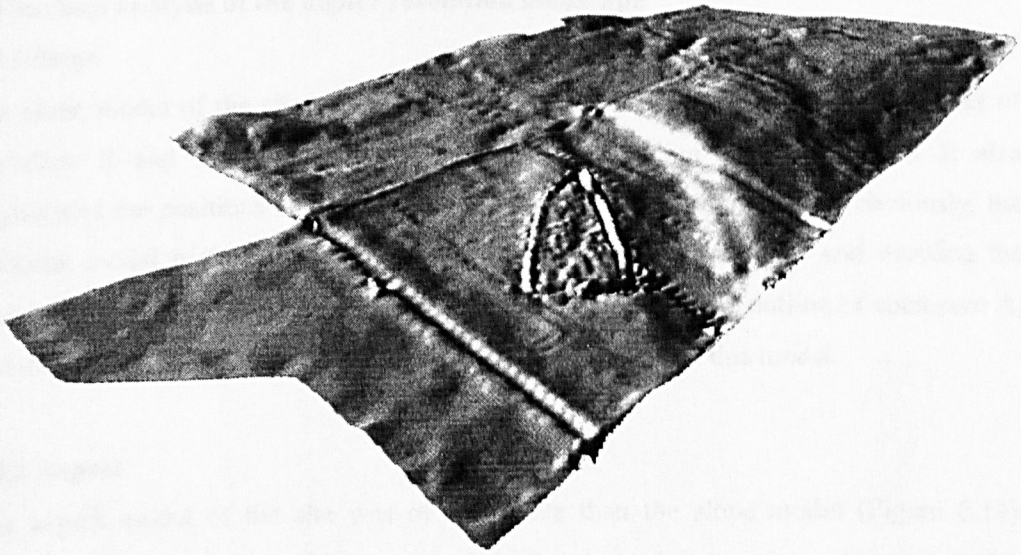


Figure 6.12c Hillshade model of Sutton Common draped over the exaggerated DEM (x 10) looking towards the northeast.

6.8 Surface analysis of the higher resolution landscape

6.8.1 Slope

The slope model of the site demonstrated the stark contrast between the earthworks of enclosure B and the relatively flat landscape surrounding it (Figure 6.13). It also highlighted the positions of the track, open drains and filled drains. Less obviously, the resulting model highlighted a larger island surrounding enclosure B and marking the island to the northwest (Sydes and Symonds' (1988) SUT1). The outline of enclosure A, including the detail along its western edge, was also visible on this model.

6.8.2 Aspect

The aspect model of the site was of less value than the slope model (Figure 6.14). Though it identified parts of features, such as the channel, its curving nature meant that its aspect changed along its length. It was therefore not possible to trace the feature for its entirety. Some features were highlighted including the western scarp of enclosure A and the shelving of land towards Shirley Wood and, similarly, areas of localised lowland, such as to the southeast of enclosure A, were highlighted. Despite this the overall effect was limited.

6.8.3 Visibility

The main application of visual analysis to this model was to follow the route through the site suggested by Parker Pearson (1997: 255), and refined by the above analyses (section 6.7.1). The height of the earthworks of enclosure A was not recorded prior to their levelling. In order to provide an understanding of the positions of the earthworks, the areas of the banks of enclosure A as surveyed by Bennett and Hill (Whiting 1936: 60) were exaggerated on the DEM by one metre above present levels. This value is almost certainly much lower than their original height as attested by the heights of the standing earthworks of enclosure B, and as such should have a limited effect on the visibility analysis other than providing location. The results from the various viewsheds are shown in figure 6.15.

a. Stage 1 - approaching the southwestern corner of enclosure B

The approach on the ground is obstructed by the position of the modern drain, though the above analysis has suggested a route across it. The viewshed was calculated at two points along this route; from the edge of the survey area, and half way to the southwestern entrance of enclosure B.

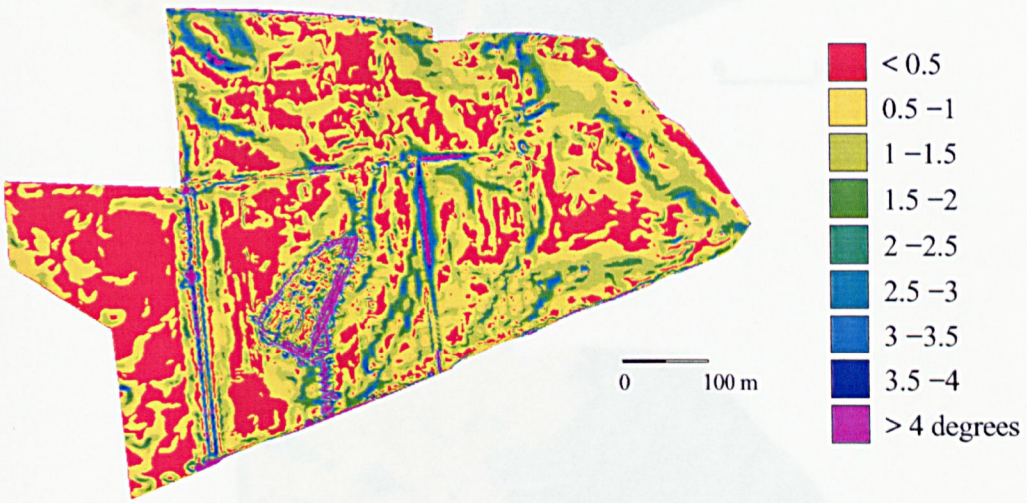


Figure 6.13 Sutton Common slope model.

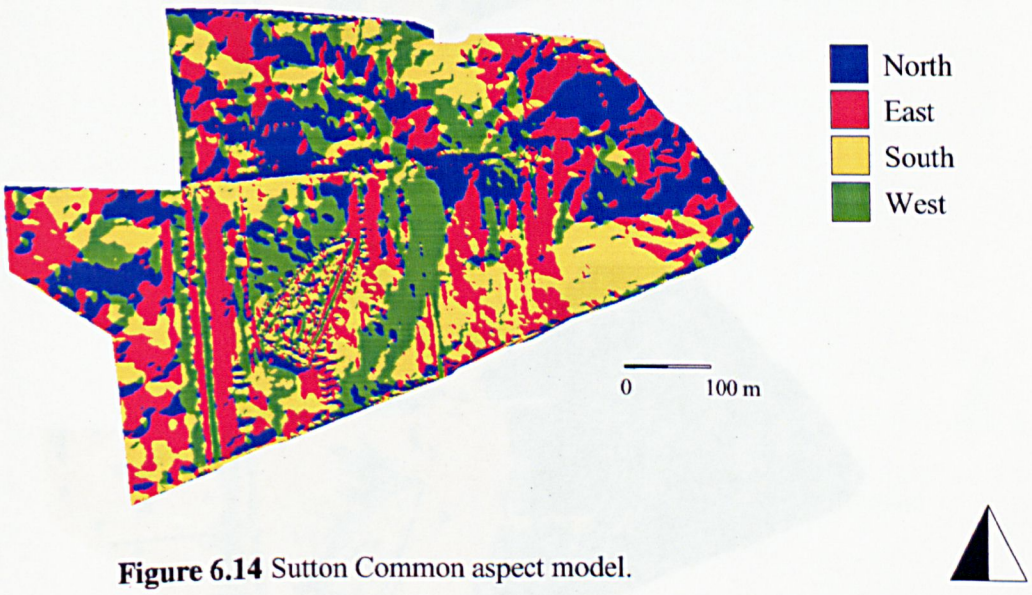


Figure 6.14 Sutton Common aspect model.

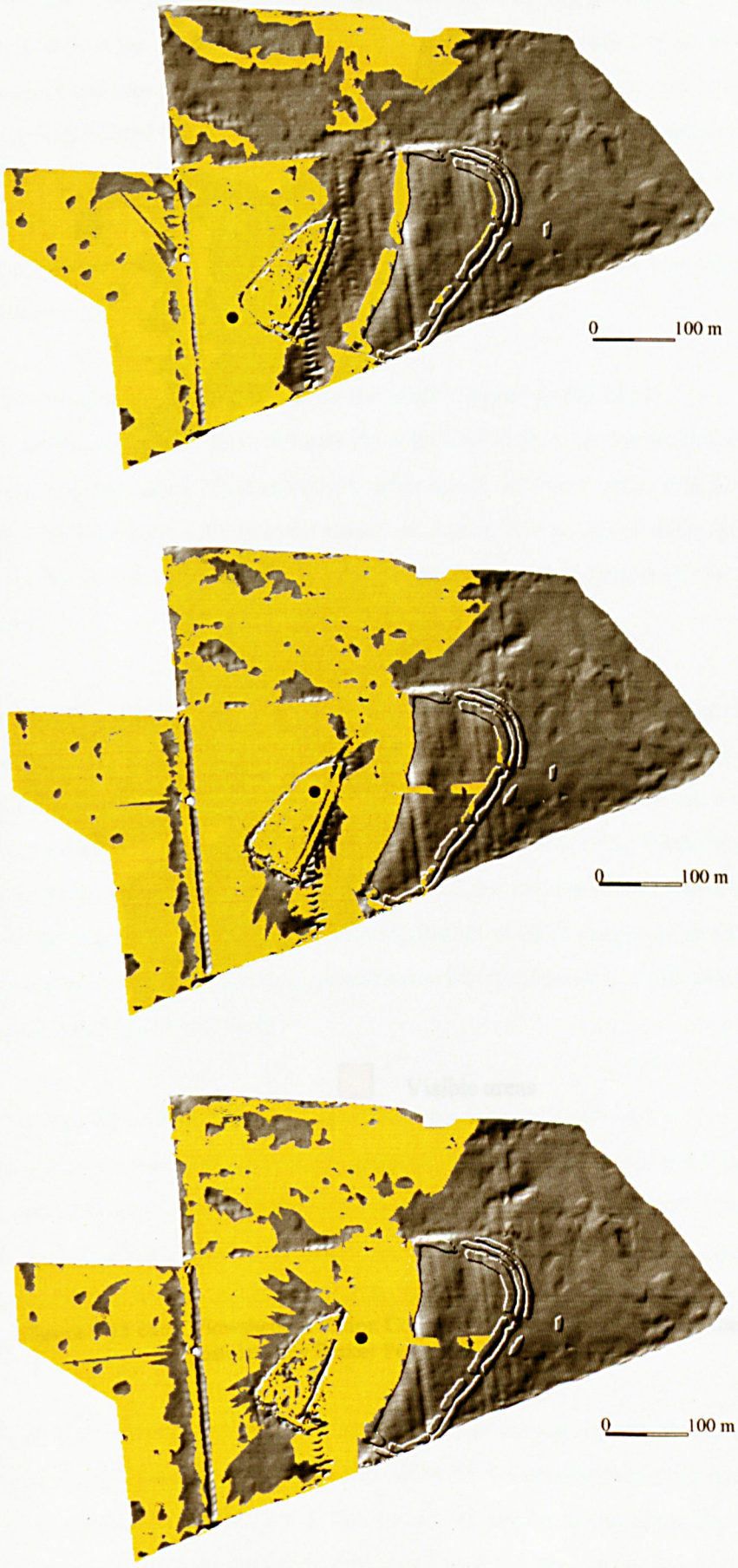


Figure 6.15 Viewsheds at Sutton Common following a path through the site postulated by Parker Pearson & Sydes (1997).

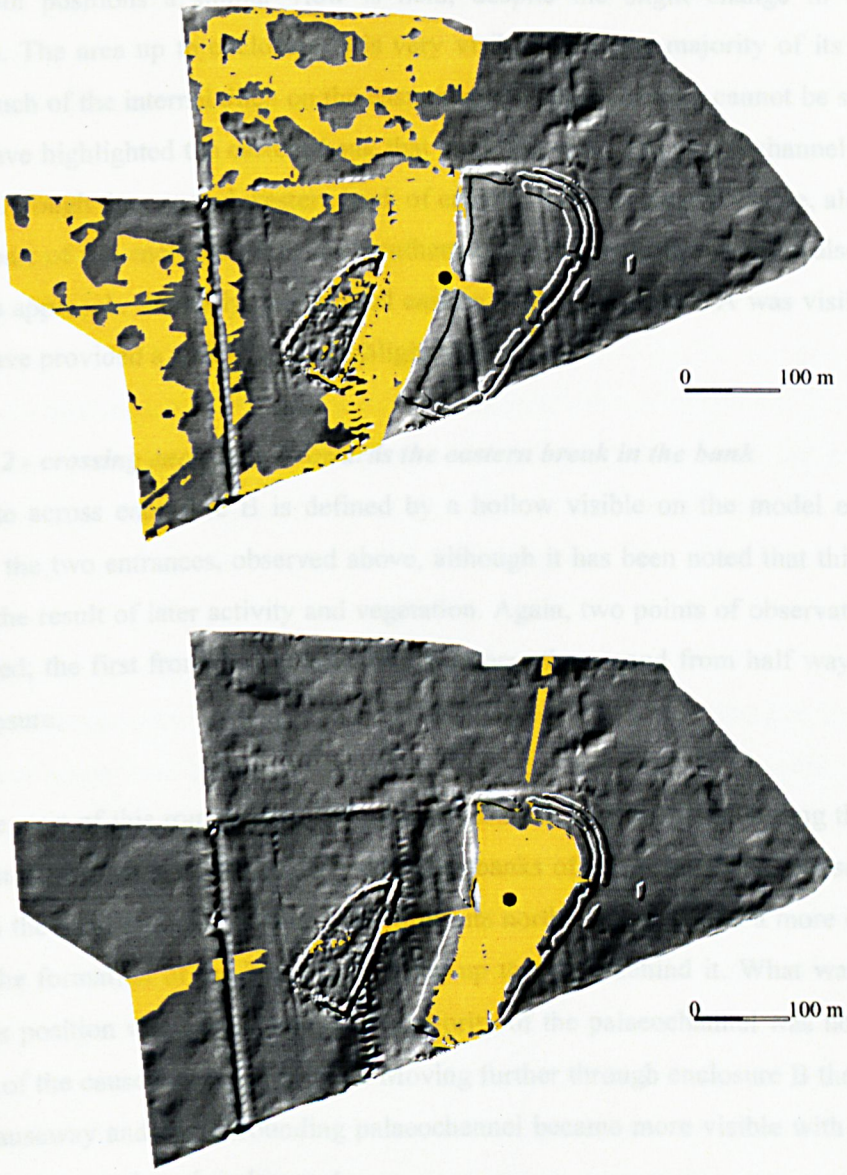


Figure 6.15 cont. Viewsheds at Sutton Common following a path through the site postulated by Parker Pearson & Sydes (1997).

From both positions a similar view is held, despite the slight change in observer elevation. The area up to enclosure B is very visible, as is the majority of its interior. While much of the internal ditch on the eastern side of the enclosure cannot be seen, this would have highlighted the eastern bank that could be seen. The palaeochannel was not visible, although the revetted western bank of enclosure A was clearly visible, along with the top part of the enclosed area. The southern banks of enclosure A were also visible from this approach. Similarly, the internal eastern bank of enclosure A was visible. This would have provided a wall of three highlighted banks.

b. Stage 2 - crossing enclosure B towards the eastern break in the bank

The route across enclosure B is defined by a hollow visible on the model extending between the two entrances, observed above, although it has been noted that this feature may be the result of later activity and vegetation. Again, two points of observation were considered; the first from the southwestern entrance, the second from half way through the enclosure.

From the start of this route the majority of enclosure B was visible including the nature of the internal ditches on the eastern side. The banks of enclosure A were also visible, although the position of the higher land within its northern half played a more dominant role in the formation of the horizon, dividing up the bank behind it. What was notable from this position was that, although the majority of the palaeochannel was not visible, the area of the causeway could be seen. Moving further through enclosure B the position of the causeway and the surrounding palaeochannel became more visible with no break up to the western edge of enclosure A.

c. Stage 3 - traversing the causeway from enclosure B to enclosure A

The route across the causeway was more complex than for the stages 1 and 2 because of the more variable topography in this area with sharp changes in elevation across the palaeochannel. The first observation point was taken from the entrance of enclosure B, the second from just outside the enclosure, the third from the centre of the causeway and the fourth from just outside enclosure A.

As the route turns to face enclosure A the viewshed is marked by the ability to see the palaeochannel, the facing western bank, the inside of the eastern bank and much of the interior of enclosure A. Further along the causeway, where levels drop, the viewshed becomes more restricted so that only the banks and the top of the highest northern

interior are visible. Upon entry to enclosure A, as the land level rises again, the majority of the interior can be seen, though visibility to the east of the eastern bank is almost entirely restricted beyond the inner bank.

d. Stage 4 - reaching the entrance to enclosure A

At the entrance to enclosure A at the end of the causeway it is still not possible to see within the interior.

e. Stage 5 - arriving within the interior of enclosure A

Once inside of enclosure A the visual picture changes dramatically. It is not possible to see beyond the boundaries except through the breaks in the bank, though it is not certain whether these would have been open.

f. Summary of visibility

The overall impression from this visual route through the site is that the viewshed is channelled rather than entirely restricted. Full restriction of the view could only have been possible through raised banks or an elevated palisade. The approach to the site from the west would have provided a constant view of the two enclosures in terms of rows of banks. At enclosure B this is marked by the positions of external ditches on its western and southern sides, but an internal ditch on its eastern side that would have helped to define the edges of them. Upon meeting the presumed entrance to enclosure B the viewshed would have been limited to the enclosures, though moving northwards through the enclosure the context of the palaeochannel would have become visible, initially with the causeway coming into view, and later with the channel visible surrounding it. The possibility for high wetland vegetation in this area would have defined it as different to the islands occupied by the enclosures, and this would have become more visible further north within enclosure B with the increased vantage gained from higher elevation. To approach the causeway, a turn to the right would have been necessary before walking through a break in the bank, much narrower than visible on the ground today. A narrower gap would have restricted the final turning point to fewer individuals and to a more sudden moment as the corner was turned.

Upon turning, the majority of the palaeochannel could have been seen along with the banks and hill of enclosure A. If the visibility of the causeway had earlier been obstructed by vegetation, this final turning point would have suddenly brought it into view. The view of the revetted western bank of enclosure A would have been distinct

from this position, as from earlier positions, but with the break visible in it. Prior to this the angling of the entrance to the enclosure would have restricted visibility to the nearer inside areas, so an immediate revelation of this with the causeway may be understood. Continuing along the causeway, the drop in elevation would have made the inside of enclosure A less visible, with the restriction again to the outside of the western bank and the inside of the eastern banks. The sharper rise on the eastern side of the palaeochannel would have meant a rapidly increased visibility of the interior of the site as the entrance was passed through. Interestingly, at this juncture the eastern bank of enclosure A would have still formed the horizon, with extremely limited visibility beyond it other than for the higher areas of vegetation.

Overall changes in the viewshed can be categorised into a number of phases. Firstly, as the site is approached the enclosures are externalised, but seen as rows of impressive banks. Secondly, upon reaching enclosure B, greater detail of the interior can be understood, but from a distance. This is then provided with context with the ever-increasing view of the palaeochannel revealing the enclosure as an island, particularly since the area further east could not be seen. Only at the last moment of traversing enclosure B does the full understanding of the causeway and entrance to enclosure A become visible with a broader, though still distant, view of the interior. Crossing the causeway this view becomes restricted with the main focus being the looming western bank with the eastern banks on the distant horizon. Finally, the rapid rise in land provides a view of the inside of enclosure A, but for the first time from an internally focused view. Very little can be seen beyond the boundary of the enclosure, bringing the feeling that one has arrived within a bounded space.

