SETTLEMENT, LAND USE AND WATER MANAGEMENT SYSTEMS IN ROMAN ARABIA: AN INTEGRATED ARCHAEOLOGICAL APPROACH

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by

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Abstract

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The aim of this thesis is to gain a greater understanding of water management systems, land use and settlement patterns in Roman Arabia. Using an integrated approach, based on Geographical Information Systems (GIS), archaeological data, historical sources, landscape and surface survey this thesis explores the application of water management systems, particularly those technologies used to capture and control floodwater. This information is then used to address some the major issues and models which have been postulated to account for, or contribute to, the settlement of marginal regions of the Levant during the Roman period. Many theories proposed in the recent past have attempted to explain the development of these peripheral zones, and these range from climate change, population increase, growth in trade and economy, through to imperialism and Romanization. The first part of this thesis critically assesses the range of evidence on which many key arguments have been constructed, and clearly shows that much of it is incomplete and/or inadequate to explain such a complex phenomenon. Using the site of Wadi Faynan, Jordan, as a case study, it has been demonstrated that the study of water management systems has provided a great deal of information with which to understand the dynamics present in the occupation, development and abandonment of marginal sites. Furthermore, an analysis of the regional evidence has emphasized the regional diversity of Roman Arabia and the major factors affecting such diversity. In particular, the innovative use of a GIS has provided a clear analytical tool with which to model large amounts of complex data, and move towards exciting new interpretations and new applications of such technology.

Key words: GIS, Water management, Roman, Arabia, Wadi Faynan, floodwater farming, marginal settlement

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1.0 Research issues

1.1 Introduction

Vincentius, who was acting as chief of the bodyguard of Basius, observing that many of the outlying pickets had been ambushed and killed by the Saracens while fetching water for themselves, laid out and constructed a reservoir for the water. He did this in the consulship of Optatus and Paulinus.

(Iliffe 1942)

The inscription of AD 334 quoted above was found in present-day Jordan, incised onto a rectangular block of basalt, which lay on the open desert surface about 60 kilometres to the northeast of Amman. Other than adding a human scale, a vivid snapshot into the very specific concerns of some contemporaries (albeit two particular interest groups, and perhaps not of the majority of the local provincial population), this inscription and the events it describes can serve as an interesting allusion to some of the major themes and issues with which this thesis will be concerned. If we read carefully between the lines, we can see at work, through the presence of the Roman official Basius, the actions and concerns of the Roman authorities and their attempts to control the desert environment; the position and importance of the control of water resources within such an environment; a personal initiative by an army officer (Vincentius) to invest in a simple but effective technology to manage water resources; and although this is an exceptional example, underlying the whole episode is the interaction and relationship of seemingly different ethnic or cultural groups with one another. Such broad notions of control, and social relationships form the background to much of the research contained within this thesis. However, the particular research focus is concerned with the application of water management techniques in marginal landscapes within the southern Levant, and its relationship to land use and settlement.

The last decade has seen radical change or renewed interest in the analysis and interpretation of the 'marginal' regions of the empire. Relating to this work, intensive archaeological field surveys of marginal regions, and their derivative historical reconstructions, have contributed to new understandings of imperial hegemony and development within such peripheral areas (e.g. Alcock 1993; Barker 1996; Isaac 1990). The primary conclusions arrived at by this work provide the practical foundation upon which the following research has been constructed.

It will be noted that a high percentage of these new analytical approaches has been centred on the western provinces of the empire, with significantly fewer comparative syntheses having been produced for the eastern provinces. This is perhaps still an influence of the long standing East-West divisions which have constricted historical and archaeological analyses of the Mediterranean basin in the past, and which to a large extent continue to do so (Horden and Purcell 2000; Shaw 2001: 420, n7). Such divisions in turn, it has been suggested, are a consequence of the historical growth of European nationalism, western colonial misadventures, and the construction of a disparaging Orientalist discourse (Meskell 1998: 2-5; Millett 1997: 201; Said 1983). This is not to say, however, that the eastern provinces have been completely ignored, for in the last decade or so there has been a substantial increase in the number of general accounts of the archaeology and history of the Roman and Byzantine East; particularly important with reference to the southern Levant are: Alcock 1997b; Ball 2000; Dauphin 1998; Humphrey 1995, 1999; Kennedy and Riley 1990; Millar 1993; Safrai 1994; Sartre 1991; Swain 1996.

As will be observed below, while the survey and related studies of rural landscapes within the Near East are at a comparatively early stage of development, one of the few accessible avenues open to analytically based research is the study of water management techniques within the region. Detailed and rigorous analyses of water management systems in other arid marginal regions of the

Roman Empire have proved very successful in recent years for a number of key reasons: firstly, they have helped to clarify the engagement and negotiation involved in a core-periphery relationship; secondly, such studies have been able to outline the impact of Roman hegemony and the forms and processes through which this control operated; and finally, a heightened awareness of the general development of such regions has been obtained (Barker 1996; Mattingly 1995). The potential of similarly based research has been alluded to in recent years for the Transjordan region (Gilbertson and Kennedy 1984; Kennedy 1995a). Other assessments of water management techniques in marginal environments of the Roman empire, but in these cases the analysis of past approaches to wetland areas, have also in due course appeared and helped to develop similar ideas, with some similar conclusions to the exploitation of dryland regions (e.g. Fincham 2001; Rippon 2000).

The research which follows aims to operate within the same theoretical paradigm as the recent work on the western provinces, extending such approaches heuristically to evidence presented in the Near East and so seeks to cut across the east-west divisions that have dogged the disciplines of Roman archaeology. In view of this principal aim I intend to consider and synthesize particular evidence from within the boundaries of the Roman province of Arabia, which essentially extended from the Hauran in the north to the Red Sea and the Hijaz in the south; from the coast at Gaza on the Mediterranean sea, incorporating the whole of the Negev Desert and Sinai, to the Dead Sea; and then following the line of the River Jordan up to the foothills of Mount Hermon at the southern end of the Anti-Lebanon Mountains. Hence Roman Arabia presents a manageable area of assessment, and one which to a large extent can be seen as homogenous in terms of culture and climate.

The investigation of field systems, which utilised an array of simple to complicated methods of water control in semi-arid and arid regions of the southern Levant, will form the core of this study.

Hence, this study aims to: assess the distribution of water management systems within the bounds of the former province of Arabia; survey the range of techniques employed to successfully operate such systems; and to chart the diachronic and spatial development of such systems. Finally, I shall investigate and give some explanations for the wholesale abandonment of such systems, and contribute to the debates on the collapse of permanent sedentary settlement within entire regions of the southern Levant until resettlement at the turn of the twentieth century.

When complex studies have been completed, such as have occurred in the Negev, valuable insights have been gained into the development of water management systems and land use through several time periods. However, on occasions the inability to accurately date systems of floodwater farming by type of wall construction or through the material evidence, in the form of sherd scatters, has often limited interpretations of settlement and land development to general statements. In other words, a system in the Negev can often be described as being of the late Roman period or the late Byzantine period, but there is no indication of adaptation or change beyond this. By this the systems are treated as static entities, constructed at a particular time and then existing as a monolithic whole, almost unchangeable through succeeding periods. In many examples this does not equate with what is known of the local environment, or of changes in society and cultural practice, or with the simple materials, usually piles of stones, used to construct the systems.

It can be seen that what is required is a rigorous integrated approach which would narrow the focus further to the close study of an individual system. Using such an integrated approach, which would not only collect sherd samples but also survey in detail the methods of wall construction, issues of dating, systems of water management use, land use and settlement types could all be usefully explored. An integrated approach can be achieved through the use of intensive field survey in combination with the analytical power of a Geographical Information System (GIS).

The opportunity to operate such a combination on a substantial series of field systems arose with the survey of the Wadi Faynan in southern Jordan, which forms the subject of a particular case study. In furthering such a study and in order to become familiar at first hand with the issues involved, I undertook to visit as many sites within the region as was possible and where appropriate made detailed observations of particular sites. In addition it has to be stressed that the emphasis of this research is that of water management systems, and the technology and evolution of these over the period concerned. Settlement and land use are important to the understanding of such systems and so the relationship of these to water management systems will be looked at in turn.

As a further consideration, it is important to note at this point that the term 'Classical period' in this study is used as a general term to refer to a number of periods from the Hellenistic to the commencement of the early Islamic period. This is sometimes used in works on the region as a catchall phrase to define the 1,000-year period of rule by the external cultures of the Mediterranean, and will be used in this study for convenience. Appendix One gives a short breakdown of the standard period chronology used by scholars working in the region, which in some details is different from that used for the western areas of the Roman empire.

1.2 Romanization, imperialism and water management in Roman Arabia

Without making direct comparisons, in questions of agency, evidence from several parts of the Levant seems to replicate that presented to scholars of Roman North Africa. In an influential paper, Brent Shaw outlined a number of these important questions, which he and other scholars have suggested necessitate answers in any explanation for the development of large agricultural areas within Roman Africa, which also utilised forms of water-management technology (1984:

121-22). The most fundamental of these questions are equally applicable to the development of the marginal regions of Roman Arabia and are concerned with, in Shaw's words: 'How and by whom was water exploited for purposes of agricultural production? Was there a conscious policy [by 'Romans' or the 'Roman state'] to develop...agricultural potential by the extension of an existing hydraulic technology or by the introduction of new water technologies?' (1984: 121).

It has proved very difficult to provide convincing answers to such basic questions from the empirical evidence collected in North Africa, though recent studies of the field systems of Tripolitania have succeeded in providing some interesting insights (Barker 1996; Grahame 1998a; Mattingly 1995, 1996). Notably, these have centred on who was responsible for the construction of floodwater farming systems in the pre-desert of the Libyan valleys. Unlike previous research which postulated that the Libyan valleys were settled by Roman colonists or veterans, this recent work has concluded that the phenomenon of cultivated semi-arid valleys is the result of a process initiated by the indigenous people of the region (Barker *et al.* 1996). A major input into the process of settlement and agricultural development of these marginal areas seems have been the reaction generated by the growing prosperity of the Roman-controlled coastal zone, and from which the peoples of the interior wished to profit (Mattingly 1996). This occurrence of 'Rome without Romanization' has opened up new debates centred upon issues of cultural change and the impact of Rome in marginal environments (Grahame 1998a, 1998b). So far, one critical key to such debates in explaining cultural change and the development of arid marginal regions has been the investigation of water management systems and their relationship to settlement.

For the Levant, a series of long running discourses have sought to understand the processes behind the sedentary occupation within the marginal areas of this region, particularly the province of Roman Arabia. The marginal regions of the Negev desert, the southern Levant and Sinai, impressed researchers at the end of the nineteenth century and the beginning of the twentieth century AD, with extensive remains of sedentary settlements and extensive agricultural fields in what otherwise seemed to be barren desert (e.g. Huntingdon 1911; Woolley and Lawrence 1914). Since these initial interpretations were written, a number of theories have been developed to explain the phases of sedentary occupation. Many of these have sought answers through changes in the environmental regime, others from an historical viewpoint (e.g. Issar 1995; Negev 1993f; Safrai 1994; Sperber 1978). However, the answers provided from these two separate approaches have often proved to be contradictory. This is in part due to the mismatch and inconsistencies of surviving historical documents and the physical evidence.

Although a number of ground-breaking studies have been undertaken in the Negev desert over the last forty years, particularly the seminal work of Evenari *et al.* (1982), little attention has been paid to other marginal regions of the southern Levant. Hence, the findings of intensive studies of the rural landscape and agricultural systems of the Negev desert may only apply to this region alone. To understand fully issues of Romanization, cultural change and sedentary occupation within the province of Roman Arabia explanations should be sought across the whole region. In addition, much of the archaeological survey work completed in the Negev has suffered from the absence of detailed chronological typologies of the material evidence. Therefore, the conclusions offered to explain the occupation of the marginal regions have had to be constituted within relatively vague temporal periods constructed using a general framework built with the aid of the few historical sources available.

The significance of this information is to question many of the arguments put forward to explain the processes behind the development of marginal regions. In other words, poor evidence has been used to justify significant issues, which can lead to either self-validating or contradictory arguments. Therefore, the material evidence provided by water management systems, if approached using integrated, rigorous methodologies, such as archaeological evidence, historical sources, geomorphological and environmental analyses, can be seen to be a potentially valuable tool in addressing questions of water management and its wider implications. Furthermore, the application of a detailed GIS to a particular case study, that of Wadi Faynan in southern Jordan, has allowed for the enhancement of the integrated approach which forms the basis of this thesis. First of all, however, it is necessary to define the main technologies and structures that constitute water management systems.

1.3 Applications of water management in the ancient world

Various simple techniques, which could be classed as examples of 'intermediate technology', were devised in the past to utilise to maximum effect the limited amounts of water available in many parts of the world, particularly in the Near and Middle East. Many of these simple but efficient technologies are still in use today. These techniques can be roughly categorised according to the number of tasks they were designed to fulfil. Hence, some operations involved the initial acquisition of water, others the conservation of adequate amounts for long periods. In most cases the place of water capture was spatially a long way from the place where water was required, and so many different ways of transporting water with limited loss and maximum efficiency were devised. In addition, it is necessary to consider the different purposes for which water was required. In considering this question four general spheres of use can be delineated. The first, concerns the accessibility of drinking water for a particular population and, sometimes more importantly, their animals. Secondly, water is of vital importance for many agricultural usages. The third important sphere in which water is often required in large quantities is for industrial or utilitarian-type operations, for example, the washing of clothes. However, the systems used for such activities are more often than not impossible to separate from those which provide water for the first two spheres of use. Finally, water was utilised, when the technology was available, as a means of providing power in the operation of simple but effective machinery. The following section presents a range of evidence for the early history of this technology (except for the third sphere, whose evidence for such falls within the other categories), beginning with simple techniques employed in regions of low annual precipitation for the collection of drinking water.

The pre-pottery Neolithic site at Beidha, Jordan (dating to the late eighth to the early seventh millennium BC) has revealed some of the earliest evidence in the Near East for the acquisition and long term storage of water, in the form of permanent wells purposely dug (up to a depth of five metres) to provide unpolluted drinking water (Haelbeck 1966). These wells were a later development, according to the excavators, of an initial stage in which a succession of shallow pits was excavated into the wadi floor to tap into the natural groundwater (Haelbeck 1966). Recent research, has located a series of wells in an aceramic Neolithic (Early Pre-Pottery Neolithic B) site in Cyprus. Such wells have not been found as yet within the Levant, which has suggested to the excavators that the' use of wells may have been a western hydrological development (Peltenburg *et al.* 2001: 48). The earliest wells within a settlement seem to appear in Mesopotamian villages of the Halaf period during the late sixth-early fifth millennium BC (Miller 1980: 333). Contemporary with the idea of building wells was initial attempts to transport and store water in the more convenient form of ceramic vessels and jars. The earliest of such storage containers that could have been used for such a purpose have been found to date to the late Neolithic period. However, it may be the case that previous to the use of ceramic-based containers animal skins were used, as there continued to be used throughout antiquity, but for at least the earlier periods there is no surviving evidence of these.

By the late Chalcolithic, the Levantine tradition of water engineering can be said to have emerged, in one reasonably datable site at least. Jawa in Jordan is a large abandoned settlement on the southeastern slopes of the Jebel al-Arab, which displays a unique suite of different types of water technology designed to control the brief annual floodwaters of the surrounding Wadi Radjil (Fig. 1.1). According to Helms, the settlement appears to have been occupied only for a generation, and some of the hydrological works seem to be unfinished (1981). However, recent research has suggested from analysis of the ceramics that occupation could have been episodic throughout a good part of the early Bronze Age (Betts 1991; Philip 1995). The extensive remains of the settlement have been dated to the end of the fourth millennium BC at the earliest, and by association with the settlement remains, the original surveyor has suggested that the surrounding water control networks may also date to this period (Helms 1981). Though in view of recent work, some if not all of the water systems could date to a later period. The techniques utilised were engineered specifically to capture water from seasonal flash floods and then accommodate its long-term storage. By the application of such systems the population would have been able to subsist through the long hot, dry season, which in most years persists in this region from March until December. Consequently, it would seem the majority of the water required was collected during the brief annual spates. However, there is also evidence to suggest that localised surface runoff was collected, in the rare event of its occurrence, from the slopes of the low relief that surrounds the settlement.

The system as a whole consisted of an integrated network of diversion canals and underground cisterns, along with a series of open-air reservoirs/cisterns. Furthermore, these reservoirs would also have had the capacity to tap into areas of groundwater storage. It has been calculated that the system could process an estimated 75,000 cubic metres of water annually – the total runoff has been estimated at 2,000,000 cubic metres per year – and it would only have been required to work at an efficiency level of four per cent to sustain the Jawan population (Helms 1981). However, this would only have occurred if there had been snow during the winter months on the nearby Jebel al-Arab massif, the source of the flood spates, which lies twenty kilometres or so to the northwest. If snowfall failed to appear over a number of years, then the settlement positioned deep within a semi-arid environment, would have had trouble surviving, and this vulnerability may have contributed significantly to its early demise.

As civilisations became more complex, so did the arrangements for storing water. In terms of technology used, cisterns have, at least in the Near East, become the preferred method for capturing and storing drinking water. At the emerging early town of Arad in the third millennium BC, systematic efforts were made by the townsfolk to acquire and utilise the maximum amount of water that was potentially available to them (Miller 1980). Hence the streets themselves were orientated so as to permit rainwater from a chance storm to flow down them towards a large centrally located storage reservoir, the basis of which was a naturally occurring depression. The townsfolk of Ai (2700-2550 BC) in Israel went one stage further, channelling water from the town to the surrounding fortification walls using drains lined with stone slabs and sealed with clay (Calloway 1978: 51). In this way the reservoirs at Arad and Ai could provide a useful secondary role as a line of defence. By the time of third and fourth Dynasty Egypt (*c.* 2700-2500 BC) societies had acquired the organisational skills to construct large-scale dams, far larger than earlier examples such as at Jawa. Hence, although almost impossible to date precisely, the impressive dam at Wadi Gerrawi in Egypt (116 metres long by ten metres high) could plausibly only have been built to supply water to the workers in the nearby quarry, which has been dated to the early Dynastic period (Murray 1955).

The 'Kish civilisation' palace at Ebla, in Syria (*c.* 2350-2200 BC) displays an early example of water provision as an integral part of the design plan, revealing a system of wells and cisterns placed around a courtyard. By the Middle Bronze Age (*c.* 1800-1650 BC), examples of domestic water storage can be found: the dwellings of Hazor in Palestine have adjacent to them underground plaster-lined cisterns which appear to have collected precipitation runoff from the house roofs (Miller 1980). In addition, the town exhibits one large underground cistern hacked out of the limestone bedrock, although the date of its construction is difficult to assess accurately.

Underground rock-cut cisterns of all shapes and sizes are to be encountered everywhere in the Near East, but are less common in Egypt (Murray 1955: 175). By being underground, these cisterns reduced the loss of water through evaporation – an important consideration in arid regions. Many also show evidence of plastering, to lessen seepage. In addition, such cisterns, whether open to the air or underground, were usually located at the centre or base of a suitable catchment basin. The only visible evidence for many underground cisterns, for example, those located at Humayma, are the presence of runnels cut into the rock of the catchment area. Such runnels lead to a small drain hole, which is the entrance to the cistern, and is often to be found located in the face of a natural cliff or low hill (Eadie and Oleson 1984: 56).

In the Iron Age, it seems the preferred type of cistern to use was the rock-cut bottle cistern, as the name suggests these were shaped like a bottle with a small neck but widening out below the lip to an interior width of three to four metres in diameter (Oleson 1995: 709). These bottle cisterns were easy to plan and straightforward though probably difficult to construct. Another type of cistern common in the Levant is the Ma'agura cistern, which are usually to be found cut into a soft chalk layer (non-porous when wet) immediately below a layer of hard limestone or flint which acts as the roof (Rubin 1988). These Ma'agura tend to be rectangular in shape, the larger examples having uncut chalk pilasters as additional roof supports. However both the bottle and the Ma'agura types of cistern were restricted in their use for they required either a suitable position within a particular catchment area or an appropriate bedrock. Later on, using improved construction techniques taken from the Hellenistic world, larger square cisterns, lined with stone ashlar walls were built. These could be placed close to a settlement site and linked to the catchment area by an aqueduct, of which there are many varieties within the Middle East (e.g. Costa 1983; Eadie and Oleson 1984). To conserve the maximum amount of water, many of these cisterns were roofed over using transverse arches across the reservoir. Such reservoirs can still be seen at many locations across the Levant, and often, continue in use as public cisterns for an entire community. Examples of such roofed cisterns are still particularly common within what was the kingdom of Nabataea. From studies of these cisterns, it seems that the Nabataeans experimented with the use of roofed reservoirs and at some point realised that the maximum effective span they could achieve was six to seven metres. (Oleson 1995: 717). For private use some Nabataean residences had circular cisterns up to five metres in diameter placed underneath their houses to collect rainwater from the roof. In this way the development of earlier roof collection systems was continued and many examples of these later cistern types have been recorded throughout the Near East (Rubin 1988: 233).

Even harder to date, in terms of their origins and primary uses, are the various forms of water collection (still sometimes used) in the very arid desert regions. I shall highlight a few of the many variations of such collection systems found in the eastern desert of Jordan. There are essentially three types of water storage in this area. The first, termed *ghadir* (pl. *ghudran*) enhanced naturally occurring basins in the beds of local wadi courses (by digging them deeper or by building walls) (Lancaster and Lancaster 1997: 371). *Mahfur* (pl. *mahafir*), on the other hand, are specially constructed earthen basins up to 100m in diameter at the bottom of slopes at the base of drainage basins (Agnew *et al.* 1995). The side towards the upslope is open, allowing runoff water to enter and be held by the surrounding dikes. In many examples, the mahafir were supplemented by small underground cisterns, with stone-built corbelled roofs, placed at the centre of each drainage basins (Betts and Helms 1989). Generally these three water-collection structure types are notoriously hard to date, but it has been proposed that they could represent a Neolithic innovation (Betts and Helms 1989: 10).

As for the techniques involved in farming the drier regions, a number of technologies was practised which have been found to have been well-adapted to the specific underlying needs of the environment and to the constraints of the local physical geography. Hence, two systems of techniques were developed to overcome the general lack of water using the following practices. In the first system, any surface runoff that occurred was controlled, and then channelled to water crops. Secondly, at many places floodwaters of both perennial and ephemeral streams and rivers could be used for irrigation purposes if control was gained. The various terms used for these farming operations need to be accurately defined to avoid confusion. Therefore it can be said that there were essentially four forms of farming which relied on the capture, control and distribution of water. These forms can be listed as Runoff farming, water harvesting, floodwater farming and irrigation farming.

The ancient system of 'runoff farming', as the term suggests, chiefly relied on runoff processes from unprepared slopes. Agricultural practices usually associated with such a technique were often characterised by small-sized fields, often placed where they obtained maximum runoff, the most common position being at the base of a natural catchment area. The walls of the fields were often low stone or earthen walls; if they were placed along the contours of hillsides, terrace fields eventually developed. The building of check dams across small intermittent streams encouraged, in conjunction with runoff fields, the development of small garden plots. Such methods as outlined above, helped in the conservation of water resources at the immediate location where it was required.

The second type, 'water harvesting', has at first glance a strictly hydrological meaning: it does not make clear whether it was rainwater or river water that was being harvested, or what purpose it was eventually used for. Therefore, this term can be applied not only to water used for agricultural purposes, but in a general sense to water collected for a multitude of uses (Bruins *et al.* 1986: 15). There is a similar ambiguity in the expressions: 'rainwater harvesting' and 'waterponding'. When applied to agriculture, the terms have indicated the collection of runoff from prepared surfaces

(Lawton and Wilkie 1979: 4). In these prepared surfaces, the slopes were cleared of vegetation and loose stones, with what remained being deliberately compacted to increase the amount of runoff, which was then channelled straight to the fields where it was required. To varying degrees, both runoff farming and water harvesting methods were often employed in arid and semi-arid regions by different cultures over the world.

The other method whose remains are often encountered in these dry regions is that of 'floodwater farming'. In this method, the fields were watered directly by the encroachment of floodwater, the result either of a short and small flash flood in an otherwise dry stream valley, or of the inundation of large river floodplains by annual flood cycles. In each of these the 'floodwaters are concentrated by natural watersheds rather than runoff from adjacent slopes' (Lawton and Wilkie 1979: 4). This has made the term confusing. Bruins *et al.* (1986: 16) prefer to make a distinction between these two processes, preferring to define all farming methods which used water flow running towards the thalweg or lowest point in a valley as 'runoff farming' or 'runoff agriculture', and that involving the flooding of perennial rivers as 'floodwater farming'. For Bruins *et al.* suggested that the term 'runoff farming' might be confused with the farming method using just runoff, and because in general such systems not only use runoff, but other water harvesting methods as well. Furthermore, they suggested a general term for the all types of farming which employed flow resulting from precipitation as 'rainwater-harvesting agriculture'. They defined this in the following terms, 'Rainwater-harvesting agriculture is farming in dry regions by means of *runoff rainwater* from whatever type of catchment or ephemeral stream' (Bruins *et al.* 1986: 16). However, such a term is perhaps too general and unwieldy for specific applications. Hence, for the purposes of this study the term 'floodwater farming' will be used to indicate agricultural regimes in arid and semi-arid regions which using water management techniques captured the water they required from flash floods. (Fig. 1.2 illustrates several schemes of floodwater farming in the Wadi Marhah, Yemen using deflected waters from a wadi in flood.)

Finally there is 'irrigation farming'. This relies on regular supplies of water from more permanent sources, particularly perennial streams and rivers but sometimes from well-stocked reservoirs, wells and qanats. In many recorded examples, a number of methods were combined to achieve a constant supply of water when required. Thus an integrated system would have contained: a dam or a series of dams to impound the stream flow; often contained within the dams were head gates which allowed the water to be accessed when required; leading out from these were networks of canals and ditches to transport the water to the fields. In many cases, the fields were completely flooded for a desired length of time with the water held in by surrounding dikes. In many societies, a combination of all these methods is used to varying degrees of each. It can be seen that many of these systems have evolved over time. For example, there is compelling evidence to suggest that in Egypt the dominant form of farming slowly changed from one based wholly on forms of 'floodwater farming' to purely that of irrigation (Butzer 1976).

These ancient farming systems are not to be confused with the process known as 'dry farming' agriculture which relied on the direct action of precipitation, a common practice which continues today. In areas which still dry farm, it has been found that the minimum amount of precipitation needed to grow crops within such a farming regime needs to be above the average rate of 200 millimetres per annum (Ionides 1940). Hence by analogies with the present, it can be suggested for the agricultural regions that achieved this minimum rainfall in the past, the acquisition of additional water through irrigation or runoff processes was not essential, but supplementary.

The earliest example of ancient farmers taking advantage of rainfall runoff, at least in the Near East, again seems to be suggested at Beidha (Haelbaek 1966). As for irrigation schemes by perennial sources of water, the earliest were perhaps in Mesopotamia and Iran, where there is evidence for early farmers breaching the natural levees and simply flooding the adjacent fields, at least in Iran (Maisels 1999: 80-87). It has proved much harder to find evidence on the Mesopotamian plain, as the regular build up of alluvium has buried any remains, although David Oates claimed to have found evidence for simple irrigation channels in exposed areas near a tell that were of an ancient character, but proved impossible to date (Oates and Oates 1976). However, whenever the practice of irrigation commenced, 'once irrigation was begun, it must have become clear to these early farmers that it not only solved problems of erratic rainfall, but also tended to increase crop yields and the physical size of plants' (Lawton and Wilkie 1979: 10).

What cannot be doubted is the huge influence Mesopotamia and later Egypt had on irrigation agriculture throughout the Middle East generally. Evidence has been collected which suggests that irrigation began in Mesopotamia in *c.* 3500 BC, consisting of small-scale patches of irrigated land around many towns (Adams 1981). Not until around 900 BC, with presumably the direction and input of an organised system of government, was large-scale irrigation works put into practice. One example has been studied in southwestern Iran (Adams 1962a). At the head of the River Diz, water was diverted into a canal that led to the flood plain of a nearby tributary river. This action had proved necessary, as the tributary river had cut too far down into its own flood plain for its water to be used for irrigation purposes. In Egypt the River Nile annually inundated its floodplain, and all that was required was to wait for the waters to subside before planting on the wet soil. However, this was a fairly haphazard system to rely on, so the Egyptians made the process more organised by breaching the natural levees, constructing various channels and introducing bucket systems, notably the shadouf or pole and bucket lever to raise water to smaller plots not otherwise flooded. By the Ptolemaic period, saqiya (mule-operated water wheels) allowed the farming of large areas to be attempted. Furthermore, systems of large radial canals diverted some of the Nile flood into the Fayum depression adding an extra 1300 square kilometres of cultivable land (Butzer 1976). Similarly throughout the Middle East, other large developments in water management for agricultural purposes were taking place in the period between the third and first millennia BC.

These culminated in the 'magnificent aqueducts, irrigation works and many other devices for conservation of water in marginal areas' of the Roman period Levant (Lawton and Wilkie 1979: 14).

One of the key instruments in catering for this progress, and one that has been widely studied by archaeologists, was the introduction of the 'chain of wells' systems which were not only used for agriculture but often act as general providers of water. Probably developed in the Near East, these well systems are still utilised today in many dry countries of the 'Old World' from China to Spain under a variety of different terms, the most well known being qanats, foggaras, karez, falaj or 'well chains' (Cressy 1958). They proved particularly successful in the North African Sahara region and the highlands of Iran; thus the question of their origin has highlighted processes of diffusion (English 1968). One such example concerns the rare instances of ancient qanats whose remains have been discovered in parts of Israel. For in several cases, among and inside these qanats have been found Persian potsherds, which the excavator suggested were proof that these particular qanats were built by Persians while Palestine was under their control, or even by Israelites returning home from exile in Babylon (Evenari *et al.* 1982). However, a more prosaic explanation might be that the potsherds merely prove the existence of trading caravans. Each qanat was composed of three parts, which were constructed in a three-step procedure. Alluvial fans are the most likely place where ground water is to be found. Hence, near the top of a suitable alluvial fan, the first part, a vertical well or 'mother well', was dug down until the water table was reached. Consequently, using a series of wells dug in line down the slope, a gently downward sloping tunnel at the base of the wells would have been constructed to the foot of the slope, which eventually opened out at the surface onto storage reservoirs and irrigated fields (Figs 1.3 and 1.4). The system as a whole is termed a reticulation system, for through gravity, the water seeps out into the tunnel and a continuous stream of water flows out into the storage reservoirs. Well chains are very rarely constructed today, but the vast networks of qanats in Iran, up to 40,000 by one estimate, until very recently provided around 35 per cent of that country's total supply of water (Cressy 1958: 39).

In the Near East, Saudi Arabia and North Africa, various systems of 'rainwater harvesting agriculture' were also developed where there was not the right topographic conditions or enough water to justify the construction of a network of qanats. A number of different systems of rainwater harvesting agriculture have been employed at various times in these dry regions. The simplest can be defined as a 'micro-catchment system' (Bruins *et al.* 1986: 22). Such a system, may involve the creation of artificial slopes from which runoff can occur; an example of this which may not have been used for the growing of crops but merely as a animal watering point has already been mentioned that of the mahafir (Agnew *et al.* 1995). The maximum trajectory flow of runoff in a micro-catchment is normally less than 100 metres from the runoff contribution area to the receiving area. Hence, micro-catchment systems are limited by the potential low crop yield compared with the total area required to provide this amount.

A 'terraced wadi system' involved the construction of low wadi check-dams at regularly spaced intervals across the bed of a small or medium sized wadi. These dams had the effect of slowing and retaining the runoff water within the wadi bed, increasing the potential for soil saturation. Large wadis were not suitable, as from time to time they suffer from very large floods that often have the capacity to wash the dams away. 'Hillside conduit systems' occurred in situations where 'the length of runoff overland flow over a slope is long' (Bruins *et al.* 1986). In other words such systems were used when the velocity of the overland flow would have been slow and therefore subject to a high percentage of water loss, through evaporation or absorption into the soil. To counter such losses, it was necessary to construct channels on the upper or middle part of the slope to capture the runoff and bring it to where it was required. Such hillside conduit systems were usually highly complex and of a much larger scale than the simpler terraced wadi systems, although combinations of the two were often to be found in arid areas. If a tributary wadi widened out onto a large plain, then a 'liman system' might be have been used. A liman was a large field around which a dike of earth or a stone wall was built and to which runoff water was admitted and regulated by a spillway. These liman systems are sometimes constructed today; the word liman is derived from the Greek *limne* (lake) and aptly describes their appearance after a flood. Furthermore, series of contiguous limans, connected by spillways, were, and are now, sometimes constructed.

Finally, where potential arable land was to be found at a higher elevation than the wadi bed, 'diversion systems' were utilised as a solution. These systems consisted of a stone dam/barrage or barrages (constructed across the whole width of the wadi bed or partially into the wadi bed at an oblique angle to it), which deflected some of the wadi floodwater into a conduit system. The conduit system was constructed at a suitable gradient to permit a controlled flow of water to the area to be irrigated (Fig. 1.2). The remains of such water management systems, which exist within a large-scale range, are very frequent in occurrence and have been discovered throughout the entire Middle East. The best-studied regions containing such systems have been the Yemen wadis (Brunner 1997; Brunner and Haefner 1986), the Negev Desert in Israel (Aharoni *et al.* 1960; Evenari *et al.* 1982) and the pre-desert of Libya (Barker 1996). What each example of a diversion system seems to share is an 'ingenious use of wall technology' (Gilbertson 1986: 5). Uniquely among these, the Negev study included the experimental reconstruction of two farms which used the same runoff methods as revealed in the archaeology of the area. Essentially, these methods revolved around two main strategies. The first involved clearing small catchment areas (one to three hectares in size) in the upland slopes of a watershed of ten to 50 hectares in size. By this measure rainwater runoff potential was increased: as has been demonstrated, the farmers only removed the stones lying on the surface and not those embedded into it, the cleared stones being placed in large cairns running in lines down the slope of the hill (Lavee *et al.* 1997). Experiments have thus indicated this selective removal of stones increases the volume of runoff generated over one square metre by 250 per cent (Lavee *et al.* 1997: 347). The surface flow derived by this technique was collected into small channels that led to different sections of the fields. In this way the farmer gained easy control of a flood and limited its potentially destructive force. The fields, which formed the second part of the system, were arranged in terraces down the valley and ranged in size from 0.5 to two hectares, each field being separated by small boulder spillways, which fed the surplus water from terrace to terrace in a controlled manner.

Different versions of the fields were discovered, with perhaps the oldest being formed by simple walls twelve to fifteen metres apart crossing the valley bottom at right angles to the wadi sides hence creating simple series of 'check dams' or 'cross-wadi walls'. Similar series of cross-wadi walls have been found in numerous places, particularly in large numbers in the Libyan valleys, parts of Jordan and the Americas (e.g. Barker 1996). Through observation at the experimental farms, Evenari could see that these low cross wadi walls had the effect of causing the flood water to pond behind the terraces, whilst stopping the soil from being washed away, an example of flood and erosion control. As the farmers became more aware of the actions of a flood, they were able to create more complex diversion systems involving evermore sophisticated channels and spillways.

The oldest reliable archaeological dating evidence for rainwater-harvesting agricultural practices in the Negev has been found to date to Iron Age II (1000-539 BC) (Aharoni *et al.* 1960). However, it was only in the Nabataean and Roman periods that rainwater harvesting agriculture reached its peak in terms of development and acreage covered (around 4000 hectares out of 200 000 hectares available) (Evenari *et al.* 1982). This pattern was echoed in other parts of the Middle East: farmers built similar systems of run off farming using cleared catchments and 'cross wadi walls', for example in northern Jordan (Gilbertson and Kennedy 1984; Kennedy 1995) and Libya (Gale and Hunt 1986; Gilbertson and Chisholm 1996). Gale and Hunt (1986) and Gilbertson (1986) highlight a particular adaptation of the Libyan valleys, in which shallow sloping basins, off the edges of the main wadis on the plateau, were used as catchment areas from which collection channels brought the runoff water out into the main wadi field systems below. By covering as great an area as possible with these channels, the farmers were able to maximise the amount of water available to the fields in a region where storms are very local affairs and of short duration. In this way, although it might rain on only a small area of the plateau, some of the narrow wadi valley fields would obtain some water even if no precipitation fell near to the wadi valley (a very likely event in a region of average yearly rainfalls of only 25mm.)

In the North Yemen a slightly different approach was taken, which conforms to Heathcote's 'Seil flood system'. This could be seen as a very large 'diversion system'. Instead of the rainwater being distributed almost as soon as it arrived, the rainwater was, at one location at least, first collected at the head of the valley behind a large well-constructed dam. The best documented case the Great Dam at Ma'rib, was 680 metres in length (Brunner and Haefner 1986: 82). At either end of the dam, sluices and stilling basins were constructed; here the floodwater overflow was first calmed and then, when required, released under control through the sluices into canals on either side of the wadi leading down to vast networks of fields on the flat floodplain below. From calculations of the yearly increase in sediment deposition, Brunner calculated that irrigation of the floodplain might date back to the early second millennium BC (Brunner 1997; Brunner and Haefner 1986). From all accounts the system worked spectacularly well, until a large flood washed part of the dam away in the seventh century AD (commemorated by a verse in the Koran), leaving the fields high and dry and causing the dispersal of the large population reliant upon its successful operation. A long detailed inscription dated to AD 455 reveals in a catalogue of events that 20,000 people were involved in repairs to the dam (Hoyland 2001: 87-88).

Dams linked to irrigation systems are a widespread phenomenon in arid areas, and come in many shapes and forms. In the 1920s, the pioneering French archaeologist Poidebard photographed a particularly impressive example, the Harbaqa dam, which lies not far from Palmyra in Syria (Poidebard 1934) (Fig. 1.5). The Harbaqa dam at Qasr el-Heir el-Gharbi measures 345 metres in length, reaches a height of 30 metres, is 28 metres wide and is faced by large regular blocks of stone stepped upwards. At its base are three outlets from which a controlled measure of water could be released to a large reservoir downstream. From this reservoir an intricate system of canals led to an irrigated valley system and a large artificial oasis garden. In essence the system as a whole can be seen to be an ancient version of the modern reticulation system combining dams and canals, and practised in many parts of the world today (Heathcote 1983; Fig. 1.6). In between the reservoir and garden, a large mill complex was installed to make use of the power the flowing water could generate (Schlumberger 1939, 1986). The whole complex has been dated to the first century AD. It must have been the work of a prosperous Palmyran government that needed to, or simply desired to, expand its agricultural production.

An integral component of the system at Qasr el-Heir was the watermill, an ancient technology that has been identified at a number of locations in the arid lands of the Middle East. There were a number of variations in design, a reflection of several factors including the type of use the mill was put to, the position of the mill in relation to the rest of the water system in terms of available waterpower, and the state of technical knowledge at the time the mill was constructed. Some mills used water wheels in their operation, but others obtained more power by using primitive turbines: hence the development of the '*Arubah* penstock', or 'drop tower mill'. In this system, a regular supply of water under high pressure needed to operate the machine, was obtained by the use of an aqueduct or canal leading to a vertically-set thin tube or penstock; the latter narrowed at the bottom to a very small drain or millrace, cutting down the flow of water. The water quickly filled up the penstock and so maintained a constant high pressure as it gushed into the millrace. A small turbine was placed at the exit to the millrace, and the power generated by the rotation of the turbine was used to operate a set of grinding stones (Avitsur 1960; Neely 1974). The date of origin of such drop tower mills, which have been found throughout the Middle East, has been much disputed in recent years (McQuitty 1995; Wilson 1995). Some examples in Iran and Jordan have been dated to the early Islamic period (Gardiner and McQuitty 1987; Neely 1974), but cement in the drop tower mill at Wadi Faynan seems to contain material which would suggest an origin for these types of mills at least as early as the Roman period (Barker *et al.* 1997). This conclusion has been supported by the discovery of a more technologically advanced turbine mill of the Roman period at Chemtou, Tunisia which had three parallel turbines operating from one canal using an intricate sluice system (Wilson 1996).

In conclusion, I have not shown every variation of water technology that can be found in the Near and Middle East, but some common or influential system types and technology elements whose remains can be encountered. As far as the technology available to ancient peoples in the use and control of water, particularly in arid regions, we are only now just beginning to uncover the complex solutions to this most important aid to survival.

1.4 Thesis approach

Given an understanding of the technologies and structures that form the subject of water management systems, and a critical view of the larger issues affecting settlement in the peripheral regions of the Levant, it remains to be stated how this subject will be approached. To achieve a fully integrated approach for the reasons proposed in Section 1.3, it is necessary to first outline the underlying geographical and historical framework for the Roman province of Arabia (Chapter 2). This exercise provides an essential backdrop which all subsequent discussion is referenced against.

In making an assessment of the physical environment of the present time, further questions on the physical environment of the past, whilst the water management systems were in operation, have been investigated also. From this work, it has been possible in some subjects, particularly that of climate, to complete comparative analyses of the evidence of the past environment with that of the present. The final part of Chapter 2 assesses the range of historical sources and what we can say about the history of the region. For although historical sources are unable to provide all the answers required, it is necessary to be aware of what source evidence is available, and which have been used to defend some arguments.

Chapters 3 and 4 bring together the results of recent archaeological work, particularly in the field of landscape survey. Chapter 3 is concerned specifically with the methodologies employed and the essential conclusions so far reached in the investigation of regional settlement patterns. Chapter 4 narrows the focus, in that it seeks to highlight the evidence for land-use systems with which marginal region settlement is associated. Chapter 4 concludes with an analysis of the body of evidence currently available for the Roman province of Arabia. Chapter 5 explains the approach taken to extend our knowledge of marginal zones of Roman Arabia, using the landscape of Wadi Faynan as a case study and to which a detailed GIS has been applied in interpreting the evidence collected from an intensive field survey. The initial results from the GIS analyses of a large field system within Wadi Faynan form the subject of Chapter 6. Chapter 7 incorporates the implications of the Wadi Faynan study when placed in a broader context and to which direct comparisons are made with the evidence outlined in Chapters 3 and 4. The final chapter (Chapter 8), reflects on the wider issues posed at the start of this chapter and the extent to which these have been modified by the new inferences which have resulted from the integrated approach taken in this thesis. The chapter concludes with an assessment of the strengths and weaknesses of this study and how future work needs to be developed.

2.0 The geographical and historical context

2.1 Introduction

The absence or presence of sufficient year-round supplies of water is the key parameter by which human existence within much of the Levant is maintained at present, and was in the past. In order to understand the application of water-supply techniques and their relationship to the distribution and development of settlement within the Classical period, it is first essential to acquaint ourselves with the availability of water within the region as a whole. Furthermore, in order to understand why water can be utilised in one place and not another, it is vital to assess the physical constraints that influence the spatial distribution of water throughout the Levant. The notable variables which influence sustained human existence at any particular point include climate, topography, landscape, geology, soils and to a certain extent vegetation (Roberts and Wright 1994: 508).

In addition, the extent of what is generally known of the history and transformation of what actually constituted the province of Arabia will be briefly outlined. This section is not a comprehensive survey of all the evidence, but is merely meant to indicate the variety of literary source evidence available. Through the information as is available at present, ancient historians and epigraphers have been able to piece together a complex history of political changes and administrative changes through the Classical period. It is against the background of these changes that the application of water management systems, and changes in land use and settlement will be framed.

2.2 Physical geography

The former province of Arabia contained a number of distinct geographical regions which present a contrasting diversity of topography, geology, soils and vegetation that in different combinations produce: mountain and plain; barren hills and fruitful valleys; lakes and coastlands; deserts and fertile soils (Admiralty 1943b: 8). It is probable that such a variety existed throughout the Classical period as well.

The lands which at various times constituted the province of Arabia, its close neighbour Palaestina and their successors, can be conveniently divided into around thirteen distinct geographical regions, based on substantial differences in physiography, and the natural environment (Fig. 2.1). These are as follows:

1. the Mediterranean coastal plain
2. the mountain districts of Galilee, Samaria and Judaea
3. the Negev desert
4. the Sinai tablelands
5. the Sinai highlands
6. the northern Hijaz (Midian)
7. the northern Hijaz sandstone plateau
8. the central Jordanian limestone plateau
9. the Wadi Sirhan depression
10. the northern Harras
11. the volcanic Jebel al-Arab, the Hauran and the Golan
12. the Ajlun highlands
13. the Wadi Araba – River Jordan – Rift Valley

Some of these regions, for example the Central Jordanian Limestone Plateau, and the Ajlun highlands are one and the same from a strictly geological perspective, but because they are generally different in such aspects as topography, and hydrology, with consequences for land use and settlement, they have been treated as separate geographic regions. The mountain districts of Galilee, Samaria and Judaea are included in this description, for although these regions and much of the coastal plain were never incorporated within the province of Arabia, their topographical position in relation to the other regions has an important bearing upon the climate of the rest of Arabia. As to where the actual boundaries of the province of Arabia, these are discussed in detail in Section 2.6.3 below.

Before each of these areas is characterized, it is important to understand the main structural divisions which underlie the surface relief. There are three structural divisions apparent within the region being assessed. The foundation structure underpinning the whole, and influencing the surface geography, is the very old and immovable block of crystalline rock – the Nubo-Arabian shield area – which straddles central Arabia and northeast Africa (Admiralty 1943b: 8; Bender 1974: 16, 1975; Bowen and Jux 1987; Dixon and Robertson 1984). The intransigence of this very large mass of Pre-Cambrian igneous rock and the movement of the African, Arabian and Eurasian plates are thought to have been responsible for the development of the second major structural feature of the region, that of the Rift Valley (Roberts and Wright 1994: 508). This distinctive geological phenomenon is perhaps the most prominent feature within the region, physically dividing the realm of the Nabataean kingdom and its successor, provincial Arabia, into two distinct geographical parts with important consequences in terms of communication and settlement (Baly 1957: 27). What follows is a simplified overview of the main geographical characteristics of each region, which ultimately influenced the density of settlement across the region as a whole.

2.2.1 The Mediterranean coastal plain

The coastal plains bordering the Mediterranean coast form the far western boundary of the province of Arabia. Although there is a coastal plain along the entire length of the Mediterranean from Syria to Egypt, it has significant variations in width with occasional disruptions by spurs of highland, such as those in Israel where Mount Carmel forms an intersecting ridge in the environs of the port of Haifa. South of this ridge, where the lowland is at most only 200 metres wide, the plain increasingly widens until at a point beyond Gaza it reaches around 30 kilometres in width (Admiralty 1943b: 13; Fig. 2.2). Beyond this point it widens further and runs across the north of the Sinai peninsula until the edge of the Nile delta is reached at the line of the Suez canal and a junction with the narrower Gulf of Suez plain which runs down along west coast of Sinai (Admiralty 1946: 43; Fig. 2.3). This coastal lowland can be subdivided into three broad areas which roughly coincide with changes in surface deposits and climate.

The majority of the coastal plain is composed of tertiary alluvial deposits brought down from the highlands of Galilee, Samaria, Judaea, the Negev, and Sinai by perennial rivers and streams in the north and seasonal wadis in the south. At a point to the south of modern Tel Aviv, seasonal wadis replace the perennial flows. Facing the edge of the coast is an almost continuous line of sand dunes, which increases in width as one travels south until just south of Gaza. Within the plain of northern Sinai open sandy plains interspersed with isolated ranges of hills account for most of the land surface (Admiralty 1946: 43). The plain of Sharon, which constitutes the northern half of the coastal lowland from Caesarea to modern Tel Aviv, has long provided a large acreage of rich agricultural land, but only when sufficient water supplies could be directed from rivers and wells to the fertile soils (Admiralty 1943b: 13). Commencing south of Tel Aviv, the plain of Philistia, though gradually increasing in width, becomes increasingly drier and is consequently less cultivated with fewer perennial rivers and springs to provide enough water with which to irrigate large areas of land (Horowitz 1979: 13). Hence, beyond Gaza, sustainable agriculture is limited even with the modern technologies available today, and this was certainly the case in the past, though the substantial vineyards around the ancient settlement of Gaza were renowned in the Byzantine period (Mayerson 1985; Safrai 1994: 394).

2.2.2. The mountain districts of Galilee, Samaria and Judaea

These important highland areas form the backbone to the former Roman province of Judaea, and in the south lower ridges extend beyond into the Negev desert (Fig 2.2). Composed on the whole of limestone, apart from volcanic outcrops in Upper Galilee, the highest points are generally only around 1000 metres above sea level (Horowitz 1979: 16). Lower Galilee and Samaria never reach the heights of Upper Galilee or Judaea between Jerusalem and Hebron, and so do not totally interdict the passage of rain-bearing fronts into the interior. Although at a lower altitude than Galilee to the north and the Judaean highlands to the south, Samaria can be characterised as an area of mountain and valley (Admiralty 1943b: 16-17). The other regions can be seen as flatter plateaux less dissected by stream or wadi courses. Samaria can also be seen as the transitional zone between the wetter Galilee to the north and drier Judaea to the south.

The Judaean plateau is a direct continuation of the Samarian mountainous region, but here there is a marked difference in the topography. As one moves further south, the landscape becomes progressively more harsh and rugged in appearance, consisting in the main of loose rocks and fields of boulders, with here and there small-cultivated patches (Admiralty 1943b: 18). The western slope to the coastal plain consists of an abrupt escarpment, facing a lower area – in altitude, midway between the plateau and the coastal plain – of undulating soft chalky limestone intersected by wadis (Horowitz 1979: 16). This small shelf (48 kilometres from north to south and around 8-12 kilometres in width) is filled with fertile valleys and is known as the Shephelah or Shefela (Admiralty 1943b: 20; Horowitz 1979: 16). The eastern part of the plateau in Judaea which lies within the rain shadow, 'the wilderness', endures harsh desert conditions. At the eastern edge lies a steep precipice, on average over 300 metres in height, leading down to the Dead Sea, carved by a number of deep gorges (Admiralty 1943b: 20). However, as there is so little precipitation beyond the watershed, most of these wadis are perpetually dry, with only occasional oases persisting in the wadi beds.

2.2.3 The Negev desert

The Negev, which lies to the south of the Judaean plateau and the plain of Philistia can effectively be divided into two sections: a long gentle slope inclining up to the southeast, and beyond this a region of harsh mountain and desert (Admiralty 1943b: 23; Horowitz 1979: 14). Rainfall amounts to very little, hence the only permanent cultivation undertaken in the recent past before the expansion of population consisted of some scattered plots along the line of the slope, 20-25 kilometres from the coast, where in springtime fields of grass appear (Admiralty 1943b: 24; Horowitz 1979: 325). Immediately to the east of this slope lies a large expanse of sandy desert 20 kilometres wide before the first of a set of broken hills and ridges are encountered, the low-lying continuations of the Judaean highlands to the north. To the east and south of these lies the Negev highlands, a ridge of rocky desert country which extends in a southwesterly direction from the southern end of the Dead Sea down into the Sinai peninsula. For most of their length, these stony ridges average between 400 and 600 metres in height above sea level, but towards the southwestern part, these increase to heights above 900 metres (Admiralty 1943b: 25).

2.2.4 The Sinai tablelands

In many ways the various broad elevated tablelands of Sinai resemble the 'wilderness' of Judaea and the Negev in their desert constitution (Fig 2.3). However, they do possess more water resources, with numerous springs and aquifers present both in the northerly Badiet at-Tih and its eastern counterpart al-Hezim (Admiralty 1946: 44-45). Consisting of various sedimentary layers of sandstones and Cretaceous limestones which reach heights of between 1100 and 1600 metres, these tablelands are again widely cut by dry wadi networks. The al-Hazim is more broken up, dissected by several unconnected wadi systems running down to the Gulf of Aqaba, whereas at-Tih is drained by the single network of Wadi al 'Arish and its tributaries running down to the Mediterranean in the north.

Superimposed upon these tablelands is the structurally different Jebel Egma tableland. This consists of white chalk and chalky limestone dipping gently to the north which is edged by an escarpment the southern face of which ends in steep cliffs over 400 metres high (Admiralty 1946: 46). The highest point is Jebel Ganeina (1617m), which is the highest altitude in Sinai apart from the peaks in the south, ensuring that the region receives much of the available rainfall. The latter provides unexpected but welcome pasture for local Bedouin goat herds, though the permeability of the chalk and limestone ensures that there are few permanent water supplies.

2.2.5 The Sinai highlands

In the southern third of the peninsula reside the highest peaks and fractured ridges, composed of crystalline granites and schists (Admiralty 1946: 43; Fig 2.3). From the Gulfs of Suez and Aqaba the layers of igneous rocks progressively rise in tilted steps in the manner of a roughly stepped pyramid up to the central point, the adjoining summit peaks of Jebel Musa (2271m) and Jebel Katherina (2621m). Part of the same massif, one of these peaks is undoubtedly that of the biblical Mount Sinai, but there has been much debate over exactly which one. To the north of Jebel Musa lies the small plain of al-Rahab, in which is situated the fortified convent of St. Catherine founded in 530 AD by the emperor Justinian (Admiralty 1946: 47). Here there are numerous running streams which are utilised to irrigate the extensive gardens of the convent. As with other parts of Sinai, the mountains are heavily dissected by the courses of (usually), dry wadis, which because of the hardness of the granite have cut deep gorges in many places. This is particularly true of the eastern side of the massif, which drops more steeply down to the Gulf of Aqaba, and where the coastal plain is very narrow, if practically non-existent. The coast on the western side has a more extensive plain, al-Qa'.

2.2.6 The northern Hijaz (Midian)

To the east of Sinai, across from the Gulf of Aqaba in the modern state of Saudi Arabia, lies the Northern Hijaz (Figs 2.4 and 2.5). This has three components: the mountainous region of Midian; the associated Wadi Ifal plain area or 'Midian triangle'; and the adjoining coastal plain (Admiralty 1946: 38; Ingraham *et al.* 1981: 64). Geologically the inland mountainous region is a continuation of the Sinai highlands granite massif, which has been divided by the formation of the Jordan Valley – Gulf of Aqaba – Red Sea rift. Hence the landscape is somewhat similar to that of Sinai, with large irregular-shaped mountain peaks heavily dissected by deeply gorged wadis, and further to the southeast by other wadis which divide these highlands into separate massif blocks, with the low-lying country between them penetrating far inland (Admiralty 1946: 39). The highest peaks are Jebel al-Lawz (2580m) and Jebel Debbagh (2350m), which are situated towards the southwestern end of the region (Admiralty 1946: 13; Ingraham *et al.* 1981: 62).

Along the western and eastern edge of the Gulf of Aqaba coastal plains are virtually non-existent, the coastal region being cut by deep gorges producing small alluvial fans into the sea. The triangular plain of the Wadi Ifal occupies the angle between the junction of the Gulf of Aqaba with the Red Sea proper. It is covered in thick evaporate beds which form secondary saline deposits; hence there is little vegetation (Ingraham *et al.* 1981: 64). The wider coastal plain by the Red Sea and the mountainous region behind forms the ancient region of the Midian. To the southeast, the mountainous ridge, which runs parallel to the coast, continues as the Hijaz mountains roughly beyond the line of the Wadi Hamadh (Admiralty 1946: 38). The Hijaz mountains are distinguished from the mountains of Midian in their geological make-up being composed of mainly sedimentary rocks rather than those of volcanic origin (Bowen and Jux 1987: 6-8).

2.2.7 The northern Hijaz sandstone plateau

The plateau immediately to the east of the Northern Hijaz has a mixture of plain, highland, and lava flow features, but an underlying sandstone geology matrix unites all the elements (Fig 2.5). Most of the plateau is taken up by the Hisma, a large broad plateau of red sands just beyond the edge of the rocky Hijaz and Midian mountain ranges (Ingraham *et al.* 1981: 64). These wide sandy stretches are interspersed by isolated sandstone tabletop *jebels* (Arabic for mountain) from which the sand has been eroded, with steep sides and flat tops and ledges. Further to the northeast, the broad flat ridges of the Jebel Shera cut into the plateau from Jordan, and runs roughly from the northwest to the southeast (Admiralty 1946: 41). A distinctive feature of this structure is the deep layer of yellow clay contained within it. Included as part of this range are the impressive tabletop jebels of the Ram highlands which lie astride the border between Jordan and Saudi Arabia. Similar sandstone tabletop jebels form the Tubeiq highlands and their outliers the Hausa hills further to the east (Admiralty 1946: 41). Throughout the region, water is scarce and vegetation limited, although there are a few oases present, including the oases of the great Tabuk basin and Harras, al-Hul, and Teima.

2.2.8 The central Jordanian limestone plateau

The next clearly distinct landscape to the north of the Hijaz limestone plateau has been termed the central desert area of East Jordan or the Jordanian limestone plateau (Admiralty 1943b: 419-20; Baly 1957: 29-30; Bender 1974: 8; Figs 2.5 and 2.6). It covers an extensive part of modern Jordan, extending as far south as the Ras en-Naqb escarpment and the Tubeiq highlands, with the eastern highlands of the Wadi 'Araba bordering the western edge. The area is characterised by sedimentary layers of limestone, which form cuesta scarps (meaning concave and upturned, like the edge of a dish) around its edges. These scarps generally subside to the large flat oval dish-shaped depression of al-Jafr in the southern half of the region, which has a maximum catchment of 150 kilometres. The whole region is covered in fractured, sharp-edged chert detritus, thus giving a rough indication of the length of the arid weathering cycle. The Arabic for such a bleak landscape is *hamada,* the greatest extent of which is known as the Ardh es-Suwwan (Arabic for Flint desert), which lies to the east of the al-Jafr depression and forms a gentle descent down to the Wadi Sirhan depression (Baly 1957: 254-55).

Along the southeastern edge of the central desert area, the sedimentary layers dip upwards, exposing the underlying sandstone layers in the form of the Tubeiq highlands or Jebel Tubeiq (Admiralty 1946: 39-41). These highlands are essentially long lengths of parallel scarp slopes up to 100 metres high, deeply incised by wadis, and interspersed by flat dune-filled depressions. To the southwest, the limestone plateau ends in the escarpment of Ras en-Naqb, which slopes down in a long arc, first towards the southeast, before turning up to the northeast. Lying to the southeast of this escarpment are the impressive highlands of Ram. Within this area, steep-sided sandstone massifs resting on granite rise up to 600 metres out of surrounding mud flats and detritus-filled basins.

The highlands situated along the eastern edge of the Wadi 'Araba also present very steep slopes towards the west and the main valley of the Wadi 'Araba. For example, just to the west of Kerak, the highlands reach a height of 1700 metres above the floor of the Wadi 'Araba. Towards the central plateau, however, the slope is gentle. At certain points these highlands have been deeply cut by wadis flowing westward to the Wadi 'Araba; impressive examples can be seen at the Wadi Mujib and the Wadi el-Hasa, where the wadis have exploited deep secondary transverse fault lines or 'hinge faults' of the main Rift Valley fault (Baly 1957: 21). The average width of this highland region is approximately 25 kilometres, but this increases in width to create an extensive plateau area 50 kilometres wide north of Madaba.

2.2.9 The Wadi Sirhan depression

Southwards from Azraq the Wadi Sirhan depression is encountered, a large enclosed drainage basin (Admiralty 1943b: 420; Admiralty 1946: 39-40; Figs 2.5 and 2.6). Here, within the depression, the slope down from the eastern scarp of the Jordanian Limestone plateau to the west becomes less steep, so that the altitude drops only a further 50 metres far to the south in Saudi Arabia. Bordering the eastern boundary of the Wadi Sirhan is the long barrier of the Harra lava flows. Beyond the Harra flows lies a continuation of the Ardh es-Suwwan, a monotonous, flat and stony limestone plateau named the al-Hamad, which to all intents and purposes lies outside the Nabataean and Roman province (Betts 1998: 2). The Azraq-Wadi Sirhan depression runs for 300 kilometres in length from the southeastern edge of the Harra lava flows, as far as al-Jawf, now in modern Saudi Arabia. The wadis that have developed on the adjacent and sloping Ardh as-Suwwan and to a lesser extent on the Harra, drain into the depression. Hence in a good year, groundwater can be found and located through the construction of wells at many locations, and there are often opportunities for winter grazing in this otherwise dry environment (Lancaster and Lancaster 1999: 109-10). There are also a number of important oases such as Azraq, which lies at the head of the depression in the northeast is a large oasis with perennial springs. There are also examples of smaller oases, such as those at Kaf and Ithra in the south (Nelson 1973). Just beyond the southeastern end of the Wadi Sirhan is a plain of Cretaceous sandstone, which contains the depression of Juba in which can be found the historically important oases of al-Jawf and Sakaka (Admiralty 1946: 40).

2.2.10 The northern Harras

East of a line from modern Mafraq–Azraq–Wadi Sirhan lies the northern end of the desert which covers much of the Arabian peninsula to the south, known as the Bilad esh-Sham or Syrian desert (Fig 2.7). From Mafraq in the north, the whole plateau dips gradually towards the south-southeast from the north-northwest. Hence, altitude varies from 1100 metres above sea level around Mafraq down to 550 metres at Azraq. Bender (1974: 6) divided this area into two morphological units, that of the al-Hamad and the Harra. The topography of the region is dominated by an extensive area of lava flows and basalt rocks up to 100 kilometres wide and reaching 250 kilometres in length towards the southeast (Betts 1998: 1-4; Helms 1981: 19; Wirth 1971).

Around 45,000 square kilometres are covered by basalt lava flows, from the edge of the Damascus basin down to the Wadi Sirhan depression in Saudi Arabia, interrupted only by shallow wadis, isolated hills, and strings of small low volcanic cones. This rough lava and rock-strewn country, which is difficult to traverse, has been long called by the Bedouin the Harra or Harra es-Shabha (which aptly, means burnt land in Arabic) and 'The Black Desert' by European travellers (Braemer *et al.* 1996b: 1). The lava emanated from a number of fissures in at least six successive flows over a relatively short period of time (Tarawneh *et al.* 2000). These flows solidified into layers of hard basalt, each on average 30 metres thick. The resulting flattish plateau is broken by a number of fissure cones and the downcutting of a series of generally easterly flowing wadis. These wadis radiate out from the high relief of the Jebel al-Arab cutting across the lava flows, and have long formed the main lines of communication across this difficult area. In a relatively waterless region they also provide the main access points to water, hence any forms of settlement are naturally to be found located along the edges of these wadis.

2.2.11 The volcanic Jebel al-Arab, the Hauran and the Golan

This volcanic region, generally known as the Hauran, marked the northern boundary of the Roman province of Arabia. Dominating the region is the large basalt mass of the Jebel al-Arab (formerly named the Jebel Druze) that forms a large ellipse some 136 kilometres from north to south by 72 kilometres east to west (Admiralty 1943a: 29-31; Wirth 1971; Fig. 2.8). Although this mass reaches a peak of some 1785 metres above sea level, the ascent to it is gradual, so that its scale is lessened. The summit area forms a large flattish plateau broken by occasional small volcanic cones. The altitude of the Jebel ensures there is plenty of rainfall during the winter months, and many watercourses drain the slopes, however, these are generally dry for much of the year (Dufourg 1955). Furthermore, many small perennial springs have developed on the slopes, particularly on the western side. The rainfall and springs have ensured the western slopes are covered in vegetation, though moving east the plateau becomes progressively drier and very stony.

To the west of the Jebel is the Hauran proper or as it is sometimes known, the Nuqra plain whose rocky extention to the west, has been long called the Golan (or Jaulan) (Admiralty 1943a: 31-32; Miller 1984). This plain is a large, dry, treeless, undulating expanse at a height on average of 600 metres above sea level with many boulder patches and basalt outcrops, and dissected by wadi beds. However, it receives plenty of rain in the winter months, which has led to the decomposition of the basalt, and the development of a rich cultivable soil (Admiralty 1943a: 32; Villeneuve 1986a: 67-71). To the northeast of the Nuqra plain is the seemingly impenetrable hardened basalt lava flow of al-Ledja, one of several which have emanated from the volcanic cones of the Jebel, and whose edges rise eight to ten metres above the surrounding plain (Admiralty 1943a: 31). To the south, the plain becomes progressively more arid, and hence basalt boulders and stones become more prominent. This is the sub-region of the Southern Hauran, which is now within the borders of the modern country of Jordan (Kennedy and Freeman 1995).

2.2.12 The 'Ajlun highlands

Although structurally part of the Central Jordanian Limestone Plateau, the 'Ajlun highlands present a distinct landscape, bounded by the courses of the Yarmuk and Zerka wadis and the River Jordan in the east (Admiralty 1943b; 407). Rising to a height of 1000 metres, the highlands represent a dome of Cenomanian limestone which has been pushed up in a large upwarp, which subsequently split into two plateau masses which are today heavily dissected by valleys (Baly 1957: 226). The central region is rich in springs, but these are generally absent on the eastern slope and the western high plateau (Admiralty 1943b; 407). The region today is thickly forested, interspersed with many small cultivable valleys and plains, and so resembles a typical Mediterranean environment in contrast to the rest of modern day Jordan.

2.2.13 The Wadi 'Araba – River Jordan – Rift Valley

Finally, the Wadi 'Araba, Dead Sea, Jordan valley and Bekaa valley of Lebanon and Syria form one continuous rift which is part of the Great Rift System extending to Mozambique in southern Africa (Fig. 2.9). This Great Rift extends for a distance of about 6000 kilometres, of which the Wadi 'Araba–Jordan valley runs for around 360 kilometres in a north-south direction from Lake Tiberias to the Gulf of Aqaba (Bender 1974: 25). The width of the valley floor averages from around five to 25 kilometres, and is covered in Quaternary deposits eroded from the surrounding highland plateau regions. From the Gulf of Aqaba the floor of the Wadi 'Araba gradually increases in height up to 250 metres above sea level at a point 80 kilometres from the sea, from here it drops down to 390 metres below sea level to the small planar region of the southern Ghor and the Dead Sea. The entire length of the eastern edge presents a high mountainous escarpment, whereas the western edge in the southern half is lower lying hills, which gradually increase in height. The very saline Dead Sea occupies a steeped walled trench for its entire 80 kilometre length, to its north lies the valley (or el-Ghor) of the River Jordan, which extends for a further 100 kilometres up to the freshwater of Lake Tiberias, at which point the valley floor is 212 metres below sea level (Bender 1974: 11). Due to its very low elevation the valley as a whole receives minimal precipitation in comparison with adjoining areas. The northern half receives perennial surface water from the surrounding highlands, but moving south this increasingly lessens in quantity, so that the Wadi 'Araba, with the exception of small perennial springs, is a particularly dry desert environment.

2.3 Climate

The various climatic zones of Jordan are the result of two main factors: topography, and the dominant synoptic climatology of the eastern Mediterranean basin (Wigley and Farmer 1982). At present, the latter weather feature alternates between winter and summer cycles (Shehadeh 1985: 29; Taha *et al.* 1981).

2.3.1 The winter synoptic cycle

In winter, the relatively cold land masses of southern Europe and the Atlas mountains and the warm waters of the Mediterranean sea affect the air above them, leading to the collection of different centres of pressure as follows:

2 High Pressure – develops over Turkey, Armenia, northern Iraq and the Arabian peninsula.

3 Low Pressure – because of the thermal difference between the Mediterranean sea and its adjacent land masses in the north and the south, low-pressure systems develop in the central and eastern Mediterranean basins.

4 High Pressure – the Azores high-pressure system often expands to include the land mass to the south of the Atlas Mountains.

As areas of low pressure, such as those over the central and eastern Mediterranean, draw into them air flows from high pressure areas, the Mediterranean comes under the influence of cold air masses originating either in the Arctic (cA) or the north polar region (cP). The disturbance they create results in the development of a series of moisture-bearing depressions. Squeezed between two regions of dominant high pressure sitting on the adjacent Mediterranean land masses, a developing cyclonic system is inevitably pushed along the line of least resistance across into the Near East land mass.

Studies have shown that most depressions formed during the winter in the eastern Mediterranean move across the Near East along three general directions. The specific direction a depression will take depends largely on the strength and position of the high-pressure air masses over Armenia, northern Iraq and the Arabian peninsula. Observations over many years have revealed the following ratios of cyclones for each direction over an average winter cycle (Meteorological Office 1962):

10.5 cyclones	North East – through northern Syria and southern Turkey
11 cyclones	East – over southern Syria/northern Jordan, of which a few reach northern Iraq
1.5 cyclones	South East – into southern Jordan.

Hence it is clear that as one moves from the north of Jordan to the south, the potential amount of precipitation received in the winter months will normally decrease.

2.3.2 The summer synoptic cycle

As the European/Asian and north African land masses warm up during the summer months, new zones of air pressure develop:

2 High Pressure – develops over the Mediterranean

3 Low Pressure – originating over the Indian Ocean, a large belt of low pressure gradually extends into north Africa, India and Pakistan

4 High Pressure – forms over the large dry land masses of Turkey, Iraq and central Asia.

The hot, dry continental air masses are subsequently drawn from the high-pressure zones of Asia towards the low-pressure zone of the Indian Ocean. Consequently, the Near East as a whole receives very little precipitation throughout the summer. If a temporary low-pressure zone forms over the northern Red Sea and the Arabian peninsula, warm air masses are drawn directly to it over Syria and Jordan, leading to very high temperatures.

2.3.3 Precipitation

As can be seen above, most of the Near East receives the majority of its annual precipitation during the winter months. Apart from the specific course of a depression over the Near East, the other major factor to influence the spatial distribution of rain and snow is the region's topography (de Brichambaut and Wallén 1963).

Along most of the Near East coast, a barrier of high relief confronts incoming rain-bearing depressions. To the north, the Lebanon and anti-Lebanon Mountains, which run almost parallel to the coast, constitute a considerable block. South and west of these mountain ridges lies the large mass of the Jebel al-Arab, and much of modern Israel consists of a high plateau. To the east of this, on the eastern edge of the Wadi 'Araba-Jordan Valley rift, the highlands constitute the highest elevations in Jordan. All these areas receive most of the precipitation from the incoming depressions in the form of relief rainfall.

Due to the adiabatic heating of these moisture-bearing winds, which occurs as air descends on the lee slopes of a relief area, the decrease in rainfall is often very dramatic and sudden. For example, the University of Jordan, which lies in the eastern outskirts of Amman near the summit of the plateau, has an average annual rainfall of 474 millimetres, whereas Amman Airport less than ten kilometres to the east receives on average only 290 millimetres (Shehadeh 1985: 30). Variability of rainfall is increased by the topographical location of high relief as well. As a high percentage of moisture falls as rain on the Judaean plateau, there is a much lower amount available when depressions encounter the relief areas of the interior, so total annual rainfall is significantly lower.

2.3.4 Summary

The average annual rainfall map for the Near East reveals a picture of marked contrasts (Fig. 2.10). The amount of rain varies considerably, from both east to west and from north to south. This simple fact has enormous significance for the settlement patterns of the Near East, although other factors such as the availability of perennial springs and natural aquifers distort the picture somewhat. It also has to be borne in mind that a particular region's climate has been shown to be subject to change over time (Lamb 1995). The potential effect of long-term climate change on settlement patterns has been suggested as one major factor to explain the expansion of settlement in the Roman period. Hence in view of current knowledge of climate change, the climate regime enduring in the Roman period might have been quite different from the present, a problem that will be discussed further below (Section 2.5).

2.4 Geomorphology, soils and hydrology

The largest influences on the availability of surface water are the climate and the influence of altitude; within localised areas, orographic (altitude) controls can increase the amount of rainfall. The other main source of water in the Near East is that of groundwater, which is either stored close to the surface in wadi and other alluvial sediments or deep below the layers of sedimentary rocks in an aquifer as a fossil groundwater (Burdon 1982: 76; Roberts and Wright 1994: 513). Based on a number of different factors, perennial rivers and streams persist in certain regions of the southern Levant. The factors which lead to surface flow in the form of streams and rivers are in areas of high precipitation, as both rain and snow; or through the seepage of groundwater from aquifers in the form of springs. Both such phenomena occur within the former province of Arabia. However, the vast majority of perennial stream flow derived from precipitation is to be found mainly in the northern regions.

Of the perennial rivers within the region, the most important in terms of volume of flow is that of the River Jordan and its tributaries. The Jordan river network forms a self-contained inland drainage system; that is, there is no outlet to the sea, a feature of many river networks in dryland regions. The River Jordan itself rises at the junction of four tributaries, three of which originate on the slopes of Mount Hermon, just north of the former Lake Huleh. The water of these tributaries is spring water which derive a large proportion of their volume from snow-melt water that covers the summit of this very high mountain for much of the year (Ionides 1940: 135). After flowing out of the Huleh region, the Jordan continues into the larger Lake Tiberias. At the southern end of this lake there is a river outlet into the Jordan Valley proper.

Between Lake Tiberias and the Dead Sea the River Jordan is joined by a number of perennial tributaries which drain the highlands on either side. The largest of these, that of the Rivers Yarmuk and Zerka, both lie at the base of deeply incised valleys, and their drainage systems embrace a huge area of the plateau to the east of the Ajlun Highlands region (Admiralty 1943b: 406). In the case of the Yarmuk this includes part of the Jebel al-Arab, which generally receives a substantial amount of precipitation in the form of snow during the winter months. Hence, in relation to the Zerka system, the Yarmuk obtains a higher volume of snow-melt water, and as the Jebel al-Arab has a higher average rainfall per annum than the plateau which the Zerka drains, higher rates of rainfall runoff. In addition, the Jordan, Yarmuk, and Zerqa rivers all receive a substantial proportion of water supplies from spring sources. The output from the springs, particularly in the sedimentary limestone and sandstone region of Ajlun, is in turn influenced by rainwater infiltrating down into the water table and aquifers. Consequently, within certain parameters, each of these rivers have variable discharge rates from month to month with peak flows at different points in the winter season.

This is just one example of the multitude of factors which influence the volume of flow in one particular perennial river at any one point in time. As well as temporal variables, a spatial variable in terms of the particular latitude and geographic position of a drainage basin becomes increasingly influential as one moves further south and east. This is because the overall influence and input of precipitation into perennial streams gradually decrease, and consequently the output of springs becomes proportionately more important. In addition, the potential loss through evapotranspiration increases, until a point is reached when the average daily output from springs is insufficient to replace the losses through evaporation; the watercourse for much of its length then remains dry, except following a period of precipitation when flashfloods can be expected. In the south, in regions of high relief which have been heavily dissected by the various processes of erosion, particularly those of salt and water, the natural aquifers have often been reached so springs often occur.

Therefore, streams of perennial water are quite common in a number of highland regions where groundwater basins with stocks of fossil water have been exposed, but such streams are commonly not very extensive in length as in the warmer conditions of the south evaporation is strong. For example, the deep gorged Wadi el-Hasa has cut through a number of aquifer basins, resulting in the volume of water from the small perennial stream of el-Hasa into the Dead Sea being consistently higher (0.75 cubic metres per second) than other comparative wadis such as the Wadi Mujib (less than 0.5 cubic meters per second) further north (Ionides 1940: 176-78). Other highland areas are very much drier, such as the highlands of Midian, which are composed of relatively impervious igneous granite. On the flat plateau regions where there is less erosion and the aquifers are buried below up to 500 metres of sedimentary rocks, the opportunities for spring development are few. In the few locations where springs have developed, such as at Azraq and Ma'an, these thermal springs, often associated with volcanic activity, have been responsible for the development of oases.

A combination of climatic factors and relief ensures that south of a line from Tel Aviv on the Mediterranean in Israel, across to the highlands of Samaria and to the line of the Wadi Zerka in Ajlun, perennial rivers cease to exist, with the exception of one or two spring-fed examples. Beyond this point any surface water flow is generally ephemeral, and is dependent on sporadic episodes of concentrated rainfall. In turn, such surface flow as occurs is influenced by the ground environment it encounters, both in terms of topography, such as the steepness of slope, and the specific surface conditions, such as the presence and condition of any soil and vegetation.

Various geomorphological investigations have sought to explain the processes operating in the production of flashfloods within these otherwise semi-arid and arid regions. The key factor in the generation of a flashflood is the production of rain from stormclouds. Within this southern region, as we have seen above (Section 2.3.1), these are often isolated penetrations beyond the usual paths of depressions. Furthermore, when rain does occur, it is often associated with discrete convective cells, as has been demonstrated for precipitation in the Negev (Sharon 1972). This means that rain is generally only precipitated from small discrete areas, typically with a diameter less than ten to fourteen kilometres, within a frontal depression at any one time. Consequently, each discrete cell may only bring rain to part of a drainage catchment, while groups of cells will bring rain to different parts but not others (Schick and Lekach 1987: 382). Therefore, the acquisition of rain is highly variable even within small areas, so that some tributaries within a drainage basin could theoretically produce a succession of floods within a short period of time, while a neighbouring tributary could remain dry for successive years (Reid and Frostick 1997: 207).

When a particular area receives rainfall, overland flow can be generated in two ways (Baird 1997: 165). The first of these, referred to as 'Hortonian overland flow', occurs when the rate of rain arriving at the surface exceeds the rate of infiltration, and eventually flow events begin when small surface depressions fill to overflowing (Horton 1945). The second is generated by a rise in the level of the water table, usually as a consequence of earlier infiltration by rainwater, until the ground becomes saturated and excess rain flows on the surface. Both phenomena take place within arid and semi-arid zones, but the first type, the Hortonian overland flow, is a far more common event. Soil surfaces within drier regions and the high intensity rainfall of a storm often combine to increase the problem of surface flow, for uncovered bare soils in arid zones can often develop a variety of seals or crusts rendering the soil impervious to high amounts of infiltration (Baird 1997: 169; Dunkerley and Brown 1997: 58-60). One such seal tends to form during or soon after a rainfall event. These 'rainbeat crusts' result from the breakdown of the soil surface by rainsplash and slaking, causing soil particles to move around and clog pores and eventually compact. The compaction is strengthened as the soil surface dries out, creating a hard smooth and quite impervious crust. Other crusts are formed by the evaporation of water from the surface and by microscopic algae and mosses.

In many regions the surface is a mixture of soil particles and rocks or may even be almost purely a stone-covered landscape. The presence of stones and rocks assists in the evolution of surface flow, as has been successively demonstrated in a number of studies. The result of precipitation falling on these hard impermeable surfaces or soils covered in impermeable crusts is the rapid generation of large surface flows, which can quickly gather in the wadi bed creating a flashflood. However, some water is inevitably absorbed by any soil surfaces into which it comes into contact through the eventual breakdown and erosion of the soil crust by rainsplash (Dunkerley and Brown 1997: 63). When surface flow is created, material is rapidly dislodged and transported in suspension by the water. This means that erosion levels are very high, flood events have produced the highest values of suspended sediment, as much as 68 per cent of the flow has been recorded as being of solid material (Reid and Frostick 1997: 215). This demonstrates the high erosive power of water in a desert environment, but because of the short length of time in which such flows occur, there is also rapid deposition of this sediment as soon as velocity and volume of water decreases (Reid and Frostick 1997: 220).

As a result of the interaction of different localized climatic conditions, geology and geomorphological processes, a variety of soil types have developed across the region, which in turn can affect vegetation growth, an important consideration in land use and the production of crops. Nine general soil types can be ascribed to the region of which the most agriculturally useful are the 'Terra Rossas' (Bender 1974: 187-193). These 'Terra Rossas' or Red Mediterranean soils cover large areas of the northeastern parts of the southern Levant, particularly much of northern Israel, the Ajlun highlands, and the crest of the highlands east of the Rift valley as far as the settlement of Shaubak on the Edom plateau (Bender 1974: 187; Fisher 1978: 87). Being low in sand and humus content, but high in clay and carbonates, these soils hold a great amount of moisture, but can form a hard crust surface, which makes them hard to plough and increases surface run off. However, because of their high fertility, such soils are capable of supporting a wide range of crops, including cereals, vines, and fruits (Bender 1974: 189: Fisher 1978: 82). Between the Red Mediterranean soils and the Yellow Steppe soils is often found a transitional zone of so called Yellow Mediterranean soils (Bender 1974: 189). Yellow Mediterranean soils are a consequence of the breakdown of loess-like sediments, calcareous rocks and basalts within a semi-arid climate where the precipitation is between 250 and 350 millimetres per annum (Bender 1974: 189). These Yellow Mediterranean soils can vary from silty clays to clay loams, and often contain many stones (Fisher 1978: 81). Furthermore, these yellow soils have a high gypsum or carbonate content which develop into concretions below 50 centimetres depth mark but can be used for the cultivation of cereals in a dry farming regime or for pasture (Bender 1974: 189).