6.9 Multiple surface analysis of the higher resolution landscape

As outlined in chapter 3 (section 3.3.2), the ground water levels were monitored over the site through a system of 50 piezometers that were monitored once every two weeks from the autumn through to the start of spring. The monitoring of this water table was aimed primarily at understanding the interaction between ground water and surface water as part of a management plan to rewet the site. However, the data from this provided an interesting avenue for modelling multiple surfaces locally in order to understand the site in terms of interpretation and in terms of management. A number of results were obtained from this (Figure 6.16).

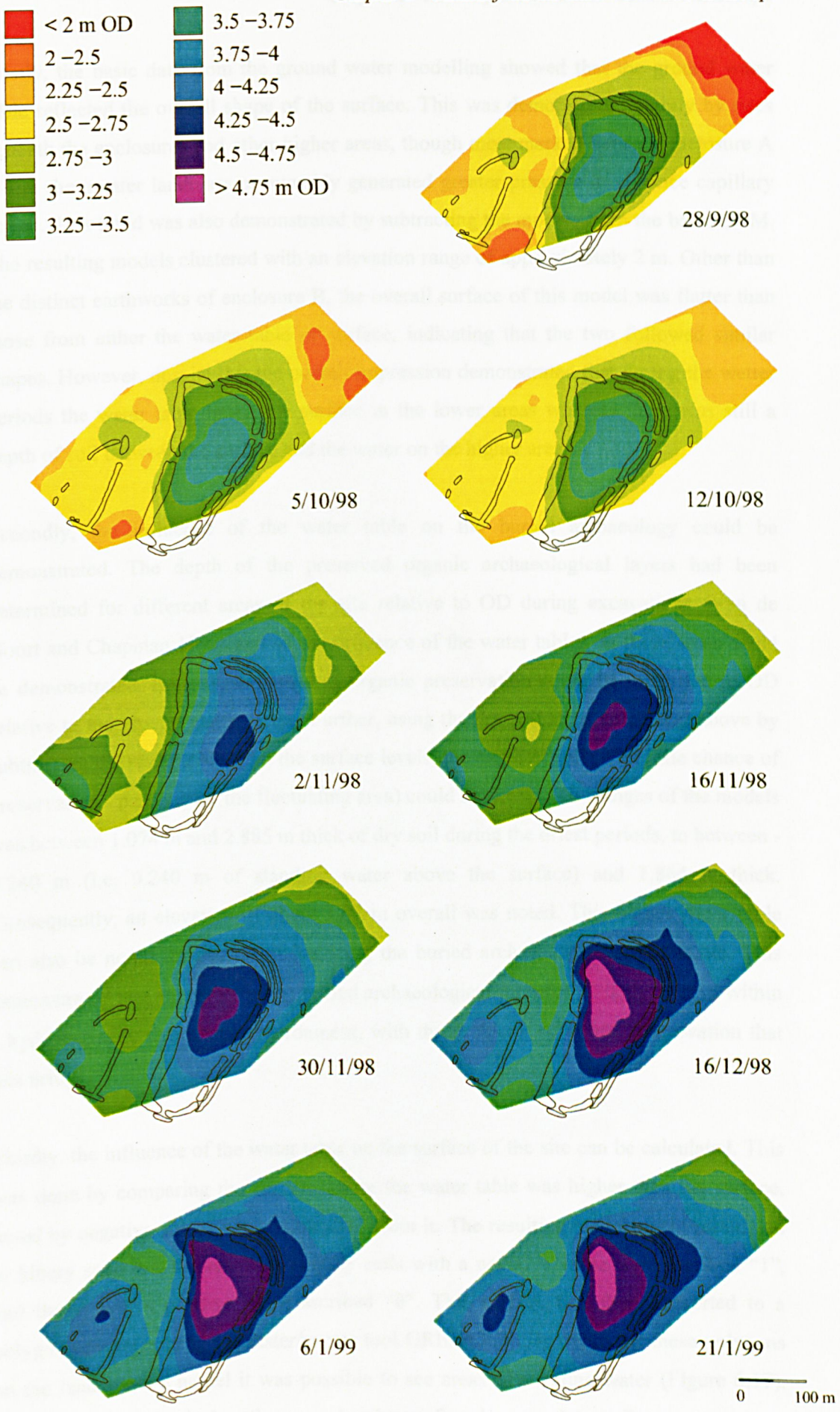


Figure 6.16 Water table models generated from the piezometer data (north is to the top of the images). Outlines of the enclosure banks overlain after Whiting (1936).

Firstly, the basic data from the ground water modelling showed that the ground water table reflected the overall shape of the surface. This was demonstrated mainly by rises beneath the enclosures and other higher areas, though most marked beneath enclosure A where the greater landmass presumably generated greater pressure to enhance capillary action. This trend was also demonstrated by subtracting the models from the basic DEM. The resulting models clustered with an elevation range of approximately 2 m. Other than the distinct earthworks of enclosure B, the overall surface of this model was flatter than those from either the water table or surface, indicating that the two followed similar shapes. However, despite this the overall impression demonstrated that during the wetter periods the water table broke the surface in the lower areas whereas there was still a depth of soil between the surface and the water on the higher areas.

Secondly, the influence of the water table on the buried archaeology could be demonstrated. The depth of the preserved organic archaeological layers had been determined for different areas of the site relative to OD during excavations (Van de Noort and Chapman 1999) and so the influence of the water tables on these areas could be demonstrated. Initially, the areas of organic preservation could be measured to OD relative to the ground water model. Further, using the dry soil areas calculated above by subtracting the water table from the surface levels, the depth of soil (with little chance of preservation - particularly the fluctuating area) could be shown. The ranges of the models was between 1.074 m and 2.885 m thick of dry soil during the driest periods, to between -0.240 m (i.e. 0.240 m of standing water above the surface) and 1.864 m thick. Consequently, an elevation of about 1.02 m overall was noted. This higher water table can also be noted for directly influencing the buried archaeology across the site. This demonstrated that almost all of the buried archaeological resource is likely to exist within a hydrologically fluctuating environment, with the problems of *in situ* preservation that this brings.

Thirdly, the influence of the water table on the surface of the site can be calculated. This was done by comparing the models where the water table was higher than the surface, noted by negative values when subtracted from it. The resulting models were resampled in binary such that the resulting surface cells with a negative value were ascribed "1", and those with a positive value ascribed "0". This surface was then converted to a polygon coverage using the raster/vector tool GRIDPOLY. By overlying these polygons on the land surface model it was possible to see areas of standing water (Figure 6.17). These were then checked on the ground and were found to correlate well.

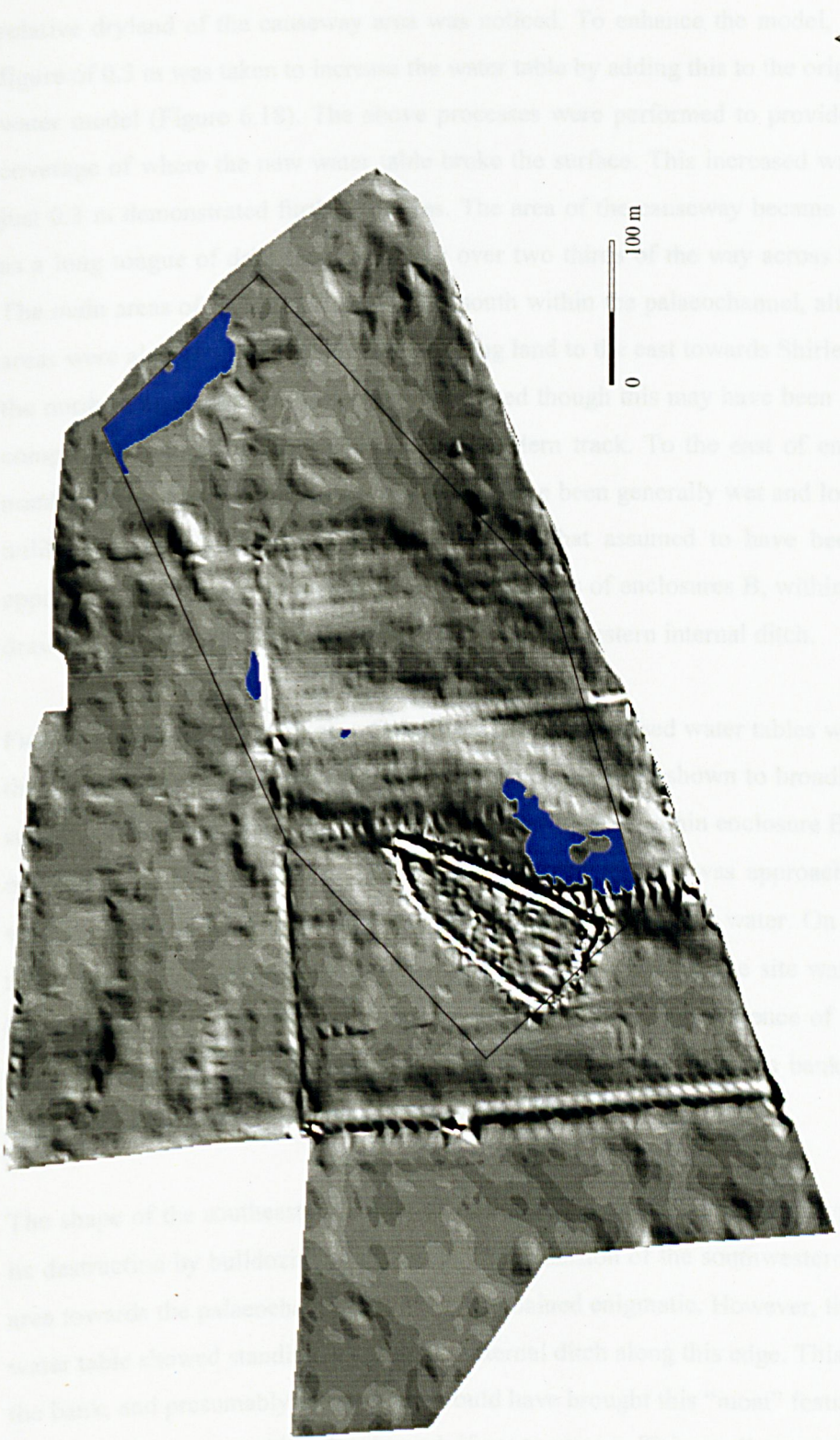


Figure 6.17 Surface water at Sutton Common calculated from the water table data from 21st January 1999

The significance of this model was that a number of features were noticed. Firstly, standing water was recognised in some of the ditches of enclosure B and, secondly, the relative dryland of the causeway area was noticed. To enhance the model, an arbitrary figure of 0.3 m was taken to increase the water table by adding this to the original ground water model (Figure 6.18). The above processes were performed to provide a polygon coverage of where the new water table broke the surface. This increased water table of just 0.3 m demonstrated further features. The area of the causeway became very visible as a long tongue of drier land extending over two thirds of the way across the channel. The main areas of high water were to the south within the palaeochannel, although other areas were also very wet including the sloping land to the east towards Shirley Wood. To the north of enclosure A a large pool was noted though this may have been the result of compaction caused by the position of the modern track. To the east of enclosure A a number of pools suggest that this area would have been generally wet and locally varied, unlike the areas to the west of enclosure B - that assumed to have been the main approach. Water was also seen in most of the ditches of enclosures B, within the modern drain feature of enclosure A, and partially within its western internal ditch.

Further significance may be seen from the model of increased water tables which reflects the general shape of the ground water table which has been shown to broadly reflect the surface of the landscape. This is of particular significance within enclosure B. The theory mentioned by Parker Pearson (1997) and above that the site was approached from the west is further enhanced by the possibility that the ditches held water. On approaching the southwestern corner of the site it would have appeared that the site was surrounded by a narrow moat within its two external ditches. Further, the presence of water within the internal ditch lining its eastern bank would have meant that this bank would have appeared more impressive and well defined.

The shape of the southeastern corner of enclosure B has always been a mystery, despite its destruction by bulldozing in this area. The extension of the southwestern bank in this area towards the palaeochannel has always remained enigmatic. However, the heightened water table showed standing water in the external ditch along this edge. This extension of the bank, and presumably of the ditch, would have brought this "moat" feature very close to the standing water within the channel, if not to meet it. This small extension, therefore, would have provided the appearance of a continuous moat surrounding enclosure B as it was approached from the west, increasing the impression that the site lay on an island. Further, this extension would have given the perspective impression that this side of the

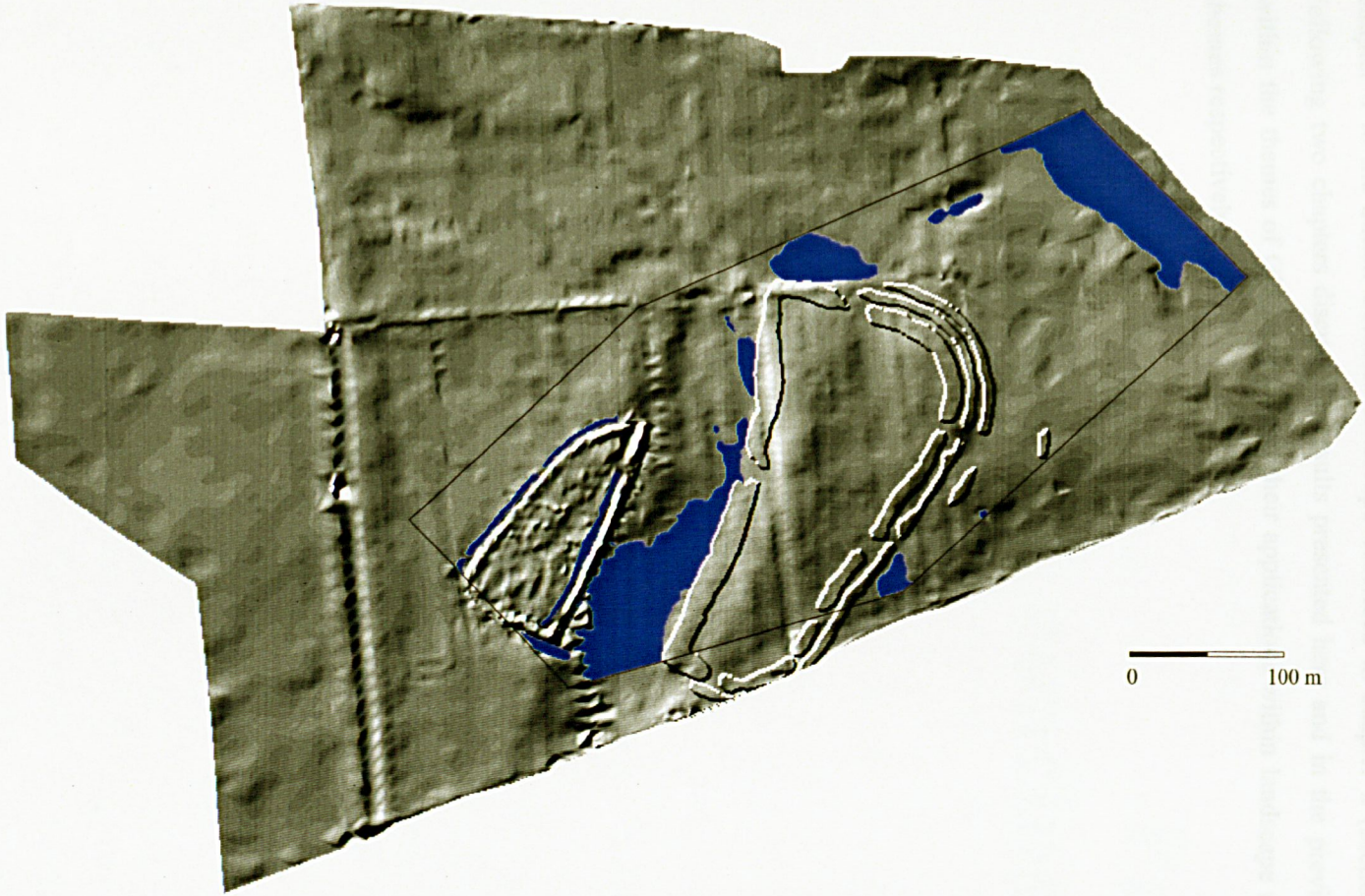


Figure 6.18 Surface water at Sutton Common exaggerated by 0.3 m (using water table data from 21st January 1999).

enclosure was as long as its western side, which may have been purposely visually shortened by its curving shape towards its northern end.

6.10 Summary

This chapter has presented the results of the application of the GIS tools described in chapter 4 to the Sutton Common landscape described in chapter 2 (section 2.3). The following two chapters discuss the results presented here and in the previous chapter within the themes of GIS methods and their applications within landscape archaeology themes respectively.

Part 4
Discussion & conclusions

Chapter 7

Analysis of GIS methods

7.1 Introduction

The previous two chapters presented the results from the application of the GIS methods outlined in chapter 4 to the two study areas described in chapter 2. This chapter discusses these results in relation to the themes of GIS methods and the following chapter (chapter 8) discusses their applications within landscape archaeology.

In this chapter an assessment of both the input-data and output from each of the GIS techniques is presented. These results are considered by comparison of the two contrasting topographies and the two contrasting resolutions. The chapter begins with an assessment of each of the different groups of tools as outlined in chapter 4, focused on each of the two resolutions in turn. This is followed by an appraisal of the issue of resolution. The chapter concludes with a commentary on each of the groups of GIS techniques and a note on their limitations.

7.2 Lower resolution contour data

7.2.1 Surface generation

The variety of surface generation tools available for creating the DEM was far more limited for the contour data than for the point data obtained from the GPS surveys. Of the techniques available, the most useful proved to be TOPOGRID. This method produced an aesthetically realistic surface devoid of notable interpolation artefacts. The CREATETIN/TINLATTICE function also created a realistic surface when used with the quintic smoothing, but the major downside was that the interpolation technique only extends the DEM to the edges of the data rather than to the edges of the boundary.

It was noted in chapter 1 that previous research has been concentrated on topographically variable landscapes to the neglect of flatter landscapes. This trend appears to make more sense from the experiences within this study when dealing with contour data. For a given area, and for a given contour interval, the greater the topographic variability the greater the number of contours. Therefore, the more topographically variable a landscape the greater amount of raw data there are available for generating a DEM. For a flatter landscape, a much larger area would need to be used in order to obtain the same volume of raw data, but with a reduced value locally within the DEM. This is in contrast to van

Leusen's (1993) assumption that a given DEM resolution may be used for data of a given contour interval, highlighting that this depends upon the number of contours within the given area of study. In terms of the landscapes themselves, this trend is seen by the greater number of applications that were possible with the topographically variable Rudston landscape (chapter 5) compared with the flatter Sutton Common landscape (chapter 6). Further consideration needs to be made of the potential DEM surface resolution as a ratio with the surface density of the raw data. Such an approach could be to quantify the density of data by a vector/raster conversion at a given raster resolution. This would provide a coefficient that could be calibrated with the surface DEM resolution.

Further consideration of the 'edge effect' is needed. The fact that some interpolation techniques did not continue the DEM surface to the edges of the map sheet, but rather were limited to the edges of the available data, was considered a downside. This raises a further issue. The raw data may be purchased from the Ordnance Survey in quarter sheets that each measure 5 x 5 km. On each sheet the contours represent whole values at regular vertical intervals, the division dependent upon resolution. However, if the edges of the map do not reach a height represented by a contour, there are potentially large areas that are unrepresented, and are therefore unrepresentable. This becomes more of an issue within the lowland landscapes where the contour density is reduced with the potential for edge gaps increasing. Statistical interpolation techniques such as TOPOGRID will generate a DEM surface that extends up to a predetermined boundary. Therefore there will be fundamental errors within it, but which remain invisible without overlaying the raw contours for comparison. Conversely, the CREATETIN/TINLATTICE function generates a surface up to the edges of the data. Whilst this reduces the potential for increased error it also reduces the value of the purchased data. The effect of this was particularly marked with the Sutton Common landscape (chapter 6, section 6.2.2). Ideally, an area larger than that being studied should be purchased and then the study area should be cut from the DEM inside of the outermost contours. However, this increases the financial cost of any project and the memory requirements of the hardware with the increased DEM area. These issues need to be considered within any GIS study based on interpolated contour data and, preferably, on a site-specific level, dependent upon the distribution of the raw data. Without such considerations any results have the potential for being fundamentally flawed.

7.2.2 Surface representation

Different methods of representing the DEM surfaces of the 10 x 10 km landscapes have been significant in relation to landscape archaeology. Aesthetics were the main element in relation to this with the surfaces derived from the lower resolution contour data. Without further analysis the value in creating different surface representations was in their realism as a backdrop for overlain vectorised data. This provided a third dimension that is not possible on conventional mapping or on two-dimensional GIS packages. This was found to be of particular significance when multiple layers of data were concerned. The three-dimensional topographic backdrop provided an easily understood context for looking at archaeological distributions.

Different types of representation provided different levels of comprehension in terms of providing a direct understanding of the relationship between archaeological distribution (vector coverages) and the topography. Elevation-based representations provided an immediate understanding of relative heights, expressed particularly well through the contour banding techniques. Non-elevation based representations, and in particular light shaded models, provided a more realistic view, particularly when using a greyscale shading providing a similar appearance to aerial photographs but without the problems of modern features causing obstructions and shadows. However, the effects were variable. Hillshading assisted in making the Rudston landscape more realistic, but had the converse effect on the Sutton Common landscape, presumably due to the low density of input-data. However, such realism was notably only possible within the upland landscape where the topographic variation was greater and there was increased data density. The representations of the lowland landscape, where the data density was reduced, were dominated by single blocks of a single shade, regardless of the position of the light source. It appears that the lack of topographic variability, due to the sampling limitations, meant that there was insufficient surface variability within the DEM to make an interesting modelled landscape.

Surface exaggerations were also useful in quickly defining the contextual relationships between the archaeological distribution and the topographic base. Vertical exaggeration of each of the models provided a clearer understanding of the distribution of the archaeological sites and features when draped over it. In both cases, the vertical range was insufficient to provide perspective models that displayed an understanding of the topography. However, various exaggerations of the surface provided more readily understandable models of the topography. This was again most marked with the Rudston

landscape where the relationship between the cursus features and the chalkland slopes could be made immediately.

7.2.3 Surface analysis

Surface analysis using techniques such as slope and aspect calculations has been used widely within previous GIS studies relating to landscape archaeology. Within areas of landscape interpretation visibility has been seen as important in keeping with work outside of the realm of GIS by landscape theoreticians (e.g. Thomas 1993, Tilley 1994, Bender *et al.* 1997). Surface analysis approaches focused on cultural resource management (CRM), however, have concentrated on the generation of surfaces, particularly using slope and aspect functions, as input-data for inclusion within multiple surface models. Such models have been used for more complex approaches such as the predictive modelling of site location, though such approaches are beyond the remit of the present study (see chapter 1, section 1.7).

The principal results from the applications of the surface analysis techniques were in relation to landscape interpretation. Visual analysis was found to be the most useful technique, particularly with the Rudston landscape where a number of interpretations of the prehistoric architecture were possible. For example, it was noted that cursus A appears to follow a curving plan in order to maintain a visual contact with long barrows on the horizon to its west (Figure 5.8). Further advantages were discovered from following the trends observed by previous landscape archaeologists (e.g. Bradley 1993, Tilley 1994) in using a narrative approach to describe changes in visual experiences as the route of each of the cursuses was 'walked' using the GIS.

Slope analysis was also useful when applied to the Rudston landscape but was of limited value to the Sutton Common landscape. It provided an indication about the choice in the location of cursus B. Correlation between the slope model and the vector overlay highlighted that this feature occupied a very narrow strip of locally flatter land, with an increase in slope to both sides. Slope analysis was also useful in understanding the locations of the long barrows and great barrows. It was noted that, with the available evidence, the long barrows occupied a greater slope than the great barrows that occupied flatter land.

It was found that the development of a technique of using 'digital narratives' constructed over the abstract surfaces, such as those created using the slope function, enabled

landscape elements to be broken down into separate units that each have cognitive implications. Hence, each of the cursuses within the upland landscape could be walked along with the experiences observed from each of the surfaces being recorded in a narrative way. By building up abstract layers it was found that a deeper understanding of the landscapes was possible. By tracing each cursus it was possible to build up an interpretation of how the overall landscape worked. This demonstrated that the cursuses were most likely to have been walked along and, in particular, it provided an insight into the more likely direction of movement and how various experiences were usually unravelled along this route.

Aspect analysis was of the most limited value within this study, although it complemented the results from the slope and visibility analyses of the Rudston landscape, including the narrative approaches. However, this may be partially due to the nature of the archaeology being studied. For example, the distribution of settlements in relation to aspect may indicate a different pattern in relation to solar exposure and thereby present a degree of reasoning. This was not observed within this study.

Overall, the results from the application of surface analysis techniques to the lower resolution Sutton Common landscape were extremely limited. The reason for this appears to be one of input-data resolution. Fundamentally, it appears that the interpolated DEM was of poor quality due to the very high (but also variable) ratio between input-data and cell size (see 7.2.1 above). This meant that surfaces derived from it through techniques of surface analysis perpetuated these limitations, producing results of restricted value.

7.2.4 Multiple surface analysis

The results from the analysis using more complex methods and multiple surfaces generated the most useful information in relation to the 10 x 10 km landscape. However, the multiple-surface theme provided a change in approach from technique-led to question-led and, consequently, the results were more variable and less comparable. Three main approaches were used as a basis for this analysis: cost surfaces, cumulative viewsheds and environmental modelling.

The results from the cost surface analyses were of use for the interpretation within the Rudston landscape where a 'route' could be assessed, although analyses were conducted only on an abstract and extremely fundamental level (*cf.* Bell and Lock forthcoming). This approach had the advantage of backing up the results from the visibility analysis at

the site (see section 7.3.3). The least-cost path between the terminuses of cursus A indicated a route that deviated widely from that of its plan, keeping straighter. Although the evidence is limited, it does strengthen the claim that continued visibility to the long barrows on the western horizon may have had a more important role in the construction of the cursus than the overall plan of the site.

The second approach used cumulative viewshed analysis (*cf.* Wheatley 1995) which was applied successfully to the Rudston landscape. Multiple viewsheds were generated from many of the features within the area, following the approach used by Lock and Harris (1996) which demonstrated the likely territoriality of long barrows within the Danebury landscape. This territoriality was echoed (though with more limited evidence) within the Rudston landscape, although a larger study area and greater number of archaeological features would be needed to substantiate such a conclusion. Further, the cumulative viewsheds from different classes of monuments demonstrated a similar territoriality on the basis of viewsheds not overlapping. The evidence from this indicated that a changing pattern of territories throughout the Neolithic could be suggested. This fitted in well with the pattern of other monuments within the landscape.

The third approach, under the umbrella title of 'environmental modelling', was much broader. Two methods were used. The first made calculations by combining the various models derived from the application of surface analysis techniques to the original DEM. The second introduced input-data from other sources (see chapter 3). The results demonstrated the huge value of GIS as a tool that can combine and model multiple layers of data. Using the former method to model the surface hydrology and areas of water accumulation in the Rudston landscape, a relationship was implied between those areas where crop marks had not been recorded and those areas of highest surface-water accumulation, perhaps indicative of colluviation. The masking effect of colluviation on the archaeology of arable landscapes has been established previously (e.g. Lillie 1995), and this process has been observed on the Yorkshire Wolds (Foster 1978). The results from the present study indicate that colluviation, and the subsequent deepening of sediments in localised areas, might be an influential factor in the visibility of features from aerial photography (see chapter 5, section 5.5.3).

The second method of 'environmental modelling', using input-data derived from sources other than the DEM, was applied to the Sutton Common landscape. Here, the effect of vegetation on the visibility of features was investigated. An area of peat between the area

of the enclosures on Sutton Common (see chapter 2, section 2.3.3) and the area of higher land to the southwest was noted from the geology map (Geological Survey of Great Britain 1969, 1971). Pollen samples from this peat have shown that the contemporary landscape is likely to have been densely wooded by Alder (chapter 2, section 2.3.1). Using this information, the DEM was enhanced by increasing the height of cells within the mapped area of peat in order to simulate the visual barrier that might have been created by such vegetation. Subsequent visual analyses, however, proved to be of limited value, perhaps owing to the accuracy restrictions of the DEM (see chapter 6, section6.2). However, the method presents one way of approaching issues of vegetation cover and their influence within spatial analyses such as visibility. There is much room for expanded research into this area of GIS analysis (*cf.* Spikins 2000).

7.3 Higher resolution point data

7.3.1 Surface generation

As outlined in chapter 4 (section 4.3.1), a wider range of interpolation methods was available for generating surfaces from the point data obtained by the GPS surveys compared with the Ordnance Survey contour data. However, the present study also demonstrated that the range of interpolation methods available for generating an acceptable DEM was also dependent upon the regularity of the input-data. The two surveys presented both a regularly spaced (Rudston) and a variably spaced sample (Sutton Common). The variability between the two was based upon the contrasting visibility of features on the ground within each landscape. Fundamentally, upstanding earthwork features required a greater number of input-data points in order to generalised their form (*cf.* Fletcher and Spicer 1988). The results from the application of the range of interpolation methods to each demonstrated that differences between the resulting models were much more obvious within the variable Sutton Common landscape than they were within the more regular sample of the Rudston landscape. This presented two main results. Firstly, a wider range of interpolation techniques can be used for the generation of DEMs from regularly spaced input-data without creating highly noticable interpolation artefacts. Secondly, the interpolation methods could only be tested efficiently for archaeological requirements by using variably spaced input-data. These data better reflect the potential variability of archaeological sites, and thereby present a more rigorous challenge for the methods used. Further, this highlights the need for investigations into the advantages and disadvantages of different interpolation methods.

In relation to the resolution of the interpolated surface, the results from this analysis noted that any DEM needed to be at a resolution that was as high or higher than the highest resolution displayed by the input data. For example, there should be a maximum of one surface data point per DEM cell. Following this principle, the variability of survey data resolution has a direct effect upon the accuracy of the interpolated surface since some areas will be highly represented by input data, whereas others will require interpolation over larger gaps in it. In such areas different interpolation techniques produced different results. For example, approaches that combined a TIN produced very few interpolation artefacts in areas between widely spaced input-data points, whereas statistical techniques, such as TOPOGRID, produced artefacts on the higher resolution DEMs.

The appropriateness of the method of interpolating a DEM from the data was best understood from the variably spaced data for the reasons mentioned above. In terms of the analyses of accuracy, the quantified approach proved to be useful in identifying the generation of significant sinks and peaks as with the spline interpolations of the Sutton Common data. However, this approach was less useful than the visual assessment of the resulting DEMs; an approach that demonstrated some dramatic effects. For example, trend was notably useless for archaeological purposes in both cases since it failed to identify anomalous features of the landscape that reflect anthropogenic activity.

Overall, the best process for interpolation was found to be a two layered approach using a TIN and the TINLATTICE function. It was found that the greatest errors occurred within the sample data when the density was uneven (as for Sutton Common) as will be the case on many archaeological sites. TOPOGRID was extremely poor in reaction to such irregular surfaces. Other methods including spline, IDW and kriging were good but, overall, the approach using an intermediary TIN stage was useful for all processes and was the best at avoiding surface interpolation artefacts.

7.3.2 Surface representation

The results from the application of different surface representation techniques to the higher resolution archaeological landscapes may be grouped into three main themes. The first of these refers to the potential of GIS to highlight elements of the environmental context for the archaeology, thereby providing a deeper understanding of its topographical relationships. This relationship was best demonstrated with the application of elevation-based representation techniques. At Sutton Common this approach

highlighted the nature of islands within the landscape, reflecting the locations and shapes of the enclosures and marking a relationship between the architecture of the site following the topographical trends and environmental conditions (chapter 6, section 6.7.1). At Rudston an environmental relationship was also demonstrated from the elevation-based representations. Here, the relationship between the slope and the cursus terminus was demonstrated, although a larger survey area would have been beneficial in this respect (chapter 5, section 5.7.1).

Secondly, it was possible to highlight the positions of anomalous archaeological features including those that could not be seen on the ground. This was particularly marked at Sutton Common where much of the outline of the larger enclosure could be traced, particularly by non-elevation based representation techniques such as hillshading, despite the site having been ploughed regularly for nearly two decades. Other features within this landscape were also identified using this method. These included a causeway extending across the palaeochannel between the two enclosures that had not been seen previously but which had been speculated upon (chapter 6, section 6.7.2). The causeway feature was since confirmed by excavation (Van de Noort and Chapman 1999). At Rudston, similar results were obtained, although on a less dramatic level. The outline of the cursus terminus was highlighted by all representations, but particuarly through hillshading.

Thirdly, the possibility of understanding the nature of preservation was noted from different methods of representing the surface. At Rudston, both elevation and non-elevation based representation methods highlighted the survival of the cursus terminus despite its ploughing, evidenced by the blocky appearance of the DEM (chapter 5, section 5.7.1-2). At Sutton Common, the visibility of the ditches of enclosure A, which had also been ploughed, indicated that the ditch was still preserved. This was interpreted as a reaction to the effects of de-watering (through drainage) and the subsequent differential shrinkage of the different types of deposits. The biogenic sediment forming the fill of the ditch would shrink more than the minerogenic sediments that it was cut into. It may be noted that organic sediments that have shrunk will lose their structure and therefore cannot re-expand upon re-wetting. Because the field was being ploughed annually (thereby levelling the surface) such observed shrinkage was interpreted as being from a single season's drying and shrinking. For biogenic sediments to be shrinking, it is logical to assume that there are still some deposits that are well preserved and that there was still a waterlogged resource (chapter 6, section 6.7.2). At this site this evidence highlighted the possibility that the level of organic wetland preservation was probably

greater than previously presumed and this was later verified by excavation (Van de Noort and Chapman 1999, 2000).

7.3.3 Surface analysis

a. Visibility analysis

Visibility analysis was the most useful of the surface analyses attempted with the higher resolution landscapes, with its main contributions shown by its application to the Sutton Common landscape. Here, the postulated route through the site suggested by Parker Pearson and Sydes (1997) could be followed to create a visual narrative of experience (*cf.* Tilley 1994) but in a quantifiable and repeatable way that could contribute to the interpretation of the site. Through this route it was possible to understand more about the architecture of the site and in particular the use of the gentle topography in the creation of an impressive visual journey. Hence it was possible to begin to understand the interaction between the natural landscape and the archaeology, and some of the past decision-making processes when the site was constructed. On a more general level, this also demonstrated the way in which even a gentle surface with only slight variations in its topography can affect visibility greatly.

At Rudston, such an approach was not found to be useful since nearly all of the DEM could be seen from all positions on it due to its small size relative to the height of the observer and the presumed lack of obstructing topographic features. However, this highlights a further issue. The sizes of the high-resolution survey areas were determined by the sizes of areas surveyed previously. However, in this had implications for the interpretation of the sites. At Sutton Common, the interpretation was of complete archaeological monument, whereas at Rudston, it was only of a part of it. In this respect, it appears that the analyses of the two sites were not directly comparable.

b. Slope and aspect

Other surface analyses applied to the surveyed landscapes built upon the values highlighted by the methods of surface representation. Both slope and aspect analyses highlighted the positions of anomalous features within the landscape, particularly reflecting areas of past anthropogenic activity. These did not expand on the results from the surface representation approaches, but demonstrated the potential of using such techniques.

7.3.4 Multiple surface analysis

Analyses using a combination of surfaces were found to be useful in three main ways. Firstly, data from previous surveys could be integrated within the same environment for comparison. At Rudston this was made possible by a contour plot from a survey conducted in the 1960s. By generating a DEM from this data and comparing it to the DEM generated from the GPS survey it was possible to understand the erosive effect of ploughing on the thin soils (chapter 5, section 5.9) better. This augmented the understanding of the state of preservation by providing an indication of erosion rates. However, such results need to be tempered in relation to the potential inaccuracies in the previous surveys and within the interpolation of the DEM from them in order to enable the most useful basis for comparison. This was not attempted at Sutton Common since topographic surveys do not exist for the area prior to its bulldozing and ploughing.

A second useful feature of multiple surface analysis is the possibility of using other layers of previous survey data to create a level of archaeological reconstruction. This was only attempted at Sutton Common where it was possible to re-constitute the damaged landscape through the reconstruction of the ditches in the smaller enclosure and the earthworks of the larger enclosure (chapter 6, section 6.9). This approach provided a landscape that was easier to comprehend and which could be compared with other surfaces more readily for further analysis. This enabled features that could not be seen on the ground to be visible within an environment where spatial relationships could be examined.

A third advantage of using multiple surface analysis is that elements of the landscape may be reconstructed by incorporating non-topographic data with the original DEM. Such reconstruction has two advantages in being able to aid in the understanding of the nature and threats to the preservation of deposits as well as providing a basis for interpretation. The results from the Sutton Common landscape demonstrated this dual role (chapter 6, section 6.9). In terms of preservation, the oscillating level of the ground water could be compared with the land-surface DEM to understand the areas that remained waterlogged with the implications for the long-term survival of buried organic material. The comparison between the DEM and the water models made it possible to highlight those areas at different levels of risk and thereby it was possible to advise on its management. In terms of interpretation, exaggeration of this ground water model and integration with the DEM enabled a prediction of Iron Age surface water to be created. This had purpose in relation to the overall architecture of the site and the integration of

the archaeology and the environment. This was also linked to the issue of reconstructing elements of the palaeoenvironment. It has been previously noted that, despite a good palaeobotanical record for their study area, it was "not possible to reconstruct vegetation with sufficient detail for visibility analysis" (Fisher *et al.* 1997: 587). This is a real problem within analyses of this type, although the approach used within this study does present a certain level of environmental integration. Further, through this examination it is possible to understand the depths to and from the water and therefore to begin to build up a picture of the location of different contemporary vegetation on the basis of palynological data.

7.4 Resolution

Resolution has been one of the four fundamental issues of this study (see chapter 1), concentrating particularly on the contrast between higher and lower resolution input-data for each of the two landscapes.