The Yellow Steppe soils cover a wide expanse east of the Yellow Mediterranean, and parts of the Rift valley and Negev. They have similar rock bases as the Yellow Mediterranean, except on the eastern side of the Wadi 'Araba where they are formed from sandstones, in a dry warm semi-arid climate. These steppe soils can usually only support grazing, apart from the Amman region where barley can be grown. However, Bender has pointed out that often 'the yields of Yellow Steppe soils can be improved by intensive irrigation' (1974: 190). Different types of Grey Desert or lithosoils soils occupy more than half the area of modern day Jordan soils and are undeveloped as soils, that is, not subject to chemical weathering, shallow in depth, and contain less than half a per cent of organic matter (Bender 1974: 190 Fisher 1978: 80). Patches of accumulated salt are also common in these areas, along with coarse sand, gravel, gypsum and sandy loams (Fisher 1978: 80). In large parts of the Negev, Sinai and parts of the Wadi 'Araba, for example, loess type soils have developed through the transportation by wind of fine sands, silt and clay. Such Loessic type soils if irrigated with non-saline sources of water can produce good crops (Fisher 1978: 81). Other more localized soil types include; the dark humus-rich Rendzinas of the Ajlun highlands, and wadi beds along the edges of the Rift valley; these are often associated with Grumosols or Marl soils (Bender 1974: 192). In areas of high groundwater, humus-rich Solonchak soils have developed, characterized by a high sodium, calcium and magnesium salinity. The southern Ghors and depressions and mudflats of the semi-arid and arid zones have such soils (Bender 1974: 193).

2.4.1 Summary

This overview of geographical, climatic, topographic, geological, and hydrological variations within the southern Levant has highlighted the huge differences apparent within this relatively small region. It serves to emphasize the many restrictions to the foundation and growth of settlements and points to the fact that agriculture and permanent settlement could only be maintained in certain productive regions and locations where certain parameters permitted this. Most notable of these parameters is a reliable source of water, for the sustenance of humans, their domesticated animals and crops. Access to sufficient supplies of water alone is not enough to guarantee a successful settlement; when the practice of agriculture is being considered other considerations have to be taken into account because many areas with water are unsuitable for the growing of crops, or is subject to devastating erosional processes or the threat of salinization. This is particularly the case when we consider some of the southerly wadis containing perennial streams of water: the wadi el-Hasa, to name one example, occupies a very deep valley with little acreage that can be usefully farmed (Ionides 1940: 179).

2.5 Climate and environmental change

2.5.1 Introduction

Although knowledge of the topography, geology, soils and climate is fundamental to any exploration of settlement, land use and water management of the Levant in antiquity, it is vital to understand that the environmental conditions which prevail at present may not have been those of the past. For example, environmental conditions, particularly climate, may have been more beneficial to people of the Classical periods, thus making settlement in what are now arid regions more easily attainable. The subject of climate and environmental change has therefore naturally attracted a wealth of research and a succession of explanations have been posited to confirm or deny critical changes in the evolution of human societies from many time periods. Since the beginning of serious archaeological research in the early twentieth century, the apparent mass settlement of marginal regions of the Levant within the Roman and Byzantine periods has been explained as a consequence of higher rainfall during these periods. The first to suggest such an argument was the American historian Edward Huntington to explain the extensive ruins of settlement in the arid Negev Desert (1911). The debate has continued intermittently since then, with renewed interest in recent years brought about by developments in four key areas: the development of sophisticated technology and computer models in meterological science; new methods to analyse evidence in the study of past environments; and two crucial issues, the scientific investigation of the increasing effect on today's climate from carbon dioxide and CFC gas emissions, and concerns about the apparent spread of desertification by various causes (UNESCO 1997).

2.5.2 The evidence for climate and environment change in the Classical Levant

A review of the available evidence put forward as proof of climatic change in the Roman and Byzantine period presents a confused picture of conflicting data and arguments. However, none of this evidence in any way suggests that the Levant then experienced a different climate compared with today. Most writers agree that the general climatic conditions prevalent in all parts of the Levant today emerged during the Early Bronze Age II and III (3000-2400 BC) (Goldberg and Bar-Yosef 1982: 404). What is still actively argued over is the existence and date of a general period of slightly higher precipitation, at some time between the years 34 BC to AD 640 (e.g. Bintliff 1982; Rubin 1989; Wagstaff 1985: Yair 1994). Various forms of evidence for this climate and environmental change have been collected to argue if and when such a change in climate may have occurred (Newson 1997: 13-30). Such studies have included interpretations of historical sources which allude to climatic conditions, either directly, such as the very basic weather diary of Ptolemy which covers two years of weather in Alexandria around the mid second century AD, or more commonly to unusual climatic events, such as droughts, storms, hail and frost, recorded in texts and documents such as the works of Josephus in the *Antiquities* and the Jewish Talmud (Josephus XV.9: 299-310; Butzer 1958: 122; Sperber 1978: 70). Chance references to environmental conditions at certain locations in antiquity can also give slight indications and provide useful comparisons with today. For example, Strabo (who lived in the first century AD, but whose work is based in part on that of the third century BC Greek geographer Eratosthanes of Cyrene) wrote of the country around Petra in these terms: 'most of the territory is desert, in particular that towards Judaea' (16.IV.21). Further, a certain Nilus described his journey in the fifth century AD as being from Sinai 'to the desert city of Elusa' (Rubin 1989: 74).

Written records are one course of enquiry, but palaeoenvironmental methods have proved useful, with potentially accurate indications of the general pattern of climate and any associated change over decades and centuries rather than years. There are four main groups into which this 'proxy-data' evidence can be divided, each providing physical evidence in the present of climatic conditions in the past (Lamb 1995: 105-107; Rubin 1989: 73). The first concerns the interpretation of various archaeological remains for clues to climate.

As shown in Chapter 1 the different housing types, water and aqueduct systems of the Near East can provide useful general indicators in terms of areal and temporal use. Recent geological and geomorphological history form a second area of interest, and one which has been extensively analysed in the arid Near East for lack of other suitable strands of evidence. Erosion and sediment profiles; hydrological indicators revealing sea, lake and river levels; rates of soil development; aeolian movements of sand and loess – all have here provided dates of varying precision and accuracy (e.g. Bruins 1994; Frumkin *et al.* 1991, 1994; Goldberg and Bar-Yosef 1990; Klein 1982; Schuldenrein and Clark 1994; Vita-Finzi 1969, 1976; Wagstaff 1981; Yair 1994). Another area is environmental isotope data gained from analysis of the variations of carbon and oxygen composition of various hydrologic materials, particularly speleothems, marine and limnologic sediment cores and marine and limnologic mollusc shells (e.g. Geyh 1994; Goodfriend 1991; Issar *et al.* 1992; Neev and Emery 1967; Stiller 1984). Such analyses, according to Geyh (1994: 131-2), can provide the most precise chronometers of climate available. Finally, three strands of botanical evidence form the final area of analysis: palynology, dendrochronology, and dendroarchaeology (selected botanical remains in archaeological contexts) (e.g. Baruch 1990; Horowitz 1979, 1992). However, because pollen and wood survival is rare in arid regions, palynological and dendrochronological studies have been restricted to a few exceptional locations and finds (Rösner and Schäbitz 1991: 77; van Zeist and Bottema 1982: 277).

One of the chief pillars in support of a wetter period, 'the Historical Fill' theory, has come under severe criticism in the 30 years since it was first postulated by Vita-Finzi (1969). Vita-Finzi argued that the fills were the products of climatic change rather than human agency because of their apparent ubiquity and synchrony across the Mediterranean basin. The change in climatic regimes altered the course of the rivers and streams as a direct result of increased precipitation and its more even distribution across the year (Vita-Finzi 1969). Due to these changes, the erosional and transportational capacities of streams also increased, though these were not capable of completely removing the acquired load and so sedimentation took place only a short distance downstream. The finer grained, better sorted, and well-bedded characteristics of the 'Younger Fill' suggest that the streams behaved less erratically than during the earlier Pleistocene 'Older Fill' aggradation and also suggest that there was a higher water table, with standing water for much of the year even in the drier areas (Vita-Finzi 1969: 113). Many of the recent surveys of the last 20 years or so, particularly in other parts of the Mediterranean, have credited people with causing the development of both historical fills rather than climate change for a number of reasons (Barker 1996; Davidson 1980; Wagstaff 1981).

However, the whole process of fill formation must be the result of a number of complex interactions involving water and soil mechanics of which many have not been fully understood. The existence of sediment at a particular place in a valley could reflect a climatic change or human interference on the environment, but it also reflects aspects of the local topography, soil quality, vegetation, and the stream itself. Investigations of the stream regimes based on precipitation amounts in Greece have revealed that erosion rates, sediment yields, and transport capacities are unlikely to be similar in different regions or even those of adjacent valleys due to unique combinations of physical factors. Even the amount of rain received from year to year in one particular region varies considerably in comparison to others. All these variable factors combine in governing a stream's regime and have been suggested as 'sufficient to explain the characteristics of the Younger Fill' (Wagstaff 1981: 258).

Bintliff has argued that 'only if the input of sediment is far beyond stream capacity will alluviation normally develop along the full length of a river system.' (Bintliff 1982: 157). The only scenario that would suit such conditions would be locations where rapid erosion could take place on exposed hill slopes. For the southern Levant the hill slopes have always been exposed, so only two variables can really be held responsible for increased erosion. The first is an increase in annual precipitation generally. For the Classical period, although the annual amount of precipitation might vary from year to year, some years might be still extremely arid, but over a long period the precipitation would on average be a lot higher than previous periods, enough to shift large quantities of sediment. The second is the effect on the environment by humans. Following the abandonment of the desert farming systems, centuries of soil would have been released to choke the streams. Eventually the system would have stabilised again, with any natural vegetation colonising and holding the soil back in certain areas. Erosional activities, once the excess had been cleared away, would resume at their normal rates (Bintliff 1982: 157). The other option is that the fill might be the result of a combination of both these variables. The evidence for any of these options is impossible to distinguish clearly and has been seen as 'a major stumbling block' to further progress (Wagstaff 1981: 261). The argument over the appearance of the 'Younger Fill' cannot however be properly settled without more detailed information on the complex interactions of land use, erosion, vegetation, soils and the seasonality and/or intensity of precipitation (Gilbertson 1996: 293).

The essentially complicated nature of the formation of the 'Younger Fill' means that at the moment it cannot be used with confidence as an argument for or against the influence of humans or climate change on the environment of the Near East. Other more unequivocal evidence has to be used if we are to present a clearer picture of climatic conditions 2000 years ago. Palynological investigations seem to offer concrete evidence in favour of humans interacting with their immediate environment. The pollen diagrams available for Lake Van, Huleh Basin, the Ghab Valley and Lake Kinneret show noticeable decreases in the percentages of arboreal vegetation and an accompanying rise in pollen of other taxa such as the weeds of arable cultivation, grasses and cereals (Baruch 1990; Rossignol-Strick 1993; van Zeist and Bottema 1982).

The abundant archaeological evidence for olive production supports the view for substantial anthropogenic interference upon the local landscape (Baruch 1990: 284). This view would no doubt have been enhanced if more delicate pollen of other taxa, notably vines and walnuts, known to have been cultivated in the area (as mentioned by Josephus e.g. *The Jewish War* III.46) had survived. Anthropogenic interference begins somewhat earlier in other areas of the Levant, as is shown by the declining numbers of deciduous oak pollen percentages in the Ghab valley (*c.* 3500 to 4500 years ago) and Lake Huleh (*c.* 4500 years ago). In the Ghab valley and Lake Huleh appreciable rises in *Olea* sp. and *Pistacia* sp. pollen at these times have already been noted (van Zeist and Bottema 1982: 280-284). Even at Khatouniye the high sedimentation rate of 0.87 centimetres per annum, which continued for 135 years during the period of the third to first centuries BC, has been interpreted as 'a consequence of advancing the border of cultivated land far towards the desert steppes' (Rösner and Schäbitz 1991: 85). On the other hand, the collapse of the steppic vegetation as revealed by the pollen in Wadi Faynan, could represent the consequences of a shift to pastoral agriculture rather than climatic change (Hunt and Mohammed 1998). After centuries of overgrazing, there would be a cumulative loss of soil and vegetation from slopes and hillsides, and this could well have been the case in Wadi Faynan. On the general point, most writers agree that the removal of vegetation from semi-arid land and its subsequent cultivation will result in undue levels of erosion (Wagstaff 1981: 258).

Such events are well attested for Asia Minor and the Fertile Crescent, which have been considerably altered by intense human activity. Among countless examples of human impact on the landscape of these regions can be mentioned the conversion of rivers into canal systems, and the development of vast irrigation networks, subsequently rendered useless through salinization, and their total deforestation (Butzer 1995). Consequently, 'rainwater ran off rapidly and surged in downstream floods, failing to replenish underground reservoirs of water' (Butzer 1995: 124), soils were eroded and springs and streams once perennial became permanently intermittent. Increased erosion correlates well with cultivated crops if the pollen diagrams and sedimentation rates of cores taken from Lake Kinneret are compared (Baruch 1990; Stiller 1984). Both sequences reveal increase in pollen from cereals from around 3000 years ago, along with a relative increase of non-siliceous algae, thus pointing to human interference in the environment of the local region (Goldberg and Bar-Yosef 1990: 81-82; Rubin 1989: 76).

If the change of vegetation types in the Wadi Faynan is an example of humanly-induced desiccation, this could in theory be usefully interpreted as physical evidence of the consequences of anthropogenic interference as predicted by the 'Charney Model' (Gilbertson 1996: 247). The model predicts that large-scale removal of vegetation by overgrazing will result in bare land surfaces with a higher albedo (the reflectance of incoming solar radiation back to space). Hence, air crossing this surface, which is now cooler and more reflective, will itself be slightly cooled and sink downwards. As it does it will be heated and compressed. Accordingly less rain is inclined to fall and 'under certain conditions this humanly-induced drought may become self-perpetuating' (Gilbertson 1996: 297). The model was devised as an explanation for the prevailing conditions in the Negev. Although Gilbertson surmises this effect would not be of regional climatic significance unless 'bad practice' was administered on a large scale, he does not believe that recent land changes in the eastern and central Sahel, of the Sudan were affected by it (1996: 298). It is also conceivable the reported droughts in Palestine during the late third century AD were the result of this 'Charney Model' effect. However caution must be exercised in taking the Rabbinic sources, of the Jewish Talmud, at face value for use as evidence, as many of the documents seem to follow a kind of literary formula or *topos*. First the Rabbi prays for rain, but none arrives. The Rabbi then despairs and exclaims that times were better for the previous generation and becomes very upset. Then it rains (e.g. Sperber 1978: 76). This could perhaps more readily describe the not-infrequent seasonal rain cycle in Palestine, with the rains arriving late, rather than a long period during the third century of increasing dryness, as it has been presented (Bruins 1994: 307; Sperber 1978). Of course this does not mean that severe droughts never took place, just that the written evidence in such cases has to be looked at very carefully and used with great caution when attempting to prove that climate change occurred.

Prolonged drought is listed as just one of the principal causes of the agricultural decline of certainly Palestine, and perhaps much of the Levant. Other reasons for the growth of *agri deserti* in the late third century AD have been identified, such as soil exhaustion, erosion, pressure of barbarians, labour shortages and perhaps more importantly land abandonment, caused by excessive taxation (Sperber 1978: 45). A ten to fifteen per cent reduction in agricultural area has been claimed, with a high proportion seemingly among difficult-to-farm marginal areas, as many parts of the south and east Levant along the line of the 200 millimetre isohyet undoubtedly were (Jones 1964: 812-823). It is at this time that the sharp decline in olive pollen occurs in the Lake Kinneret cores and so rather than reflecting any change in climate, the pollen might represent an economic downturn in the fortunes of the Roman Empire (Baruch 1990: 284; Wagstaff 1985: 141). The same analysis could be used in interpreting the end of the high sedimentation rate for Khatouniye (Rösner and Schäbitz 1991).

The disturbance of the natural landscape in southwest Asia in terms of vegetation change and erosion effects on topsoils had been an ongoing feature for centuries before the Roman period. Hence, in the pollen profiles of the Huleh basin and the Ghab valley, a very high percentage of the *Quercus* sp. forest cover seem to have been cleared by the Middle Bronze Age (2150-1500 BC) (van Zeist and Bottema 1982; van Zeist and Woldring 1980). Most of the forest at Lake Kinneret was cleared during the Middle Bronze Age, but olive cultivation did not appreciably rise until between 2,400 and 1,400 BP (400 BC – AD 600), which might initially have been started by a slight increase in moisture (Goldberg 1986: 81; Horowitz 1979: 227). If the assumption is made that some of the clearance was achieved by widescale burning of the vegetation, then a fair amount of charcoal survival should be evident in the local alluvium, as has been the case for evidence of Australian prehistoric forest clearance. This is, however, very rare for the Holocene (Goldberg 1986: 82), making climate change seem more plausible.

The idea of a moist period is increased when the evidence for algae is analysed. At Wadi Faynan the presence of algae is held as testimony to periods of standing water (Mohammed and Hunt 1999). The same is true of snails such as those found in the fill of the now arid Wadi Rama (Vita-Finzi 1969: 86). The palynological and sedimentological evidence from Khatouniye suggests a slightly more humid climatic oscillation during the Roman period (Rösner and Schäbitz 1991). There is as yet no other reasonable explanation to account for the large quantities of *Quercus* sp. pollen at this time, unless they had blown in from the north, which still suggests a consistent change in wind direction and hence climate. Issar *et al.*, in comparing the composite $\delta^{18}O$ and $\delta^{13}C$ time-series for speleothems (secondary cave deposits usually composed of calcium carbonates) and cores from Lake Kinneret, obtained a very good match (1992: 220-222). Considering the two data collection areas are in different climatic zones (the speleothem isotopes being obtained from caves in the very arid Dead Sea area, the cores from the more humid north), the results cannot be surprising if the best explanation and correlation between the two are a prevailing moister climate. Certainly there has to be a simplification of other factors, but the message from such a comparison seems clear and reasonable.

It is also hard to dispute the changing levels of the Dead Sea. Klein has argued for a 70m discrepancy between the height of the Dead Sea in the years AD 18 and 135 based on her interpretation of the archaeological evidence (1982: 90-91). Frumkin's findings in the salt caves largely corroborate Klein's work (Frumkin 1997; Frumkin *et al.* 1994), however, it would seem reasonable to consider Frumkin's more modest rises, based as they are upon standard pieces of dateable driftwood and the cave structure (1994). If there was a very high rise of 70-plus metres to submerge Qumran as suggested by Klein, then it is difficult to explain the much older pieces of driftwood surviving in the salt caves at levels which are above Frumkin's maximum for this period of time, but well below rises in water level proposed by Klein. There is perhaps a much more complex physical action at work here than Frumkin or indeed Klein has realised or accounted for, as recent work on the Dead Sea seems to suggest (Issar and Yakir 1997). Bruins states that a detailed curve from AD 930 to the present has been derived, which reveals variations in height over the years of –350 metres *c.* AD 1050 to –406 metres at present (Bruins 1994: 301). This gives an increased height in water level during the eleventh century of around 50 metres, which indicates a moister climate, a fact also reflected by study of local tree-ring data (Butzer 1995: 137).

That there have been changes in the level of the Dead Sea is clear; that these changes are a result of changes in climate can be questioned, but current evidence strongly suggests they are. Although it may be the case that clearance of the forests and vegetation to the north of the Dead Sea led to increased run-off into the rivers and to larger drainage basin discharges, it would not account for a high percentage of the rises in level and certainly not the decreases in level. What has to be thoroughly assessed in the future is the extent of the rise and falls in level. Research into recent levels of rise and fall show that, even though an increasing amount of water is being siphoned off for human use before it enters the lake, climatic conditions still underpin the water level. For example, in the rainy season of 1968-69 the catchment area received 121 per cent of the 1938-1954 mean. This resulted in an inflow into the Dead Sea of 3400 million cubic metres of water, 89 per cent above the mean yearly amount. Consequently it was found that the water level had risen by 1.6 metres (Klein 1982: 92).

2.5.3 Summary

In contemplating the evidence for the climate of the Near East during the Roman period several themes have been presented. Perhaps the most important has been the need to try and distinguish in the surviving evidence, that which has been caused by the impact of people on the landscape rather than any which might have been a consequence of climatic change. The formation of the 'Younger Fill' has proved particularly problematic in this respect, and has hindered its potential usefulness as a major source of interpretation. Particular attention must also be paid to micro-climatic factors which affect a particular location, and consequently the formation of any climatically or environmentally altered evidence that may have been produced at this location. Potentially the evidence collected from such points for analysis may only reflect the local conditions and not the general weather patterns for a wide region. Hence as Wigley and Farmer suggested, local effects such as topography and aspect 'are extremely important and need to be given due weight in any analysis of palaeoclimatic data.' (1982: 35).

By taking all the evidence into account, the collection of which continues apace, a few points can be suggested (e.g. Frumkin 1997; Issar and Yakir 1997). Although the environmental and climatic conditions are in essence the same as at present throughout the Levant, it can be postulated, that the region experienced a slightly moister environment at one or two points during the Classical period. However, much more work needs to be undertaken before a clearer assessment can be made, and the implications upon the peripheral regions can be deduced.

2.6 Historical context

2.6.1 Introduction

Perhaps the only key event, which can be placed with any certainty in the early history of the Roman province, is that of its annexation by Rome under the emperor Trajan in AD 106. All that is known of this singular event is the short sentence written by Cassius Dio: 'about this time also Palma the governor of Syria subjugated Arabia around Petra and made it subject to the Romans' (Cassius Dio LXVIII, 14, 5.; Millar 1993: 93). As will be clear, there is little in the way of direct available from ancient sources from which a complete historical narrative of the region can be constructed. The following short section is merely intended to give a broad indication of the types of sources from which a history can be developed. However, particular attention has been paid to the changing boundaries of the province of Arabia, which will both help to delineate the region which forms the subject of this study and provides a rough indication of the pace of change.

2.6.2 Historical sources

The region which is known to scholars as the kingdom of Nabataea is first brought to western attention through the work of two authors who wrote during the lifetime of the emperor Augustus, that is from the late first century BC (Bowersock 1983: 12). The earliest account was by the Greek historian Diodorus who, working from older sources, wrote a lengthy description of the Nabataeans during the mid first century BC. It seems that his main source was a supposed eyewitness account by the earlier writer Hieronymous of Cardia written in the fourth century BC (Millar 1993; Negev 1977c). The other major source was the Greek geographer Strabo, writing near the end of the first century BC, who obtained first hand knowledge from a visitor to Petra, in addition to other written sources such as Agatharchides of Cnidus, whose work has been lost (Bowersock 1983: 13). In academic literature much emphasis has been placed on the apparent differences between these two source descriptions, which are practically the only real insight into the rise of the Nabataeans from very obscure beginnings. Diodorus' description of the Nabataeans of the fourth century BC paints a picture of, as Bowersock puts it, 'uncommonly energetic and successful nomadic people' (1983: 16). In stark contrast, the contemporary Nabataeans of Strabo pursue a completely sedentary lifestyle, dwelling in luxurious stone-built houses, within a rich kingdom with its impressive capital at Petra (Bowersock 1983: 17). Furthermore, Strabo states the Nabataeans have mastered the arts of irrigation, and enjoy rich harvests of cereal and fruits from across the kingdom (Strabo 16.4.21, C784; Bowersock 1983: 17).

Beyond these sources there are only glimpses and hints at the presence of Nabataeans. Papyri such as the archive of Zeno indicate the appearance of Nabataeans in the Hauran around 259 BC and an early inscription from Elusa in the Negev points to the movement of Nabataean influence into this region perhaps as early as the early second century BC (Bowersock 1983: 17-18; Negev 1977c: 545-46; Peters 1977). In the Hauran region over a hundred Nabataean inscriptions, of the first century BC and the first century AD, have so far been found indicating dense settlement particularly in the region immediately south of the city of Bosra (Starcky 1986). This strong tradition in the Hauran of dedicatory inscriptions for buildings and stele continued into the Late Roman period, though the majority of these were now written in Greek. This large corpus of inscriptions has been the subject of several important studies that have revealed much concerning the rural inhabitants of the Hauran (Grainger 1995; MacAdam 1986; Sartre 1986). The survival of inscriptions within the Hauran may in part be due to the hard-wearing nature of the basalt they were inscribed on, for other regions of Arabia have far fewer survivals of inscriptions in Nabataean, Greek or Latin (Sartre 1993).

Outside the settled regions, other types of inscription have been found which have provided indications of a different, contemporary viewpoint of Roman Arabia. These are the so-called Safaitic and Thamudic inscriptions, which have been discovered scratched on rock faces and basalt stones in the tens of thousands, of which 18,000 have so far been recorded (e.g. Harding 1969; Jobling 1985; M. Macdonald 1993; M. Macdonald *et al.* 1996). Inscribed by nomadic peoples of the first to fourth centuries AD, using an adapted Greek script and symbols, and in a proto-Arabic language these inscriptions usually contain only basic familial information, though some mention herds and crop growing. However, occasional mention is made of significant events within the province and, perhaps, the ruling Romans (but these are few, perhaps as little as twenty in number) (M. Macdonald 1993: 328-33). Other Safaitic inscriptions mention journeys to or connections with the Hauran, although such inscriptions are again very low in number of the order of a dozen (M. Macdonald 1993: 342). However, it seems clear from the distribution of the majority of Safaitic inscriptions that the inscribers were transhumant nomads who generally moved from the Harra east to the Hamad in the summer (M. Macdonald 1993: 345). This evidence poses interesting questions about the power of Rome and the relationship of certain cultures and populations nominally under its control. As Macdonald has pointed out the Safaitic inscriptions at least 'show that the vast majority of their authors were for the most part entirely concerned with their own pursuits and were largely indifferent to the imperium' (1993: 346).

For the Roman period in general, there are few texts from ancient authors that provide more than basic information on such things as settlement names within the province. Examples include the works of Josephus and Ptolemy the geographer. Again, for much of the Byzantine period, direct information is lacking, although the works of Eusebius the ecclesiastical historian provides much secondary information, as do the works of early Christian pilgrims and clerics, such as Egeria (Mayerson 1963). Hence, for the most part information has come down to us through the interpretation of stone inscriptions, and chance finds of papyri, such as those of the Barbatha archive, Nessana, and the Petra church (see Kraemer 1958; Koenen 1996; Lewis 1989; Schick 1994).

2.6.3 Provincial boundaries

The actual provincial boundaries of the Nabataean Kingdom, the early Roman province of Arabia, and their successors in the Byzantine period have attracted a certain degree of speculation over the years (e.g. Bowersock 1983: 90-109; Tsafrir 1986). The exact boundaries will probably never be wholly identified, particularly when consideration of the desert regions to the east and Sinai is taken into account (see Fig. 2.11). As was common with many territories of Arabia until very recently (for example the border between Yemen and Saudi Arabia remained ill-defined until the second half of the twentieth century), these desert boundaries undoubtedly did not exist. After all, the Roman authorities were only concerned in governing people, certain important places and protecting strategic interests (Isaac 1990: 394-401). There is little evidence that they perceived the empire in a geographical sense, but rather as rule over different peoples. This concept is made explicit in ancient sources, for example, Josephus and others may occasionally refer to 'the Roman empire', a term which at other times is clarified as specifically meaning 'the peoples subject to Roman rule' (Josephus, *Antiquities* xviii 8.1). Given this fact it can be seen that the power or *provincia* given to a Roman governor, was never for a set territory, but for jurisdiction over a certain population (Lintott 1981: 54).

Boundaries were only necessary to divide populations for the purposes of control and administration. Boundary markers were employed essentially to define the limits of taxable property, such as estates and the limits of administrative units, predominately cities, villages and their territories (Isaac 1990: 397). Hence, the boundaries between the provinces were demarcated through an unfocussed practice whereby the provincial governor maintained control of a specific collection of cities, villages, estates and territories, which were subject to taxation and government by his administration. This is especially true in respect to the populated areas along the Mediterranean seaboard, and the eastern highlands of the Jordanian plateau. Beyond these populated areas Roman governors authorised the self-perceived Roman right to control wherever was considered necessary. Through this dictum certain strategic points, notably oases, enjoyed a high-profile Roman presence (see examples in Kennedy and Riley 1990). Often this took the form of a permanent military deployment, which for the province of Arabia had a number of duties to perform including the protection of trade between southern Arabia and the empire, the policing of nomadic peoples and proclaiming a visual message of authority over the region (Isaac 1990; Newson 2000). Such oases included Nemara within the Syrian Black Desert and the oasis of Azraq and al-Jawf in the Wadi Sirhan (Bowersock 1971; Kennedy 1982). The extent of the penetration of Roman control into the Hijaz further south is unclear. Graf argued against this area being formerly included within the province, pointing out the general absence of Roman material found at oasis sites within this region (1988: 182). Greek inscriptions written by soldiers of an auxiliary cavalry unit have been located at Meda'in Salih, but it is not clear for how long they were at this important Nabataean centre (Bowsher 1986: 23; Millar 1993: 95)

The major exception is that of the Ruwwafa inscription, a large bilingual Greek-Nabataean dedicatory inscription to the cult of the emperor Marcus Aurelius found deep within the Hisma of Saudi Arabia. It has been suggested, the inscription and the building of a major stone temple infers a diplomatic agreement had been made by Rome towards the Thamudic tribes inhabiting the area at the time of Marcus Aurelius (Fiema 1991: 13). The boundary has therefore been variously set as being along the southern slopes of the Shera range (Musil 1926: 255-9) or encompassing the Roman settlements up to the port of Ayn Una, west of the large oasis at Tabuk (Fiema 1991: 13; Graf 1988: 180). However, as indicated above, there probably never was any real boundary set within this area, only spheres of influence with certain points of control, perhaps visualised like occupied islands within the Mediterranean sea. Such notions probably can be entertained for the Sinai peninsula, which had definite physical boundaries imposed by the Gulfs of Suez and Aqaba, but warranted little real occupation or interest by the Roman authorities, apart from the security of the road along the north coast from Gaza to Egypt, the old trade route across from Aqaba to Egypt, and the control of copper mining sites at Timna and Wadi Feiran. Therefore, until the Byzantine period when ascetics and pilgrims, such as Egeria, journeyed to Mount Sinai, the region as a whole remained on the periphery (Isaac 1998: 449). It is not clear if the province extended to the Mediterranean coast but certainly the Negev and Sinai were included, for the latter were part of the former Nabataean kingdom which essentially formed the boundaries of the new province (Millar 1993: 96).

In the north the new Roman authorities simplified the complicated division of settled lands, though many problems of interpretation remain to be resolved because of the scant literary evidence available. Much of the academic discussion has focussed on the status of the so-called Hellenistic Decapolis cities, of which discrepant lists exist from a number of ancient sources (Millar 1993: 410). However, it seems that those cities located to the east of the River Jordan, including Umm Qeis (*Gadara*), Jerash (*Gerasa*) and Amman (*Philadelphia*), and Qanatra (*Kanatha)* on the slopes of today's Jebel al-Arab were transferred to the new province. The stimulus for this was the transfer to the province of Arabia of the lands previously given by Rome to the control of Herod

Antipas in compensation for the direct rule by Rome over Judaea (Dentzer 1986). These lands are known were known by the ancient names of Auranitis, Batanea Trachonitis, and Gaulan, which essentially cover modern-day Golan and the northern half of the Hauran, including the Jebel al-Arab. The Nabataean kingdom at this time controlled the Nuqra plain around its new capital at Bosra and the southern Jebel al-Arab to its east. Thus, it made perfect administrative sense to unite the two halves of this homogeneous landscape within the same province. In essence, then, the regions bounded by the overlap between the Nabataean kingdom and the early Roman province of Arabia form the subject of this thesis: from the Hauran in the north to the Red Sea and the Hijaz in the south; from the coast at Gaza on the Mediterranean sea, incorporating the whole of the Negev Desert and Sinai, to the Dead Sea; and then following the line of the River Jordan up to the foothills of Mount Hermon at the southern end of the Anti-Lebanon Mountains, which remained in the province of Syria.

2.6.4 Outline of provincial history

For the Classical period, the history of the region of the southern Levant begins with the conquest of the former Persian controlled satraps of the area by the armies of Alexander the Great (Berlin 1997; Smith 1990). According to ancient Greek sources, several Macedonian or Greek colonies, were founded in the region by Alexander or his immediate successors (Parker 1997: 236). After the break-up of the empire of Alexander, the region came under the control of the Ptolemies of Egypt, whose effective control continued until some time at the end of the third century BC. Currently, very little is known about the Hellenistic period within the southern Levant, either through historical sources or archaeologically (Smith 1990: 123). However, it is known that by the end of the fourth century BC the Nabataeans had established themselves in the southern Levant, and the Zenon papyri have indicated that Nabataeans were present within the Hauran by the mid-third century BC (Peters 1977). In the following centuries the Nabataeans, as a culture and later, as a regional power, were increasingly acknowledged and remarked on by Greek writers. The first attested King of the Nabataeans was Aretas I who ruled from about 170 to 160 BC. By 200 BC, the northern part of the region had been conquered by the Macedonian-descended Seleucids' whose power base was Antioch in northern Syria (now Antakya in Turkey). This heralded the development of a number of cities, particularly those settlements which later became known as the 'Cities of the Decapolis'. With the decline of the Seleucid empire in the early first century BC, control of the region was split between the Nabataeans and Jewish Hasmonean state. Several scholars have linked this process to the earliest evidence for a change in Nabataean lifestyle from a pastoral to a sedentary one (Negev 1977c).

The takeover in 62 BC by Pompey of much of the remaining Seleucid state within Syria ushered in a change of political power within the region. The rulers of Palestine and the Nabataean kingdom gradually became client kings of the increasingly influential Roman empire, and the Hellenized Decapolis cities gained their autonomy. It was during this time that the Nabataeans moved their capital from Petra in the south to Bosra in the Hauran. Eventually the Nabataean kingdom, which formed the bulk of the new province of Arabia, along with the Decapolis, and the territories of Herod Antipas in the Hauran, was annexed by Rome under the emperor Trajan. The causes and reasons for this takeover have been the subject of a number of papers: it may have been a power vacuum caused by the sudden death of the last King Aretas IV; a provision in his will to leave the kingdom to the Roman empire on his death; or purely for commercial reasons, the securing of the Arabian spice trade and the copper ore deposits of Faynan and Timna for the empire (e.g. Freeman 1993b). An immediate measure was the construction of an important road, labelled by modern scholars the *via Nova Traiana* (Trajan's new road), from the provincial centre at Bosra to the port of Aqaba on the Red Sea (Graf 1992a, 1997). Again, little is known about the specific history of the province from ancient writers and most information has been gleaned from the discovery of papyri, inscriptions and archaeology. From a passage by Eusebius and inscriptions it seems that Diocletian in his re-organization of the imperial administration split the province at some point in the 290s AD into two parts (Bowersock 1983: 143; Millar 1993: 192). The southern part, south of the Wadi el-Hasa, which included the Negev, Sinai, the Wadi 'Araba and the Edom plateau were transferred to the province of Palestine, which had previously been Judea before the time of Hadrian (Millar 1993: 192, 374; Tsafrir 1986: 7). In addition a new line of military establishments were constructed along the line of the *via Nova Traiana* about which there has been much debate as to their purpose (e.g. Isaac 1990: 213-18; Parker 1987c).

The reign of Constantine marks the transition archaeologically to the 'Byzantine period' for the provinces of the east and an important cultural change with the adoption of Christianity as the official religion (Lenzen 1997: 238). Furthermore, at some point in the late fourth century AD, the southern portion of the province of Arabia, which previously, had been handed over to the province of Palestine, was established as a separate province under the name Palaestina Tertia (Salutaris) or Third Palestine (Bowersock 1983: 143; Gutwein 1981). The acceptance of Christianity had a great impact on the culture of the region as the impressive number of churches bears witness to. Furthermore, the Byzantine era also marks the height of prosperity for the region as evidence for churches and numerous settlements indicate (Piccirillo 1985). In AD 451 the region of Moab was added to Palestina Tertia, and by the 640s the region had been taken over from the control of the Byzantine regime and entered within the realms of the expanding Muslim Arabs of the Arabian peninsula (MacAdam 1994: 50).

2.6.5 Summary

This brief overview of the historical sources, and what they can reveal about the history of the province has not been intended to be exhaustive. However, what such a review does indicate is the extent to which these are found lacking in many different areas. The region of provincial Arabia is perhaps one of the least represented provinces within the written texts of Classical authors. To counter this, the region has yielded a number of important and insightful papyri, and contains hundreds of information-rich inscriptions. These partly fill the void, but not sufficiently for written sources to construct a full history of the province. In terms of their usefulness to inform archaeological discourses, it should be remembered that if written sources are wholly relied upon, or are given undue precedence, there is a danger that circular arguments can ensue. Hence, although written sources can provide useful illustrations and usefully supplement debates, the key to understanding complex social processes over time, can be better answered by the acquisition of contextualised archaeological data. The next chapter will be concerned with the collection of such data relating to past settlement within the region of Roman Arabia.

3.0 The regional survey record: settlement in Roman Arabia

3.1 Introduction

In the last thirty years interest has grown in exploring the nature of the Roman East, particularly the former Roman province of Arabia, centred on the modern kingdom of Jordan, but including territory in Saudi Arabia, Egypt, Israel and Syria. The following is a brief summary of the major surveys of settlement and the most influential aspects and theories that have been proposed to explain settlement distribution.

In many areas of Southwest Asia large-scale archaeological surveys have been undertaken, and until recently most of these were mainly concerned with cataloguing the huge number of abandoned sites. This process only really commenced at the end of the nineteenth century with the long expeditions of Brünnow and Domaszewski in the southern part of the region and those of Princeton University under H. C. Butler in the north (Brünnow and Domaszewski 1904, 1905, 1909; Butler 1909-1949). The process continued with the surveys of southern Jordan by Frank and Glueck, which are still invaluable today (Frank 1934; Glueck 1934, 1935, 1946, 1951). However, it was not until the 1970s that a new generation of archaeologists began surveying particular areas of Jordan. From these, a number of important publications have resulted, notably Burton MacDonald's Wadi el-Hasa and Southern Ghors Survey and Miller's Kerak Plateau Survey (B. MacDonald 1988, 1992a; Miller 1991). With a few exceptions, however, there is a disappointing lack of any detailed analysis of the survey results. These surveys, in what can be termed marginal zones of the Near East, have revealed a wealth of evidence for different forms of settlement in different time periods. Dating of many of the hundreds of small settlements in the marginal areas has usually relied on the cursory analysis of surface pottery sherds and chance coin finds. This technique is obviously subject to many severe limitations, which will be explored in more detail later in this chapter.

3.2 Survey coverage

Fergus Millar has identified ten distinct geographical and cultural zones that constituted the initial province of Arabia in the second century AD (1993: 398). Of Millar's ten regions, only the area of the Decapolis and parts of the Hauran and Moab plateau could not be described as marginal in climate, i.e. with precipitation of less than 200 millimetres per annum. However, even these regions presented an almost deserted aspect to the travellers of the late nineteenth and early twentieth centuries (see for example Bell 1909). What follows is a brief review of the survey work in each region and a discussion of what is revealed for each in terms of settlement patterning and diachronic change. Although following similar boundaries to the regions proposed by Millar, here the regions are classified in terms of geography alone as this allows for simpler comparison with the physical aspects outlined in Chapter 2.

3.3 The regional survey evidence

3.3.1 The northern Hijaz

Recent debate has focussed on whether this region was ever formally administered as an integral part of the Roman province of Arabia (Graf 1988: 182; Figs 2.4 and 2.5). Certainly, Roman-period artefacts and sites have been located within the region, though these are relatively sparse. However, such a low density may to some extent reflect the lack of detailed survey to which this immense area has been subjected. Bowersock noted recently that, though there is huge potential, there has been no significant survey work completed on Nabataean and Roman sites since the 1960s (Bowersock 1996: 556-57). Graf has suggested that archaeological evidence of settlements shows Roman administrative control extended roughly to up a line which can be drawn from the port of Ayn Una on the Red Sea Coast to a point just west of the oasis and trading settlement of Tabuk, which coincides approximately with the change in geographical regions (see Section 2.2) (1988: 180). Beyond this, the protection and control of the trade routes were the main Roman interest, as suggested by Fiema (1991). What can be stated beyond doubt, is that Nabataean influence and settlement of the first century AD penetrated far into the southern limits of this very arid region. This reflects both a preoccupation with control of the caravan trade routes from Yemen, and also that much of the region may have been considered an integral part of the Nabataean kingdom.

There were two major Nabataean settlements in the northern Hijaz. The first was at Mada'in Saleh (*Hegra*), the majority of whose stone-cut tombs date to the first century AD (McKenzie 1990: 11-31); the second was the port of *Leuke Kome,* perhaps located near the head of the Gulf of Aqaba or maybe further south along the Red Sea coast, which served as the *entrepôt* for goods coming from the Persian Gulf and beyond. Though there has been much speculation, the location of this important port has not been identified with certainty (Kirwan 1984). Recent suggestions have equated modern 'Ainuna with *Leuke Kome,* as this ancient port, with access to the Gulf of Aqaba and the Red Sea proper, stands near the site of a very sizeable, but largely unrecorded, Nabataean settlement at Maghayir Shu'aib (Bowersock 1996: 558-59; Kirwan 1984: 55-61; Parr *et al.* 1971). Beyond these three towns (Mada'in Salih, Maghayir Shu'aib and *Leuke Kome),* settlement of the region was sparse but certainly present, as the brief survey by the University of London in the late 1960s and other indications reveal (Bowersock 1996: Parr *et al.* 1970; 1971; 1978). However, settlement on the presumed land route along the east shore of the Gulf does seem to have been absent (Millar 1993: 389).

What settlement there was seems to have been concentrated along the ancient caravan routes, or where water could be easily retrieved. The survey by Parr, Harding and Dayton (1970; 1971) was the first serious archaeological survey in the area, rather than brief notes by earlier travellers on impressive ruins. However, because of the huge size of the region and the limited time available (three weeks), the survey concentrated on obtaining more detailed information for previously known sites mentioned by such travellers (Bowersock 1996: 556; Parr *et al.* 1970: 194). Of the sites visited, Qurrayyah was the largest and most complex (Dayton 1973: 21-25; Parr *et al.* 1970: 219-41; Fig. 3.1). A number of important features distinguish this seemingly isolated site from smaller sites. A small rocky promontory set within a narrow plain formed the nucleus of the site that was subsequently dubbed the 'Citadel Hill', due to the fortified walls built across it. Adjacent to this defensive area, to the north-east, a small settlement had developed (the 'CITY' of Figure 3.1). Beyond this lay a number of large enclosed areas linked to the numerous wadis which cross the plain and that were bounded by long linear mounds (Walls E to M) (Parr *et al.* 1970: 225). Within the enclosed areas were fields, some divided into smaller parcels by lines of single course stones, and the linear mounds were the remnants of walled deflection channels which redirected flood waters from the wadis to the plain. Apart from these structures, three substantial buildings were also recorded. Architectural features dated two of these to the Nabataean period, and the largest of the three (the 'Roman Site' in Fig. 3.1) to the Roman/Byzantine period (Dayton 1973: 21; Parr *et al.* 1970: 228-29). Significantly, the majority of sherds collected from the site as a whole were of a painted type termed 'Edomite Ware', which has been dated to the late Bronze Age and has since been renamed Midianite ware (Bawden *et al.* 1980). As the walls of the settlement and citadel structures are of the same construction as those of the enclosed areas and deflection channels, the surveyors concluded that they were all of a contemporary date, that is from the late Bronze Age.

Since that time other, more comprehensive investigations have been attempted, concentrating on the ancient South Arabian spice trade routes, and small excavations have been undertaken at a number of oasis and trading settlements, such as Khuraibah (*Dedan*), Kheif el Zahrah (Bawden 1979) and Tayma (Bawden, *et al.* 1980; Livingstone, *et al.* 1983). Water management systems were also surveyed at the settlement of al-'Ula (al-Najjam 2000). A detailed survey programme of the entire region has also been instituted, but again because of limitations of time and the scale of the region, certain areas were given more detailed treatment than others (Gilmore *et al.* 1983; Ingraham *et al.* 1981). Ingraham's survey has added immensely to our knowledge of Nabataean to Byzantine levels of settlement. In all, 25 new sites were found which yielded sherds of Nabataean and/or Roman date (Ingraham *et al.* 1981: 75). One of these sites (Site 204-76) displayed evidence of an extensive gravity-flow irrigation system. Among the relatively dense network of sites of Classical date in the coastal area of the Wadi 'Aynunah, an aqueduct used for the distribution of spring water was also observed (Ingraham *et al.* 1981: 76-77).

Approximately 350 kilometres south of Ayunah lies the major Nabataean site of Mada'in Saleh. Since its 're-discovery' and description by the explorer Charles Doughty in 1876, a number of projects have documented the site (Doughty 1926). Most of these have concentrated their work on the 80 or so monumental tombs, detailing the Diwan (used for religious feasts) and transcribing the hundreds of Nabataean inscriptions and graffiti carved on the sandstone mountains that surround the site (Jaussen and Savignac 1909; McKenzie 1990; Winnett and Reed 1970). The least known part of the site is the actual settlement area itself, located at the centre of the site, but almost totally buried beneath layers of windblown sand (Healey 1986: 113-14). There has also been little investigation of the settlement's water supply, or of any possible agriculture undertaken in the immediate vicinity, although traces of water conduits have been noted skirting the base of the sandstone massifs which enclose the site as a whole.

3.3.2 Sinai

In the Sinai it is clear from the thousands of Nabataean inscriptions collected from the Wadi Mukateb ('Wadi of Inscriptions') that there was at this particular place a strong Nabataean and later Roman presence (Negev 1977a). However, the majority of the inscriptions attest to the thriving caravan trade that passed along this route to and from Egypt and Petra, and so such a presence was, in the main, transient. Other areas of the Sinai peninsula became the subject of selective fieldwork in the early 1970s, the results of which have been published in a number of works (e.g. Bar-Yosef *et al.* 1986; Beit-Arieh 1984; Dahari 1993; Finkelstein 1985; Meshel 2000; Oren 1982; Rothenburg 1970). Archaeological investigations here began, along with other districts of the Levant, in the first decade of the twentieth century, with excavations by Petrie and Curlley (Petrie 1906), and by Clédat in northern Sinai (1910).

However, from an archaeological viewpoint much of this barren and inhospitable landscape remains *terra incognita*. For example, the major surveys by Rothenburg and Beit-Arieh were purely vehicle searches for visible sites, with no field walking being undertaken (Beit-Arieh 1984; Rothenburg 1967, 1971: 212). With this in mind, a number of points can be made, drawn from the work that has already been completed. From the time of the ancient Egyptians, southwest Sinai was, in many periods, a prominent centre for mining (Valbelle and Bonnet 1998). The Southern Highlands became a pilgrimage destination in the early Christian era, and eventually several important monasteries were established in the early Byzantine period (Finkelstein 1985). Several trade routes criss-crossed the peninsula linking Egypt with Palestine, along the northern coast (*via Maris*); Aqaba and Egypt, along the line of the later Darb el-Hajj pilgrim trail; and Arabia to points along the Mediterranean coast, by a small network of routes, including a road (the Darb Ghaza) from Aqaba or Yotvata in the Wadi 'Araba to Gaza (Graf 1998b).

From infrequent investigations it has become clear that a number of caravanserai and other trading settlements became established at certain stopping points. Archaeological evidence of buildings excavated at several points along the northern Sinai coast route and the cross routes has shown such stations to have been firmly in the control of the Nabataeans (Meshel 2000; Oren 1982). However, beyond these stations other Nabataean sites have yet to be discovered around these routes (Meshel 2000: 106). In contrast, at an isolated site by the Darb Ghaza road in the Wadi Lussan, was recorded evidence of two or three building structures with associated agricultural installations, notably dams, boundary walls, and diversion channels, along with sherds and coins of the fourth century AD (Meshel 2000: 110, Site 41). The surveyors were tempted to label this site a farm and noted 'the site represents interesting activity in the Roman period in such a remote area' (Meshel 2000: 110). It is perhaps a small indication of what remains to be discovered.

South of the line of the trade routes to Petra, again only occasional settlements and hamlets have so far been located, for example along the Wadi Qudeirat (Glueck 1935: 120-21). The only major settlement seems to have been the site of Pharan, situated along the road from *Clysma* (modern Port Said) to Mount Sinai, but no detailed investigations of it have been made (Gutwein 1981: 24). Indeed, Woolley and Lawrence in their pioneering expedition to the region found that all remains of cultivation ceased south of Wadi Pharan, a wide wadi that cuts deep into the peninsula from the Wadi Araba (its length being in the order of 150 kilometres), and which thus may demarcate the limit of sedentary activity from the north (1914: 29). Thus the region's cultural history and Sinai's position in relation to the successive powers of Nabataea and Rome remain something of a mystery. Even basic questions about the level of settlement cannot yet be determined, although it has to be said that sedentary occupation may have been for a specific purpose; i.e. to serve mining operations, trade or religious needs in most instances. The majority of the population of Sinai throughout the Classical period continued to practise a pastoralist way of life, one still much in evidence today. To underline this point, a hypothesis of a nomadic lifestyle has recently been demonstrated to explain the appearance of Nabataean rock inscriptions in the southwestern part of Sinai (Teixidor 1998).

3.3.3 The Negev desert

The northern Negev was extensively settled in the past, and since the 1950s has been the subject of a number of ground-breaking studies by Israeli archaeologists, particularly in the research of ancient water management techniques (for surveys: Aharoni *et al.* 1960; Evenari *et al.* 1958; Glueck 1959; Rothenburg 1967; for water management studies: Evenari *et al.* 1982; Kedar 1957a, 1957b; Mayerson 1962). These surveys concentrated on particular research goals, and so did not involve full site surveying for all periods over large areas. Only in the last two decades have systematic and comprehensive survey projects been attempted, following the signing of the peace treaty between Israel and Egypt in 1976. This extensive programme, labelled The Negev Emergency Survey, has collected a wealth of information and produced a large number of publications, including the first seven Archaeological Survey Maps of a series which will provide complete area coverage (Figs 3.2 and 3.3). (Amongst many such works are: Avner 1990; Avni 1992; Cohen 1981; 1985; Govrin 1991; Haiman 1986, 1989, 1991; Lender 1990; Rosen 1985; also of note are important summaries in *Excavations and Surveys of Israel* 1982; 1983; 1985).

The Negev has attracted such interest for a number of reasons. Most of the region can be classed as semi-desert: over much of the area, annual rainfall is often less than 100 millimetres per annum (Shanan *et al.* 1967). However, the area exhibits widespread archaeological evidence for dense sedentary settlement from a number of distinct time periods. Early Bronze Age, Iron Age, Nabataean, and Byzantine periods are all reflected by the material remains of numerous comparatively large settlements. Associated with each settlement can usually be found an extensive suite of remains relating to various agricultural strategies, often intimately connected with wide scale remains of comprehensively applied techniques of water management, a vital requirement in such a relatively arid zone with few natural sources of water available. As a consequence of this recent programme of intense archaeological survey, a number of syntheses reassessing the implementation of water control techniques in relation to sedentary and nomadic strategies have appeared. Of particular concern in many of these works are the relationships between rural and urban, and sedentary and nomadic, during the flourishing Byzantine period (Avni 1996; Bruins 1986; 1990; Finkelstein 1995; Gutwein 1981; Moran and Palmach 1985; Nevo 1993; Rubin 1990; Shereshevski 1991). Major Byzantine settlements include the so-called 'towns' in the central Negev of Elusa, Nessana, Mampsis, and Oboda (Avdat), and Shivta themselves the subject of long-term excavations and detailed surveys (Negev 1993a, 1993b, 1993c, 1993d, 1993e).

3.3.4 The Hisma

The Hisma has become the subject of archaeological surveys only in the last two decades, the dearth of earlier research reinforcing its perceived identity as an arid backwater in terms of settlement during most periods of history compared to other nearby regions. The few surveys that have been undertaken have for the most part had a very narrow focus aimed at obtaining basic data in answer to particular research questions. Hence, Eadie and Graf have been mainly concerned with information on the defensive frontier and road network of the Roman province at this point (Eadie 1984; Graf 1983; 1988). Jobling's surveys were fundamentally aimed at the collection and distribution of prehistoric rock art and Thamudic inscriptions across a relatively small section of the region between Humayma and Wadi Ramm, although some evidence for settlement, water collection and management was obtained incidentally (1981; 1983a; 1983b). Both these surveys indicate that, as in the Hijaz and southern Sinai, there was some very small-scale and sparse settlement during the Classical period at certain strategic points to serve trade traffic, and/or where water could be obtained in adequate amounts.

The only major Classical period settlement in the region, and one which has been studied intensively in recent years especially in terms of its provision of water and other resources, is the site of Humayma (*Auara*) (Oleson 1997; Fig. 3.4). Archaeological evidence from the site dates back to the first century BC in the form of Nabataean sherds, and continues until well into the early Islamic period. The extensive water-supply system has been the subject of detailed survey work over a number of years (Eadie and Oleson 1984; Oleson 1991, 1992). The main characteristics of the system include: a network of independent cisterns in the hills surrounding the settlement, where water could be easily collected and used to serve livestock; a couple of large covered reservoirs served by an aqueduct which tapped water from a nearby spring; and a large agricultural area to which floodwater from the nearby Wadi el-Gharid could be redirected (Oleson 1997: 176).

3.3.5 The Wadi 'Araba

The 'Araba occupies a special position within the former province of Arabia, cutting a long arid gash deep into the province, almost dividing it into two (see Chapter 2.2.14). On the western side of the southern part of the Jordan Rift Valley lie Sinai and the productive cities of the Negev, on the eastern, the fertile Edom mountains and the former Nabataean capital of Petra. Communications between the two plateau areas are extremely limited, as there is only a handful of useable passes through the high mountain ranges fringing the Wadi; this is particularly true of the eastern escarpment. The surface of the 'Araba alternates between sand and gravel, with the addition of swamps of high salinity following the winter floods. The potential for agriculture and consequently sedentary settlement is therefore limited only to places 'exceptionally favoured by nature' (Rothenburg 1971: 211). Archaeological surveys undertaken in the region tend to support this view, with most sites located at the foot of the mountain slopes, close to perennial springs and away from the sandy wastes. Given these facts, a surprising amount of archaeological evidence has been revealed, as Raikes put it: 'Everywhere that one turns, in what at first sight appeared to be an almost deserted region, occupied only by Bedouin and their camels and goats, traces are found of previous organised and settled occupations' (1985: 95).

Major site mapping was first seriously entered upon in the 1930s by Fritz Frank and Nelson Glueck, and their published accounts are still important today (Frank 1934; Glueck 1935). Recent surveys recommenced, as with other areas, in the late 1960s and early 1970s (King *et al.* 1989; B. MacDonald 1992a; Rothenburg 1967, 1971; Fig. 3.5). More detailed survey work has begun at several important locations, especially the mining regions of the Wadi Fidan/Wadi Faynan complex of wadis (Adams 1991; 1992; Barker *et al.* 1997, 1998, 1999, 2000a, 2000b; Finlayson and Mithen 1998; Fritz 1996; Hauptmann *et al.* 1989; Levy *et al.* 1999a; Levy *et al.* 1999b). In addition, specific evidence of sedentary occupation in the Nabataean-Byzantine periods has been investigated at Yotvata on the Israeli side (Rothenburg 1971), and at Bir Madkhur and Gharandal on the Jordanian side (Smith *et al.* 1997).

Settlements such as et-Tlah, Bir Madkhur, Gharandal, and Yotvata were in fact military stations sited along the lines of caravan trade, where a guaranteed supply of sweet water from springs or artesian wells could be easily obtained. Usually this situation can be found at the confluence of a tributary wadi with the Wadi 'Araba. Associated with many of these posts are small-scale, but in some cases elaborate, field systems which utilised the winter floods down these side wadis. The field system at et-Tlah, which now does not survive, was of considerable interest, as the fields were laid out on a small plain below the fort on a regular grid pattern (Kennedy and Riley 1990: 205-07). Other field systems, such as those at Bir Madkhur and Yotvata, were more irregular as local circumstances dictated.

3.3.6 The plateau of Edom: the Jibal, and 'Arabia Petraea'

This roughly coincides with the area of the Iron Age kingdom of Edom, and constituted the original heartland of the Nabataean kingdom, centred on the settlement and cult centre of Petra. The boundaries of this high plateau region and which, to the north and south, formed the boundaries to the Edomite kingdom (Baly 1957: 239-51). Are formed by the steep escarpment edge down to the Wadi 'Araba in the west, and the slope down to the Wadi el-Hasa in the north. The Ras al-Naqb escarpment in the south marks the southern edge, and the eastern edge fades away into the desert beyond the oasis at Ma'an (see Section 2.2.9). The northern section of this region, from Shaubak to the Wadi el-Hasa is known as the Jibal (or Gobolitis) (Villeneuve 1992). The region south and east of Petra has been given by modern scholars the designation of 'Arabia Petraea', a region that remains largely a marginal zone of sparse settlement today (Graf 1992a). As with other regions, archaeological explorations began with the pioneering work of Musil, Glueck, Alt, Frank, Stein, Harding and Kirkbride, for the most part in the 1930s (Alt 1935; Frank 1934; Glueck 1935; Kirkbride and Harding 1947; Musil 1926; Stein 1940). A large volume of more recent work has naturally concentrated on unearthing the mysteries of Petra, and its immediate surroundings. Some of this work in and around Petra has analysed in detail the water distribution systems to the city and its suburbs, particularly the Nabataean contribution (Lindner 1985; al-Muheisen 1990). Further afield, surveys have mapped the settlement patterns, with often a cursory look at the agricultural and water supply element (Hart 1986a; Hart and Faulkner 1985; Killick 1983, 1986, 1987). The most influential survey in this respect has been that of the Wadi el-Hasa, which endeavoured to locate settlement patterns of all periods along the southern edge of this major wadi (B. MacDonald 1988, 1992b; Fig. 3.6). As a result of this work, some analysis of the settlement evidence for particular periods within this region have been attempted (Schick 1994: Villeneuve 1992).

Towards the south, one of the first systematic surveys of recent years was executed under the directorship of Burton Macdonald in a prescribed area facing, and inclusive of, the southern slopes of the Wadi el-Hasa (B. MacDonald 1988). The survey collected evidence for structures and lithic scatters from all periods, from the confluence of the Wadi with the Dead Sea in the Southern Ghor, across the plateau and the various tributary wadis, up to the line of the modern Desert Highway, which follows the old Hajj pilgrimage route. A vast range of material evidence was collected relating to the Nabataean, Roman, Byzantine and Islamic periods. This has significantly increased our knowledge of the development of settlement within this region, which can be utilised to illuminate other adjacent areas.

Apart from a huge number of villages, the survey encountered a number of other structures relating to these periods, ranging from isolated farms, to terraces, cisterns, caves, cemeteries, cairns, mills and aqueducts, even the occasional olive press. These structures reflect a picture of prosperous sedentary agricultural communities in a region which since the Islamic period has been on the whole populated by pastoralists. Even today, most of the village sites remain uninhabited, and this picture can be seen in other regions of the former province of Arabia. The conclusions from the Wadi el-Hasa Survey can be summarised in the following way. From 37 settlement sites (most of these were described as villages, although several were of a smaller 'hamlet' size), surface Nabataean style pottery sherds were collected. Thirty-five settlements also contained distinctly Byzantine period sherds, although of these only twenty also had Nabataean sherds. Therefore, seventeen of the supposed Nabataean villages may no longer have been occupied by the Byzantine period, with a similar number of new villages taking their place in other locations.

Hart's survey of villages and other settlements in the area 20 or so kilometres to the south of Petra, along the range of hills known as the al-Shera, located more than 130 sites, with most being dated by surface sherds to the first and early second centuries AD. Terraced fields and the necessary apparatus for the capture of spring water or valuable rainwater often accompanied these sites, a common necessity as similar techniques have been found to be listed in the recently discovered papyri from Petra (Koenen 1996). Significantly, the majority of sites was found to lie west of the line of the Kings Highway, which later became part of the *via Nova Traiana* (Hart 1986b: 341). Even more importantly, this relatively high density of settlement that seemingly arose in the later years of an independent Nabataean kingdom disappeared quickly, shortly after the Roman annexation. Hart suggested a number of ideas to explain this brief growth of settlement in an otherwise unattractive region, some of which will be assessed below.

3.3.7 The Moab plateau

The highlands of the Moab Plateau, from Amman in the north to the Wadi Mujib in the south, formed the heartland of Nabataean settlement in a thin corridor east of the ancient King's Highway. Among the fairly fertile plains of the plateau developed a 'world of villages and small towns' (Millar 1993: 390). Later settlement seems to have developed out towards adjoining areas, to the east as far as the *via Nova Traiana*, and north towards Amman and beyond, south as far across the Wadi Mujib as far as the Wadi el-Hasa. It is a pattern that has been increasingly identified in other regions of the province. The most influential work undertaken in this region is the long-term research of the Tell Hesban survey and excavations, which has been published in many articles and a series of fourteen volumes (e.g. Geraty 1976; Ibach 1976, 1978, 1987; LaBianca 1990; LaBianca and Lacelle 1986; Sauer 1973). Besides the Hesban survey, surveys in this region include those of Miller on the central plateau, that of Worschech to the northwest of Miller's and Parker's survey of the Roman *limes* to its east (Miller 1991; Parker 1987a, 1988, 1992; Worschech 1985, 1992).

The project at Tell Hesban included detailed excavations of the tell, and a site survey of all the sites within a ten kilometre radius of the tell (LaBianca 1990). To the south a smaller survey, the Madaba Plains Project investigated another tell – Tell al-'Umayri and its vicinity (Geraty and LaBianca 1985). In both projects major changes in the settlement patterns were discerned through the Classical period. For the Hellenistic period, a total of eleven farmstead sites were identified, the majority of which lay on the gentle hills (named by the survey the northern hills) to the northwest of Tell Hesban (LaBianca 1990: 184). By the late Roman period, the majority of the 21 farms identified, lay on the plateau ridge to the northeast of the tell (compare Figs 3.8 and 3.9).

The Byzantine period seemed to present the greatest density of sites, with 61 farmsteads being identified through the collection of Byzantine sherds from the sites. Settlement in this period as well as intensifying on the plateau ridge had also expanded down the scarp slope to the west, where eighteen sites were recorded, and back to the east onto the northern hills (LaBianca 1990: 184). This prosperity is reflected in the large number of richly decorated churches, which have been excavated in the region, particularly at the large settlements of Madaba and Umm er-Rasas

(Piccirillo 1985). However, the Tell Hesban survey found very little evidence for the succeeding Umayyad and later periods (seventh to eleventh centuries AD) at most sites, although Tell Hesban itself yielded evidence of occupation (LaBianca 1990: 241; Sauer 1973: 39-49). The evidence seems to be repeated in the Madaba plains to the south. The survey in 1984 collected evidence of continuous settlement from the early Roman/Nabataean to the Umayyad, but there was no evidence for the succeeding 'Abbasid period; of the 55 sites surveyed in 1985, only one yielded sherds of the Umayyad period (MacAdam 1994: 82). More recent papers have disputed this apparently abrupt decline, pointing to the construction of the so called 'desert palaces' further out into the eastern steppe with their associated agricultural estates (King 1992: 369).

3.3.8 The southern Ghor

Around the southern shores of the Dead Sea lies the region known as the Southern Ghor. Archaeological work here was limited until recently, as the area was only accessible from the south. The first intensive survey of the region was not undertaken until the 1970s when an area of the south-eastern plain of the Dead Sea was investigated, centred on the ancient settlements of al-Safi and Feifa (Rast and Schaub 1974, 1980). The construction of the Dead Sea road caused an increase in archaeological interest, and was surveyed incidentally by the road engineer Thomas Raikes, who highlighted the potential for archaeological research in a number of papers (Raikes 1980, 1985). In the last twenty years important studies providing detailed information on the Classical period have included, King's and MacDonald's wide-ranging site surveys (King *et al.* 1987; B. MacDonald 1992a; B. MacDonald *et al.* 1987; Fig. 3.7). Excavations have also been carried out at selected sites, notably the Byzantine monastery Church of Saint Lot located on the escarpment edge near al-Safi (e.g. Politis 1990).

From the work so far completed, evidence has come to light of nucleated farming settlements in the Bronze Age at least (King *et al.* 1983, 1987). However, commencing in the late Nabataean period, large populations developed as they took advantage of the fertile soils and implemented irrigation practices. This expansion of settlement on the rich plains around the southern end of the Dead Sea continued into the Roman period. In relation to this, a number of important papyri documenting aspects of the life of a Jewish family who lived in the southern Ghor village of Maoza in the late first century AD, were found in the 1950s and 1960s (Isaac 1992; Lewis 1989). These give us vital clues as to the nature of land-holdings within the province of Arabia and the implications of these will be looked at in more detail below. Macdonald's survey suggested from collected surface sherds that the Byzantine period was the time of greatest prosperity, with Byzantine period ceramics being recovered from a total of 65 sites within the search area, in contrast to the totals of Nabataean and Roman diagnostic pottery obtained from 25 and 27 sites respectively (B. MacDonald *et al.* 1987: 404). The earlier survey by King *et al.* came to the same conclusions, but did not find much evidence for settlement in the early Islamic period, that is the Umayyad (King *et al.* 1983). However, by the Ayyubid and Mamluk periods, this situation seemed to be reversed, with the southern Ghor experiencing growth in settlement (King *et al.* 1987).

3.3.9 The Decapolis (cities and adjoining territories)

There has been much speculation as to what constituted 'The Decapolis' and what its special status might have been, if indeed it had any (Bowersock 1983; Browning 1982; Graf 1986). A number of cities east of the river Jordan seem to have claimed Decapolis status including: *Philadelphia* (modern Amman), *Gerasa* (Jerash), *Pella* (Tabaqat Fahl), *Dium, Hippos, Gadara* (Umm Qeis), *Abila* (Qweilbeh), *Adraa* and perhaps *Capitolias* (Beit Ras). The overriding bond between all these settlements is to be found in their Hellenistic foundation or at least the adoption of a

Hellenized culture (Browning 1982). The site of Dium is at present unknown, but all the other towns have been identified and have witnessed a substantial amount of archaeological excavation and survey since the 1930s, work that continues apace today (e.g. Freeman 2001; Kennedy 1998b; Northedge 1993; Watson 2001). Much less attention has been given to the exploration of the rural hinterland, but the situation is slowly beginning to change (e.g. Watson 1996). Work here has been hindered, as much of the region is today heavily cultivated (Palmer 1998).

Each city had its own territory, and recent discoveries of a remarkable series of small stone boundary markers from the second century AD at Jerash have highlighted the importance of such territories (Kennedy 1998b: 48-52; Seigne 1997). The location of this city's territory is important in many respects, as has been recently discussed by David Kennedy (1998b: 52-54). For the boundaries that have been demarcated, those of the east and south follow the watershed line between adjacent river basins. Crucially, the eastern boundary also coincides with the edge of the 300 millimetre precipitation isohyet and the southern part of the territory has been extended to include a portion of the important valley of the perennial River Zerka (Kennedy 1998b: 52). The steppe lands begin to the east of the isohyet, which until recently marked the boundary between the sedentary farming of olives, fruits and wheat, and the pastoralism of Bedouin tribes (Kennedy 1998b: 52-53; Mundy 1996).

Therefore, as Kennedy suggests, this tells us that in the second century and earlier, the steppe lands were considered unproductive and were consequently ignored by Hellenistic Gerasa (Kennedy 1998b: 53). To the east, beyond these city territories on the steppe edge, control and settlement seem to have increasingly come within the sphere of the expanding Nabataean kingdom of the first century BC, which had gained control of the southern half of the Hauran (see Section 2.6.3). Unfortunately the evidence on the ground is very sporadic, so the suggestion that this marginal area was under Nabataean control remains uncertain, although it seems probable given that there is much evidence of Nabataean culture to the north, within the Hauran far to the east, in the Wadi Sirhan, and indeed within Decapolis cities such as Jerash itself (Graf 1996; Wenning 1992). Therefore, it seems that the increase in Nabataean hegemony and the later imposition of Roman rule slowly transformed some regions of the steppe to the east. This means that by the late Roman–early Byzantine period stone-built villages had been established, equipped with churches, reservoirs and cisterns. The remains of these can still be seen today near modern Zerka, but they have yet to be systematically explored and recorded (Kennedy *pers. comm.*, 1998a: 53-54).

3.3.10 The Hauran and the Harra

The region of the Hauran is a complex mix of different physical areas and had a very fragmented cultural, social and political history before the second century AD (See Section 2.6). It is also renowned for the hundreds of rectangular basalt dwellings standing in scattered villages across the whole area, which in the majority of cases seem to date to the third to sixth centuries AD (Dentzer 1986; Graf 1992b). Naturally these standing buildings, many of which have been re-occupied in the last 100 years by Druze, have attracted great archaeological interest. The surveys of Princeton University and of the French archaeological institute in Damascus (IFAPO) are particularly notable (Butler 1909-49: Dentzer 1986). Although traces of settlement have been uncovered from many earlier periods, the Hauran seems to have become densely settled in the first century AD, particularly the fertile Nuqra Plain. On the southern edge of this plain the Nabataeans established a new capital at the city of Bosra (*Bostra*) in the period just before the Roman annexation (Miller 1984). During the Roman period, Bosra continued as the provincial capital and also as the garrison town for the province's only legion (Sartre 1985). Again, as with other areas, for example to the east of the Decapolis, archaeological research has indicated that later settlements of the second to fourth century AD spread out, moving east across the Jebel al-Arab into the more marginal areas along the edge of the Harra, and south into the more arid southern Hauran (de Vries 1998a; Villeneuve 1986b; Fig. 3.10).

As well as the detailed documentation of architectural and historical developments within the city at Bosra, such as the villages, the houses, and water management systems, much of the French survey work was concerned with understanding the relationship between village and countryside (e.g. Braemer 1988, 1991; Dentzer 1986; Graf 1992b; Sartre 1985). Intensive surveys were undertaken in several areas, especially on the western slopes of the Jebel al-Arab in the environs of the Roman city of *Dionysias* (modern Suweida), the Hellenistic city of *Kanatha* (modern Qanawat), and the important Nabataean cult centre of Si' (Gentelle 1986). Studies of aerial photographs from the French Mandate period of the 1920s and 30s have provided evidence of centuriated fields in the vicinity of Qanawat and Suweida (Leblanc and Vallat 1997: 54). From the analysis it seems that these fields were centuriated at different periods: the fields around Qanawat were laid out to Hellenistic proportions, whereas fields one or two kilometres away, at the next settlement of Atil, were on a different orientation and to a Roman scale (Leblanc and Vallat 1997). The northern half of the Hauran had been under the control of the Herodian kings before it passed to direct Roman control in the early first Century AD. Therefore, there was probably a real difference between the southern and northern halves of the Hauran, in terms of culture, language and social history, when they were united within the new province of Arabia in AD 106.

The southern Hauran has produced evidence of a flourishing of settlement into the Umayyad period at least (de Vries 1998b). Excavations and surveys of the 'desert palaces' to the south of this region indicate that some new development occurred within the Umayyad period (King 1992). Particularly important in this respect is the site of Qasr el-Hallabat, the site of a late Roman fort which became the centre of a large Umayyad agricultural estate using water management systems (Bisheh 1982).

3.3.11 The Wadi Sirhan

Little permanent settlement has been found in this inhospitable region due to the generally arid nature of the climate, and few locations with perennial supplies of water. Consequently, little substantial archaeological survey has been completed, particularly as the region is still quite inaccessible, but there are a few indications of what could be unearthed (Adams *et al.* 1977). A single Latin and several Nabataean inscriptions have been discovered, and on occasion pottery assemblages of a Nabataean or Roman provenance have been collected at a number of discrete locations (Winnett and Reed 1970; 1973). Such locations are normally watering points, positioned on the route from Asraq to al-Jawf, and at points further along the ancient caravan routes (Bowersock 1996; Glueck 1944; Kennedy 1982: 188-90). The Latin inscription recorded at the oasis of al-Jawf (*Dumaitha* in Ptolemys' Geography), has proved to be a dedication by a Roman centurion to Jupiter Hammon or Sulmus, the local patron deity of camel-caravans and desert routes (Bowersock 1983: 98 n26; MacAdam 1988). Therefore this inscription, along with the fragmentary Nabataean inscriptions, could be seen as providing evidence for a significant Nabataean and later Roman presence at certain periods within the Sirhan (Speidel 1977: 694). These locations may represent the vestiges of Nabataean or Roman establishments, either for military or trading purposes or both, as the Wadi Sirhan formed a major caravan route across from Mesopotamia, and from Teima and points south to the Saudi interior, via the large oasis resort of Asraq, to Bosra and Damascus (Bowersock 1996: 562). However, as with many other regions on the periphery of the Nabataean kingdom, and the succeeding Roman province, many questions remain unanswered.

3.4 Settlement history

Given that there are many problems with the archaeological and source evidence, particularly in the region south of the Wadi Mujib, a number of general hypotheses have been argued to explain the changes of fortune for the regions of Roman Arabia. From the surveys detailed above, it appears that analyses of the ceramics seem to date the largest number of sites to the Nabataean and Byzantine periods. However, it must be remembered that study of the region's ceramics is still very much in its infancy, particularly in terms of dating and typology. Even easily recognisable types such as Nabataean Fine Painted Wares are still inadequately dated, especially the date for cessation of production.

Other regions show evidence of a Nabataean presence, but in some cases the evidence for widespread permanent settlement seems to be lacking. For instance, MacDonald's survey of the Southern Ghors and northern-eastern 'Araba collected large numbers of Nabataean sherds from all over the survey area. However, very few were associated with what could be described as permanent settlements. Apart from a few major sites such as fortresses and caravanserai, the majority of finds consisted of isolated sherd scatters, which may or may not have some significance. Some of these sherd scatters were collected near grave sites and supposed campsites dotted across the region (B. MacDonald 1992a: 86-89). Moreover, other regions have yet to be fully surveyed. All of this means that the settlement picture is very variable, which reflects two important issues. First, that a comparison of the various fieldwork projects undertaken shows them to be both patchy in spatial coverage and inconsistent in terms of the quality of results. This point should always be borne in mind when contemplating the settlement levels across the Province. Secondly, even when the variability of survey work is accounted for, some areas apparently reveal large differences in the intensity of settlement. Furthermore, comparison of the spatial distribution across the region displays large differences in intensity of settlement between the Nabataean and Roman periods. Obviously, if these differences are real, they will reflect the changing fortunes of different regions due to a number of different causes.

It seems that Nabataean settlement commenced on a large scale during the first century BC. Apart from Petra, the majority of the population lived initially in small rural communities, whose existence depended on farming and animal herding (Fiema 1991: 87; Graf 1992a). Some of these communities grew into regional market centres, and the population of these small towns fluctuated according to the season and the different needs of the caravan trade, markets and agriculture. Examples of such towns were Humayma and Mampsis in the Negev (Negev 1993b; Oleson 1997). Besides these two settlements, the other towns and market orientated villages/stations include: Meda'in Salih, al-Bad', Qurayya, Tayma, Ramm, Aqaba, Humayma, Sadaqa, Udruh, Thawana and the towns of the Negev, for example Oboda and Nissana. All of these major administration and market centres developed on the lines of the major trade routes through the kingdom, from the Yemen, the Persian Gulf, Damascus and the Mediterranean. Surrounding these important nodes were a multitude of smaller sites, various villages, hamlets, single farmsteads and campsites. Some areas seem to be more populated than others, for example the Edomite Plateau and the Wadi el-Hasa have a large number of sites, but this may be more a reflection of the intensive surveys undertaken, particularly along the Wadi el-Hasa by MacDonald. There are more Nabataean-dated sites in the Shera region and out into the Hisma, though those in the Hisma are quite small and scattered in number. The southern Ghor region also exhibits heavy settlement, as does Moab and the southern Hauran.

Certain commentators have observed changes in this general settlement pattern, following the annexation of the province by Rome in AD 106. For the region of the Hisma, most settlements ceased to be occupied, although there is the notable exception of Ramm. Only those sites on the line of the new *via Nova Traiana,* or in the region to the east show evidence of continued occupation (Graf 1992a). However, there is some doubt as to when these sites gradually became abandoned, either immediately following the annexation, or at some time during the late second century or third century AD. The southern part of the Edomite Plateau, around the al-Shera escarpment, seems to exhibit a dramatic increase in the number of sites established in the first to early second centuries AD, of which over 130 were recorded (Hart 1986a; Wenning 1987: 86-98). Again, at some point during the second to third centuries site occupation ceased and the entire region became practically deserted (Graf 1992: 256; Hart 1986b: 341). It has been suggested the village settlements within the al-Shera region had quite small populations, with the largest supporting 200-300 people (Hart 1986b: 340). Other less arid environments, particularly the northern section of the Jibal, Moab, the northern Negev and around Ajlun, had a denser covering of settlements which may have also supported larger populations (Villeneuve 1988: 5). These regions were in essence the heartland of the Nabataean kingdom, and show no decline following the Roman annexation. With regard to most of the major trading settlements at positions along the major trading routes (such as al-Jawf, Ramm and Humayma), there seems to have been a thin pattern of settlement spread around and between them. Areas within the Wadi Sirhan, the Hisma and the northern Hijaz, particularly the 'Midian Triangle', show evidence of a widely dispersed Nabataean settlement (Adams *et al.* 1977: 36-38; Fiema 1991: 91; Jobling 1983b: 202; Ingraham *et al.* 1981: 57 and 76). East of the King's Highway and line of the later *via Nova,* the only major site which had a Nabataean presence is Udruh, shown by the pottery kiln and numerous Nabataean ceramics uncovered, but the extent of the settlement is not yet known.

MacDonald extensively surveyed the northern part of the Jibal leading down to the Wadi el-Hasa for sites in the early 1980s, with a high density of Nabataean sites being recorded. In fact the

Nabataean–Roman period was represented by the greatest of number of sites: a staggering 236 out of a total of 363 sites from the Classical period had mostly Nabataean sherds (Fiema 1991: 94; B. MacDonald 1988: 11). The sites were to be found predominantly in the eastern and central zones of the survey area, near the lines of the north-south running tributary wadis of the wadi el-Hasa. The Southern Ghors attest to a Nabataean presence, but here it was much less intense when compared with the later Byzantine period (King *et al.* 1987: 451; B. MacDonald 1992a). Further south only isolated sites at points of specific importance, notably where perennial supplies of water are to be found, display evidence of a Nabataean presence, such as Bir Madhkhur, Qasr al-Saidiyn, Yotvata, Qasr Wadi Musa and Qasr Wadi et-Tayyiba. For Sinai, which has not been fully explored, the only major Nabataean settlement is that of Tell el-Mekharet, which is thought to have existed in some form in earlier periods (Fiema 1991: 96).

The evidence for the settlement patterns of the late Roman period is very hard to come by, and there have been a number of explanations for this dearth. Methodologically, ceramic analyses have had severe problems isolating and recognising the differences between pottery produced in the late Roman and the early Byzantine Period. This is partly due to the lack of detailed excavations which would allow the construction of more refined typologies. Hence the frameworks constructed for ceramic typologies are far too broad in scope, and so sherds of local wares which are similar in fabric and style to those sherds found in association with imported Byzantine finewares, such as ARS (African Red Slip ware), are automatically classified as Byzantine in date, when they may have come from earlier periods.

One area in which differences in settlement patterns have been postulated, however, is that of the al-Shera range. Here few later pottery sherds were found beyond those of classical Nabataean styles. Therefore, a region that was well populated during the first century AD seems to have gone into a terminal decline, with many settlements being abandoned. Hart (1986b) has suggested that the decline in population began in the second century AD, and has given a number of reasons as to the causes. The first of these was the removal of the Nabataean capital from Petra to Bosra (*Bostra*) in the Hauran, at some point in the first century before the Roman annexation. Secondly, Hart has explained the sudden emergence of settlement, as he saw it, in the Shera region, which is inhospitable climatically, as being a result of deliberate settlement policies by the King Aretas IV, to strengthen the kingdom to the south of Petra. With the removal of the capital to Bosra, this policy became redundant, and lost state involvement. Thirdly, Hart has also suggested that these settlers might have quickly exhausted the soils with excessive and reliant use of irrigation techniques, with the result that the water table was made substantially lower and agricultural activity became non-viable. Consequently, the region did not receive any investment when it was taken over by Rome, and as the local people lost any income from involvement with the trade routes and from waning agriculture, they gradually abandoned the area for better opportunities elsewhere.

Some of these processes may have played a part in the changing fortunes of the region, but they are unlikely to have been a major cause. As Fiema has pointed out, the settlements could have already existed in the first century BC, and there is no evidence for a supposed settlement policy by the Nabataean government (1991: 117). Furthermore, he suggests there is no real evidence that irrigation, which would have undoubtedly relied on capturing run-off flow from precipitation, would have caused exhaustion of the soils. Fiema sees the main cause of the decline of the Shera settlements resulting from the region being effectively by-passed through changes in the overland trade routes, particularly the growth of the sea-borne trade route to the port of 'Aqaba and across the Negev to the Mediterranean, and through the Wadi Sirhan to the new capital at Bosra (1991: 117). In turn, this may well explain the move from Petra to Bosra in response to a decline in the importance of the overland trade routes, and certainly placed the Nabataean court closer to the centre of Levantine culture and population, as well as at the centre of an up-and-coming rich agricultural region which was gaining in importance in the kingdom. Fiema suggests that when trade declined, some of this population may have moved to new dry-farming territories between Udruh and Ma'an, along and close to the route of the *via Nova Traiana* where trading opportunities might present themselves (1991: 118).