7.4.1 DEM cell-size versus input-data density

It has been noted that raw input-data from topographically variable landscapes will normally be of variable density. Contours represent a surface at given vertical intervals, being closer together or further apart depending upon localised vertical change. Point data from archaeological surveys is also likely to be irregularly spaced when dealing with the variable survival of surface features (see Fletcher and Spicer 1988 for a comparison between regular and irregular sampling of archaeological sites). Interpolation of such data then creates a DEM constructed of regularly spaced cells. In order to avoid error by under-representing data (i.e. two data points represented within one DEM cell) it is necessary to generate a surface at a resolution the same or higher than that of the highest resolution of the input-data. Two main issues relating to this may be highlighted from the present study. Firstly, such a requirement means that the number of interpolation methods available is reduced. The ratio between the input-data sample and the cell size will becomes greater in areas of lower survey resolution, thereby presenting stresses on the interpolation methods (see section 7.3.1). Secondly, the reasons for the variety in the resolution of the input-data must be considered. For example, the variability of contour input-data resolution is an objective function of the vertical range of the landscape. As such, it may be expected that micro-topographical features will be missed in those areas lying at elevations between the contour intervals. Therefore a higher resolution DEM interpolated from such data cannot be expected to provide greater detail than that of the contours and so the resulting model carries the risk of being misinterpreted. In contrast,

the variability of a sample of survey points from an archaeological survey is more likely to be the result of a subjective and reactionary approach to the survival of visible features on the ground. Whilst the resolution of the DEM may be higher, the model should not be considered to be an objective generalisation of the landscape.

7.4.2 Resolution and landscapes of lower topographic variability

There is a positive relationship between topographic variability and the need for higher resolution data. This is clear with regards to contours where an increased resolution is required to avoid large areas being devoid of input-data. This was emphasised by the higher resolution surveys within each of the landscapes that highlighted significant local topographic variation, but was particularly marked within the Sutton Common landscape where the general flatness meant that the contour density was relatively low. It seems therefore that lowland landscapes in particular, such as Sutton Common, need either to be investigated at a much lower resolution or otherwise a much higher resolution sample of input-data needs to be collected in order to have meaningful results.

7.4.3 The case for reactionary approaches to archaeological needs

The evidence from the Rudston landscape of the Yorkshire Wolds demonstrated that the survey of just the terminus of one of the cursuses was insufficient in providing useful answers and that more information could be gained from the lower resolution DEM covering a larger area derived from the contour data. One main reason for this appears to lie in the nature of the monuments themselves. At Rudston the GPS survey covered only part of the archaeological monument. This is in contrast to the Sutton Common landscape where the survey included both the principal site and much of the surrounding landscape. It seems that the appropriate input-data and area used for a GIS-based study, as well as resolution, is at least partially dependent upon the nature of the archaeological sites and monuments being studied.

7.5 Overview

7.5.1 Comments on surface generation

The accuracy of the DEM used for GIS analyses is fundamental to all further work. This study has reflected the results seen through previous studies that have demonstrated the potential differences in DEMs generated using different interpolation techniques (*cf.* Carrara *et al.* 1997).

a. Contour data versus point data

For landscape archaeology, point data has been found to be more useful than contour data for a number of reasons. Firstly, there are a wider variety of tools available within GIS for generating surfaces from point data than there are for contour data. Secondly, and more importantly, the nature of contour data means that it provides elevation values at regularly spaced vertical intervals. Principally, such an objective means that data storage is liable to miss the anomalous features that form the mainstay of landscape archaeology. Further, within flatter landscapes the contour density will inevitably be reduced so that any resulting DEM will be of less value than for a landscape with greater vertical variability. Also, contour data will provide difficulties at the edge of a DEM as an absolute edge is rarely established. In order to use such data effectively an area larger than that required should be generated as a DEM and then the study area may be cut from it. These problems with contour data conform to observations made elsewhere that contour data is a less valuable method of storing topographic data since it is itself derived (Gillings and Wise 1999: 35).

b. TOPOGRID and contour input-data format

Of the available interpolation methods for generating DEMs from contour data, TOPOGRID proved to be the most appropriate, interpolating surfaces to the boundaries of the study area and keeping closely to the contours themselves. The resolution of interpolated surfaces was dependent upon the raw data, with higher resolutions possible for the area displaying closer contours. Hazards exist within areas that display a range of contour densities so a balance must be found between over and under interpolation. Within the study, a value of 50 m was found to be appropriate for the given data in each case, though it is important to remember the variable accuracy that this will provide within different parts of the DEM.

c. TINLATTICE (quintic) and point input-data format

The evidence from the study demonstrated that, within the parameters studied, the TINLATTICE function provided the most accurate surfaces overall. This was more marked in those areas of increased topographic variability. A wider range of interpolation techniques may be appropriate in those areas without earthworks.

d. Sample/surface resolution ratio

Both the contour data and the point data provided samples with a higher resolution for areas of greater topographic variability. This variable density of the input data meant that

the DEM generated would reflect variable accuracy in relation to the raw data. This relationship has been investigated previously by Fletcher and Spicer (1988) who showed that such a variable accuracy of the input data is preferable to purely systematic data collection for reflecting archaeological earthworks. However, it does present the need to provide meta-data relating to the DEM, highlighting the variable sampling of the surface.

e. Contour data resolution

Expanding upon the previous point, the resolution of the input-data contours used in the study was at a 10 m vertical interval. The study demonstrated that this interval was essentially insufficient for providing a useful DEM of the Sutton Common landscape since the majority of this area lay at a distance of some kilometres from any sample data. The variability of much of the land in this area lies below 10 m OD and so even the highest resolution data available commercially (Ordnance Survey Profile), which is set at 5 m contour intervals, would provide a very limited basis for interpolation.

f. Summary of surface generation

No direct archaeological application of different interpolation techniques was established. Rather, the different techniques of interpolating DEMs may be seen as a basis for all further analyses. To suggest that different types of interpolated surface are more appropriate for either CRM or landscape interpretation at this stage would be deterministic with regards to the applicability of analytical tools and their relative value. This also highlights the issue of the ability to re-use data for multiple functions other than those for which it was originally collected (see section 8.9 below).

7.5.2 Comments on surface representation

a. The representation of lower resolution landscapes

The application of representation techniques to the lower resolution landscapes demonstrated some of the limitations of the GIS method and showed reasons for the trend within previous research of using topographically variable areas. The elevation based representations provided a basic level of understanding for each type of landscape, but more complex representations provided more varied results. Within the Rudston landscape the application of a light source provided a visually realistic and aesthetic model that reflected the distribution of archaeological features well. Within the Sutton Common landscape this process over-generalised the landscape and made it appear to be unrealistic, though this was a consequence of the limitations of the raw data source (see chapter 6, section 6.3). Examination of similar areas modelled using GIS has shown

similar results (*cf.* Van de Noort and Ellis 1997) and it appears that such low-lying areas are best depicted as a part of a larger landscape in order to make them meaningful.

b. The representation of higher resolution landscapes

Within the Rudston landscape elevation-based representations of the higher resolution area were useful, although the natural slope obscured the visibility of the southern terminus of cursus A. The application of hillshading improved this, but this in turn was rendered less realistic due to the blocky nature of the field. Within the Sutton Common landscape elevation and non-elevation based representations each highlighted many details concerning the environment and the archaeology, assisting the understanding of how the archaeological features related to the landscape. Different representations highlighted different aspects of the landscape. Elevation-based models highlighted the natural topography and features such as the causeway (confirmed by excavations - Van de Noort and Chapman 1999). Light shading highlighted many more features including the upstanding earthworks, the positions of bulldozed and ploughed banks and other features from the differential desiccation and shrinkage of biogenic ditch sediment in relation to the surrounding minerogenic sand islands.

c. The value of surface exaggeration

Surface exaggeration was useful in providing perspective images of each landscape due to the natural topography being too restricted to be understood. Further it enabled different surfaces to be draped together so that both elevation and non-elevation based representations could be observed together. However, in none of the examples did surface exaggeration assist in the understanding of the surface further than could be understood from the other analyses.

7.5.3 Comments of surface analysis

a. The dominance of interpretative applications and the role of visibility

Techniques of surface analysis can form the basis for further multiple surface analyses but were found to have the potential for being valuable in their own right. When used alone these tools were found to be more useful for interpretative functions, although part of this could have been due to the emphasis placed upon visual analysis by landscape archaeologists (e.g. Thomas 1993, Tilley 1994, Bender *et al.* 1997). This type of approach worked very well within each of the landscapes that were of a large enough study area with an adequate density of raw data points, therefore focusing on the lower resolution Rudston landscape and the higher resolution Sutton Common landscape. A

relationship with the nature of the archaeology was also hinted at. Large 'landscape-scale' monuments (such as the cursuses) would have required a greater area of the landscape to be covered in order for viewsheds to be more meaningful. The more focused monuments on Sutton Common, however, required a relatively smaller area of the landscape to be modelled in order for visual analyses to be appropriate for interpretation. This may also be linked to the likely vegetation of the region, with the more open landscape at Rudston enabling longer views compared to the more densely vegetated Sutton Common. The value of viewshed analysis was only possible within the framework of previous research into landscape perception, particularly in terms of movement through each of the landscapes, highlighting processes of space and place (Tuan 1977), or the psychological effect of anticipation and arrival.

b. Surface analyses, interpretation and other methods

Other surface analyses techniques were also most appropriate for interpretation when considered alone, although slope and aspect were able to highlight anomalous parts of the landscape, suggesting CRM value with regards to the *surface as archaeology* (issue 4 – see chapter 1). This type of result was only possible within areas that had been surveyed at a higher resolution. In terms of interpretation, slope and aspect were found to be of use within the Rudston lower resolution landscape. Here, the location of sites was on flatter or steeper ground and their aspect were found to be useful in conjunction with the multiple surface analyses in defining different trends between different periods of construction and different foci indicating territoriality.

c. Narrative interpretation methods

Slope surfaces were also found to be of particular value when used as an abstract surface upon which activity takes place. It was possible to indicate perceptual changes in a similar way to the viewshed analyses as the landscape was walked through. This role of creating narratives is well established within landscape archaeology. For example, Tilley (1994: 31-3) outlined the usefulness of narratives in understanding archaeological landscapes and demonstrated this through a photographic essay representing movement through three different landscapes. The advantage of digital approaches to landscape lie partially in their ability to reconstruct monument distributions and to remove later obstructions. However, the present study has also shown that it is possible to deconstruct a landscape into abstract elements such as slope or visibility and analyse them separately and then combine them to create multiple narratives. These enable a multifaceted understanding of a landscape to be achieved in a way that is otherwise impossible.

7.5.4 Comments on multiple surface analysis

The value of multiple surface analyses is that they provide an opportunity to synthesise the results obtained within the previous three areas of analysis. This enabled a shift in approach from being technique led to being question led. In this respect, the focus of the multiple surface analyses was determined by questions of CRM or landscape interpretation. A number of key points may, however, be made in terms of the overall applicability of the tools towards the main areas of archaeological research.

a. Multiple applicability of input-data for different functions

On several occasions the present study has demonstrated that data obtained for one purpose may be applied to another. At Sutton Common the hydrological data, obtained in order to understand threats to the buried organic resource (i.e. CRM), were found to be useful in contributing towards a reconstruction of the past landscape to use within an interpretative framework. Similarly, surface hydrological data, collected in order to understand the positioning of monuments on the lower resolution Rudston landscape, indicated that it may be of greater value in understanding the visibility of crop marks across the Wolds landscape. It seems therefore that data can be of use for a number of functions and not just those for which it is initially collected (see chapter 10, section 10.5).

b. Visibility and interpretation

Following the themes of cumulative viewshed analysis (*cf.* Wheatley 1995, Lock and Harris 1996, Llobera forthcoming a & b), the application proved to be useful for the interpretation of the lower resolution landscape of the Yorkshire Wolds. Here the application of this approach provided evidence that indicated territories and showed ways in which these may have shifted with time (see chapter 5, section 5.5.2). The results from these approaches highlight a need to examine these trends on a larger scale to include a greater number of archaeological features. Within the lower resolution Sutton Common landscape an attempt was made to examine the barrier effect of vegetation of different heights on visibility. Although the results from this study were restricted by the DEM this approach demonstrated ways in which vegetation may be incorporated into interpretation models.

c. Applicability of surfaces generated from other input-data sources

With both of the areas of higher resolution GPS survey it was possible to compare the interpolated surfaces with those generated using other data. For the Sutton Common

landscape this data related to the level of the water table and for the Rudston landscape it related to a previous contour survey of the cursus terminus. In each case it was demonstrated that other data sources in the form of DEMs can provide additional information for understanding issues of both landscape interpretation and CRM.

7.6 Some limitations

GIS approaches to landscape archaeology have been criticised for being normative and deterministic (*cf.* Gaffney and van Leusen 1995). Although this has been argued against (e.g. Llobera 1996), problems relating to the application of such a mathematical structure still exist. At a more practical level, certain difficulties are inherent with regards to how a GIS may be used as an archaeological tool. For example, the necessary attributes for the accurate calculation of cost surfaces is currently a subject for debate (e.g. Bell and Lock forthcoming, De Silva and Pizziolo forthcoming). Similarly, a re-defining of approaches are being conducted with regards to visual analyses (e.g. Gillings and Wheatley forthcoming, Llobera forthcoming a & b).

Within the present study, a problem with approach was found when using tools such as visibility analysis that assume an observer to be within the landscape. In these cases a cell of the DEM is chosen as the observation point. The first problem is that this cell does not just represent the position of the observer, but rather it represents a square area of a pre-determined size. For the lowest resolution landscapes used in this study, such positions represented an area measuring 50 x 50 m. The same problem arises with analyses that move through the landscape such as the slope-based narratives (chapter 5, section 5.4.1 and 5.4.3).

7.7 Summary

This chapter has discussed the results presented in the previous two chapters in relation to the methods of GIS analysis that were used, highlighting some their values and limitations. It has outlined the main observations from each of the areas of GIS study defined as surface generation, surface representation, surface analysis and multiple surface analysis. It has also examined the role of resolution and has highlighted some of the main methodological issues relating to the study of archaeological landscapes using GIS.

The following chapter reassesses the same results in relation to the archaeological themes within landscape interpretation.

Chapter 8

GIS applications within landscape archaeology

8.1 Introduction

In the previous chapter the results presented in chapters 5 and 6 were discussed in relation to GIS procedures and methods. This chapter discusses the results from the perspective of the applications of GIS within landscape archaeology. It is divided into the two main sections of landscape interpretation and cultural resource management (CRM). Each section begins by presenting an overview of the principal themes within that part of landscape archaeology, exploring the ways in which the results have addressed them. This is followed by an assessment of the results in relation to the questions outlined in chapter 2 for each of the two landscapes. The chapter concludes with a synthesis of the strengths and limitations of GIS within the two main themes of landscape archaeology.

8.2 GIS and landscape interpretation

8.2.1 Overview

a. Identification of sites

The higher resolution surveys, particularly at Sutton Common, demonstrated how GIS approaches could highlight features that cannot be seen on the ground (see chapter 6, section 6.7). The identification of these features provides a more complete picture of the archaeological landscape that forms the foundation for landscape interpretation. For example, the outline of enclosure A was discovered as a causeway connecting the two enclosures across the palaeochannel. This significantly influenced the interpretation of the site and reinforced previously postulated theories about movement through it (*cf.* Parker Pearson and Sydes 1997).

b. Chronology

The ability to demonstrate relative chronology is dependent upon the interpretation of spatial relationships and also upon the assumption that themes such as visibility were important in the past, forming a structure by which the landscape was understood. Overall, there were no occasions where a chronological relationship could be unequivocally demonstrated. Issues of chronology were only implied within the analyses of the lower resolution landscapes. Within the Sutton Common landscape, the potential intervisibility between all sites could not be interpreted as contemporaneous due to the limitations in both the DEM and the understanding of previous vegetation patterns that

will both have influenced the perception of landscape in the past. In relation to the Ruston landscape, a wider range of archaeological data meant that a more rigorous assessment of the landscape was possible. Here, the main issue was the relative chronology of the monolith compared with other monuments (see chapter 2). The role of the monolith within the viewsheds of the cursuses indicated its importance by the later Neolithic in terms of its position. This is echoed by the distribution of contemporary artefacts that are concentrated around its location (Pierpoint 1980).

A separate chronological relationship between the cursuses was also defined. Each of the various analyses implied that, of these monuments, cursus D had a different role within the landscape. Although this did not directly highlight the chronological relationships between the cursuses, it echoed the evidence from excavation (Kinnes 1982) that cursus D was the most recent of those that could display any chronological relationship (cursuses A, C and D – see chapter 2, section 2.3.4).

c. Interaction between different monuments

The interaction between monuments was demonstrated on a number of occasions. In the Rudston landscape, for example, the position of cursus A appears to have been located to ensure that the earlier long barrows to the west maintained a visual position on the western horizon. The consistency of this visual relationship suggests that it may have dictated the route of the cursus and therefore its curving shape in plan. Such a link between cursuses and earlier Neolithic features has been demonstrated elsewhere (e.g. the Dorset cursus - Barrett *et al.* 1991, Tilley 1994) and so it seems reasonable to suggest that such an interaction was continuing at Rudston.

d. Interaction of monuments and landscape

Expanding the issue of monument interaction, the present study has demonstrated the close relationship between monuments and their landscape. Bradley (1993) suggested that a landscape might be re-defined by monuments forming a kind of updated 'natural' landscape. Within the lower resolution Rudston landscape and the higher resolution Sutton Common landscape close relationships with features of the natural landscape were demonstrated. With the former, the role of the Great Wold Valley was emphasised, as was the Gypsey Race, as a focus for activity, following the conclusions of Dent (1998) who suggested a chronological shift from a focus in the valley floor to one on the higher periphery. In relation to Sutton Common, issues including the role of islands and the influential role of water within the construction and architecture of the site were

highlighted. Essentially, the GIS environment enabled the comparison of various layers of data to be understood and so correlation of this type was possible. The other two surfaces also provided evidence indicating the interaction between monuments and landscape, but in a less dramatic manner. The higher resolution DEM of the terminus of cursus A showed the relationship between slope and earthworks, though this had greater implications with regards to CRM (see section 8.3.2 below). Equally, the positioning of features within the lower resolution Sutton Common landscape highlighted the contrast in location between the enclosures within the wetlands and the field systems on the higher areas. However, the contribution of GIS to this understanding was limited.

e. Function of monuments

The interpretation of the function of monuments, particularly without excavation, is a relatively difficult and potentially subjective affair. As for relative chronology mentioned above, it requires an assumption that issues such as economic, cultural and spiritual factors have always been influential in the choice of location for a monument within the landscape. However, the approaches used within the lower resolution Rudston landscape (see chapter 5) and the higher resolution Sutton Common landscape (see chapter 6, Figure 6.15) re-enforced previous theories over the function of the principal monuments. It was demonstrated that the relationship between archaeology and landscape facilitated movement through each landscape in order to provide the participant with a series of experiences in a specific order.

8.2.2 Interpretation of the Rudston landscape

Chapter 2 (section 2.2.5) highlighted some of the outstanding issues relating to the interpretation of the Rudston landscape. This section re-visits these issues following the results from chapter 5.

a. The function of the cursuses

In chapter 2 the possible roles of cursuses were divided into ten sub-areas - procession ways, ancillary monuments, racetracks, funerary monuments, monuments to fulfil a social function, sacred places (*temenos*), monuments linked to natural processes, astral observatories, geometrical constructs or centres for trade. The results from this analysis have not been able to test each of theories in any hypothetico-deductive manner, but have enabled a number of observations to be made as to their possible function or functions.

Fundamental to many of the theories on the function of cursuses is the question of whether or not they were designed for movement along them. The evidence from this study has suggested that, for the majority of the cursuses, movement appears to have been a function of their architecture, assuming the importance of an *anticipation/arrival* or *space/place* duality. Further, the evidence has suggested that for each of the cursuses, a single direction of travel seems likely.

A relationship with earlier monuments appears to have been crucial in the positioning of the cursuses. The shape of the southern part of cursus A may be explained partially by slope, curving to keep on flatter land. However, a more convincing argument was presented by the visibility analyses suggesting that the curving plan may have been designed to maintain a visual relationship with the long barrows to the west, keeping them on the horizon. This was echoed by the cost-surface analysis that shows the cursus deviating from the least-cost route. Such a relationship between monuments appears to reinforce interpretations of the cursuses as routes through a pre-determined set of experiences. A second relationship between the cursuses and earlier monuments may be interpreted in relation to issues of territoriality. The position of cursus D draws the areas occupied by Willie Howe and Southside Mount together, perhaps joining two earlier territories.

The question of whether each of the cursuses fulfilled a similar function to the others has also been approached by this study. Cursus E produced very little data due to its relatively short length. Unlike the other cursuses, cursus D displayed very little evidence to indicate that its function was centred upon movement. However, it did provide a link between the visual territories defined by the earlier great barrows of Willie Howe and Southside Mount suggesting that the function of cursus monuments had changed. This theory is feasible since the evidence from excavation suggests that cursus D is the most recent of the cursuses (see chapter 2, section 2.3.4).

Finally, cursus morphology has been shown to be an interesting theme in relation to the Rudston landscape. Loveday (1988) used morphological diagnostics to define typological relationships between cursuses. Within the present study the plans of the cursuses have displayed some interesting themes. The curving plan of the southern half of cursus A appears to reflect a need to maintain a view of long barrows on its horizon and does not follow a route designated by the least cost path. Cursus D displays a relatively straight plan that again deviates from the least cost path but without obvious relationships with

other monuments. It seems, therefore, that the builders of the presumed earlier cursus (cursus A) were influenced more by visual relationships with the earlier landscape, but that the later cursus builders (cursus D) maintained architectural form over other factors. Clearly many other factors need to be explored in order to strengthen this interpretation.

The previously held interpretations of cursuses have not been explored individually and may not each be fully explained by GIS alone. However, a number of themes have been highlighted.

- Movement along at least some of the cursuses appears to have been important, providing contrasting psychological states of anticipation and arrival as have been used by previous authors to interpret landscapes.
- Movement along cursuses appears to have been focused on a single direction rather than in both directions.
- There appears to be a link between the positions of cursuses and the visibility of other archaeological monuments from them, suggesting a respect for the earlier landscape.
- The positions of the cursuses appear to redefine earlier territorial divisions.
- The functions of the cursuses appear to change through time within this landscape.

Two main issues have not been fully explained. Firstly, the relationship between the cursuses and the Gypsey Race is interesting since cursuses A and C certainly cross it. One answer for this may be that the Race is a small and seasonal watercourse that would have been fordable at different times of year. However, the relationship between cursuses and watercourses elsewhere (*cf.* Hedges and Buckley 1981) indicate that a more vigorous assessment is needed. Secondly, the crossing of cursuses C and D is interesting. The excavated evidence suggests that cursus C was visible when cursus D was cut across it. No evidence of timescale between the construction of the two was obtained. This feature provides interesting context for the concepts of chronology and movement through the landscape.

b. Landscape chronology

The issue of landscape chronology was classified in chapter 2 as relating to three points - the date of the monolith, the chronological relationship of the cursuses and the influence of earlier monuments on the location of later features. On the basis of this study a

number of chronological interpretations may be made within the context of the previous dating evidence and the apparent changes in the function of these features through time. The long barrows demonstrated the earliest phase identified within the landscape. The evidence from this study is limited due to the small sample of only three long barrow monuments. Despite this, the evidence from the analyses of the positions of these features reflects a territorial function as suggested for those in the Danebury area (Lock and Harris 1996). The two definite long barrows within the landscape are both on slopes with different aspects and command viewsheds that do not overlap.

The territories defined by the long barrows appear to change by the later Neolithic with the advent of the great barrows whose positions command views that join the different viewsheds from the long barrows together to produce a different pattern of viewshed 'territories'. Also these lie on flatter land indicating that they are not uni-directional, in the way that may be suggested for the long barrows, but that they have been located so that they can be seen from all sides. However, it must be stressed that these sites lie on the edges of the study area, with their viewsheds extending beyond its boundaries. A larger study area with a greater number of monuments would be required to substantiate these claims. A third phase identified in relation to territories was found with the cursuses. Their position appears to have lined the great barrows' visual territories together in a focus within the Great Wold valley.

The chronological relationship between the cursuses is still not clear. The previous understanding of a relative chronology of cursus A, cursus C and then cursus D has been used, along with the interpretation that each of the earlier cursuses were visible on the ground when the later cursuses were being constructed. The time period between the different constructions is still unclear, although it appears that the apparent architectural and functional differences between cursus D and cursuses A, B and C (see above) indicate that a longer period may have existed between their construction.

The relative chronological position and role of the monolith remain unclear. The ground position of the monolith has been shown to have nearly as much visual influence as the top in relation to the other monuments. It forms a point that is visible from the full lengths of each of the cursuses and appears to be an influential factor in the positioning of other monuments. It can also be seen from the positions of the Rudston and Denby long barrows. The similarities between the viewsheds from the top and the base of the monolith mean that direct chronological relationships cannot be made although a focus

within the base of the Great Wold valley may be assumed. The location of Maiden's Grave henge and the Greenlands hengiform monument (if it is assumed to be of this period - see chapter 2) provide a differing visual pattern whereby the whole of the Great Wold valley is no longer central. This theme is continued by the early Bronze Age by which time there appears to be no systematic visual correlation between the distribution of round barrows and intervisibility with the monolith.

In visual terms it seems that the monolith continues a changing tradition that can be measured in this region. The earlier phases provide shifting territoriality that is brought together within the Great Wold valley with the construction of the cursuses and possibly the erection of the monolith. This focus is lost again by the later periods with the henges, followed by the round barrows, forming a less systematic visual concentration. Whether this reflects a reduction in the importance of this location, or a reduction in the importance of visibility is unclear.

8.2.3 Interpretation of the Sutton Common landscape

Chapter 2 (section 2.3.5) raised a number of unresolved issues concerning the interpretation of the Sutton Common landscape. This section re-appraises these issues following the results of this study (chapter 6).

a. Location of monuments and the development of the archaeological landscape

Chronologically there is a development in the archaeological landscape, as described in chapter 2, beginning with the construction of the barrow to the east of Shirley Wood, followed by the construction of the enclosures at Sutton Common. This was succeeded by the development of the agricultural landscape in the form of the various field systems. The contemporaneity of much of this sequence is uncertain due to questions over the longevity of individual sites. The present study has highlighted a possible visual relationship between all of these classes of site and it seems that the evidence is too restricted to present further understanding of why locations have been chosen without a clearer understanding of the contemporary environment.

b. Location of monuments and the environmental landscape

The high water tables within wetland landscapes appear to have had an influence upon the architecture of the enclosures on Sutton Common. Principally this was reflected by the location of the enclosures upon the raised islands (chapter 6, Figure 6.9). However, the influence of the high water table was also indicated by the raised (and presumably

drier) areas on the line of the route through the site, including the approach to the site from the west (Figure 6.11) and the causeway running between the two enclosures. The integration of the water table surface with the land surface DEM highlighted areas of surface wetness. An exaggeration of the wettest results showed that areas of standing water raised a number of issues relating to the position and architecture of the enclosures (Figure 6.18). The high water table would have provided a moat around enclosure B in conjunction with its western and southern ditches. Modelling of the southeastern corner of this enclosure indicates that the earthworks were extended to the edge of standing water in the palaeochannel to form the moat on this side. In relation to enclosure A, there is a correlation between those areas with fewer ramparts and those with increased surface water. It seems that the architecture of the site reflects some kind of defence (either visual or physical) that was enforced by multiple ramparts or by standing water. The present study has highlighted this relationship between the contemporary environment and the architecture of the site. This was especially marked using a land surface with the reconstructed location of the banks of enclosure A (Figure 6.18).

c. Function of the various monuments

The assessment of monument function was limited, perhaps due to the lack of topographic variation, and it appears that many of these features would be better understood through an assessment of other environmental factors. However, it does appear from the viewshed evidence that occupants of the different field systems on the Sherwood Sandstone ridge in the southeastern corner of the region would have been cognisant of one another. This would have been particularly significant since excavations in this area have hinted at a considerable longevity identified through many phases of recutting and cleaning of the ditches that form the field systems (see chapter 2). Also, it seems possible that the people at the Sutton Common enclosures could have known of the field system occupants if they were contemporary, which appears possible given the excavation evidence. The apparent visual link between the two was demonstrated in the present study although it is likely that such intervisibility would have been enhanced by the visible smoke from fires that may have extended above the vegetation line. Further, the palynological evidence from this period suggests a degree of woodland clearance that might have also enhanced this (see chapter 2, section 6.4.3).

A fundamental issue relating to the function of the enclosures on Sutton Common was access to the site (see point *b* above). Parker Pearson and Sydes (1997) and Lillie (1997) suggested that a dryland access from the west was likely, though this was not

demonstrated. The higher resolution DEM and profiling approaches (Figure 6.11) showed that this dryland access was not only likely, but probable, as it revealed a raised area extending from the west to the southwestern entrance of enclosure B.

The visual analysis at Sutton Common presented some indication of the function of the landscape assuming a path was taken through it (after Parker Pearson and Sydes 1997). A sequence of *anticipation* and *arrival* was generated and measured in terms of the presence or absence of a feature from view, distance and position within the viewshed. This analysis produced more evidence to suggest that Parker Pearson and Sydes' (1997) interpretation of enclosure B as an annex or gateway to the larger enclosure A was probably correct and that the site was indeed built to be approached from the west.

d. Further understanding of the Sutton Common landscape

The relationship between the two enclosures and the palaeochannel of the Hampole Beck was not understood prior to this study. The survey of Sutton Common revealed a protruding tongue of higher land extending across the palaeochannel from the eastern entrance of enclosure B. This higher land was accentuated by the reconstructed water table (Figure 6.18) and appeared to represent an anthropogenic causeway rather than an accretion of sediment due to its distinct shape. Subsequent excavations have shown this feature to represent part of a sandy causeway built over the peaty wetland surface (Van de Noort and Chapman 1999).

8.3 GIS and cultural resource management

8.3.1 Overview

CRM in archaeology may be divided into a number of key themes that can provide a test for the tools analysed within this study.

a. Archiving

A DEM provides a temporal benchmark of a landscape against which further analyses may be compared. This is only possible in certain cases. Firstly, it can only be considered in relation to the higher resolution surveys that provide sufficient detail and, secondly, the surfaces must be accompanied by details of the raw data itself (*cf.* Wise and Miller 1997, Gillings and Wise 1999). This study has shown the potential for generating GIS models from earlier sources of data, although the value of their application is limited by knowledge about the raw data. For example, in the case of Rudston, the input contour data is already a derived format and so its value is therefore reduced. Overall, such issues

of data storage (*cf.* Gillings and Wise 1999, Richards 1997) highlight the need for the recording of metadata.

b. Site assessment

The assessment of sites is a broad field consisting of elements including the validity of the available data, the potential for new discoveries, the state of *in situ* preservation and the assessment of possible risk to the site. In terms of assessing the value of the data it has been suggested that, for the lower resolution Rudston landscape, flow-accumulation models may be used to indicate the validity of distributions of crop marks. If accumulation is interpreted as colluviation with a subsequent masking effect, then the question of what the crop marks represent may be better understood.

With both of the higher resolution surveys archaeological features were revealed that were not visible on the ground. At Rudston, the southern terminus of cursus A was identified despite having being ploughed over many years. At Sutton Common more features were identified. The outline of the larger enclosure (enclosure A) was seen on different representations of the DEM, as were other features such as the causeway. Even in areas that had been ploughed regularly for nearly two decades the objective, regular sampling of points was able to provide sufficient data to effectively prospect for buried archaeology that could not be seen on the ground.

The state of *in situ* preservation of archaeological features was also assessed by the present study. The higher resolution surveys at both sites demonstrated the state of preservation of the earthworks despite their regularly ploughing. At Rudston this was augmented by a comparison with a DEM of the site derived from a previous contour plot (after Dymond 1966). This enabled comparisons over a period of more than thirty years to be made in order to understand damage to the site from soil erosion (Figure 5.26). At Sutton Common it was also possible to hint at the *in situ* preservation of buried deposits. Through an understanding of differential shrinkage of biogenic (ditch fill) versus minerogenic (natural) sediments, and the fact that desiccated biogenic sediments lose their structure, it was possible to assume that the visibility of ditches on the surface model indicated shrinkage in the buried sediment since the last period of ploughing. This was used to suggest that deposits in the ditches were still preserved, but that they were actively desiccating.

The assessment of the *in situ* preservation highlighted issues relating to the future risk of damage to the sites. At Rudston, this was indicated through the comparison of the surveys from the 1960s and the 1990s that were able to provide an indication of the rate of erosion. At Sutton Common the evidence of sediment shrinkage demonstrated that the deposits were actively desiccating. This evidence was enhanced by the integration of various water table models that showed the water table was fluctuating, thereby harmfully exposing buried organic sediments to an oscillating environment of wetting and drying. This modelling also demonstrated that some areas of the site were at greater risk than others, indicating that parts of the site could be preserved *in situ* while others could not. This was subsequently verified by excavation (Van de Noort and Chapman 1999, 2000). Further, it was possible to model the likely outcome of re-wetting the site though exaggerations of the water table.

c. Mitigation

This area of CRM relates to the ability to prevent or manage the future destruction of the archaeological resource. The present study has shown a number of themes that may be included within this broad heading. Firstly, and continuing from the previous point, the ability to assess the state of preservation of buried deposits on an archaeological site and the nature of threats to it provides answers that may help to advise upon its future management. Therefore, the understanding of the hydrology on Sutton Common will demonstrate the needs of the site in order to achieve *in situ* preservation as saturation is a key determining factor in the preservation of organic deposits. Similarly, understanding the rate of surface erosion on a ploughed site, such as the cursus terminus, will also assist in understanding the nature of the threat to it. In each case, this work has demonstrated that the basic processes of protection (both sites are Scheduled Ancient Monuments) are inadequate without some understanding of the monitoring requirements of a site.

The value of the larger landscapes is less clearly defined with regards to mitigation. It is possible to provide an understanding of areas more prone to erosion and those more prone to colluvial accumulation, but the resolution of such analysis is limited (see chapter 5, section 5.5.3). Further, it is dependent upon the nature of the raw data and the surface - the Sutton Common landscape would be inadequate for such an analysis.

8.3.2 Interpretation of the Rudston landscape

Chapter 2 (section 2.3.6) highlighted some of the key issues concerning the cultural resource management of the Rudston landscape. This section re-assesses those issues in the light of the results from the present study (chapter 5).

a. Agricultural erosion of monuments

An assessment of colluviation/erosion of the terminus of cursus A was achieved in part by a comparison with previous data and this study showed that, over the 35 years between surveys, significant erosion had taken place. However, the detailed quantification of this was not possible due to the lack of vertical datum for the earlier survey in order to provide a direct correlation. Despite this, the results have shown the potential for monitoring the erosion of monuments within an arable landscape.

b. Visibility of monuments

The issue of monument prospection relates to the methodological approach for identifying hitherto unknown sites. The assessment of the DEM generated from the lower resolution Ordnance Survey data in relation to surface hydrology has provided some indications of areas that are likely to yield future sites. This study indicated that correlation might be found between areas where crop marks have not been found and areas of sediment accumulation. It may be assumed that deeper soils are more likely to restrict the visibility of archaeological features in these areas by aerial photography.

The fragmentary crop marks have not revealed terminuses for all of the cursuses and this has been discussed in the present study. Evidence from the analysis of the viewsheds along cursus C (Figure 5.10) indicates that the position of its western terminus is close to the end of the recorded crop marks since it follows a visual pattern similar to that of cursuses A and B that have visible terminuses (see chapter 5, section 5.4.3).

8.3.3 Interpretation of the Sutton Common landscape

This section re-appraises the CRM issues highlighted for the Sutton Common landscape in chapter 2 (section 2.3.6) following the results of this study presented in chapter 6.

a. Nature of the preservation and identification of enclosure A following bulldozing and ploughing over 17 years

Through different methods of representing the surface generated from the GPS survey it has been possible to highlight the position of enclosure A despite its flattened nature.

This study has identified a reduction in surface ground levels over the areas of archaeological ditches due to the desiccation and shrinkage of the organic deposits contained within them. This indicates that the ongoing decay is irreversible since desiccated sediments cannot re-expand. For such decay to be taking place a well-preserved deposit must exist that can be decayed. Hence this evidence implies that a wet-preserved archaeological resource still remained at the time of survey. This has since been confirmed by excavation (Van de Noort and Chapman 1999, 2000).

It has also been possible to highlight some errors in the 1930s survey of enclosure B. The western bank was shown on the earlier survey as a series of isolated mounds indicating a number of possible entrances to the site. The present study has shown that the bank on the edge of the enclosure was more complete and continuous.

b. Potential for the* in situ *preservation of archaeological and palaeoenvironmental source material on Sutton Common

The modelling of the ground water table revealed an irregular fluctuating surface that reflected the overall pattern of the land surface. Analyses comparing both surfaces together displayed areas of higher potential for preservation generally, with higher water tables. Further, this enabled the modelling of the shape of the water table in order to investigate the effects of re-wetting. The results of this analysis showed that the potential for the *in situ* preservation of archaeological and palaeoecological source material across the site was different in different areas.

8.4 Synthesis - the contribution of GIS

This study has shown how the use of GIS provides an insight into each of the two areas of landscape archaeology - interpretation and CRM. With interpretation, GIS has assisted in identifying sites, understanding chronological relationships and understanding the interaction between different monuments and between monuments and elements of the natural landscape. GIS has also enabled the better understanding of the function of different monuments. Although reinforcing the dominance of visibility on interpretation, it has shown that a GIS environment provides a suitable background for developing understanding using other abstract surfaces. In relation to CRM, applications assisting with archiving, site assessment and mitigation have been demonstrated, particularly expanding upon the range of information that may be gained through non- or minimally-invasive means.

In addition to the contribution that GIS has been shown to have within both landscape interpretation and CRM, it has been demonstrated that there is a strong overlap between the two. On a number of occasions, data obtained for one of the two purposes has been found to be useful in answering questions relating to the other. Similarly, GIS approaches have been found to be transferable between the two. This suggests that GIS provides an environment that may be used to explore data in ways that need not conform to structures, reflecting conclusions drawn by Gillings and Goodrick (1996) that GIS was increasingly becoming a 'place to think'.