Given the problems of identifying settlement patterns for the late Roman period (the second and third centuries AD), the next period, the 'Byzantine', has revealed a wealth of information in terms of material remains. The term Byzantine can in some respects be seen as slightly misleading, as it covers, in many cases, the late fourth and fifth centuries as well as the sixth century. The period is usually thought to have ended with the Muslim conquest of the region in the decade following AD 630. The general picture that is currently emerging is one of 'overwhelming rural increase in the Roman Near East from the fourth century onwards: in settlement, population, productivity and wealth' (Ball 2000: 243). However, there is still notable disparity between different regions. Mention has already been made of the demise of settlement in both the Hisma and the Shera range in the second century AD. In the Shera range, settlement dwindled from around 100 sites which have so far yielded Nabataean and early Roman ceramics, to much lower levels (Hart and Faulkner 1985: 269-71; Wenning 1987: 86-98). At around nineteen sites Byzantine period sherds have been collected. Nine of these, including Petra itself, are large sites; others are clusters of hamlets and farmsteads. In the environs of Udruh, fifteen kilometres to the east of Petra, there is evidence for increased Byzantine occupation. Besides the fortress and its accompanying large *vici* at Udruh, many other sites rely on elaborate catchment systems and dams, such as Jarba, and Jebel al-Tahuna (Killick 1983: 127; 1986: 438-40; 1987: 25-35).

Further north in the Jibal region, MacDonald's survey has shown that, although the area to the south of the Wadi el-Hasa was occupied at a relatively high density, almost equal to that of the Nabataean period, the site distribution changed somewhat. Compared to 236 sites (of all types) of generally Nabataean to Roman date, 125 sites show evidence of Byzantine occupation. However 70 of these sites are new, with no evidence of previous occupation. These new sites are generally to be found much further away from the wadis, and are more often than not located on the plateau areas between the wadi valleys (Fiema 1991: 218; B. MacDonald 1988: 295). Although fairly evenly distributed across the survey area, the greatest density of sites occurs at the western end. In this western area, these Byzantine-dated sites were generally founded on previously unoccupied ground, whereas those Byzantine sites at the eastern end continued to occupy earlier Nabataean–Roman period villages.

In the adjacent Wadi 'Araba, evidence was collected for the establishment of around six permanent settlements dating to the Byzantine period, at a number of points along the edges of wadis as they flowed out from the slopes of the plateau onto the valley floor (B. MacDonald 1992a). These villages were to be found sited in the region to the south of Qasr et-Tlah and above the Wadi Fidan, which for previous periods shows little permanent settlement. Therefore, the whole region of southern Transjordan reveals a distinct change in the pattern of settlement between the Nabataean–early Roman periods and that of the Byzantine. Whilst some older settlements continued to be inhabited, other areas in more marginal landscapes began to be settled. These were not huge in scale, and could not have involved a very large and dense population, but these new settlements were of a number significant enough to be noticeable in the landscape, and to effect changes within it. It is interesting to note at this point that MacDonald, in his highly influential survey of the Wadi el-Hasa region, found virtually no evidence for occupation during the early Islamic period. The impression seems to have been repeated in the survey of sites within the southern Ghor (B. MacDonald 1992a, 1992b). The significance of this apparent desertion and discontinuity of settlement, and the reasons put forward to explain this phenomenon, will be discussed in more detail below.

A similar growth of settlement during late antiquity has been observed in other parts of the former province of Arabia, to the north of southern Transjordan, which had been absorbed into the new province of Palaestina Tertia. For instance, in the region of Hesban a detailed surface collection of sherds disclosed a total of 148 occupation sites within a 100 square kilometre area. Of these, 57 contained ceramic evidence dated to the Nabataean/early Roman period, 45 showed signs of late Roman occupation, and 126 revealed Byzantine pottery (Ibach 1987: 170-86). The area around Hesban, although not as arid as many parts of southern Transjordan, is still by all accounts marginal in terms of climate and is limited in the amount of water available to it. The same degree of expansion has been demonstrated in other areas which seem to have been of marginal status prior to the Byzantine period, notably the southern Hauran, and the southern Highlands of the Negev (Avni 1996; de Vries 1998b: 234; Haiman 1995).

3.5 The survey record: strengths and weaknesses

3.5.1 Survey comparison: progress and limitations

As described above, the archaeological survey work undertaken within the bounds of the former Roman province of Arabia has been huge and varied in nature. The last two decades have witnessed an unprecedented amount of change within all the present-day countries (Egypt, Israel, Saudi Arabia, Syria and Jordan) that now contain the evidence relating to Roman Arabia. As the region has benefited from increasing stability on the political front, so have the infrastructure and economy developed. These twin interrelated processes of political stability and economic development have in turn led to an explosion of archaeological work, as researchers have striven to document the region's rich archaeological heritage, making use of improved access, and before future development threatens to destroy it.

The majority of archaeological work undertaken in the last twenty years has been regional survey work, for a variety of reasons. The general aims of such survey work have been varied, depending on a number of exigent circumstances, such as limited time, numbers of people involved and particular research aims. As a result the scope, methodologies employed, size of area covered, amount of data collected, and interpretations made all vary greatly, which makes any comparison between surveys difficult.

3.5.2 Survey coverage

Survey coverage for the region under discussion cannot be said to be uniform in any way. Some areas, notably the Negev, have been subject to large numbers of detailed surveys of small areas within them, which when accumulated cover a high proportion of the total area. Other regions, particularly large parts of the Hijaz, Sinai and some parts of the Hisma, Edom have not yet had a site survey of any kind. This illustrates the great disparity of information available from region to region. In addition, the particular methodologies and goals employed by each survey have been different. This means the quality of the research, and the interpretative methods employed, also vary considerably from survey to survey.

Many surveys have been purely purposive in nature, such as aimed at site location only, particularly in the more remote regions. Hence, the surveys of Rothenburg and Beit-Arieh in Sinai, the Hijaz surveys of Ingraham, King, Miller, and MacDonald in Jordan, were all vehicle-based site surveys. This meant success depended on collecting information about previously documented sites, new sites located by eye, or through knowledge given by local inhabitants. Given the huge areas available to survey, it comes as no great surprise to find that few surveys have employed extensive combing of terrain, through the use of transects and pedestrian reconnaissance. Exceptions to this have occurred in the Negev and some small areas of Edom, the Jordan Valley and the Hauran. For example, a few long transects were undertaken during the Wadi el-Hasa survey by Banning as a control method to explore site and artefact density within the survey area as a whole. Thus it can be generally stated that across the region as a whole, there is a very uneven degree of archaeological exploration.

3.5.3 Survey Limitations

The data collected by the surveys must also be treated with care. Actual recorded information on a site can be misleading in many ways. Site descriptions and designations are often necessarily vague. Sometimes the evidence of a structure is difficult to interpret, and so questions of function frequently remain unresolved or when a label is given to a particular feature it can be open to charges of inconsistency or be challenged. Essentially this inaccuracy in the data is a reflection of two key problems. The first is a consequence of frequently insubstantial physical remains or large piles of stones which could have formed a myriad of structural types. Secondly, are problems of definition, what exactly constitutes a fort as opposed to a fortified farmhouse, and how can the material remains be distinguished and subsequently placed in a coherent typology. There may have been in the past many structures whose specific use has now been lost to us, or indeed which may have had multifunctional uses, or which changed in use over time. With all these problematic variables it is understandable that many surveys , for example that of Killick around Udruh seems to have had difficulty in distinguishing whether a site was a small military fort or a fortified farmhouse. For similar reasons estimates of changes in settlement size cannot be determined easily.

Dating of structures depends in most cases upon the collection of dateable surface finds, but here too, there are inherent problems. On the whole, pottery forms the basic material collected from which most analyses are made and interpretations formed. However, at many sites there is often a lack of any ceramic evidence which consequently impairs attempts at dating a site. When sampling a site can take place, this can often vary in thoroughness and so will affect the site history. Miller has identified a number of factors that might influence the effectiveness of site sampling (1991: 10), the amount of time available for the collection of sherds in relation to the overall size of a site; the control procedures utilised in the collection of sherds; and the time of day all have a large bearing on the results obtained. Therefore, a small site with few sherds will be sampled much more thoroughly than a large site, even if it has a large numbers of sherds. Control procedures, such as random grid sampling, have been developed to overcome such bias, but time factors often do not allow this. Finally, the time of day is also very important, with the best period usually being in the morning, when visibility is sharper and workers are less tired and consequently more observant. The variability of results obtained by sampling is usefully outlined by Miller in his observations of the site of Kathrabba in Moab, which was surveyed twice within a few years, first by Mittmann and later by Miller (Miller 1991; Mittmann 1982). Both survey teams surveyed the site with completely different results, which would have had a bearing on dating the site. Mittmann found no sherd from before the Byzantine period, whereas Miller's team found two Iron Age and two Nabataean sherds (Miller 1991: 20).

In addition, the act of collecting surface sherds is not a guaranteed indication of a site's occupational history, as excavation inevitably reveals earlier activity. Surface sherds are themselves sometimes difficult to date, not least due to their long exposure to taphonomic processes, which frequently mean they are in a poor condition when retrieved. Furthermore, the sherds collected are generally locally-made coarsewares. For many areas, especially the more remote arid regions, such as in Moab, Edom and the Hijaz, this has caused particular problems due to the limited number of published excavation reports. As a result, even basic ceramic typologies have yet to be realized for many areas. Some projects, such as the *limes Arabicus* and Hesban projects, have conducted limited excavations and have managed to construct a basic stratified sequence of comparable ceramic material. However, these cannot be fully employed in other nearby regions with any certainty, because of the limited distribution in the past of local coarsewares. Consequently, many surveys have had to content themselves with broad and ambiguous labels for their ceramics. The surveys of the Hijaz, for example, often can only point out that a site may be of the Classical period, when it could, in theory, range from the Hellenistic age to the late Roman at least.

This dating dilemma is not helped by the styling of local coarsewares which seems to have been slow to change over many years, and which in itself has caused problems. Mayerson (1996) has highlighted the difficulty of the Negev surveyors in assigning sites to the Byzantine or Umayyad periods (AD 660-750) on account of the ambiguous date of the surface sherds collected. This point is re-iterated by the current excavations at Gharandal in the Jibal (Walmsley 1998, Walmsley *et al.* 1999). In both cases it was previously assumed that the Byzantine pottery styles ceased with the Muslim conquest. However, there is no inherent reason why this should be, as recent archaeological excavations suggest that the population remained virtually the same, continuing a similar lifestyle, which included a continuation of Byzantine-styled pottery production (Walmsley and Grey 2001).

3.6 Conclusion

This chapter has shown that a large number of surveys have been completed in the last few decades. These have shown a wide range of settlement patterning for the Classical period; from the Hellenistic through to the early Islamic period. It can be seen that some regions experienced more intense settlement than others, and this was linked to a number of factors, particularly local environmental constraints. Hence, in the more fertile and better-watered regions of the plateau areas, settlement remained high through all periods. Fluctuations in settlement density seemed to have occurred between certain periods and in certain areas. These may reflect to some extent the differing levels of consistency in the methodologies employed by the various surveys. Some surveys have been undertaken in areas which are heavily populated today, which has meant a high proportion of evidence has been obscured, whereas others have been able to collect large amounts of information from areas still scarcely developed.

All surveys have been handicapped by two factors. The first is the variation in the definition of a 'site'; the second concerns the lack of secure pottery typologies for any of the regions surveyed. This has consequently led to problems with the interpretation of the evidence. For example, for many surveys the settlement of their survey region ends almost abruptly with the transition from the Byzantine into the early Islamic period. However, this contrasts with the literary evidence, which suggests that settlement continued at least until the sixteenth century AD (Johns 1992: 363). Given such problems of dating, the next chapter will be concerned with the evidence presented by differing land use systems and the exploitation and control of water resources in the region. By looking at the evidence for land use and water management systems the problems outlined in this chapter will be refocused. For by concentrating on specific regions where detailed survey work has been undertaken of both the land use, water management systems and settlement, better indications of the cultural, socio-economic and political changes, which the evidence for settlement has only partially shown, can be made explicit. In other words the focus will be narrowed down to specific regions, and a more detailed approach taken.

4.0 The regional survey record: land use systems in Roman Arabia

4.1 Introduction

The previous chapter has shown that there is evidence for Classical period settlement in the semi-arid and arid regions of the Levant in varying levels of size and preservation. In order to sustain such settlement, it is undeniable that various methods of water-management were employed to different degrees. For a population to survive in such marginal regions the acquisition of adequate supplies of water was a vital concern, both for consumption and for other domestic, industrial, and more importantly, agricultural purposes. A wide range of technologies was utilised by the inhabitants of these settlements to control and make efficient use of the limited amounts of water that were available to them. Intensive investigations of the techniques used in former times in the Negev Desert were carried out in the 1950s with a view to assessing the viability of re-introducing them. The outcome was a number of groundbreaking publications, which have set the standard for all later work on the subject of water management in marginal areas. The work produced by Mayerson and Evernari is still particularly important in this respect (Evenari *et al.* 1982; Mayerson 1962). Recording the archaeological evidence for water management techniques has continued and intensified in all areas of the former province of Arabia, resulting in a number of studies dedicated to the subject (e.g. Braemer 1988; Bruins 1986; Helms 1981; Kennedy 1995a; Olesen 1992).

In order to consider the extent to which available evidence within Roman Arabia can provide answers to such questions, four specific regions will be examined in detail. These regions have been chosen because they have extensive remains of Classical period settlement, yet are to be found beyond the limits of what was considered the extent of sedentary settlement, until the advent of modern technologies, such as deep well drilling (Admiralty 1943b: 487) (Figs 4.1 and 4.2 shows the extent of settlement, cultivation and water resources in Jordan at the end of the second world war). The first of these, the Negev, has numerous and substantial water management installations and has been the subject of intense research for many decades, as we have seen earlier (Chapter 3), and lies to the immediate south of the more populous province of Palestine.

On a similar scale in terms of settlement, is the second region: the eastern slopes of the Jebel al-Arab and the southern edges of the densely settled Hauran. In contrast to the Negev, this area has been subject to much less archaeological investigation. Furthermore, the eastern slopes of the Jebel al-Arab are dissected in a similar fashion to the scarp slopes of the Wadi ‘Araba which forms the third region. The Wadi ‘Araba contains two very different but adjoining settlement environments, those of the Southern Ghor and the ‘Araba proper, each of which will be considered. Finally, the fourth region lies immediately to the east of the settled areas of the Jordanian plateau, such as the Jibal, from the Wadi el-Hasa down to and including the extensive settlement at Humayma and out to the east to the desert proper (Fig. 3.5). Each of these regions could be considered marginal to other adjacent regions which have consistently been settled through many periods. Each area was administered as part of the Nabataean kingdom and the succeeding province of Arabia. Each area has been studied to varying degrees for evidence of field systems and will be examined for differences and similarities in terms of the system used; the size of the system; constraints imposed in terms of topography, geology and climate; who the system was designed for; and any dating evidence which has presented itself.

4.2 The Negev

The Negev desert, in what is now southern Israel, can be split into a number of regions which exhibit slight variations in terms of topography and consequently varying patterns of climate, precipitation, vegetation and remains of past settlement and land use. There is a distinct difference in the type of settlement remains visible between the areas in the wetter northeast and the drier parts of the Negev highlands in the southeast (Rosen 2000: 48-51; Fig. 4.3). The former region displays a more dense settlement which is also composed of on the whole substantial buildings of a sedentary agricultural population. The drier region to the southeast, however, exhibits more dispersed, smaller and less substantial settlements, which have been interpreted as having been utilised by semi-nomadic pastoral peoples (Avni 1996: 61; Haiman 1995: 31-32; Rosen 1992). However, how the evidence from semi-nomadic and nomadic peoples in this region can be distinguished has formed the subject of recent debates (e.g. Finkelstein 1992; Finkelstein and Perevolotsky 1990; Rosen 1992).

The demarcation line between these two types of settlement is not clear-cut, and in some areas there is some intermixing of the two types. In addition, in terms of variation in the intensity and type of settlement apparent, the northeastern area can itself be divided into regions of more or less dense settlement and with different proportions of diverse settlement types, which depends on a number of factors. These areas have been differentiated as the lower lying lands of the northern and central Negev and uplands of the Negev highlands (Hirschfield 1997a: 50). The northern Negev, which in general has a moderate pre-desert climate with an annual average rainfall of 200 to 300 millimetres per annum, is characterized by a range of settlement types from villages with dense housing to hamlets, scattered farmhouses and field towers (Govrin 1991; Hirschfield 1997b: 52).

The city of *Elusa* (Arabic - el-Khalasa, Hebrew - Halutza) lying in the central Negev, although fairly small in size, can claim to be the only true settlement of city status within the Negev, and indeed, it may have been the capital of the Byzantine province of *Palestina Salutaris (Tertia)* (Dan 1982; Mayerson 1983). There were a number of other large settlements to the south and southeast of Elusa, which have variously been described as 'cities' or 'towns', although they are closer in size and status to large compact villages, and indeed from the surviving Classical period literary and documentary evidence, were always referred to as κῶμαι (*komai*), that is villages (Hirschfield 1997a: 38; Mayerson 1963).

Besides Elusa, there were five other large settlements of this large village type (the common toponyms are listed in order of Arabic, then Hebrew, with the Classical name in italics): Khirbet Ruheibeh/Rehovot-in-the-Negev (perhaps *Bethomolchon),* Subeita/Shivta (*Sobata*), Nizzana/Nitzana (*Nessana),* 'Abdah/Avdat (*Oboda*) and Kurnub/Mamshit (*Mampsis*) (Negev 1993d; Shereshevski 1991). Three of these large village/town settlements, Elusa, Oboda and Nessana, on the basis of Hellenistic period finds, seem to have been established by the Nabataeans at the end of the fourth or the beginning of the third century BC, as stations on the important caravan trade routes from Arabia to the Mediterranean littoral and the port of Gaza (Negev 1993a: 379, 1993c: 1147, 1993d: 1155; Segal 1983: 22).

However, apart from ceramics, occasional coins, an inscription in archaic Nabataean and evidence for large campfires, no permanent building remains dating to this early Nabataean period have so far come to light (Negev 1993f: 1133). Avraham Negev has suggested that the Nabataean inhabitants of this time were living in tents (Negev 1993f: 1133-34). The earliest evidence from the other three settlements (Rehovot, Sobata and Nessana) dates to the period following the re-conquest of the Negev by King Obodas III (30-9 BC), when more permanent military camps and/or public buildings were constructed at all six major settlement sites in the central Negev. However, it was not until the years just prior to the annexation of the Nabataean Kingdom in AD106 that there appears any evidence, most of which is circumstantial, for more permanent private dwellings at any of these major settlements (see Negev 1993c: 1134).

The majority of the substantial building remains at these settlements can be ascribed to the Byzantine period (fifth to seventh century AD), when the central Negev experienced what can only be described as a period of high prosperity. Associated with this period and lying within the hinterland of these large village settlements are the remains of an intricate network of small hamlets, isolated farmhouses, field towers and the occasional seasonal farms (Cohen 1981; 1985). Furthermore, many of these structures were accompanied by the extensive remains of well-preserved agricultural systems, particularly in the environs of the settlements of Nessana, Oboda and Sobota (Evenari *et al.* 1982: 97). Indeed, archaeological surveys have revealed that the measures and techniques employed by the inhabitants encompass the whole area between Mampsis and Nessana (over 200,000 hectares). Therefore, the studies particularly of Evenari, Kedar and Mayerson, which will now be examined in turn, have successfully highlighted the different methods of water management utilized by the Byzantine farmers from all the various settlement types to maximize the limited supplies of precipitation to maximum effect (Evenari *et al.* 1982; Kedar 1957a; Mayerson 1962).

From the three studies the water management systems of the central Negev can generally be classified into two basic modes of operation: those that used structures to control runoff surface water; and those that sought to capture floodwaters. Each of these operations had been used separately, or in various combinations throughout the Negev. However, systems which sought to control runoff waters exclusively are usually to be found in the upper reaches of a wadi course, where the wadi stream course is shallow and narrow and the surrounding slopes form a catchment basin for the runoff to flow towards the wadi. These runoff slopes can vary widely in gradient and the total catchment area is usually proportionate in size to steepness of slope; hence, the steeper the slope the smaller the natural catchment area size, although, as we shall see, techniques were employed in the Negev to extend the catchment areas where possible, using a number of simple techniques.

The other system was employed much further down the course of a wadi, usually at the point where a wadi course leaves the narrow confines of a gorge or steeped-sided valley and enters a proportionately wider 'floodplain' area which may indeed be physically open, such as an expansive alluvial fan. In essence, there has to be a reasonably large flat expanse of land adjacent to the wadi course, onto which wadi floodwater can be conveyed. Usually only a small proportion of the total floodwaters potentially available could be siphoned off into such a system, or was indeed required for such a system to operate successfully. Hence the main difference theoretically between the two systems was that one system sought to collect and utilise all the available surface water, whereas the other required or could only control and use a proportion of the total water potentially available for use.

The three major studies on the Negev field systems have in turn identified both these basic operations, but have each produced different terms to describe them. The generally upland catchment systems have been described as: 'wadi bed' systems (Kedar 1957b: 181), 'tributary-wadi cultivation' (Mayerson 1962: 212) and 'individual terraced wadis' (Evenari *et al.* 1982: 97). In addition, Evenari's survey team proposed a more complex variation, in which a group of terraced fields and an accompanying farm should be considered as a discrete entity, which they labelled a 'runoff farm' (Evenari *et al.* 1982: 99). However, there is in reality not much to differentiate the two systems apart from differences in time period and complexity, and they should be considered as using the same basic methods of water collection. This basic type of system will here be referred to as a 'runoff' system. The downstream wadi floodplain systems referred to by Mayerson as 'main-wadi cultivation' systems instead can be labelled simply as 'diversion' systems (Evenari *et al.* 1982: 110; Mayerson 1962: 212).

The runoff agricultural systems are the most common type of system to be found in the Negev, particularly in certain areas of the many shallow tributary wadis which dissect the hilly areas at the base of the Negev highlands, to the south and east of the large settlements in the central Negev. The simplest version of a runoff system comprised a series of low terrace walls of six to twenty metres in length set at right angles to the wadi course and directly cutting across it, with intervals of around twelve to fifteen metres between each terrace, commonly known as cross-wadi terrace walls (Evenari *et al.* 1982: 97). Thus the terraces simultaneously acted to limit erosional processes and control the low-level floods occurring following any precipitation within the catchment area.

In the region of Ramat Matred, which lies around seven kilometres to the southwest of Oboda, there are a number of these simple runoff terrace systems, which were investigated as they lay beyond the region of dense Classical period occupation. It was originally thought that because these systems are relatively near to some Bronze Age settlement sites (Early Bronze IV, c.2350-1950 BC), that they could originally have been established in this period (Evenari *et al.* 1982: 99). However, in close proximity to the systems themselves, and seemingly forming a planned farming entity, were discovered a number of small farm dwellings, which upon excavation was found to date to the Iron Age II period (ninth to seventh century BC). Two notable examples of these simple terrace systems and the accompanying farm settlements are Sites 108 and 159 (Aharoni *et al.* 1960).

A similar situation was discovered further south at the edge of the habitable region of the Negev, in the vicinity of the Mishor ha-Ruah Plateaux (Arabic – Sahil al-Hawa) and the neighbouring Upper Nissanah Valley (Wadi 'Ajram) (Evenari *et al.* 1958). Within this region, mean average rainfall in the present day is quite low, between 75 to 100 millimetres. However, the wadi valley bottoms are generally wide, and are filled with relatively deep loess soils, which allows for potential settlement. As in Ramat Matred simple but effective runoff systems with cross-wadi terrace walls characterize many of the valleys, along with strategically placed cisterns at intervals along the valley slopes. Both the terraces and the cisterns were fed by a series of low gradient collection channels, up to a kilometre in length, with the whole system being enclosed by a low stone wall (Evenari *et al.* 1958: 234).

The majority of both the enclosure walls and the terrace walls were constructed of a single line of large rectangular-shaped oblong boulders, a notably different type of construction to the walls located in the vicinity of the large settlements of the central Negev, where the walls are composed of smaller stones in well-made courses (see below). Furthermore, while the boulders in the enclosure walls were generally placed in an upright position, that is orthostatically, the terrace wall stones on the whole were laid horizontally (Evenari *et al.* 1958: 235). Again, this is a significant departure from other areas, which along with the adjacent position of dwellings containing pottery sherds of the Iron II period, helped to convince the surveyors of an Iron II date for the walls. This was despite the presence of substantial settlement remains dating to the Early Bronze IV. However, it was acknowledged that, although no direct evidence could relate these remains to flood-water farming structures, it was a possibility that there existed similar water management structures in the earlier Bronze Age (Evenari *et al.* 1958: 239).

Caution must be introduced at this point, as conclusive dating evidence for these field systems is lacking, and very few sherds of pottery were found within any of the field systems, for any period. This situation is seen not only in Ramat Matred and the Mishor ha-Ruah, but is echoed throughout the whole of the Negev (Mayerson 1962: 232). Although most of the Early Bronze IV sites lie in the southwestern part of the survey region, away from the shallow wadis in the east, it is accepted by the surveyors that some sort of runoff agricultural system may still have been employed by the semi-nomadic Bronze Age peoples (Aharoni *et al.* 1960: 26; Evenari *et al.* 1982: 99). Having said this, the relational position of the Iron II farming settlements to the field systems would seem to indicate that there is a high probability that these two elements are contemporaneous (Borowski 1987; Evenari *et al.* 1958). Furthermore, as there are only five recorded Classical period sites in the survey region compared to eighteen for the Iron II period, this would seem to discount a large proportion of these field systems from being of Classical construction.

Closer to the settlements of the central Negev, general surveys have discovered examples of the more sophisticated 'runoff farm' systems running into the hundreds, if not thousands in number. Several of such farm units have been the subject of a more comprehensive investigation (Evenari *et al.* 1982: 99-110; Mayerson 1962: 233-41). These detailed surveys have distinguished a number of elements common to the majority of such systems. These include adjoining stone boundary fences, within which are contained the ruins of a farmstead or a watchtower, as well as the usual series of stepped terraces.

The major differences between these and the earlier systems of Ramat Matred, Mishor ha-Ruah, and other areas on the margins of the Negev, are dependent on two aspects. The first is the extension of certain of the terrace walls up the wadi slopes to form a series of water conduits to capture and control the runoff flow from the immediate slopes, and beyond up to the natural wadi watershed. Secondly, the construction techniques of all the walls involved in the system differ from earlier simpler systems. Hence, each field within the wadi bottom retains its own catchment area from the plateau (Evenari *et al.* 1982:104). The total area actually cultivated, being that which forms the agricultural terraces within the wadi bottom, varies depending on the width and other physical attributes of the wadi. Furthermore, it has been suggested the areas cultivated by individual farming units can be isolated and distinguished, for some of the catchment channel walls continue along the watershed line and return back down into the wadi. In this way large enclosures are formed, and a number of these can be seen along the course of the same tributary wadi, each with a farm dwelling or watchtower (Mayerson 1962: 239). Such farm units vary in size, which makes for interesting questions concerning how land ownership was organised and developed, and rights to water and so forth established.

Some cultivated areas in the wadi bottom of some farm units covered as little as 0.6 hectares, for example 'Yoram's Farm' investigated by Evenari *et al.* (see Fig. 4.4). Other farm units were on a noticeably larger scale, such as 'Yehuda's Farm', which extends for 2.2 hectares of cultivable wadi bed terraces (Fig. 4.5) (Evenari *et al.* 1982: 104). It is probable that landowners controlled different parcels of land in several locations, to spread the risk due to the fact of the almost random geographical distribution of the rainfall: for whilst rain may fall in one particular wadi, the adjacent wadi often may not receive any precipitation for the whole year. In addition, the non-literary papyri documents unearthed in Nissana, particularly *p.Colt* 82 reinforce this feature, as it specifically mentions parcels of land belonging to one family, which are in separate locations (Kraemer 1958: 238; Mayerson 1962: 226). Such a scenario may help to explain to some extent why certain runoff farm units do not contain a farmhouse, but merely a watchtower, or in some cases no such farming structure of any sort.

The construction of the walls and the specific techniques to control the water flow also exhibit a distinct increase in sophistication compared to the simpler systems on the fringes to the south and the southwest. The cross-wadi terrace walls are often six to twenty metres in length, and rise to a height of on average 0.6 to 0.8 metres tall. This height is achieved by using several courses (five to seven is the usual number) of well-laid, medium sized stones that protrude above the higher field by on average 0.1 to 0.2 metres (Evenari *et al.* 1982: 97). Instead of the earlier single line of stones, it is often the case that the terrace wall will be of double-line construction, of a thickness of 0.7 to one metre in width, with occasionally on the thicker examples an infill consisting of smaller stones and soil (Mayerson 1962: 233). In addition, double-faced wall construction is almost universally employed for the construction of the enclosure walls. The spacing between the terrace walls varies depending on the survey, so for Mayerson the average distance oscillates between twenty and 35 metres, whereas Evenari *et al.* maintains that it is twelve to fifteen metres (Evenari *et al.* 1982: 97; Mayerson 1962: 235).

Within these terrace walls are to be found certain spillways (or sluices) designed to allow the controlled flow of excess floodwater down through the whole terrace system. These spillways were carefully constructed stone shelves positioned just in from the edge of the slope within each terraced section, thus allowing the easy but controlled transfer of overflow water from one terrace to the next. In some instances these spillways have been found to be of a more elaborate construction, particularly when forming a distribution point at the end of a channel conduit, as is clearly evidenced by the well-built spillway and flow distribution box at 'Michael's Farm' (Evenari *et al.* 1982: 104). The spillway controlled the flow of water from the water conduit into the distribution box, which by means of sluices, operated using a board or a large stone, could channel the water into three different channels and so on to three different terraced fields, whichever required water at a particular time.

In some runoff systems, the edges between the slopes and the wadi bed also have long low running walls parallel to the direction of the wadi course, which Mayerson designated 'Basin walls'. At 'Yoram's Farm' the basin walls form a fence of around 1.5 metres in height encircling the cultivated area, with spillways set into the walls at certain points to allow water to enter the cultivated area from the wadi or conduits (Evenari *et al.* 1982: 99). The apparent purpose of these walls was to contain the floodwaters within the fields and prevent substantial losses into the uncultivated areas (Mayerson 1962: 239). It could also be suggested that in certain cases these basin walls in steep slope areas, helped prevent the development of gullies and damaging erosion on the adjacent slopes. The presence of a lattice of long running stone conduits also helped in this regard, guiding water from sections of slope into the adjoining field in the wadi bed.

The conduits themselves are small, with an average cross-section of only 0.1 square metres, and each conduit has been found to drain only a small area, not more than 1.0 to 1.5 hectares in area (Evenari *et al.* 1982: 109). In this way the runoff was controlled from the outset into a series of numerous small streams, which were subsequently directed to the specific areas where the water was required. Hence, no potential runoff was lost and the process eliminated the possible danger of uncontrollable flash floods building up further down the tributary wadi. The ratio between the area of cultivated fields to the area of the catchment basin for each wadi varies between 17:1 and 30:1, with an average ratio of around 20:1 (Evenari *et al.* 1982: 104).

With this ratio figure, Evenari has calculated the estimated water yield to the cultivated areas. Experimentally it was found that fifteen to twenty per cent of the annual total rainfall was transformed into runoff water, due to the relatively high impermeability of the crust-covered loess soils and the high stone cover. Therefore an average annual rainfall of 100 millimetres per annum would generate ten to twenty millimetres of runoff water. Consequently every hectare would provide on average 100-200 cubic metres as one millimetre of rainfall would provide ten cubic metres of water per hectare. Hence, at a ratio of 20:1 each hectare of cultivated land would receive 2000 to 4000 cubic metres of runoff in addition to 1000 cubic metres of direct rainfall. Therefore, in effect such a hectare would be receiving the equivalent of 300 to 500 millimetres of rainfall (Evenari *et al.* 1982: 109). Such an amount would be more than adequate to grow certain crops, providing that the particular wadi received rain that year.

As for the diversion systems on the main wadi areas, the problem here was usually not the general lack of water in the vicinity, as this was supplied in adequate measures in most years by flash floods. However, the difficulty in this environment was to capture sufficient quantities of water within the short timespan of the flood season with which to saturate the fields. As a result intricate structures were required, and thus the systems are usually on a larger scale than the 'runoff farm' systems, and are generally less common. Again a number of these diversion systems have been surveyed to varying degrees of intensity. The largest and most complex example to have been studied in the Negev lies just over three kilometres to the southeast of the major settlement of *Sobota* (Shivta) along the Wadi Abiad or Abyed (Hebrew – Nahal Lavan) (Evenari *et al.* 1982; Kedar 1957a; Mayerson 1962; Figs 4.6 and 4.7). Other examples of diversion systems are simpler in layout than the Wadi Abiad, but as with the runoff systems, each diversion system exhibits a common number of necessary and practical elements most of which are found in all diversion systems even in other areas. These include diversion dams, channel networks, and large enclosures, divided into a series of gently stepped terraced fields (Mayerson 1962: 241-44).

In most cases the evidence for diversion dams is very limited, as they have been washed away by successive floods over many years. What evidence remains suggests there may have been a variety of techniques used to capture the required amounts of water to irrigate the enclosed fields.

Mayerson cites the examples found in the Wadi Auja near the settlement of *Nissana,* where at a point upstream from the enclosed fields, the remains of a number of diversion dams were surveyed (Mayerson 1962: 244). The majority of dams were curved structures which led out from the bank of the wadi course, but only obstructed a section of the wadi bed. From their rough unstructured construction, these were identified as successive Bedouin versions. However, upstream the base of a more substantial barrier was encountered. In construction terms, the dam was a carefully built double faced wall, which at the bank side was three metres in width, but this successively narrowed to 1.2 metres as it gently curved upstream, culminating in a spillway across the remaining stretch of wadi bed.

In this way the dam could siphon off in a managed operation all the floodwaters up to a certain level. Beyond this point, the floods would be in danger of damaging or even washing the dam away, so the insertion of the spillway ensured the excess water be cleared and the dam could continue to provide water to the fields at the same time. It is possible other diversion systems employed dams running across the entire wadi bed, constructed of stone or that earthen banks were built to raise flood waters as occurs elsewhere, particularly Saudi Arabia. In any event, practical factors would finally decide which type of dam would be constructed, including the width of the watercourse; the maximum and minimum expected volume of flood water; and the height difference and relative topographic position of the fields to be flooded in comparison to the position of the dam (Mayerson 1962: 245). This latter determinant was perhaps the most critical in the long term, for as the fields silted up over time it would have been periodically necessary to rebuild the deflection dam at a point further upstream, in order to maintain the required difference in height to allow water to flow under gravity onto the fields.

As the dams needed to be constructed at an elevation higher than fields, channels were obviously required to convey the water to the enclosures. At Wadi Auja the large dam led directly to the remains of a water channel, which measured six to eight metres wide, with the downslope side faced by a double-faced retaining wall one metre thick (Mayerson 1962: 244). Other systems had similarly large, wide channels, for example at Wadi Kurnub, the diversion system two kilometres south of *Mampsis* relied on a channel 400 metres in length which progressively narrowed over that distance from a maximum width of nine metres down to five metres (Evenari *et al.* 1982: 110). Furthermore, over the whole 400 metre length, the channel was carefully constructed so as to produce a very gentle and constant gradient of around 1:2000. The widest channel so far surveyed measures twelve metres and other systems have channels up to 1.5 kilometres long with a width of three metres and a depth at least of 2.5 metres (Kedar 1957a: 183). Generally, it can be assumed that the large width of the channels, in addition to the position and construction of the deflection dam, would have had the effect of decreasing the high velocity of the floodwaters to a manageable flow.

The channels were thus able to deliver potentially large volumes of water to the enclosed sets of terraced fields. Unusually for the Negev, the fields at the large system situated at Wadi Abiad were served by three such large-width channels (five to ten metres wide and two to three metres deep in places), which captured floodwaters from a point 700 metres upstream of the field system (Fig. 4.6) (Evenari *et al.* 1982: 114; Kedar 1957a: 183). These channels distributed water to an area of around twelve hectares in size, (760 metres long and on average 140 metres wide), and according to Kedar divided into twenty individual plots on several levels (1957a: 182). However, if a comparison is made in terms of field layout, between the earlier plan of the field system as drawn by Kedar with the later plan by Evenari *et al.,* an inherently more complicated picture emerges (Figs 4.6 and 4.7). This evident difference in the visualization of the same field remains has had a significant impact on the resulting interpretations concerning both the methods employed in operating the system and the system's development over time. Hence, Kedar in his interpretation split the field system into two conjoining but differently operated sections; an upper level of eight fields and a lower level of twelve or more fields (1957a: 182-83).

The upper level fields did not receive any water from the network of channels, but instead obtained their water from runoff gathering in the large gully/tributary wadi which cuts into the slope lying to the northeast of the field system. In fact these fields actually rest on the alluvial fan of the gully, which consequently meant the runoff to some extent naturally spread evenly across these fields. The lower level fields were supplied directly by the channelled water, each channel serving a distinct collection of fields within this area. Spillways were provided along the downslope boundary of each field which ensured that excess water did not go to waste but was circulated around the field system.

The field system boundary walls also contained spillways, those placed along the northern boundary wall which was constructed at the foot of the slope, ensured that any runoff of the slope could enter the system and the wall itself limited the development of gullying within the slope. Whilst also containing spillways, the wall facing the wadi is also a highly significant feature of the system as a whole, for it is a very well-built construction using roughly-dressed which in places still stands to a height of four to five metres above the adjacent wadi bed (Evenari *et al.* 1982: 114; Kedar 1957a: 183). Mayerson designated such a structure an 'anti-scour' wall, correctly suggesting that such a wall was constructed to prevent wadi flood waters from eroding valuable agricultural land (1962: 242-43). Perhaps a more interesting point to note is the presence of such an anti-scour wall as an indicator of the rapid deposition of alluvium over a relatively short period of time, which may have eventually necessitated the construction of such a protective device. As

Kedar noted the surface of one field within this system lies around four metres above the natural alluvium of the river terrace. Hence, he calculated the potential within the field system as a whole for there to be deposited around 0.5 million cubic metres of mostly channel borne alluvium (Kedar 1957: 183). This leads to the question of when such a system, and the many similar smaller examples, was being used.

4.3 The Hauran and the Harra

The basalt-steppe regions of the southern Hauran, the eastern slopes of the Jebel al-Arab, and points within the Harra (or Black desert) beyond, exhibit evidence for phases of extensive sedentary settlement during the Classical period (see Section 3.3.10). Much of the southern Hauran remained deserted until the late nineteenth century when it was observed during the first serious archaeological survey that sedentary settlement had recommenced (Butler 1904). As the modern population of the region has grown, archaeological interest has been renewed in the last three decades, and a number of surveys have been completed (de Vries 1998a; Kennedy 1995a; Kennedy and Freeman 1995; King 1982; King *et al.* 1983). Much of this work has concentrated on examining the evidence for settlement, and particularly on the close examination of the small Byzantine-early Islamic town of Umm el-Jimal (MacAdam 1994: 55-56). The settlement of Umm el-Jimal was the largest settlement in the region, and has been the subject of intensive study for the last few decades, the results of which are now in the process of being published (de Vries 1998a). Fortunately, much of the settlement has been preserved, and so has been saved from the process of re-occupation and re-development which has affected most of the other ancient settlements in the region.

The study of Umm el-Jimal has proved to be of great interest, for although it is situated only twenty kilometres or so to the southwest of Bosra and the settlements of the Nuqra plain, it reveals important differences. The town seems to have experienced a large increase in development during the fifth to the seventh centuries AD, a later development than either the Decapolis territories to the west, and the Nuqra plain to the north (MacAdam 1994: 57). Another major difference can be seen in the large corpus of funerary epigraphy to the inhabitants. For although inscribed in Greek, the names are of a distinct Arab identity, which is in stark contrast to the Greek names of the later inhabitants of the Nuqra plain (MacAdam 1994: 58). As for water management systems, all the settlements of the region, including Umm el-Jimal relied on an extensive system of aqueducts and large storage reservoirs and covered cisterns into which the water was channelled (de Vries 1998a). Similar systems have been recorded at other village settlements in the vicinity, for example at Umm el-Quttein and Deir el-Kahf, the sites of late Roman forts and later, village settlements (Kennedy 1995a; Kennedy and Freeman 1995). These systems have been found to involve the damming of wadis and the diversion of floodwaters along simple channels to birkas (cisterns) located in the centre of the village (Kennedy 1995a: 280-87).

As yet, little study has been made of the extensive remains of farming landscapes of the southern Hauran. However, Kennedy has shown the potential of such a study from an assessment of the evidence revealed by aerial photographs of the 1950s (Kennedy 1998a). These reveal a complex network of cross-wadi wall systems along the courses of the numerous wadis which cross the region from their source in the Jebel al-Arab (Fig 4.8). Dotted at almost regular intervals along the banks of these shallow wadis numerous farmsteads, of either circular or rectangular shape, corrals for animals, occasional terracing and possible barns have been identified (Kennedy 1998a: 67-72). Hence, visually, this landscape in some respects reflects certain similarities in land use systems to those observed in the Negev (MacAdam 1994: 61). The date of these farming units has yet to be undertaken, but it seems reasonable to suggest they are connected with the growth of the village settlements, such as Umm el-Quttein and Deir el-Khaf, and Umm el-Jimal (Kennedy 1998a: 84).

Further to the east, the Black desert has experienced limited permanent settlement in certain periods linked to the utilisation of water-harvesting techniques with varying degrees of sophistication (Betts 1998). Some of the earliest systems have been dated to the third millennium BC, notably at Jawa on the southeastern edge of the Jabal al-Arab (Helms 1981) and on a smaller scale at Khirbet el-Umbashi to the northeast (Braemer *et al.* 1996a). Although it must be stated that recent analyis of the Jawa ceramics would place the earliest occupation to the fourth millennium BC (Betts 1991; Philip 1995). However, this discussion will concentrate on the methods of water management which current evidence suggests were used at settlements in the Harra during the Classical period. In relation to this, the focus will be on the archaeological evidence at three such places, although evidence can be found at other locations as I have discovered on visits to the region.

The first of these sites, ad-Diyatheh, is located on the western edge of the Harra where it confronts the steep descent of the Jebel al-Arab (Figs 4.9 - 4.11). At a point almost in the middle of the northern part of the Harra is the second site, al-Namara, situated at the confluence of the Wadi al-Cham and a tributary wadi (Figs 4.12 and 4.14). The third site, Qasr Burqu', is to be found located on the eastern edge of the Harra, just before the commencement of the Ruhba, a large fertile alluvial plain, which significantly 'has provided highly-prized grazing for nomads from time immemorial' (Braemer *et al.* 1996b:1; Fig. 4.13). Other evidence, can be found in certain other of the deeply cut wadis on the edge of the Jebel al-Arab, particularly to the south of ad-Diyatheh where I observed a number of small diversion systems and water channels at certain locations where the opportunity to take advantage of floodwaters could be achieved. For example, along the course of the Wadi Ruseideh a number of small field systems can be seen fed by diversion channel systems and containing Classical period sherds (Fig. 4.15).

Ad-Diyatheh lies on the line separating the settled Hauran in the West from the Hamada steppe, of the Badiyat al-Sham that stretches to the east. This demarcation line also echoes the important 100 millimetres precipitation isohyet which follows the relief edge of the Jebel al-Arab. The site is also crucially situated along the edge of a deep-cutting wadi, the Wadi Cham, one of a number of wadis whose floodwaters have etched deep-sided valleys into the Jebel as they head east out into the Harra. In relation to this wadi the site of the fort (labelled A on Fig. 4.9) was carefully chosen, being a small flat plateau above the north bank of the wadi, with commanding views across the Harra.

Clustered around the fort and along the edge of the north bank of the Wadi are to be found the remains of around a hundred stone-built buildings (B on Fig. 4.9), all of a similar construction and with a homogenous layout. Many of these houses are in a very good state of preservation, some having underground rooms in extensions excavated back into the wadi bank. Consequently it has been suggested that this collection of structures forms a village of contemporaneous construction (Villeneuve 1986b). Apart from a walled meeting/function area, no public building of any other sort has been identified and there seems to be no indication of a stone-lined *birket* or reservoir (Sadler 1993). This is contrary to normal expectations, as invariably settlements of the Jebel region have such reservoirs. However in the wadi bed south of the village and fort, and continuing up onto the right bank, can be seen the entrances to some stone-lined wells (which are still utilised) tapping into the underground water flow of the Wadi Cham. In addition, there are the extensive remains of stone-cleared fields and walls.

The construction of the village houses on two floors, with the lower floor in some buildings containing evidence for stone troughs, at first seemed to indicate an economy based on the production of cattle, as in the areas of the limestone massif in northern Syria (Villeneuve 1986a; Tate 1992). But as the French survey of the village was coming to a close, it was realized that the agricultural operation was on a very large scale. Initially this operation seemed like a simple diversion of wadi floodwater onto the Harra plain, below the fort and village, but further investigation revealed the remains of a complex floodwater farming system. Within this system can be found other significant features including watermills built on to leats seen extending out onto the plain of the Harra on the north side of the wadi course.

In a review of these, Sadler (1993) outlined the main features in the following terms. At a point 300 metres downstream of the village occurs the first major diversion (C on Fig. 4.9), across the wadi bed and there are at least two other such diversions (D and E) situated a further two and three kilometres downstream from the first (Sadler 1993: 428). The first is by far the best preserved and constitutes a long low barrage of medium-sized stones which cross the wadi bed at an oblique angle to the flow. The barrage leads directly into a long straight canal (F) constructed on a shallow gradient which would allow the momentum of water flow to overcome the height difference between the Harra plain and the wadi bed, which lies several metres below it.

Although the networks have been eroded somewhat by the action of floodwaters and neglect, the course of the main canal can be identified as running more or less in a parallel direction to the main wadi and as it approaches the plain a succession of tributary canals lead off it down towards the irrigated zones. This process is repeated with the other diversion barrages and their associated primary, secondary, and tertiary canals further downstream. Each secondary canal in the first network, of which there are two (G and H), feeds its own self-contained network of smaller-sized tertiary channelways or canals. These smaller tertiary canals (up to several hundred metres in length) lead off from the secondary canals and directly feed a number of rock-cleared fields which are scattered at intervals across the gently sloping plateau (Fig. 4.11).

The second of these secondary canals (H) is the longest in extent (around three kilometres in length) and serves a larger but more dispersed field system. The canal heads in a northeasterly direction almost as far as the next wadi coming down from the Jebel, the Wadi Gharaz. Running from this canal in an easterly direction, and at regular intervals along its course, is a succession of parallel tertiary canals up to 800 metres in length which feed a large number of rock-cleared spaces that constitute the fields of this sub-network. Hence, it has been calculated that the total area which could be irrigated by this first barrage and its associated main canal, secondary and tertiary canals amounts to around 1200 hectares (Sadler 1993: 431). At the end of each sub-network, there is evidence for the collection of any excess water into a small canal which then appears to lead into the following network, so no water is wasted or allowed to erode the canals or fields by ponding or similar.

Around the slopes to the north of the village, along the edges of a shallow valley leading off from the Jebel, evidence for another water capture strategy was recorded (Area J on Fig.4.9). This valley is at too high an altitude for the canals to irrigate, and seems to have produced too low a natural amount of water to allow the growing of cereals. Yet there are remains of stone-cleared fields and the vestiges of long low parallel walls, some leading down the slopes at regular intervals and others at lower levels parallel to it, thus forming low terraces (Sadler 1993: 433). It seems to present a different strategy, more concerned with collecting surface runoff water from higher up in the valley and leading it in a controlled way to a terrace system in which both water and water borne sediment could be captured and controlled. Such systems dating to the Roman period have been documented in other dry environments such as the Libyan Valleys, (Barker 1996) and the Negev (Evenari *et al.* 1982). The fact that much of the central part of this system has been destroyed by erosion since it was abandoned testifies to the extent to which this concentration of runoff was successful (Sadler 1993: 434).

Illustrating the overall success of this scheme of floodwater farming, in an otherwise difficult climate, are the remains of a number of watermills, which presumably were utilised for the grinding of winter cereals which were undoubtedly grown here on a large scale, and which are still cultivated by the local Bedouin when the conditions allow. The remains of eight such mills have so far been located. All display a similar construction and are usually located along short millrace canal sections leading off from the secondary canals. The position of the first two mills immediately below the village settlement at ad-Diyatheh, and the similarities in stone construction techniques between these and the village houses and other mills that can be found situated amongst the canal networks of the Harra plateau, has led Sadler to suggest that the field system and the village are of a contemporary date (1993: 435). Villeneuve in his cursory assessment of the pottery from the remains of the fort and village suggests the main phase of occupation to be from the late third century to certainly the fifth and perhaps even into the seventh centuries but this is by no means clear (1986b: 713).

The site of al-Namara lies some 60 kilometres east of ad-Diyatheh out on the Harra plateau, at the confluence of the Wadi Cham and a small tributary called the Wadi Saad (Fig. 4.12). The name al-Namara refers to the large basin etched into the plateau by these two wadis coming together; at the basin's centre is a 'island' of resistant rock, the remains of a volcanic plug. At points in the wadi beds around this island, water which has flowed down from the Jebel in the spring floods, naturally forms pools well into the summer. Therefore, the combination of ample water in an otherwise arid region, and the strategic vantage point of the island, has long attracted local pastoralists, travellers and the attention of regimes trying to control the area.

On the flat top of the island or 'citadel' are the few remains of re-used structures of the Roman army and a later Arab occupation, while in the surrounding basin and beyond are the extensive remains of water catchment systems and encampments. Not much work has been done at the site, apart from an initial assessment and topographical plan of the citadel and its immediate environs within a two by one kilometre area, completed whilst work was being done to construct a modern reservoir on the wadi course at the eastern end of the site (Braemer *et al.* 1996b).

The Wadi Cham has eroded the Harra plain to an average depth of fifteen metres and an average width of 200 metres. At some points this has widened to form small alluvial plains from between 500 metres to one kilometre wide. Al-Namara is to be found in an S-bend of the wadi, and here due to the erosive action of the wadi a small plain can be found around 800 metres long and 400 metres in width. The island, being composed of more resistant basalt, intrudes into this plain, rising to around ten metres in height, and has caused the wadi to curve its course around to the south of the island. Hence the south bank of this curve has gentle slopes, whereas the north bank forms a cliff between two and eight metres in height. Downstream of this point, the banks lower in height to around one metre in height, and the distance between them widens into a plain up to one kilometre wide. The northern terrace of this plain exhibits substantial evidence for simple irrigation systems up to one kilometre in length, whereas the southern side has more limited evidence (Braemer *et al.* 1996b: 4).

The remains of around five diversion barrages have been located linked to canals leading off from them. The four barrages on the Wadi Cham are of a similar construction, consisting of a line of large othostatic boulders positioned on an outcrop of hard basalt and placed at an oblique angle to the flow of the wadi. The boulders were bound together with smaller stones placed around them. The low dams thus formed only obstructed the wadi course partially so as to capture water in a controlled manner but not be open to destruction by the force of the flood, as also occurs at ad-Diyatheh. Three of the barrages in fact only partially cross the full width of the wadi course (Braemer *et al.* 1996b: 9). The canals which lead off from these barrages seem to have served two purposes. The two canals positioned upstream from the citadel are fairly short in length (around 800 metres long) and seem to serve a similar function in capturing water from the wadi to bring it to the basin to the south of the island where the water naturally pools. Downstream of the island are two of the other barrages and their associated canals; these capture water from the wadi and lead it to areas where fields have been cleared of stones and laid out for irrigation (Irrigated areas A and B on Fig. 4.12).

The first canal (Canal 3 on Fig. 4.12) lies on the northern terrace of the wadi and is around 2.5 kilometres long. The length of the other canal was not able to be measured because it has been partially obscured by the new reservoir. The area irrigated by the first canal lies immediately adjacent to the wadi and forms a small terrace up to 100 metres in width and roughly two kilometres long (Irrigated Area A on Fig 4.12). This canal follows a similar pattern in its construction to all the other canals, in that it has a channelway of one to two metres in width, with a wall 0.5 to one metre high of medium sized boulders lining the downslope of the channel, which follows the contour of the terrace bank (Fig. 4.14). The wall was made waterproof with the packing of smaller stones and earth in the gaps between the larger stones. Behind this low wall the floodwater would flow, being let into the field area below at certain points by the means of simple spillways. At the end of the canal is a small secondary stretch of canal which stops the remaining water from entering back into the wadi and instead redirects it back into the area to be irrigated.

There are two further canals along the course of the Wadi Saad, which are short in length (250 metres and 800 metres respectively) and seem to have been constructed to capture water to irrigate small stone-cleared fields immediately adjacent to this wadi.

The site of Qasr Burqu' lies some 100 kilometres east of ad-Diyatheh, and some 70 kilometres southeast of al-Namara. At this location stone structures have been built alongside a point in a natural shallow basin where water from surface and sub-surface runoff from the surrounding slopes naturally ponds (Betts *et al.* 1990: 6) (Fig. 4.13). The most significant structure is a tall, rectangular stone tower, which rises to a height of around five metres and study of the arches and floor levels within it suggests may have reached a height of thirteen metres (Betts *et al.* 1991: 16). Immediately surrounding this tower is an irregularly shaped quadrangle of a series of rooms, which appear to have been constructed at a later date. An analysis of the architectural details apparent in the construction of this complex of tower and enclosure structures, along with the evidence from two burial inscriptions written in Greek, led Svend Helms to suggest the site to be a monastic foundation of the Late Antique/Early Islamic period (Betts *et al.* 1991: 16). Initially only the tower may have been constructed as the residence for a recluse, sometime between the fourth and seventh century AD. However, the possibility that there might have been an earlier presence by the Roman army, which perhaps was even responsible for the initial construction of the tower, cannot be totally discounted (see Gaube 1974; Kennedy and Riley 1990). On this point, the pottery found within the structure was for the most part late antique/Early Islamic, but earlier Roman pottery has been found in the area (Betts and Helms 1989: 8; Betts *et al.* 1991: 22).

Later, this tower could have served as the focus for a monastery which grew up around it, and changed its function to that of a 'watch tower' and possible refuge from any unfriendly nomads. Alternatively, the tower and enclosure buildings may have had a military purpose for the Arab government of the sixth century Arab Ghassanid client period (Betts *et al.* 1991: 17). Whatever the function of these buildings, it was vital for the occupants to secure an adequate all-year-round supply of water. Natural ponding of flood and rainwater occurs at this point due to a bed of more resistant basalt rock crossing the wadi valley. It is supposed that the quantity of water collected behind this natural barrier was not sufficient to sustain an adequate population throughout the year. Therefore to improve the volume of water the natural water pool or 'lake' was enlarged and secured by the building of a dam downstream of the buildings, and on top of the low ridge which was responsible for the natural pooling of floodwater within the wadi bed.

This dam, whose lower courses still survive, was composed of large-sized roughly dressed basalt boulders, laid in a series of stretcher courses, capped by one of headers. Two such walls, around ten metres apart were built following the top of the ridge. The space between was probably filled with earth and rubble. Along the side facing the water is evidence for plastering, which together with the form of wall construction, has been suggested as supporting the idea that this dam is of a similar date to the establishment of either the tower or the enclosure (Betts *et al.* 1991: 12). The edges of the reservoir are lined with low roughly coursed stone walls, from which two short stone staircases lead down to the reservoir, one on each side of it.

A point of major significance was that there appeared to be no evidence for a sluice gate of any type within the wall of the dam, which supposes that the water was not used to irrigate a network of fields in a manner well illustrated by the impressive dam and field network further to the north at Qasr el-Gherbi near Palmyra (Schlumberger 1986). However, one of the 'rooms' of the enclosure (room eleven) has been tentatively identified as a windmill (Betts *et al.* 1991: 17), which suggests that it may have been used (if it existed) to grind locally-grown cereals. Around the 'lake' and its associated buildings are huge numbers of encampments, burial cairns, and corral remains along with scatters of artefacts from all periods, in a manner similar to that at al-Namara. Therefore, it can be postulated that the main function of Qasr Burqu' was 'as an oasis on a series of north-south and east-west 'desert' routes' (Betts *et al.* 1990: 6).

As for evidence of field systems, none seems to have been found at this site by the recent survey. However, at the nearby fixed Bedouin encampments of Feytha, ar-Risha al-Fawq and ar-Risha al-Taht in the more fertile and stone-free Ruhba are today 'fields of barley, planted for animal fodder and watered by flood irrigation' (Helms 1989; Lancaster 1981). Hence it may well have been the case that any permanent members of population at Qasr Burqu', be they Roman or Arab, were served by equivalent field systems to those situated in the Ruhba.

4.4 The plateau of Edom

The plateau region immediately to the east of the Wadi 'Araba forms the fourth area of comparative land use. As noted in Chapter 3 some archaeological work has been undertaken within this region, however, much of this has been site-based, with most attention placed on the city of Petra, the location of settlement in its environs 'Arabia Petraea', and in the northern Jibal region (see Section 3.3.6) (Graf 1992a; Hart 1986a; B. MacDonald 1988). Therefore, any evidence for land use within the region appears very fragmentary in nature. Consequently, as part of a comparison with evidence from the Negev and with those methods employed in the Wadi Faynan immediately to the west of this region, I was keen to investigate the potential of the farming systems on the Edomite plateau to the east of the Jordan valley, which have had little attention from specific archaeological research as yet. The Dana Archaeological Survey (DAS) provided such an opportunity, and from which much of the following evidence has been obtained.

The evidence represents examples from a range of sites within the region and therefore whilst this is not comprehensive, it does identify the main applications of water management and land use systems that functioned within the region during the Classical period.

The land use of today can generally be ascribed to two differing farming systems based on the annual levels of precipitation. Along the eastern edge of the plateau, sufficient amounts of rainfall (above 200 millimetres) are usually received to allow the cultivation of cereals in most years (see Fig. 2.10). At certain opportune points surrounding this region of dry farming, and indeed in some of the valleys within it, small units of irrigation farming are occasionally observed utilising the many strong perennial springs of the area, for example at Gharandel in the Jibal (Walmsley 1998: 435). Recent years have seen the tapping of fossil water using deep well technology, and fruit trees and olive groves can be seen at the eastern edges of the dry farming region, covering extensive areas of the gentle slopes down towards the arid hamada beyond. From the fragments of evidence which can be gathered from this region, it seems that a similar mixed farming regime, of dry farmed cereals, and small acreages of irrigated olives and fruit trees, existed for much of Classical antiquity.

A good indication of the farming practices of the Byzantine period of the sixth century AD has come to light recently with the unearthing of the carbonized papyri from the storeroom of a Petra church (Koenen 1996). Although not fully published yet, these papyri, of which most are in the form of legal contracts, have provided a wealth of information concerning the administrative organisation and agricultural methods of the plateau region. The most important evidence in this regard has come from roll number ten, which is concerned with the division of property and land between three brothers (Koenen 1996: 183-85). Mention is made in this papyri of sown lands for wheat, vineyards and houses with adjoining orchards (which would have been irrigated by hand

and which are common in the region today). A further roll fragment mentions a 'regular orchard' which has been interpreted as referring to an irrigated orchard, as seems to be the case with similar papyri from Nessana in the Negev (Koenen 1996: 184). It is also interesting to note that the land divided up in roll ten was scattered in plots across a relatively large geographical area, and that the individual fields were small in size from around 2.6 acres up to an occasional maximum of around sixteen acres. As Koenen suggests, this reflects a well-known method of risk management where the availability of water could fluctuate wildly from year to year at different locations within a very localised area (1996: 184) (see also Section 4.3 for similar evidence in the Negev).

Subsequently, it would be logical to assume that these scattered fields would not have been farmed by the family alone. In this regard the papyri refer to two types of land management for it seems the fields were either 'leased' to other landowners or 'farmed' by professional farmers, who although free seem to have been more indentured than leaseholders. Such rare evidence highlights the complexity, at least in the Byzantine period, of the social and agricultural organization. To some extent, this complexity evolved as a consequence of the mechanisms employed to maximise the efficiency of the land and lower the collective risk by for example the diversification of crops and the wide distribution of landholdings. The only written evidence for land organization in the plateau region before the Byzantine period comes from a short Nabataean dedication stone of eight BC from the large cult centre at Khirbet at-Tannur, dedicated by the 'curator' of the source of Wadi La'ban. Villeneuve suggests this may hint that there was a local organisation for the control of spring water and irrigation within the valley (1992: 281). However, another explanation could be that the curator may have been the keeper of the spring water in a purely spiritual sense, which would lessen the importance of such evidence.

The Wadi La'ban is one of the many tributaries which dissect the south bank of the Wadi el-Hasa, and was included in the extensive survey of sites by Burton MacDonald (1988). As has already been noted (Section 3.3.7) most attention was paid directly to locating settlement sites in this survey, though subsequent interpretations of the evidence have put forward a number of explanations for the spatial distribution of settlement and subsequent changes in this distribution (Hill 2000; B. MacDonald 1992). Furthermore, a number of sampling transects were completed to identify evidence and densities of campsites and other less visible sites of human activity such as tombs (Banning 1986: 31-36). The evidence collected from these transects was then used as data to test models of nomad–peasant mutualism through the analysis of site location in particular microenvironments in the transect region during antiquity (Banning 1986: 37-42). The results of the simple statistical tests proved that there was a strong correlation between the location of Roman-Byzantine dated settlement, be this village, farmhouse or campsite, to the terra rossa soils of the higher, flatter areas above the wadi courses. This in some ways might have been expected, but the interesting aspect was that the campsites were generally to be found in this region as well, and not in the wadi valleys, on the periphery of the band of permanent settlement set on the plateau areas. The general conclusion reached by Banning was that the sedentary inhabitants and those of the campsites, which he assumed to be of nomadic peoples, were thus engaged in a symbiotic relationship centred around the exploitation of the plateau soils through dry farming agriculture (1986: 42-45). Such mutually beneficial symbiosis between settled and nomad is still important in some farming regions of the Levant today, particularly on the Jebel al-Arab and is further evidence of the development of appropriate systems to maximise the agricultural potential of marginal lands (Finkelstein 1995: 59-63; Lancaster 1981; Lancaster and Lancaster 1999: 212-13; Palmer 1998).

From the site survey evidence it seems this particular agricultural regime along the Wadi el-Hasa had developed during the Classical period, for the distribution of sites and their morphology is different for the Nabataean/Early Roman period compared to the Byzantine (B. MacDonald 1992). Therefore, given the problems of dating the sites in this region (Section 3.3.8), it does seem that the Nabataean/Early Roman settlements are generally smaller 'hamlets' than the later Byzantine 'village' settlements (B. MacDonald 1992: 157). Again using simple statistical tests, and the application of GIS techniques, Hill has shown that in the earlier period these smaller settlements can be seen to cluster significantly near to the tributary wadi courses, whereas by the late Byzantine they have moved a significant distance away from the wadis onto the higher and drier plateau regions (2000: 229). Hill discovered this phenomenon was not just restricted to the Classical period alone, for both the Early Bronze Age and the Ottoman (post fifteenth century AD) periods experienced similar settlement shifts to the higher ground (2000: 231). He proposed such settlement distribution was a reflection of political factors, in that during these periods the peoples of the Levant were subject to the rule of external political powers. Consequently, the distribution reflects the presence of a strong central authority, which 'may have allowed agri-expansion into areas otherwise subject to raiding by nomadic peoples' (Hill 2000: 232).

There may be some truth in such a hypothesis, but such a view is too simplistic to completely explain this change in settlement, as there were undoubtedly more immediate local concerns which affected the settlement. What is important to note in terms of land use, is that there was a distinct change in the land use of the Nabataean period in contrast to the Byzantine. It is clear that the sedentary settlements which were established in the late Nabataean/early Roman periods were making use of the wadi beds, both for supply of drinking water, and for the growth of crops using simple floodwater farming techniques. The growth of complex systems of land management and social relationships encouraged the settlement of the higher plateau areas and a subsequent increase in population.

Not only is there evidence for local shifts in settlement, but also the evidence presented by archaeological survey and the small amount of excavation in the region has indicated the intensity of settlement of the region as a whole varied from period to period. As discussed in Chapter 3, survey work has found that the southern part of the region (commonly labelled the al-Shera by commentators) was more intensely settled in the first century AD and all but abandoned by the end of the second century AD (Hart 1986b). Furthermore, to the east of Petra it seems that a period of intensive settlement grew in the Byzantine period, centred on the large settlement of Udruh (Fiema 1991: 219-20; Killick 1987).

Killick, the excavator of Udruh, a major fortress and later large settlement site of the late Roman to early Islamic periods, has proposed a Nabataean date for the earliest activity at the site (1987: 173). Its position and continued existence, twelve kilometres east of Petra, out into the dry hamada, depended on access to a perennial spring, which is still the basis for the modern settlement. From the air an extensive system of fields, just to the north of the main area of settlement, can be seen which resembles in many ways that of Wadi Faynan in the Wadi 'Araba to the west, and of some systems in the Negev (Fig. 4.16). However, it seems the strong spring, supplemented by occasional floodwaters, was used to irrigate this extensive area of land in antiquity, as it continues to do today. Evidence for later qanats (or foggaras) has been seen from the air a few kilometres to the southeast of the settlement, which may have been used to irrigate further systems of fields and a number of water mills whose remains stand at the edge of the settlement remains (Kennedy and Riley 1990: 131-33).

It seems that the settlement of Udruh stood at the centre of a small but significant network of settled sites of various sizes which appears to have been established in the surrounding district during the late Roman – early Byzantine periods. Killick reported on a number of these sites, but does not seem to have appreciated the significance of such settlements far out into the pre-desert, where rainfall and natural water resources were few and far between. One of the largest of these settlements is situated close to the hill of Jebel at-Tahuna (Killick 1986: 438-40, 1987: 25-35). The village is sited near a small spring, which appears to have been used largely for drinking water: to obtain water to irrigate the surrounding fields, it was necessary to construct two large dams and a network of channel and field walls (Figs 4.17 and 4.18) (Findlater *et al.* forthcoming; Killick 1986: 438). In addition, an aqueduct was constructed to take springwater a few kilometres east to the settlement at Ma'an, the scattered remains of this can still be seen today. It is interesting to note, that a modern pumping station has been built at this site with the object of supplying water to the large population living at Ma'an today.

Beyond the oases of Ma'an evidence survives for ingenious engineering techniques to use various sources of spring and occasional floodwaters to irrigate substantial areas of land for agricultural purposes. These works can be seen at the locations of al-Mutrab and al-Hammam which were surveyed during the DAS survey (Findlater *et al.* forthcoming). The outstanding architectural feature at al-Hammam is a large stone built reservoir and aqueduct which fed it, alongside what was presumed to have been a late Roman military fort (Brunnow and Domaszewski 1905: 3-4; Musil 1926: 328; Parker 1986).

However, as suspected by Sir Aurel Stein, these remains appear to be elements of a large, irrigated agricultural estate, which remained unfinished in certain parts (Stein 1982: 260-63). Comprising an aqueduct which runs from the large reservoir at al-Hammam, this divides at certain points into smaller channels which lead to cisterns and into a large area of land to the east of al-Hammam (Fig 4.19). Surrounding the whole area is the rubble remains of a wall. At certain points along its length are placed three or so courtyard buildings. One of these, at al-Mutrab, was originally surveyed by Parker and was thought to have been a small fort of the Roman *limes* (1986). However, when the surrounding landscape is taken into account, it is clear that this building, and the others, were large courtyard-style farmsteads, and an integral part of the estate. Other features of the estate include: small rectangular buildings at some of the channel junctions, which could have been occupied by workers operating sluice gates and thus controlling waterflow (see Fig. 4.20); a series of long wall divisions within the estate; a series of low cross wadi walls in the wadi region immediately to the south of the estate.

The materials used in the channels and reservoir is worth pointing out at this point. The channels are built of rough medium-sized stones and are for the most part plastered inside and out, with a pinkish mortar which contains smashed pieces of pottery fabric. The walls of the reservoir are of roughly coursed limestone interspersed with thin courses of more flattish stones (Fig 4.21). The estate seems to have remained unfinished in part, for the main aqueduct suddenly stops after a kilometre or so, with no other evidence associated with it. The area is now slowly being re-developed using water pumped up from a deep well, and local workers reported that in preparing parts of the land the roots of old olive trees had been discovered. As for the date of this estate, a number of late Byzantine sherds were recovered from the sites of the buildings, but as noted earlier these could date to the early Islamic period, which would certainly be more in keeping with the development of other irrigated estates at this time, for example at Qasr al-Hallabat, in northern Jordan and Qasr el-Gharbi in Syria (Bisheh 1982; Schlumberger 1986).

Closer to Shaubak near the modern village of Bir Khidad, an abandoned settlement (DAS site no. 265), typical of many on the eastern edges of the modern settled areas of the Jibal, lies on the saddle of a ridge between two wadis cut valleys; on the eastern edge of the high plateau which at this point drops down a couple of hundred metres to the desert plains of Ma'an (Fig 4.22). The settlement structures at this point are the most eastern of a large number of villages and farmsteads sited in and around the numerous wadi valleys between Shaubak and Petra. Most of these have since been re-occupied by permanent settlement within the last two centuries, but not along the eastern edge. The wadi to the north of the settlement has cut quite deeply into the high ground forming a steep sided v-shaped valley. The one to the south comprises a number of shallow minor wadis which flow in a generally southerly direction to the main wadi, which lies around half a kilometre to the south of the settlement. Hence the slope to the south is for the most part formed by a series of gentle undulations. There are a few small cross wadi walls in the bed of the wadi to the north of the main settlement, which could have been of recent construction. Also, there are a number of short lengths of walling parallel to the sides of wadi at the base or near the base of the valley slopes. The purpose of these walls seems very obscure; they may have been enclosure structures for animals, or the remains of channelling to cisterns which have since been destroyed. There was until very recently one such cistern still extant in an adjacent wadi to the north, but this has also recently been destroyed (Findlater *pers. comm.*).

The wadi to the south did not display any visible structures whatsoever. However, the slopes did contain a significant number of pottery sherds, as did the flattish areas above on the plateau, and there has been widespread stone clearance. These areas had also been recently ploughed (within the past few years), but displayed no signs of crop growth from the past year or so. It seems that these fields are used for speculative dry-farming agriculture by nearby villagers or Bedouin when there has been enough winter precipitation, though according to local people the last three to four years have been very dry.

To the east and west of the village itself, two large threshing floors are visible. That at the eastern end of the village is composed of flat stone blocks which together form a roughly circular paved area around six metres in diameter. However, the threshing floor in the west was created by extending and enclosing a roughly rectangular section (approximately six metres by three metres) of exposed limestone bedrock. These seem to testify to the growing of cereals in the past, in a dry-farming environment. Along the northern edge of the village, the collapsed entrances of between six and seven large rock-cut and plaster lined cisterns can be discerned. Similar singular cisterns can be observed in the vicinity of the nearby farmsteads. In conclusion, it can be said that this particular village and its associated farmsteads, operated a system of dry-farming, but relied on cisterns for drinking water. It is also possible that there was also a locally accessible perennial spring which has since become dry.

Typical of the landscape immediately above the Wadi 'Araba is DAS site 113. This is interesting as the relationship of a farm to its well-preserved fields can be clearly discerned. The site itself is a large mound of basalt stones and has cisterns cut into the bedrock below what is presumed to have been a large rectangular farmstead. From this site Byzantine period sherds were collected. Immediately to the south of the site is a shallow wadi, which contains a series of long, large well-built cross-wadi walls (Fig. 4.23). The central sections of these walls are constructed of very large boulders that in effect have created a series of stepped dams down the valley and behind these a large amount of sediment has accumulated. Connecting the fields and the farm are a number of walled tracks, which ultimately lead to the *via Nova Traiana* which passes within half a kilometre of the farm. The presence of this road may help to explain the development of the farmland in this region, which although containing fertile soil is filled with many basalt stones.

Along the edge of the scarp face leading down to the Wadi 'Araba, there are many locations where natural springs have developed, and it seems that these provided another point for sedentary settlement in the past. The village of Shamakh is one such example, which lies just off the line of the *via Nova* a few kilometres to the northeast of Bir Khidad and some ten kilometres to the south of Shaubak. The village lies just below the summit of the plateau, along the northern edge of a deep and narrow wadi. The village originally grew up here to take advantage of the perennial spring which produces an ample supply of sweet water at the head of the wadi. This spring has for a long time been used to irrigate an elaborate series of terraces within the bottom of the wadi. So as not to waste valuable irrigated land, the main nucleus of the village was strung out along the slope just above the irrigated areas. The traditional mud brick dwellings have been deserted in the last few decades for new houses above on the edge of the plateau itself, which have ready access to electricity cables. However, the terraces of the old village are still retained for the growth of olives, pomegranates and other fruiting trees creating a sharp green contrast to the aridness everywhere else.

4.5 The Wadi 'Araba

As has been noted, settlement in most of the Wadi 'Araba is limited to particular sites through much of its length (Section 3.3.5). The main exception to this restriction is the region around the southern shores of the Dead Sea, known as the Southern Ghors (Section 3.3.8). The eastern half of the Ghors region has been subject to a number of archaeological surveys of varying intensity (Frank 1934; Glueck 1935; King *et al.* 1987; B. MacDonald 1992; B. MacDonald *et al.* 1987). Little direct evidence remains of the land use of this region, or of the substantial settlement which grew up here. However, the discovery of a collection of papyri in a cave on the eastern shore of the Dead Sea in the early 1960s has added a wealth of information, not only for the southern Ghors itself, but also for the administration of the new province of Arabia in the decades immediately after its establishment in the early second century AD (Lewis 1989). The Babatha Archive comprises around 35 personal and financial documents of a Jewish woman landholder of the village of Mahoza in the neighbourhood of the town of Zoara (Bowersock 1983: 76-77; Lewis 1989). Neither of these settlements has been identified with any accuracy as yet, but it is probable that they lie in the vicinity of the modern town of Ghor es-Safi (Broshi 1992: 231).

The papyri are interesting for a number of reasons, not least because they provide information on the administration of the province. For example, it seems that the southern Ghors lay within the territory of the city of Petra in the early years of the province and not under the jurisdiction of the closer assize centre of Kerak (ancient *Characmoba*) (Isaac 1992). According to the archive Mahoza was, in the early years of the province, a mixed settlement of Jews and Nabataeans who farmed an extensive area using irrigation techniques (Bowersock 1983: 76). This was possible because the Wadi el-Hasa and a number of other lesser wadis enter into the Dead Sea at this point, which are in their lower courses perennial sources of water. However, of these wadi flows, that of the Wadi el-Hasa is the most consistent, plentiful and stable of all, so it provides the bulk of irrigation supplies (B. MacDonald 1992: 16). At present to supplement these streams there are many springs, and this is likely to have been the situation at the time of the Roman annexation (see Section 2.6) (Ionides 1940: 178). The Aramaic and Hebrew papyri specifically refer to water rights in a couple of documents in relation to the irrigation of Babatha's land, such as 'Water rights: Sunday, half an hour from the wadi's water...' (Broshi 1992: 232). Most of the property, which Babatha had inherited from her father and two husbands, consisted of seven date-palm groves (Broshi 1992: 232). Other documents mention that figs, dates, olives and vines were cultivated in the region (Isaac 1992: 71). It is interesting at this point to relate the level of tax which Babatha was responsible for paying on the produce of these date groves, this seems to have been as much as 50 per cent of the produce value (Broshi 1992: 236-37). This high level of produce tax, or as it was named – crown tax – may have been instituted in the Hellenistic period, for such a produce tax was operated during this period in Palestine (Josephus *Antiquities* XIII.49-50; Rostovzeff 1941; 467).

To date, no specific archaeological evidence has been found for the agricultural use of the southern Ghors in the Classical period, this in itself reflects both high rates of deposited alluvium from the wadis entering the Ghors, and intense agricultural use over hundreds of years (Broshi 1992). Of the surface sherds which have been collected from building structures, those from the Byzantine period have been found to predominate (King *et al.* 1987). However, evidence for ancient irrigation systems has been documented from isolated sites immediately to the north, along the wadis Numeira and 'Isal on the east bank of the Dead Sea, and at Ein Boqeq on the west bank, and to the south, most notably at et-Tlah (Figs 4.24 and 4.25; Frank 1934: 198-99, 213-15; Isaac 1990: 190-91; B. MacDonald 1992: 95). Et-Tlah is an impressive site just beyond the southern Ghors, some 24 kilometres south of Safi, on the eastern edge of Wadi 'Araba proper at the point where the deeply gorged Wadi et-Tlah emerges from the plateau escarpment. In terms of the current study, the site is important, for until recently a cohesive and regular grid pattern of irrigated fields were clearly discernible, particularly from the air (Fig. 4.25; Frank 1934: 214; Kennedy and Riley 1990: 205-07). MacDonald described the field walls as measuring 0.5 to one metre in thickness, but does not discuss detail further, and on a recent visit to the site it was noted that the area had been extensively altered for agricultural re-development obliterating much of the remaining evidence (Fig. 4.26). However, other elements of the site are still visible and have been the subject of limited surface survey (including those by Frank 1934: 213-15; Glueck 1935: 12-17; King *et al.* 1989: 199-202; B. MacDonald 1992: 89; Musil 1907a: 209-14).

From these surveys, the main constituents of the settlement have been found to comprise a small fort of around 40 square metres, and a large rectangular stone reservoir (34.2 by 33.6 metres) fed by aqueduct on the north bank of the Wadi et-Tlah, and on the south bank opposite, the remains of what may have been a village with additional fields (Glueck 1935: 12; King *et al.* 1989: 199; B. MacDonald 1992: 89). The sherds collected from the site range in date from the Early Bronze Age, Iron Age and Hellenistic through to the Byzantine periods, with Byzantine period sherds being the most abundant in number (King *et al.*1989: 202; B. MacDonald 1992). From the limited evidence still visible, it seems that a system of aqueducts carried diverted floodwater from upstream in the Wadi et-Tlah to the reservoir or down to the irrigated fields as required. The reservoir is the best preserved structure at the site and is interesting in that it bears many similarities in construction to that of the reservoir at al-Hammam near to Ma'an; which consists of courses of roughly squared blocks of limestone, interspersed with thin courses of narrow limestone and plastered inside and out with layers of rough mortar and smoother plaster (Section 4.4; Fig. 4.27). The similarities of construction with al-Hamman, which dates to late Roman–Byzantine period, and the abundance of Byzantine sherds would suggest that both reservoir systems were constructed during this period. Furthermore, as the regular field system at et-Tlah forms an integral part of the water management system, it would seem reasonable to suggest that this system may have been of a contemporary construction date with the reservoir. However, such a premise cannot be easily proved at this point in time.

It is clear that throughout the Classical period the location of et-Tlah was a major staging post in the line of communication between the southern Ghors and the plateau regions to east and west, with connections to Petra and Aqaba to the south. As mentioned above (Section 3.3.5), there are a number of other staging posts along both edges of the length of the Wadi 'Araba, such as Bir Madhkur and Gharandal on the eastern edge, and Hatzevah and Yotvata on the western side (Rothenburg 1967, 1971). As well as controlling lines of communication between the Negev and the Edom plateau, these way stations were located at convenient points with accessible supplies of perennial water, which camel caravans could use (Isaac 1990: 129-30). Where the fort and caravanserai are located by a wadi course, usually fragmentary evidence exists at these posts for the operation of an irrigated field system which utilised the floodwaters of the wadi. For example, at Bir Madhkur and Yotvata, which are located at similar locations to the settlement at et-Tlah, evidence for substantial field systems have been noted (Glueck 1935: 35; Rothenburg 1971: 218). Little intensive study has been attempted on such field systems; in most cases only surface sherds have been collected from remains of a fort, caravanserai or settlement at each oasis/way station. These have indicated a variety of settlement histories, with some sites indicating occupation in the Bronze, Iron and Hellenistic periods previous to the Nabataean. Some sites have only yielded Nabataean or Byzantine period sherds, whereas other sites seem to have been continually used well into the early Islamic period. A interesting example, in terms of settlement and land use is the oasis at Yotvata (Arabic – 'Ein Ghadyan) (Avner and Magness 1998; Glueck 1935: 40; Isaac 1990: 188-91; Meshel 1993; Musil 1907b: 254; Rothenburg 1971: 218-19).

At this important crossroads and oasis, with connections to the nearby copper mining centre at Timna, the earliest remains found so far date to the Chalcolithic period, with settlement evidence from the Bronze and Iron Ages, and from the Nabataean/Roman through to the Abbasid (ninth century AD) periods (Meshel 1993; Rothenburg 1993). There is also evidence for at least three forts or fortified buildings, which have been dated to the early Iron Age, late Roman and Islamic periods, in the vicinity of this well-watered oasis (Avner and Magness 1998: 49; Meshel 1993). One has been identified through a building inscription as being occupied at least in the period of the tetrarchy (late third century AD) (Isaac 1990: 188; Roll 1989). However, from limited excavation this building appears to have been abandoned at some point in the mid-fourth century AD (Meshel 1989, 1993). Another of these forts, which was probably in reality a khan or farming-centre (see al-Hamman in Section 4.4), has been identified as dating in construction to the early

Islamic period (seventh century AD), and continued in use throughout the eighth century (Meshel 1993: 1520).