8.5 Some limitations

By definition, cell-based GIS is bound by its abstract data structures. However, in relation to archaeology it has been shown to be useful in and applicable to a wide range of archaeological scenarios. The principal question of its limitations therefore lies in whether these conclusions could be obtained in other more useful or efficient ways. In terms of interpretation, GIS can only provide an abstract representation of the landscape, so the understanding of its perceptual elements will be limited. However, GIS provides the opportunity to quantify at least some of these and to reconstruct different phases of the landscape. In terms of CRM, other methods may be used to obtain some of the conclusions drawn here from the input-data. For example, specialist software such as Visual MODFLOW (created by Waterloo Hydrogeologic) exists for modelling the interaction of ground water with varying sediments. This could have been used at Sutton Common. However GIS provides a common platform for data storage, comparison and manipulation.

Although it is advantageous that GIS can store and manipulate multiple layers of data in high quantities, the fact that it also *creates* data (*cf.* Savage 1990) highlights certain problems when archiving the data. No record is automatically stored when the GIS makes calculations and so the reliability and value of new data cannot be understood with ease. This highlights the need to generate metadata (Wise and Miller 1997, Gillings and Wise 1999) and demonstrates the high potential for confusion when re-using data.

GIS provides a platform for exploration but its use also presents the question of whether it is too narrow a discipline to be relied upon in isolation. Ultimately GIS should be seen as one of many tools available to the archaeologist.

8.6 Summary

In this chapter the results presented in chapters 5 and 6 have been discussed within the framework of landscape archaeology. The conclusions from the analyses of the two study areas in relation to the themes of landscape interpretation and CRM have been presented. It has been shown that GIS can help to answer a range of questions relating to landscape archaeology and that the only limitation to the types of landscape that may be suitably analysed in this way are those where input-data is of an insufficient resolution. This chapter has also shown that data obtained to answer questions relating to one area of landscape archaeology may be useful in answering questions relating to a quite different area once placed within the GIS environment. Similarly the various GIS methods may be applied to other archaeological analyses.

The following chapter summarises and concludes the thesis following the aims outlined in chapter 1.

Chapter 9

Conclusions

9.1 Introduction

As outlined in chapter 1, the aim of this thesis was to investigate cell-based GIS techniques and their application within different landscapes of different resolution in order to satisfy the limitations of past research. These limitations were defined.

1. Past archaeological GIS research has been limited to topographically variable areas, concentrating particularly on upland landscapes.
2. Comparative research has been limited within archaeological GIS research.
3. The concept of resolution and its influence on the capabilities and potential of GIS tools for answering archaeological questions has rarely been approached with regards to either raw data (sample density) or the DEM surface.
4. There continues to be a bias whereby research is conducted upon abstract surfaces upon which archaeology is overlain and analysed rather than the surface being considered as part of the archaeological landscape. This is largely a result of the commercial availability of data and limitations in access to higher resolution surface data.

To satisfy issues one and two, contrasting landscapes were chosen that included both one topographically variable landscape (Rudston) and a topographically flatter landscape (Sutton Common). These were selected to be the same size and chosen from the same resolution Ordnance Survey contour data to ensure comparability. An area within each of the two landscapes was surveyed at a much higher resolution on the ground in order to satisfy the third issue of comparing the effect of changes in resolution. Finally, the areas were chosen and defined on the basis of where previous surveys had taken place and where earthworks either still existed or had been ploughed and, preferably, were a mixture of both.

The suite of main GIS tools available was applied to each of the surfaces. These tools were classified within four groupings - surface generation, surface representation, surface analysis, and multiple analyses (chapter 4). For the first three groupings, a selection of GIS tools was applied to the data and the results observed and compared. The fourth

grouping then expanded upon these data and results and GIS was applied to answer specific questions relating to the archaeological landscapes (outlined in chapter2).

The results from the application of these techniques to each of the landscapes (chapters 5 and 6) were then discussed in relation to GIS approaches (chapter 7) and their application for the interpretation and management (chapter 8) of archaeological landscapes. This was done in order to understand the value and applicability of the tools to different landscape types, at different resolutions and for different archaeological requirements.

In this concluding chapter a summary of the main results is provided, firstly focusing on each of a suite of GIS tools and their effects and applicability on the different landscapes. This is followed by a summary of the usefulness of these techniques for interpretation and CRM in landscape archaeology. The chapter continues with a reflection upon these results in relation to the research aims outlined in chapter 1. Finally, the approach used is considered and the wider implications of this research are reflected upon.

9.2 GIS methods

The range of the GIS methods applied to the two study areas displayed varying benefits. This highlighted the usefulness of different tools to contrasting landscapes in terms of both topographic variability and input-data resolution.

9.2.1 Surface generation

Surface generation tools were shown to have a significant influence on the usefulness of the DEMs created. Further, different methods were found to be the most appropriate for different types of input data. Through the analysis of quantitative and aesthetic factors, it was found that the TOPOGRID function was most appropriate for creating surfaces from contour data. This technique has the added advantage that it can be interpolated to pre-determined boundaries rather than to the edge of the data. This means that a study area may be investigated in its entirety, although it must be considered that areas not supported by data at the edges will be potentially inaccurate. Ideally, larger areas should be interpolated and the study area cut out from it, although this raises financial implications. For point data, such as from high resolution GPS survey, a wider range of interpolation methods were available. Of these methods it was found that a two-phase approach that used a TIN (triangulated irregular network) stage followed by a conversion to form the DEM was most appropriate.

The resolution of the input-data was also found to be crucial in assessing the accuracy and value of different interpolation approaches. Firstly, it was found that the variability in topography reflected a variability in contour density This meant that the accuracy of cells within the more topographically variable parts of a landscape would be greater than within flatter areas due to increased data density. Given that Ordnance Survey data is supplied at constant contour divisions, the data will be more accurate for topographically variable landscapes than for flatter ones. This explains some of the limitations in the previous use of topographically variable landscapes for archaeological study.

It was also found that the chosen resolution of the DEM (i.e. cell size) most suitably follows that of the raw data. The spatial variability that input-data can follow means that the DEM should be of the same or greater value than the highest resolution displayed by the input-data in order to avoid multiple data points being represented by a single cell. However, variability means that the level of interpolation across the DEM will be greater in some areas than others. These issues should be considered when creating DEMs and when preparing metadata for archives.

9.2.2 Surface representation

Different surface representation techniques were found to have varying usefulness depending upon the landscapes being studied. In all but the lower resolution Sutton Common landscape, different representation techniques provided a level of aesthetic realism that made them more tangible. This was accompanied by a clearer understanding of the spatial and topographic relationships between the monuments and the landscape. With the higher resolution survey areas the different approaches to representation had added advantages. Particularly through the application of analytical hillshading it was possible to identify features that were not visible on the ground due to ploughing. Further, it was possible to highlight the state of preservation of the features, including both the condition of standing earthworks and, as at Sutton Common, the desiccating condition of buried deposits.

9.2.3 Surface analysis

Visibility analysis remains the principal method of surface analysis when techniques are considered alone and are not combined as with multiple surface analysis (see below - section 9.2.4). It has also been a principal method of interpretation within landscape archaeology (e.g. Thomas 1993, Tilley 1994) and within GIS interpretation (e.g. Fisher *et al.* 1997). The results from the present study demonstrated that visual analysis was still

the most beneficial approach, but with a number of changes. It proved to be an extremely useful technique within the lower resolution Rudston landscape, but the higher resolution survey area was found to be too small to enable a useful visual analysis to be accomplished. The value of visual analysis was also highlighted with the higher resolution Sutton Common landscape. This demonstrated that flatter landscapes could still be useful for such analyses if the input-data and DEM resolution is high enough.

Other surface analyses were also found to be of use within the framework of narrative interpretations of the landscape. It was found that the other surface analysis tools such as slope and aspect could be used to separate different elements of the landscape. Each of these tools contributes to the perception of landscape and movement through it. Together, several layers may mean that the abstract nature of GIS can contribute to the perception of past landscapes.

9.2.4 Multiple surface analysis

Multiple surface tools are hard to define since they may be applied in a wide variety of ways. The three broad themes that were analysed may be termed cumulative viewshed analysis, cost surface analysis and environmental modelling. Cumulative viewshed analysis, as first used by Wheately (1995), was found to be useful especially with the lower resolution Rudston landscape where the contour data covered a large enough area with a sufficient number of contemporary archaeological monuments. The results from this were similar to those of Lock and Harris (1996) indicating territories and landscape divisions where overlap between viewsheds was limited, although it would be useful to expand the study to a wider area with a greater number of monuments.

Cost surface analysis is a complex discipline in itself, as demonstrated by recent work (e.g. Bell and Lock forthcoming, De Silva and Pizziolo forthcoming), due to the question of whether social or physical factors should be included within a cost surface. In terms of physical factors the effects of the relationships between angle of travel and slope are not fully understood. Despite this, a very simple cost surface analysis was applied to the lower resolution Rudston landscape. Even at a very basic level it formed an interesting basis for comparing economic routes (i.e. effort) of the cursuses with their actual route, reinforcing conclusions made from visual analyses of the site.

Environmental modelling is a vague term relating to multiple surface analysis. A number of approaches identified how multiple surfaces, both those derived from the DEM and

from other sources, could be used to highlight states of preservation. The effect and rate of erosion were explored at Rudston through the comparison of the recent survey with an earlier contour survey within the GIS environment. At Sutton Common, the likelihood for the long-term *in situ* preservation of buried organic materials were investigated through comparison with previous surveys and the modelling of the water table in relation to the land-surface DEM. The results from these analyses were also found to be applicable to both areas of landscape interpretation and CRM (see below).

In summary, multiple surface analysis is where cell-based GIS is most useful and this is reflected by the results of the present study. The tools available mean that multiple surface analysis provides huge potential to pursue archaeological questions.

9.3 GIS and its applications within landscape archaeology

The usefulness of GIS for landscape archaeology could only be assessed within the context of archaeological themes by which levels of success could be understood. Two broad themes within archaeology may be identified. These are landscape interpretation, aimed at understanding the roles of the various monuments and their function within the landscape, and cultural resource management (CRM), aimed at understanding the resource itself, recognising threats to it and reacting against them.

9.3.1 GIS and landscape interpretation

The value of applying GIS tools to landscape interpretation has been demonstrated and it has been shown that the value of different GIS tools is relative to the accuracy of the different surfaces.

a. The role of visibility analysis

Visibility analysis remains as important to the interpretation of archaeological landscapes as in studies that do not use GIS. This technique was shown to be useful within both the Rudston and Sutton Common landscapes, although the applicability of the technique was found to be of greater use where sufficient surface input-data existed. Palaeoenvironmental factors were not modelled in relation to their effect on the visibility from monuments except for very generally at the lower resolution Sutton Common landscape, although the evidence from work in this area could be applied to interpretations. Visibility analyses were found to be of some use in understanding the physical spatial relationships of monuments, their function and their chronology.

b. Hydrological analysis and palaeoenvironmental reconstruction

Although not universally applicable, it was shown how, in areas of marginal ground water, modelling and exaggerating the water table can be useful in providing an approximate reconstruction (within a limited framework) for understanding the positioning of monuments within the landscape. Despite difficulties observed in previous GIS studies in attempting to reconstruct the palaeoenvironment (*cf.* Fisher *et al.* 1997, Spikins 2000), this study has demonstrated that, to a certain degree, the reconstruction of palaeoenvironmental elements of higher resolution landscapes is possible.

c. Narrative approaches to interpreting landscapes

GIS has been accused of being normative and environmentally deterministic as a tool for interpretation and this concern has been approached by the genesis of new GIS approaches (Llobera 1996, forthcoming a & b, Raczkowski *et al.* forthcoming, Tschan forthcoming). This work has attempted to develop approaches in a theoretical way. Within this thesis more traditional humanistic methods of landscape interpretation borrowed from anthropology and human geography have been applied to abstract surfaces. It has been shown that the creation of multiple narratives based upon abstract surfaces such as those showing slope and aspect, used alongside more traditional methods such as viewshed analyses, can provide a deeper understanding of movement through the landscape. This has implications for understanding past perception and cognition at a more comprehensive level than may be obtained through calculations alone. This study has shown that GIS allows the various layers of landscape perception to be segmented and viewed separately to create multiple narratives that, together, may assist in the interpretation of the landscape. The narrative approach allows for greater freedom and therefore potential, as has been highlighted by Llobera (forthcoming: b) who suggested that descriptions may serve the archaeologists more appropriately than 'results' when dealing with 'humanistic' aims. This issue would need further research in order to provide answers to the questions of robusticity of the data.

9.3.2 GIS and cultural resource management

Traditional uses of GIS for CRM have revolved particularly around database management and display and as such are being used increasingly within the planning process. On a statistical level, CRM has been attempted through the modelling of predicted site locations as part of a mitigation procedure, although the main developments within this sphere of activity have occurred outside of British archaeology (e.g. van Leusen 1996). Such approaches have not been explored within this thesis (see

chapter 1). However, a number of conclusions relating to other areas of CRM have been made during the present study.

a. High-resolution sites and multiple surface analyses

The greatest advantages for issues of CRM of the tools applied within this study have been in relation to the higher resolution survey areas of the Rudston and the Sutton Common landscapes. In each case the tools with the most direct value were those used in the multiple surface analyses and particularly through their integration with other surfaces to provide information regarding erosion and the potential for *in situ* preservation for the Sutton Common and Rudston landscapes respectively. These two themes were related directly to the threats to the archaeological resources in each case; arable landuse on thin soils on slopes and the de-watering of a wetland environment with the intrinsic effects on both the buried organic archaeological resource and palaeoenvironmental source material.

b. High-resolution sites and surface representation tools

This study has demonstrated that in each case the modelled GPS survey data has provided indications into the preservation of the archaeology on site. At Rudston this was relatively straight forward as the extent of earthwork preservation within the flat arable landscape could be measured. At Sutton Common, however, the dynamic sub-surface hydrological environment was found to be affecting the surface, providing an indication of the preservation of the buried resource through irreversible peat shrinkage. This was highlighted in both cases by the surface representation techniques.

The modelling of other surfaces in a more comprehensive way was only investigated with the lowland landscape of Sutton Common, where the fluctuating ground water, as well as the topographic surface, was modelled. Whilst this was intended to be ancillary to an understanding of the preservation of the burial environment, mentioned above, it also highlighted other intriguing factors about the shape and apparent capiliarity of the ground water and its interaction with the surface. This modelled areas of surface water, along with those that could expect surface water given a programme of re-wetting. This had the added advantage of providing an indication of the types of vegetation that could be expected across the site, thereby affecting the burial environment, such as the depth of *phragmites* roots and the potential damage to the buried archaeology (Coles 1995).

The results of the present study have demonstrated further ways in which to apply GIS to CRM requirements rather than following the themes already explored elsewhere. They have demonstrated the potential of GIS to incorporate wider sources of data in order to answer specific question regarding the site.

9.3.3 Landscape interpretation, CRM and data compatability

Two further themes exist within the literature on archaeological GIS that have not as yet been discussed in this thesis, but which are of reflective interest at this point. The first of these relates to the role of archives that serve to preserve archaeological data for its eventual re-use. It has been highlighted that digital storage provides exceptional opportunities for the re-use of data (Richards 1997). This is contradicted by the second (constructivist) theme that suggests that data are always collected in order to satisfy a particular requirement and that it is therefore not universally re-useable. These two apparently contradictory themes highlight the question of the extent to which spatial databases are comparable and re-useable when collected for either interpretation or for original CRM purposes. Evidence from the present study has demonstrated the possibility for the re-use of digital data for both of the landscape archaeological themes of CRM and landscape interpretation. This was seen in two main instances.

Firstly, the generation of DEMs was approached in order to provide the most accurate model in relation to the assessment standards outlined in chapter 3. These requirements were not set in relation to either CRM or landscape interpretation since this would have provided a deterministic, and therefore biased, influence within the subsequent analyses. Rather, it was found that the most accurate surface, insofar as it could be measured, should be created before all further analyses. This demonstrated that once such a DEM had been created it could be used for both types of application.

Secondly, this study found that data collected for a single purpose could be applied to a secondary and quite different function. The ground water data was collected at Sutton Common purely for CRM purposes, but was useful in the 'reconstruction' and interpretation of that landscape. This contradicts the constructivist view that data collection is determined by its purpose and that it is therefore inapplicable to other uses.

This suggests that the polarisation of data collection is perhaps an unrealistic generalisation. It also highlights the need for a programme of work exploring the compatibility of datasets to assess their 'value'.

9.4 Overview

9.4.1 Reflection on aims

In chapter 1, and reiterated at the beginning of this chapter, four limitations of previous research were mentioned. Following the work presented in this thesis a series of main conclusions have been made.

a. Topographic variability

The limitation of previous research to concern itself with areas displaying greater topographic variability was approached through the inclusion of a flatter lowland landscape within the study. Within the lower resolution model the Sutton Common landscape displayed a number of problems and limitations, based mostly around the low resolution of the available data, with contours set at intervals of 10 m. It was noted that, even with the best resolution Ordnance Survey data, provided at 5 m vertical intervals between contours, this problem could not have been overcome with much of this landscape lying beneath 5 m OD.

The higher resolution approach to the Sutton Common landscape showed, however, that positive results might be obtainable from flatter lowlands if a significantly higher resolution dataset is obtained. It seems therefore that either a higher resolution survey is required or else a much lower resolution approach to the landscape is needed. This restricts the capabilities of many GIS approaches for flatter landscapes.

These observations complement previous research that has tended to concentrate on areas that display greater topographic variability for similar research (e.g. van Leusen 1993), but raise the issue of using higher resolution input-data. This may provide a foundation for the use of airborne laser mapping as a method of rapid survey as it can provide a vertical surface accuracy of 0.25 m, sufficient for the generation of meaningful lowland topographic DEMs. Other methods include the use of high resolution topographic modelling from photogrammetric paired photographs as has been used on lowlands in France (Roughley forthcoming).

b. Comparative research

The recognised need for research to be comparative was approached in two main ways - through the comparison of topographically variable and flatter archaeological landscapes and through the comparison of high and low resolution raw data within cell-based GIS models. This was considered important in order to assess the value of each for GIS

research and the value of different GIS tools within each scenario. It was considered that value may only be understood relatively and so it was important to provide comparisons.

The comparative approach has shown some of the limitations and values of each of the landscapes relative to one another at all levels from surface interpolation to the applicability of the various tools in relation to landscape interpretation and CRM. In terms of lower resolution datasets, the main results from this approach showed that the Rudston landscape was fundamentally more useful for all analyses than the flatter Sutton Common landscape. This was on the basis of the use of higher density data due to the greater topographic variability and hence the greater number of contours. From the generation of a surface to its analysis the Rudston DEM was found to be favourable. Further it was noted that, for a lower resolution flatter landscape such as Sutton Common to be of use archaeologically, it could only be understood in a much wider landscape context. This could be done through studying a much larger area and consequently changing the types of questions that may be asked of it. It appears that a finite amount of data is required for a DEM to be meaningful.

In terms of comparative resolution, it was noted that the lower resolution landscapes were generally more useful for interpretative approaches, whilst the higher resolution surfaces produced results that reflected CRM issues more closely. However, this was partially due to the exclusion of predictive modelling techniques of site location from the study (see chapter 1) and the choice of areas for higher resolution survey on the basis of previous surveys.