In addition, a number of farming settlements have been located in the immediate vicinity; particularly important in this respect is the nearby large farming establishment at Evrona (Avner and Magness 1998: 47). Associated with these settlements are a large number of complicated water management systems, which made extensive use of the strong springs emanating from the shallow aquifers of this area, and presumably occasional floodwaters flowing out from the low hills to the west. In the early Islamic period the flow of water from the aquifers was regulated and increased by the construction of a number of qanats (Avner and Magness 1998: 46; Evenari *et al.* 1982: 172-78). At three locations, these qanats were found to have cut through the earlier Nabataean–Byzantine water systems which seem to have been based on the cutting of open pools into the high water table below (Avner and Magness 1998: 48). The qanats transported the water to large stone-cleared areas divided into small fields, where the fragmentary wall remains that still exist show they were arranged in a regular grid system (Avner and Magness 1998: 47).

The farm at Evona utilised a similar system of qanats and fields on a previously uncultivated area of desert scrub (Avner and Magness 1998: 47). Furthermore, the qanat water emptied into a reservoir of around seventeen by thirteen metres, adjacent to which was placed the main farmstead, which eventually covered an area in dimensions of 26 by 29 metres. There were two other farms on this irrigated estate, the boundary of which was surrounded by a stone and mudbrick wall (Avner and Magess 1998: 48). It is interesting to note at this point, the similarities in the checkerboard pattern of fields to those at et-Tlah and the layout of the farm estate at Evona to that of al-Hammam near Ma'an. As the oasis at Yotvata is close to the large copper mining district of Timna, it is reasonable to suppose that at times in its history the dates, olives and cereals grown at

Yotvata were used to sustain the mineworkers, particularly those working at Be'er Ora, just to the south of Timna, during the Roman and early Islamic periods (Rothenburg 1993).

Beyond these controlled oases there are indications that small, rough settlements existed at advantageous points throughout the length of the Wadi 'Araba. Evidence for these usually consists of rough piles of stones for dwellings and scattered lines of stone which indicate the remnants of field or cross-wadi walls, positioned along the edges of the 'Araba escarpments at a point where tributary wadis enter the rift valley, or where small springs appear. Some surveys have documented some of these settlements and collected whatever sherds were present. For example, Smith *et al.* recorded a number of these in the southeastern quarter of the Wadi 'Araba where Nabataean/early Roman sherds predominated at most of the sites with far fewer yielding Byzantine or Islamic sherds (1997: 65-67). In the north, between the southern Ghors and Wadi Faynan a number of sites were visited by MacDonald and indications here seemed to suggest that small settlements were most widespread during the Byzantine period, although a number of sites presented sherds from the previous Hellenistic, Nabataean and late Roman periods (1992: 157-58).

4.6 Summary

This survey of the evidence for land use in four key regions has produced a number of issues which shall be considered briefly. The first fact to note is that there is a great deal of evidence for the utilization of water management structures and systems in conjunction with specific types of land use in the Classical period. Much of this evidence remains undocumented as brief periods of fieldwork in the Hauran, the Wadi 'Araba and on the Edom plateau have shown. From the evidence presented a combination of appropriate land use and water management systems can be seen to differ both chronologically and spatially across the region as a whole. However, of the evidence collected by the numerous surveys, interpretations remain incomplete for a variety of reasons. Few surveys have been specifically oriented to the investigation of land use questions and the relationship between the land and its settlement. An interesting example of this has been the interpretation of the sites at al-Hamman and al-Mutrab as forts in the late Roman *limes* frontier (Section 4.4), which if the immediate landscape had been considered, would have been seen to be, in reality, estate complexes.

Other surveys have documented the land use, such as evidence for field boundaries or systems of cross-wadi walls and associated settlements, but in many cases have been unable to progress far beyond simple hypotheses. In some cases factors of scale, lack of sufficient dating evidence and time to make a thorough study with comparative analyses of other land use systems elsewhere have contributed to impede progress. The region of the southern Hauran is one region where future work on analysis of the settlement-landscape relationships could improve our knowledge of the causes behind the development of this marginal region. Having surveyed the evidence for settlement and land use within the province of Arabia, the next chapter seeks to qualify this using as a case study the large extensive field systems of Wadi faynan in southern Jordan.

5.0 The Wadi Faynan: a case study in GIS

5.1 Wadi Faynan as a case study: introduction

Wadi Faynan (Feinan or Finan) is the catchall name for an extensive wadi system network some 50 kilometres south of the Dead Sea, on the eastern side of the Wadi 'Araba (Fig. 3.7). The main Wadi Faynan runs through an impressively wide valley which cuts into the escarpment of the eastern highlands of the Jordanian plateau along the line of a major fault, separating a dome of igneous porphyry to the south from sandstone sedimentary rocks to the north (Blake 1940: 45). In the course of merging into the Wadi 'Araba, on reaching the linear low ridge of hills of the Jebel Hamrat Fidan, the main watercourse of the Wadi Faynan changes its name to that of the Wadi Fidan which acts as a natural enclosure wall to the valley of the Faynan (Fig. 5.1). From these hills the Fidan continues, spreading out in a wide fan across the plain of the Wadi 'Araba in a northwesterly direction, until it merges with the main dry wadi bed south of the Dead Sea. The Wadi Faynan itself is a combination of three large tributaries, those of the wadis Dana, Ghuwayr and Shayqar (known as the Wadi esh-Sharqa in some accounts), which almost immediately coalesce upon emerging from the foothills of the plateau escarpment (Fig. 5.2). Below this point the topography gradually opens up into a wide flattish plain, some eight kilometres east to west and around three kilometres at its widest point. Surrounded by outliers of the plateau escarpment, of sedimentary limestones to the north, and granitic outcrops to the south, and closed off by the low ridge of the Jebel Hamrat Ifdan to the west, a large and sheltered natural 'amphitheatre' has been created.

The valley of the Wadi Faynan is highly significant for a number of important reasons due in part to its geographical location, the general topography, the presence of perennial water supplies, and the large mineral deposits, particularly of copper in the surrounding hills and slopes of the escarpment (Glueck 1935: 32; Hauptmann and Weisgerber 1992: 61). In terms of topography, it is the only wadi south of the Dead Sea with an exceptionally large and wide 'floodplain' which had the potential to offer large acreages for cultivation. Secondly, a number of perennial springs are located in the upper courses of two of the major tributaries of the Wadi Faynan, those of the Wadi Ghuwayr and the Wadi Shayqar. The strong aquifer-fed springs of the Ghuwayr are by far the most important, with a significant surface stream flow for most of the year as far as the confluence with the other main tributaries of the Faynan. The springs of the Shayqar are to be found where the wadi comes up against the foothills of the plateau escarpment and are of only localised value. Further springs are to be found located in the shallow gorge cut through the hills of the Hamrat Ifdan by the Wadi Fidan, for at this point the wadi crosses a sill of granite which forces the groundwater flow to come to the surface (Raikes 1980: 40).

Hence, the Wadi Faynan has the basic elements for sedentary existence in this harsh semi-arid environment – a wide plain with potential for floodwater farming, and perennial supplies of freshwater – that are virtually unique in the Wadi 'Araba. As discussed in Chapter 2 (Section 2.5.2), although there is some evidence for slight changes in precipitation during the Classical and other periods, the overall climate regime, that of a semi-arid environment, has essentially remained constant since the Neolithic period (see for example Lamb 1995; Rossignol-Strick 1993). Furthermore, the presence of perennial springs over time is related to the existence of large bodies of fossilized groundwater, which ensure an almost enduring and constant flow of water (Khouri 1982). Therefore, it would prove an irresistible combination for human settlement, and thus so it appears from the extensive body of archaeological remains which is to be found within the Faynan valley as far as the Hamrat Ifdan. Although the valley has in recent centuries been virtually free of sedentary settlement until the recent construction of a permanent Bedouin village (Quayqurah), European travellers of the early part of the last century and before have often been struck by the impressiveness of the evidence for sedentary occupation from antiquity (Frank 1934; Glueck 1935; Lagrange 1898; Musil 1907a). In the latter half of the twentieth century investigations of these structures and research into the mines began in earnest (Adams 1991; Adams and Genz 1995; Barnes *et al.* 1995; King *et al.* 1989; Hauptmann *et al.* 1989; Hauptmann and Weisgerber 1987, 1992; al-Najjar *et al.* 1990; Raikes 1980, 1985, Ruben *et al.* 1997).

The quality of the archaeology has resulted in a number of major projects being instigated to examine various aspects of the landscape, with emphasis on particular periods (Findlater *et al.* 1998; Finlayson and Mithen 1998; Freeman and McEwan 1998; Levy *et al.* 1999; McQuitty 1998; Simmons and al-Najjar 1996; Wright *et al.* 1998). These projects have highlighted the rich evidence for continued human occupation of the wadi through many time periods: from early settlement sites along the Ghuwayr of the Epipaleolithic and PPNA (Pre-Pottery Neolithic A) and PPNB (Pre-Pottery Neolithic B) (Finlayson and Mithen 1998; Simmons and al-Najjar 1996); the riverine settlement of the Pottery Neolithic (al-Najjar *et al.* 1990); through the settlements and early copper smelting sites of the Early and Late Bronze Ages (Levy *et al.* 1999; Wright *et al.* 1998); to site-specific aspects of the Classical period (Findlater *et al.* 1998; Freeman and McEwan 1998). In addition, in 1997 a multi-disciplinary team commenced a detailed investigation of the landscape and the environment. Termed the Wadi Faynan Landscape Survey, this had a number of aims which will be outlined in detail below and of which this research was a component. First it is necessary to outline what is known of the valley from ancient sources, and the main features of the classical landscape.

Dominating the landscape of the Wadi Faynan valley is the large, high, tell-like and rubble-strewn hill of Khirbet Faynan. Positioned at the head of the valley, within the acute angle formed by the converging courses of the wadis Dana and Ghuwayr, the '*Khirbet*' (Arabic for 'ruin') is in an excellent defensive location with commanding views of any approach across the valley. Consequently all lines of communication, either across or into the valley, or from the valley to the plateau along the few accessible passes which use the wadis Dana and Ghuwayr, can be controlled from the Khirbet. As has long been recognised, the Khirbet forms the main settlement site of the region, with the majority of the rubble mass being the remains of stone buildings and structures, from perhaps many successive periods (Glueck 1935: 33).

Although no part of the Khirbet has ever been excavated, the ground plans of buildings have been surveyed, and some of the numerous sherds of pottery, which litter the site, have been collected (Barnes *et al.* 1995; Ruben *et al.* 1997). These exercises have revealed quite a large settlement of certainly Roman and Byzantine periods, which has been equated with the ancient *Phaino* mentioned by the ecclesiastical historian Eusebius (*c.* AD 260-339) and other minor documents (Millar 1993: 201-02; Schick 1994, 1996). Eusebius mentions that Phaino had a Bishop, and as if to emphasize this fact, at the foot of the hill on the north side are the remains of three churches, a cemetery and a large rectangular building identified as a monastery, though the latter identification is by no means certain (Frank 1934: 222). As has been noted, the existence of so many churches 'all testify to the regional importance of the town in the Byzantine period' (King *et al.* 1989: 203). It is probable that a few of the churches, if not all, were built to commemorate the sacrifices made by early Christian martyrs of the third and early fourth centuries AD, whom Eusebius states were imprisoned for their beliefs and sent to the copper mines of Phaino by earlier pagan Roman governments (Eusebius: *Martyrs of Palestine* 7,2).

The evidence for the mining and smelting of copper ore within antiquity is to be seen throughout the valley and beyond. Situated around the Khirbet and at a position opposite, to the south of the Wadi Ghuwayr, are large slag heaps, and at many locations in the hills to the north and the mountains to the southwest are hundreds of worked out mineshafts. Investigations have indicated that the exploitation of the mines reached its peak during the Roman period, that is during the second and the third centuries AD, and continued on a smaller scale into the Byzantine period and perhaps beyond into the Early Islamic period (Hauptmann and Weisgerber 1992: 64-65). The intense mining activities during the Roman period may account for the large-scale development of the settlement at the Khirbet, which probably also acted as the main operational hub and bureaucratic centre for the mining industry.

Scattered around the Khirbet, particularly to the south of the Wadi Ghuwayr, are a number of smaller settlements and other structures associated with the mining industry and the settlement at the Khirbet. These include: a satellite settlement of the Khirbet with at least one additional church; a large cemetery of early Byzantine date, where some burial inscriptions were found, and which has also been the subject of limited excavation; and the remains of an elaborate water distribution system, in the form of a stone aqueduct, large rectangular reservoir and watermill (Findlater *et al.* 1998; Freeman and McEwan 1998; Sartre 1993: 139-48). Further out into the valley, other structures have been noted or explored. For example, on the summit of a steep conical hill, Tell el-Mirad, a few kilometres to the west of Khirbet Faynan, a possible lookout structure has been recorded by several visitors, which has yielded numerous Nabataean, Roman and Byzantine sherds, along with the occasional Mamluk sherd (Frank 1934: 225-26; King *et al.*

1989: 204). In the environs of the Hamrat Ifdan, other Nabataean to Early Islamic structures connected with the mining operations and their control have been noted, including a small Roman fort guarding the approaches from the Wadi 'Araba, smelting sites, and small systems of fields along the upper course of the Wadi Fidan (Frank 1934: 219-21; Glueck 1935: 20-2; King *et al.* 1989: 204-5; Raikes 1980: 43-4).

The sites mentioned represent a fraction of the archaeological evidence visible and largely undisturbed within the region of the Faynan. Such extensive remains of human activity suggest intense periods of sedentary settlement and exploitation of the copper ores over time, especially during the Classical period when both settlement and copper mining seemed to have reached new levels of intensity. As part of its extensive remit to understand the processes of environmental degradation and human history within the valley, the Wadi Faynan Landscape Survey aimed to survey comprehensively other smaller sites which had hitherto been neglected or had gone unnoticed by earlier surveys (Barker *et al.* 1997: 19). Furthermore, it aimed to complete a detailed survey of a large number of ancient field systems located throughout the Faynan, some parts of which were in danger of being destroyed by modern irrigation schemes (Barker *et al.* 1997: 21).

5.2 The Wadi Faynan Landscape Survey

5.2.1 Introduction

The Wadi Faynan Landscape Survey used an inter-disciplinary team of geomorphologists, environmental scientists and field archaeologists to survey and study various aspects of the valley, using a wide array of techniques. As outlined in the 1998 field report, four broad aims were stated (Barker *et al.* 1998). The first was the development of a chronological framework for the geomorphological and ecological processes that have affected the region, and the input of both human and natural influences in shaping these processes. The second was to elucidate the chronology, working mechanisms, and function of the large area of field systems. The third was the assessment of the field archaeology outside these field systems. The final goal was the complete integration of all the geomorphological and archaeological data into a comprehensive model of landscape history (Barker *et al.* 1999: 255). An integral part of this process was to be the establishment and operation, by Patrick Daly and myself, of a fully inclusive GIS (Geographic Information System) with which to conduct detailed analyses of the collected data. Thus, in a five year fieldwork project, significant studies which have important bearings on the interpretation of the human history of the southern Levant, and marginal landscapes in general, were completed in a number of interrelated subjects. These include: the geomorphological evolution of the landscape; palynology from alluvial sediments; ethnoarchaeology of Bedouin sites; environmental studies of the impact of smelting on flora and fauna; the palaeohydrology of the water systems; the archaeological site survey and fieldwalking of the survey area; and lithics, pottery and other artifactual studies (Barker 2000; Barker *et al.* 1997, 1998, 1999, 2000a, 2000b, forthcoming; Pyatt *et al.* 1999, 2000).

The initial results from the various survey studies have been both significant and impressive in scope. Samples analysed from the pottery of the Neolithic site at Tell Wadi Faynan, and from sediments nearby, have revealed fragments of reed, grass and freshwater organisms, indicating the presence of a significantly wetter climate during this period (Barker 2000: 70). The identification of over 1,000 'sites' of all periods throughout the valley region has assisted our understanding the settlement patterns of the early Bronze Age in particular. For this period, three types of settlement form have indicated a complex series of interrelated economic systems of sedentary agriculture, pastoralism and metal-working (Barker 2000: 73). The analysis of sediments collected from a number of large circular catchment cisterns, and the remnant constructions of large boulder terraces, have strongly suggested the increasingly arid nature of the Bronze Age climate, with the local populations adopting strategies of simple water management (Barker 2000: 75; Barker *et al.* 1997: 36).

In the Iron Age, when the Wadi Faynan was controlled by the kingdom of Edom, evidence suggests that deep mines were being developed, both in the hills around Faynan, and in the neighbouring Wadi al-Ghuweib (Hauptmann and Weisgerber 1992: 63-64; Hauptmann *et al.* 1989). At central locations within both these wadi systems, at Khirbet en-Nahas in Wadi al-Ghuweib and at the foot of the Khirbet Faynan within the region of what was classified as site WF424, thick deposits of Iron Age slag and structure complexes bear witness to the increasingly organised large scale extraction and smelting of copper ores (Fritz 1996; Glueck 1935: 27-29). Other much smaller Iron Age settlement sites were found during the survey at locations along the edge of the main Wadi Faynan, thus emphasizing the dominance of the settlement at Khirbet Faynan at this time (Barker 2000: 76). In addition, a number of the field systems to the north of the Wadi Faynan exhibited evidence for their initial construction within the Iron Age, and the development of sophisticated water control techniques, to which I shall return below.

Settlement patterns had altered by the Nabataean period, with a series of large farmsteads appearing on the low ridge to the south of the main wadi course, overlooking the field systems (Barker 2000: 77). Other smaller single rectangular dwelling structures of late Nabataean-Early Roman date have been located at points within the landscape, examples of which were excavated within the significant Bronze Age region of WF100, or WF4.13 as this zone was designated in the Wadi Faynan Landscape Survey (Wright *et al.* 1998: 37-40). A number of groups of these simple dwellings, in what could be described as 'hamlets', were also located at certain places within the valley (Barker forthcoming).

From the evidence accumulated by the survey, and that studied by the Bochum Mining Museum, the annexation of the Nabataean Kingdom by Rome resulted in a massive expansion of mining operations, with important consequences for the local environment (Barker 2000b: 79; Hauptmann and Weisgerber 1987). Several large slagheaps top the ridges in the environs of the Khirbet Faynan, and the hills around the valley are honeycombed with large mine workings of various types, such as the impressive Umm el-'Amad, first noted by Glueck (Glueck 1935: 90-92). Sediment samples taken by the Wadi Faynan Landscape Survey from a number of points around the Khirbet and which have been subjected to Energy Dispersive X-ray Microanalysis (EDMA), have indicated very high levels of chemical and heavy metal pollution within the immediate environment (Gilbertson *et al.* 2000: 44-45; Pyatt *et al.* 2000). In addition, the pollen counts from samples collected from behind a barrage immediately to the north of the Khirbet reflect an increasingly degraded landscape at this time, with fewer species of trees and shrubs, and with a increase in steppeland species (Barker 2000: 79; Hunt and Mohammed 1998: 21-23; Mohammed and Hunt 1999: 261-62). Ethnoarchaeological and environmental studies of the valley indicate that parts of the landscape have remained polluted by concentrations of heavy metals to the present day, with consequences for the local ecology and population (Gilbertson *et al.* 2000: 44; Pyatt *et al.* 1999).

The early Islamic period and later settlement evidence remain unclear, but increases in smelting pollutants, and the presence of simple encampments at the foot of the escarpment slopes, indicate some level of industrial and pastoral activity within the valley at least during the early second millennium AD (Barker 2000: 81). It is within this basic framework that the evidence collected from the detailed study of the field systems is placed. What follows is a brief overview of the methodologies involved in the assessment and understanding of the main features of the water management systems and the field survey from which a GIS-based spatial database was eventually constructed.

5.2.2 Water management structures

As part of the survey, investigations were conducted on the channel/aqueduct system which previous studies, notably by Frank, had indicated fed first the large reservoir and then the stone watermill (1934: 217-25). On most technical grounds this system has been assumed to date to the Roman–Byzantine period, although there have been doubts about the age of the aruba penstock mill, as the only other examples of this type of mill have so far been found to date to the Islamic period (Gardiner and McQuitty 1987; McQuitty 1995). The water to feed the reservoir and the mill was siphoned off at a point upstream in the Wadi Guwayr where a strong flow of perennial water could be guaranteed. Evidence for a conduit, of at least two distinct phases, was discovered skirting the edge of the steep gorge cliffs of the wadi (Crook 1999: 279-80). This conduit had a plaster lining, and where necessary was supported on stone wall supports or cut through rock outcrops of the cliff edge to follow the same contour down to the open valley below, thus maintaining a good flow rate. An impressive stone aqueduct, of which only the part of two arches survives, was built to carry the stream-water over the course of the Wadi Shayqar and across to the large stone-built reservoir.

The reservoir is a spectacular and well-built rectangular structure measuring 31 by 22.4 metres, with ashlar-faced stone walls descending at least four metres in depth from an overflow, giving the tank a large potential capacity of around 2798 cubic metres (Crook 1999: 280). Due to its position, to the south of the Khirbet, it is likely that this reservoir was used mainly for the storage of water both for drinking and for the industrial processes associated with copper smelting, for to the west and south of the reservoir are substantial slag heaps, and the lower courses of a number of stone-built rectangular structures which may be connected with smelting (Fig. 5.15). Along the western rim of the reservoir the line of a channel is cut into the stonework, leading to the mill leat and a smaller tank. Although Crook (1999: 280) suggests that the water for the leat came directly from the reservoir, it seems probable that this channel connected directly with the channel leading to the reservoir, circumventing the water tank, and thus overcoming periods when the amount of water in storage was low, although no evidence of this now remains. There is another potential reservoir lying to the north of the Khirbet, which takes the form of a low, coarse-stone built wall which dams the natural outflow from a shallow valley between the Khirbet and the next hill to the north. This may have formed an earlier storage tank for the settlement, perhaps abandoned when the large reservoir was built, or whose demise through infilling and pollution necessitated the rectangular reservoir to be commissioned. The older reservoir has been completely filled with silt, and it was from these sediments that samples were taken for palynological and chemical analysis.

As mentioned earlier, the penstock mill represents something of a dating problem, for no other examples of this type of mill from a specific Roman period context exist elsewhere – the examples that do exist have all been dated, generally by association, to the Islamic period (McQuitty 1995). Two plaster samples from the lining of the mill leat were taken for analysis, representing two phases (samples A1 and A2, which conform to the secondary phase and the first phase respectively), and compared with samples taken from the channel going into the reservoir on the east side (sample C), and the channel exiting from the reservoir on the western side (sample B), which only had single plaster phases (Morgan 1997: 38).

Sample	*'gravel'* >2mm.	*'sand'* <0.15-2mm.	*'silt'* <0.15mm.	*soluble %*	*comments*
A1	3	63	34	69	upper, brick/tile
A2	83	12	5	46	lower
B	67	25	8	43	
C	55	30	15	48	

The results are interesting as both the reservoir channel samples, and the first phase sample of the mill leat (B, C and A2), exhibit strikingly similar compositions of the basic components of gravel, sand, silt and lime, which have produced a white mortar. By contrast, the second mill leat sample (A1), although a heavily lime based mortar, (which would suggest a classic Roman *opus signinum*) is quite different in the proportion of basic components to the other three samples. The pinkish colour of this lime-clay mortar, and the numerous inclusions of brick and tile, are comparable to the mortar linings of the water channels at Ma'an, suggesting a date in the late Byzantine to perhaps the early Islamic period (see Section 4.4). In turn this could suggest that the penstock mill seen today is a later rebuild of an earlier Roman or early Byzantine mill contemporary with the building of the reservoir.

The survey found very little evidence for other Classical period water supply structures within the valley, apart from a large open cistern at a group of structures to the northwest of Khirbet Faynan, dubbed 'the little Khirbet' (Khirbet Ratiye: WF1415), which also had marble fragments that may have related to a government building, bathhouse, or chapel. The evidence from the general water-management structures points to two factors to take into account when investigating the classical landscape of the Faynan. The first of these is the high level of technology, scale, and investment into securing the water supply. Secondly, we are reminded that these were subject to periodic change in relation to changing needs and conditions, and that what we can see now in the aqueduct – reservoir – mill system is the remains of a final arrangement. This second point has implications for the interpretation of all other structures within the survey area, particularly those structures of the field systems which by necessity and convenience were low-technology constructions easy to adapt and modify to suit changing circumstances (Barker *et al.* 1997: 37).

5.2.3 Field systems

The structures which cover the largest area in the valley of Faynan are the field systems, of which there are several situated across the valley. These vary hugely in size, topographic location and structural elements. Until the commencement of the Wadi Faynan Landscape Survey, no previous work had been undertaken to interpret the relationship of these to the settlement of the valley or the mining industries. Several observers merely noted that substantial numbers of surface sherds dating to the Nabataean, Roman and Byzantine periods could be found within them (Barker *et al.* 1997: 21; Barnes *et al.* 1995). Glueck wrote of the 'large stretches of formerly cultivated fields....strewn with Nabataean sherds' (1935: 35).

The largest area of fields, through which Glueck travelled, and which seem to form a single entity, lies immediately to the south of the wide watercourse of the Faynan itself (see Figs 5.5 and 5.6). This entity was designated WF4 in the original site register of the initial site survey of 1995 and forms the central subject of analysis within the case study in this thesis (Barnes *et al.* 1995). Other smaller systems of fields lie at several points to the north of the wadi and to the west of WF4 (Figs 5.2 and 5.8). These systems were also surveyed by the Wadi Faynan Landscape Survey, but have not been subjected to detailed GIS analyses, due in part to the relatively simple and homogeneous nature of their wall structures. However, the information gleaned from these field systems has proved of invaluable importance for understanding the development of the operating mechanisms of these systems within the valley, and for the interpretation of structures within WF4.

5.2.4 Field system recording methodologies

WF4 forms a large 250-hectare area to the west of the Khirbet, stretching for around six kilometres in length from east to west and up to one kilometre from north to south at its widest point (Barker *et al.* 1998: 9; Mattingly *et al.* 1997: 27). To record effectively such a large area, with some 800 individual fields of varying size, a variety of approaches was tested in the first season of 1997 to establish the most efficient methods to accomplish this mammoth task within the terms of a five year project. A series of detailed aerial photographs, taken some years earlier, provided the initial point of entry to disentangling the system. From these air photographs, a photogrammetric map was drawn which included: every observable wall within WF4; height contours; the courses of small tributary wadis that crossed the fields; and any additional structural feature, such as cairns, that could be distinguished. In the field the features marked on the photogrammetric map were checked by surface examination or 'ground-truthing' (Mattingly *et al.* 1997: 27). In addition, several other operations were tried for use in future seasons, including: the planning of several interesting or complicated areas using an EDM, in order to make a useful comparison with what could be identified from the air photographs and to explore issues of flow gradient; the evaluation of new methods for the sampling of surface sherds, again in selected areas; a reconnaissance of the types of archaeological sites within the field system, including other periods outside the classical period; and allied to this an assessment of the wall structures for different construction methods and functional use in relation to presumed hydrological functions (Mattingly *et al.* 1997: 27).

Therefore, from the work of this first season several conclusions were reached, which guided the work of the following four (Mattingly *et al.* 1997: 27). Firstly, the process of ground-truthing was able to make clear many features obscured on the air photographs and added many new features which had been completely omitted or missed on the photogrammetric map. Secondly, both the trial sampling of surface sherds, and the preliminary classification of the various wall types and sites, highlighted the immensely diverse nature both of the surface finds and the structures in their distribution and densities across the system as a whole (Mattingly *et al.* 1997: 29). A decision was made to subdivide the field system into twenty large, manageable sub-units based on groups of fields (numbered WF4.1 to WF4.20) which displayed similarities as a group in terms of structure and topography or were in certain circumstances seen to be isolated from other fields by naturally occurring divisions, such as the course of a tributary wadi (Mattingly 1997: 27; Fig. 5.4).

Each field within a sub-unit was then allocated an individual identifying number, a process carried out during the successive field seasons as each sub-unit was recorded and sampled. The fields of each particular sub-unit were first visited to establish whether each group of fields conformed to the layout details as represented on the photogrammetric map. However, in most cases a number of adjustments had to be made depending on different situations, and two examples may be cited to highlight these. In the first, a particular field was sometimes found to have a wall not shown on the photogrammetric map, dividing the field into two. In this case, separate field numbers would be given for each section of the original field. Secondly, fields in some areas had suffered from recent modern irrigation development, with the removal of walls shown on the photogrammetric map and subsequent ploughing into equal sized acreages. In this case, arbitrary areas would be assigned a field identity coinciding with each individually ploughed plot of land. All the adjustments which had had to be made in terms of field size, shape, and topology, and the individual field identities, were then plotted on a new trace map (the Field Unit Map) over the photogrammetric map. The individual field was then allocated its own *pro forma* sheet or Field Record Sheet: for example, there were 38 fields within the sub-unit WF4.1, so these fields were given records numbered from WF4.1.1 to WF4.1.38 (Barker *et al.* 1998: 9).

Each Field Record Sheet was designed to cover the structural and style aspects of one individual field within a sub-unit. On one side a quick sketch of the field in question was drawn, which would also show orientation with adjoining fields and an indication of slope and thus the direction of potential surface flow. From observation in the initial field season, and from a study of the photogrammetric map, it was shown that the majority of fields was generally rectangular in shape. Hence, a field could have its perimeter divided into four 'wall' sides or boundaries (labelled Wall 1, 2, 3, 4), with a fifth or sixth wall for the occasional irregularly-shaped field. Each of these wall boundaries could then be catalogued using the Field Record Sheet according to sixteen distinct descriptions for different wall types. In addition to the wall types, eight associated wall features were listed on the Field Record Sheet (see Appendix 2). These basic categories were adopted for data entry onto the Field Record Sheet, the categories having been defined during the preliminary reconnaissance of the first season which found that these categories covered most types of wall construction (Mattingly *et al.* 1997: 30).

The initial survey had also discovered that many walls comprised more than one style or type of construction even within a short stretch. However, the system of wall categorisation allowed great flexibility, for by using this system each change in style or construction along a wall length could be noted, merely by making the appropriate number of checks along each wall boundary. Other information in specified categories which required true or false statements, such as 'is there good surface visibility of the sherds?', could also be filled in on the form. Features, which were deemed of significant interest, were recorded in more detail on a Site Record Form and given unique WF Site Numbers. Significant features included settlements and burial cairns, and well-preserved structures relating to water control such as sluices, baffles, and spillways (Barker *et al.* 1998: 9).

The sampling of the mass of surface finds littering the fields of WF4 was undertaken using a scheme of systematic fieldwalking (Barker *et al.* 1998: 9). Each field was traversed by a team of fieldwalkers in a series of transects, each ten metres apart, with the surface scanning being restricted to a one-metre wide strip along the path of the transect. Artefact density could be calculated as a result of a combination of two methods of recording used during the fieldwalking process. Depending on the size of the field, at least two transects, and occasionally more, comprised counts of surface sherds from clicker counts. On alternate transects, usually one in number between the clicked transect, the sherds present within the one-metre wide strip were systematically collected whilst a regular walking pace was maintained. In addition the fieldwalker on the clicked transect would collect a 'Grab' bag of interesting or diagnostic sherds, particularly rims or bases along the length of the transect, but which was kept separate from the systematically-collected material of the other transects.

Information collected from the fieldwalking exercise was again entered onto *pro forma* forms for each field, such as the number of 'sherded' and 'clicked' transects and the numbers and weights of pieces of pot (and flint) observed by clicking and collected in the systematic fieldwalking grab samples (Barker *et al.* 1998: 12). Using these two methodologies of wall and feature recording and fieldwalking, thirteen sub-units of the twenty were recorded in the second season (1997), with the remainder of WF4 and the smaller outlying field systems (WF site numbers WF406, 408, 409, 410, 424, 442, 443) recorded using these methods in the following two seasons 1998 and 1999 (Barker *et al.* 1998; 1999; 2000a). The information collected on all three types of recording form was collated and used to create the Wadi Faynan Database, which was to provide much of the basic information required for the GIS analysis.

On completion of the field recording and fieldwalking exercise, emphasis was placed on the detailed refinement and verification of the evidence gathered from the main field system WF4 in the previous seasons, specifically for the preparation and development of an analytical GIS (Daly and Newson 2000: 42). A number of interesting issues had been brought to light during the field recording and these formed the focal points for the re-study. The first of these concerned the methods of recording, the second involved more detailed investigation into the circumstantial evidence for water management structures, including a variety of what were beginning to appear to be fragments of a channel distribution system or systems (Barker *et al.* 1999). In terms of the recording, the WF4 field system had been disconnected to some extent by being dissected into twenty easily recordable sub-units (WF4.1-4.20), but it had been noticed during the fieldwork that some walls of the same construction had been cut by modern tributary wadis, and so had originally spanned different sub-units. Furthermore, some substantial wall constructions, again of the same construction techniques and dimensions, could be traced across several sub-units. In addition, a large number of widely spaced parallel walls were being distinguished in certain parts of the WF4 system, but some of these were being recorded as a succession of separate wall boundaries for a series of adjacent fields. For example, it was noticed that some adjoining fields of WF4.15 were recorded as having a parallel wall along there southern edge, which at first was not picked up as being of a continuous channel feature. Hence, the sub-units of WF4.1 to WF4.20, designed at the start of the project to facilitate the organization and recording of a mass of data into a convenient and manageable form, could potentially incorporate implicit assumptions about the nature and operation of the field system, and mask real connections (Daly and Newson 2000: 42).

At the conclusion of the main unit-by-unit recording, therefore, the unit boundaries used in the earlier recording were put aside and all the relationships between walls and related features were re-assessed. In this exercise, which I initiated, a series of maps were drawn by Patrick Daly and myself, in which general observations in the field were made with a new set of criteria. Important criteria to note in this exercise included: the similarities between the structural integrity of series of walls and groups of adjoining fields, particularly in their shape and topographical location; the relationship between types of archaeological structure, for example burial cairns, and the positions and terrain on which they were to be found; the direction of surface water flow across the field system; and the series of integrated structures intended to facilitate this flow to maximum effect.

These Corrected Field Observation Maps, as we termed them, contained sketch information showing the position of similar walls, locations of groups of features, and information on waterflow across whole areas (Fig. 5.7).

5.2.5 Summary of results

A vast amount of data has been collected on the various field systems, particularly that of the large field system WF4. This section summarises the findings made during the fieldwork process, and which has provided much useful background information to the development and operation of water management systems of several periods. It was initially thought that all the various field systems were essentially of a contemporary date. However, observation of the wall structures and the collection of surface sherds from several of the smaller satellite systems have revealed a different story.

The systems to the north of the main wadi course, that is WF406, 408, 409, 424, 442 and 443, were found to be fundamentally different to WF4 in terms of both wall structure and field layout. Essentially, in terms of water management technology, all the systems were of the cross-wadi wall type, apart from WF424 which seems to be a complicated arrangement of smelting structures, enclosure walls and field walls, perhaps of different dates (Mattingly 1999b: 274-75). The other field systems are located along the line of small tributary wadis that have cut shallow valleys through the hills down to the Wadi Faynan (Barker *et al.* 1999: 274). These walls were arranged to suit the local topography in each individual case, providing each system with roughly equal sized fields. Therefore, the fields of WF408, although small in number, are of a similar area to each other, as are the fields contained within WF409, 442 and 443 (Fig. 5.8).

The fields of WF406 are more complicated, for it is clear from even a cursory observation that there are at least two, structurally different, cross-wadi wall systems superimposed one on top of the other. One of the system constructions of WF406 appears to have consisted of large, high and wide walls, almost forming a series of banks of cairn like rubble, in parts of the system (areas C, D and E on Fig. 5.8). On top of these banks and between were narrower walls on the same north-south alignment, at right angles to the water flow. By contrast, the walls in areas A and B were simple lines of othostatic boulders (Barker *et al.* 1999: 274). Furthermore, the wall structures of the other systems were to a large extent entirely homogenous within each system. For example the walls of the fields in WF442 were predominately composed of single orthostatic boulders, whereas the terraces of WF408 were in general low, single-coursed medium-sized stones of limestone. The layout of each system and the wall structures of the fields provide indications that each of the systems was either constructed to maximise water control efficiency or was constructed at different periods. The pottery sherds collected from the systems have reinforced the notion that differences in wall construction and field size tend to reflect the primary period when each of these small systems was operational.

In comparison with the fields of WF4 fewer sherds were collected from these smaller systems, and of these sherds few were seen to be comparable to the majority collected within WF4, that is of a Classical date (Barker forthcoming). Some Classical sherds were collected from regions C, D and E of WF406, but the majority from these areas were of Iron Age date. In contrast the few sherds of pottery from areas A and B of WF406 were from the Bronze Age, as was the majority of sherds from WF442 (Barker *et al.* 1999: 274). Such areal distributions of period-specific sherds allow us to make qualified inferences about the construction date of certain types of field system and water management techniques. Hence, for WF406 we can propose an Iron Age date for the large wall-banks, and a Classical date for the narrower walls superimposed upon them, whilst the single lines of orthostatic boulders probably represent the remnants of simpler, earlier systems dating to the Bronze Age.

The knowledge gained from being able to perform this rough measure of dating structures, allowed certain basic judgements of period to be made for parts of the large complex field system WF4. It was concluded that the majority of orthostatic walls within WF4 consists of remnants of early Bronze Age fields. Investigations of WF4.13 (WF100) by David Mattingly underlined this fact, in that this sub-unit, which contains a high density of Bronze Age sherds, when examined in detail revealed substantial fragments of othostatic walls, and almost certainly of early Bronze Age fields (1999a: 269-71; Wright *et al.* 1998).

On walking around the field system WF4, it became clear that other areas within it exhibited certain similarities in structure. Furthermore, long lengths of parallel walls could be seen in particular regions, notably on the flattish plain abutting the Wadi Faynan, but not others. The reviewing of the system as a whole and the production of the Corrected Field Observation Maps, served to crystallise a number of hypotheses increasingly posed by the survey teams concerning the complex nature and organisation of the field system (see for example Barker *et al.* 1998: 13; Creighton and Newson 1999: 275-76; Mattingly *et al.* 1997: 31-32). By general observation of areas with notable similarities in terms of wall construction, field size and layout, it appeared that we were able to confirm such ideas, in that there appeared to be a network of discrete systems contained within the system as a whole, that may have been fed by a complex network of water channels (Barker *et al.* 1999: 276).

To confirm that these were indeed water channels, I excavated a number of sections (Trenches One to Ten) across different candidates at suitable points (Fig. 5.9). For eight of the trenches the results proved positive, with lenses of fluvially deposited silt and clay and layers of fine gravel being observed. Samples from a number of these water channels were taken for OSL (Optically Stimulated Luminescence) dating, the results of which were not yet available at the time of writing. Three of the water channel trenches proved of significant value in helping to demonstrate certain important facts. Trench One was placed in a small parallel channel (site number WF288), which seemed to be diverting water off a modern tributary wadi within sub-unit WF4.4. This continued across into sub-unit WF4.5 (via channel WF259), but a few metres on was cut by another tributary wadi which runs between units WF4.4 and WF4.5 (Figs 5.10 and 5.11) (Barker *et al.* 1998: 15-16). The fact that fluvial deposits were found in Trench One, proved beyond doubt several interesting points; firstly, that this had originally been a diversion channel; secondly, that it was constructed to distribute water from some point within the field system to an area of fields in the central part of WF4.5 which display the signs of a small self-contained system; thirdly, that the landscape and more importantly the drainage were significantly different when the field system was in operation. Furthermore, it seemed that the channel was diverting water from the line of one modern tributary, running west-east, which therefore must have existed in some form when the diversion channel was in operation, but that more recently, a second, later, tributary wadi had developed running south-north and had dissected the channel. Therefore, the landscape of the field systems can be seen to be highly dynamic with major changes occurring within relatively short periods of time.

This activeness of the landscape can be demonstrated in many other instances. For example, it seemed from the Photogrammetric Map that in parts of the eastern half of the field system tributary wadis had cut through a succession of field walls, as a number seemed to be on the same alignment but separated by wide gaps. These suspicions were confirmed during the ground inspection as these walls exhibited the same construction techniques. However, further to the west along the course of some of these wadis, the field walls generally respected the course of the wadi, that is the walls instead of running across the line of the wadi turned to line its banks. Secondly, along some deep cuttings of the modern tributary wadis, the rapid accumulation of sediments could be seen in section; this is particularly true for the tributaries within the eastern end of the field system (WF4.1-4.3). At some points, the truncated ends of earlier buried rubble terrace walls could be clearly delineated, and a few examples of these were cleaned up in section and recorded. Along the tributary wadi edge of the field WF4.2.18, a buried wall was found a few metres beneath and to the south of a surface rubble wall (Fig. 5.9). When the earlier wall was cleaned, a number of Iron Age sherds were discovered lodged within it. This suggests two things: firstly that at this point sediment had accumulated at a very rapid rate: secondly, that earlier landscapes lie buried in certain places, particularly close to the main wadi course.

Trenches Two and Seven proved important in this respect, as they revealed developments and remodelling of the channel systems over time, perhaps in part as a response to the deflation of soils in some parts of the system, and accumulation in others. Trench Two was placed in the middle of a long pair of parallel walls which form the eastern edge of field WF4.6.47 (the trench was subsequently given a Wadi Faynan site number: WF1531), to the north of Trench One (Fig. 5.12). On the surface, this series of parallel walls resembled a wide stepped-terrace wall boundary and not necessarily a channel, as the ends did not appear to connect with other channel fragments. However, the position of these channel walls immediately to the north of WF259/288 led us to suspect that once there may have been within WF4.6 a channel-fed system of fields complementary to those of WF4.5. The dug section revealed water-lain sediments and below these, much narrower lines of parallel-set large flat boulders, the remnants of an older conduit (Figs 5.10 and 5.11) (Daly and Newson 2000: 43). The pottery recovered from the infill was of Roman date, suggesting that the conduit was used during this time, and was remodelled during the Byzantine period or after. Trench Seven (WF1526) was placed across a low line of boulders, a third of the distance along the westward course of an impressively large series of parallel walls WF50 and WF85, which traverses sub-units WF4.10 and 4.15 (Mattingly *et al.* 1997: 31). The interesting fact about this boulder line was that it cut right across the course of the parallel walls, thus blocking the supposed channel flow. However, the section again confirmed that the parallel walls did line the edge of a very large channel; there were several beds of water-lain silts, clays and gravel present. The boulder wall obstruction demonstrated that at a late date in the channel's history, when the fields further downstream had perhaps become abandoned, efforts were made to divert the remaining flow to another area of fields.

The five seasons of fieldwork undertaken by the teams of the Wadi Faynan Landscape Survey ensured the collection of a mass of high quality data concerning the various discrete field systems within the valley. The fieldwork also provided a number of indications for the development process of the field systems and some clues to the manner in which they were operated. Initial impressions were received of a highly dynamic landscape and very complex systems of water management, which evolved over time to changing environmental and cultural circumstances. However, all the evidence collected was of a fragmentary nature and dispersed within the database and other documentary evidence. Hence, an ideal opportunity was presented for the application of a rigorous GIS approach in order to assess the data fully and thus obtain a fuller history and use of this landscape. It is to the construction of such a GIS that we now turn.

5.3 GIS as a useful tool

5.3.1 Theory and limitations

A very broad and all encompassing definition of what GIS (Geographic Information Systems) actually are, has recently been put forward in these terms: 'GIS are computer systems whose main purpose is to store, manipulate, analyse and present information about geographic space' (Wheatley and Gillings 2002: 9). Hence, potentially a GIS can involve a multitude of different approaches to the analysis of spatial data using different combinations of computer software packages. There has been a wide-ranging debate in recent years amongst practitioners of GIS applications in archaeology over the usefulness of GIS as a tool for interpreting data. In effect the arguments have centred upon the inherent bias of GIS modelling in its interpretation of data towards an implicit environmental determinism, as a result of the inadequacies of recording physical realities into discrete and manageable data (Gaffney and van Leusen 1995). In other words how can the 'grey' of the real world be sufficiently represented in the 'black and white' of electronic media. It is beyond the realms of this thesis to investigate the detailed reasoning behind this reality. Needless to say, there have been a number of attempts to overcome the shortcomings inherent in the functional capabilities of GIS software and the inbuilt limitations of data classification that are inevitably encountered.

Some of these attempts have been more successful than others in breaking free from the inherent restrictions that geographically defined data imposes on a GIS. They have been notable in their success not by doing anything new or special to the data that they hold, but in the application of new theoretical frameworks within which to analyse and interpret the data. To achieve anything meaningful from the Wadi Faynan data, especially in terms of extracting ideas of cultural behaviour, such an approach needed to be seriously considered along with more usual approaches to digitising and interpreting the immense amount of information collected in the seasons of fieldwork. To undertake such a sensitive and appropriate analysis it will be necessary to consider the full range of information that had been collected at Wadi Faynan, and ideally, the range of questions we wanted this information to answer. For a GIS can be applied indiscriminately to all areas of research, to different levels of intensity and with different approaches in mind. In establishing the appropriate use of GIS in this context, it is useful to examine how GIS have been utilised within archaeology since their introduction into the discipline a decade ago.

5.3.2 Methodologies employed

Since the seminal publication of three collections of conference papers in the early 1990s the use of GIS in archaeology has grown considerably (for the conference papers see: Aldenderfer and Maschner 1996; Allen *et al.* 1990; Lock and Stancic 1995). A number of recurrent themes were apparent within this early work, reflecting the initial use of the technology in North America (Wheatley and Gillings 2002: 18-19). Hence, cultural resource management figures heavily in the early work, with emphasis placed on the predictive modelling of archaeological sites in archaeologically untouched, but development-threatened landscapes. However, archaeologists concerned with the analysis of spatially dispersed archaeological material, particularly in the realm of regional surveys, realised the potential of GIS in providing dynamic insights to theoretical problems.

Instrumental in presenting the value of this approach was the work undertaken on survey data from the island of Hvar (Gaffney and Stancic 1991). This influential project alerted landscape archaeologists to the benefits of using a GIS approach. Hence, in recent years GIS technology has become an integral part of any landscape survey project, with many good examples of GIS applications helping to provide valuable new insights through the marshalling and exploration of vast amounts of complex survey data (Gillings and Mattingly 2000: 1-2). Other uses have been concerned with the precise contextual establishment of artefact data within archaeological excavations (Wheatley and Gillings 2002: 235); or with phenomenological theory through the application of approaches such as visibility analysis (see the review by Gillings and Wheatley 2001). Such applications have often been limited in value through the impracticalities of collecting adequate spatial information, in the case of find contexts, or the cost-benefit problems of undertaking sufficiently expansive programmes of viewshed analysis. However, good results can be achieved within the arena of landscape archaeology with the use of a GIS, given a realistic approach to the methodology utilised in the collection of data, and an understanding of the limits of the GIS technology in data handling.

There are now many recent examples where an integrated approach to landscape survey has been undertaken, that is, when a set of key research problems have been identified, a GIS has been considered the best approach to answer these questions, and the appropriate methodology has been devised to document the data with the limitations of a GIS in mind (e.g. Gillings *et al.* 2000 Peterson 1998; Slapsak 2001). Furthermore, the dynamic action of water on and in past landscapes has also begun to be contemplated in several important studies (Gillings 1998; Vermulen *et al.* 1998). Such studies have indicated the flexible application of a GIS within the environment of landscape studies, and have shown how given a solid theoretical framework and a rigorous approach a GIS can facilitate complex and highly nuanced palaeohydrological investigations.

5.4 Construction of the GIS

5.4.1 Introduction

The initial stage was to convert the mass of data collected in the field into a comprehensive database, in this case using Access, and to digitise the information on the field plans into a new vector-based map, using the Cartalinx package. Undoubtedly the most problematic part of the process concerned the attribute information collected for the field walls and how this could be effectively utilised by a GIS. This issue was eventually solved by assigning each field wall its own individual identity and attaching specific attributes to these, the details of which will be explained below.

In considering the required functions of the GIS, it was important that the spatial database constructed should not only be used as an elaborate map-linked database, but as a tool for the thorough analytical exploration of the landscape. The information collected for the Wadi Faynan Landscape Survey presented four main areas with investigative potential. However, for the purpose of this thesis, only one of these potential avenues of inquiry has been pursued in depth. Fundamentally, analysis has been directed towards obtaining explanations for the complex structure of the field system WF4 that has in turn provided insights into processes of development, chronology and the operation of the field system.

In constructing a workable GIS, a number of operations were initially performed to transfer the information on the Wadi Faynan database from the various map sets to a useable format, that could be accessed and manipulated in a GIS package. First, discrepancies within the data set had to be corrected. The next phase was to establish a number of separate digitised maps for the core component features to be assessed within the GIS, those of topography, the fields, and the walls. The next sections outline the main procedures undertaken to achieve these aims, and some of the problems encountered. First, the dataset will be reviewed, and then there are sections on the preparation of the three main GIS map coverages, for the fields, the field walls and the terrain.

5.4.2 Problems with the data set

The actual numbers of fineware sherds picked up in the fieldwalking exercise was very low, the maximum number found in any one field being only four. Therefore it could be reasonably surmised that in some cases the sherds in any one field might in fact be pieces from just one pot-burst. However, examination of the database reveals the probability of this occurring is very low; the sherds are often of the same fabric but apart from the Nabataean finewares, are on the whole from identifiably different pot types. Otherwise no other obvious problems with the dataset could be seen at this point.

5.4.3 Digitising the Fields of WF4

The primary digitised map coverage was of the many fields which together compose WF4. These are represented in the GIS as a series of discrete contiguous polygons. Each polygon represents an individual field, as constructed on the unit maps, bounded by walls, wherever possible, which are represented by simple lines (arcs). If evidence for walls was absent, the field boundaries were formulated using other physical features such as gullies or tracks. In many cases, these features were missing, so purely arbitrary boundaries were drawn during the field walking to complete a field. Moreover, some areas had suffered extensively from modern bulldozing, which had removed the original walls (Barker *et al.* 1997). In such cases boundaries, and for that matter fields, had been arbitrarily set for the purpose of convenience in the collection of surface artefacts during the field walking exercise. Such arbitrary fields had been mapped also, and were given unique field identities (see Section 5.2.4). As such it was necessary to include these as separate fields for the purpose of data analysis within the proposed field system coverage, although in reality the fields did not exist on the ground. To obtain as accurate a representation of the fields within WF4 as possible, three different sets of maps produced in the field seasons were used in the digitising process: the Photogrammetric Map drawn from the recent aerial photographs; the Field Unit Map based upon the original Photogrammetric Map; and the Corrected Individual Field Operation Maps.

It is practical at this point to explain the inherent inaccuracies present within all these map sets and how they might have affected the final representation of the WF4 field system as a digitised coverage, and any subsequent modelling that might be attempted. Probably the most accurate in terms of topology and spatial relationships across the field system is the original Photogrammetric Map drawn from the recent series of aerial photographs taken of the region. However, even with this map there are many inaccuracies: for example, walls have been missed out, or are slightly out of line, or appear disproportionately larger on the map than on the ground. Secondly, many areas and their original structures and features within the field system have since been fundamentally altered by recent attempts to establish agricultural fields. Therefore, large portions of the walls and structures represented on the Photogrammetric Map are no longer visible on the ground. Thirdly, the Photogrammetric Map was used at an enlarged scale of 200 per cent as the base map for the production of the second set of maps, the Field Unit Maps, which identified the fields within those units (Section 5.2.4). Consequently, a certain amount of photocopy distortion has been added in, which has to be accounted for in any future analyses.

For practical purposes it was necessary to utilise the Field Unit Map as a base map in the digitising process. There were a number of reasons why this decision was made. Firstly, the Field Unit map incorporates drawn information on all the field boundaries plotted and collected during the field walking seasons, with each field forming a discrete entity. Secondly, all these bounded fields are labelled with their own individual identities. However, the Field Unit Map itself suffers from errors and distortions, a result of its rapid but necessary progressive production during the field walking seasons. The point has already been made that significant areas within the field system have been recently systematically bulldozed; this led to problems of orientation whilst formulating the field boundaries on the ground, and subsequently errors in a number of places.

5.4.4 Development of the field wall coverage

The second element in the construction of the GIS concerned the integration of the wall data (collected during the field seasons and compiled within an Access database) to the Digitised Map of the main Wadi Faynan field system WF4. The Wadi Faynan database contains detailed information on all the walls within the field system including: variations in wall structure and style; differences in wall architecture; features such as cairns or water management structures contained within the walls; and wall dimensions. Such information is of key importance for several reasons. Firstly, the integration of wall data within the GIS provided the opportunity for constructing an approximate dating sequence for the construction of the walls and hence the field system as a whole through comparative analyses between walls of similar construction and their relationship to diagnostic sherds collected in their immediate vicinity from the fieldwalking. Secondly, the addition of the wall data could provide an important element in the proposed Water Flow Modelling of the field system.

However, the integration of the wall data within the GIS was initially problematic due to discrepancies between the database organisation and the arrangement of the digitised coverage of the field system. Essentially, the basic element upon which both the database and the digitised coverage had been based was the individual field within each set of field units, and not the walls and features which compose the boundaries to each field. In the case of the database, the orientation towards individual fields and not individual walls had been a necessary operation of the fieldwalking exercise, for such a policy successfully helped to prevent duplication of data and increased the recording accuracy, efficiency and speed within the short time-frame available (see Section 5.2.4).

To complete the GIS analyses, the focus of both the Faynan Database and the Digitised Map had to be re-engineered so that the lowest common element would be the walls surrounding the fields and not just the fields themselves. The initial changes involved altering the polygon boundaries on the Digitised Map to reflect the positions of the field walls, features and gaps, where no walls were present. Essentially, the whole operation involved breaking the boundaries of each of the field units into a series of linked compositional parts. This required the insertion of new nodes along the arc lines whenever a section of wall ended or a feature, such as a large cairn was present, the three sets of base maps being utilised to accomplish this procedure. The fields had been recorded on individual Field Record Sheets, as outlined in Section 5.2.4, and at this point it is worth re-iterating the logical strategy behind these objectives (Mattingly *et al.* 1997: 27-32). The first was the practical and effective management of the huge number of fields (around 790) and of the information presented by the field system within the project timescale. The second was to aid future interpretations of wall function, as each wall was in theory to be recorded twice, a consequence of the majority forming the mutual boundary between two adjacent fields. Hence, this would overcome any potential misinterpretation of wall function, or at least the collection of only partial evidence. A misinterpretation of wall function could result as a consequence of the visual aspect a particular field wall may present when viewed from within a particular field. Seen from one field, one face may appear to be a low rubbly free-standing wall, but from the adjacent field the other face could suggest a tall neatly-coursed terrace wall. Hence, recording each field as a separate entity ensured that such potentially important information, particularly as concerns the maximum height and width of a wall, would not be overlooked.

In terms of the construction of the GIS, the application of such a methodology caused certain constraints on the collation of the wall information, as each particular wall (an arc composed of a string of vertices in a GIS), could only support one set of applicable attribute information. The only practical solution to overcome such a constraint was to construct two separate databases of attributes for the digitised wall arcs (labelled Field Database A and Field Database B). Each database contained the information recorded for each wall within the field system from both its aspects, i.e. each wall would in most cases have been recorded as two separate faces on two or more adjoining Field Record Sheets. The arc-based coverages for each of the Databases were then plotted separately (Figs 5.13 and 5.14). This did not present a problem within a GIS environment, as information contained within separate coverages, could be compared and conjoined. Once the whole field system had been covered, and the appropriate nodes inserted, the exercise was undertaken of assigning each fragment of the polygon boundaries with individual identities reflecting the presence or absence of walls and certain important features. The individual wall identities for each stretch of wall eventually numbered around 6,000. The new identities were then matched with the information provided in the Wadi Faynan Database. One of the benefits of the insertion of numerous nodes to indicate short lengths of walling, rather than one node at the end of an arc to reflect the whole length of wall on one particular side of the field, was the level of detailed information (provided by the database), that could in many cases be assigned to the field boundaries. This additional information increased fundamentally the scope of the questions that could be asked of the wall data.

The immediate purpose of examining similarities and differences of wall structure and architecture within the field system was to obtain some indications as to the construction date of the walls and the period in which the fields they lined might have been used for agricultural purposes. Therefore, a wall of a certain structure readily identified within the field system was isolated within the GIS-based wall map, and other examples with similar characteristics were then queried. The linked Database could then reveal on the wall coverage any such walls filling the same criteria, and the distribution of such same-type walls could then be compared with the various period-themed sherd coverages. The results of these initial comparisons will be considered in the following chapter (Chapter 6). An equally necessary function of the wall coverage was to provide an essential element in the future modelling of the operational use of the field system. Other data required for this included the use of spot height information, and the distribution of modern stream flows across the system. Before such information could be effectively integrated, it was first necessary to establish a Digital Elevation Model (DEM) of the Wadi Faynan valley using as a basis the contour information supplied on the Photogrammetric map of the region. The construction of a DEM was also undertaken because it could allow visual insights to be made with regards to the topographic positioning of the field systems, i.e. which field units were on sloping ground, and which on flatter surfaces.

5.4.5 Construction of a DEM

Although the production of a DEM (Digital Elevation Model) is quite straightforward given the provision of the contour data from the Photogrammetric map, there were several problems concerning the orientation of this map, which was based on its own co-ordinate system and not that of the UTM (Universal Transverse Mercator) grid. This problem had been identified earlier and in an attempt to rectify this, a number of positions within the valley using a GPS (Global Positioning Satellite) handset had been recorded during the fieldwalking. From these readings a rough UTM grid had been produced from the points collected in the physical survey of the valley. This grid was placed onto the Photogrammetric map, and at ten easily identifiable points on the map the UTM co-ordinates were calculated; these were then used to re-orientate the map using the GIS package *ArcInfo* (Prat 1999: 7). It was then possible to generate the DEM using the standard procedures.

Once the DEM had been generated, it, along with the Digitised Field Map, were imported into the GIS package *ArcView* and overlain to assess differences in alignment. It was found that due to the imprecise nature of calculating the UTM co-ordinate system for both maps (being based on the positions observed using a rather inaccurate GPS system) and inaccuracies and distortions added in the digitising process, there was a misalignment in an East-West direction of at maximum *c.* 60 metres between the two maps, although this varied to a lesser degree in different parts of the field system. To minimise this the co-ordinates for the Digitised Field Map were recalculated to incorporate a 60 metre shift on the x-axis co-ordinates.

5.4.6 Conclusion

Once all the elements were completed through the processes outlined above, all were integrated into a single spatial database within the *Arcview* GIS programme and the analyses were begun. The initial results of these analyses and the implications to the work completed in the Wadi Faynan Landscape Survey will be assessed in the next chapter.

6.0 The results of the Wadi Faynan GIS analysis

6.1 Introduction

For the purposes of analysis in the present research, I decided to utilise a representative section of the WF4 field system as a whole. For this reason only the first twelve units out of a possible twenty had all their wall information converted to a database for use in the production of a GIS analysis (see Fig. 6.1 for the location of the relative positions of these units). The decision to concentrate on the first twelve units, as well as coinciding with the first two seasons of fieldwork and recording within WF4 (1996 and 1997), was linked to the following research considerations at the time the GIS was being constructed.

Firstly, a high proportion of the total number of sherds collected in the fieldwalking exercise (as much as 75 per cent) was obtained from these units. Secondly, the restriction in the proportion of the field system to be subjected to analysis has allowed for a more in-depth scrutiny of the huge variation in attribute information available. Topographically, the first twelve units also cover the whole spectrum of both natural and human-made physical features. This includes the upper stone-covered 'plateau' areas within units WF4.1, 4.5, 4.8, 4.11 and the predominantly stone-strewn WF4.12; the steep sided terrace regions of WF4.2, to 4.5, 4.8, 4.11 and 4.12; and the level regions of WF4.3, 4.6, 4.7, 4.9 and 4.10, which together form a continuous, alluvium-filled, 'plain' along the south bank of the main course of the Wadi Faynan. These alluvial deposits, which consist of sandy gravels three to five metres thick designated the Faynan Beds, are much younger, more silty and looser in consistency than the older, more compact, and stonier Ghuwayr Beds of the terraced regions to the south (Gilbertson *et al.* 1997: 24-26).

In terms of structures constructed within the field system WF4, these twelve units contain examples of each wall type recorded, such as parallel walls, channels, terraces, cairns, tombs and the occasional building (Appendix 2: 'Wall data categories' lists the classifications under which the structure types were recorded on the individual Field Record Sheets). Furthermore, the units also present a wide variety of field-types, from the small compact fields common in the first three units, long linear terraced fields as in WF4.8 and 4.11, through to the large rectangular fields apparent in WF4.9 and 4.10 (Appendix 2: Field information categories lists the categories of information under which present conditions of an individual field were recorded on the Field Record Sheet).

The analysis of the GIS constructed from the information available for these twelve units will be recounted in the following way. First, an initial appraisal of the wall data will be offered, followed by an evaluation of the pottery data as displayed in the GIS project. Conclusions from both types of information will then be combined in a series of further analyses to assess potential spatial relationships between wall-types and the sherd scatters, before a final set of more complicated spatial techniques will be applied to investigate further any correlations present. The chapter will conclude with a discussion of the various strands of evidence highlighted by the GIS and the successes, limitations, and shortcomings apparent in applying such techniques. Taking all such factors into account, an assessment of the results and their implications will be suggested for the general interpretation of the major field system WF4, in terms of its development history, operation and any socio-economic insights it may provide for the Wadi Faynan region during the Classical period.

6.2 Wall analyses

The initial analysis of the walls within the WF4 began with an assessment of the data presented in the wall coverages formulated from the two separate databases of wall information (Field Database A and Field Database B) as discussed in Chapter 5.4.4. As can be clearly observed in Figures 6.2 and 6.3, there are substantial discrepancies apparent between the two coverages. These can be explained in a number of ways. To begin with, all the walls along the perimeter of the field system and, where present, those walls aligning the 'banks' of the dissecting minor wadis and the main course of Wadi Faynan, were only described on one Field Record Sheet. The unique information for all these boundary walls was allocated to Database A, as was the majority of interior walls, which were only recorded once. Reasons for the omission of secondary recordings of these interior walls vary. In a few cases it is a consequence of recent remodelling of the fields, so certain fields were not recorded (as can be seen in WF4.9 on Fig. 6.1) and adjoining walls were recorded only once. For other walls the information was absent from the relevant Field Record Form. In some cases information on the particular Field Record Sheet was either substantially inaccurate or was so partial as to warrant its exclusion from the database. Finally, in a very few cases, the information recorded on the relevant record sheet could not be seen to correspond with the field as visualised on the digitised coverage. In such cases, omission of the information seemed necessary.

The incorporation of the wall information from the A and B databases into two separate coverages was the only practical solution available which would allow *all* the wall data available to be submitted to concurrent analyses, although in certain circumstances it still remains a major barrier to the full integration of results. In such cases other solutions had to be devised, which are detailed below. Be that as it may, when both wall coverages are active within the Arcview arena, a complete representation of all the walls still currently extant in the units of WF4.1 to 4.12, in addition to arbitrarily demarcated field boundaries within the field system can be visualised as an overlay (see Fig. 6.4).

As can be seen in Figure 6.4, there are areas, particularly noticeable within the central region of WF4.6 and the southeastern environs of both WF4.8 and 4.11, where walls are largely absent. This could have always been the case, reflecting the particular land-usage of such areas in the past, or it may be the result of very recent field clearances when there was an attempt to re-develop some of the fields using water piped from the springs of the Wadi Ghuwayr. This was channelled into a trickle irrigation network of plastic pipes, the evidence of which still litters the field system in some parts (Barker *et al.* 1997: 37; Lancaster and Lancaster 1999: 154). Direct evidence of this recent agricultural phase was viewed from the collected Wadi Faynan database and expressed in the GIS (see Figs 6.5 – 6.7).

The Field Record Sheet contained a number of categories into which wall information could be classified, which are listed in Appendix 2. The information contained within these varies according to what the recorder perceived a specific wall's dimensions to be. A particular length of wall usually varied in terms of both height and width as one walked along its length, and the recorder judged the maximum height and width of a wall in most cases merely according to a visual perception. Hence, within certain limits, most of the information recorded could be considered to be of a very subjective and cursory nature. Although in the majority of cases this is not a problem, it would be wise to treat the collected data with caution, as standards of objective reality within a certain scale range naturally vary from person to person. This fact goes for all the information recorded on the walls as will be shown, but so long as this is taken into account, useful analyses can still be undertaken and relationships revealed.

The potential can be shown when the plots are viewed for the maximum widths and heights of all the walls for which we have information in the units under study (Figs 6.8 and 6.9). For both coverages the dimensions were split into five classes with the breaks depending on 'natural' groupings within the database. A number of common and significant features can be pinpointed on both coverages. First, there is a preponderance of large walls in terms of both height and width in the eastern units (4.1-4.3). The only other unit to have both wide and tall walls is WF4.12. In addition, there is a large number of high walls in WF4.4 and 4.5 and the northern region of 4.11. All these regions are predominantly terraced areas with notable gradients within the majority of cases, the exceptions being the eastern end of WF4.12, the southeast area of WF4.5, and the eastern end of WF4.1, evidence that may be significant in terms of wall function and dating. In unit WF4.9 there are a number of substantially high walls, which front the almost regular series of rectangular fields, but on the whole these are quite narrow in width. Again, this could provide a key indicator to wall function and/or wall dating and construction. Hence, there are a number of potentially good indicators present which could be usefully explored in providing answers to fundamental questions of wall function and/or different periods of wall construction and style. Furthermore, although badly disrupted in many parts, a series of long walls running through several units may point to evidence of water distribution systems. This is particularly apparent for the series of walls outlined in red on Figure 6.36. These whole wall complexes in WF4.3-4.6, and 4.2 may be the vestiges of channel distribution systems and will be looked at in more detail below.

A display of the information recorded for the ten preliminary categories of wall, as recorded by the survey teams on the Field Record Sheet (see Appendix 2), reveals other details. For example, the distribution of walls classified as single-faced terraced walls, taken from Database A, is shown in Figure 6.10. At first sight, there appears to be a random distribution of this type of terrace wall across the whole of the field system. However, closer inspection suggests that there are significant clusterings in some units; if anomalies are discounted in the way the walls were classified (Section 5.4.4). As is to be expected, a high number of the total count of terrace walls is to be found in the sloped regions of 4.1-4.4, 4.5, 4.11, and 4.12. It is interesting to note that, in addition to these areas, the whole of WF4.10 contains a very large number of single-faced terraced walls, in an area where such wall types would not necessarily be expected: the topography of this unit WF4.10 is very similar to the adjacent unit WF4.9, and both units lie on the alluvial plain that gently dips towards the west. In addition, few of the many walls encountered within WF4.9 are single-faced terraced walls, which is in stark contrast to the position within WF4.10. This may signify something significant in terms of wall function, and/or date, though it has to be stated that terracing may have been necessary along a few fields bordering the north and south, where the unit topography dips down to the boundary tributary wadi and the main bed of the Wadi Faynan. In other words, the unusual clustering of terrace walls within WF4.10 may suggest that the walls within WF4.10 were all constructed at a particular point in time to an overall plan for the entire area, and with a particular construction technique. It is also interesting to note that, along the northern and southern edges of the adjoining units WF4.6 and 4.7, single-faced terraced walls are also quite common, suggesting again that these walls are contemporaneous as a group.

Single-faced wide terrace walls within Database A (Fig. 6.11), are a lot less frequent. It may be that many walls listed as simply single faced terrace walls should be in this category, as judgements as to what constituted a wide terrace wall were based on whether the wall appeared to the recorder as being greater than one metre in width, in most cases purely from a visual assessment. However, having said this, outside the easternmost units (WF4.1-4.3), the largest concentration of wide single faced terrace walls is undoubtedly to be found within WF4.12, and again this is important in terms of the implications for homogeneity of wall construction with respect to both style and date. Also, it is significant that most of the walls surrounding and within the oval complex of fields within WF4.2 are significantly large, tall, single-faced, and terraced, which again points to these fields perhaps corresponding to a possible single construction episode within this part of 4.2. Figure 6.12 displays the double-faced free-standing walls of Database A. Although very few in number, it does suggest that most are either in relatively flat areas or run against the slope gradient in terraced areas. In terms of distribution, Units 4.3 and 4.5 seem to display a higher number of such walls than the other units.

Therefore, it can be seen that the attribute data for the field boundary walls of the field system WF4, although it does have limitations in terms of the way it was recorded, can reveal many aspects of the field-system. The next step is to integrate the various wall indicators with the information provided by the pottery collected on the field system to see if any correlation can be made between the areas where certain wall types predominate and the distribution of certain types of pottery.

6.3 Pottery analyses

The pottery sherds scattered across the field system in substantial numbers were recorded using the two standard field survey methods, as described in Chapter 5 (Mattingly *et al.* 1997: 29). Therefore, information is available from both the clicked transects and the total collected sherds in terms of both total sherd weight and sherd numbers for each field. (See Appendix 2 – Click and pick categories, which lists the various categories under which the fieldwalking information was recorded.) Figure 6.13 shows the coverage that can be constructed using the information on total numbers of sherds collected per field. The results, as observed during the fieldwalking exercise, highlight the unevenness of the distribution across the field-system. For much of the field system there is a low background level of sherds per field, of between 0 and 15, but in certain areas the number of sherds collected is very much greater. Within the field-system as a whole, there are three such sherd concentrations or 'hotspots': in WF4.1-4.3; the region of WF4.6-4.7 with parts of the adjoining unit 4.5; and WF4.13 (Fig. 6.14). This situation is echoed if we generate a coverage of the totals for clicked sherds and total pottery weights. Density coverages of this information are particularly useful in revealing more accurate distribution levels of the pottery within the field-system. Figures 6.15, 6.16 and 6.17 show the density per field unit of area for the total number of clicked sherds, the total pottery weight, and the total collected number of pottery sherds. All three coverages for the units WF4.1 to 4.12 maintain the two 'hotspot' regions, although there is a level of variation within these, as particular fields in some coverages have a more dense or dispersed spread of pottery according to the method employed to record the sherds within the particular field. How can this variation be explained?

Large numbers of pottery sherds within the fields could be the consequence of a number of actions: there may have been a site or several sites within the vicinity; sherds could be the by-product of ancient manuring processes on arable land with particularly favoured or fertile areas of greater crop yield potential receiving the most attention (Wilkinson 1982); water and other geomorphological processes might have caused an accumulation of sherds in certain areas; the distribution may also be the result of methodologies employed in recording the sherd information. First consideration of the data suggests that the latter accounts for the production of one of the three major sherd 'hotspots'. Figure 6.18 shows the dates when the fieldwalking of the fields were undertaken. From this, we can see that the fields walked in the initial pilot season (1996) correspond to a large degree with the highest densities of sherds within the three density coverages for the 'hotspot' region divided between WF4.6 and 4.7 (Figs. 6.15-6.17). It would therefore seem that this region of high density sherds should possibly be disregarded, as the distribution may be the consequence of a methodological bias in that an excessive number of sherds was collected during the first season, the result of need to establish the extent of the pottery range within the field-system. However, though the results for this 'hotspot' may have been to some extent amplified by the reason stated above, they cannot be wholly disregarded. This is because the fields immediately adjacent to the west of the 1996 fieldwork area and particularly to the south in the unit WF4.5, although exhibiting on the whole lower densities than the fields within the 1996 region, are still very much more dense in pottery compared to most other fields within the overall field system. A more likely explanation is that this particular region was the most productive and attractive agriculturally, and remains so today, for it was one of the first areas to be re-ploughed during the recent attempts to irrigate parts of the Wadi Faynan. However, it was precisely because this particular region had not yet been ploughed, that it was chosen for the trial fieldwalking exercise (Barker *et al.* 1997). It is likely that a higher percentage of manuring took place within this region, and that soil deflation over time increased the visibility of the sherds on the surface leading to distortions in the sherd counts, as they were both plentiful, and more visible against the soil background on which they lay. The surrounding parts of this same area had been ploughed by 1996, and the modern ploughing had the affect of diminishing the number of sherds visible in subsequent years.

Therefore it can be seen that the field system contains three distinct regions of very high pottery sherd densities. What can explain these distributions adequately? The anomalies in 4.13 and adjoining (peripheral) fields are almost certainly connected to the intense Bronze Age activities within this area, which probably included ore-crushing and/or smelting, as a high proportion of the sherds collected in this region are large hand-made prehistoric sherds (Mattingly 1999a: 269-271; Wright *et al.* 1998: 36). The 'hotspot' of dense sherd matter in WF4.1-4.3, can be partly explained by the relative position of this area just a few hundred metres to the south of the main settlement site of Khirbet Faynan, across the course of the Wadi Faynan (see Section 5.1). Sherds collected from its surface are representative of many periods, which indicate settlement from early times, presumably a consequence of its ideal position (Rubin *et al.* 1997). Therefore, it seems reasonable to assume that the fields of units WF4.1-4.3, because of their convenient position relative to the Khirbet, were subject to long and/or intensive periods of use over many years. Consequently, it would be reasonable to expect a high density of sherds, with representatives from many periods. It is interesting to note that there are significant variations between the different density coverages within the units of WF4.1-4.3, which could be the result of several processes interacting in different combinations.

For both the Total Collected Pottery Sherds per unit of Field Area (Fig. 6.15) and the Collected Sherd Weight per unit of Field Area (Fig. 6.16), the distributions are practically identical. This means the high densities are to be found in the fields of the 'herring bone' system which align the parallel walled channel in WF4.3, the fields which adjoin the tributary wadi which forms the boundary between units WF4.2 and 4.3, and the small steeply terraced fields in the northeast of unit WF4.2. Medium-dense areas include the western section of WF4.1, and the central sections of WF4.3 from the 'herring-bone' system down to the course of the Wadi Faynan at the northern edge of WF4.3. It is interesting to note that the six or so fields which together form the large ovoid field system within WF4.2 are on the whole much less dense in sherds than adjacent fields, which may be a significant indicator in establishing the chronology of field morphology and land-use within this area as a whole. In addition, the eastern section of WF4.1 has scant sherds throughout its entire area, which in part is a reflection of the essentially stony cover present in this region. For the units WF4.1-4.3, the clicked pottery sherd density coverage (Fig. 6.17) shows some distinct differences in comparison with the other two coverages, particularly in the northern section of WF4.2 in which the highest densities occur.

The dense sherd areas of WF4.1-4.3, as with the central region of WF4.6 and 4.7, must reflect to some extent the agricultural practices within this area, through processes of manuring (Wilkinson, 1982). The fields of the 'herring-bone' system in WF4.3, which align the edges of the large water channel and forms the spine (site number WF253), would have been intensively utilised, and the sherd densities reflect this fact. This could also explain the dense sherd numbers in the fields aligning the edge of the tributary wadi between WF4.2 and WF4.3. Perhaps a series of low barrages had been constructed along the length of this wadi, with the aim of capturing some of the annual floodwaters into pools, from which water could be drawn and placed on the adjacent fields. Alternatively, it could be that prior to the wadi commencing a cycle of downcutting, floodwaters were able to overflow directly into these fields in the period when the sherds were deposited. Another possibility is that as the tributary wadi has downcut, the adjacent fields have suffered major soil deflation, resulting in a denser sherd cover on the surface in comparison to neighbouring fields. Issues of soil deflation may also apply to the steep terraces running along the northern edge of WF4.2. On the other hand, the high clicker results for this terraced area suggest that there are numerous small fragments of pottery (Tomber *pers.comm.)*, and these may have accumulated in run-off episodes down the steep slopes from the gentler slopes above, with the fragments becoming trapped in large numbers behind the terrace walls.

An additional factor could well have been the overflow water from the penstock mill positioned halfway along the southeastern boundary of WF4.2, and feeding directly into the 'ovoid system' of fields in WF4.2. These fields are arranged into a series of very gentle low-lying terraces running north from the mill. It seems from their position, lying directly in front and stepping down from the mill and its projected outflow of water, that they formed part of an integrated system with the mill, and were designed to make full use of the outflow water being emitted from it. Furthermore, the insertion of a small extra terrace step in the southeast and the partitioning of the northeast corner of the 'ovoid' system into a separate field, add to the evidence for this being an organised system involving outflow water from the mill. The reasoning behind this statement lies in the local topography, for the eastern side of the 'ovoid' field system dips gently down towards the course of the Wadi Faynan, becoming a steep incline in the terraces immediately adjacent to it. The construction of the extra structures in the eastern side of this mini field-system would have been designed to control and limit the erosive power of discharge water in the eastern half of the system. That excess water from the mill continuously flowed down towards the east, and onto the steep terraces, may partly explain the higher density of sherds recorded in this particular part of WF4.2. The assumed continual flow of water from the mill onto these particular fields of WF4.2 may also help to explain another peculiarity of this area: the general low density levels of sherds in comparison with neighbouring fields.

In addition to flushing out the small fragments of pot onto the eastern terraces, the outflow water could have been responsible for bringing into the fields, new sediment and more importantly a continual, and rich supply of nutrients from the source of the spring water in the Wadi Ghuwayr. Consequently, sherds could have been buried quickly and dispersed in the ploughsoil, as these fields would have been attractive to agriculture for the potentially high yields and so subject to heavy ploughing, resulting in a less dense sherd count. This fact is highlighted in the clicked pot density coverage (Fig. 6.17), which reveals an increasing density of sherds in the fields the further to the northwest from the mill their position, indicating higher levels of introduced sediment behind the terrace walls, and a greater number of sherds the further away from the mill. A similar process, but one based more on the rapid deposition of sediment, can be invoked to explain the density of pottery progressively increasing in the long finger of seven to eight fields which cut across the northern portion of WF4.3, which will be looked at in more detail below. A final consideration, in conjunction with the 'ovoid' field system and the accumulation of sediment and the continuous action of overflow water, is that the fields would have periodically required remodelling and adjustments to counteract the continual processes of erosion and deposition affecting them. Hence, the system we see today may well be a very late modelling of the fields (even recent Bedouin activity) overlying earlier schemes.

Besides the problems with methodology outlined above, there are undoubtedly two other important factors influencing the high pottery densities displayed in the centre of the field system, which reflect land use within this area. The first factor, which at the present time is hard to quantify precisely as the coarseware pottery data is currently being studied, is the siting of Tell Wadi Feinan. The 'Tell' is a Neolithic settlement located on the edge of the field-system, just to the north outside WF4.6 and WF4.7 and half eroded by the Wadi Faynan (Najjar *et al.* 1990). An abundance of large cooking jars and other coarseware pottery has been excavated from this site, and it seems probable that sherds of this pottery will be located in the fields which surround the site, and which now border the southern bank of the Wadi Faynan in units WF4.6 and 4.7. Through soil deflation processes and ploughing, many of these sherds must at present have found their way to the surface, and this fact may partially account for the high sherd densities in the fields surrounding the site of the tell. This fact should be borne in mind when assessing any sherd densities within the region of WF4.6 and 4.7 as a whole.

However, probably the most important factor to influence the pottery distribution within the entire central region of the field system is the use of this area for intensive irrigated agriculture within the Classical period. As mentioned above, there is suggestive evidence, albeit fragmented, for a succession of water channels which carried floodwater from the three tributary wadis which run into units WF4.3 and WF4.4 (Sections 5.2.3 and 5.2.5). The evidence is reinforced by trenches cut into suspected water channel positions at three points within WF4.4 and 4.6, whose past use as water channels was subsequently confirmed by the presence of water-deposited soil lenses (Daly and Newson 2000: 43; Fig. 5.10). The western half of WF4.6 and the whole of WF4.7 are topographically and geomorphologically ideally suited for such an operation, being a large region which almost imperceptibly slopes down to the west, and which even today is richly covered in fertile alluvial, colluvial and aeolian sediments. The presence of this fertile soil mass also accounts for the extensive damage to the structures of this region by attempts at drip-irrigation agriculture in recent years (Fig. 6.5).

The northern half of WF4.5 can be considered within this region of rich agricultural land, and was unquestionably an integral part of the system, as testified by the presence of a parallel wall channel at the northwestern tip of WF4.4 (WF288). A trench cut into this section of parallel wall again revealed a series of silt lenses deposited by relatively fast-flowing periodic water flows (Daly and Newson 2000: 42; Fig. 5.10). However, today the course of this channel has been deeply dissected by a tributary wadi flowing towards the north, an indication that the patterns of tributary wadis, and for that matter the topography across the field system, were rather different in the Classical period, being in a constant state of flux. Indeed, these processes would have been exacerbated and accelerated during the period when the tributary wadis were not downcutting, but were controlled and adjusted to serve the operating channel networks and field system. Consequently, as with the 'ovoid' system of fields in WF4.2, the provision of floodwaters by a network of channels would obviously introduce tonnes of alluvial sediment over a short period, necessitating periodic remodelling and continuous maintenance of the channel network. Some fields would be suffering from soil deflational and erosional processes, whilst others would be steadily accumulating sediments, which would have to be held by whatever means were available.