The differences between types of landscape and data collection reinforce the need for an assessment of the validity of tools. This study has approached these themes, though there is a continued need to assess GIS tools in relation to archaeological situations. It also demonstrates the need for researchers using GIS to document their processes (in order to create metadata) as outlined by Gillings and Wise (1999).

c. Resolution

Resolution was investigated in a number of ways within the study. Firstly, the value of using vastly contrasting density input data was explored (mentioned above in issue 2). Secondly, the interpolation of this data to created DEMs at different resolutions was investigated in relation to the various interpolation techniques. This work has shown that variable density input data provide a more limited range of appropriate interpolation

techniques that may be used. This expands upon Fletcher and Spicer's (1988) work by adding the dimension of variable interpolation techniques.

One of the issues mentioned in chapter 1 relating to resolution was the difference in focus between traditional and digital survey. The former has normally been approached in relation to the scale at which the final mapping is required. This is in contrast to digital approaches that may be less clearly defined. The contrasting resolutions used within this project highlighted the different types of information that was obtainable from modelling at the different resolutions. Although the two types of resolution were extremely contrasted, being high and low, the evidence suggests that the resolution of the data capture and the DEM, along with the size of survey area, will have a direct influence on the types of information that may be gained. This provides a difficult situation for representing archaeological features that have been shown to be most accurately represented by a variable density survey (see chapter 3, *cf.* Fletcher and Spicer 1988). While a DEM resulting from a highly accurate survey may be re-sampled and generalised to a lower resolution DEM, it cannot be made more accurate. In principle, this again highlights the dangers of storing data without accompanying information, or metadata, describing it and the need for its inclusion.

A significant issue relating to resolution was the interpolation of raw data collected at a variable density into a continuous surface, assuming the need to interpolate to the highest resolution of the data. This study highlighted the most appropriate processes of interpolation in each case, but it showed that for some landscapes, such as the low-resolution lowland landscape, it was not possible to produce a meaningful surface when studying an area of only 10 x 10 km. It was observed that the resolution of the DEM was related to that of the input data and that in cases where the available data is of insufficient density it is only possible to study the landscape at a broader scale. Again, this has implications for the types of information that may be gained.

d. Archaeology as surface

This study has approached landscapes at two resolutions in order to explore the contrasting concepts of archaeology as a draped outline or distribution over a DEM and of archaeology represented by the DEM itself. The higher resolution surveys demonstrated the nature of features on the ground as they were at the time of survey, as well as providing an indication of their original dimensions. Further detail was obtained from assessing archaeology as a surface with implications for both CRM and landscape

interpretation. With the Sutton Common landscape in particular, the high resolution surface revealed intricate relationships with the topography, that could not have been understood from the lower resolution data, which had wide reaching implications in terms of the interpretation of the site and its future management.

The results from this part of the analysis demonstrate the value of investigating sites at different resolutions and thereby provide overlaps with the issue of resolution (issue 3) mentioned above highlighting the benefits that may be gained from higher resolution investigations using GIS. However, although file size is becoming less of an issue, due to ever faster processors and cheaper data storage, it is important to understand what the requirements and expectations are of using the DEM. Increasingly higher resolutions will not bring a paralleled increase in information from their analysis. This point is emphasised by the survey of the terminus of the cursus that was conducted while the field was blocky owing to recent ploughing. This was visible on the DEM as uneven ground, but a higher resolution investigation would have brought very little to the overall understanding of the site.

9.4.2 Comments on approach

It has been argued on more than one occasion that GIS tools have the potential of being technologically deterministic, whereby they are merely transferred into an archaeological context rather than being used to test theories or to follow archaeological data themes (*cf.* Gaffney *et al.* 1996, Harris and Lock 1996). The method presented here is introspective, analysing the applicability of the GIS techniques to contrasting landscapes. As such the methodological structure was technologically determined. For the first three stages of the analysis (DEM generation, representation and surface analysis) study was structured around the application of a technique to different sets of data and the results were obtained for comparative study between differing resolutions and landscape types. The fourth stage (multiple analyses) was different. At this point technological determinism was inverted so that the results from the first three could be analysed together in a theory-driven way, in an attempt to answer those questions regarding each landscape outlined in chapter 2 but not necessarily answered by the preceding three analyses.

The approach used may be justified in four ways. Firstly, the criticisms of technological determinism may arguably be destructive. As for environmental determinism, technological determinism is only damaging when one is not mindful of it (e.g. Gaffney and van Leusen 1995). While the criticisms are well justified (*cf.* Llobera 1996), a

neglect of such approaches may result in possible applications never being attempted or understood, such as the application to flatter, lowland landscapes. Therefore an approach structured around techniques may be helpful. Secondly, any theoretical approach requires a fundamental structure. The broad range of literature regarding the potential for errors at the data collection, GIS algorithmic and human interpretation levels suggests that a more introspective analysis of the various stages of analysis is important. By clinically examining the results from the application of different GIS approaches, the techniques themselves may be understood more clearly. This in turn makes the more complex levels of analyses, driven by theory, more robust and useful. Thirdly, through an assessment of GIS techniques within a comparative framework, the applicability of different techniques to different situations may also be better understood. For example, previously it was suggested that topographically variable landscapes were more apt for archaeological research using a cell-based GIS (*cf.* van Leusen 1993). The present study has demonstrated that this need not be the case and that valuable results can be obtained by using GIS to assist in the analysis of flatter landscapes. Finally, as noted by Gillings and Goodrick (1996), GIS is increasingly becoming an arena to think and explore so, following this inspiration, the application of a full suite of tools to a landscape may be considered useful.

A further philosophical conclusion relating to method can also be made within the sphere of archaeology. A simplification of method can split most approaches into two polarised paradigms. Firstly, positivist approaches test hypotheses through applying a specific method to draw conclusions. Secondly, hermeneutic approaches investigate using narrative methods in order to draw conclusions. GIS approaches have used both. The need to provide testable and repeatable models has been noted (Bell 1994), and Fisher *et al.* (1997) demonstrated a positivist method aimed at testing a hermeneutic theory (*cf.* Tilley 1994). As mentioned above, it has been noted that the development of GIS was becoming a 'place to think ...' (Gillings and Goodrick 1996). The present study has provided a positivist structure based around testing the applicability of GIS tools to a variety of archaeological scenarios. These scenarios are widened by the varying paradigms that are currently followed, particularly with regards to landscape interpretation. This study has shown that GIS provides a space where the various paradigms may be brought together. The GIS tools provide an eminently repeatable framework, with structures from its positivist framework. However, this provides a foundation for seeing/perceiving elements of the landscape that is impossible on the ground but which can be understood through heuristic and narrative means. Some

elements, particularly of landscape interpretation, have been shown to be unquantifiable. These elements are best approached using other methods based upon phenomenology and experience. By abstracting landscapes, GIS provides a framework within which measuring these elements become feasible.

So, to what extent do the results from this research apply to other archaeological landscapes? A limitation of the approach used is that each chosen landscape was centred upon a 'significant' and enigmatic (in terms of location and interpretation) archaeological site in order to limit variables for a clearer comparison. Variability within the archaeological record, and the variability of sites within such contrasting environments, means that from the archaeological perspective, the approach was not and could not have been truly comparative - the archaeological 'constant' was unachievable. Against this backdrop the applicability of the results to other landscapes may appear to be limited. However, the themes that this work has demonstrated and outlined above suggest a wider usefulness of the results. The thesis has provided some direct results into each of the levels of GIS application, from surface generation to complex analyses, and has highlighted the overall potentials and limitations of each in relation to archaeological themes. From a specific level the results are directly applicable to other archaeological landscape analyses using GIS. From a more general point of view, a number of fundamental results have been made that may have wider implications than on GIS alone. In particular, themes including the re-use of data for different archaeological requirements, the use of 'digital narratives' in landscape interpretation with the combination of quantifiable and theoretical approaches and the use of multiple cell-based surfaces from different sources for approaching archaeological problems may be significant to other projects.

9.4.3 Legacy

Elements of this work have been presented at various conferences including *Archaeological Sciences 1999* in Bristol (Chapman forthcoming: a), at *Beyond the map* in Ravello, Italy (Chapman forthcoming: b), and at *WARP in Florida* (Wetland Archaeological Research Project annual conference) in Florida, USA (Van de Noort *et al.* forthcoming). The prospection results have been published briefly (Chapman 1999b) and more comprehensively (Chapman and Van de Noort forthcoming). As a direct consequence of the work presented here further research has been developed following the same themes, in relation to data accuracy and re-use (Chapman forthcoming: c), and in its application to other period landscapes and environmental change (Lillie and

Chapman forthcoming). Criticisms of unquantified landscape theory, a theme that has developed from this work, have also been published (Chapman and Gearey 2000).

The results of the work presented here have been integrated into a number of other projects and have acted as a basis for further work and management, particularly in relation to the higher resolution approaches. Firstly, the surface model of Sutton Common identified some of the potential for the survival of preserved organic layers and also the threats to them. This highlighted the need for an intrusive assessment of deposits, which was conducted using the GIS model as a basis for all work (Van de Noort and Chapman 1999, 2000).

Secondly, the GIS approach for modelling the water table has demonstrated the dynamics within an archaeological wetland landscape (Van de Noort and Chapman 1999). It has been used as a basis for a programme of re-wetting of the site at Sutton Common in order to preserve those deposits that may be stable *in situ*. It is planned that for those areas that cannot be successfully preserved *in situ*, as defined by the GIS model and assessment trenches, a programme of extensive excavation will be undertaken. This study has also formed the foundation of a PhD studentship investigating the fluctuation of the water table in relation to the preservation potential of burial environments and the effect of re-wetting.

Thirdly, the method of GPS survey/GIS modelling has become a standard prospection and recording method for the Centre for Wetland Archaeology (now the Wetland Archaeology and Environments Research Centre) at the University of Hull. The process has been applied on many other sites in a range of environmental contexts (Chapman 1998b, Chapman and Van de Noort 2000, Hamza *et al.* 2000, Thomas and Chapman 1999).

9.5 Recommendations for future work

9.5.1 Work within the study area

Within the Rudston landscape the results from the study have augmented the interpretation of the archaeological landscape and have provided some indication of the state of preservation and possible threats to one of the monuments. Expansion of this research could be through obtaining higher resolution surface data for the landscape. This would provide a useful record of the state of preservation of the ploughed monuments and would also provide a clearer basis for interpretative approaches. A basis

for such data may be through extensive survey (e.g. Newman 1997) or through remotely sensed topographical data.

At Sutton Common, studies of the wider landscape may only be possible with higher resolution input-data. The GIS approach to the current study area has had a number of implications for the site. Firstly, the GIS data have suggested that wet-preservation of deposits across the site is present but degrading (since confirmed by excavation - Van de Noort and Chapman 1999). Further, the integration of the water table indicates that this preservation is variable and that, in some areas, long-term *in situ* preservation will not be possible (also confirmed by excavation - Van de Noort and Chapman 1999, 2000). A combined programme of re-wetting to preserve those areas that may be sustained *in situ*, as well as excavation of those areas that cannot, has been recommended on the basis of this work (Van de Noort and Chapman 2000). For interpretative purposes, developments following excavation and analysis should be incorporated into the GIS model. This would provide a foundation of high-resolution data that may be used to develop ecological and further archaeological models for the site.

9.5.2 The wider context

The wider implications of the research presented here extend into several areas of GIS research within archaeology. These may be considered in terms of both how the results from this study have added to previous research and the ways in which this forms the foundations for recommendations for future research. This may be further divided into considerations of methods and their application within landscape archaeology.

a. Methods

Firstly, this study has added an archaeological framework to DEM interpolation. Primarily, the anomalous nature of anthropogenic activity means that the study of geographical structures (e.g. Haigh 1993, Carrara *et al.* 1997) may be insufficient. This work expands on that by Spicer and Fletcher (1988) by applying their conclusions to real, rather than simulated, examples. Further it reinforces Kvamme's (1990) conclusions that identified the need to examine the potential for error within any DEM prior to its being used for further analysis. Continued research is needed within this area of study particularly in relation to the resolution of input-data compared with that of the DEM, and the different values of different types of data storage. Fundamentally, the subjectivity of surveys creating variably-spaced point data needs to be addressed further.

Secondly, this study has demonstrated that various representations of a DEM generated from survey data hold the potential for understanding archaeological landscapes even prior to any further analysis being conducted. It has been shown that different types of representation are more appropriate for different types of landscape (e.g. a variety of topographic variability) and resolutions. It is understood that survey plans present a different, and perhaps more holistic, understanding of spatial relationships of monuments within a landscape than is possible on the ground (Bowden 1999). This study has additionally shown that high-resolution surveys of archaeological sites and landscapes present the potential for finding features that are not visible, and therefore not measurable, on the ground. It would be useful to explore this result particularly due to poor correlation often seen between transcribed aerial photographic plots and what is on the ground. By examining some of the dynamics of the inter-relation between different sediment types (such minerogenic/organic), coupled with a systematic approach to applying different representation methods to the DEM, it may be possible to provide a useful layer of accurately located surface excavation. This has the added advantage of being able to produce contour surveys.

Thirdly, this study has shown that simple analytical approaches to DEMs can provide information relating to the understanding of archaeological landscapes. Previously, the primary analytical tool that has been used in isolation had been visibility analysis. Developments from this have moved towards multiple surface approaches for interpretation of landscapes, for example through the creation of gradient viewsheds, providing an abstract perception surface based upon the inversely weighted relationship between visibility and distance (Llobera 1996). Whilst concentrating upon single methods of approaching archaeological landscapes, the present study has provided an alternative approach. Through the use of the single techniques of slope, aspect and visibility, it is possible to reconstruct narratives of landscape, following the traditional anthropological approaches to the subject of understanding landscape (*cf.* Tilley 1994). Effectively, this also creates perception surfaces by exploiting certain elements of landscape, each in isolation, and providing a platform for the integration of multiple narratives. Perhaps the desire to use GIS for perceptually based approaches could be developed through further application of the techniques used within the social sciences.

Fourthly, this thesis has highlighted the re-useability of both input-data and GIS techniques for apparently contrasting functions; for example landscape interpretation and CRM. Such re-use has been demonstrated particularly with the modelling of ground-

water at Sutton Common where the same dataset has been used for both assessing and understanding the potential for *in situ* preservation on the site and also for the reconstruction of the palaeoenvironment in order to assist in its interpretation. This, like the use of different surface representation tools mentioned above, highlights the need to use a range of GIS approaches to sites rather than just those that may seem directly applicable.

Finally, and continuing from the previous point, the present study has begun to address the current problem of understanding ecology within archaeological GIS (*cf.* Gillings and Wise 1999: 8). There is something of a consensus that high-resolution palaeobotanical data are difficult to incorporate within GIS studies (Fisher *et al.* 1997: 587, Spikins 2000). However, other factors have been modelled, such as ground water, which has a partially deterministic effect upon vegetation. A site-specific understanding of the palaeoenvironment could be built up by incorporating global palaeobotanical data.

b. GIS and landscape archaeology

Landscape archaeology may be divided into the two areas of landscape interpretation and CRM. In terms of landscape interpretation, current concerns within GIS research focus upon the incorporation of meaning following concurrent trends within landscape archaeology (e.g. Tilley 1994). Current studies have attempted to either formalise perception through abstract modelling (e.g. Llobera 1996, forthcoming a & b) or to develop phenomenological approaches (e.g. Gillings and Goodrick 1996, *cf.* Gillings and Wise 1999). The present study has highlighted the importance of previous approaches that have been used towards achieving landscape interpretation, such as visibility analysis, but have expanded upon this research, demonstrating that such analyses are not limited to topographically variable landscapes and that they can also be applied to smaller areas on a site specific level. This study has also expanded upon previous approaches demonstrating that further interpretation of landscape is possible through a narrative approach (*cf.* Tilley 1994) to multiple DEMs so that multiple layers of interpretation from single elements of the landscape (e.g. visibility or slope) may be examined separately. It has been shown that such a process, although less elegant than procedural methods, can build up complementary sets of data adding depth to understanding. Also, previous approaches aimed at interpretation have been developed by the inclusion of modern environmental data (e.g. ground water) within databases that has been shown to have the potential to 'reconstruct' parts of the palaeo-landscape and therefore to assist in its interpretation.

In terms of CRM, a result of this research is in the identification of sites that cannot be seen on the ground. This has implications for archaeological prospection, depending upon relative shrinkage of sediments within particular environmental conditions. The relationship between the approach illustrated, that makes use of high-resolution survey data, and aerial photography is shown by the accuracy on the ground of identified features. On a number of occasions it has been demonstrated that aerial photographic transcriptions can contain errors resulting in identified features not being recognised on the ground (e.g. Atkinson 1993). By maintaining a local grid from which such high resolution survey may be referenced, and through maintaining a GIS database, it will be possible to locate features on the ground (see above).

Secondly, the present study has demonstrated how GIS may be used as a technique for assessing the state of preservation of archaeological features. This has included both the physical state of the surface (erosion) and has hinted at the state of preservation of the buried resource through the application of different surface representation techniques.

Finally, this approach has demonstrated how the database may be extended and combined with other data in order to provide a predictive model of the potential for long term *in situ* preservation. This has been of primary use for wet-preserved sites, although the nature of erosion and likely colluviation has also been shown.

Overall, this thesis has assessed GIS methods and their applications within landscape archaeology, investigating some of the current approaches and expanding upon them within a comparative framework. The focus of GIS within landscape archaeology has expanded from managerial functions into the realm of interpretative theory. It has become a heuristic tool whereby alternative models may be explored. It is recommended that such heuristic approaches include a wider range of GIS methods than are currently being used. A further development that this study has deemed necessary concerns the capture of digital topographic data. This is particularly important for the interpretation and subsequent preservation of archaeology within less topographically variable landscapes where higher resolution data capture is necessary.

This thesis has provided an assessment of cell-based GIS methods and has recommended ways in which their applications may be enhanced for the benefit of landscape archaeology.

Part 5
Appendices & references

Appendix 1

Glossary of terms, abbreviations and acronyms

Alnus	Alder.
AML	ARC/INFO Macro Language. A programming language employed by ARC/INFO.
ARC/INFO	GIS system created by ESRI (Environmental Systems Research Institute).
ASCII	American Standard Code for Information Interchange.
Attribute table	A table associated with a vector file (point, line or polygon) that contains data about it to provide an associated database.
Betula	Birch.
Breakline	Line added prior to surface generation to indicate areas where interpolation should not pass, such as cliffs or lakes.
CAD	Computer Aided Design.
Cell	The basic element within a grid data set. Cells are always square and are located by Cartesian co-ordinates. Each cell contains an attribute, or *z* value that may, for example, refer to height.
Corylus	Hazel.
DEM	Digital Elevation Model. Within a grid data set this represents a 2.5 D surface with continuous x and y values forming cells of a given size (resolution), each with a z-value (or elevation value).
DXF	Data Exchange Format. A format for storing vector data, used by AutoCAD and other CAD packages.
ESRI	Environmental Systems Research Institute. The manufacturers of ARC/INFO.
Fraxinus	Ash.
Georeference	Georeferencing is the process whereby a dataset is spatially referenced.
GIS	Geographical Information System/Science.
GLONASS	Russian satellite positioning system similar to GPS.
GPS	Global Positioning System. The name of the American satellite positioning system.
Grid	Type of raster-based spatial data structure consisting of two-dimensional cells each with a value forming the vertical plane. May be used as DEMs and for spatial calculations.
IDW	Inverse Distance Weighting. DEM interpolation technique that uses distance from input data points as an indicator of their significance when interpolating values for cells between them.