Such constant movement of sediment, in addition to the affects of modern plough dispersal, may help to explain why some fields exhibit surprisingly less dense sherd scatters, particularly the eastern half of WF4.6 and the adjoining western section of WF4.3. This rectangular shaped block of fields may represent a late re-modelling of this particular region of the field system, in an attempt to redevelop and utilise this reduced area following years of successive sediment accumulation. Contemporary with this area remodelling, or perhaps completed at a slightly earlier date, could have been the construction of the gently sloping 'finger' of seven to eight fields across the northern section of WF4.3, as these also contain sparse quantities of sherds compared with adjacent fields. However, Figure 6.5 suggests that the majority of these very same fields, in WF4.3 and for that matter those of WF4.6 and 4.7, have been subjected to modern ploughing and agriculture. It might be surmised that dense quantities of sherds have been dispersed and turned over in the ploughsoil, so were simply not visible to be recorded or collected. On the other hand, the few fields in the 'rectangular' area, which have not been ploughed recently, also exhibit low numbers of sherds, and fields in WF4.6 and 4.7 that have been ploughed produce high sherd counts. Therefore, although the numbers of sherds may have been lowered slightly by ploughing, recent agricultural usage does not fully explain sparse quantities of sherds in the topsoil.

Further evidence, which may justify this theory of successive sediment deposition and re-modelling, was produced by the section cut across the parallel walls along the eastern edge of field WF4.6.46 (Trench 2: Fig. 5. 12). This series of parallel walls lies halfway into this low sherd rectangular area, and in fact almost bisects it, the distance between the walls being approximately three metres. Today the parallel walls mark a distinct boundary, and form a substantial terrace on this fairly level plain, the surface of the field to the east lying approximately one metre higher than the field to the west (WF4.6.46). At the base of the section were found two lines of substantial boulders, approximately one metre apart, which thus gave the impression of being a well-constructed and highly structured water channel. Water-deposited lenses of fine silt were also present in the section, as were sherds of Nabataean and late Roman pottery, but no Byzantine sherds or sherds of a later date (Barker *et al.* 1999: 43). Such evidence seems to corroborate the hypothesis that beneath the fields of this large 'rectangular' system lies an earlier network of water channels and accompanying fields which at some point in time had to be rearranged to accommodate successive and rapid accumulations of sediment over a relatively short period of time. Does this theory stand up to the distribution of diagnostic pottery sherds collected from the surface of the fields in the field-walking exercise?

6.4 Fineware distribution patterns

Only data relating to the diagnostic sherds of the Nabataean and of imported finewares of the late Roman and Byzantine periods were available at the time of this GIS study. (Future studies will have the full pottery typology available to make more detailed analyses.) The dating of the sherds follows the basic period divisions as outlined by Parker (1986). These divisions are as follows:

Early Roman / Nabataean	63 BC – AD 135
Late Roman / early Byzantine	AD 284 – 363
Byzantine	AD 363 – 551

Parker separated the Byzantine into early and late, but these have been combined for this study, as further work is required in dating specific types of imported finewares.

The Nabataean sherds consist of all rouletted and painted examples, their associated forms, and the occasional Eastern Sigillata A. The late Roman and Byzantine sherds consist of all recognisable imported finewares as detailed by Hayes (1972). These include African Red Slip wares, Phocaean Red Slip wares and Cypriot Red Slip wares. In the case of the Cypriot Red Slip wares it is hard to distinguish the body sherds of sixth Century Byzantine date from examples in the seventh Century, so the majority has been included in the late Byzantine–early Islamic coverage (Fig. 6.23). The information concerning the finewares from these four roughly drawn periods was fed into the GIS and a distribution map was produced for each encompassing the whole of the field system (Figs 6.19 to 6.23). As noted above, many body sherds from these finewares cannot be specifically dated, as the fabrics from which they were made existed without much change over many years, even centuries. Therefore, some decisions had to be made on the assignment of many of these sherds to the three later period coverages, and these categories have been allocated as listed in Appendix 3.

It is immediately apparent that the numbers of fineware sherds of datable well-known fabrics for each of these long periods are very low: they are spread across the entire field system, with never more than seven sherds per field. This means any conclusions drawn from the distribution pattern should not be heavily stressed, nor indeed be viewed as concrete evidence for any given theory. The real value of completing this exercise is in establishing the idea that valid comments might in future be able to be put forward on important issues of the field system development, and its changing structure and morphology over time. It may also shed light on the crucial issue of whether it might be possible to date specific wall constructions to certain periods, and also give indications of land ownership, land-use and other changing social and economic aspects of the field system that the distribution of dateable sherds might offer. All of the above ideas cannot be fully explored until the whole pottery database can be linked to the GIS in the near future. This in turn is likely to mean that some of the ideas stated below will need to be re-assessed.

Figure 6.20 shows the Nabataean and early Roman period distribution across the whole field system WF4. If to some extent the high numbers of sherds in the fields of the 1996 field season are discounted, for the reasons stated above in Section 6.3 and because of the colour of the majority of sherds, then there appears to be a widespread and almost even distribution over three-quarters of the area of the field-system. The visibility of these sherds is an important point to keep in mind, for many sherd types of this period were particularly susceptible to being retrieved as they stand out against the surface background due to their bright red coloration. However, two areas display a slightly higher density: the northern section of WF4.2, and WF4.12. In addition, there are distinct absences of pottery in the whole of WF4.5, 4.6, 4.11, 4.17, 4.18 and 4.19. Furthermore, it is perhaps significant that the rectangular series of fields in the northern and central sections of WF4.10 is also bereft of these early period sherds.

The late Roman finewares (Fig. 6.21) show a distinct variation in the distribution pattern, with sherds limited to the central and eastern sections of the field system. It is noticeable that there is a complete absence of sherds in the southwestern regions of the field system, particularly WF 4.12, 4.13, and 4.17 through to 4.20. Higher densities of sherds appear in the eastern area particularly WF4.2 and 4.3, the central area of WF4.5, 4.6, 4.7 and 4.8, and some parts of WF4.10 and 4.15. Figure 6.22 (Byzantine pottery) and Figure 6.23 (late Byzantine/early Islamic pottery) show very similar distribution patterns, which are in all likelihood in part a reflection of the pottery dating problems. Having said this, however, it is probably true that the areas in use during both these eras did not vary significantly over time: the sediment-rich plain bordering the Wadi Faynan has furnished most of the diagnostic pottery finewares, particularly WF4.6 and 4.7, and WF 4.10 and adjoining fields of 4.15. Fewer sherds are located in the eastern region of WF4.2-4.3 than in the earlier two periods, and there is a further 'retreat' from the southwest, with only a single sherd being found in WF4.14.

Although the sherd numbers are quite low, it is still possible to make some valid comparisons between the different periods, and put forward some general ideas about what the patterns might suggest. The Nabataean distribution has clearly been affected by the sediment changes on the flat plain area bordering the Wadi Faynan, which effectively means that many Nabataean sherds lie buried beneath the surface in this area. WF4.12 has a significant high sherd count, especially at two points, which coincide with the presence of two rectangular building structures (Fig. 6. 24). It is probable that the Nabataean pottery at these locations can be directly associated with these buildings. The structures are of very similar design to two other structures in the adjoining unit WF4.13, which were partially excavated in 1997, and contained Nabataean/early Roman period pottery (Wright *et al.* 1998: 37-40). It can therefore be supposed that all four structures represent small Nabataean-period farmsteads or farm outbuildings, situated along the edge of the useable farmland immediately to their north. The presence of only Nabataean/early Roman sherds and of none of the later periods within the southwestern section of the field system strongly suggests that many of the features of this area, particularly the walls, must have Nabataean origins, or be even earlier in date. To temper this statement is the fact that some areas within this region (WF4.12) are lacking a thick soil cover at present, which might always have been the case. This means that the walls and structures may have been constructed and used in later periods, but the fields were not subject to manuring processes, and so lack later sherds. Alternatively, the land-use of this area could have been different, with less ploughing or manuring processes involved, for example orchards (Mattingly, *pers.comm).*

The emphasis in the pottery distribution shifts significantly in the late Roman coverage (Fig. 6.21). Three key regions dominate the distribution, all of which lie in the eastern and central sections of the field system. There are relatively high sherd counts in: WF4.2, particularly outside and to the west of the 'ovoid' system of fields; in the area of WF4.5 to 4.7, which could also include the northern part of 4.8; and (less densely) in parts of WF4.10 and 4.15. Furthermore, although the numbers are very low (only three sherds!), there is a grouping in three adjoining fields of WF4.14, immediately to the west and at the end of a parallel wall complex, which although heavily disrupted can be followed to the tributary wadi to the north of WF4.14. This situation is echoed in other areas where denser concentrations of late Roman sherds tend in most cases to have been found in fields which adjoin or lie in close proximity to the course of parallel wall/water channel systems. This is shown for example, along the 'herring-bone' channel in WF4.3, around the channels in WF4.7, fields adjoining the wide channel which cuts through the southern part of WF4.15 (site number – WF75), and fields around the channel complex in the north of WF4.15 (WF85). This relationship of late Roman sherds to channels is much more apparent than for the sherd/field distribution of the Nabataean coverage. The strong impression is that these channels were constructed and used, at least in their present form and position, in the Later Roman period. Today only fragments remain of what must have been an extensive and complex feeder channel system which served large parts of the plain and other readily usable areas, such as WF4.14, and which date to the late Roman period. The 'dense' collection of late Roman sherds in WF4.10 is even more intensive in the later two periods of the Byzantine and late Byzantine/early Islamic periods (Figs 6.22 and 6.23). There is also continuity within the units WF4.6 and 4.7, as in the earlier period, though this is slightly less intense. The interesting comparison to make with the earlier late Roman period is the apparent decline in the number of sherds within the easternmost units. The dense late Roman distributions in WF4.2 and 4.3 are replaced in the Byzantine period by a more diffuse spread, which continues into WF4.6.

Therefore, the limited evidence available does suggest that we should view the WF4 field system as a composite of many systems of fields, constructed, conjoined, and adapted over many years, with parts within the system used and possibly abandoned and reused over centuries, rather than a complete, monolithic whole. Further to this, it appears that within WF4, some regions, and the structures contained in them, point to usage and construction at certain points in time. The next section will look at specific evidence which may help us achieve specific correlations of the dating evidence with particular structure types.

6.5 Statistical analyses

In this section some provisional attempts will be made to isolate certain walls and structures within the first twelve units and to see whether they can be in anyway linked to the sherd scatters of the three classical periods. Figures 6.24, 6.25 and 6.26 show the fineware sherd distributions of these periods – Nabataean, late Roman (early Byzantine) and Byzantine – within the first twelve units of WF4. All three coverages reveal higher sherd densities within the central section of WF4.6, perhaps for some of the reasons outlined above. It will also be noted that for both the Nabataean and the following late Roman coverages, there is a higher density of sherds in the northern sections of WF4.2. The adjacent unit of WF4.3 exhibits sherds from all three periods, but this is noticeably high for the late Roman coverage. The Nabataean sherds seem to be particularly prevalent in WF4.12, and Byzantine sherds seem to be high in number in WF4.10, although there are also a few fields of WF4.10 which contain some sherds from the earlier Nabataean and late Roman periods. These three areas, WF4.3, WF4.10 and WF4.12, which have concentrations of sherds each from a different period, will be looked at in further detail below.

To establish whether such concentrations are in fact significant, it might be useful to employ some measure of association through statistical analysis methods. A helpful beginning in assessing the correspondence between these distributions and certain areas can be achieved with the application of the chi-squared test in its 1-sample version (Shennan 1997: 104-115). In this way we will be able to state whether the sherd concentrations in WF4.3 for the late Roman period, WF4.10 for the Byzantine period and WF4.12 for the Nabataean period, are indeed significant, and require closer study. However, it should be noted that the chi-squared test only informs on the probability of a relationship existing and nothing beyond this, as it only measures the differences between expected values from observed values. In other words, in the case of WF4, the test will highlight the difference in the amount of sherds we should expect in such an area and the amount actually obtained in the fieldwalking exercise. The test exercise is detailed in Appendix 4.

The results are revealing in a number of ways. For WF4.10, a very high value is revealed which is statistically significant: a result of 142.0405, which is substantially above the significance level of 3.84146. Therefore we can clearly infer that a far higher number of Byzantine fineware sherds was collected in this unit than would be reasonably expected. By association, it would seem highly likely that many elements of the surrounding walls and features within this unit date to the Byzantine period as well. We can have no definite proof of this, but unless pottery from other periods shows a similar degree of density within the unit, and on present knowledge it does not, it seems reasonable to suggest that there is a high probability of many of the visible structures within this part of the field system being Byzantine in construction.

The results for the Nabataean sherds of WF4.12 are different, and reveal that there is no inherent significance in the distribution within the fields of the unit. The result for the test, 0.450596, falls well below the significance indicator of 3.84146. At first sight, this perhaps seems surprising considering the high numbers of Nabataean sherds shown on the GIS coverage within this unit. How might this apparent discrepancy be explained? The chi-squared test was set up to test whether there was a relatively equal distribution across the fields of unit WF4.12 compared with what could reasonably be expected. In other words, the unit simply has more than its fair share of sherds in proportion to its total area, but in comparison to other areas, it does not. A re-examination of Figure 6.24 suggests that within the large surface area that comprises WF4.12, the majority of Nabataean sherds are to be found clustered in two relatively small areas.

These two areas lie in the western half of the unit, on the summit of a low ridge, and down the terraced fields which cover the slope that drops down towards the west. Even if the test is re-done to comprise this summit and terraced area, as shown in Figure 6.27, the results still do not become significant. The chi-test for this reduced area produces a result of 3.18239, which is just below the significance level of 3.84146. Therefore, we cannot say that there is a definite association between the construction of the terraced walls and the sherds within this unit. The cluster of Nabataean sherds on the summit of the ridge within WF4.12 lies in close proximity to the site of a building of similar structure to those excavated in unit WF4.13 (Wright *et al.* 1998: 37-40). These revealed Nabataean and early Roman pottery, so it is a strong possibility that the Nabataean sherd scatters in the fields around this building can be directly linked to the activities of its residents in classical times.

As for the sherds on the terraced slope of WF4.12, it may be that they are connected with some low level use of this region in Nabataean times. It is significant that these terraced fields were prominent in the field system for exhibiting a wealth of evidence for different construction phases. Many of the terraced walls show distinct signs of two different phases, the lower courses being composed of large tightly packed stones with courses of smaller stones above. The large stone courses have strong similarities with the boulder walls of the adjacent unit WF4.13, which have been discussed as forming remnants of a Bronze Age landscape (Mattingly 1999a: 269-71). It may be that the upper courses date to the partial reuse of this area during the Nabataean period. Otherwise, the lack of sherds from other periods might be related to the landuse requirements of this area, which may not have required extensive manuring. Further evidence for differing landuse activities is provided by the fact that this area was certainly not fed by channelled water as occurred on the northern sections of WF4; instead, the terracing served to collect run-off upon the slope itself, and to maximise the beneficial use of the limited amounts of water.

The final series of chi-squared tests focussed on the eastern section of WF4.3, which exhibits a high percentage of late Roman period fineware sherds (Figs 6.25 and 6.28). The section of the unit chosen for the chi-test conforms to the terraced and 'herring bone' field areas of the unit, which seem to form a cohesive water management system within the unit. As there are a number of sherds present in this area from the other two main periods under analysis (see Figs 6.24 and 6.26), additional chi-tests were undertaken to compare with the results of the late Roman sherds. The results for the late Roman period seem conclusive in showing that there are substantially higher levels of sherds dating to this period within this area (the chi squared result amounts to 26.7203, much higher than the significance level of 3.84146). The results for the all three periods within WF4.3 are as follows:

	Result of Chi-Test	*Significance Level*	*Significance*
Nabataean Period	1.7487	3.84146	No
Late Roman Period	26.7203	3.84146	Yes
Byzantine Period	12.6988	3.84146	Yes

It can be seen that the Nabataean results, as with WF4.12, show that there is no real significance to the sherds of this period in relation to the selected fields of this unit. The Byzantine period sherds, along with the late Roman sherds, suggest that they may be associated in some way with the agricultural use of the fields selected. It may be noted at this point that the significance level for the Byzantine sherds is much lower than the corresponding result in WF4.10. Any direct comparisons in terms of levels of association between the late Roman period and the Byzantine period would be unrealistic, as the test cannot account for such comparisons. In other words, from the results obtained above, it is impossible to suggest that the lower level of significance for the Byzantine period compared with the late Roman period means that the fields were used less or manured less in the Byzantine than in the late Roman Period. However, the failure of the Nabataean period sherds to form significant levels in both WF4.3 and WF4.12 could suggest that most of the Nabataean sherds scattered across the whole of the field system WF4 are mainly residual in nature. This suggests that the majority of fields and their associated structures which comprise the field system as we see it today probably date to the late Roman and later periods. Therefore, fields from earlier periods, particularly those of the Nabataean, may be incorporated within this matrix and survive as scattered fragments throughout the field system, with more significant remains from later periods forming a more cohesive whole.

6.6 Modelling the System

Having reviewed the evidence for the different elements from which the GIS is composed, this section will attempt to piece together the various strands and propose some hypotheses to explain the development of the field system.

Initially, it is important to ascertain whether the evidence provided by the high density of sherds from some periods in particular areas provides clues to the construction and hence dating of particular wall types in those areas. Therefore, the two areas with large significant densities of sherds WF4.3 and WF4.10 were analysed for evidence of particular wall types. The first, WF4.3, shows both a high concentration of Byzantine sherds, far in excess of any other area apart from in WF4.6, and smaller areas in WF4.7 and 4.9. Whilst the second WF4.10, Byzantine sherd numbers are higher in quantity compared to sherds from any other period, and certain distinctive wall types predominate. A direct correlation, and thus a provisional construction date for those types of walls within this area, may be forthcoming. As an example, Figures 6.29 and 6.30 show various wall types, in these cases parallel walls and neatly-coursed walls, in comparison with the coverage of Byzantine sherds. There are very few neatly-coursed walls within WF4.10, but examples of parallel walls are more concentrated here than in other areas, apart from the northern section of WF4.11. This suggests that there might be a link between this type of parallel wall and the Byzantine sherds. In addition, although there are no neatly-coursed walls within WF4.10, there are some groupings within WF4.3 and WF4.5, which seem to correspond precisely to areas with late Roman sherds, more so than either Nabataean or Byzantine sherd distributions (compare the distributions in Fig. 6.31). This could suggest that in areas with steeper gradients and neatly coursed terraced walls, such as WF4.3, these structures are essentially late Roman in date, but the evidence is far from conclusive.

Other examples can be generated which show similar results for other wall types, such as terrace walls. The terrace wall coverage seems to show a large number of terrace walls within WF4.12. However, as with the earlier wall type coverages, such as neatly-coursed walls, it is hard to correlate specific wall types with particularly dense sherd areas for particular periods. Even if the wall class is restricted to, for example, single-faced terraced walls of one metre or more thickness

(Fig. 6.32), or, even single-faced terraced walls of one metre or greater thickness constructed of medium sized stones (Fig. 6.33), the results remain unclear. This seems to contradict visual impressions made in the fieldwork, that certain areas within the fieldsystem, such as the northern section of WF4.1 and the majority of WF4.4, 4.10 and 4.12, displayed a certain cohesive whole in terms of average field size, wall types, and wall construction material (i.e. stone size, stone shape etc.).

It seems from this that a combination of three factors has influenced the ability to construct complex and informed queries within the GIS, and subsequently make detailed correlations difficult to determine. Two of these factors are closely intertwined with one another and are related to the large scale of the field system and the complexity of its walls and associated structures. Firstly, as mentioned above (in Sections 5.2.4 and 5.2.5) there is the variance in the visual perception, within a certain range, by different recorders of the same wall: one person's neatly-coursed wall is another's rubbly wall. The second and related factor is concerned with the understandable difficulty in assigning walls to specific categories, for most walls are not homogeneous in nature, but present a range of wall types even along a short length. Such a consideration will account for the many diverse influences upon a wall, reflecting its specific purpose and its subsequent history. The agencies acting upon a wall over millennia are potentially limitless, but a few obvious examples include: the collapse of wall sections, with the ravages of time; sections being bulldozed or dismantled into rubble piles; sections having been rebuilt or robbed of stones over time; and of course, sections serving different purposes or adjusting to changes in the local physical environment, so that it was necessary to use different techniques of construction in the same short length of wall. Hence, the actions of observation and recording are made problematical by the evidence that a particular length of wall might present. An example of this can be highlighted in the case of walls which have become buried under piles of rubble collapse, thus obscuring the true wall type underneath. These lengths might be recorded in a wall category contrary to the wall types prevalent in the surrounding area. Subsequently this complicated scenario of observation and interpretation has been reflected to a large degree in the GIS wall coverages. As a result, the wall information, although specific and detailed, remains overly disjointed and too disparate to support detailed models of the field system in terms of construction, development and operation. The third factor concerns the pottery, as the fineware sherd distributions are far too low to make robust arguments concerning particular areas within the field system. Although, this situation may change in the future, with the addition of any dateable coarsewares, at the present time any suggestions as to the development of the field system must remain tentative. However, taking all the above factors into account, the evidence the GIS can present in terms of wall data, sherd distributions and field morphology, means that certain basic statements can be put forward concerning the field system.

Figure 6.34 is a distribution coverage of the particular area of an individual field divided by its perimeter length, and it serves to show a representation of field morphology and a proportional representation of field size. This was a useful exercise to undertake, as it is immediately clear that five large areas of the field system exhibit a surprising degree of proportionality. The areas have been roughly indicated on the figure, and have been labelled I to V. Area I comprises most of WF4.12, including the whole of the terraced slope and the flattish summit area in the east. Area II consists of the long rectangular shallow terraces of WF4.9 and 4.10, whilst Area III is made up of the small terraced fields of the majority of units WF4.1–4.5. Area IV on the other hand, is composed of the flat stony regions of WF4.8 and 4.11. Immediately below these are the steep terraces which lead down to a large tributary wadi, which could also be considered as a further group with similar field morphology, Area V. Such similarities in field morphology can only be the result of two factors.

The first and most important factor relating to field size, must be the physical conditions at the local level, so the fields of Areas I, III, and IV are generally much smaller, as these are relatively steep slope areas. Therefore, the most efficient means to maximise the agricultural use and to prevent severe erosion at the same time, is to construct a series of small terraced fields. Erosion is less of a threat on planar surfaces, so fields can be enlarged to increase agricultural efficiency, as is the case to some extent with Areas II and IV. However, although the gradients in both Areas II and IV are very gentle, each area lies in very different physical settings, which affected both the field size, and the land use of each area. Area IV consists of very large fields on high, flat, and stony ground. There is very little surface run-off in this area, and there is no evidence for water channels feeding into any part of it, indeed, the area lies far above the beds of the adjacent tributary wadis. This was probably the case even in antiquity, so it would have been impractical to attempt to divert floodwaters onto these fields. Hence, the agricultural use of the fields in this area must have been generally very limited, so even in antiquity it must have been an area of marginal benefits, reflected today in the generally very low sherd counts for these fields (e.g. Fig. 6.17).

In a similar physical setting lies the eastern half of Area I, which consists of the majority of WF4.12. It can be clearly seen that this area contrasts sharply in terms of field morphology with the fields in Area IV. The fields in the plateau area of WF4.12 exhibit the same field morphology in terms of field size and shape as the western terraced slope of Area I. It seems a distinct possibility that the fields in Area I represent a cohesive whole, laid out for the most part at one particular point in time. It may be that the local physical conditions may have determined the average size and shape of the terraced fields in the west, where the slope is far gentler than the sharper descent in Area V, and that the same field proportions of the western slope of Area I were simply continued up on to the adjacent plateau area. In other words, Area I (WF4.12) forms a near complete and integrated landscape, which in addition, incorporated the many large burial cairns that lie in this area, forming an interesting 'managed landscape'. What this means is that the area of WF4.12 seems to have been laid out to a specific well-organised plan, and that this plan respected and incorporated the remains from earlier periods. However, when this might have occurred, and to what purpose requires further study.

Area II forms another very different wholly planned landscape. Here the physical conditions are very different, as the area as a whole had complete access to the full benefits of the annual floodwaters, in addition to any surface run-off from precipitation. The whole area seems to have been fed by a series of parallel east-west running water channels, fragments of which still remain along the northern and southern edges of the large rectangular fields. It may have been that there was a central east-west channel running down the centre of the large rectangular fields, but evidence for this is fairly circumspect, as a developing tributary follows the line of such a supposed channel may have destroyed most of the available evidence. However, the presence of such a tributary wadi/gulley in this location, and the bi-convex layouts of the low north-south terrace walls, would make the presence of a central water channel of some sort desirable.

Adjoining the large rectangular fields, to their north and south is a series of smaller fields which lies at a slightly low level to the larger fields, but is clearly part of the same system (see Fig. 6.35 for a model diagram of the complete system as it may have been planned). At the western end of Area II, the regular nature of these fields becomes disrupted, and it is perhaps significant that this area is the part where large numbers of Byzantine fineware sherds were recovered, and so this area may have been remodelled later. Conversely, this part may have been abandoned when at a later period the fields to the east were remodelled into large rectangular fields. The arguments for either scenario will be discussed in detail below (Section 6.7).

Area III is a dense patchwork of small fields whose size, while being generally constrained by the quite steep gradients generally present within this area, has been subjected to a complex series of developments and remodelling over very long periods of time. Some of these can be partially understood from small clues and fragments still extant within this area. Figure 6.36 shows what remains in terms of a large complex of water channels, and major boundary walls, which in all probability utilised the floodwaters flowing down the major tributary wadis numbered 4 and 5 on the diagram. It seems for the most part that this network of channels was utilised to irrigate the large flat area within units WF4.3 to WF4.7.

This area, although very complex in terms of field morphology, and recently subjected to significant amounts of damage, can still be divided into reasonably distinct areas of fields, which are labelled A, B, C, D (and D1, D2), E, G, H and I (Fig. 6.37). The significance of these areas is that they may represent a palimpsest of different schemes laid out within the field system at different times. For example, it could be that areas C, D, G and I represent an early scheme. Overlaying these, have been placed areas A, B, D1, and D2 perhaps at different times. In addition, areas E and F seem to have been 'slapped' onto the regions they cover as small, planned systems, destroying the schemes in these areas from earlier periods. Area J seems to represent a small self-contained system which resembles in certain wall constructions the fields at the southern end of WF4.3.

It is interesting to note that the present courses of the tributary wadis 3 and 4 cut through field walls at certain points. The result of this was that, when the field system was in operation, the full flow coming down the course of these wadis was by various mechanisms diverted and controlled within the fields of the field system. This is not the case for the other wadis (1, 2, 5, and 6): in most cases a substantial part of the floodwater entering these wadis was siphoned off into channels at certain points along their course. Generally, however, field boundaries as they stand today respect the course of each of these wadis, particularly downstream.

6.7 Conclusion

The simple GIS analyses undertaken here have revealed a number of important results which will be considered in this section. Certainly, this exercise has highlighted the potential use of GIS analyses in such an operational environment and in such an archaeological context. These analyses are really only the beginning of what could be attempted, as the data within the Wadi Faynan database is so diverse. However, these investigations are for the future and it remains to summarize what the present analyses have revealed about the nature of the field system WF4 and what we can say about its development, operation, chronology and place within the landscape of Wadi Faynan.

It has been proven both by evidence collected in the fieldwalking exercise (Section 5.2.4) and by the GIS analyses above that the field system cannot be perceived as a complete homogenous system, but in fact represents a palimpsest of very complex, multi-layered, and fragmented structures; of systems within systems for the efficient management of floodwaters; of younger systems imposed over the remains of older systems; of different technique-oriented systems exploiting adjacent but different surface and topographic conditions. Such a complex set of remains has proved difficult to document and untangle fully. However, some statements about the field system as a whole can be suggested.

It is clear that the field system which exists today contains elements of systems from the Bronze Age to the present time, with the majority of structures visible today dating from the Classical period. The systems of the Classical period dominate the present remains, for this was the last period when the area of WF4 was extensively used for agricultural purposes that employed floodwater farming techniques. This seems an obvious statement to make, but it is worth pointing out as the systems could be easily altered: stones and even groups of fields could be quickly moved or adapted, and over a relatively short time period the local landscapes within the area of WF4 could be substantially changed. However, the general appearance of the fields and wall structures as seen today has not been altered since antiquity, until the recent modern irrigation schemes were initiated.

When the fields were being used in the past, periodic structural changes would be required to adjust the systems to take account of the vicissitudes of the physical environment, especially the rapid and unpredictable processes of erosion and deposition of large quantities of sediment (Section 2.4). Moreover, the evidence from the tributary wadis, and their relationship to the field systems, reveal elements of change. The layout of the fields particularly in the eastern part of WF4 suggests that the natural drainage courses had been altered and adapted to the needs of the system operation. In the mid-sections of the field system indirect evidence from along the course of the tributary wadis in units WF4.7 and WF4.9 indicates that they had been directed into artificial channels in which the erosive powers could be controlled and the floodwaters siphoned off to where they were required. Today, the modern tributary wadis have re-asserted their presence, cutting through fields and into the lines of former channel-ways where their flow had been controlled within the system.

A variety of wall types was used in various parts of the system to suit particular terrains, and two types predominate. On the slopes, terraced walls were constructed to capture run-off and trap sediment from being eroded off the slope; on the flatter regions, channel networks were built to direct floodwaters on to the fields and spread these evenly across long low gradients and large areas, with the help of series of low, gentle bow-shaped, terraces. Examples of these basic wall types have been recorded in some regions of the southern Levant particularly in parts of the Negev (Kedar 1957a). WF4 has in certain locations on wide tributary wadi courses (e.g. Unit WF4.18) examples of the simpler type of cross-wadi walls, built to trap sediment behind low terraces, which are again common throughout the Near East (e.g. Evenari *et al.* 1982; Kennedy 1998a). The incorporation of older ancient burial cairns, for example in unit WF4.4, is also significant. Within this unit ancient cairns have been used for important wall junctions and thus perhaps marked the edge of land ownership at some points. Furthermore, some walls appear more massive in construction than others, particularly a long double-faced terraced wall which still stands several courses high today and is up to two metres wide in parts which runs through unit WF4.12 and across into WF4.13. For some of its length, this wall performs a purely functional role, for other stretches it marks the boundary between the edge of the terraced system down the western slope of WF4.12 and WF4.13, and the adjoining channel systems of WF4.14. It is possible that it could also mark a boundary between different areas of land ownership or control, but this is at present difficult to prove.

What is clear is that certain types of wall construction were used at particular periods in time, but that these were subject to habitual change. Hence, today there are only fragments of different periods of construction along the majority of walls visible. The preservation of older construction types could be the result of certain areas being abandoned for agricultural use in later periods of antiquity. On the other hand, it could have been the case that particular areas were assigned to a specific type of landuse, which did not require periodic modifications. For example, the terraced areas along the south easterly edge of the field system would not have required as much maintenance or remodelling as the channel fed regions.

The analyses of the WF4 system have been restricted at times by the lack of detailed pottery typologies and chronologies for the Classical period. This is not just a constraint restricted to the Wadi Faynan region, but affects the whole region of southern Jordan (as discussed in Chapter 3). Particularly relevant are the lacunae and fuzziness in pottery dating at the end of the Nabataean period until the early Byzantine (i.e. the late Roman period – second to fourth centuries AD), and from the late Byzantine into the Islamic (seventh to ninth centuries AD). The late Roman period is difficult, for at some unknown time in the early second century AD production of the typical Nabataean finewares ended, but the diagnostic imported finewares do not appear in the valley in large numbers until the fifth century AD, leaving only undated local coarsewares. A similar gap appears at the end of the Byzantine and the early Islamic periods, but this may be deceptive, for recent research has indicated that Byzantine-type pottery continued to be produced in some areas well into the Umayyad period (Walmsley and Grey 2001).

In relation to the distribution of the pottery, it is clear that its distribution is a direct result of manuring processes, and perhaps manuring was accentuated in a misguided attempt to counter the effects of the damaging chemical pollution from the smelting processes around the Khirbet (Pyatt *et al.* 1999, 2000). Another factor for intensive manuring could be to counter the effects of soil degradation through the act of floodwater farming, although this is less likely as the duration of water flow would be relatively short (Kirk 1998). As for the factors influencing their dispersal around the entire field system, these are wide and varied. For the Classical period some areas exhibit large numbers of sherds, whereas in others sherd numbers are uniformly low. Only a small percentage of sherds have moved significant distances through taphophomic processes, particularly the action of floodwater. This suggests that only the flat plain areas were intensively manured during the Roman and Byzantine periods. It is not clear whether the Nabataeans did so at all: it seems at the moment that the evidence points to Nabataean period sherds being for the most part residual sherds, dispersed over time, around areas of Nabataean settlement.

Those regions of the field system which are lacking in Classical period sherds are, more often than not, areas which are today particularly rocky in terrain, or are the regions furthest to the west from the Khirbet. It can be presumed that they were not manured for the cultivation of cereal crops as the flat regions may have been. This suggests two likely uses for the land of these regions. Either the terraced wall structures were built to prevent erosion of the slopes onto the flat fertile areas in this unstable landscape, or more likely these areas performed a different agricultural function which did not require manuring, for example the cultivation of olives and fruits. It may be that some of these regions performed both tasks at different points during the Classical period, and at others were unused and abandoned.

The GIS analyses have given indications that the field system experienced different types of farming system and developmental growth over time through the Classical period (see Fig 6.38). From these analyses a simple model of landscape development has been suggested. There appears to be no evidence yet to support the existence of a large field system before the late Nabataean period, though that fields existed in the Edomite Iron Age is certain from both evidence for buried walls in WF4.2 and groups of fields in the satellite systems of at least WF406 and WF424. However, the early Nabataean period remains something of a mystery at present. For the late Nabataean of the first century BC and first century AD, there exist a number of small farmsteads at several locations along the low ridge to the south of the field system and indeed into the units of WF4.12 and 4.13, a couple of which have been excavated (Wright *et al.* 1998).

The evidence of the GIS analyses suggests that these farms operated small systems immediately adjacent to the farmsteads, and in many cases probably discrete and unconnected, except for the area of WF4.1 to 4.3, which may have been operated as a large simple system of terraces by the inhabitants of the Khirbet (see Diagram A Fig. 6.38). However, by the time of the late Roman period the landscape had changed, with large areas on the plain, at least, being cultivated as an integrated set of systems using complicated networks of channels (see Diagram B, Fig. 6.38). Perhaps this system was operated as an integrated system, with control lying with the Khirbet Faynan, the crops being used to feed the mine workers. It suggests that the coming of Roman administration to extract the copper ore also forced changes in the operation of the land, by centralising the system and increasing the scale of the operation.

The Byzantine period needs further investigation, but it is clear from the GIS analyses that particular regions of the plain area were being used and substantially modified in this period. It could be that only certain areas were being heavily utilised, and that some of these were the regions further downstream along the course of the tributary wadis, perhaps an indication that the tributary wadis were beginning to down cut into their courses. Also, it could reflect the fact that individuals were beginning to use opportunistically only certain areas for maximum yields, and that others were abandoned or not used for long periods. However, it does seem certain that the large integrated system of the late Roman period was beginning to breakdown, a result of many changing influences in the geomorphological, social, and administrative systems (see Diagram C, Fig. 6.38).

There are many other issues which could reasonably be explored using the information within the GIS, and integrated with the other sources of evidence collected in the fieldwork. Investigations into the place of the older structures and landscapes within the field system are certainly one approach. Another might be further analysis of channel construction and operation, along with questions of land division and water-rights. In the next chapter the inferences drawn from the analyses of the Wadi Faynan field systems will be compared with the results from other examples in the region.

7.0 Water management systems in Roman Arabia: environmental, economic and social contexts

7.1 Introduction

In the previous chapter (Chapter 6), we have seen how the application of a rigorous GIS has proved the potential of such a methodology in understanding the workings, development and position within the local landscape of a particularly complex field system in Wadi Faynan, southern Jordan. The aim of this chapter is to place such an understanding within the general framework of field systems within the whole of the former province of Arabia and to assess the position of the implementation of such techniques and the reasons for their use, development and final abandonment.

In making general comparisons of the main Wadi Faynan field system WF4, with other primarily Classical period field systems (as outlined in Chapter 4), it will be immediately obvious that this particular field system is to all intents and purposes unique in a number of aspects. In terms of scale, complexity and the water management techniques employed, no other individual system within Roman Arabia, even those present in the central Negev, can offer a direct comparison. However, all field systems, including WF4 have a number of common features, as well as exhibiting wide variations in water management applications, scale, complexity, chronology and purpose. Such issues will be explored and compared in an endeavour to explain the use and development of field systems within the province of Arabia.

7.2 Wadi Faynan in context

The field systems of Wadi Faynan are unique in the region of the Wadi 'Araba for a number of reasons. First, there is the state of preservation at Wadi Faynan compared to other systems, many of which have suffered damage or have even disappeared under modern development, such as the field system of et-Tlah (Section 4.4). Second, there is the scale and complexity of the different systems within the Faynan; there is no other matrix of systems on the eastern side of the Wadi 'Araba which cover such a large area or is either as complex in its construction and chronological development or in the application of diverse methods of water management technologies across many time periods. The only other two systems identified, which come near in terms of size, but are of simpler design, are those of the garrison town of Udruh on the plateau and the settlement and caravan station of Humayma to the south (Kennedy and Riley 1990: 131-33, 146-48; Oleson 1997). The third point to note is the spread of pottery sherds across all the field systems within the Wadi Faynan. Other field systems within the Levant do not generally have such a dense number of sherds, which makes assigning construction dates to the system concerned extremely difficult. Often such exercises in dating field systems have only been achieved by making assumed associations with other sites in the proximity (for example: Evenari *et al.* 1958). Such interpretations of the evidence, whilst understandable and in many cases intuitively correct, could be misleading given the simple and adaptable methods employed in field system construction.

A fortuitous combination of good environmental conditions and the presence of large, workable bodies of high-grade copper ore within Wadi Faynan ensured that throughout the Classical period and perhaps in other periods as well, particularly the Bronze and Iron Ages, there was a relatively large local market for agricultural produce. Consequently, this local market encouraged investment in floodwater farming. In periods when the mining industry was defunct or at a low level, the operation of floodwater farming practices seems to have been at a similar level. Hence in broad general terms, if account is made for the development of more efficient methods of water management techniques over time, it can be seen that the extent to which the field systems were employed is in direct proportion to the level of mining within the immediate area. For example, it has been demonstrated in Chapter 6 that the large field system WF4 of the Roman period exhibits intensive development on a particularly large-scale, of what might be described a 'landscape of imperialism'. Despite these unique factors, which mark the Wadi Faynan systems as being atypical and thus differentiate the landscape history of the Wadi Faynan from the rest of the southern Levant, insights gained from the findings reached in the GIS analysis can be applied to the region as a whole. In the next sections, the Wadi Faynan case study will be set as an implicit example against which evidence for other water management systems and associated settlements will be compared.

7.3 Distribution of water management systems in the Levant

Examples of field systems are not evenly spread throughout the region. This may seem a very obvious statement to make, but it is worthwhile making as it allows us to pose specific questions highlighted by the developments in Wadi Faynan as to why some areas have a dense matrix of such systems and others do not. The influential factors behind the construction and use of such systems are the key issues that need to be resolved by this discourse, from which insights will be gained for changes in settlement types, patterns and density in terms of both spatial and temporal dimensions.

From an analysis of the evidence for the marginal regions reviewed in Chapter 4, it could be stated that the presence of a large, extensive field system can be taken as an indicator of sedentary settlement. In turn permanent settlements to a large extent were only made possible at locations where the physical conditions guaranteed a usable supply of fresh water, both for drinking and in the majority of cases the growing of crops (Chapter 2). However, some areas proved more desirable than others as a particular location for intense settlement, and in many cases these settlement sites were not necessarily directly related to the availability of ample supplies of water. Furthermore, other locations for which the water supplies available were extremely limited still provide evidence of settlement, such settlement usually being present for a specific purpose. Other field systems seem to be a reflection of deliberate political policy to take control of an area, which would otherwise have remained unoccupied semi-desert or desert. These are a few examples of the factors, which have affected the distribution of settlement within the southern Levant. The areas of the southern Levant where Classical period field systems have been observed, and a general indication of their distribution can be seen in Figure 7.1. This diagram is by no means a definitive distribution map of all the different farming systems utilised or of all the farmed regions within the southern Levant during the Classical period. Instead it is merely intended to highlight, from a variety of sources, the main regions for which archaeological and literary evidence can inform us about the main agricultural regimes employed in particular areas.

Turning to the various farming regimes, it seemed convenient to divide the various water management techniques employed across the region into four basic categories. Essentially, there are two types of agriculture employed; (a) *dry farming*, where the amount of precipitation falling directly upon the crops is sufficient to allow full growth, and alternately (b) *irrigation farming*, by which crops can only grow in certain regions with the aid of irrigation techniques. Each of these two basic categories can be further divided into two, distinct types based on the quantities of freely available water. The dry farming zone (a), can be separated into; (a.1) those regions where there is sufficient precipitation which allows for the appearance of perennial streams or easy access to groundwater using wells, and (a.2) those which do not. Hence, within the slightly drier catchment zones, although there may be enough rainfall for the growth of crops, water for the use of animals and people has to be collected usually using a variety of cisterns. Irrigated agricultural zones (b) can also be conveniently divided into two distinct zones (b.1 and b.2), for which the general application of water management systems will have different emphases. Consequently, in the zone (b.1), some specific regions can be irrigated from naturally occurring sources of perennial surface water, be this in the form of a river such as the River Jordan, or springs as occurs at an oasis such as Azraq. The other form of crop irrigation (b.2), relies on techniques to utilise short periods of floods. In addition, it should be noted that some areas within the zone (a.1) – parts of the Mediterranean littoral -are irrigated by the water from perennial rivers (Admiralty 1943b).

A basic comparison with the annual precipitation chart (Fig. 2.10) reveals that the types of agricultural regime pursued during the Classical period, for the most part, closely follow present day precipitation levels. This is significant for two reasons. The first is quite obvious, in that a particular agricultural regime can generally only be operated at a certain place which attains the appropriate level of precipitation. This fact is emphasised by a map of recent modern land use before the application of modern technologies, such as deep well drilling and the expansion of irrigation techniques (Admiralty 1943b: 486-87; Figs 4.1 and 4.2). Hence, both dry farming regions (listed on Figure 7.1 as agricultural regimes with or without the use of cisterns – a.1 and a.2) lie wholly within the 200 millimetre isohyet, whereas crops that needed assistance (i.e. the irrigated agricultural types b.1 and b.2) were grown beyond the present day 200 millimetre isohyet zone. This leads onto the second significant point to note, in effectively mirroring the levels of present day precipitation, it would seem that the levels of precipitation were not significantly higher during the Classical period in comparison to today.

In the region with the densest settlement along the Mediterranean littoral, where agriculture could be pursued generally without the use of cisterns, there was on the whole enough rainfall with which to grow crops and perennial streams or shallow wells for irrigation and drinking purposes (Safrai 1994: 358-70). However, larger settlements, such as Caesarea, required the building of substantial aqueducts to transport enough water from higher ground to supplement local resources (Vann 1992). Beyond this are large areas of dense settlement, which generally received enough annual precipitation for the growth of crops, particularly of a 'Mediterranean agriculture' – olives, fruits and vine or in the drier areas – cereals. More thirsty produce was also grown in these drier areas when local circumstances permitted (see Hirschfield 1997a, 1997b). However, the perennial sources of drinking water were on the whole less frequent, consequently many settlements in these areas utilised a variety of techniques to collect sufficient quantities of water to supply their needs through the long dry season. Hence in the areas of the Golan, Nuqra plain and Jebel al-Arab those settlements not supplied by spring water, which in some instances required the use of elaborate networks of aqueducts, collected their water in open reservoirs or *birkets* (e.g. Braemer 1991). Further south open and covered cisterns of many varieties were employed (e.g. Ibach 1987; Villeneuve 1992).

Along the edges of these dry farming areas are settlements lying within notional semi-desert climatic regions, which rely on two forms of water management. The first of these were the irrigated areas that obtained regular supplies of water in large amounts from two sources. Water was supplied within the irrigated regions of the Jordan Valley and Damascus basin, (as it still is) by the perennial rivers of the Jordan and Barada respectively (Dodinet *et al.* 1990; Khouri 1988).

As for the atypical regions of the southern Ghor and Azraq, localised aquifers supplied a large volume of sweet water through numerous perennial springs (Kennedy 1982; B. MacDonald 1992; Nelson 1973). Secondly, were the areas with such low rainfall that water management structures are required for both the growing of crops and the collection of drinking water. The largest and most dense regions in terms of settlement were within the regions of the Negev and the southern Hauran (see Chapter 4). In addition there were further smaller concentrations of settlement particularly along the eastern edge of the route of the *via nova Traiana* between Udruh and Humayma (Graf 1992a, 1997). Other areas were more localised, focussed on particular points, where settlements were established for a particular purpose. Notable examples are the line of caravanserai/forts along the Wadi 'Araba, and the watching posts/forts at Nemara and Qasr Burqu' (Chapter 4).

For the most part, the high density areas of the Negev and the southern Hauran were immediately adjacent to densely settled areas that lie inside the 200 millimetre isohyet. These densely settled areas, in particular those of the Nuqra plain, the Jebel al-Arab, central Moab, the Jibal and the Judean mountains relied on obtaining adequate supplies of drinking water through springs, or the collection of rainwater in *birkets* (reservoirs). In addition, as such areas today obtain a sufficient annual average rainfall, and most probably did so in the past as suggested in Chapter 3, agricultural needs were probably then as now based wholly on dry farming methods. The settled areas beyond these had to rely on the utilisation of various methods of floodwater farming if an agricultural regime was to be followed. The most intensely settled region with corresponding well-developed and complex field systems is that of the Negev (Evenari *et al.* 1982). The next region with seemingly lower densities of settlement and simpler field systems, for the most part based on cross-wadi systems, is that of the southern Hauran (Kennedy 1995b, 1998a).

At the perimeter of these two zones there are indications, particularly in the Negev highlands, of a further less densely settled agricultural zone, whose inhabitants utilised simple floodwater farming systems to irrigate small scattered fields whenever the opportunity presented itself. Recent studies of this area have suggested that these fields, and the small single room dwellings that accompany them are evidence for occupants who shifted between semi-mobile pastoralism and sedentary agro-pastoralism (Avni 1996; Finkelstein 1995; Haiman 1995). These peoples proved highly flexible in their approach to sedentarism, which to a large extent probably reflected a strong symbiotic relationship to the lower lying regions of the Negev. Consequently, during periods when the central regions of the Negev supported dense, permanent settlement, for example in the Byzantine period, there is an increase in similar evidence for simple sedentary structures in the more marginal highland region (Finkelstein 1995: 63-64). Furthermore, this semi-nomadic highland zone can be further divided into two for the Byzantine-Early Islamic period.

In a recent paper, Haiman highlighted a zone of Umayyad settlement beyond the Byzantine zone of the highlands, and has suggested that the sedentarization of this region was the result of two processes. The first of these, the opportunistic action of the semi-nomads to benefit from the prosperity of the adjacent sedentary regions of the interior is well-documented. The second suggestion was that this process of sedentarization was the result of imperial policy to encourage agricultural development on the frontier (Haiman 1995: 45-46). This idea poses interesting questions about the distribution of settlement and water management systems in the marginal regions of the southern Levant. Before such questions can be answered it is necessary to review what we can say about the chronological development of water management systems, in the context of the dating evidence collected from Wadi Faynan.

7.4 Chronologies of water management systems in the Levant

7.4.1 Introduction

In reconstructing the chronology and development of water management systems in the southern Levant, particularly the use of field system technologies utilised within the semi-arid regions, a number of key points which necessarily influence any attempt at a constructing a chronological framework must be taken into account. These factors, (which have been alluded to in previous chapters, especially Chapters 3 and 4), for example, the variability in the recording methodologies, the area coverage and research goals of different surveys, in combination with the incomplete local pottery typologies, the dearth of excavation and a deficiency in the specific investigation of water management systems conspire to make such a task highly problematic. However, a rough guide to the processes involved can be suggested using for the most part knowledge indicators gleaned from recent archaeological work and literary finds of the factors affecting the ebb and flow of settlement within the region, and where appropriate specific evidence relating to water management systems. The illustrated results (Figs 7.2 to 7.5), are merely intended to highlight the possibility of a complex pattern of development for the region and to stimulate further questions of the issues which might affect settlement. This section will be divided into the four broad time periods for which there is sufficient evidence to make some generalisations on temporal change. For the purposes of this study, it has been found that the archaeological evidence for the Hellenistic period is too sparse at present to warrant inclusion and so this will be omitted (Berlin 1997; Smith 1990).

7.4.2 Nabataean/early Roman

As has been stated (Section 2.6.4), it was in the latter part of this period that the whole of the southern Levant finally came under direct Roman administration. However, the most significant occurrence from an archaeological viewpoint is the widespread evidence for the appearance of sedentary settlement throughout the region. In many cases this was only made possible by the application of water technology, often heralded with reference to the writings of Diodorus and Strabo, as a exceptionally proficient Nabataean skill (e.g. Parker 1997: 237; Oleson 1995).

A scrutiny of the available archaeological evidence initially confirms this conviction, but there are apparent shortcomings that restrict the development of this hypothesis. Partly this is due to the fact that most settlements, and their accompanying water storage and management systems, were subject to years of continual use. Subsequently, these installations were subject to periods of potential alteration and change. In some cases this gradation of change may well have amounted to several centuries. Therefore, it is often the case that a certain installation particularly in the case of cisterns and other such water storage features can only be roughly dated on stylistic or constructional grounds, as we have seen with watermills (see Section 5.2.2). Field systems can be even more problematic, in that, as we have seen in the example of Wadi Faynan, it may well be that in addition to the problems of directly dating the construction of a particular wall or structure, evidence for earlier field structures have been cleared or lie buried beneath later developments and hence usually only the latest phase or structure of a field system can be dated on structural grounds (Section 6.6 and 6.7).

Consequently, very few field systems can or have been directly judged to be Nabataean in design and construction. Water management structures considered to be the products of Nabataean agency are limited to storage structures; be they dams, cisterns, reservoirs and structures relating to these, such as simple aqueducts or terracing. Figure 7.2, attempts to show the main regions of the former kingdom of Nabataea, and adjoining regions which were attached to the province of Arabia, for which evidence, however circumstantial, reveals constructions of Nabataean or Early Roman date (Wenning 1987 catalogues much of the site evidence). Much of this evidence relates directly to water storage complexes, a good example of this is the work undertaken by al-Muheisen and

Lindner amongst others in the Nabataean heartland around the capital Petra (Lindner 1987: al-Muheisen, 1986, 1990). In the immediate environs of the capital, numerous complex networks of rock-cut channels and cisterns have been noted. Beyond these areas, a few, exceptional areas where Nabataean and early Roman period evidence is relatively high in comparison to evidence from the other periods under discussion have been marked out on Figure 7.2. The majority of these small sites and areas are placed in the southern half of the region. This reflects to a certain extent the economic interests of the Nabataeans towards the operation and control of the caravan trade routes from the Arabian interior (Fiema 1991: 91-96; Hoyland 2001: 107-08). However, for field systems categorical dating evidence seems on the whole to be lacking, particularly as concerns postulated systems of the Nabataean period.

This lack of direct dating evidence has not stopped some theories being offered on the development of the Nabataean kingdom, based on the literary evidence and the sudden widespread appearance of settlements with attendant Nabataean fineware pottery. It has thus been argued that during the first century BC a large-scale process of sedentarization occurred by which the formally wholly nomadic Nabataean population transformed themselves into a settled agrarian nation (amongst others proposing this view; Bowersock 1983; Negev 1986). It is important to remember that this sedentarization was only new beyond the regions of dry farming for some scholars have suggested that in certain areas, such as the Edom and Moab plateau, sedentary occupation had continued unabated in some form since the collapse of the Iron Age kingdoms (Bartlett 1979, 1989). By default it seems to most commentators that irrigated agricultural practices would have been necessary in the newly settled regions, though at present, no directly attributable evidence has been found to ascertain a specifically Nabataean date to a particular system or even to the specific nature of the irrigation methods employed by the Nabataeans.

7.4.3 Late Roman

Aside from the cities of the Decapolis, and the system of forts and associated structures (The *Limes Arabia* as denoted by Parker 1986) along the length of the *via Nova,* relatively little direct intensive investigation of the Late Roman province of Arabia has been undertaken. This again proves particularly problematic when trying to investigate the development and distribution of period specific water management systems within the southern Levant (see Fig. 7.3).

Certainly, the Decapolis cities enjoyed a long period of investment and the building of many substantial architectural monuments, which today form the most impressive ruins within these cities. It seems logical to think that the majority of water management features linked to these cities would also date their design and construction to this period as well. Notable in this respect are the impressive water collection and distribution networks beneath the city of Gadara; the large reservoirs and pipe networks that served the festival complex outside Gerasa; furthermore, the aqueducts and nymphaea of several cities for which we have evidence, for example Abila, 'Amman and Canatha (Freeman 2001; Kerner 1994; Weber 1991). In addition, the new provincial capital at Bosra was being greatly expanded, particularly with the establishment of the legionary fort for the III Cyrenaica legion. Hence, it seems probable that much of the water management infrastructure in terms of the large reservoirs and aqueducts would also date to this period.

Around Bosra important changes seem to have been taking place with the systematic development of both the Nuqra plain and the Jebel al-Arab. As discussed in Chapters Three and Four, evidence has been gathered in the last twenty years for the cadastration of large areas, and the increasing numbers of settlements and large stone-built houses both of which date to the Late Roman period (Dentzer 1986; Kennedy 1985; Villeneuve 1986b). On the periphery of these regions, further development was taking place, albeit on a smaller scale, if the claims of Kennedy (1995a) can be substantiated for the management of water resources within the southern Hauran. Further south, evidence of the continued use of water management structures and settlement established in the Nabataean period has been observed. However, in a recent comparison of the results of four large-scale surveys along the top of the plateau, in the region of Moab and Edom, the Late Roman period was differentiated from the preceding Nabataean and later Byzantine periods by a lower percentage of sites with sherds than either of the other two periods, (Parker 1992; Fig. 7.6). In other words, the total number of sites in each survey area with Late Roman period sherds was substantially lower than the total number of sites of either the Nabataean or Byzantine periods. In addition, there seems to be some apparent discrepancies in spatial distribution patterns. For three of the surveys, those of the Central Moab Survey (CMS) (Miller 1991), the Limes Arabicus Project (LAP) (Parker 1986, 1987a), and the Wadi el-Hasa Survey (WHS) (B. MacDonald 1988), the trajectory of occupied sites follows the same basic pattern. In these, a high percentage of the total number of sites exhibit sherds of the Nabataean/Early Roman period, followed by a sharp decline in the Late Roman period. There is a substantial rallying in the Byzantine period, before an almost total collapse in the Umayyad period.

In contrast, the pattern of sherds from the survey of sites around Tell Hesban (TH) (Ibach 1987; LaBianca 1990) reveals a different sequence of events. Firstly, the number of sites with Nabataean/Early Roman sherds is significantly lower than for the other three survey areas, which could be highly significant if we consider the peripheral position of the Hesban region in relation to the 'heartland' of the Nabataean kingdom, to which the other more southerly areas are part. Secondly, although there occurs a slight decline in the Late Roman period, the total percentage of sites with sherds of this period is comparable with the other regions. It could be said that this reflects a general decline in activity in all areas during this period, for which a number of theories have been postulated. Parker for one, believes it is an indication of more frequent nomadic attacks which resulted in a retreat to more urbanised areas in the west of the province, and a decline in settlement activity in areas peripheral to these (1992). The arguments explaining the evidence for this will be investigated in more detail in the next section.

The Byzantine period witnesses a huge increase in the total number of sites particularly for the Tell Hesban survey, a far larger increase in occupation seems apparent in this region compared to the other areas. Again this disparity between the regions is significant, and a comparison between the areas revealing occupation of the Late Roman period and of the Byzantine period highlights the shifting patterns of settlement within the province over time.

7.4.4 Byzantine

Byzantine period remains are perhaps the most numerous and the most visible across the former provinces of Roman Arabia and Palestina Tertia. The extensive and sophisticated water management systems of the central Negev have been commented on in previous sections, many of which must be connected with the widespread and well-documented Byzantine period settlements of the region. In the reorganised and smaller province of Arabia, widespread evidence has been found throughout the region and formed the subject of recent summaries (MacAdam 1994; Watson 2001). The southern Hauran, although not yet thoroughly investigated, displays networks of stone field walls, associated with a dense patchwork of small villages, for example Umm al-Quttayn, whose very existence depended on the capture and control of the winter and spring floods (Kennedy 1982: 331-5). The detailed study of the large regional centre at Umm al-Jimal over the past two decades has confirmed that for the entire region of the southern Hauran, settlement and hence 'prosperity' seems have reached a peak in the fifth and sixth centuries AD (de Vries 1998b).

A view of the map (Fig. 7.4) reveals that although there is a general upsurge in settlement and the widespread utilisation of the necessary water management techniques to accomplish such a phenomenon in this period, some regions exhibit a higher growth and denser settlement than others (e.g. LaBianca 1990; Miller 1991). We have already noted the differences between the region around Tell Hesban, and the more southerly areas of Moab. It seems that apart from a few exceptions, the areas in the north of what is now Jordan, experienced an enhanced period of sustained prosperity in the Byzantine period. In contrast, those regions south of the line of the Wadi Mujib, although the majority had some sort of settlement revival, compared to the earlier Late Roman period, this was less marked than for other regions such as the Negev, the southern Hauran, Ammonitis and Tell Hesban/Madaba.

This is particularly true for the environs of Petra, which although continuing to have structural investment does show signs from the ceramic sequences of gradual decline compared to the earlier Nabataean/Roman period (Parr 1986). Fifteen kilometres to the east, at the edge of the steppe lands new settlements were springing up centred on the large Roman fort and *vicus* of Udruh (Fiema 1991; Killick 1986). As we have seen (Sections 3.2.6 and 4.5) such villages depended on the employment of floodwater farming methods and qanat technologies to irrigate the surrounding fields. The utilisation of qanat technology is unusual, as from the evidence available such technology was little used in the Levant. What evidence is available, suggests that the few examples investigated date to the early Islamic period (Kennedy and Riley 1990). South of Petra, the formerly widespread Nabataean settlements reported by Hart for the most part, seem to have been abandoned (1986b). Although the Petra papyri, and the limited information about them so far published, infer that the region immediately surrounding Petra continued to be cultivated well into the Byzantine period and even beyond (see Section 4.4; Koenen 1996). Hence, although on first indications it appears that there is a linear expansion into marginal areas across the whole southern

Levant, this is simply not the case. As with earlier periods there is an uneven development and in parts even a decline over quite small areas with the province.

7.4.5 Early Islamic

The transformation of the Byzantine administered lands over to the Islamic presents a whole new set of questions, which have only recently invited more detailed investigation. As discussed previously the central obstruction to solving such issues has been the dating of the ceramics. Recent excavations are beginning to clarify the pottery chronologies in both the north of Jordan and the south (Walmsley 1997; Walmsley and Grey 2001; Whitcomb 1995). As a result, previous suppositions concerning the almost total and abrupt abandonment of settlements in marginal areas are being seen to have been wrong, and are more a perceived cultural bias on behalf of western (colonial) and Israeli investigations. As Whitcomb has stated, 'the dramatic peak of population and prosperity attributed to the Byzantine period is an archaeological fabrication – the result of ignorance and inattention' (1995: 493). Although fewer new buildings were constructed during the first two centuries of Muslim rule, the pottery sequences have for the most part indicated a certain level of continued occupation at most settlements of the Byzantine era.

However, it is still difficult to gauge the level of change within a particular settlement. It may be that over time there was a decline in the majority of settlements, but this decline was certainly not immediate. In terms of prosperity or the density of population, the absence of material evidence from early Islamic contexts could in fact be a reflection of cultural change. Therefore, it is this process of cultural change which is reflected in different quantities of material culture unearthed. For example, there may have been a gradual shift in pottery use and needs among the population as they slowly became assimilated into the now dominant Islamic/Arabian culture which had less use for pottery than the previous Byzantine culture. Figure 7.5, displays current knowledge on the use of water management techniques and settlement within the early Islamic period.

The outstanding feature to be contemplated, in terms of water management, is the establishment of several large-scale agricultural estates within, for the majority of cases, supposedly 'virgin' desert territory. These include estates centred on the so-called 'desert castles' to the east of the *via nova* of which there are similar examples in the Judean and Syrian deserts, and evidence collected from around important oases such as Azraq, Zoara and Ma'an (MacAdam 1994: 67-8). Such establishments are without exception both ambitious and complex in their scope and comprise a suite of dams, elaborate reservoirs, well-built water distribution channels, watermills and field systems in a well designed whole. Although, there is scant direct evidence to date some of these establishments, comparisons can be made between the various examples, which when collated together suggest an Umayyad date (Bisheh 1982, 1986; MacAdam 1986; 540).

It seems that on the part of the Umayyad rulers and authorities there was a concerted policy to establish agricultural estates in these formerly little invested areas, and this fact reveals something of the large cultural changes which were at this time taking place within the Levant. Direct government resources were for the first time consciously redirected away from the settled areas towards the interior by the new elites. They were at once using revenues gained from taxes to develop regions from which they came, and sending a powerful signal that the focus had turned away from the Mediterranean, towards the Arabian interior.

In addition, there are circumstantial indications that the remains of the few qanat systems which are known to exist within the southern Levant are primarily early Islamic in foundation, as also are major developments in watermill technologies (McQuitty 1995). Hence the Early Islamic period can be viewed as a significant period in the application and technological advance of water management systems, although such innovations were pinpointed to specific local points and were generally not widely distributed wholesale across the entire southern Levant.

7.5 Settlement and water management systems: establishment and change

7.5.1 Introduction

In assessing the spatial distribution of settlement and aspects of temporal change in this distribution a number of very diverse factors, both human-induced and environment-constraining, has to be taken into account. The following section divides these factors into convenient forms, although it has to be stated that for any one settlement a number of these factors will have an influence to a lesser or greater degree.

7.5.2 Environmental restraints

In terms of the establishment of field system networks within the southern Levant two geographical restraints can be seen to be at work. On the macro level, with the exception of small, site specific systems, at key points within the landscape, the geographical relationship of a particular floodwater field system or networks of systems in relation to areas of dense settlement was for a variety of reasons a major determinant. Such reasons will be scrutinised in greater detail in the next section below. However, at the local 'micro' level the establishment of field systems to maintain a particular population was based on the occurrence of two fundamental conditions: those of the local topography and geology.

A source of water in sufficient volume is the key to any successful irrigated farming operation. Depending on the local geology, and the sporadic occurrence of aquifers, perennial sources of spring water could be made available. On rare occasions there has proved to have been a plentiful water supply produced by perennial spring sources to irrigate a large proportion of the total agricultural land without resorting to the use of floodwaters, as is the case with the region around Zoara and at Udruh where substantial areas continue to be irrigated by spring waters today. However, perennial springs when present, could on the whole usually only provide enough water for drinking purposes, and so the production of crops necessarily relied on the control and usage of floodwaters. Hence, the local topographical aspect would be an essential consideration to the establishment of any field system. All locations where field systems are present reflect the coming together of; an adequate supply of potential floodwater sources; a point where such water supplies can be captured in sufficient quantities for successful agriculture; and a sufficient acreage of potential croplands to provision the local population and indeed even provide surpluses for trade.

In most years, the present climatic regime of the southern Levant continues to deliver a large enough volume of floodwater to produce reasonable harvests within the ancient field systems. Hence, when concerned with the impact on floodwater farming regimes, this essentially negates all questions as to whether there has been a fundamental change in the climate in the last two millennia, or even at times during the course of the Classical period. In other words, sufficient floodwaters are often provided at the majority of locations even in the 'dry' climate of today, without the recourse to environmental determinant arguments to prove that there was an explosion in floodwater farming practices due to there being a slightly wetter phase in the Byzantine period. A glance at the wadi flow data of Jordan collected in the 1930s would suggest that in an average year there would be ample volumes of water which could be redirected onto structured fields (Ionides 1940). Indeed, Evenari and his colleagues proved modern day floods are sufficient enough to produce adequate quantities of produce with the successful reconstruction of a floodwater farm in the Negev which used the same basic methodologies as were utilised during the Classical period (1982).

7.5.3 Purpose: socio-political factors

If the physical environmental criteria in terms of topography and geology were fulfilled, field systems could be established at judicious points to supplement or support sedentary settlements. Such settlements were founded in a multitude of different ways and at different times, but there appears to be three major influencing strategies involved in the establishment of a settlement within the semi-arid and arid zones. The first of these concerns the founding of small permanent settlements by direct authorisation of the government authorities and the few services that they operated and controlled. For the Roman period, the only institution qualified to undertake the execution of government policy and control was the army. These types of settlement we might term 'purposeful establishments'. Secondly, there are the large areas of scattered settlements by people engaging in agriculture, whose widespread use of floodwater farming techniques and decision to settle on a large scale may have occurred with the application of two different mechanisms. The first of these mechanisms may have come about as the direct result of government policies of encouragement to 'colonise' and hence make secure previously marginal, but strategically important areas of land at the periphery of zones of control. The second, may have been caused by factors which indirectly and separately did not cause the sedentary settlement of large swathes of marginal land, but which collectively created the right conditions to influence people to consider settling in places which previously were not permanently settled.

7.5.4 Specific purposes

Sites which have structures for permanent settlement and which might be considered 'purposeful establishments' include such categories as forts, caravanserai and mining settlements. The majority of such establishments are located at points that can provide regular supplies of drinking water; either from perennial sources or by the implementation of water storage methods, particularly the construction of large underground cisterns, reservoirs or both, which on the whole collect channelled surface runoff from neighbouring wadis. Examples of such establishments can be located across the semi-arid and even in more extreme arid regions at the site of oases, across the southern Levant.

Occasionally when conditions allowed, evidence for small floodwater served fields can be distinguished. These systems exhibit varieties of sophistication, from the simple diversion channels discernible at Nemara in the Syrian Black Desert, to the regularly shaped square fields of et-Tlah fort in the Wadi 'Araba (Braemer *et al.* 1996a; Kennedy and Riley 1990). Such variety of methods and construction must reflect to a certain extent the period when the fort was occupied and the local environmental conditions. What of course they do not reveal is the extent to which such systems were the direct policy of the Roman army to supply the immediate garrisons with food. It may be that some of these field systems reflect initiatives by the local commander or soldiers to grow their own food, as various papyri from Egypt indicate (Alston 1995). The large regular fields at et-Tlah indicate a well ordered large-scale system that was constructed by a large workforce. It could be that the regular fields of this location represent the nearest example we might have from the 'centuriated' evidence of the fields, of direct Roman or Byzantine authority input into the construction of a field system.

The large field system at Wadi Faynan could also represent another example of direct Roman intervention in the re-organisation and landscaping of a specific area of marginal land to suit imperial needs; in this particular case, the supply of a large workforce working in the surrounding copper mines. This would help explain both the scale of the land placed under cultivation at various times during the Roman–Byzantine periods, and the distinct change apparent from the archaeological survey work in land use patterns. By this I am referring to the apparent change from a landscape of discrete farming units centred on small individual farmsteads during the late Nabataean period, to one of centralised control, operated from the main settlement of the Khirbet, which also entailed the operation of perhaps several distinct but contiguous and co-ordinated systems over a large proportion of the field system as a whole.

7.5.5 'Social' influences on sedentarization

As mentioned above large-scale sedentarization over considerable areas may have been initiated by two distinct set of processes either directly or indirectly related to the implementation of government policies, which might be termed direct 'colonization' and indirect sedentarization.

i) Direct 'colonization'

The direct implementation of government policies to explain the colonizing and settlement of certain marginal areas has at times been suggested by archaeologists. Hence, a number of such arguments have been made for the development of certain marginal regions in the southern Levant because of government sedentarization policies in the Nabataean, Roman and Umayyad periods (e.g. Hauran – Dentzer 1986; Negev – Rubin 1997; Negev highlands – Haiman 1995; al-Shera – Hart 1986a). The formulation of these theories have helped to explain the evidence existing for dense settlement in locations which cannot be easily justified in any other way. This is not to suggest that such theories are wrong, but in most cases the evidence for such a policy is often very circumstantial.

The semi-arid region to the south of Petra, the al-Shera was subjected to enforced sedentarization during the latter years of the Nabataean kingdom, in an attempt to secure the kingdoms' southern border region, according to the theories of Hart (1986a, 1986b). In a similar attempt to control and act as a protection buffer to the populated regions of Palestine and Judea, some theorists have argued that veterans of *limitanei* settled the central Negev region with the encouragement of the Roman authorities. Rubin (1997) in his discussion of the key indicators of Romanization of the Negev noted there was a substantial importation and use of architectural elements, religious syncretism and epigraphic evidence suggesting cultural change; even the methods used for terracing the slopes and the crops cultivated indicated similarities with terracing methods and agro-systems commonly used throughout the whole of the Mediterranean basin. Considering such evidence as a whole he concludes that it 'can be assumed with some confidence that there was a limited amount of immigration into the Negev' (Rubin 1997: 279). When working in conjunction with the key components of Roman involvement and control, such as the administration, army and later, the church authorities helps explain the settlement of such a marginal region as a direct consequence of the expansion of the empire into a particular frontier zone.

This does not demonstrate that such sedentarization was a result of concerted government agency, and it remains a fact that the existence of such a scheme cannot really be proved or disproved, as direct evidence for such are generally lacking. However, it could be stated that if governments undertook such policies, why were they not echoed in other areas? It is clear that for more fertile areas, particularly the Nuqra plain, recent survey work has provided substantial evidence for centuriation of the agricultural land, which may reflect government involvement at a high level in the organisation and control of the rural landscape. Indeed, within this region is situated the legionary and provisional capital of Bosra, so such control is in some regards to be expected. The case for marginal semi-arid lands being subject to organised and deliberate policies of colonization is much more circumspect for the Classical period at least. In contrast, the innovations of the Umayyads, although at a small, limited scale, do seem to represent involvement by members of the elite at a personal level to initiate some form of permanent settlement at specific locations in the more arid regions. For example, the reinterpretation of documentary sources and the archaeological evidence for the 'desert castles', such as Qasr al-Hallabat and Qasr el-Heir el-Gharbi, and settlements, such as al-Hammam, Yotvata and Humayma are increasingly proving this point (Sections 4.4 and 4.5; Avni and Magness 1998; Kennedy 1991; King 1992; Oleson 1997; Schlumberger 1986).

ii) Indirect sedentarization

Permanent settlement of semi-arid areas on the borders of more precipitation-rich and densely populated regions seem on the whole to have been engendered by two processes either working separately or more probably in a variety of combinations. Both such processes may have worked piecemeal over a long period of time, gradually transforming otherwise former pastoral wadi valleys into settled or partially settled societies occupied in arable farming. The first such process involves the voluntary sedentarization of previously nomadic peoples living on the fringes of more fertile areas. The second process may have resulted in small groups of enterprising farmers who for a multitude of individual reasons, perhaps related to personal experiences or the need to own some land, which indirectly in turn may have been related to increasing population pressures in some areas, left the settled regions and attempted to exploit the marginal areas immediately beyond.

Diyatheh on the eastern slopes of the Jebel al-Arab, at the cusp of the settled highlands and the nomadic peopled Harra, shows many signs of being one such settlement (Newson 2000; Sadler 1993; Villeneuve 1986b). Unlike the majority of other settlements across the Hauran, this large village relied wholly on the use of floodwater farming techniques to maintain the crops in its fields. In addition, the dwellings of this settlement, although constructed from basalt stone as elsewhere in the vicinity, exhibit a roughness of construction that is atypical. Further south, the large settlement of Umm el-Jimal, and the surrounding villages which together form the nucleus of settlement in the southern Hauran, for the most part also relied on the employment of floodwater irrigation in order to survive. Again, such villages seem distinct to the norm, particularly in the design of dwellings and the street geography, compared to the majority of the settlements in the neighbouring Nuqra plain and on the Jebel al-Arab. Furthermore, an analysis of the inscriptions from Umm el-Jimal, particularly when concerning personal names, implies that the inhabitants were generally less Hellenised/Romanised than elsewhere, and instead continued to maintain strong links with the peoples of the desert interior (Grainger 1995). The discovery of several Safaitic inscriptions within the settlement at Umm el-Jimal, serves to emphasize the close interrelationships between the populations of these recently settled locations and the local nomadic population (de Vries 1998a, 1998b).

Recent debates have sought to re-focus attention on the relationship of the peoples of the desert and the sown and the interactions between them (Avni 1996; Banning 1986; Haiman 1995; Rosen 1987). Evidence from the Negev, seems to suggest that both the sedentary agriculturists and the pastoralists were locked into a mutual symbiotic relationship which altered over time depending on the inputs of economic stability and security, engendered by neighbouring power bases (Finkelstein 1995; Finkelstein and Perevolotsky 1995; Rosen and Finkelstein 1992).

In such a model, the Roman empire having pacified a province, in this case Palestine, created an atmosphere of security through strong methods of control. In turn this *pax Romana* allowed for the development of a booming stable market economy, for which goods were in demand. Consequently, a change in the relationship occurred between the settled regions and the pastoralists that supplied the sedentary population with livestock products. Simply put, the pastoralists in order to increase their surplus supplies of livestock increasingly diversified into farming crops in the wadi valleys using floodwater irrigation, whilst continuing to maintain goat herds on the upper slopes. The implementation of floodwater farming techniques over large areas required a degree of constant maintenance for such systems to remain in operation. Hence, over a period of time, such pastoralists living on the fringe of the settled areas themselves adopted a more sedentary lifestyle (Finkelstein 1995).

Archaeological evidence for such a process has been suggested for the Negev highland region, which lies adjacent to the southeast of the central Negev (Avni 1992; Haiman 1995; Rosen 1987). Scattered across the highlands are a large number of dispersed small roughly coursed dwellings with associated simple series of cross-wadi walls, which from the ceramic evidence collected at these small 'farmsteads' indicates a date for the late Byzantine–early Islamic period. A convincing argument has been made that these unsophisticated structures could well be evidence of nomadic peoples caught in the process of adopting a sedentary lifestyle (Avni 1992). For beyond this area, there is evidence for isolated dwellings, but these are without the accompanying cross-wadi walls. Suggesting to Avni that the process of sedentarization was a gradual ongoing process that had been interrupted when the settlement and economy of the central Negev slowly declined during the early Islamic period.

7.6 Disintegration–demise: causes

From the above sections it can be seen that the development of farming systems within the arid and semi-arid southern Levant were subject to a whole range of complex factors working in a variety of combinations at different times and at different locations to produce an ever changing pattern of settlement and landuse across the region. In general terms, it can be said that a similar picture emerges when we consider the processes of decline and abandonment of such farming systems within these semi-arid regions. The final phase of abandonment for the most densely settled areas of the Negev and the southern Hauran occurred during the early Islamic period.

As referred to in Chapter 1, for many years the two dominant theories proposed to explain the apparent desertification of these two areas and the region as a whole, can be summarised as significant oscillations in the climatic regime and a destructive transition to Islamic control. A few recent studies of the settlement and agricultural systems of the Negev have led to a radical revision of the factors which conspired to cause the decline and eventual abandonment of this densely settled region (Rosen 2000; Whitcomb 1995). Similar processes which seem to have acted upon the settlements and agricultural regime of the Negev could also be reasonably applied to other regions to the east of the River Jordan. Archaeologically, no site within the entire southern Levant has yielded evidence for a violent and destructive end with the coming of Islam in the years AD 630-640. Instead, much evidence for a gradual decline in the larger settlements has been collected over recent years, this is in contrast to some principally pastoral regions on the periphery of the more settled agricultural zones, which as mentioned above seem to experience an increase in sedentary settlement (Section 7.2 and 7.6.2).

As has been shown by the GIS study of Wadi Faynan the continued use of a complex, large floodwater farming system is to a great extent a reflection of the local market needs. As the mining industry declined during the late Byzantine period, if not already showing signs of decay in the early Byzantine period, so the requirement for an extensive field system network also shrank (Section 6.6). The termination of large-scale copper production within the Wadi Faynan region drastically reduced the settlement population of the Khirbet Faynan and consequently spelt the end for the operation of field systems. It could be argued that it was only possible to undertake the large-scale production of copper within Wadi Faynan due to the development of a successful floodwater farming regime. However, this is simply not the case, for studies of the quarries of the Eastern desert in Egypt have shown that where necessary Roman authorities could establish large complex systems of logistical support over relatively long distances and in a harsh environment to sustain the workforce (Peacock and Maxfield 1997).

To organize a similar system for Wadi Faynan would have been much simpler, as the valley is situated only nine kilometres from the large, dry farming region of the Edom plateau. Due to the inherent adaptability of the Wadi Faynan field systems, environmental changes, such as the effect of earthquakes or the downcutting of wadis, can be rejected as causes for their eventual demise. Hence, a major factor for change must be the condition of the local economy. In this way useful analogies can be made with other large systems using as an index the history of the Wadi Faynan field systems. By this comparison it can be argued that the use of field systems in the southern Hauran and the Negev, and consequently their associated settlement would reflect changes in the local economy first and foremost. Therefore, a terminal downturn in economic fortunes would be reflected in the abandonment of floodwater farming systems and settlement. It is this scenario that is perhaps the best explanation for the eventual disintegration of the settlement in the majority of marginal regions at some point during the early Islamic period.

7.7 Conclusion

As has been demonstrated in this chapter the immediate causes for the application of water management systems, and their relationship to the development and eventual decline of settlement in marginal regions of the southern Levant are both complex and varied. These causes include;

local physical conditions, the specific need for a settlement and consequently water management systems, or opportunistic development. The various water management solutions adopted reveal differences in local environments, elements of cultural diversity between different groups and progressive development over time. As has been shown, the extent to which these regions were settled and water management systems were utilised reflects to a certain degree a number of wider socio-political and economic conditions that imposed constraints or fostered development of particular locations and areas at particular points in time. Hence, the next chapter will address the wider implications raised by this study of water management systems, particularly the processes of imperialism and Romanization as identified in Chapter 1.

8.0 Conclusion

8.1 Introduction

By investigating the evidence for water management techniques across the southern Levant during the Classical period, this thesis has attempted to reveal how such structures were utilised and the extent to which they might provide useful insights into the social and cultural development of the region during this period. It is the aim of this final chapter to synthesise what has been achieved by such a study. We have seen that in many respects the southern Levant in terms of its position and history within the Classical world remains largely unknown. It has only been in the last few decades that a series of intense archaeological investigations, particularly in what is now Jordan, has begun to rectify this situation. However, it remains a fact that much of this research has been focussed on the development of the urban rather than the rural landscape.

Central to any debate on the influence of Roman imperialism and control, at any point within the bounds of the empire, is the extent to which such influences can be seen to be reflected in the material cultural remains. With the limited knowledge we have at present concerning the former province of Arabia, an applicable key to understanding this process of acculturation and control (Romanization), and the extent to which the province became integrated within the Roman empire was offered by the detailed analysis of the position and use of differing forms of water management. In addition, such an investigation has had the further advantage of presenting for comparison evidence from across the whole of the province by the full range of cultural groups: for example, by both rural *and* urban communities; communities with a long Hellenized background or of a nomadic/pastoral character. In some ways, Chapter 2 demonstrated how such a diverse number of cultures reflect to a greater or lesser degree the impact of varied environmental and geographical conditions and a complex social and political history.

As we have seen in Chapter 3 the field surveys, which have been undertaken in some areas of the southern Levant, have revealed areas of dense settlement, and some of these settled areas have presented field systems of varying sophistication and size. However, as has been stressed throughout this thesis, so far, most of these surveys have been able to make only basic generalisations concerning the chronological and developmental nature of settlement. The closer study of past land use patterns in a number of marginal areas undertaken in Chapter 4 has emphasized the degree to which present knowledge remains fragmentary. However, even a cursory field investigation has revealed that archaeological evidence for ancient land use, settlement and water management systems remains widespread across these regions. In addition, Chapter 4 further highlighted the extent to which most surveys, apart from those in the Negev and the Hauran, have failed to make effective studies of the local landscapes surrounding such settlements, particularly when concerning investigations of the required systems of water management.

Chapters 5 and 6 established that with the commencement of a detailed survey of the landscape of the Wadi Faynan, an opportunity arose for the intensive assessment of the local field systems and allowed for the imposition of a GIS as an interpretative tool for the collected data. Armed with the basic framework of floodwater system development that Wadi Faynan provides, it has been possible to apply this sequence of development to other areas in the southern Levant with similar systems. In other words, although unusual in certain aspects, the field systems of Wadi Faynan can be seen to be useful as an archetype for the implementation and development of water management systems across the whole region. This is particularly true when considering the evidence for the Iron Age (Edomite) and Late Roman to Byzantine periods in which the system operation and wall construction can be clearly delineated within parts of the field systems. Using a more tangential process it has even been possible to make valid inferences concerning the Nabataean landscape of Wadi Faynan, which for the most part lies buried beneath the later systems of fields.

Although the main field system of the Wadi Faynan (WF4) can be seen in many respects, in terms of scale and complexity, to be atypical of the region as a whole, (a reflection of its unique purpose to serve as a 'granary' for the localised mining population), a detailed analysis of the collective data has proved highly beneficial for a number of significant reasons. Firstly, the considerable 'carpet' of pottery sherds across all the major field systems in Wadi Faynan has aided considerably the identification of the different periods of landscape development throughout the Classical period. Furthermore, such was the density of surface sherds from other periods that interpretative readings were extended to other time periods both immediately preceding and succeeding the major phase of system use in the Classical period. Secondly, besides permitting the management and manipulation of a vast quantity of data, the employment of a GIS approach has allowed a new perspective to be constructed in regard to the operation and continual development of the water management systems at Wadi Faynan.

It was shown (Chapter 6) that the large field system that survives today (WF4) is in fact a composite of many smaller field systems, which utilised a variety of different water management strategies and which through time was subject to continual alterations and amendments by the farming population. The results of the GIS analysis suggests the system as a whole was highly flexible and could be adapted on a year to year basis to suit both the dynamic physical landscape and perhaps the changing needs of the local population. Hence, the complex patterning of sherds and wall types apparent within this field system displays evidence for a multitude of inputted factors, which include: some portions of the field system would have had a specific land use, in that some fields would have been allocated to cereals, whereas other fields could have been set aside for olives etc.; only some parts of the field system seem to have been used on a continuous long term basis, and hence were subject to successive phases of remodelling, whilst other sections were used in certain years and/or periods and not in others.

The picture such evidence provides for the late Roman and the Byzantine periods is twofold: Firstly, that the field system as a whole provided a basic framework onto which the annual agricultural requirements could be tailored; secondly, that we are dealing here with a centrally organised and highly controlled landscape. In all, the centralised, careful, management of the Wadi Faynan landscape in these particular periods if combined with other evidence concerning the distribution of army watchtowers, and mines in the surrounding environs, along with the central position of the administration and copper smelting facilities of the Khirbet itself, strongly suggests some degree of imperial control.

Consequently, such an understanding helps to explain both the similarities and the differences encountered when making comparisons between Wadi Faynan and evidence collected for other field systems in the region. As I have shown in Chapter 6 the results of the analysis of the Wadi Faynan field system can help to provide a chronology for the development of water management techniques which could be applied to other field systems. However, precisely because of the atypical nature of the Wadi Faynan system WF4, and the highly diverse nature of the evidence presented by other systems in other regions, its usefulness, it to explain in full the implementation and development of water management techniques across the region as a whole may be limited to only wider generalisations.

Chapter 7 has revealed the extent to which a reinterpretation of the sources and archaeological remains along with the information gained from Wadi Faynan can help to produce a more detailed picture of the interrelationships between the various cultural groups within the province and the ever changing interaction between them, along with responses to the physical geography of the country and the affects of changes beyond the province in the wider world.

8.2 Settlement and water management in the southern Levant

The implications of this study for the wider issues of water management are significant. The subject of water management beyond detailing developments in technology and techniques can be seen to act as an indicator for changes in settlement and land use, as a cultural group marker and more indirectly as a reflection of economic change and acculturation. Some of the issues this thesis has attempted to consider were outlined in Chapter 7, but beyond these there are wider concerns that need to be addressed, particularly in regard to the original research issues posed in Chapter1.

Fundamental to the initial inquiry has been the identification of the factors responsible for permanent sedentary agricultural settlement in such a marginal and difficult environment during the Classical period. Since serious thought was given to this problem a number of different explanations have been put forward. The most consistent have included theories on climatic changes, increased population, the deliberate sedentarization of the Nabataean population and immigrant colonists bringing new technologies. To explain the apparently sudden demise of such settlements other largely different factors have commonly been suggested; these have been found to include, primarily the Muslim conquests of the early seventh century AD, or a critical climatic deterioration. Implied alternative causes for the abandonment of practically the whole of the former province of Arabia by the eleventh century AD are notably: environmental degradation (primarily through overgrazing); a long series of devastating earthquakes and plagues; and a debilitating rise in the scale of nomadic raiding parties (e.g. Parker 1992).

All the above factors probably had some influence to a greater or lesser degree in the process of settlement creation or abandonment, but no one theory can be reasonably put forward as the prime cause behind either phenomenon, particularly in view of recent surveys and excavations. As some commentators have increasingly pointed out the main underlying factor upon any form of cultural renaissance can indubitably be traced to an upturn in economic fortunes. In the Levant of the Classical period the prime catalyst for this economic increase is of course the gradual extension of Roman hegemony and the assimilation of the whole region closer to the core of Mediterranean culture. This is perhaps not a new idea and may seem too simplistic, but an increasing body of research from recent years is helping to eliminate other theories as basically untenable, whilst reinforcing the underlying theory of economic control.

As I have attempted to underline in this thesis the broad picture emerging of the settlement and cultural history of the province of Arabia is a very complex one. Recent studies have begun to highlight the cultural diversity of the Levant within the Classical period using a variety of evidence (Foss 1995, 1997; Kennedy 1999; Millar 1998). Given the general unevenness of the archaeological and source evidence it is still clear that within certain limitations the development and final decline of the region, particularly in the rural fringes was varied; whilst some regions did not become settled until the Byzantine period for example, other areas went through cycles of development and decline throughout the Classical period. The immediate causes for local settlement histories are also complex and varied, some of which have been outlined in Chapter 7, but the driving process behind all such settlement remains a constant. The army was the main force for Roman imperialism, and may have been directly responsible for establishing only a small proportion of the total sedentary settlement in this marginal zone, but the presence of the Roman army on a permanent basis, particularly in the Late Roman period, guaranteed three long-term effects.

The first of these could be said to be security, the well-known *pax Romana,* and some theorists, particularly Parker, have based their arguments for the development and final decline of the peripheral regions around the presence or absence of the Roman army (1986, 1987, 1992). However, it seems that nomadic raiding could never have been a serious problem, as the archaeological evidence from a number of sources, from Safaitic inscriptions to excavations of pastoral campsites within or close to the settled zones reveals (see Chapter 3). As forcefully argued by Banning and others, it is more probable that a long standing relationship of mutual symbiosis existed between 'the desert and the sown', each relying on the other for subsistence, as is still the case today in many regions of the Levant (1986 etc.,). Enduring security was brought to the region by its inclusion within the Roman empire due to the suppression of internecine rivalries of the different kingdoms its rule replaced, and the forcible quashing of any internal revolts (Isaac 1990 etc.,). Hence, in such relatively 'peaceful' times the economy and the total population of the region could grow unabated, this is particularly true for the fifth century AD, which marks the peak of the rural expansion and a period free from conflict (Cameron 1993: 177).

The second effect was that the presence of the army and of army-run slaves in the large mining districts (re: Wadi Faynan and Timna) did however increase the market for goods and agricultural produce in a real sense, as has been amply documented for other provinces across the empire. Thirdly, the settlement of veterans in key areas, particularly the Nuqra plain to the west of the legionary garrison at Bosra, as well as developing these areas, also raised the attractiveness for mobile peoples in the adjacent areas of seizing the opportunities offered by a more sedentary and agricultural lifestyle. The same process can be seen with the Hellenized cities of the Decapolis, and other urbanised centres of the region which seem to have flourished in the second and third centuries AD, as the Roman authorities courted the local elites, who in turn were keen to express their status in the adornment of the cities.

Consequently, the hinterlands of these urban centres became more intensively farmed, particularly in the Later Roman period as the cities declined and there was a movement towards the rural regions. As with North Africa, there is evidence that such regions moved to a more specialised production of cash crops, particularly olive oil (e.g. Gaza) and wine (Jebel al-Arab) (Dentzer 1986; Greene 1986; Mayerson 1985). The resultant wealth generated permitted the importation and consumption of material culture. Again the effect of the hinterlands becoming intensely developed resulted in regions further away to appear more attractive to agricultural development, as may well have been the case with the Golan and the Negev regions. The attractiveness of the Mediterranean market unconsciously promoted by the adjacent Roman hegemony may also to some extent explain the increasingly sedentarized nature of the Nabataean kingdom in the last century BC and first century AD, before the kingdom was absorbed into the empire in AD 106. Loosely perceived, it can be stated that by such processes the more urbanised and agriculturally-rich inner zone expanded into a previously under-exploited outer zone, which in turn caused at various times the exploitation of the drier peripheries (Finkelstein 1995). Though as mentioned before the reality was much more complex for different geographical parts of the province and in different time periods.

Hence, the seizure of political control of the region by the Roman Empire imperceptibly and unconsciously changed economic and trading activities within this region over a relatively short time. However, it must be remembered at this point that 'The Roman Empire was not run on altruistic lines: it developed mechanisms for the exploitation of land and people' (Mattingly 1997: 135). Therefore, the Roman rule of Arabia would not have been complacent or totally laissez-faire in its attitude to the peoples of the province, but the different cultural groups which came into contact either directly within the provincial boundaries or on the periphery did have opportunities to negotiate and benefit from the economic changes the Romans brought.

Similar readings may be sought for the debates on the extent to which the region became Romanized. Urban elites were largely already Hellenized, and the 'urban' centres of the Negev and the Hauran adopted certain Mediterranean building types such as bath structures (Rubin 1990). The rural landscape, with a few exceptions, remained Semitic in nature and principally developed local traditions as can be seen in villages across the province: for example as noted in Chapter 4, Umm el-Jimal although only 30 or so kilometres from Bosra has a very different cultural context (de Vries 1998). From an archaeological viewpoint, Romanization essentially occurred in such regions with the importation of certain types of material culture, particularly ceramics. Later on in the Byzantine period, Christianity became the principal cultural bond between the various ethnic and cultural groups within the province and a primary link with the Mediterranean beyond.

The desertification of much of the province in the centuries succeeding the Islamic conquest can be essentially interpreted from an economic perspective. With the disappearance of the Byzantine administration, the strong ties to the Mediterranean economy over time were gradually loosened. Instead the new political elites increasingly re-oriented the region towards the Saudi peninsula, and Arab culture became increasingly predominant. Hence, eventually changes in material culture occurred, and so the much fewer pottery sherds may not be an indication of deterioration in economic exchange with the core regions of the Mediterranean, but rather the adoption of different cultural traits. New regions, particularly rural areas within the former province of Arabia enjoyed an increase in settlement and benefited from new water management technologies. The Negev Highlands and the regions around the 'Desert Castles' of both Israel and Jordan are two examples that prospered in the eighth and ninth centuries of the Umayyad period (H. Kennedy 1992: Rosen 2000).

It is undoubtedly true that the earthquakes and plagues of the sixth and seventh centuries AD caused disruption to the populations of the Levant, but along with any ambiguous climatic change were not responsible for the abandonment of the sedentary regions of much of the province. The ultimate cause must be the transference of political power away from the Levant in the 'Abbasid period to Baghdad, which inevitably resulted in an economic shift to the Mesopotamian region, and the loss of future investment by the political elites into the southern Levant. The loss of both these factors precipitated a final downturn in the local economy, the population fell, some people may have even moved on, and the maintenance of the peripheral farming regimes ended, apart from small scale and opportunistic agriculture undertaken by Bedouin groups.

8.3 Study implications

In terms of the wider implications posed in Chapter 1, the results of this study have been important in many respects. To return to the questions posed by Shaw (Section 1.2), an investigation of the water management techniques employed across the province of Arabia has produced a complex set of responses. The extent to which these questions can be answered has been constrained by the depth of archaeological evidence available, which is very uneven from region to region and is currently lacking for certain periods, particularly the late Roman. In addition, due to the overall time period (around a 1,000 years) with which this study has out of necessity concerned itself, any precise conclusions concerning the nature of Roman imperialism and Romanization will have been diluted. Furthermore, the marginal regions that experienced changing levels of settlement are in terms of geographical area quite small, and consequently, could only sustain relatively small populations.

However, if certain generalisations can be made, it does seem that the utilisation of water management systems within the province of Arabia can provide useful evidence for key debates on the impact of Rome on marginal regions. Hence, these regions seem to contain evidence both for landscapes of imperialism, for example, at Wadi Faynan, and landscapes of opportunity, in regions of the Negev. Furthermore, arguments could be put forward for the interpretation of some regional landscapes as landscapes of resistance. These could include regions of the Harra in which nomads developed their own responses to the presence of Rome. This study has highlighted the need for further research into questions of settlement development within the region, and some of these ideas will be put forward in the next section.

8.4 Future work

By concentrating on the methods, distribution and development of water management systems and their relationship to the settlements and diverse cultural groups that maintained them I have attempted to reflect on a number of important issues not well-served by past studies. One purpose in applying a GIS to a floodwater farming system was to test whether such an approach could help solve the enduring problem of dating particular types of wall construction. This approach has proved successful when applied to the remains of a large and particularly complex system such as exists at Wadi Faynan. Theoretically, a GIS approach could be applied to other systems with similarly constructed walls, but with fewer surface sherds. Although only general conclusions could be reached in dating walls in other systems, because of the very simple constructions used in most other systems, the majority of which are very small in scale. However, beyond this the Wadi Faynan GIS has proved very successful in measuring the complex evolution of a floodwater farming system and the essential adaptability of the technique to changing conditions.

The very detailed body of evidence collected by the Wadi Faynan Landscape Survey means that further, more extensive GIS-based studies could be undertaken, so at this point it is worth noting other approaches that could be pursued in future. The first of these, given the mass of fragmentary remains extant today, is the detailed assessment of how the floodwater farming system may have been operated in practice. A variety of water flow models could be constructed to examine the operational aspects of specific, well-preserved parts of the system, using standard flow models with a level of uncertainty, and incorporated in a detailed Digital Elevation Model (DEM) (e.g. Maidment 1993: Malczewsli 1999).

The second approach, following some of the thinking contemplated by Ingold (2000), could obtain some understandings of the cultural behaviour of the Nabataean/Roman period, i.e. their relationship to the landscape and how it was perceived. This would involve a variety of issues in considering how the field system WF4 would work and how the local farmers, be they freeholders, tenants or otherwise, fitted into this system. For although we have a large aerial view map and hence a modern Cartesian conception of the whole landscape, they would undoubtedly have not; consequently they would have conceptualised the whole system and landscape differently. A natural progression from this approach leads into the third main area that of how the landscape was used by the farmers of Faynan. A certain amount of documentary evidence on papyri concerning land and water rights has survived from other parts of the Roman empire which indicate complex agreements and land ownership systems within irrigated regions (e.g. Kraemer 1958; Rathbone 1991; Shaw 1982, 1984). Therefore, in view of this information, it seems probable that the arrangements for the Faynan field systems were just as complex. Interesting questions concerning the working relationship the farmers had with the system could be explored using a GIS. Hence, some indications could be obtained of land ownership by investigation of wall structures, if certain boundary walls could be identified, it might be that the system was divided into different operational territories, or if not the farmers operated the fields in an integrated whole, as a collective. Whatever operation was utilised, questions of neighbour liaison to ensure effective operation of the system or the implementation of outside control, perhaps imposed by Roman authorities, would also need answering.

A GIS could help in such enquiries if a cognitive approach was applied, similar to that undertaken by Llobera on the Bronze Age ditches of Salisbury Plain (1996). A basic idea to investigate these questions might be to combine a site catchment analysis along with a cumulative viewshed analysis at points in and around the field system where settlement was known to exist. Through such an analysis the relationship of farm settlement to the system at certain points may be obtained, and if the areas so developed in this way could be matched up to variables in wall width perhaps we might have the basis for farm territories. The final idea concerns an exploration into how different areas of the landscape were utilised for different practices through time, and how the local population saw these areas. In this way it might be possible to split the region into different social activity areas such as sacred, territorial and market areas. The basic phenomena were the position of the various types of cairn within and without the field system and how they relate to different aspects of the local environment, such as sections of field wall, topography, and settlement and material evidence. All such analyses could be effectively completed using a GIS to establish a number of significant correlations.

The advancement of a GIS approach along with the detailed study of an area in the southern Levant would help to answer a particularly important set of questions. The Nabataean landscape remains largely unknown; hence, identifying the extent to which the Nabataeans became a sedentary farming society, when this occurred and if it was a gradual process over centuries or was short and intensive would be an important step to take.

Even the Byzantine rural society of the southern Levant is a mystery as no detailed excavations of a small village community or one of the hundreds of isolated farmsteads has yet been undertaken. The implementation of a GIS to investigate the rural landscape of a settled region on the plateau above the Wadi 'Araba, such as in the Jibal, would help our understanding of the richer farming areas, and answer questions as to the relationship between these and the peripheral areas beyond. These are just a few of the many questions which could be answered by an intensive and detailed study of a particular rural area in the southern Levant, until the time such basic exploratory work is commenced from an archaeological and historical perspective the southern Levant continues to give rise to more questions.

Appendix 1

Chronological periods

There has been much disagreement over the nomenclature, the length in years and the criteria by which the time periods of the Levant should be delineated. Without wishing to enter into a detailed discussion of the pros and cons on the adoption of one system or another, the following period definitions have been adopted for this thesis. This is a simplified chronology of the ceramic chronology developed following the analysis of the pottery from the Tell Hesban excavations and generally adopted by Parker and others (Sauer 1973: 1-5; Parker 1986). As such, this basic chronology conforms closely to the historical periods and pottery of the southern Levant, that is, the region of Roman Arabia.

Chalcolithic	*c.* 4500 BC – 3500 BC
Early Bronze Age	*c.* 3500 BC – 2100 BC
Middle Bronze Age	*c.* 2100 BC – 1550 BC
Late Bronze Age	1550 BC – 1200 BC
Iron Age	1200 BC – 539 BC
Persian period	539BC – 332 BC
Hellenistic	332 BC – 63 BC
Nabataean/Early Roman	63 BC – AD 135
Late Roman	AD 135 – 324
Early Byzantine	AD 324 – 491
Late Byzantine	AD 491 – 640
Early Islamic (Umayyad)	AD 640 – 750
Early Islamic ('Abbasid)	AD 750 – 1260
Mamluk	AD 1260 – 1516
Ottoman	AD 1516 – 1918
Modern	AD 1918 – present

Appendix 2

Wall data categories

Wall number
Field ID number
Field number

Date
Recorders

Maximum length
Maximum width
Maximum height
Maximum dimensions

Surface archaeology: walls well preserved
Surface archaeology: walls damaged
Associated structure numbers and brief description

Type 1: cairn line
Type 2: terrace wall - not visible
Type 3: single-faced terrace wall
Type 4: double-faced terrace wall
Type 5: single-faced wide terrace wall
Type 6: double-faced large terrace wall
Type 7: un-faced wall
Type 8: double-faced, free standing wall
Type 9: wide free standing wall
Type 10: other walls

Visible phases (in wall construction)
Boulders
Medium blocks
Small blocks
Un-coursed rubble
Irregular coursed
Rough coursing
Neat coursing

Diagonally bedded terrace
Other class

L-shaped cairn junction
T-shaped cairn junction
Integral cairn
Parallel walls
Wide gap/gate
Narrow gap/ sluice

Sluice with baffle
Spillway
Attached circular/oval structure
Attached square/rectangular structure

Field information categories

Field ID number
Field number
Recorders

Landuse: under crop
Landuse: ploughed
Landuse: bulldozed
Landuse: not recently ploughed
Landuse: rough grazing
Landuse: modern irrigation pipes
Landuse: modern irrigation tank

Surface visibility: very poor 1
Surface visibility: poor 2
Surface visibility: average 3
Surface visibility: good 4
Surface visibility: very Good 5
Surface archaeology: soil deflation
Surface archaeology: dispersed through ploughing
Surface archaeology: disturbed by earthmoving
Surface archaeology: illegal excavations

Associated structure numbers and brief description
Detached circle/oval structure
Detached square/rectangular structure
Detached cairns
Detached graves
Minor walls

Click and pick categories

Field unit
Date
Team members
Number of clicked transects
Number of sherded transects
Length of clicked transect (metres)
Length of sherded transect (metres)
Clicked pot
Clicked flint
Collected pot
Collected pot Weight (in g)
Collected flint count
Collected flint weight
Collected slag
Other collected artefacts
Grab bag (Y/N)
Other artefacts (grab bag)
Total bags collected

Appendix 3

Fineware coverages

To simplify the task of constructing fineware coverages for the GIS analysis, a number of different categories of fineware sherd had to be combined for convenience. This is because some pottery styles were produced for many decades and occasionally hundreds of years, also the accuracy of the dating is often vague. From the Faynan pottery database all the following sherds were combined for each period coverage. The sherds had been initially assigned periods in line with the period division of Parker (1986) and Hayes (1972), with some adjustments in view of later research.

Late Roman coverage (covers the years AD 284-363)

Includes all fineware sherds in the database labelled:

LR	Late Roman
LR/EBYZ	Late Roman/early Byzantine

Byzantine coverage (covers the years AD 363-551)

All fineware sherds labelled:

BYZ	Byzantine
EBYZ	Early Byzantine
LBYZ	Late Byzantine
BYZ?	Perhaps Byzantine

Late Byzantine/Early Islamic coverage

All sherds labelled:

M6/E7TH	Mid sixth to early seventh century AD
L6/7TH	Late sixth to seventh century AD

Appendix 4

Chi-Squared tests on parts of the WF4 field system

The chi-squared test tests for significance, by first assuming that there is an even distribution, of in this case, pottery sherds across the whole field system. Hence, employing the chi-squared test, whose formula is:

$$x^2 = \sum \frac{(O - E)^2}{E}$$

where k is the number of categories
O is the observed number of cases in category i
E is the expected number of cases in category i
x^2 is the symbol representing chi-squared.

Once chi-squared has been computed, it needs to be tested for statistical significance, using the values in a significance table. The value required is found by employing a level of significance α, in this case 0.05, and the number of degrees of freedom associated with the sample, which for all cases equals the number of categories minus one; in symbols

$$v = k - 1$$

Hence, as there are only two categories for each, there will be only one degree of freedom, so that the value of significance for all cases will be:

3.84146

to which the value for chi-squared should be compared. Any result higher in value than this indicates a high degree of significance (Shennan 1997: 107).

The calculations for the three units follow below, testing the following form:

H : sherds are equally distributed across all field units

H : sherds are not equally distributed across all field units

WF4.10 Byzantine Sherd Distribution	
Total Area of Field System (WF4.1-4.12) (hectares)	= 1201994
Total Area of Selected Fields (hectares)	= 38741
Selected Fields as % of total area	= 3.223061

Total Number of Byzantine Sherds (WF4.1-4.12)	198
No. of Sherds in Specified Fields (WF4.10)	36
Special sherds as % of Total	

	Observed sherd numbers *O*	% of Area	Expected Sherd Number *E*
Fields of WF4.10	36	3.223061	6.3817
Remainder of Field System (WF4.1-4.9, 4.11-4.12)	162	96.77694	191.6183

$$= \frac{(36 - 6.3817)^2}{6.3817} + \frac{(162 - 191.6183)^2}{191.6183}$$

$$= 137.462384 + 4.5780789$$

$$= 142.040463$$

= a high level of significance, as well above the level 3.84146

WF4.12 Nabataean Sherd Distribution	
Total Area of Field System (WF4.1-4.12) (hectares)	= 1201994
Total Area of Selected Fields (hectares)	= 160756
Selected Fields as % of total area	= 13.3741

Total Number of Nabataean Sherds (WF4.1-4.12)	172
No. of Sherds in Specified Fields (WF4.12)	26
Special sherds as % of Total	15.11628

	Observed sherd numbers	% of Area	Expected Sherd Number
Fields of WF4.12	26	13.37041	23.003345
Remainder of Field System (WF4.1-4.11)	146	86.6259	148.9965

$$= \frac{(26 - 23.00345)^2}{23.00345} + \frac{(146 - 148.9965)^2}{148.9965}$$

= 0.390333 + 0.0603

= 0.450596

= a low level of significance, as well below 3.84146

WF4.12 (Western Section) Nabataean Sherd Distribution	
Total Area of Field System (WF4.1-4.12) (hectares)	= 1201994
Total Area of Selected Fields (hectares)	= 118906
Selected Fields as % of total area	= 9.892394

Total Number of Nabataean Sherds (WF4.1-4.12)	172
No. of Sherds in Specified Fields (WF4.12)	24
Special sherds as % of Total	13.9535

	Observed sherd numbers	% of Area	Expected Sherd Number
Fields of WF4.12	24	9.892394	17.0149
Remainder of Field System (WF4.1-4.11)	148	90.10761	154.9851

$$= \frac{(24 - 17.0149)^2}{17.0149} + \frac{(148 - 154.9851)^2}{154.9851}$$

= 2.86758 + 0.06026

= 3.18239

= a low level of significance, as the result is just below 3.84146

WF4.3 (Eastern Section) Late Roman Sherd Distribution	
Total Area of Field System (WF4.1-4.12) (hectares)	= 1201994
Total Area of Selected Fields (hectares)	= 81366
Selected Fields as % of total area	= 6.769256

Total Number of Late Roman Sherds (WF4.1-4.12)	228
No. of Sherds in Specified Fields (WF4.3)	35
Special sherds as % of Total	15.3509

	Observed sherd numbers	% of Area	Expected Sherd Number
Fields of WF4.12	35	6.769256	15.4074
Remainder of Field System (WF4.1-4.11)	193	93.23074	212.5926

$$= \frac{(35 - 15.4074)^2}{15.4074} + \frac{(193 - 212.5926)^2}{212.5926}$$

= 24.91465 + 1.80566

= 26.7203

= a high level of significance, as above the significance indicator of 3.84146

WF4.3 (Eastern Section) Byzantine Sherd Distribution	
Total Area of Field System (WF4.1-4.12) (hectares)	= 1201994
Total Area of Selected Fields (hectares)	= 81366
Selected Fields as % of total area	= 6.769256

Total Number of Byzantine Sherds (WF4.1-4.12)	198
No. of Sherds in Specified Fields (WF4.3)	26
Special sherds as % of Total	13.1313

	Observed sherd numbers	% of Area	Expected Sherd Number
Fields of WF4.3	26	6.769256	13.4031
Remainder of Field System (WF4.1-4.11)	172	93.23074	184.5969

$$= \frac{(26 - 13.4031)^2}{13.4031} + \frac{(172 - 184.5969)^2}{184.5969}$$

= 11.83919 + 0.85961

= 12.6988

= a high level of significance, as above 3.84146

WF4.3 (Eastern Section) Nabataean Sherd Distribution	
Total Area of Field System (WF4.1-4.12) (hectares)	= 1201994
Total Area of Selected Fields (hectares)	= 81366
Selected Fields as % of total area	= 6.769256

Total Number of Nabataean Sherds (WF4.1-4.12)	172
No. of Sherds in Specified Fields (WF4.3)	16
Special sherds as % of Total	9.3023

	Observed sherd numbers	% of Area	Expected Sherd Number
Fields of WF4.3	16	6.769256	11.6431
Remainder of Field System (WF4.1-4.11)	172	93.23074	160.3569

$$= \frac{(16 - 11.6431)^2}{11.6431} + \frac{(172 - 160.3569)^2}{160.3569}$$

= 1.63037 + 0.11837

= 1.7487

= a low level of significance, as the result is below 3.84146

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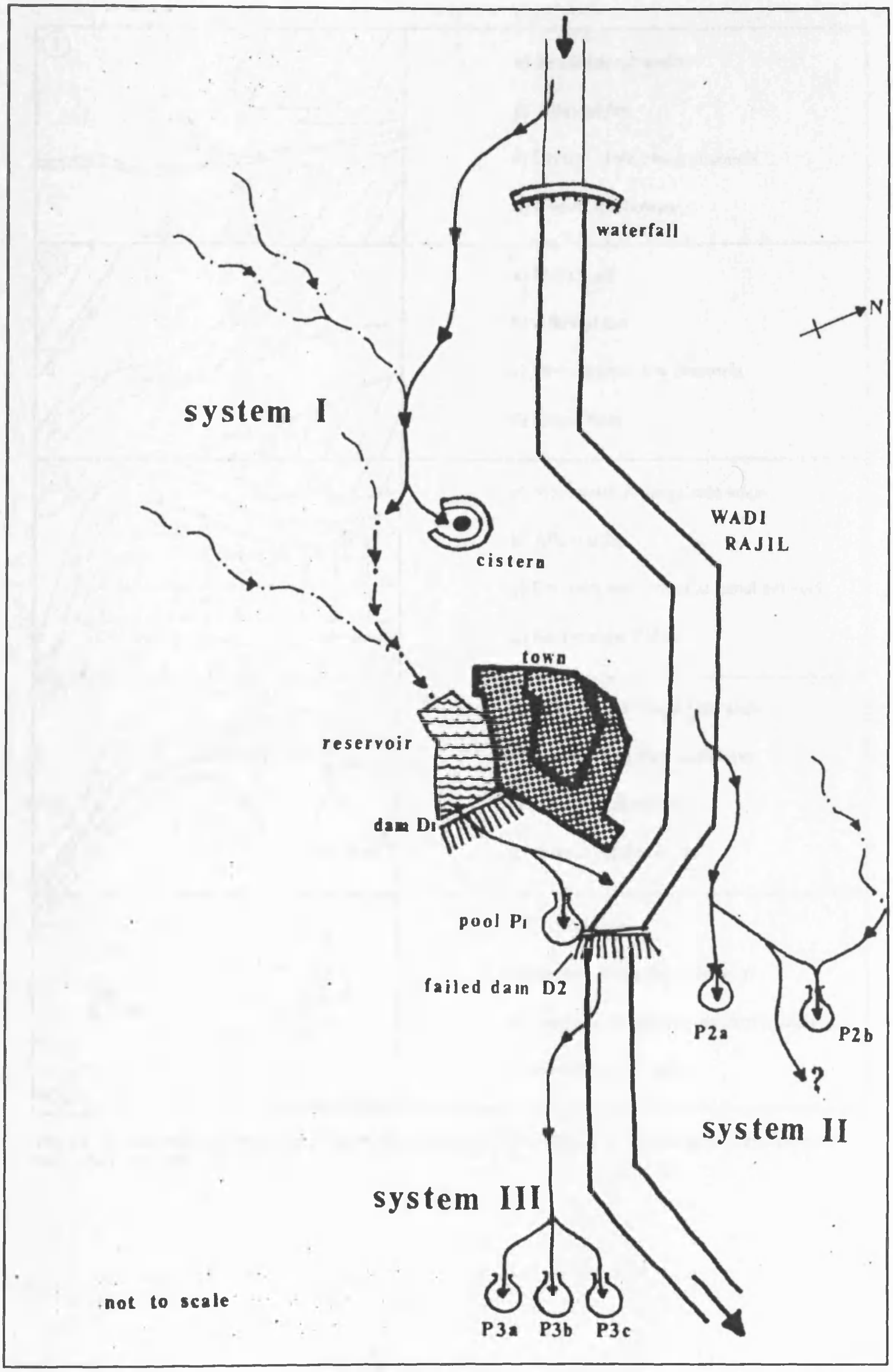

Figure 1.1 A diagrammatic view of the Bronze Age water management systems at Jawa in the Harra of Jordan (after Roberts 1977: 141, Fig.2).

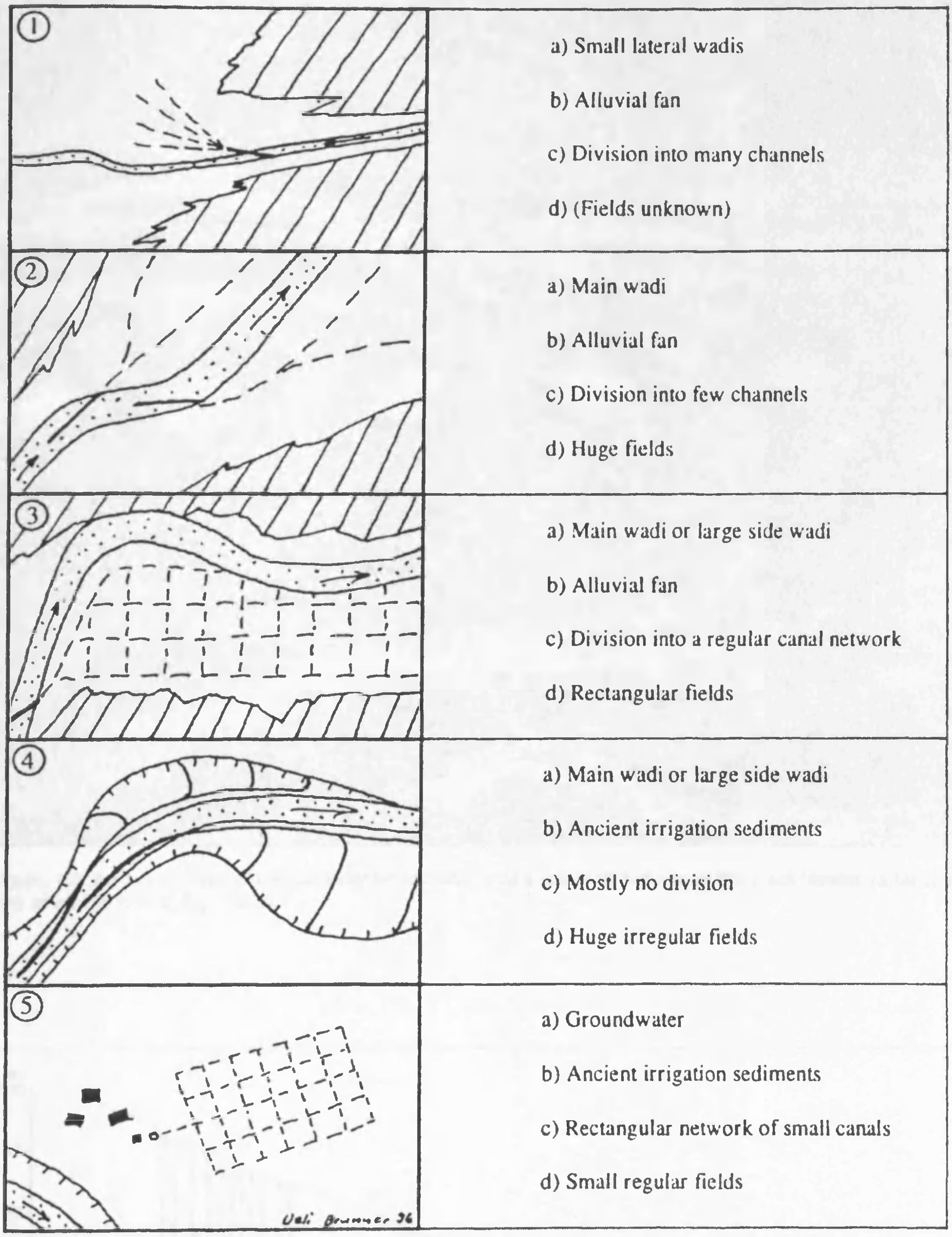

Figure 1.2 A schematic diagram of the different types of irrigation systems used in Wadi Marhah (after Brunner 1997: 75, Fig.4)

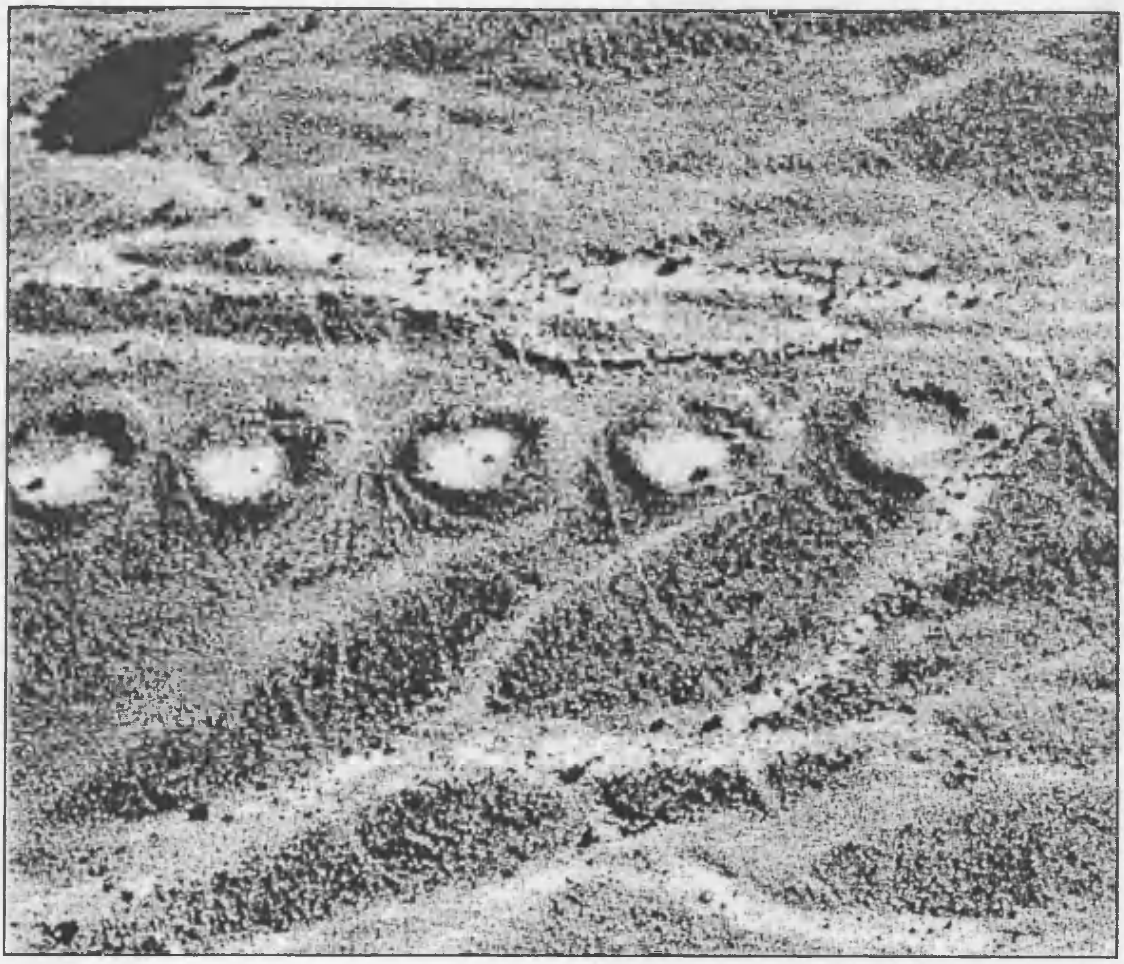

Figure 1.3 An aerial view of the sediment-filled shafts of a qanat at Yotvata in the Wadi 'Araba (after Evenari *et al.* 1982: 172, Fig. 105a).

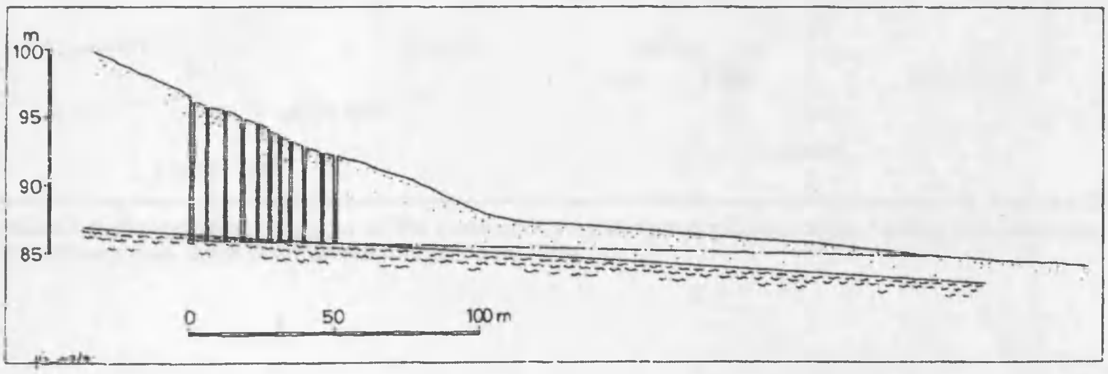

Figure 1.4 Schematic sectional view of a qanat or chain of wells, the dott– dash line represents the horizontal tunnel which transports the groundwater to the surface (after Evenari *et al.* 1982: 174, Fig. 106).

near horizontal!

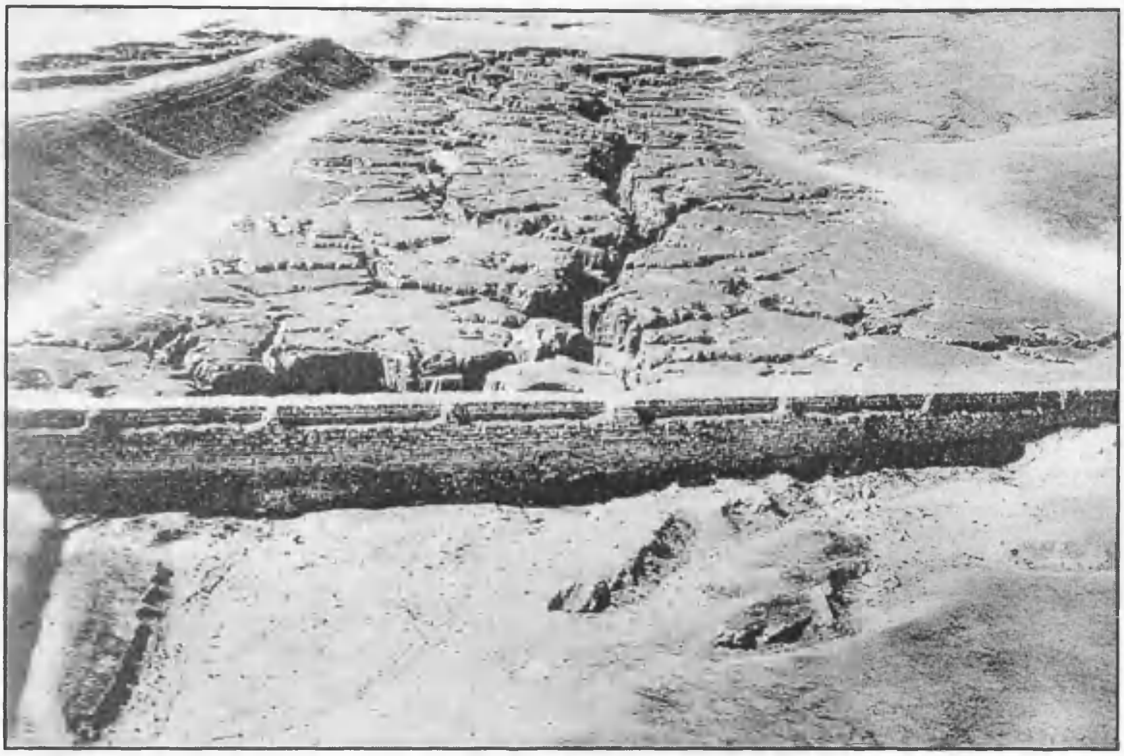

Figure 1.5 The impressive dam at Harbaqa, Syria (after Poidebard 1934, Plate 33).

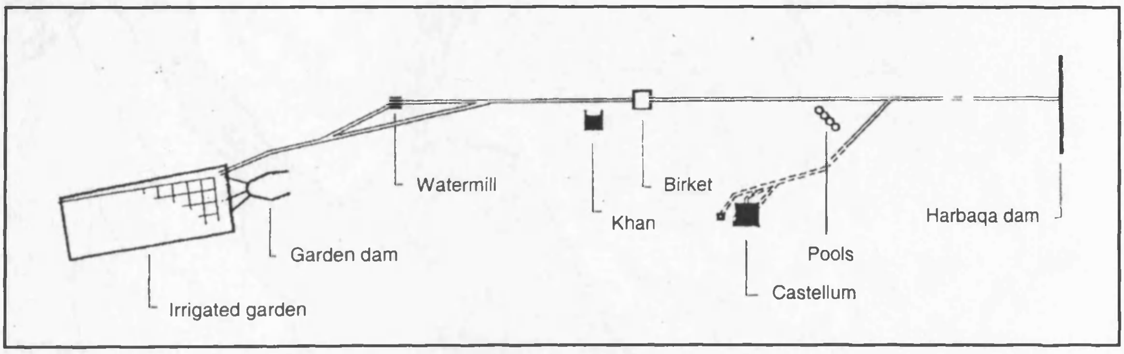

Figure 1.6 The Schematic diagram of the installations and irrigated gardens of Qasr el-Heir el-Gharbi and the Harbaqa dam, Syria (after Schlumberger 1986, Plate 1a).

Figure 2.1 The southern Levant (after Bowersock 1983: Fig.1).

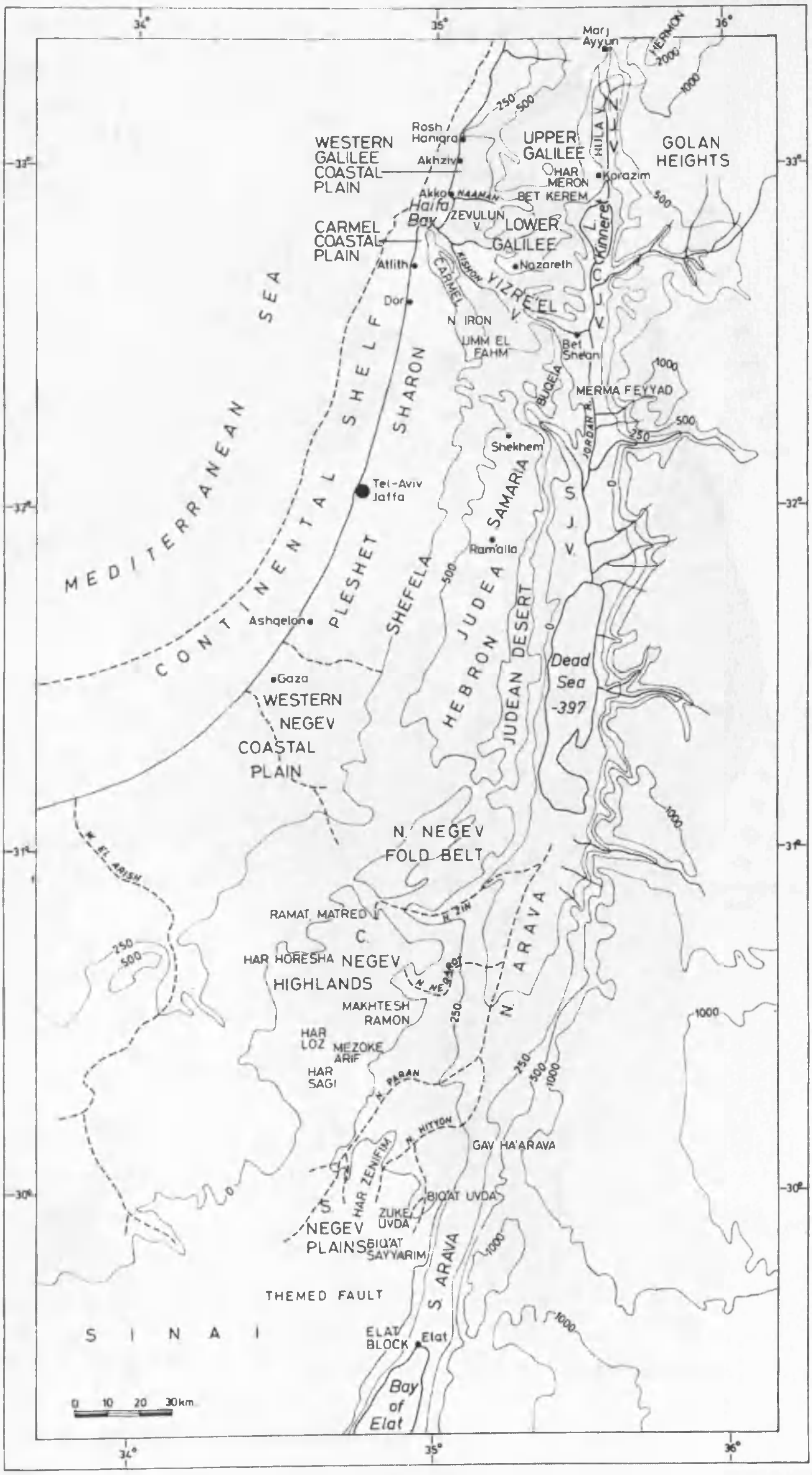

Figure 2.2 The topographic regions of the southeastern Levant (after Horowitz 1979: 12, Fig. 2.2).

Figure 2.3 The topography of Sinai (after Admiralty 1946: 43, Fig. 9).

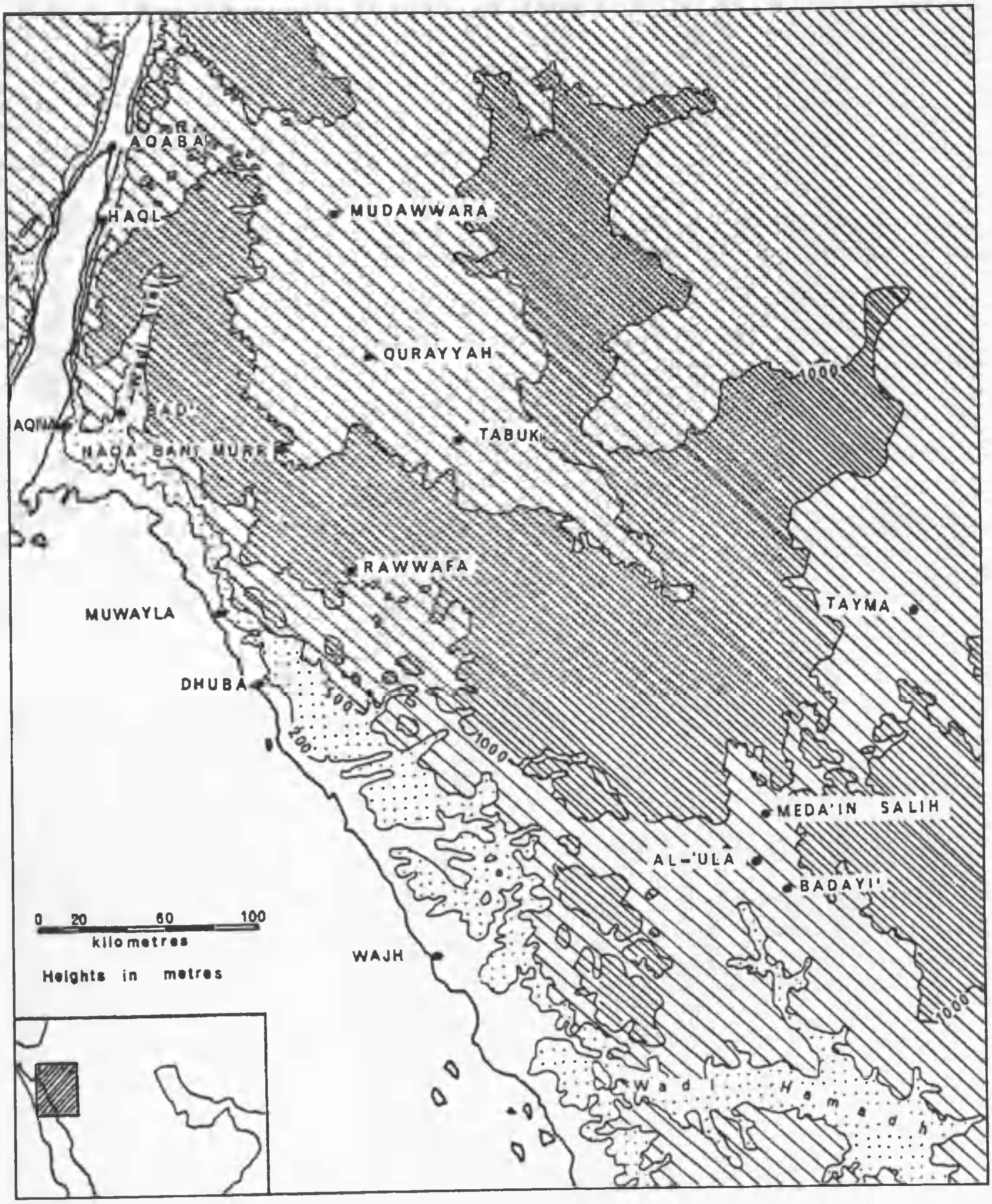

Figure 2.4 Northwest Arabia (after Parr *et al.* 1970: 195, Fig.1).

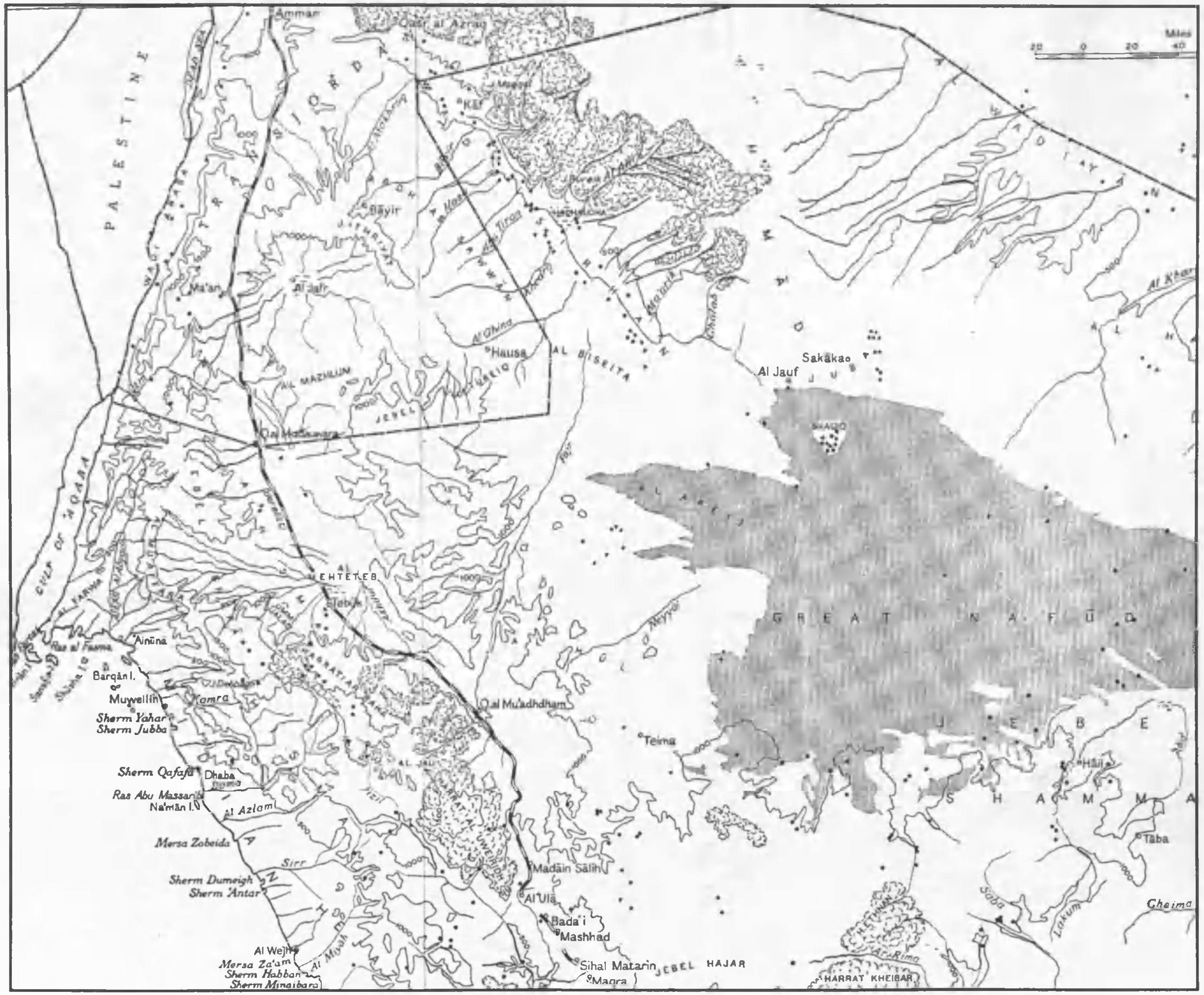

Figure 2.5 Topography of the southern Levant (after Admiralty 1946, Fig. 8).

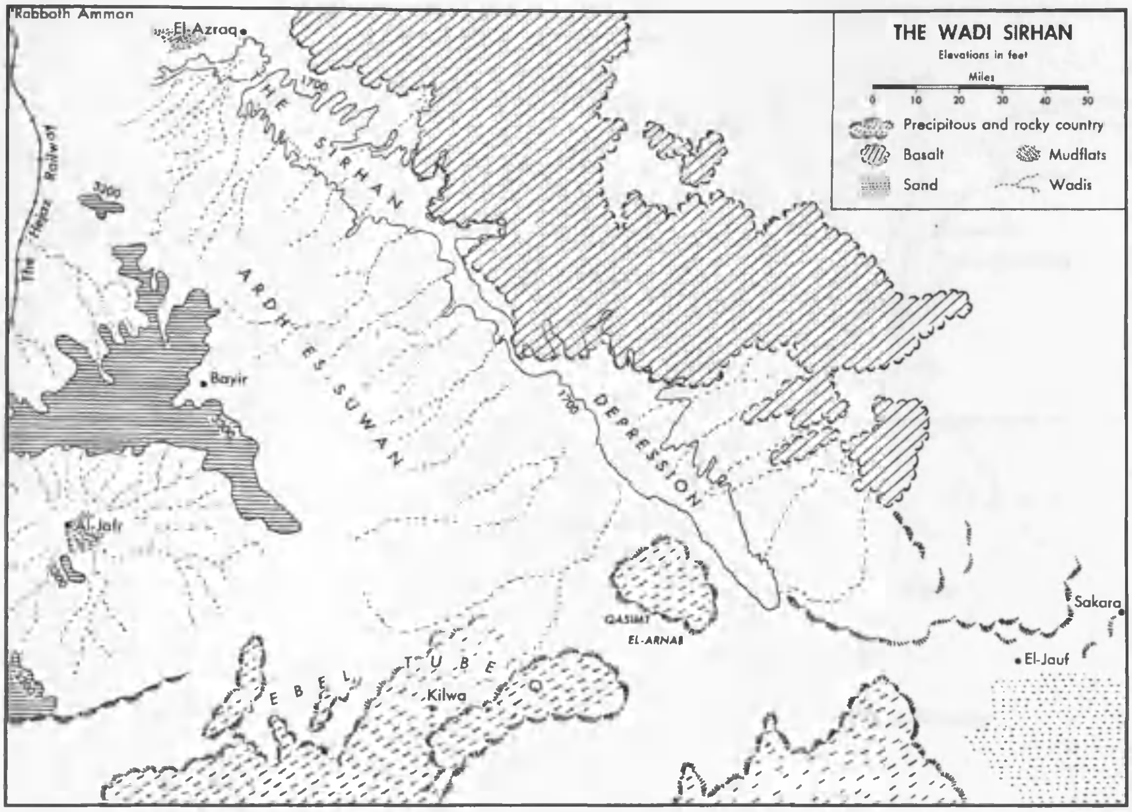

Figure 2.6 Topography of the Wadi Sirhan and adjoining regions (after Baly 1957: 255, Fig. 46).

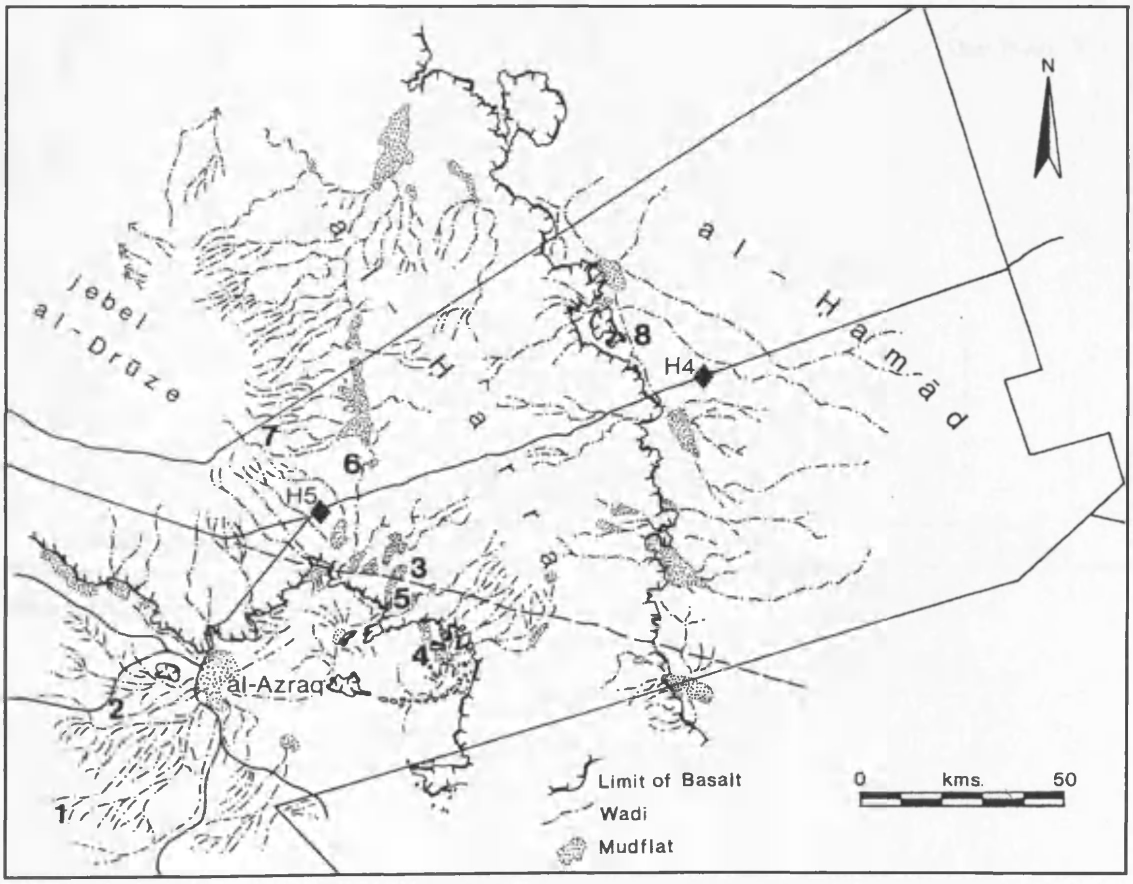

Figure 2.7 Topography of the Harra and adjoining regions (after Betts 1998: 3, Fig. 1.2).

Figure 2.8 The region of the Jebel al-Arab

Figure 2.9 Topography of the Wadi 'Araba (after Baly 1957: 208-10, Fig. 40).

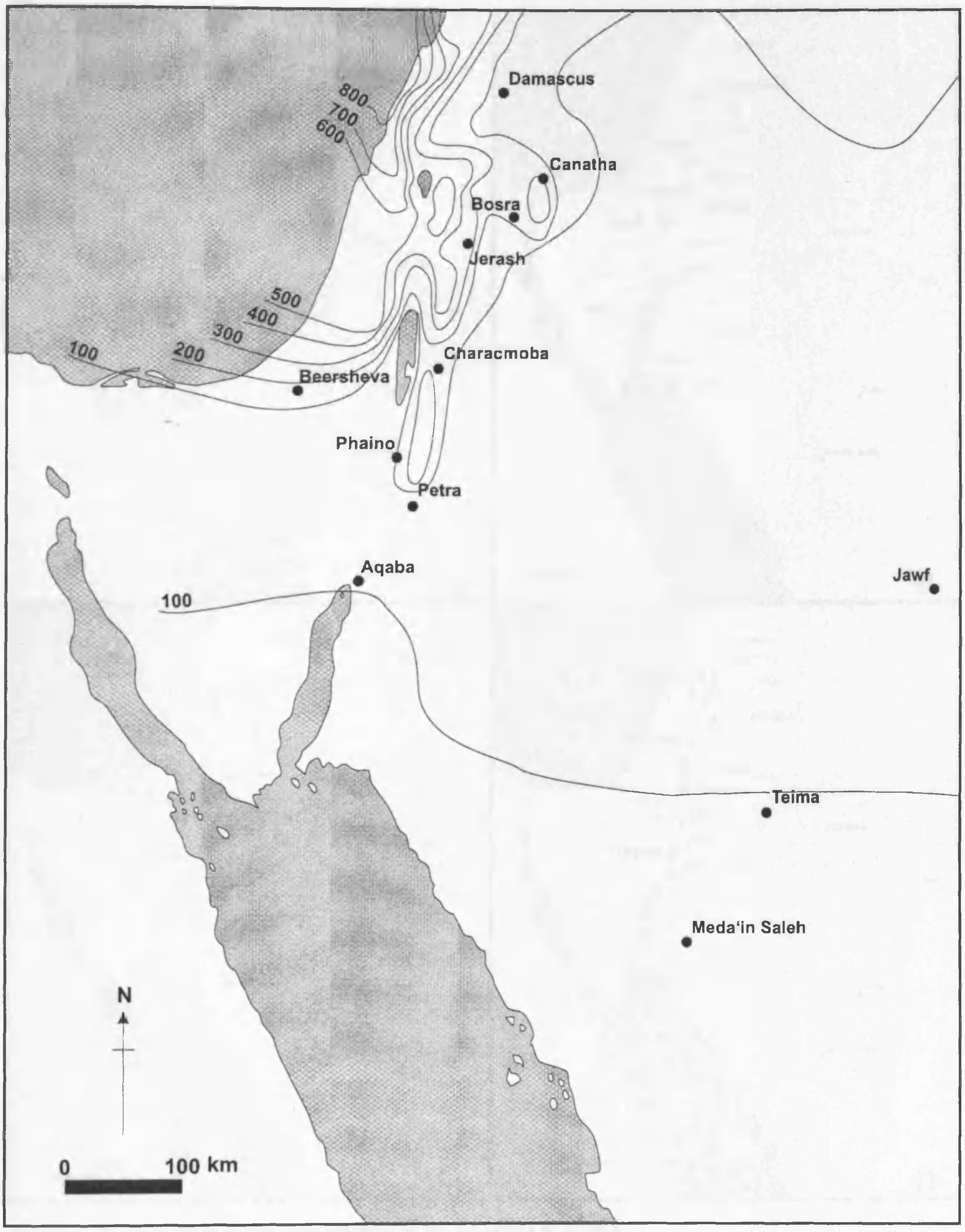

Figure 2.10 The mean annual rainfall for the Levant in 100 millimetre isohyets (after de Brichambaut and Wallen 1963: 11, Fig. 1)

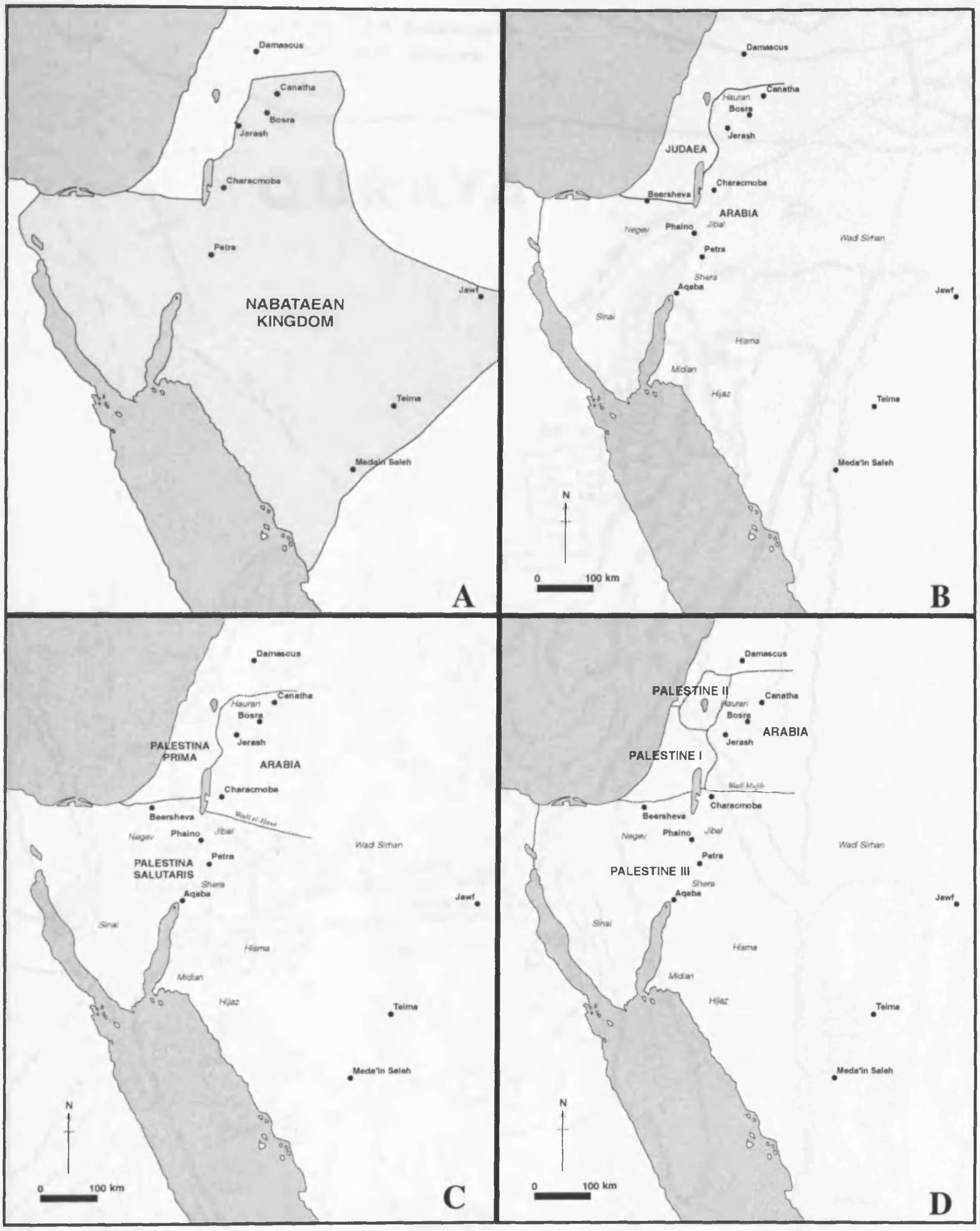

Figure 2.11 An outline of the development of the province of Arabia.

A = Nabataean kingdom 1st century BC - 1st century AD
B = Province of Arabia 2nd and 3rd centuries AD
C = Arabia and Palaestina Salutaris 4th century AD
D = Arabia and Paleatina Tertia (III) late 5th and sixth centuries AD

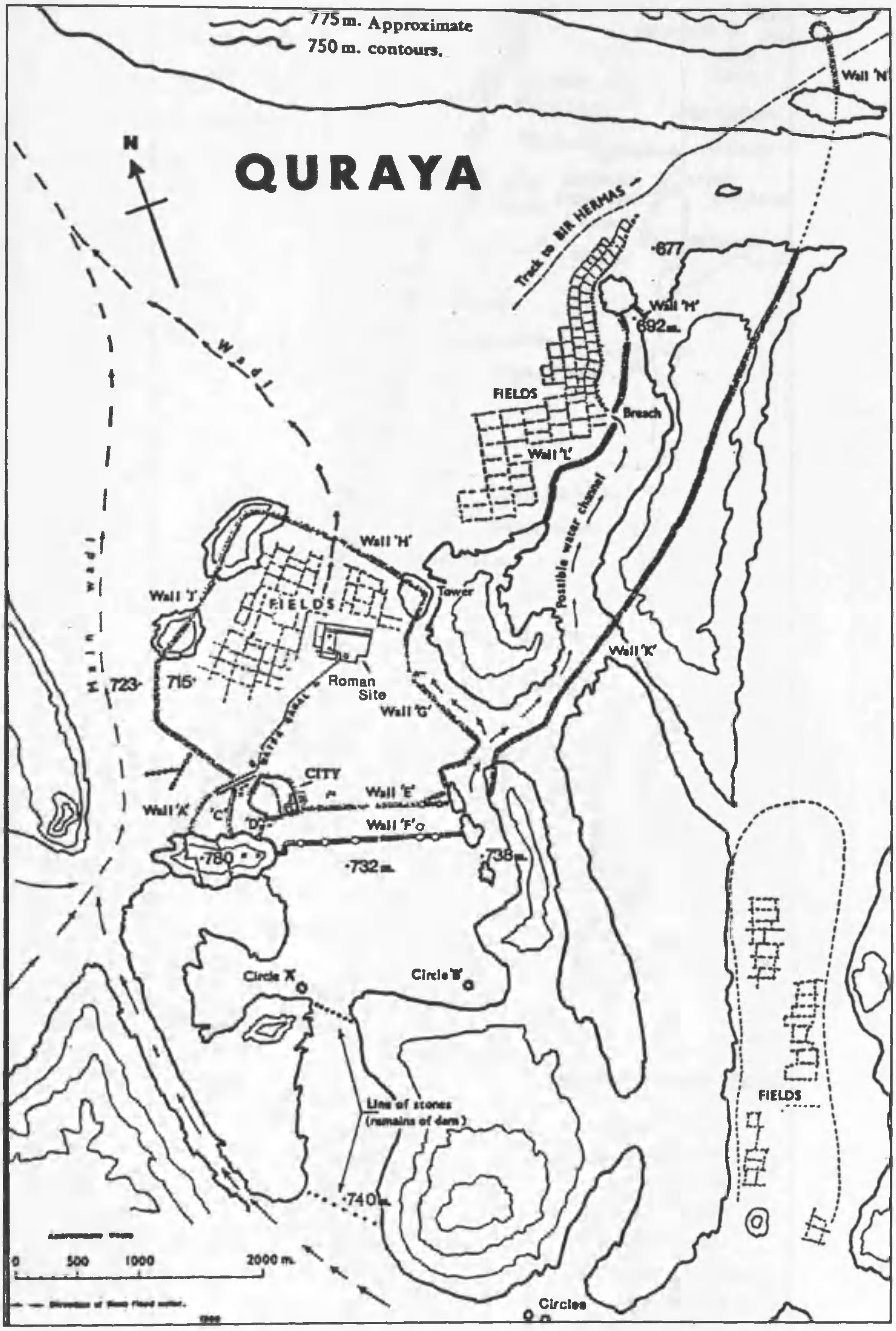

Figure 3.1 The major site at Qurrayyah in the northern Hijaz (after Parr *et al.* 1970: 221, Fig. 10).

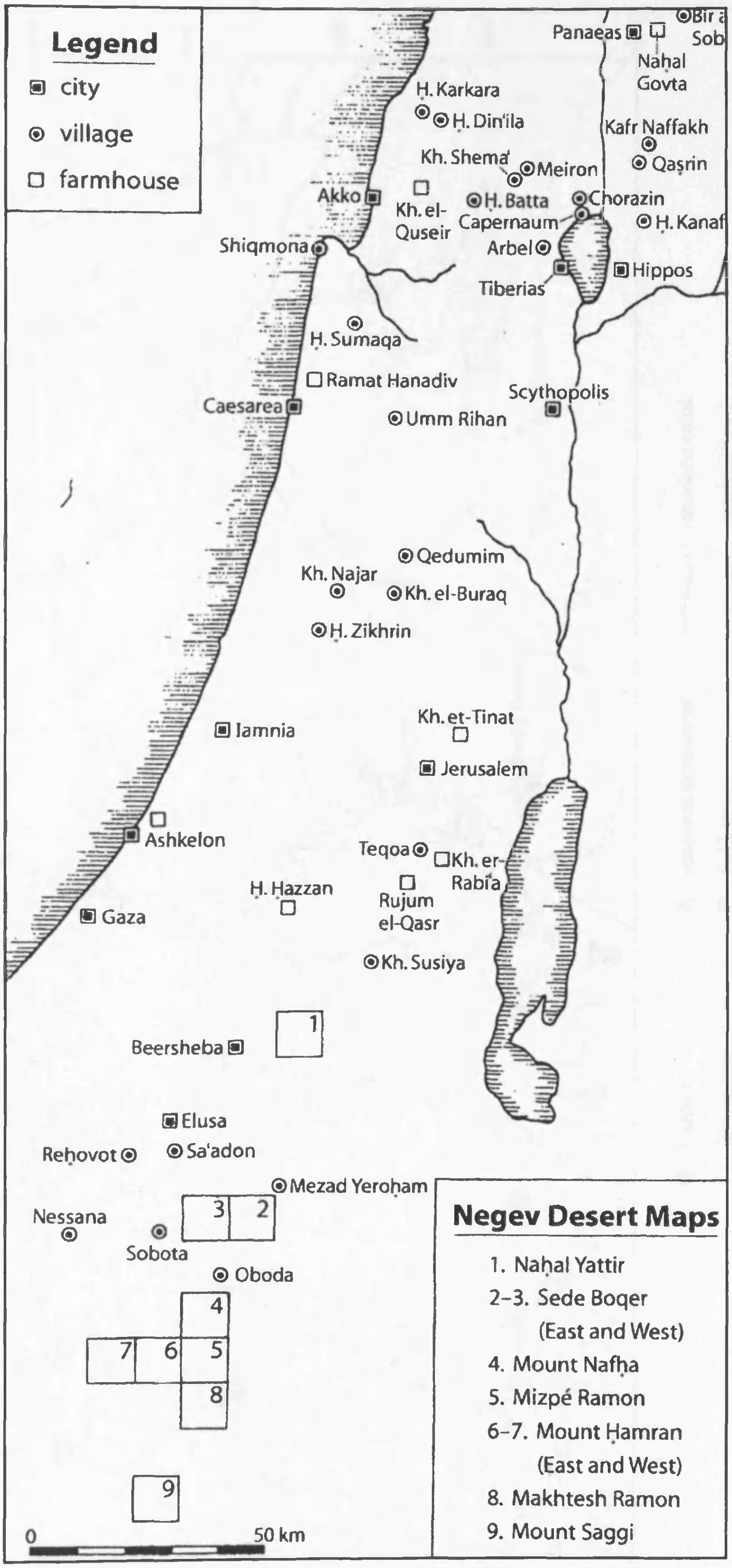

Figure 3.2 The relationship of the major settlements of the Negev, in the south, to settlements in Byzantine Palestine. In addition, are the areas surveyed by the Negev Emergency Survey (after Hirshfield 1997: Fig. 2).

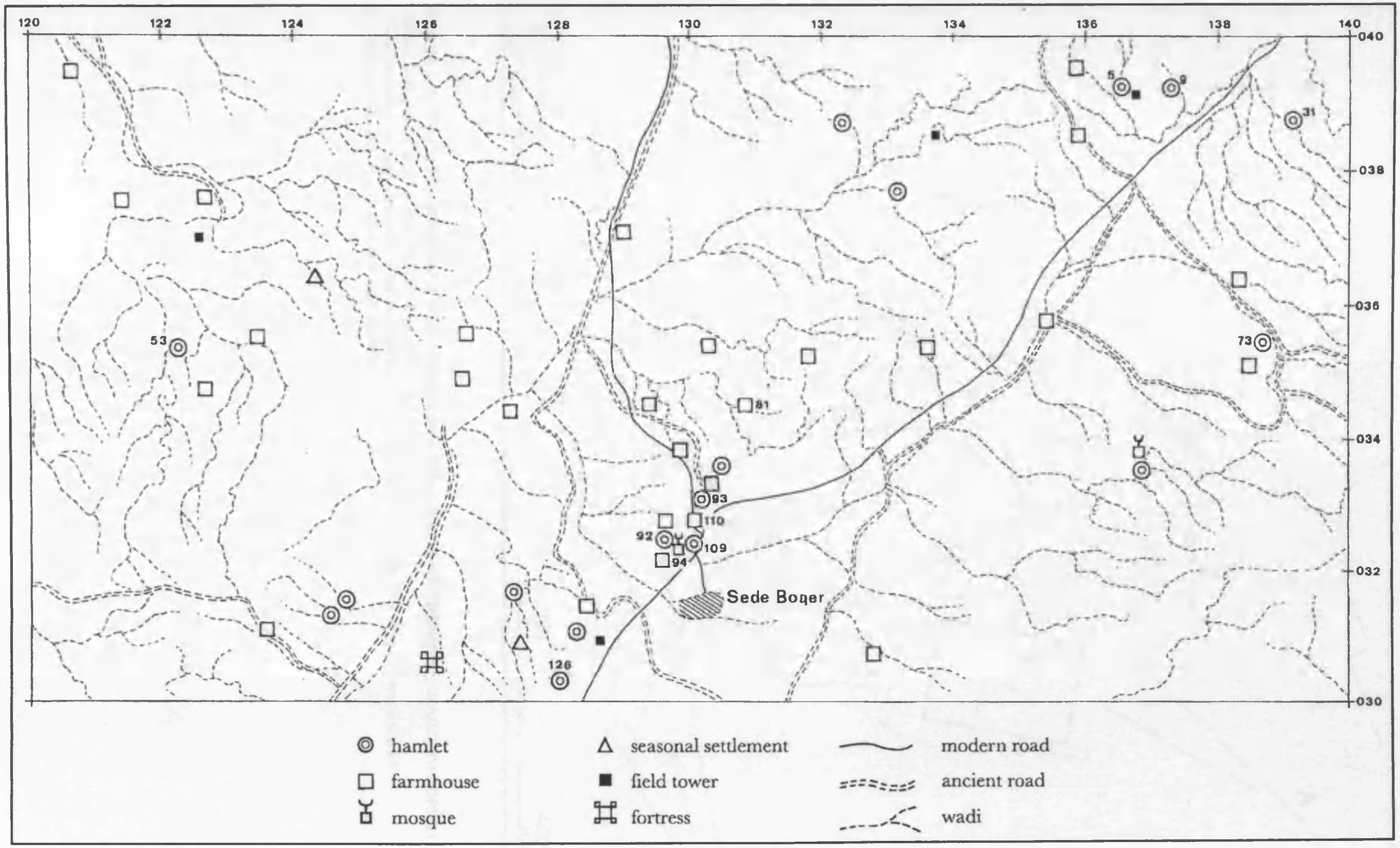

Figure 3.3 The Byzantine sites of the region of Sede Boqer (east and west), surveyed in the Negev Emergency Survey (after Hirschfield 1997, Fig. 45).