Kriging	DEM interpolation technique that expands inverse distance weighting (IDW) to include other influential factors in addition to distance when calculating cell values.
Lattice	A surface representation that uses regularly-spaced points as a sample of the surface. In ARC/INFO these are stored as grids.
Metadata	Data concerning the documentation of data quality and components – essentially, data about data. The Dublin Core provides a standard format for the creation of metadata.
Pinus	Pine.
Plantago lanceolata	Ribwort plantain.
Point	A two-dimensional single co-ordinate position.
Polygon	A multi-sided figure that corresponds to an area made up of arcs. Polygons have attribute tables that provide information relating to topological relationships.
Quercus	Oak.
Raster	A cell-based representation that may be used for images and DEMs.
Resolution	The accuracy of a map. Used in relation to GIS grid data structures with reference to the size of each cell (i.e. the area of space represented by it).
Salix	Willow.
Spline	DEM interpolation technique that creates a 2.5 D surface that runs through each input-data point.
Tilia	Lime.
TIN	Triangulated Irregular Network. A vector-based GIS surface calculated by joining all data points or contour nodes to form a network of triangles with nodal values. A TIN may be used to generate a DEM or may be used as a surface in its own right.
TOPOGRID	DEM interpolation method for generating 2.5 D surfaces from contour data, available in ARC/INFO.
Topology	The spatial relationships between features (points, lines, nodes or polygons).
Ulmus	Elm
Vector	Co-ordinate-based data structure used to represent linear features in contrast to grid data structures.

Appendix 2

Data from the GPS survey at Sutton Common[1]

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[1] Format: point no., eastings, northings, height OD

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5297, 456699.6, 412171.42, 3.98
5298, 456702.36, 412149.35, 4.37
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5301, 456331.3, 412342.46, 3.67
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5303, 456179.57, 412305.22, 3.57
5304, 456237.5, 412312.12, 3.6
5305, 456316.13, 412316.26, 3.72
5306, 456394.75, 412321.77, 4.06

Appendix 3

Data from the GPS survey at Rudston[1]

1, 509994.556, 465779.755, 49.861
2, 510027.811, 465768.253, 49.014
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4, 510021.961, 465760.812, 48.917
5, 510018.259, 465759.974, 48.968
6, 510014.355, 465759.04, 49.062
7, 510010.692, 465757.91, 49.183
8, 510006.757, 465757.001, 49.272
9, 510002.935, 465756.115, 49.349
10, 509999.311, 465755.044, 49.388
11, 509995.26, 465753.743, 49.616
12, 509991.755, 465752.711, 49.753
13, 509986.685, 465751.278, 49.993
14, 509982.468, 465749.897, 50.295
15, 509978.364, 465748.632, 50.511
16, 509974.103, 465747.415, 50.685
17, 509969.895, 465746.163, 50.712
18, 509965.446, 465744.847, 50.868
19, 509961.272, 465743.66, 50.927
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22, 509947.062, 465739.993, 51.177
23, 509942.654, 465739.161, 51.159
24, 509937.865, 465738.226, 51.307
25, 509932.903, 465736.691, 51.354
26, 509931.502, 465740.837, 51.383
27, 509936.589, 465742.118, 51.245
28, 509941.649, 465743.586, 51.083
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32, 509959.406, 465748.252, 50.829
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[1] Format: point no., eastings, northings, height above OD

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772, 509960.298, 465852.715, 48.101

Appendix 4

Water table data from Sutton Common[1]

28 September 1998		
X	Y	Height OD
456177.1	412059.5	2.46
456211.8	412023.6	2.56
456247.1	411987.7	2.61
456279.5	411950.6	2.12
456316.3	411984.4	2.01
456283.0	412020.5	2.67
456213.6	412093.2	2.37
456250.3	412127.2	2.48
456318.6	412054.4	2.63
456352.7	412017.8	2.59
456387.0	411981.4	3.01
456423.0	412015.4	3.25
456389.2	412051.7	3.22
456355.2	412088.3	2.47
456321.1	412124.7	2.81
456286.9	412161.1	2.61
456324.0	412195.7	2.42
456357.7	412158.9	2.30
456391.6	412122.0	2.62
456425.8	412085.5	3.61
456459.8	412048.9	3.41
456494.0	412012.2	2.47
456531.6	412046.6	2.53
456497.5	412083.1	3.59
456463.0	412119.8	3.64
456394.4	412192.8	2.86
456432.4	412226.9	2.63
456466.2	412190.1	3.14
456500.2	412153.5	3.37
456534.3	412116.8	3.26
456568.3	412080.4	2.64
456605.5	412113.8	2.74
456571.2	412150.5	3.00
456537.1	412187.0	3.06
456502.9	412223.3	2.94
456539.7	412256.8	2.70
456574.1	412220.6	2.73
456608.4	412184.4	2.41
456642.8	412148.2	2.48
456679.6	412182.0	1.82
456645.4	412217.9	2.13
456611.1	412254.0	1.85
456576.7	412290.2	2.04
456613.7	412323.8	1.39
456648.1	412287.6	1.72
456682.3	412251.5	1.57
456716.5	412215.7	1.96

5 October 1998		
X	Y	Height OD
456177.1	412059.5	2.43
456211.8	412023.6	2.57
456247.1	411987.7	2.62
456279.5	411950.6	2.25
456316.3	411984.4	2.21
456283.0	412020.5	2.68
456213.6	412093.2	2.46
456250.3	412127.2	2.51
456318.6	412054.4	2.55
456352.7	412017.8	2.65
456387.0	411981.4	2.98
456423.0	412015.4	3.23
456389.2	412051.7	3.23
456355.2	412088.3	2.49
456321.1	412124.7	2.99
456286.9	412161.1	2.63
456324.0	412195.7	2.48
456357.7	412158.9	2.44
456391.6	412122.0	2.75
456425.8	412085.5	3.58
456459.8	412048.9	3.40
456494.0	412012.2	2.52
456531.6	412046.6	2.56
456497.5	412083.1	3.61
456463.0	412119.8	3.61
456394.4	412192.8	2.84
456432.4	412226.9	2.65
456466.2	412190.1	3.14
456500.2	412153.5	3.43
456534.3	412116.8	3.25
456568.3	412080.4	2.69
456605.5	412113.8	2.75
456571.2	412150.5	3.00
456537.1	412187.0	3.06
456502.9	412223.3	2.93
456539.7	412256.8	2.72
456574.1	412220.6	2.76
456608.4	412184.4	2.33
456642.8	412148.2	2.51
456679.6	412182.0	2.16
456645.4	412217.9	2.29
456611.1	412254.0	2.16
456576.7	412290.2	2.52
456613.7	412323.8	2.40
456648.1	412287.6	2.43
456682.3	412251.5	2.41
456716.5	412215.7	2.46

[1] Normally readings were taken of all fifty of the piezometers. Where fewer readings have been taken, this is the result of water table not being encountered.

12 October 1998

X	Y	Height OD
456177.1	412059.5	2.48
456211.8	412023.6	2.55
456247.1	411987.7	2.61
456279.5	411950.6	2.34
456316.3	411984.4	2.33
456283.0	412020.5	2.67
456213.6	412093.2	2.51
456250.3	412127.2	2.53
456318.6	412054.4	2.54
456352.7	412017.8	2.68
456387.0	411981.4	2.95
456423.0	412015.4	3.21
456389.2	412051.7	3.13
456355.2	412088.3	2.50
456321.1	412124.7	2.77
456286.9	412161.1	2.64
456324.0	412195.7	2.47
456357.7	412158.9	2.52
456391.6	412122.0	2.85
456425.8	412085.5	3.56
456459.8	412048.9	3.37
456494.0	412012.2	2.47
456531.6	412046.6	2.52
456497.5	412083.1	3.55
456463.0	412119.8	3.59
456394.4	412192.8	2.83
456432.4	412226.9	2.68
456466.2	412190.1	3.11
456500.2	412153.5	3.40
456534.3	412116.8	3.17
456568.3	412080.4	2.66
456605.5	412113.8	2.73
456571.2	412150.5	2.98
456537.1	412187.0	3.04
456502.9	412223.3	2.91
456539.7	412256.8	2.71
456574.1	412220.6	2.74
456608.4	412184.4	2.46
456642.8	412148.2	2.57
456679.6	412182.0	2.32
456645.4	412217.9	2.41
456611.1	412254.0	2.34
456576.7	412290.2	2.54
456613.7	412323.8	2.48
456648.1	412287.6	2.47
456682.3	412251.5	2.45
456716.5	412215.7	2.47

2 November 1998

X	Y	Height OD
456177.1	412059.5	3.25
456211.8	412023.6	3.48
456247.1	411987.7	3.30
456279.5	411950.6	2.78
456316.3	411984.4	2.77
456283.0	412020.5	3.15
456248.1	412056.8	3.19
456213.6	412093.2	2.97
456250.3	412127.2	2.90
456318.6	412054.4	2.95
456352.7	412017.8	3.12
456387.0	411981.4	3.81
456423.0	412015.4	3.83
456389.2	412051.7	3.61
456355.2	412088.3	2.71
456321.1	412124.7	2.94
456286.9	412161.1	2.83
456324.0	412195.7	3.13
456357.7	412158.9	2.90
456391.6	412122.0	3.15
456425.8	412085.5	3.89
456459.8	412048.9	4.27
456494.0	412012.2	3.75
456531.6	412046.6	3.41
456497.5	412083.1	4.43
456463.0	412119.8	4.09
456428.5	412156.4	3.50
456394.4	412192.8	3.13
456432.4	412226.9	3.35
456466.2	412190.1	4.04
456500.2	412153.5	4.09
456534.3	412116.8	3.91
456568.3	412080.4	3.59
456605.5	412113.8	3.20
456571.2	412150.5	4.11
456537.1	412187.0	3.98
456502.9	412223.3	3.66
456539.7	412256.8	3.64
456574.1	412220.6	3.70
456608.4	412184.4	3.00
456642.8	412148.2	3.22
456679.6	412182.0	3.01
456645.4	412217.9	3.02
456611.1	412254.0	2.98
456576.7	412290.2	2.90
456613.7	412323.8	2.79
456648.1	412287.6	2.76
456682.3	412251.5	2.76
456716.5	412215.7	2.77

16 November 1998

X	Y	Height OD
456177.1	412059.5	3.33
456211.8	412023.6	3.60
456247.1	411987.7	3.37
456279.5	411950.6	3.05
456316.3	411984.4	3.11
456283.0	412020.5	3.42
456248.1	412056.8	3.37
456213.6	412093.2	3.37
456250.3	412127.2	3.26
456284.5	412090.9	3.09
456318.6	412054.4	3.12
456352.7	412017.8	3.37
456387.0	411981.4	3.57
456423.0	412015.4	4.09
456389.2	412051.7	3.92
456355.2	412088.3	3.05
456321.1	412124.7	3.05
456286.9	412161.1	3.12
456324.0	412195.7	3.24
456357.7	412158.9	3.15
456391.6	412122.0	3.37
456425.8	412085.5	4.52
456459.8	412048.9	4.25
456494.0	412012.2	3.75
456531.6	412046.6	3.52
456497.5	412083.1	4.32
456463.0	412119.8	4.54
456428.5	412156.4	4.10
456394.4	412192.8	3.34
456432.4	412226.9	3.49
456466.2	412190.1	4.07
456500.2	412153.5	4.33
456534.3	412116.8	4.20
456568.3	412080.4	3.71
456605.5	412113.8	3.55
456571.2	412150.5	4.15
456537.1	412187.0	4.03
456502.9	412223.3	3.82
456539.7	412256.8	3.70
456574.1	412220.6	3.75
456608.4	412184.4	3.42
456642.8	412148.2	3.71
456679.6	412182.0	3.25
456645.4	412217.9	3.41
456611.1	412254.0	3.28
456576.7	412290.2	2.93
456613.7	412323.8	2.83
456648.1	412287.6	2.75
456682.3	412251.5	2.81
456716.5	412215.7	2.81

30 November 1998

X	Y	Height OD
456177.1	412059.5	3.30
456211.8	412023.6	3.53
456247.1	411987.7	3.35
456279.5	411950.6	3.15
456316.3	411984.4	3.23
456283.0	412020.5	3.46
456248.1	412056.8	3.50
456213.6	412093.2	3.41
456250.3	412127.2	3.37
456284.5	412090.9	3.22
456318.6	412054.4	3.23
456352.7	412017.8	3.55
456387.0	411981.4	3.78
456423.0	412015.4	4.07
456389.2	412051.7	3.99
456355.2	412088.3	3.26
456321.1	412124.7	3.13
456286.9	412161.1	3.24
456324.0	412195.7	3.24
456357.7	412158.9	3.20
456391.6	412122.0	3.52
456425.8	412085.5	4.53
456459.8	412048.9	4.25
456494.0	412012.2	3.84
456531.6	412046.6	3.60
456497.5	412083.1	4.32
456463.0	412119.8	4.56
456428.5	412156.4	4.30
456394.4	412192.8	3.46
456432.4	412226.9	3.55
456466.2	412190.1	4.07
456500.2	412153.5	4.35
456534.3	412116.8	4.22
456568.3	412080.4	3.64
456605.5	412113.8	3.59
456571.2	412150.5	4.14
456537.1	412187.0	4.03
456502.9	412223.3	3.83
456539.7	412256.8	3.71
456574.1	412220.6	3.77
456608.4	412184.4	3.65
456642.8	412148.2	3.77
456679.6	412182.0	3.28
456645.4	412217.9	3.53
456611.1	412254.0	3.37
456576.7	412290.2	2.93
456613.7	412323.8	2.83
456648.1	412287.6	2.94
456682.3	412251.5	2.82
456716.5	412215.7	2.81

16 December 1998

X	Y	Height OD
456177.1	412059.5	3.76
456211.8	412023.6	3.86
456247.1	411987.7	3.71
456279.5	411950.6	3.34
456316.3	411984.4	3.43
456283.0	412020.5	3.80
456248.1	412056.8	4.19
456213.6	412093.2	3.59
456250.3	412127.2	3.68
456284.5	412090.9	3.94
456318.6	412054.4	3.82
456352.7	412017.8	3.68
456387.0	411981.4	3.95
456423.0	412015.4	4.37
456389.2	412051.7	4.15
456355.2	412088.3	3.48
456321.1	412124.7	3.58
456286.9	412161.1	3.52
456324.0	412195.7	3.59
456357.7	412158.9	3.37
456391.6	412122.0	3.73
456425.8	412085.5	4.80
456459.8	412048.9	4.55
456494.0	412012.2	4.06
456531.6	412046.6	3.93
456497.5	412083.1	4.62
456463.0	412119.8	4.79
456428.5	412156.4	4.85
456394.4	412192.8	4.00
456432.4	412226.9	3.82
456466.2	412190.1	4.34
456500.2	412153.5	4.53
456534.3	412116.8	4.44
456568.3	412080.4	3.99
456605.5	412113.8	4.04
456571.2	412150.5	4.35
456537.1	412187.0	4.37
456502.9	412223.3	4.08
456539.7	412256.8	4.00
456574.1	412220.6	3.97
456608.4	412184.4	3.83
456642.8	412148.2	3.95
456679.6	412182.0	3.33
456645.4	412217.9	3.68
456611.1	412254.0	3.55
456576.7	412290.2	3.10
456613.7	412323.8	2.92
456648.1	412287.6	3.00
456682.3	412251.5	2.93
456716.5	412215.7	2.93

6 January 1999

X	Y	Height OD
456177.1	412059.5	3.76
456211.8	412023.6	3.89
456247.1	411987.7	3.73
456279.5	411950.6	3.45
456316.3	411984.4	3.52
456283.0	412020.5	3.93
456248.1	412056.8	4.24
456213.6	412093.2	3.67
456250.3	412127.2	3.66
456284.5	412090.9	4.22
456318.6	412054.4	3.87
456352.7	412017.8	3.74
456387.0	411981.4	3.97
456423.0	412015.4	4.35
456389.2	412051.7	4.14
456355.2	412088.3	3.67
456321.1	412124.7	3.73
456286.9	412161.1	3.51
456324.0	412195.7	3.51
456357.7	412158.9	3.41
456391.6	412122.0	3.90
456425.8	412085.5	4.78
456459.8	412048.9	4.52
456494.0	412012.2	4.10
456531.6	412046.6	3.95
456497.5	412083.1	4.62
456463.0	412119.8	4.78
456428.5	412156.4	4.72
456394.4	412192.8	4.38
456432.4	412226.9	3.83
456466.2	412190.1	4.31
456500.2	412153.5	4.52
456534.3	412116.8	4.45
456568.3	412080.4	4.00
456605.5	412113.8	4.03
456571.2	412150.5	4.36
456537.1	412187.0	4.36
456502.9	412223.3	4.08
456539.7	412256.8	4.01
456574.1	412220.6	3.98
456608.4	412184.4	3.93
456642.8	412148.2	4.02
456679.6	412182.0	3.33
456645.4	412217.9	3.72
456611.1	412254.0	3.55
456576.7	412290.2	3.17
456613.7	412323.8	2.97
456648.1	412287.6	3.05
456716.5	412215.7	2.99

21 January 1999

X	Y	Height OD
456177.1	412059.5	3.68
456211.8	412023.6	3.88
456247.1	411987.7	3.78
456279.5	411950.6	3.55
456316.3	411984.4	3.58
456283.0	412020.5	4.11
456248.1	412056.8	4.23
456213.6	412093.2	3.76
456250.3	412127.2	3.72
456284.5	412090.9	4.27
456318.6	412054.4	3.87
456352.7	412017.8	3.84
456387.0	411981.4	3.90
456423.0	412015.4	4.26
456389.2	412051.7	4.18
456355.2	412088.3	3.79
456321.1	412124.7	3.74
456286.9	412161.1	3.57
456324.0	412195.7	3.53
456357.7	412158.9	3.49
456391.6	412122.0	3.97
456425.8	412085.5	4.74
456459.8	412048.9	4.42
456494.0	412012.2	4.05
456531.6	412046.6	3.96
456497.5	412083.1	4.44
456463.0	412119.8	4.71
456428.5	412156.4	4.83
456394.4	412192.8	3.99
456432.4	412226.9	3.90
456466.2	412190.1	4.30
456500.2	412153.5	4.45
456534.3	412116.8	4.40
456568.3	412080.4	3.96
456605.5	412113.8	3.99
456571.2	412150.5	4.32
456537.1	412187.0	4.29
456502.9	412223.3	4.06
456539.7	412256.8	4.00
456574.1	412220.6	3.94
456608.4	412184.4	4.00
456642.8	412148.2	4.11
456679.6	412182.0	3.36
456645.4	412217.9	3.78
456611.1	412254.0	3.57
456576.7	412290.2	3.17
456613.7	412323.8	2.97
456648.1	412287.6	3.10
456682.3	412251.5	3.12
456716.5	412215.7	3.03

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