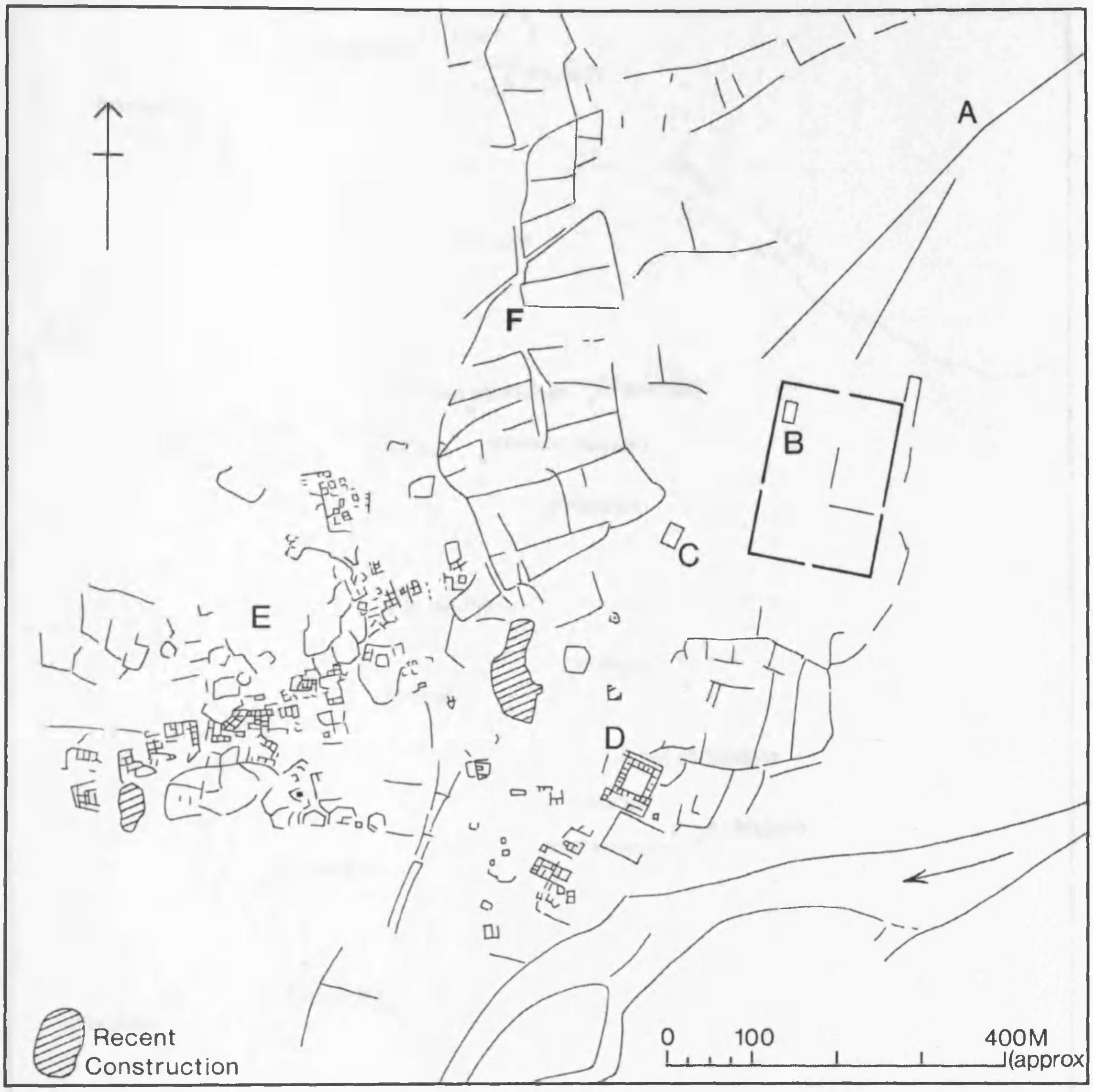

Figure 3.4 The settlement and water management systems at Humayma, southern Jordan. (after Kennedy and Riley 1990: 147, Fig. 90).
A = Aqueduct. B = Large fort with internal reservoir. C = Large open reservoir. D = Islamic caravanserai?
E = Main settlement. F = Floodwater field system

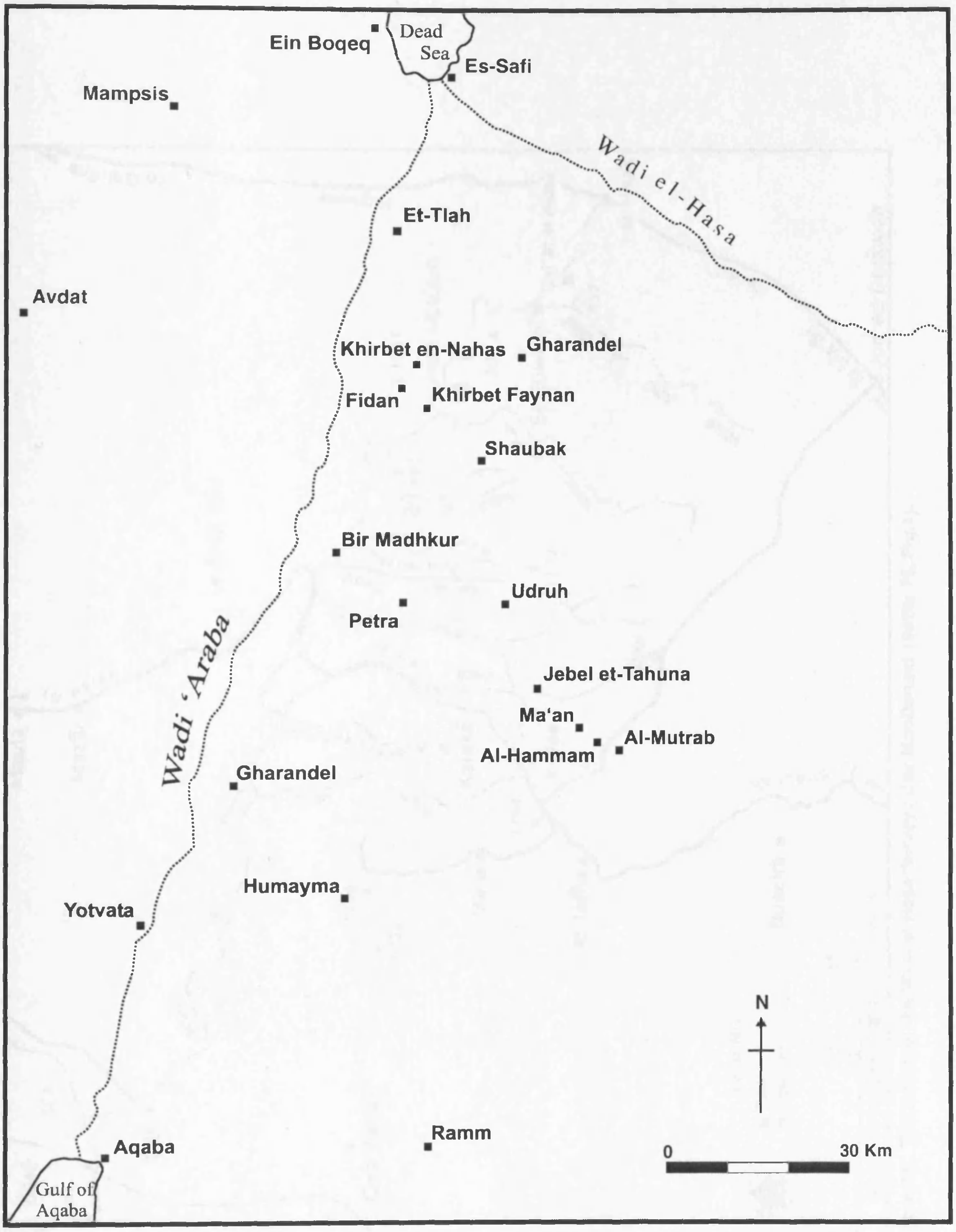

Figure 3.5 Major settlements of southern Transjordan mentioned in the text

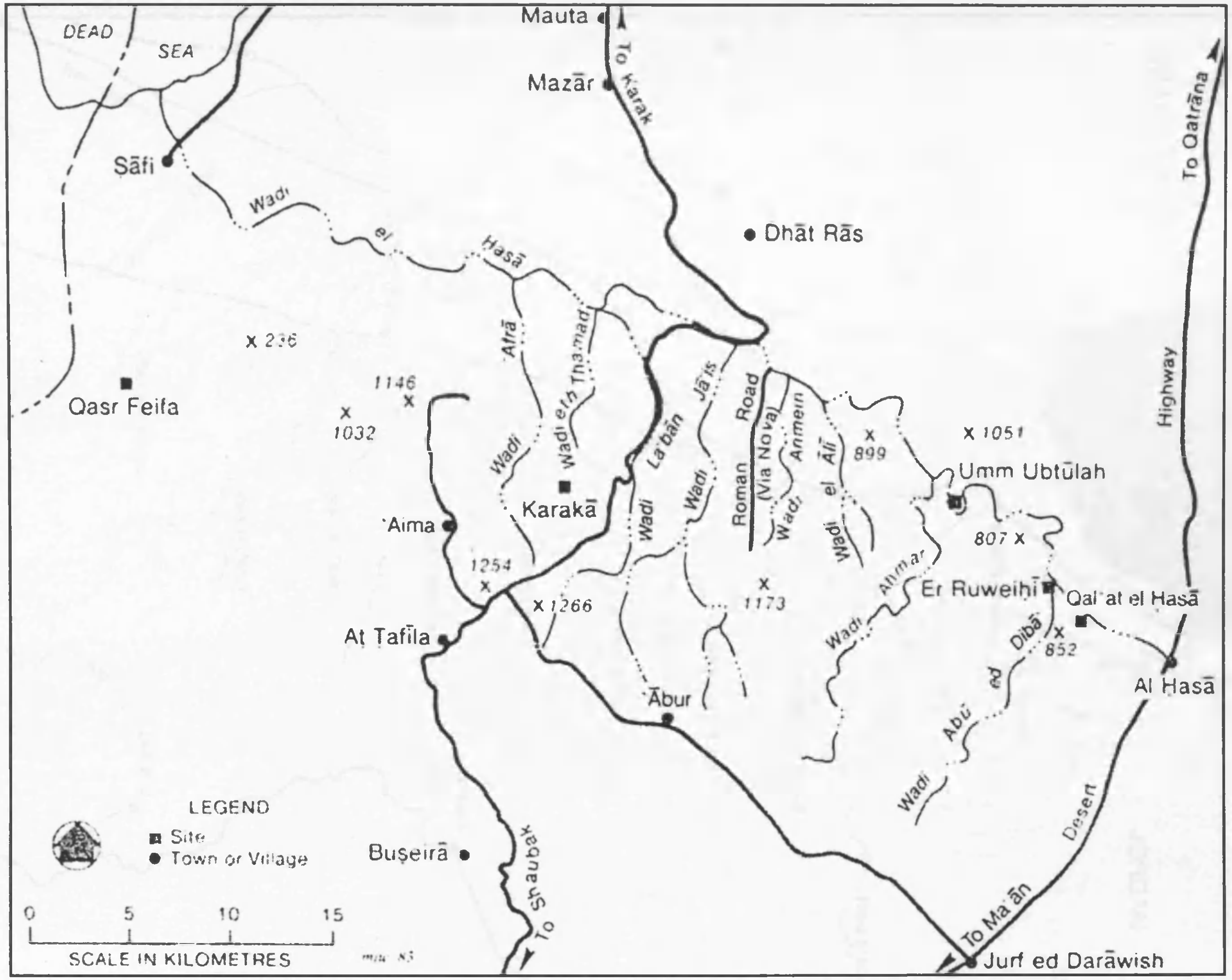

Figure 3.6 The region of the Wadi el-Hasa Survey (after MacDonald 1992b: 73, Fig.1).

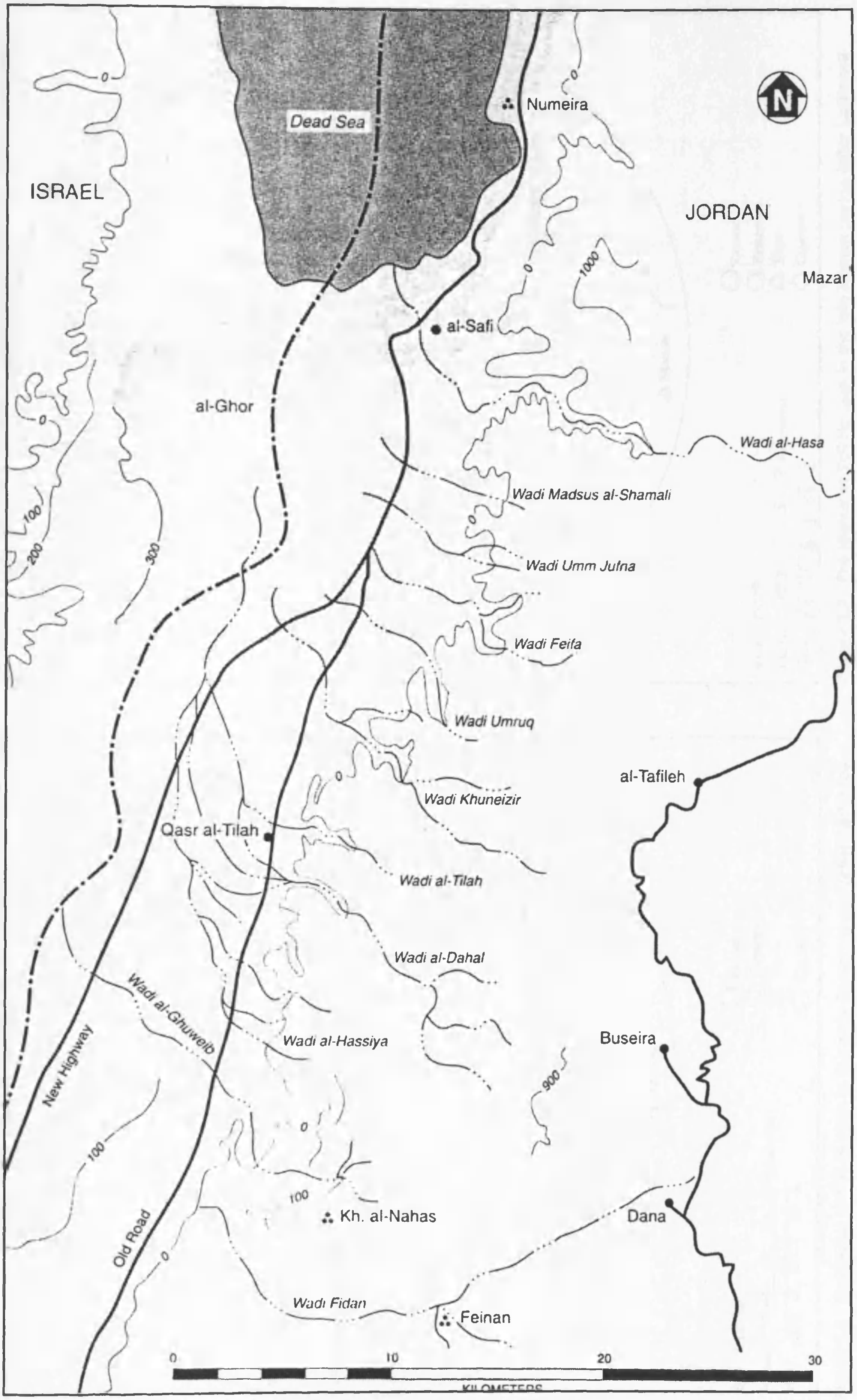

Figure 3.7 The region of the Southern Ghors Survey (after MacDonald 1992a: 2, Fig. 1).

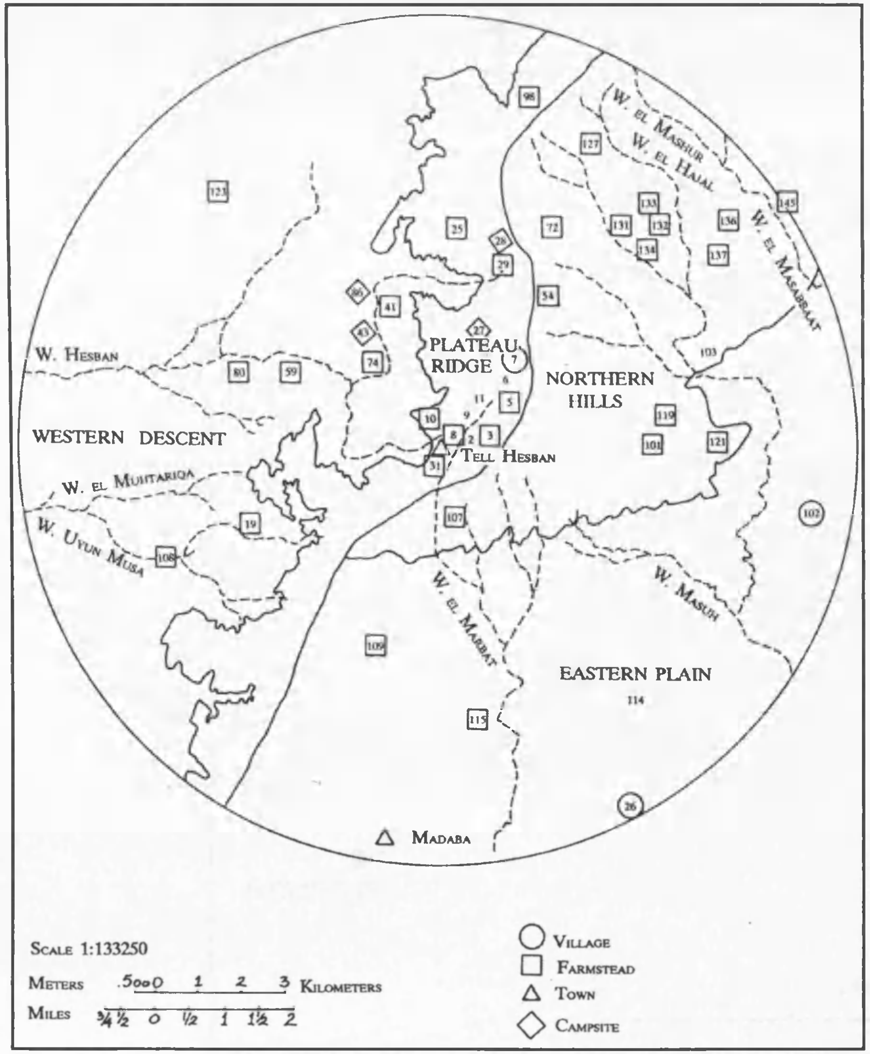

Figure 3.8 The region of Tell Hesban in the early Roman period (after LaBianca 1990: 171, Fig. 6.4).

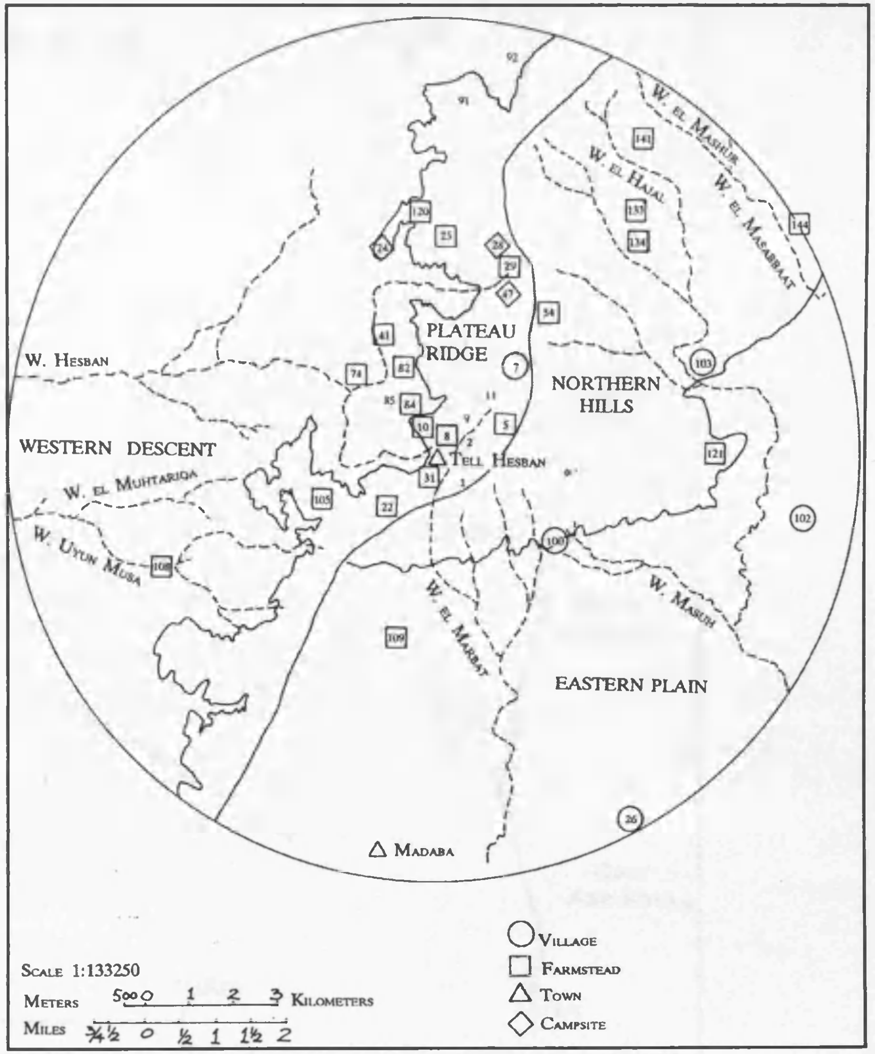

Figure 3.9 The region of Tell Hesban in the late Roman period (after LaBianca 1990: 174, Fig. 6.5).

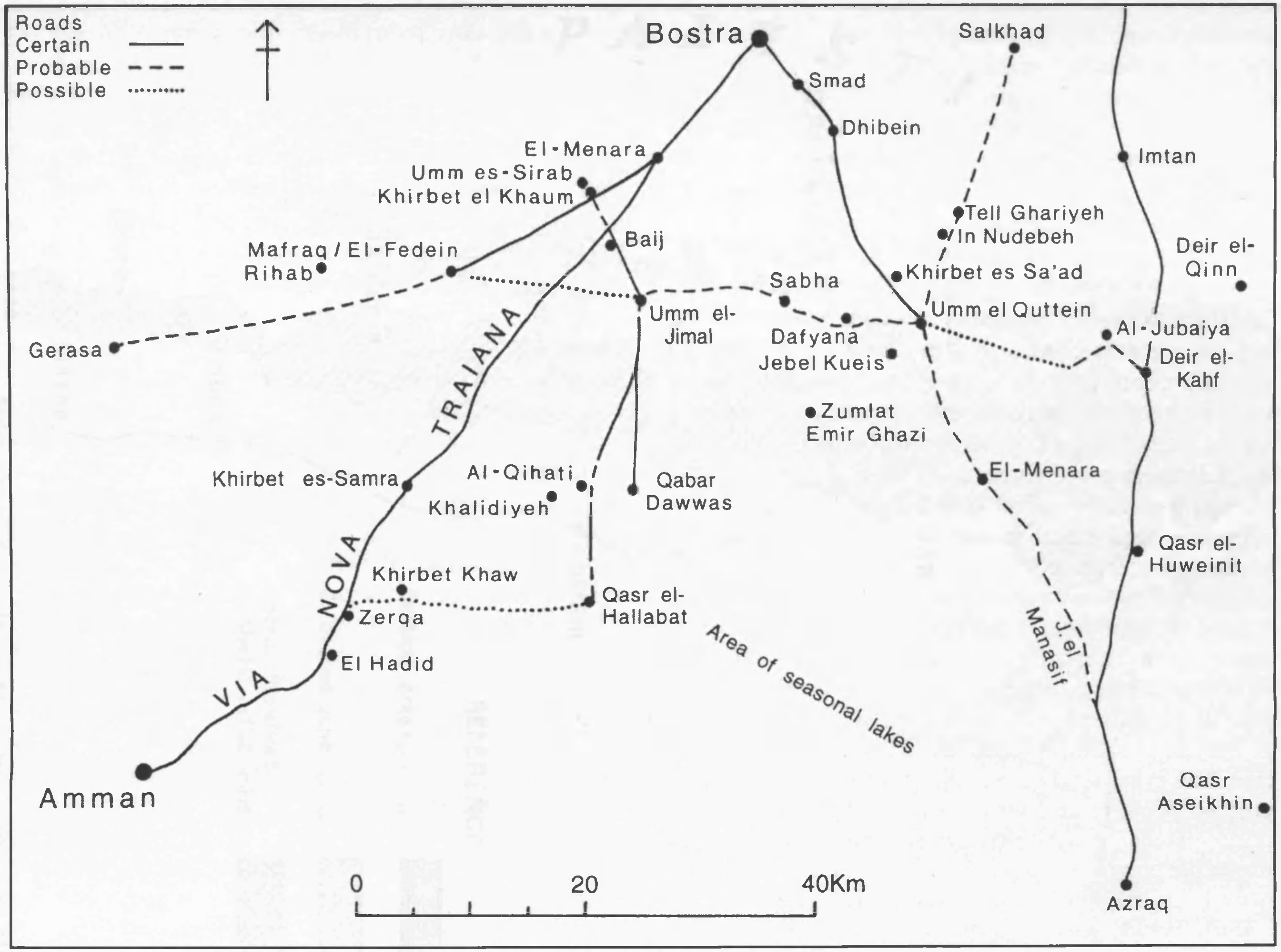

Figure 3.10 The region of the southern Hauran (after Kennedy 1995: 275, Fig.1).

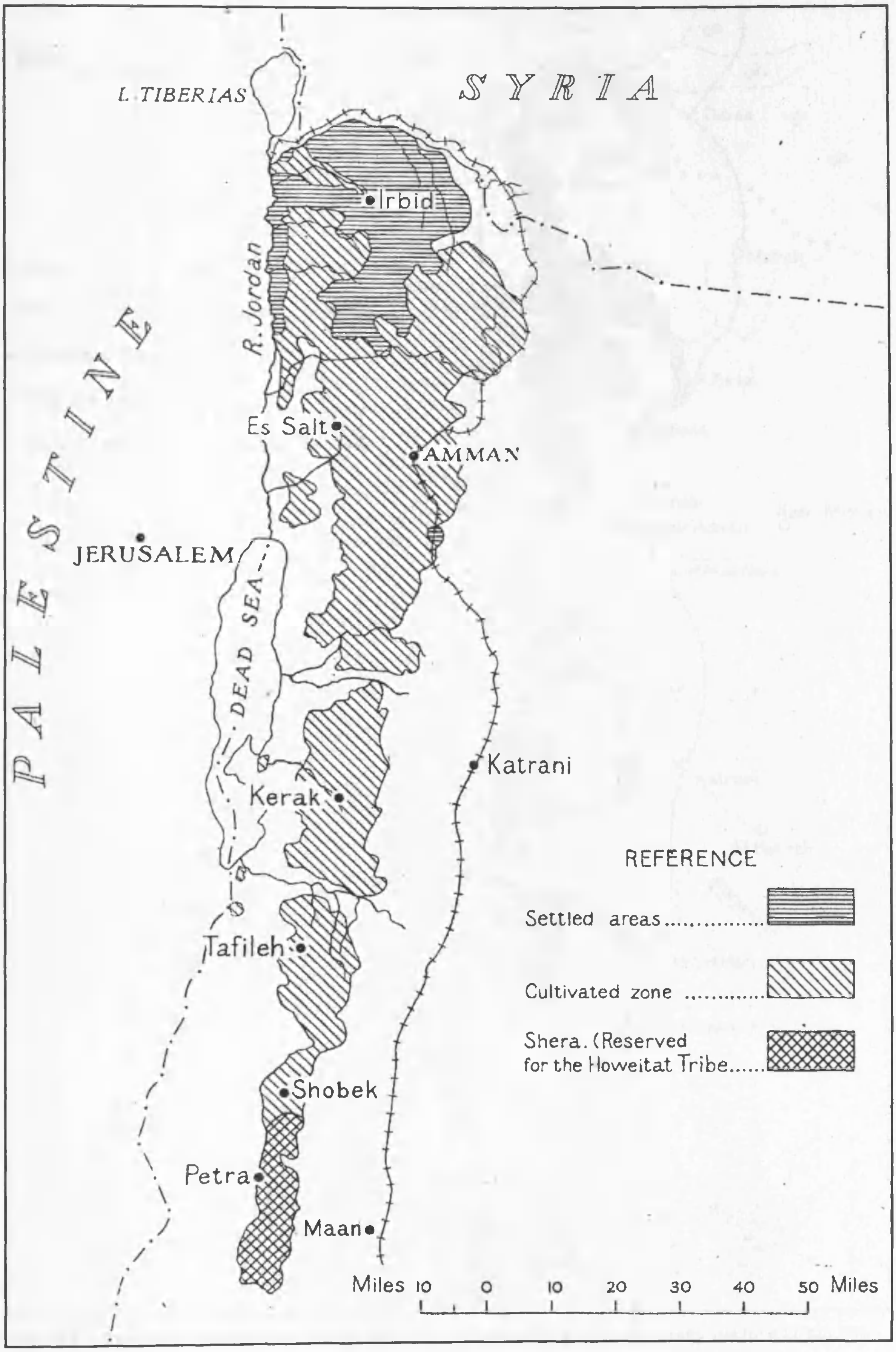

Figure 4.1 The settled regions of Jordan prior to deep-well drilling (after Admiralty 1943b: 486, Fig. 56).

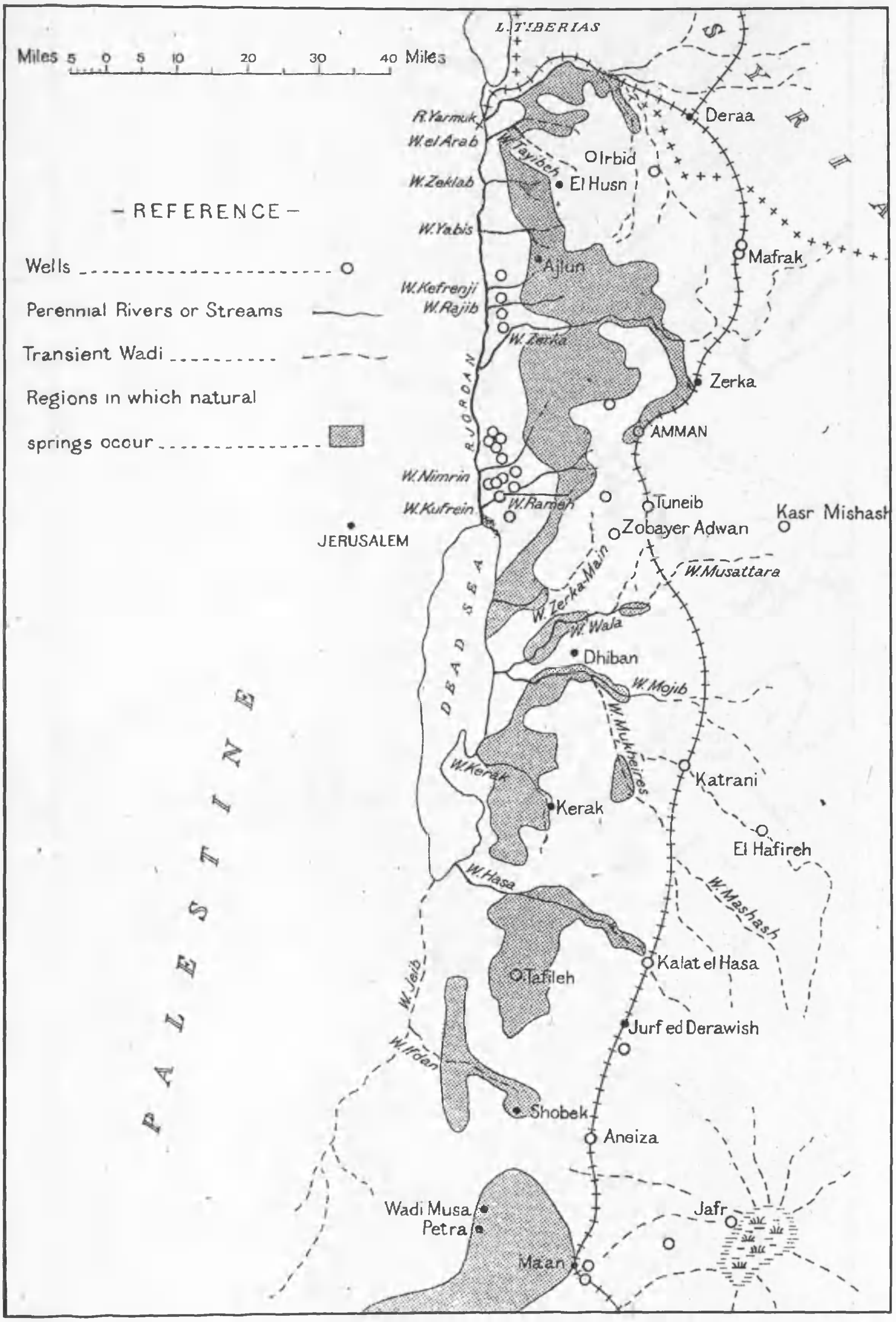

Figure 4.2 The water resources of Jordan prior to deep well drilling (after Admiralty 1943b: 490, Fig. 57).

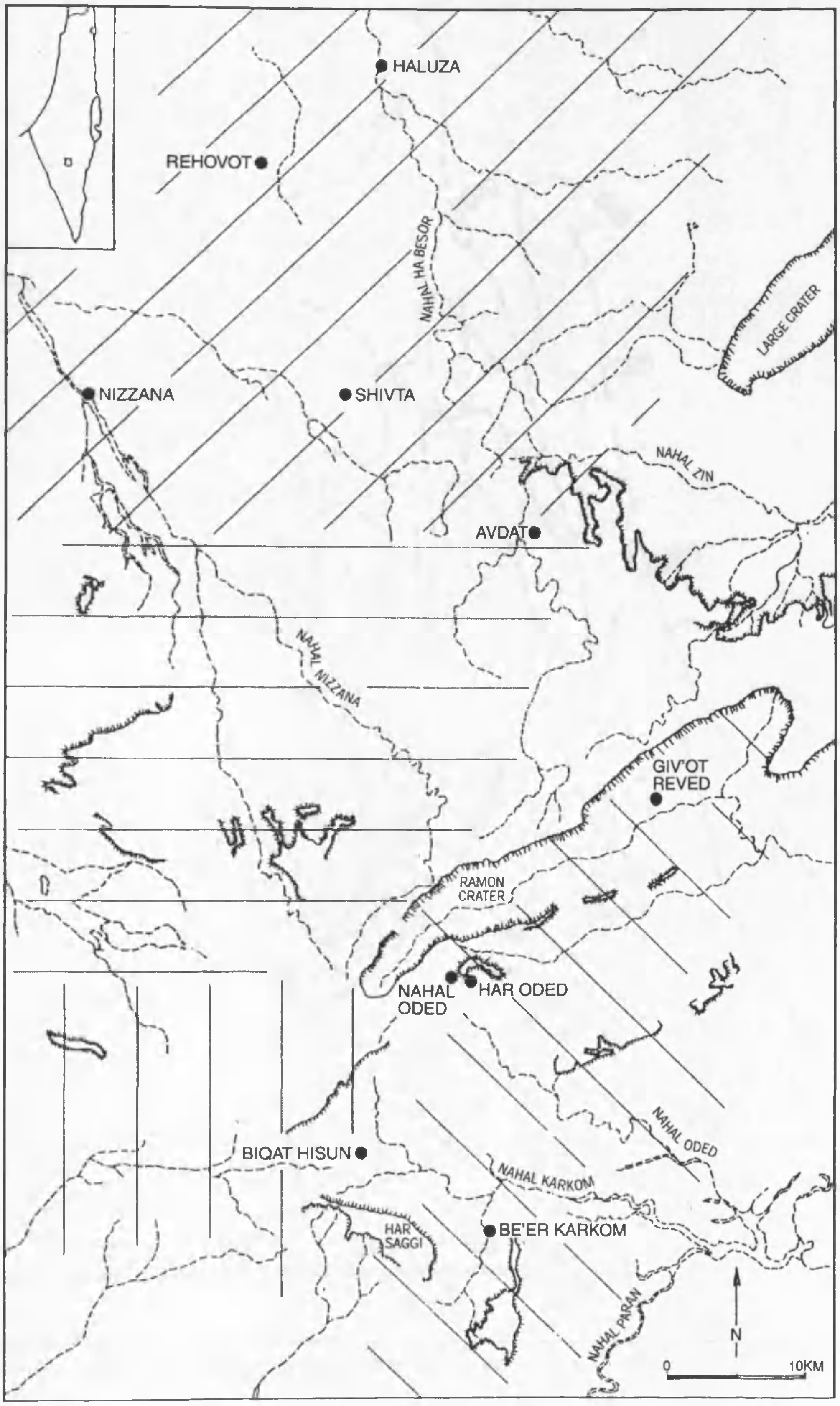

Figure 4.3 Settlement patterns within the central Negev during the late Byzantine and early Islamic periods. (after Rosen 2000: 48, Fig. 3.4)

/ / / = urban zone with agricultural support.
\ \ \ = pastoral nomadic region with no agricultural evidence.
| | | = agro-pastoral regions: pastoral sites & agricultural evidence.

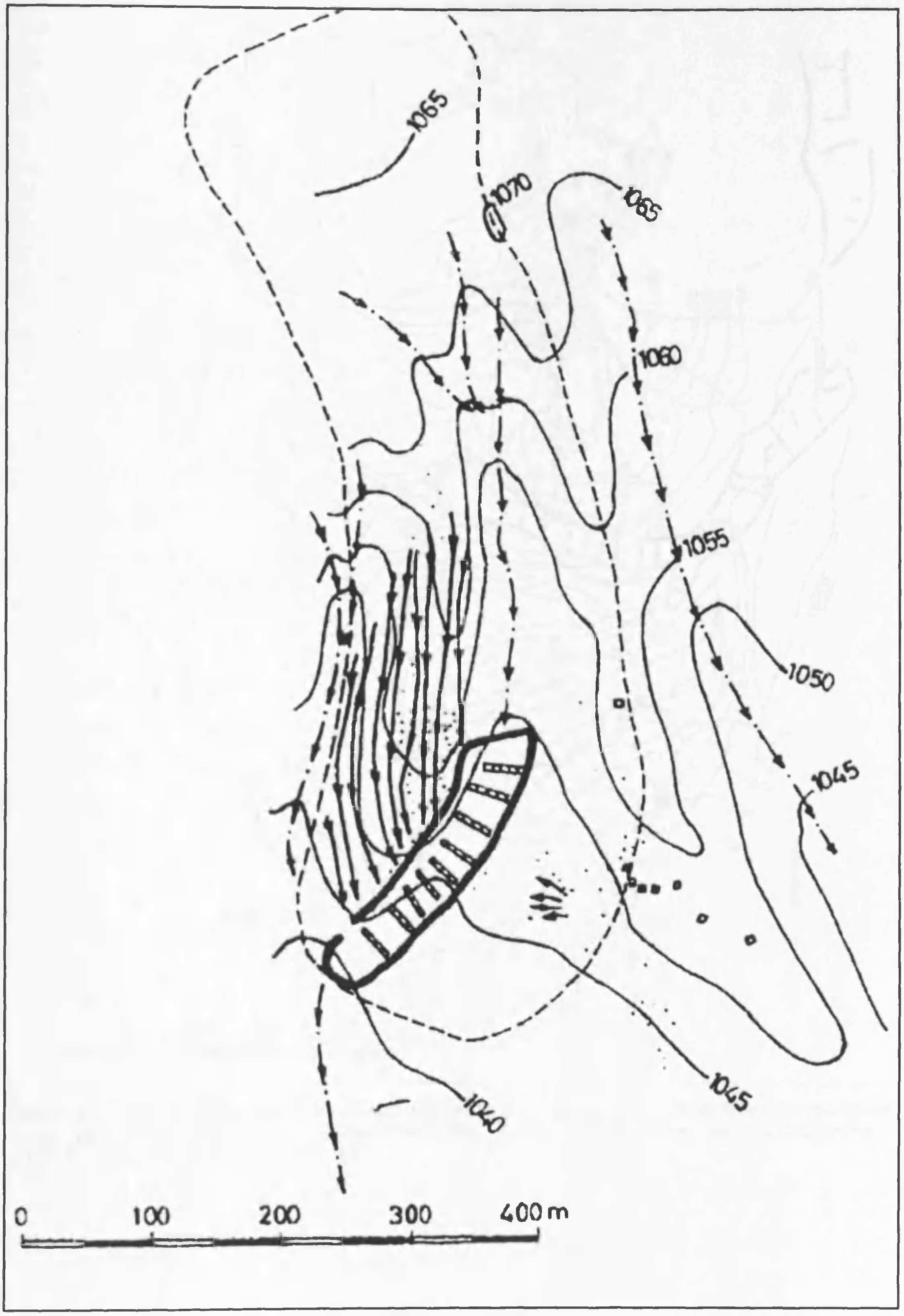

Figure 4.4 'Yorams' farm (after Evenari *et al.* 1982: 102, Fig. 68).

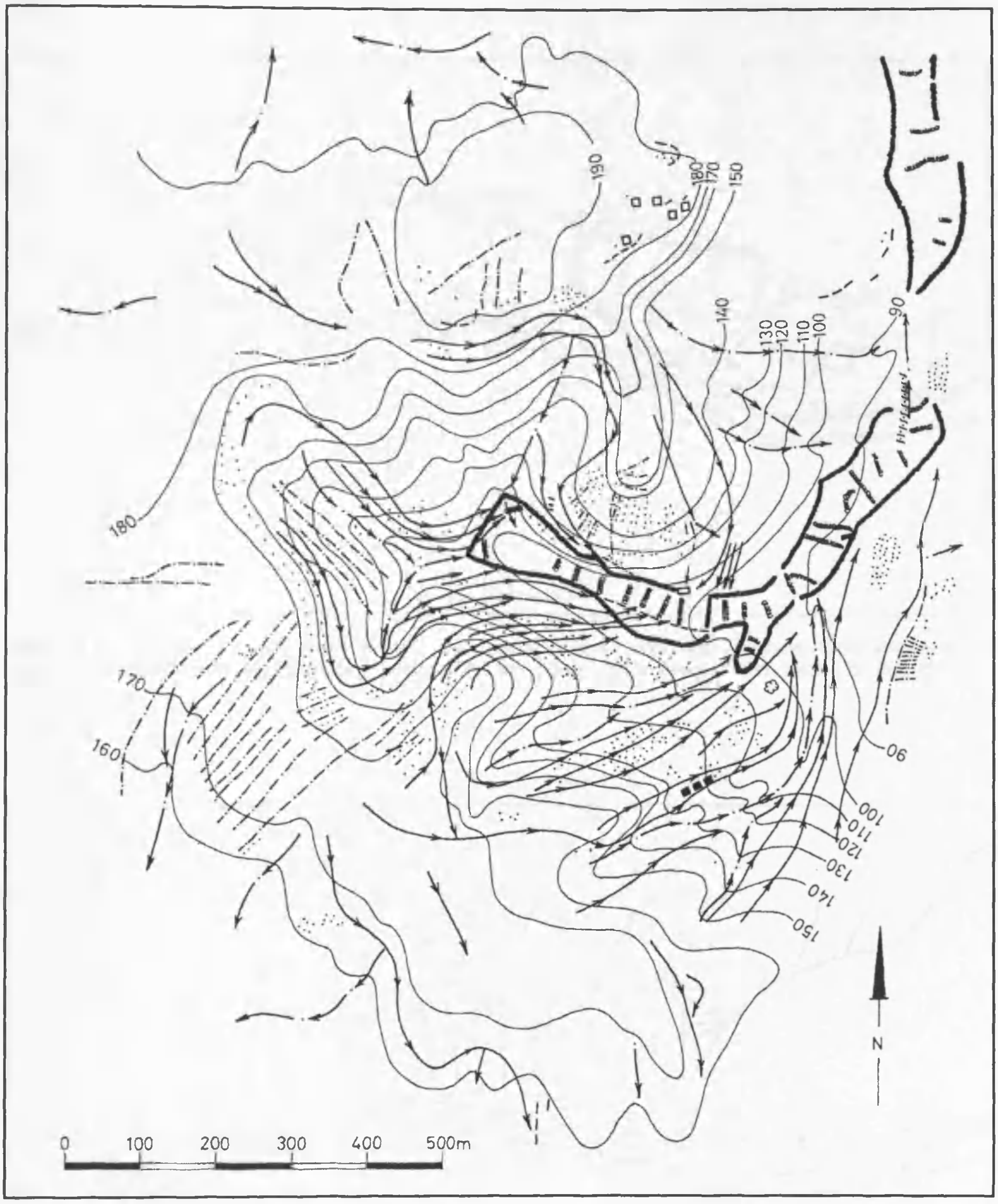

Figure 4.5 Plan of 'Yehudas' farm. The solid black line represents a stone fence surrounding cross-wadi walls, solid arrows are water conduits. Arrows with dots are small wadi courses. (after Evenari *et al.* 1982: 106, Fig. 71).

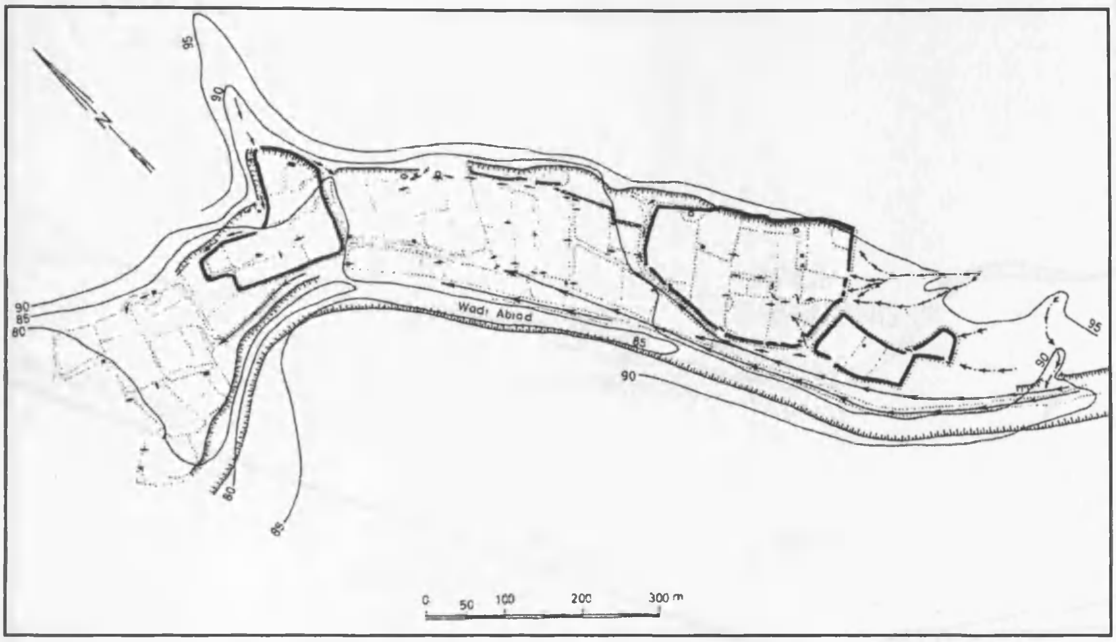

Figure 4.6 Survey of field system in Nahal Lavan. Long arrows = diversion channels. Short arrows = spillways stage II. Heavy-lined areas = runoff farms of stage III (after Evenari *et al.* 1982: 112, Fig. 75).

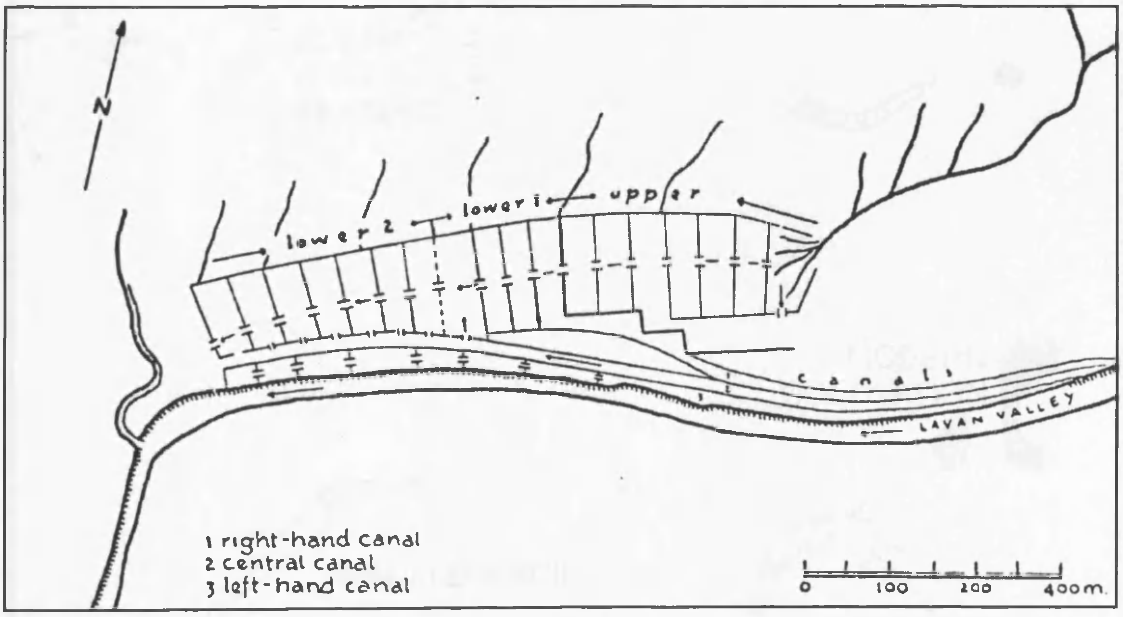

Figure 4.7 The Nahal Lavan field system as surveyed by Kedar (after Kedar 1957: 182, Fig. 2).

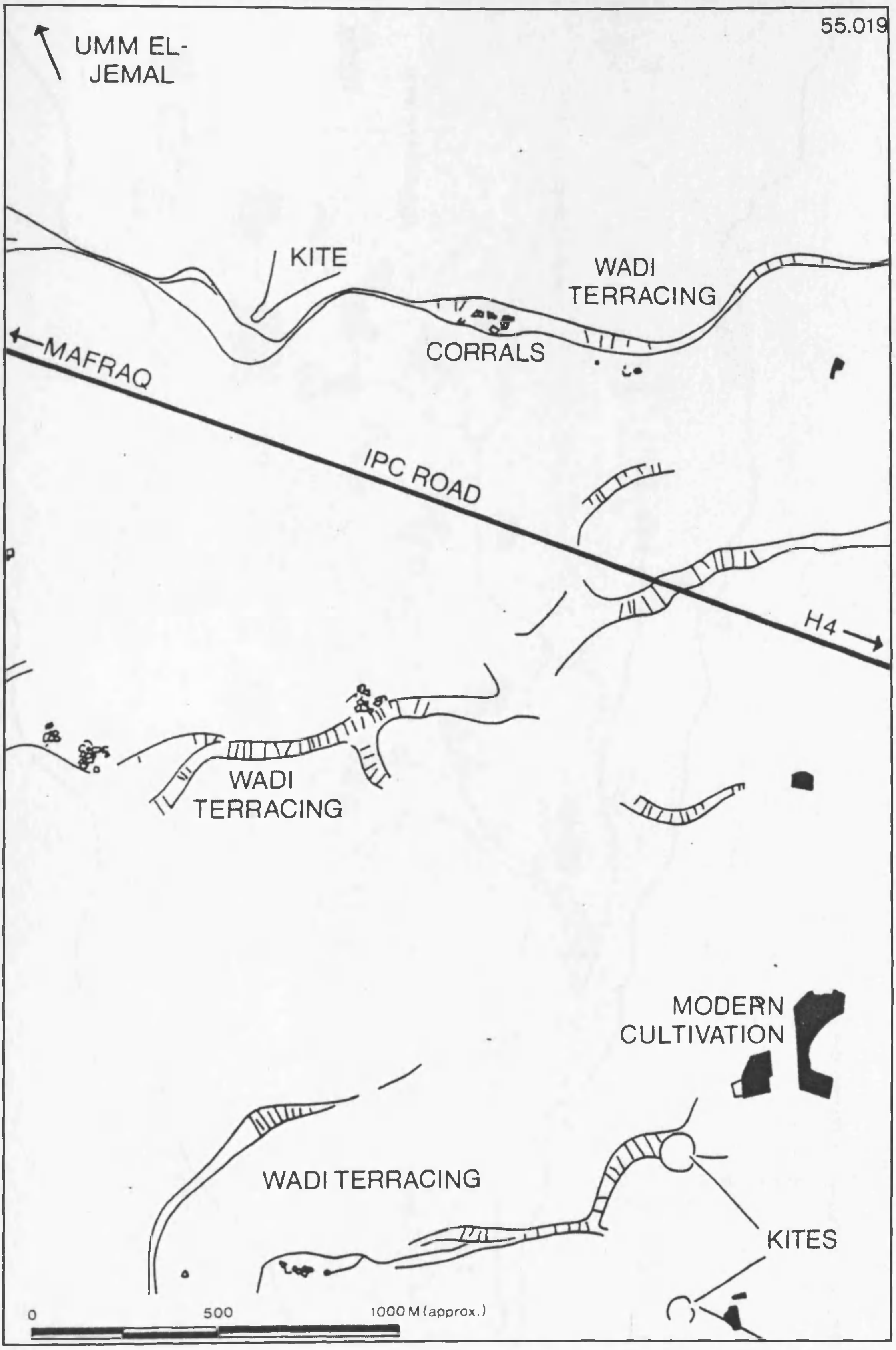

Figure 4.8 Cross-wadi wall systems southeast of Umm el-Jimal in the southern Hauran (after Kennedy 1982: 336, Fig. 44).

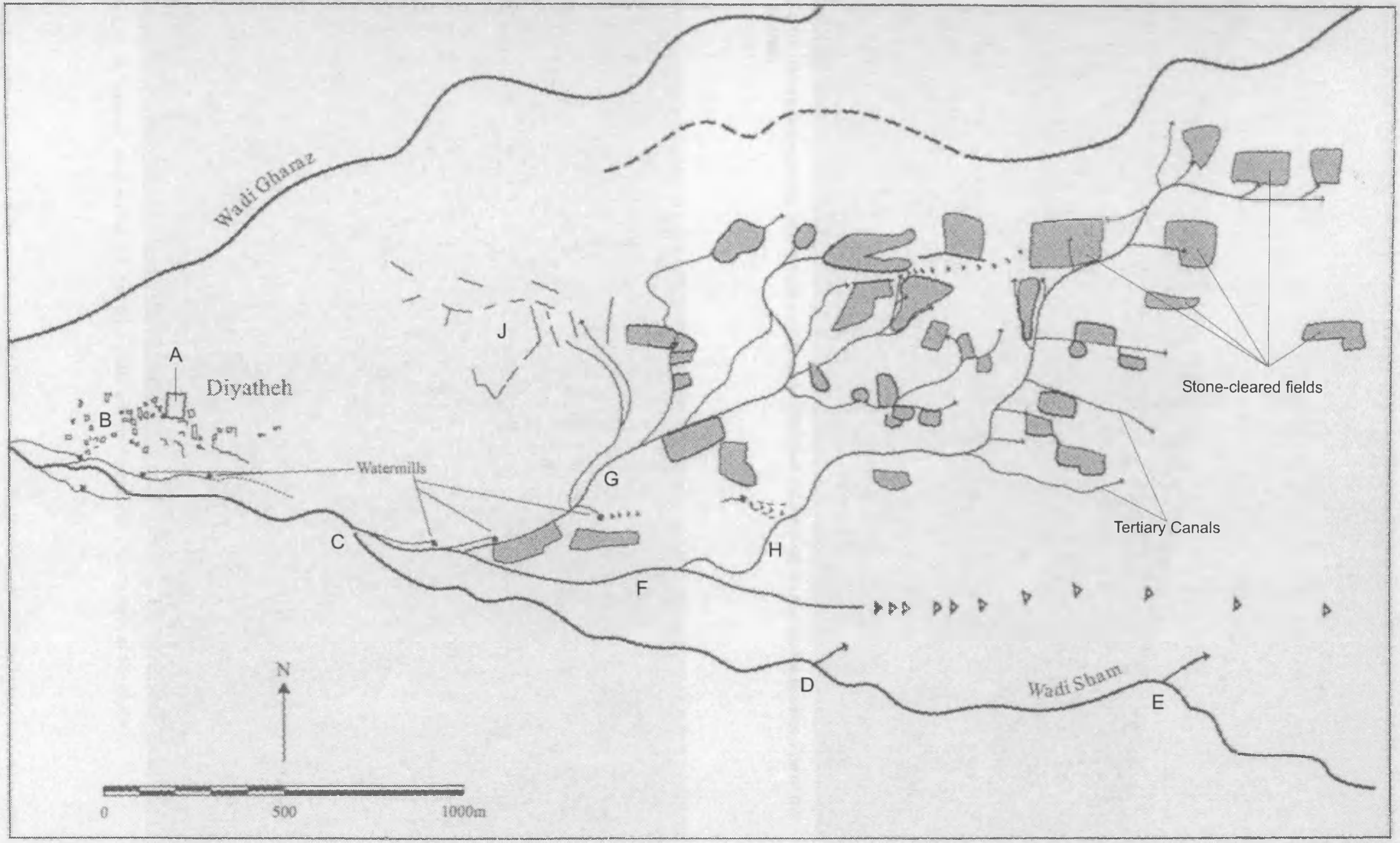

Figure 4.9 The field system at ad-Diyatheh, Syria (after Sadler 1993)

Figure 4.10 The remains of the basalt-built village of ad-Diyatheh by the wadi Cham, on the eastern side of the Jebel al-Arab.

Figure 4.11 A 'cleared' field on the left, fed by a water channel which runs to the right of the picture.

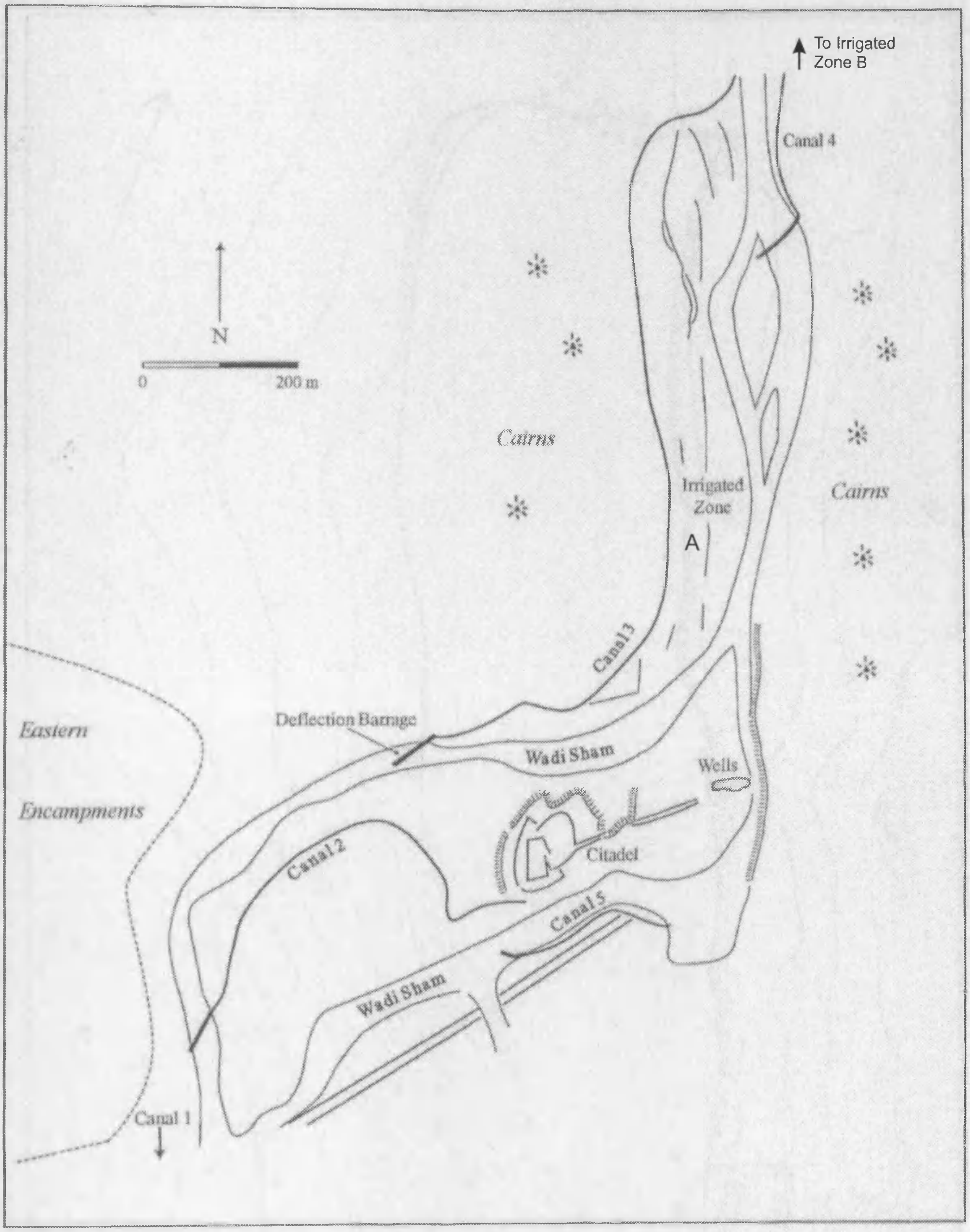

Figure 4.12 The site of al-Namara and associated field systems (after Braemer *et al.* 1996b).

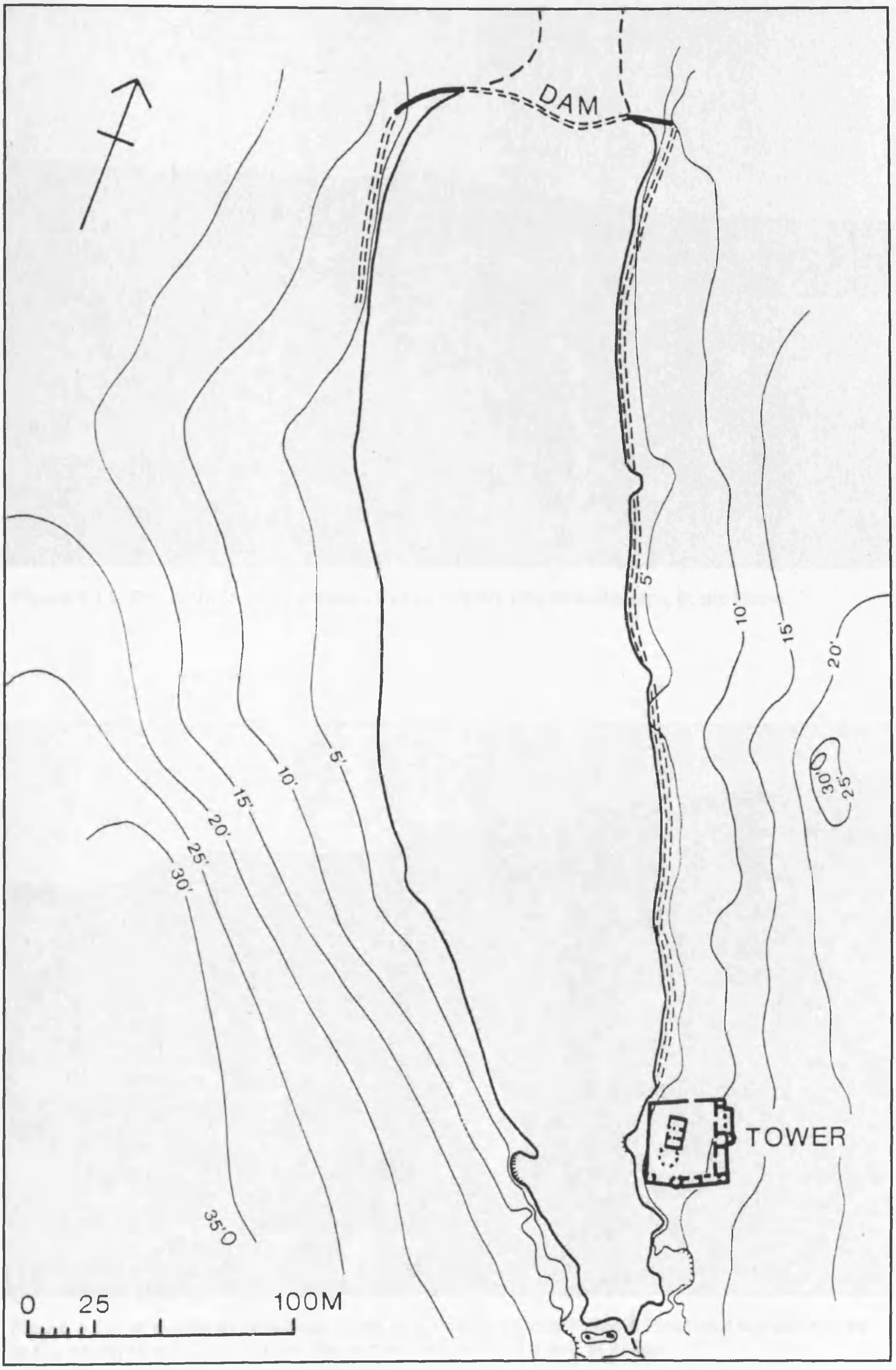

Figure 4.13 The artificial lake at the site of qasr Burqu', Jordan (after Kennedy and Riley 1990).

Figure 4.14 The main irrigation canal, Canal 3 at the site of al-Nemara, in the Harra.

Figure 4.15 A series of small aqueduct fed, irrigated fields in Wadi Ruseidah ten kilometres to the south of ad-Diyatheh, on the eastern edge of the Jebal al-Arab.

Figure 4.16 The spring fed field system to the north of the site of the settlement at Udruh (after Kennedy and Riley 1990: 132, Fig. 79).

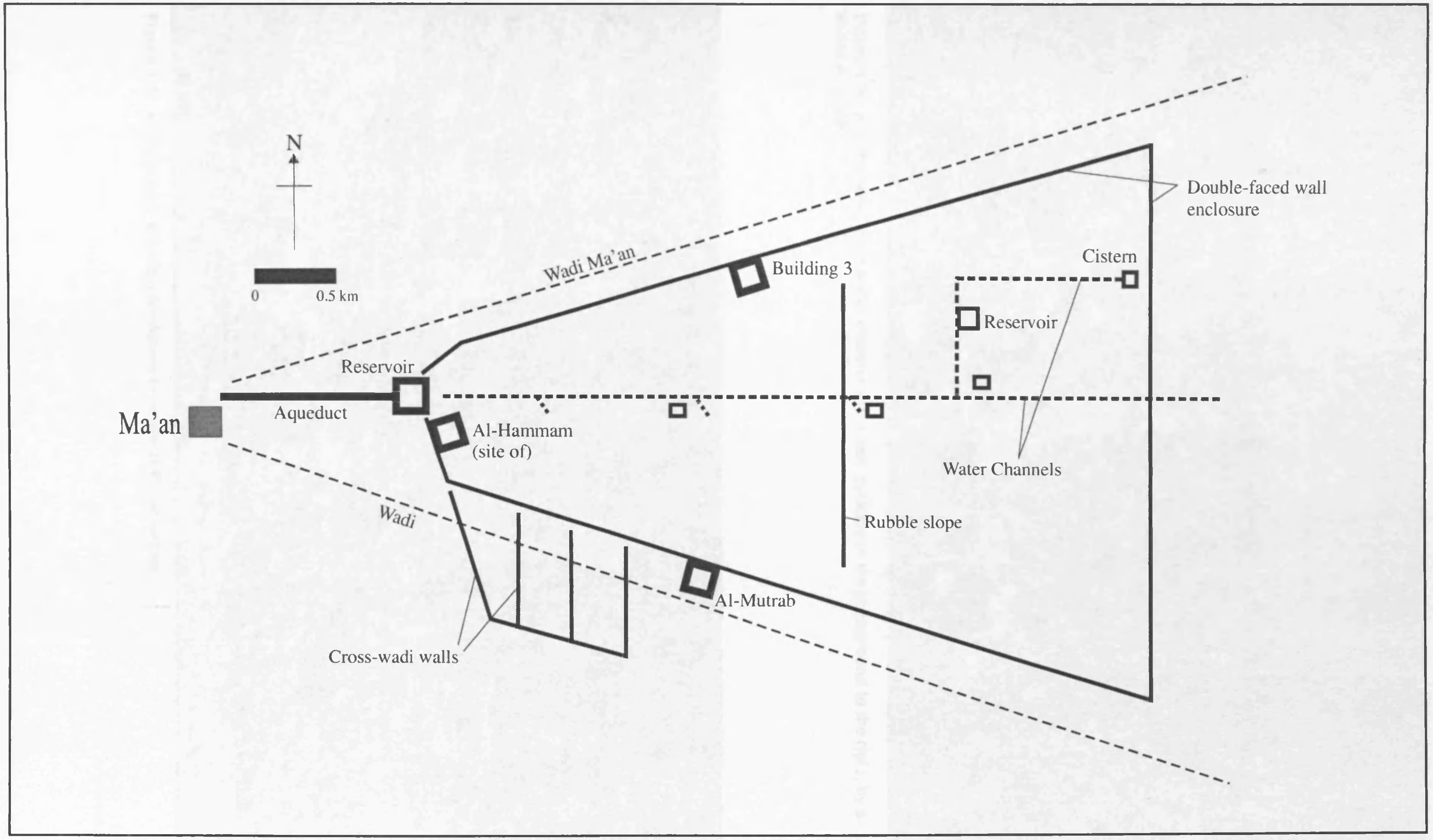

Figure 4.19 A schematic plan of the irrigated estate of al-Hammam east of Ma'an, southern Jordan.

Figure 4.20 al-Hammam: main water channel and small building in the background to the right, by a sluice junction.

Figure 4.21 al-Hammam: showing construction style of the aqueduct.

Figure 4.22 DAS site number 265: a village on the eastern edge of the settled region of the Edom plateau. In the foreground a bare rock threshing floor. Beyond in the distance, modern deep-well fed olive and fruit goves.

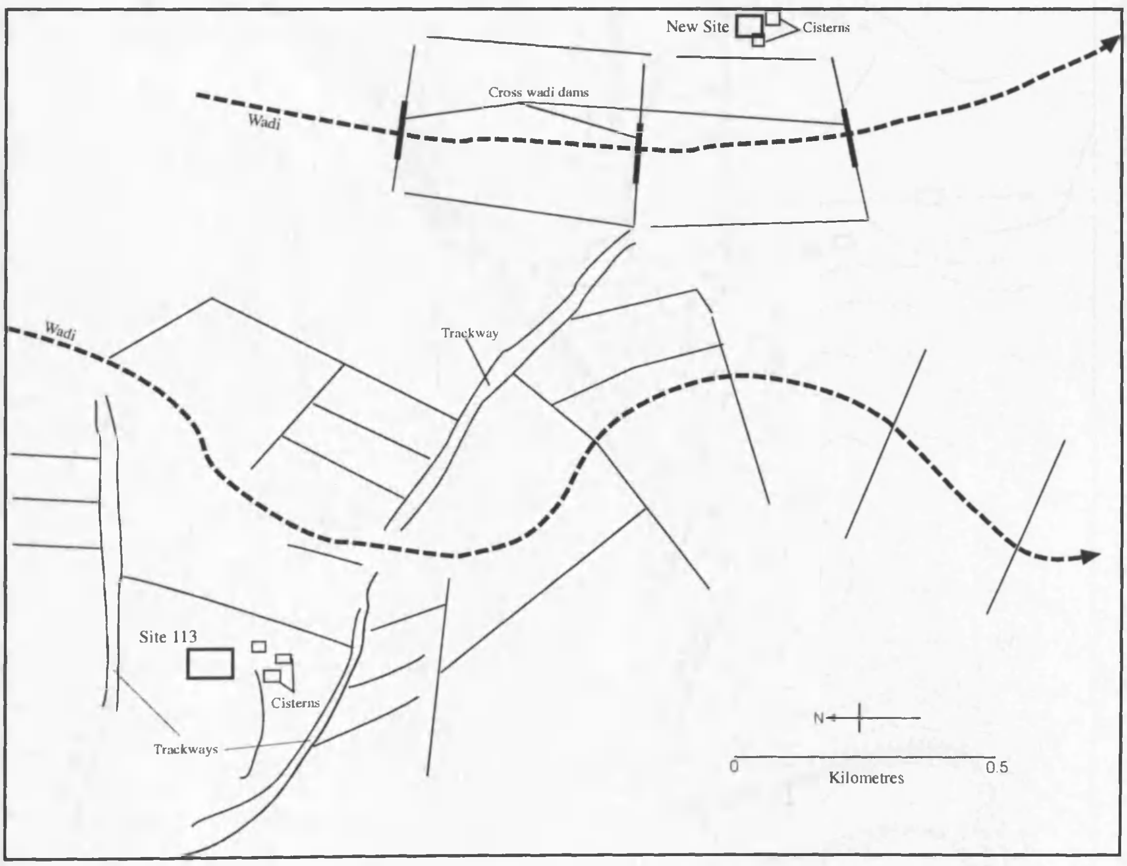

Figure 4.23 DAS site 113: a well-developed cross-wadi wall farming system by the via nova, and overlooking the escarpment near Dana, with Wadi Faynan to the east.

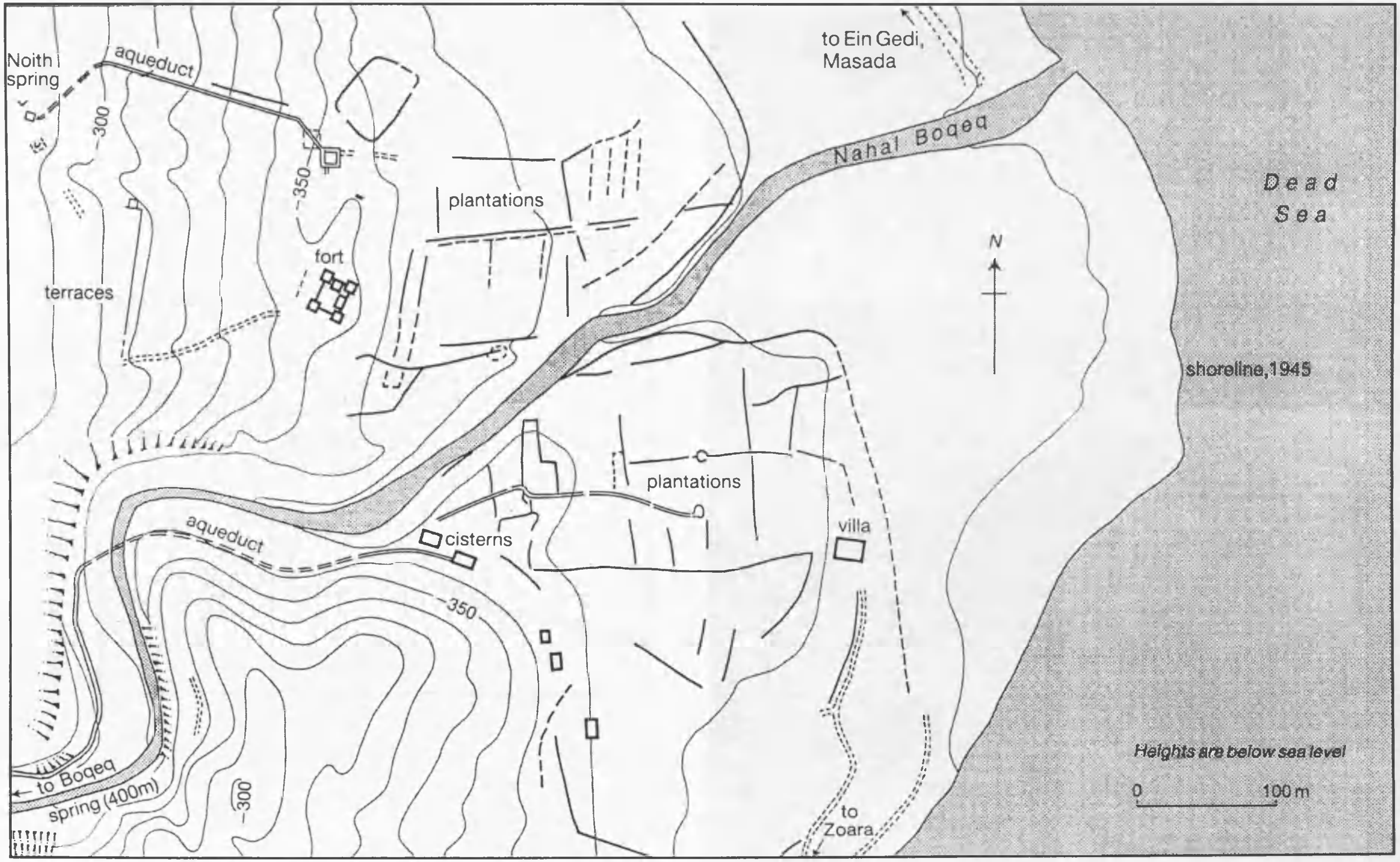

Figure 4.24 Ein Boqeq: the relative position of irrigated plantations, oasis and castellum (after Isaac 1990: 190, Fig. 5)

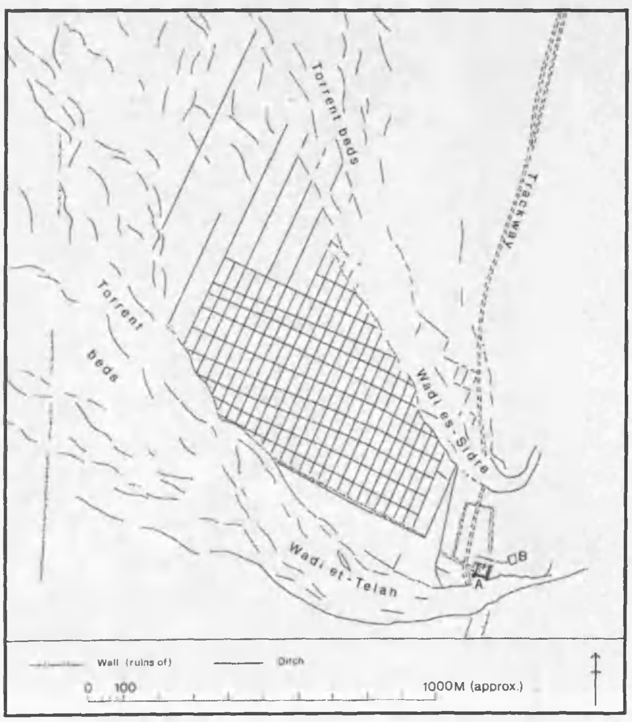

Figure 4.25 et-Tlah: the lattice field system (after Kennedy and Riley 1990: 206-07, Figs 157 and158).

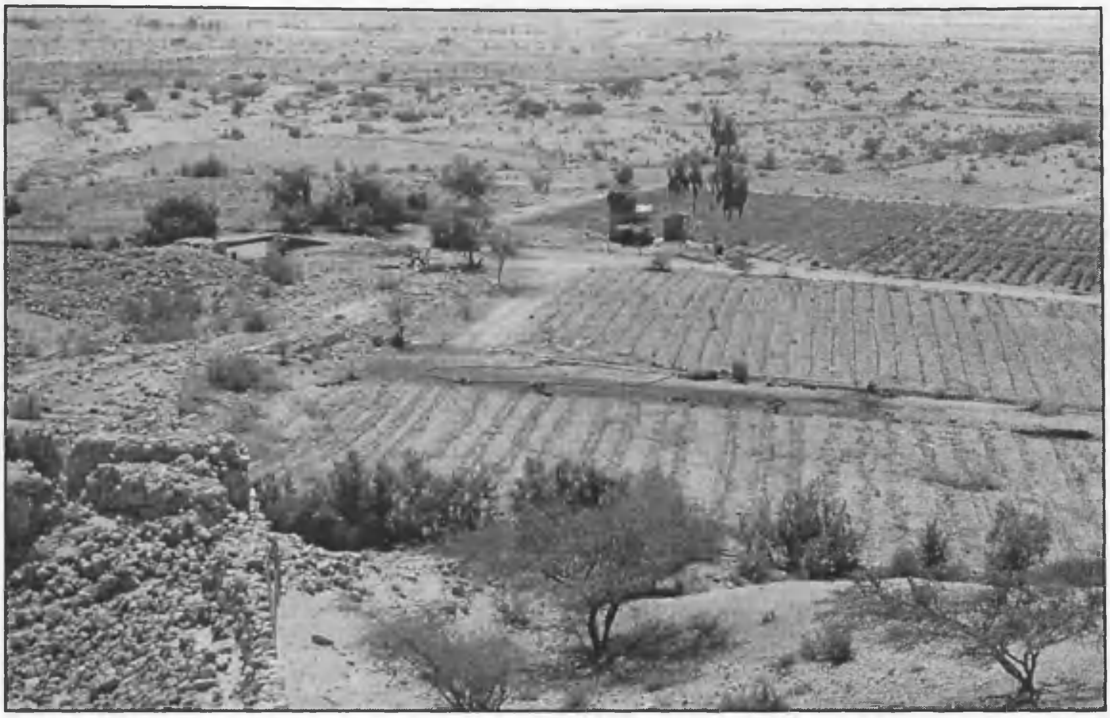

Figure 4.26 et-Tlah: the site of the grid-field system as it is today.

Figure 4.27 et-Tlah: the construction style of the reservoir, which seems similar to that of al-Hammam.

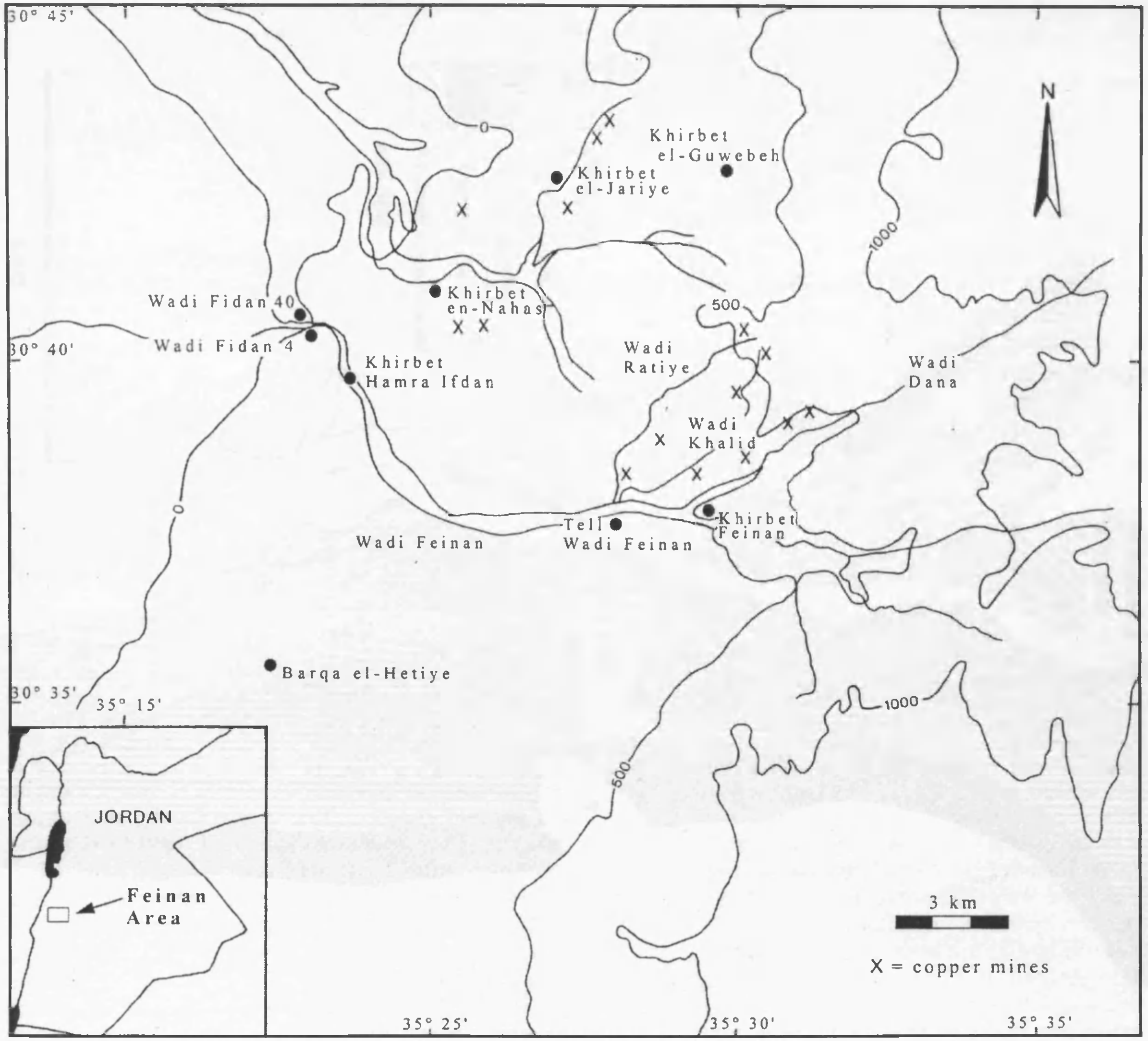

Figure 5.1 The immediate environs of Wadi Faynan (after Levy *et al.* 1999: 294, Fig.1).

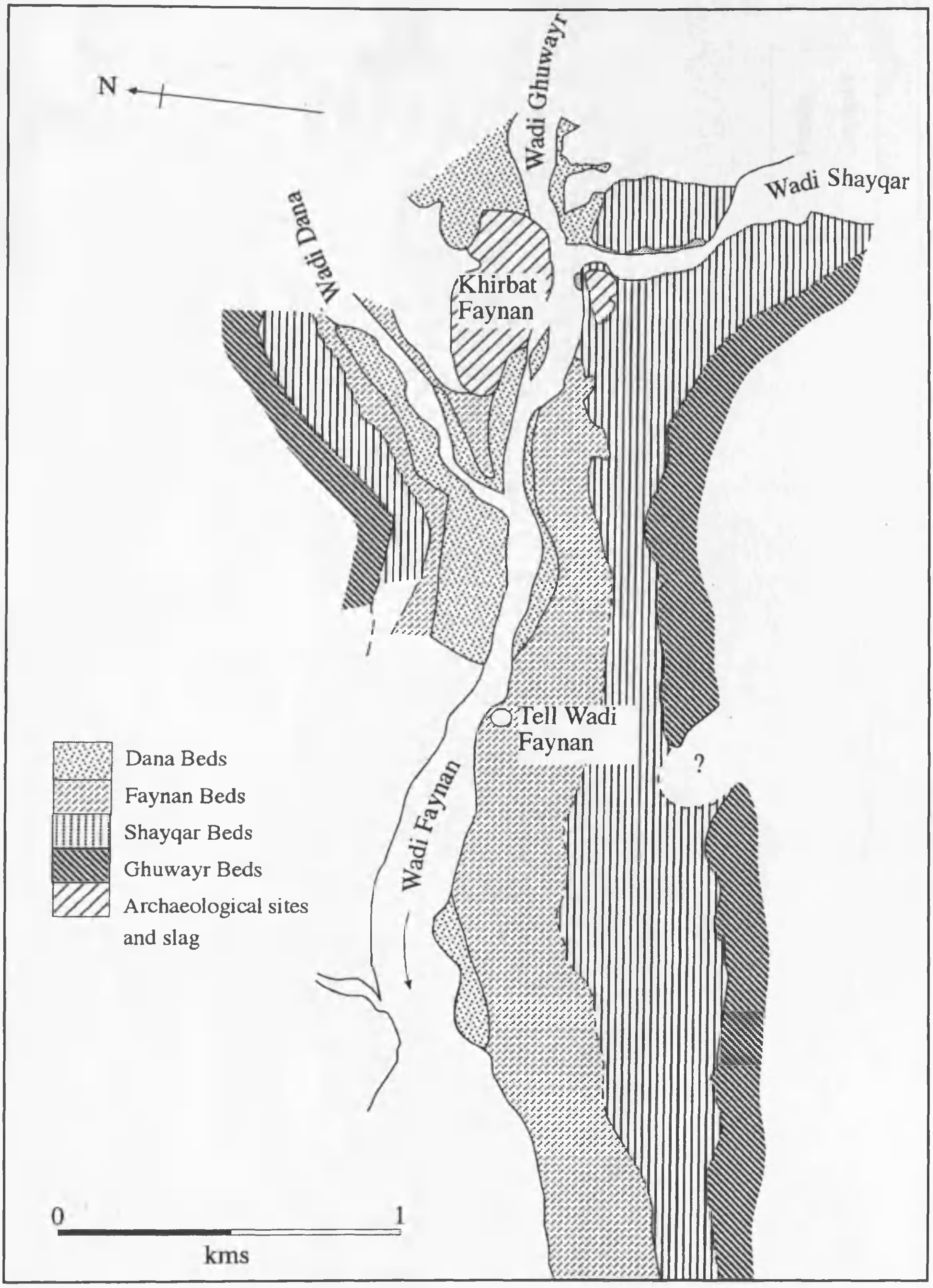

Figure 5.2 A simplified geomorphological study of the Wadi Faynan valley, showing the confluence of the three main wadis (after Barker *et al.* 1997: 25, Fig. 5).

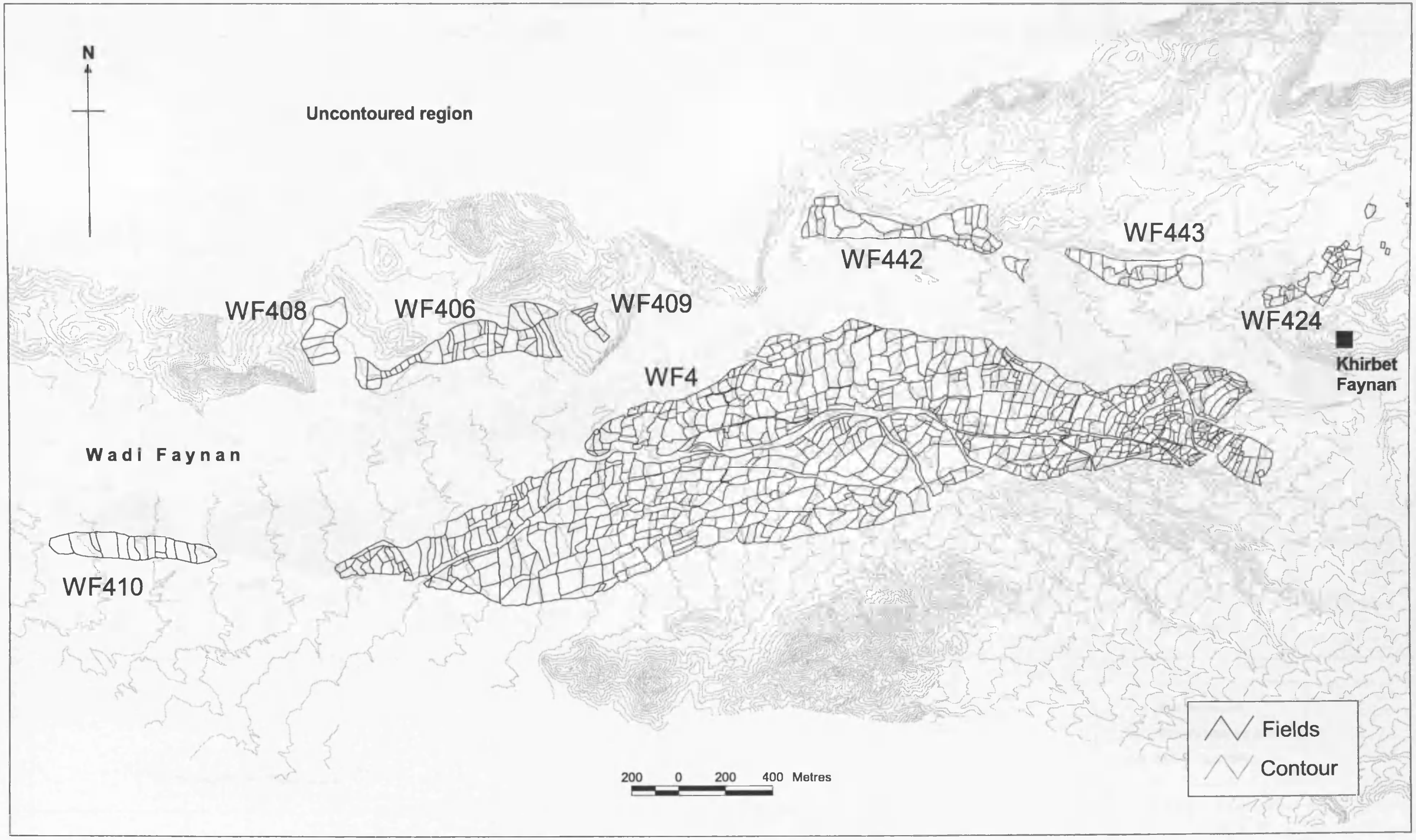

Figure 5.3 The main field systems surveyed by the Wadi Faynan Landscape Survey

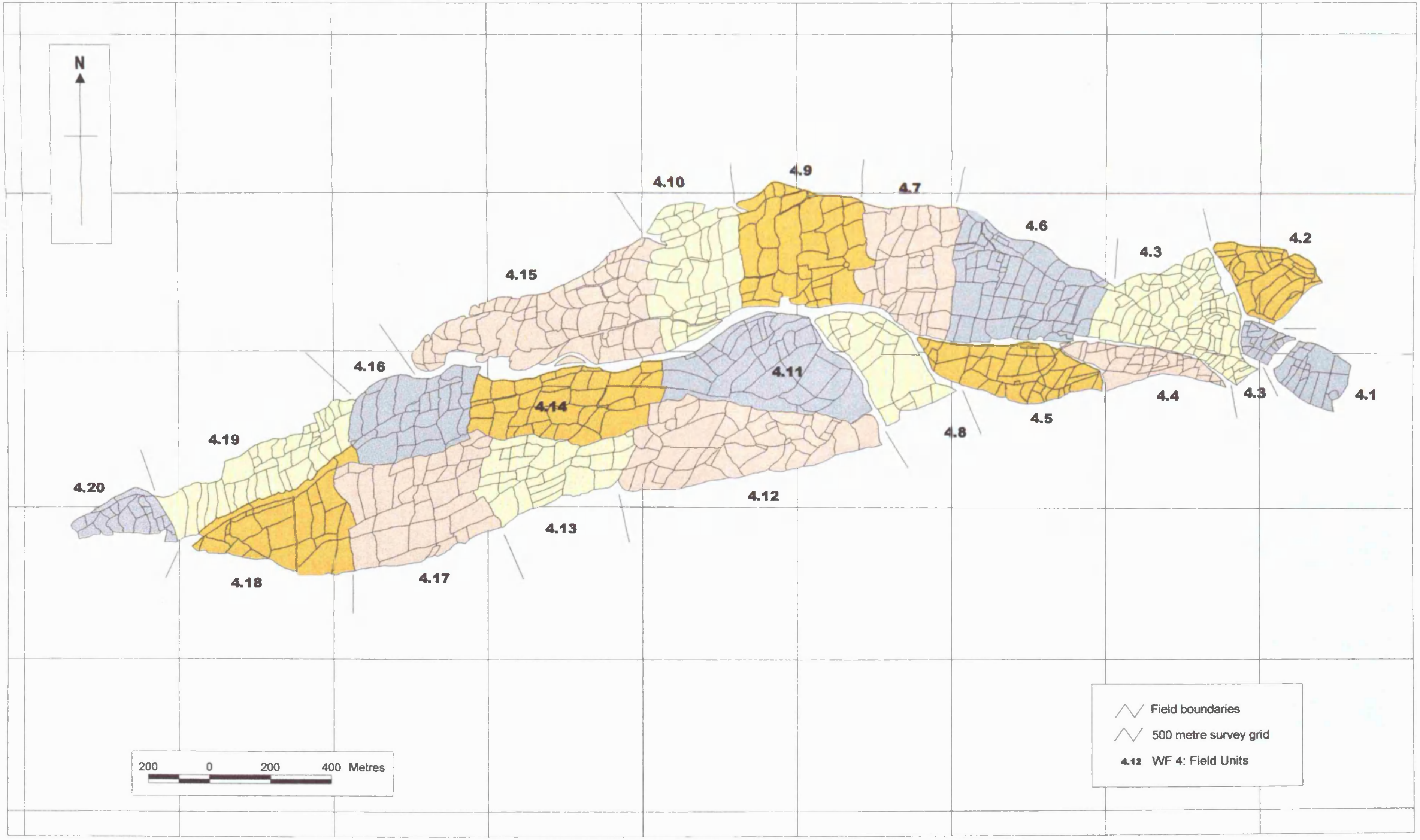

Figure 5.4 WF4: the twenty sub-units into which the large field system WF4 was divided for the purposes of the fieldwalking exercise

Figure 5.5 The gently stepped terraces of WF4.6-4.9, as seen when looking upstream, and eastwards towards the Khirbet Faynan.

Figure 5.6 WF4.3: the 'Herring-bone' fields, looking towards the north from the southern edge of the field system WF4. (Photograph I. Ruben).

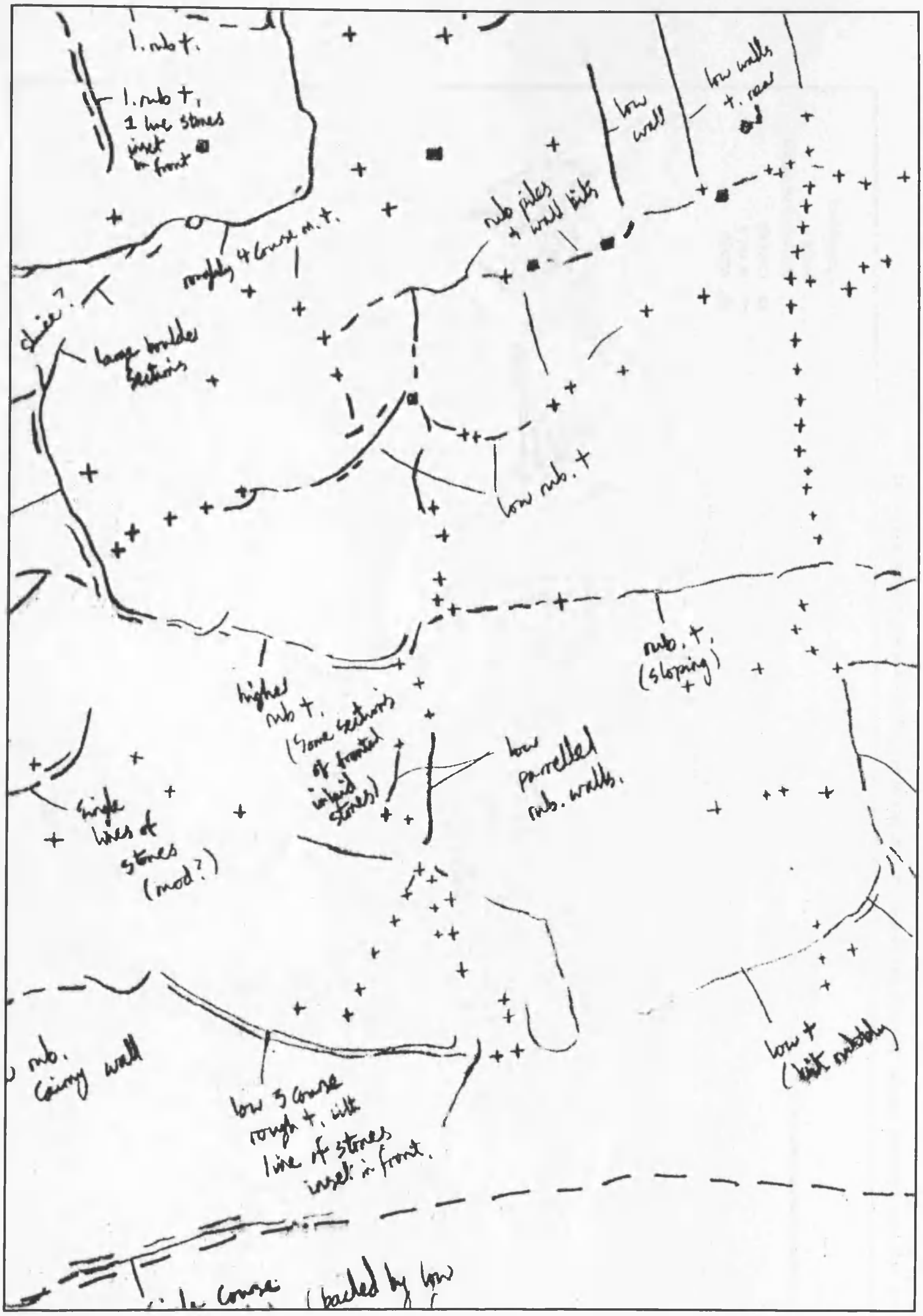

Figure 5.7 Part of the Field Correction Map for the area of WF4.7

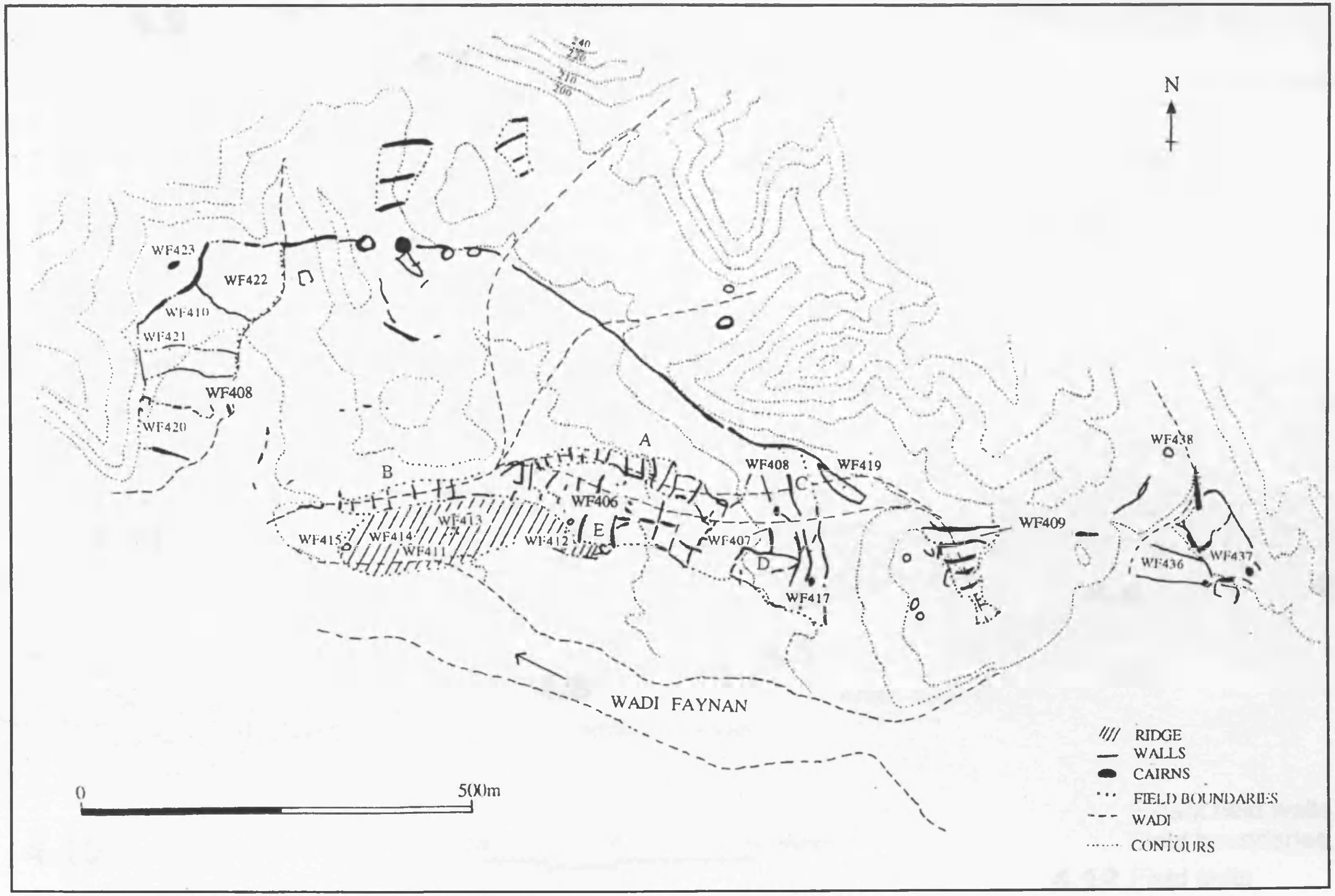

Figure 5.8 The field systems WF406, 409 and 408 to the north of the Wadi Faynan and WF4 (after Barker *et al.* 1999: 271, Fig. 13).

Figure 5.9 WF4: Sites mentioned in the text

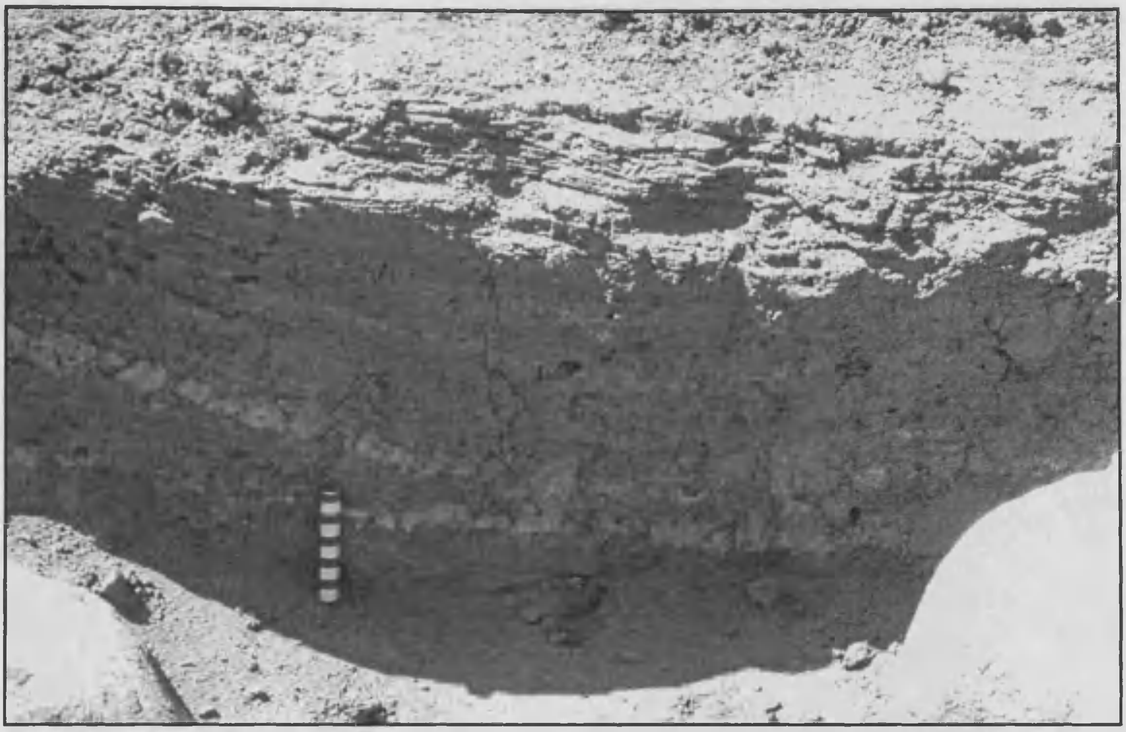

Figure 5.10 Trench 1 in WF288: the water lain clay and silt lenses can be seen as the pale layers within the channel section (Photograph G. Barker).

Figure 5.11 WF288 at the point where the channel is cut by a tributary wadi. (Photograph G. Barker).

Figure 5.12 Trench 2 as excavated in the parallel walls of WF4.6.47, looking north. In the trench in the foreground is the set boulder line of an earlier water channel, with water lain sediments in the section. (Photograph G. Barker)

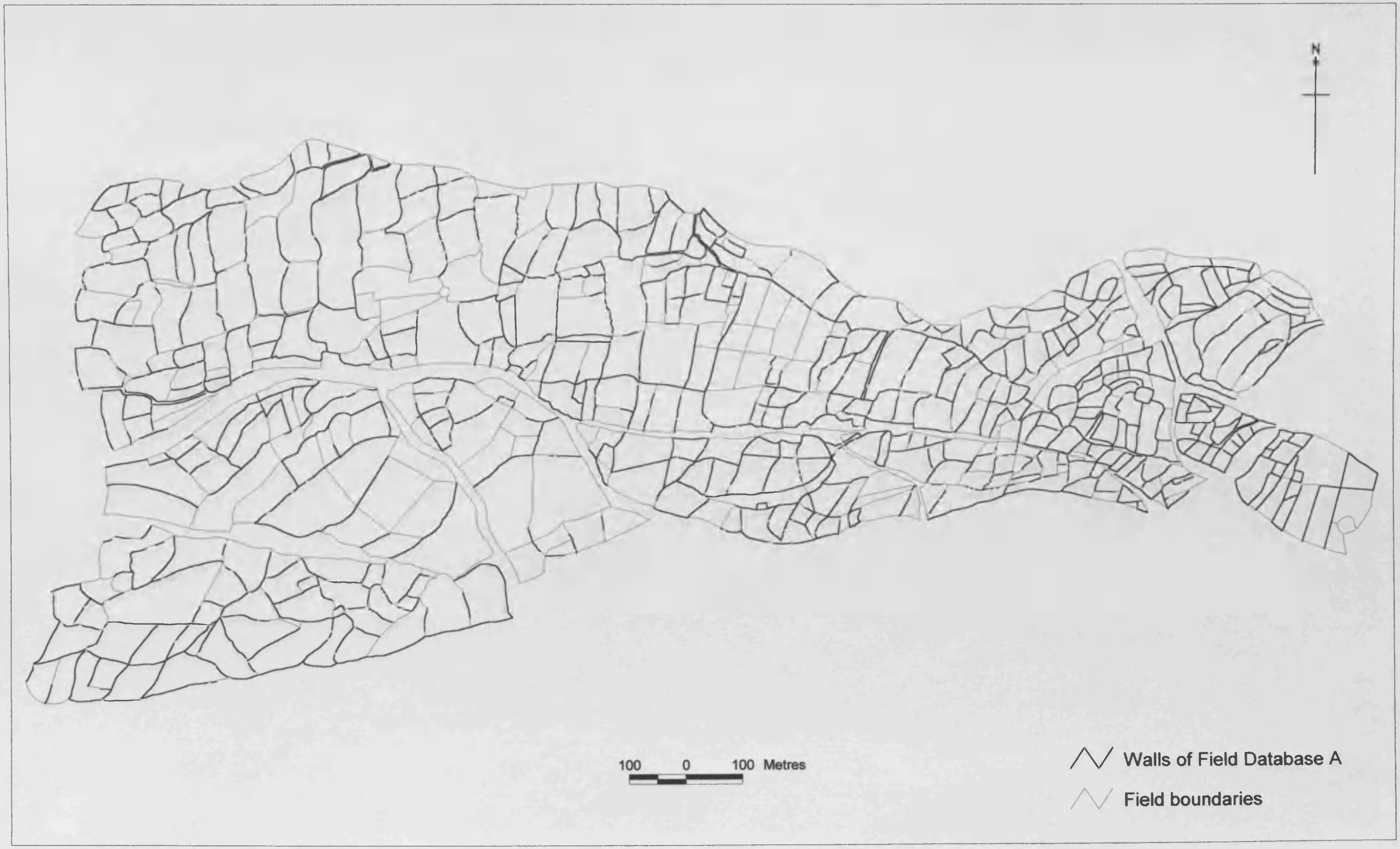

Figure 5.13 WF4: Walls within the Field Database A

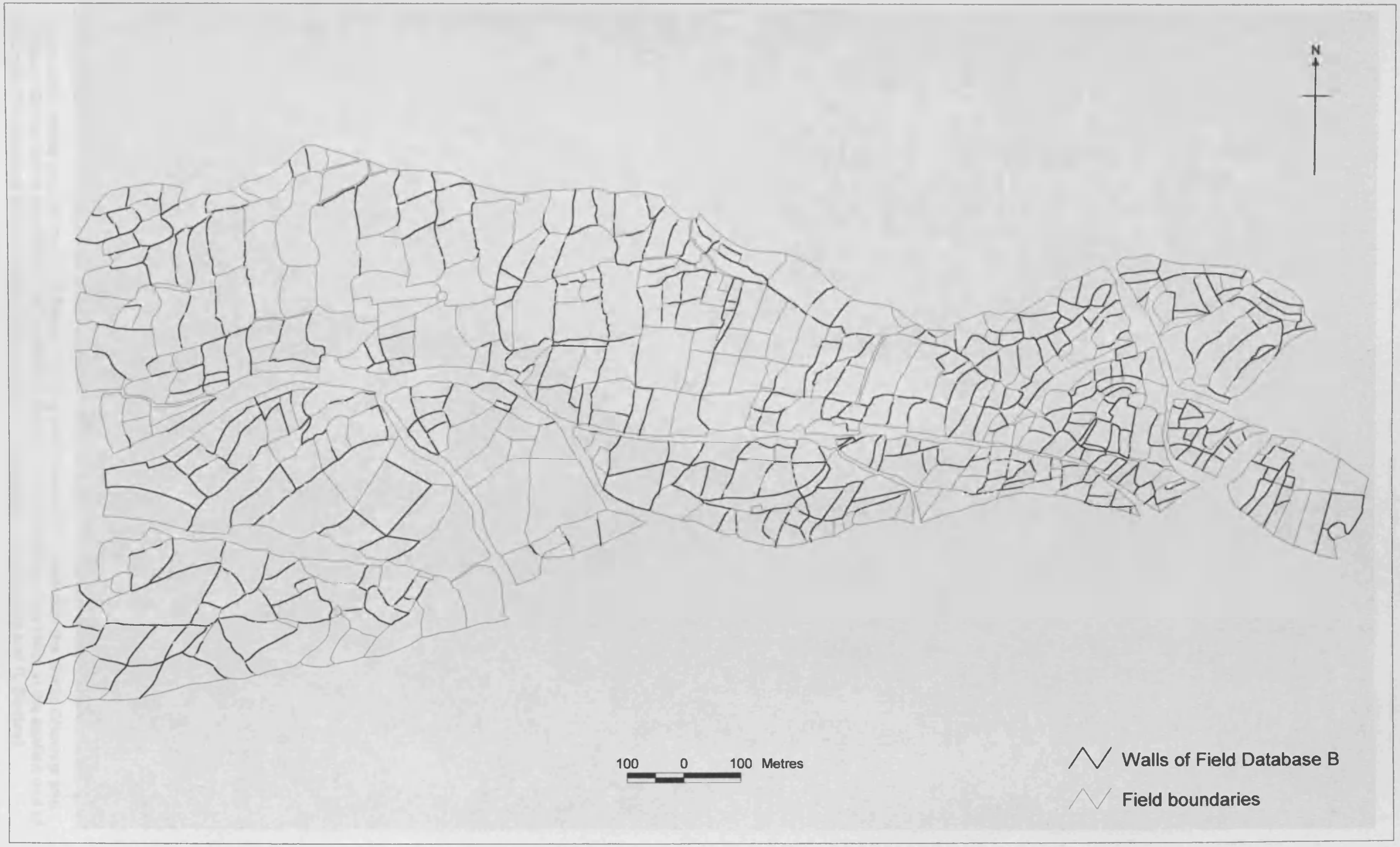

Figure 5.14 WF4: Walls within the Field Database B

Figure 5.15 Aerial view of the Wadi Faynan looking east towards the junction of the Wadis Ghuwayr and Shayqar. On the left is the remains of the Khirbet Faynan, in the foreground the fields at the eastern end of WF4, with the reservoir and smelting slag above this. (Photograph D.L. Kennedy and R. Bewley)

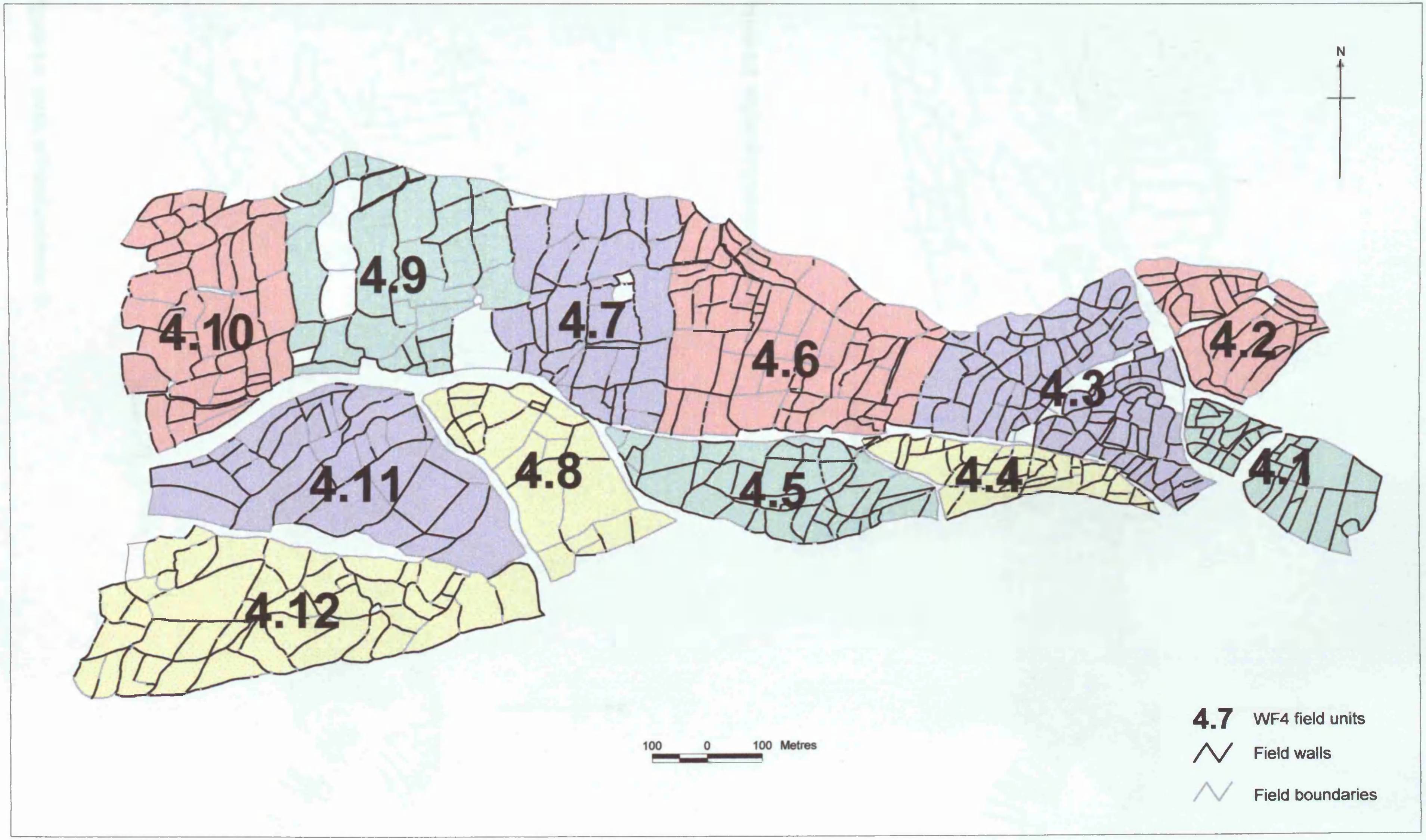

Figure 6.1 WF4: the relative position of the first twelve units of fields which form the subject of the GIS analysis

Figure 6.2 Walls of Field Database A

Figure 6.3 Walls of Field Database B

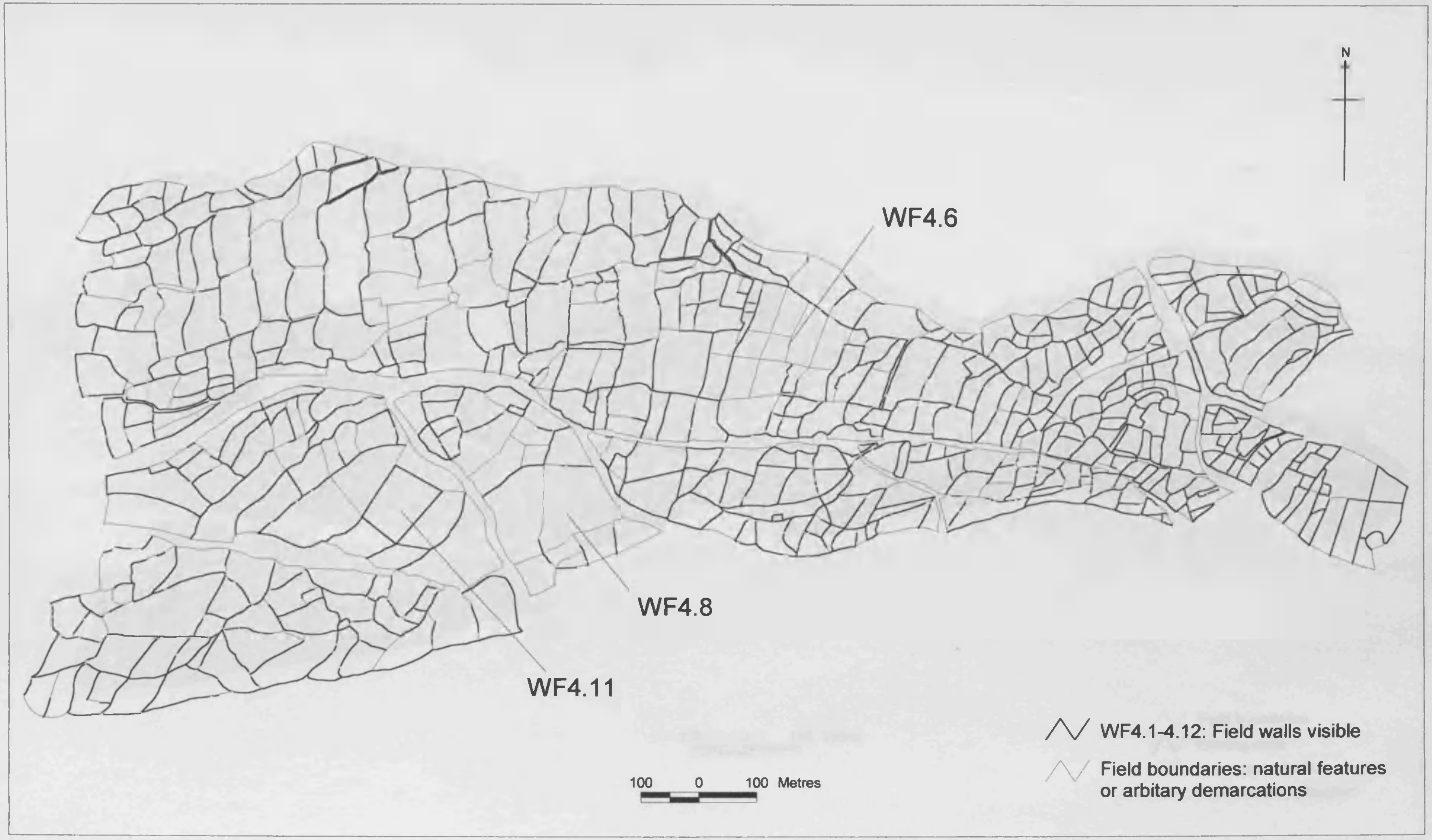

Figure 6.4 WF4: coverage of existing field walls within units WF4.1-4.12 (obtained by combining the coverages of the Field Databases A and B). Note absence of walls in WF4.6 and 4.8. Walls in the southern region of WF4.11 are bulldozed stone piles

Figure 6.5 WF4: fields recently ploughed

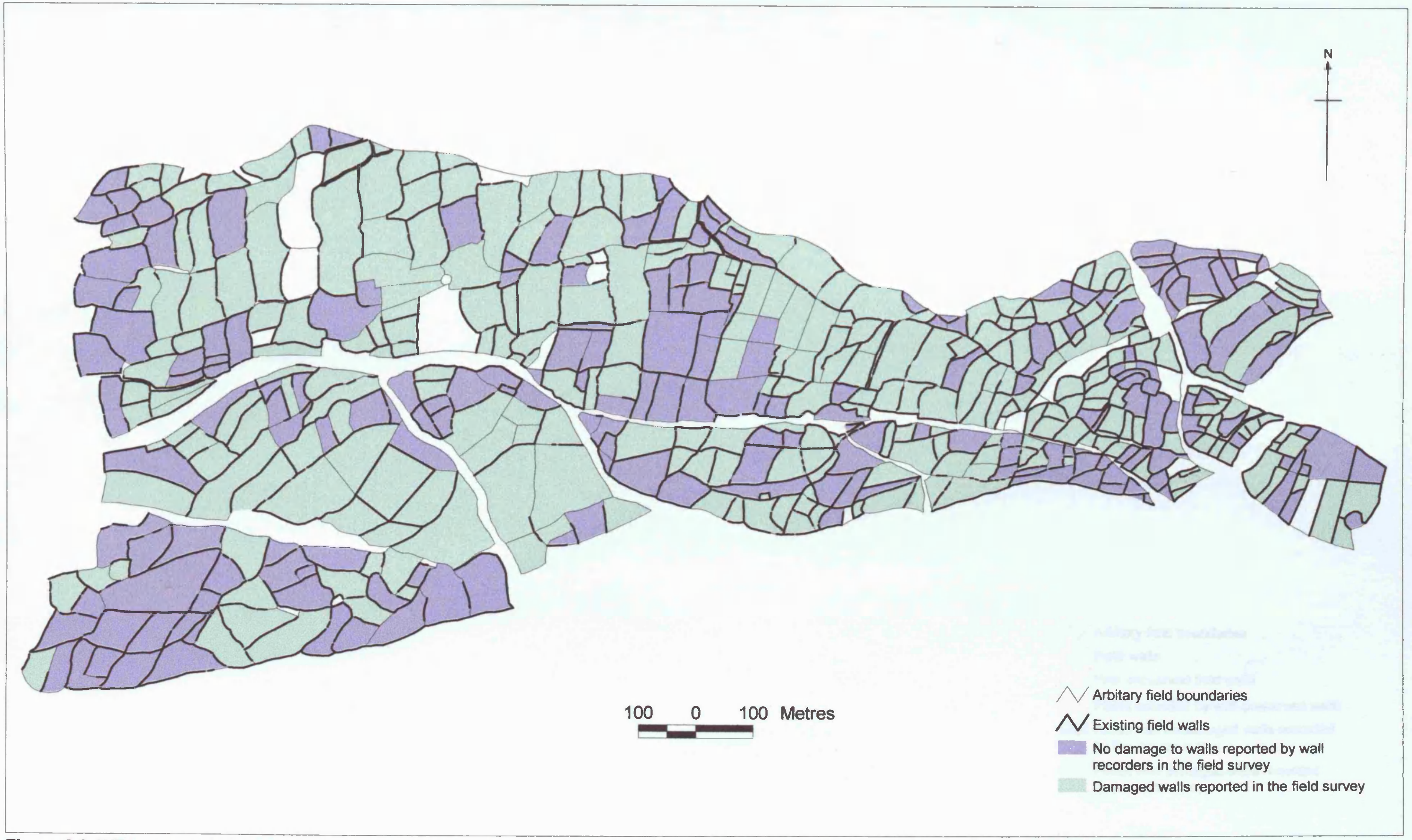

Figure 6.6 WF4: areas within WF4.1-4.12 where damaged/non-damaged walls were recorded in the field survey

Figure 6.7 WF4: areas within WF4.1-4.12 where well-preserved walls were recorded in the field survey

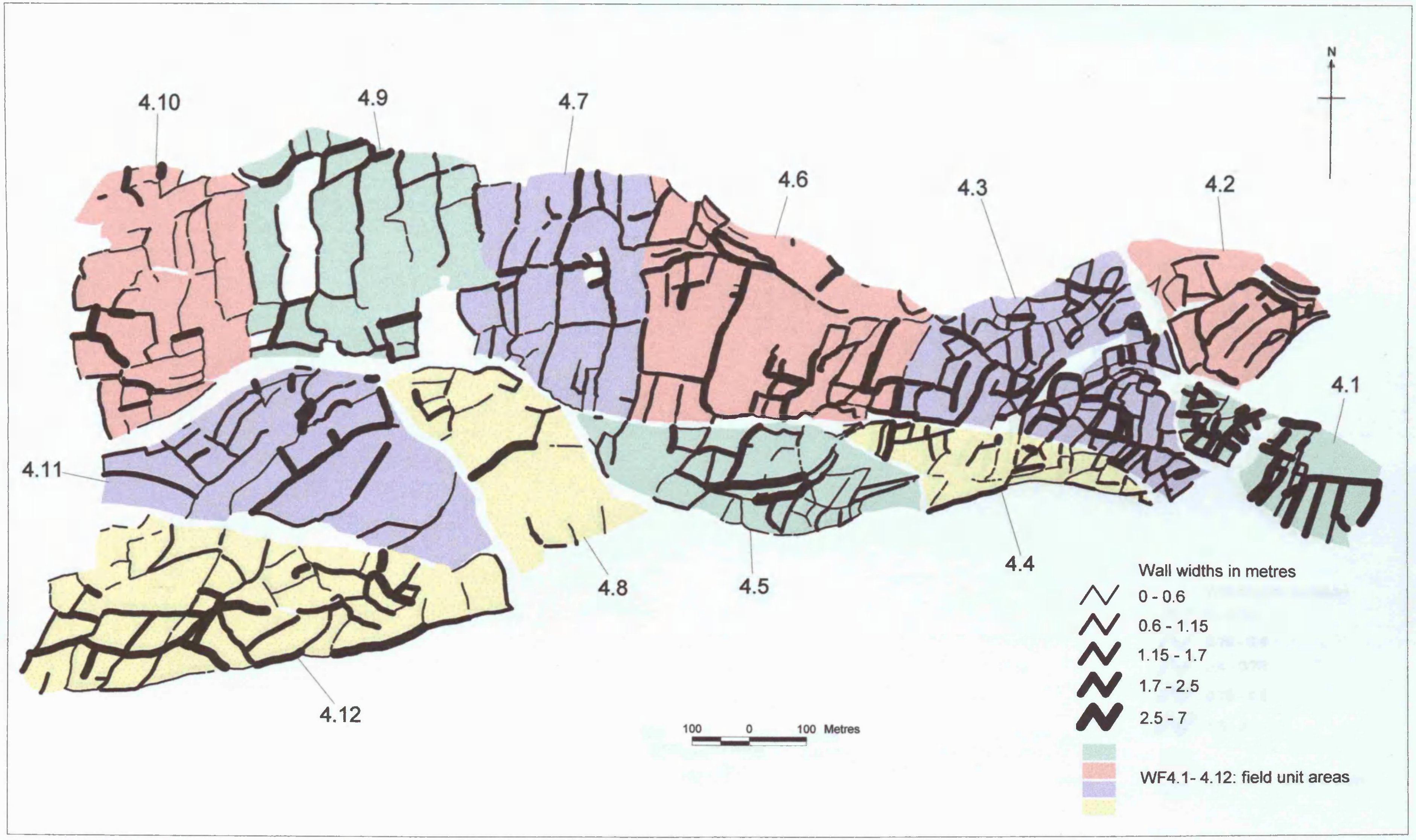

Figure 6.8 WF4.1- 4.12: maximum wall widths

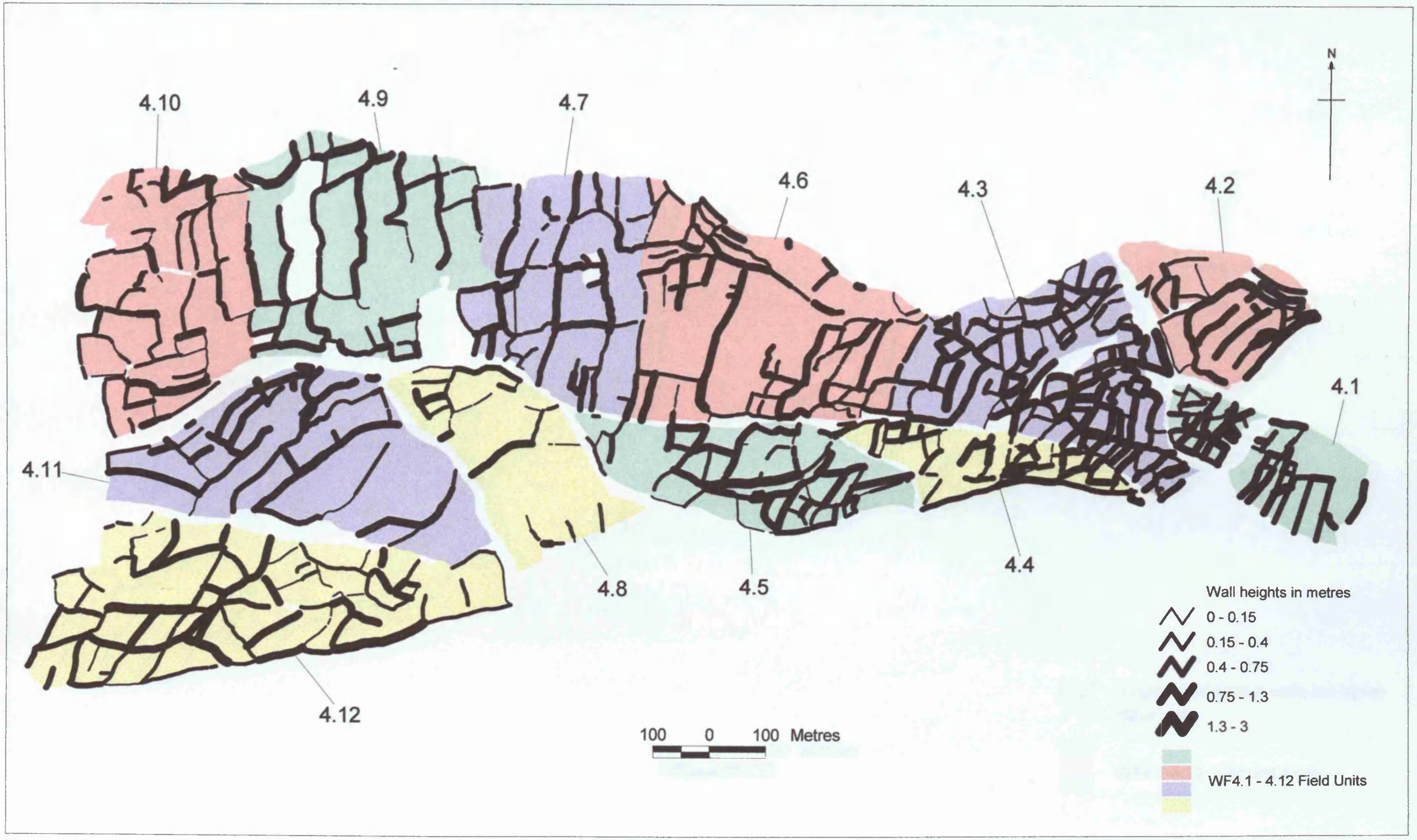

Figure 6.9 WF4.1- 4.12: maximum wall heights

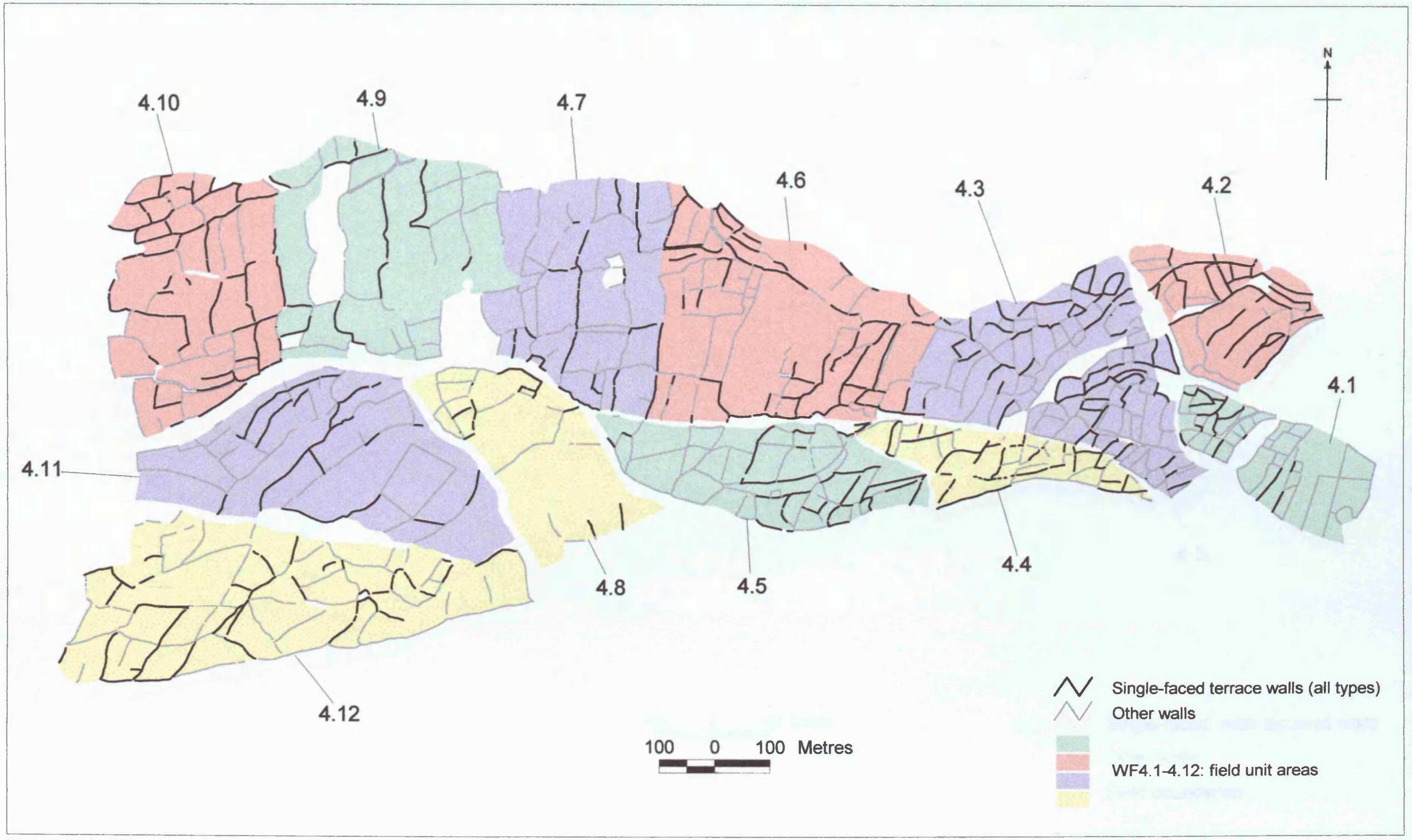

Figure 6.10 WF4.1- 4.12: the distribution of all types of single-faced terrace walls

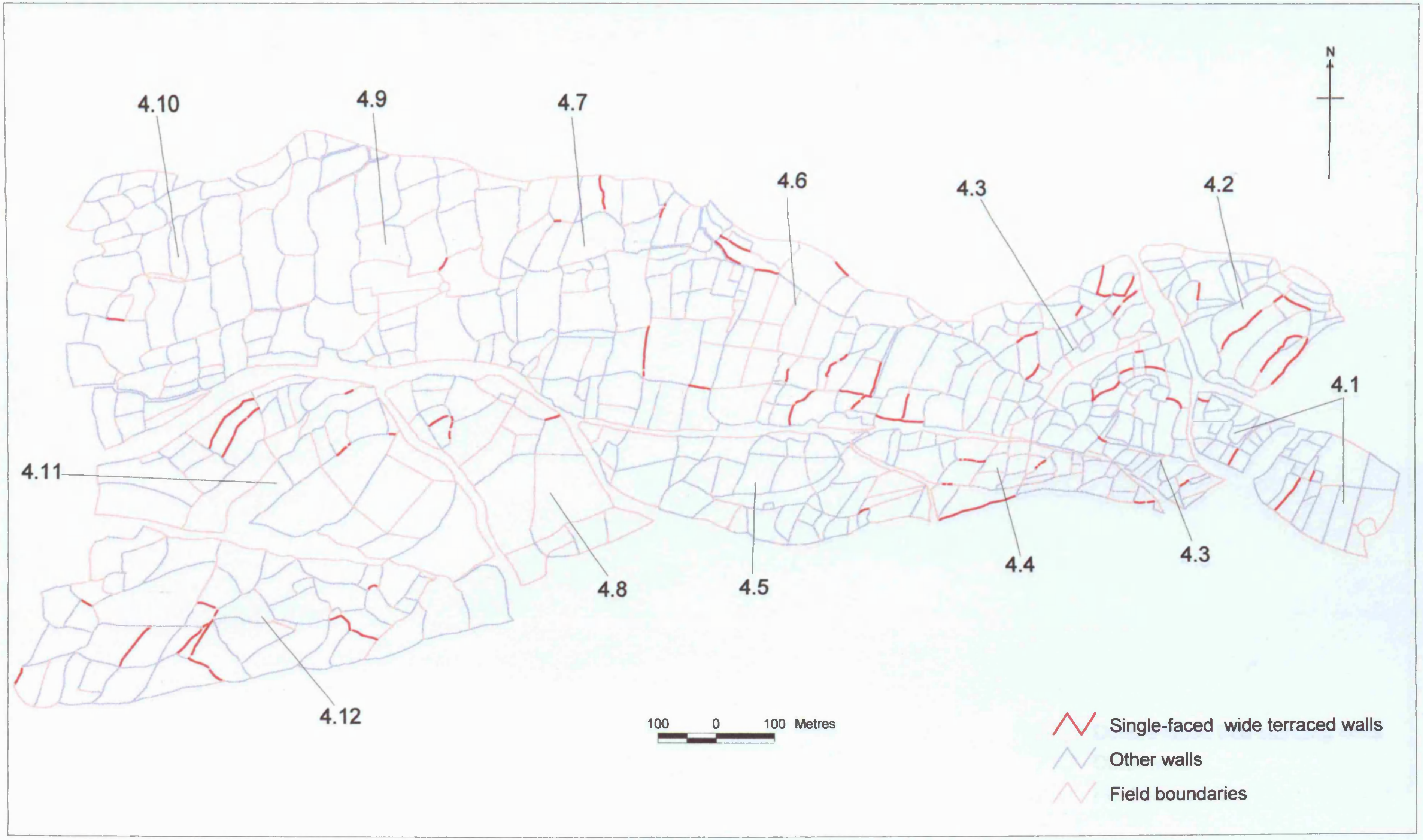

Figure 6.11 WF4.1- 4.12: single-faced wide terrace walls from Field Database A

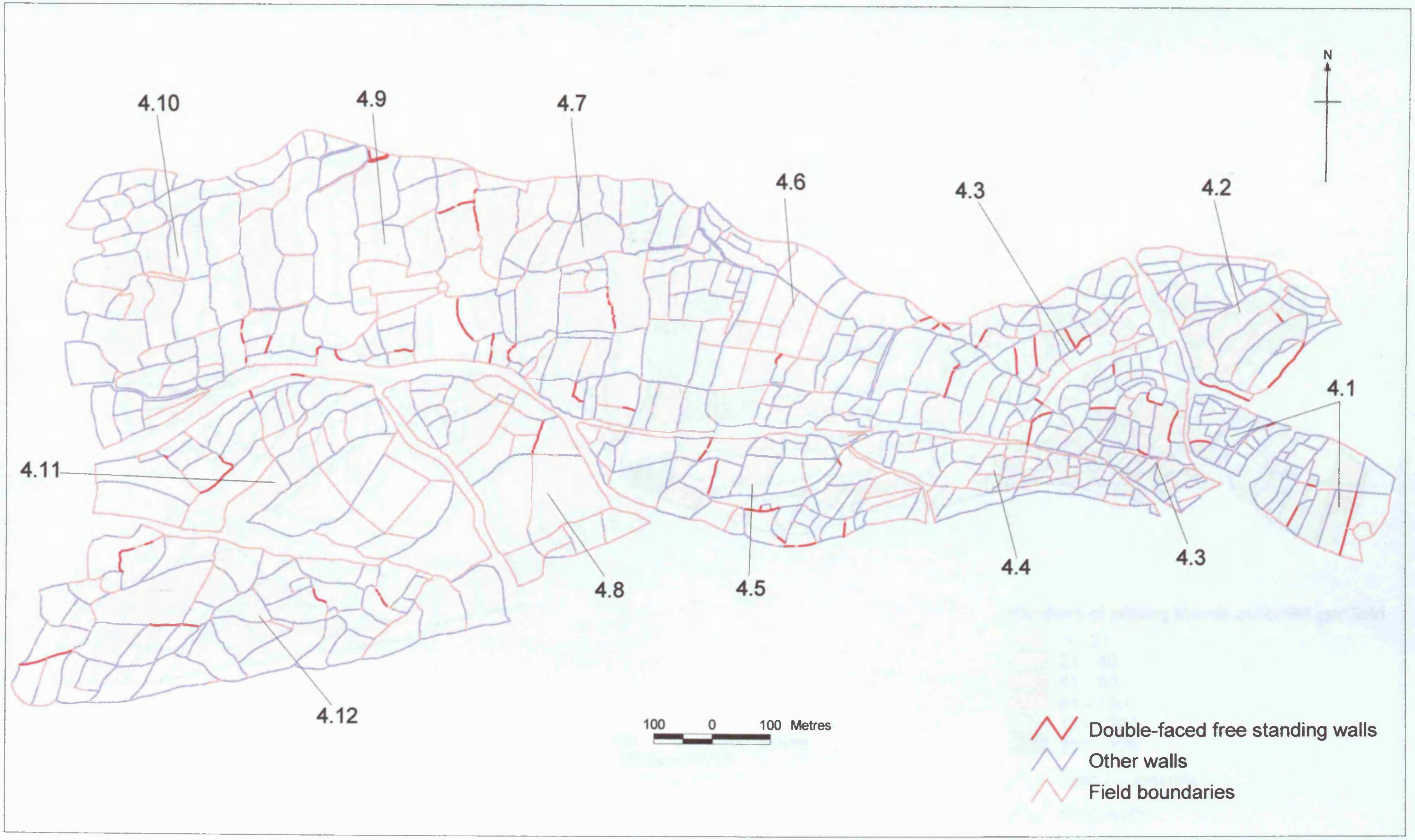

Figure 6.12 WF4.1- 4.12: double-faced free standing walls within Field Database A

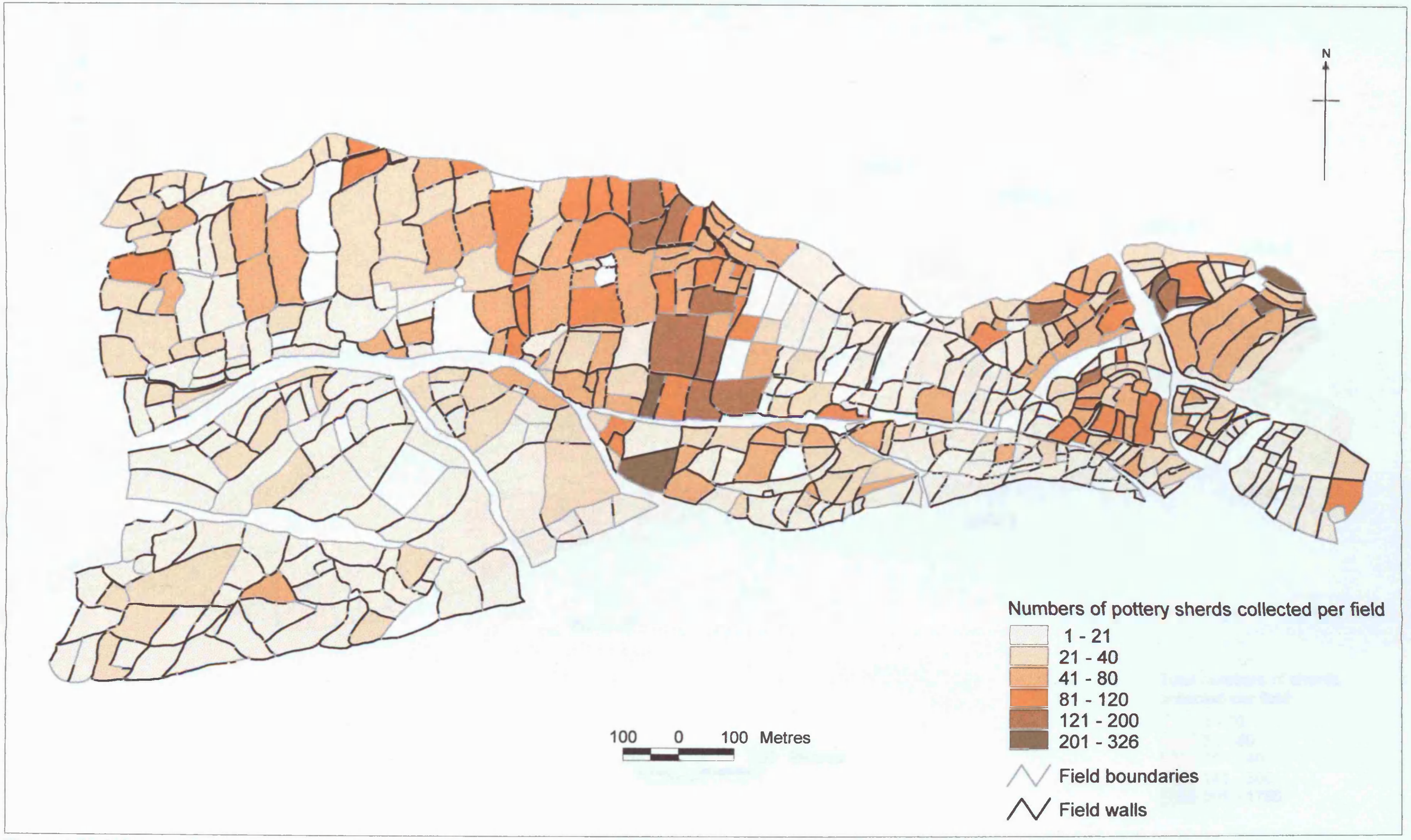

Figure 6.13 WF4.1- 4.12: total pottery sherds collected per field and divided into six classes

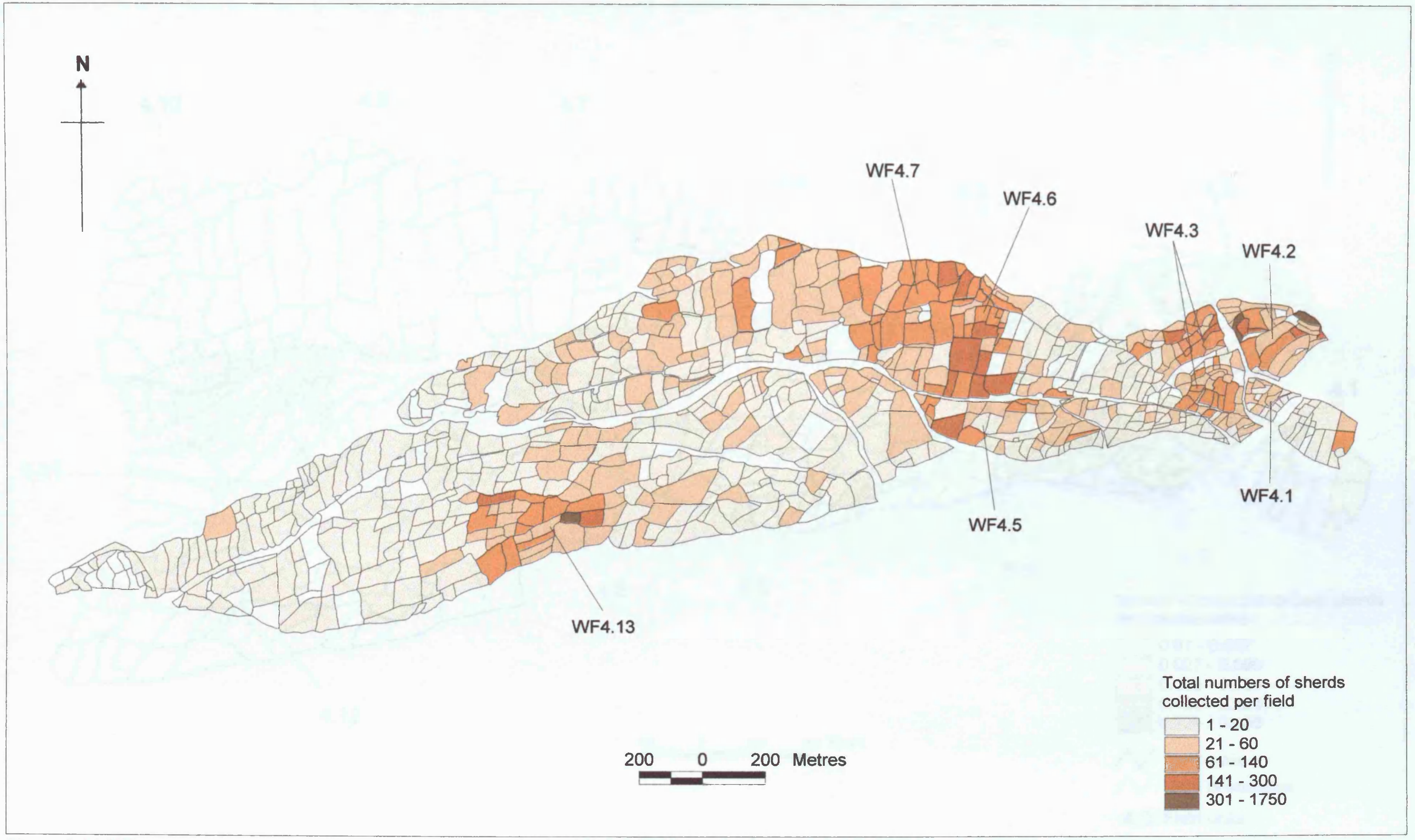

Figure 6.14 WF4: total numbers of sherds collected in the field walking exercise

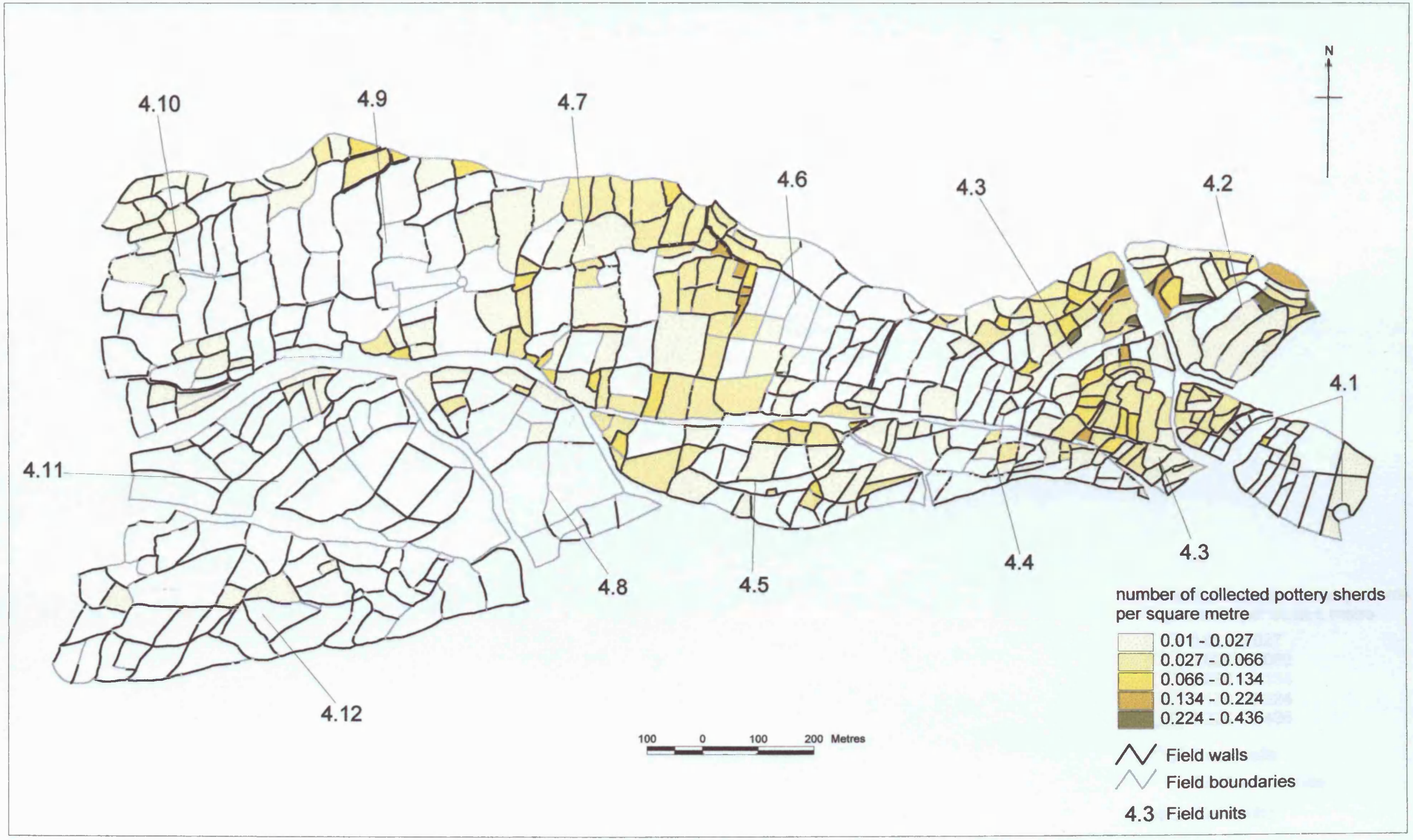

Figure 6.15 WF4.1- 4.12: collected pottery sherd density distribution

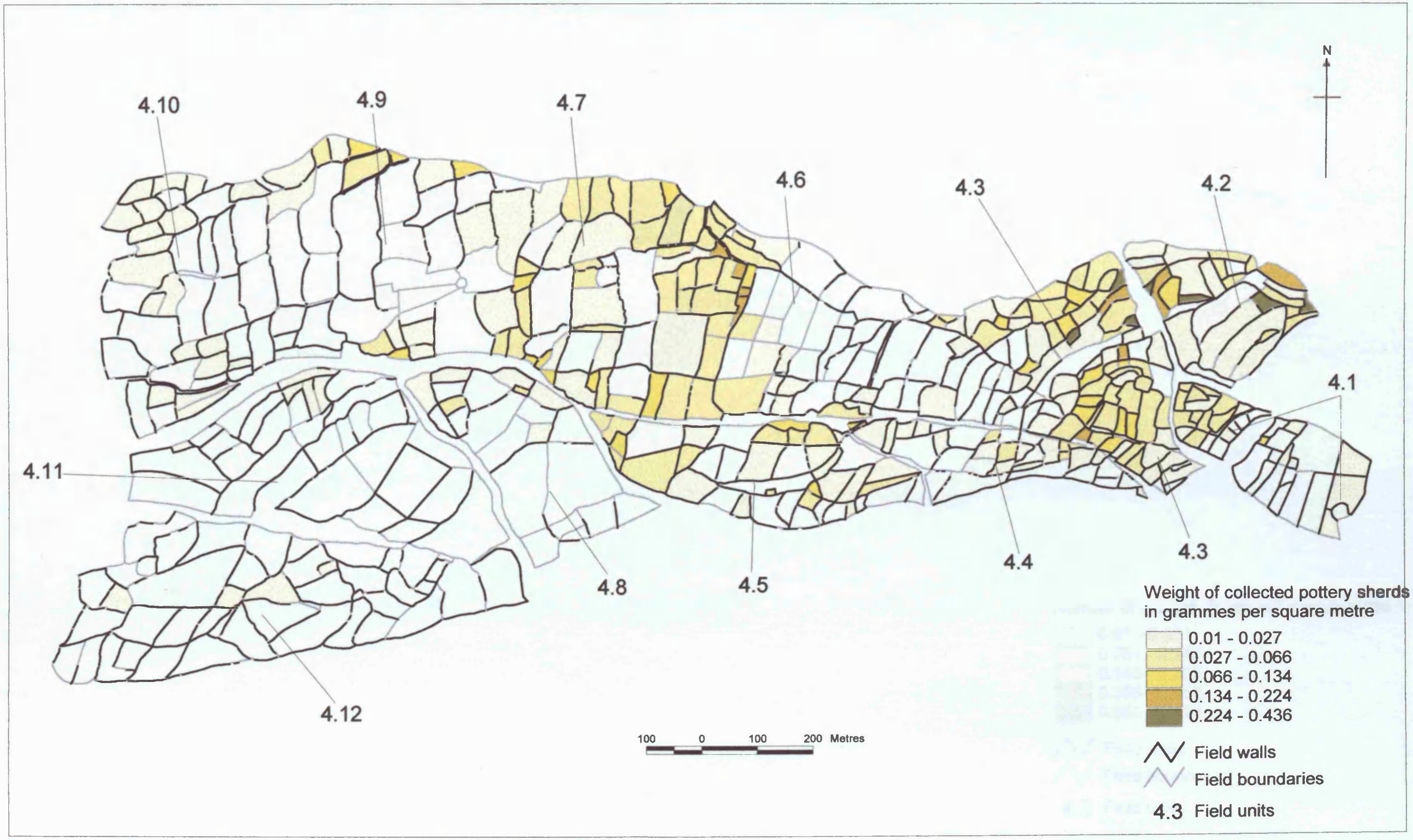

Figure 6.16 WF4.1- 4.12: collected pottery sherd weight density distribution

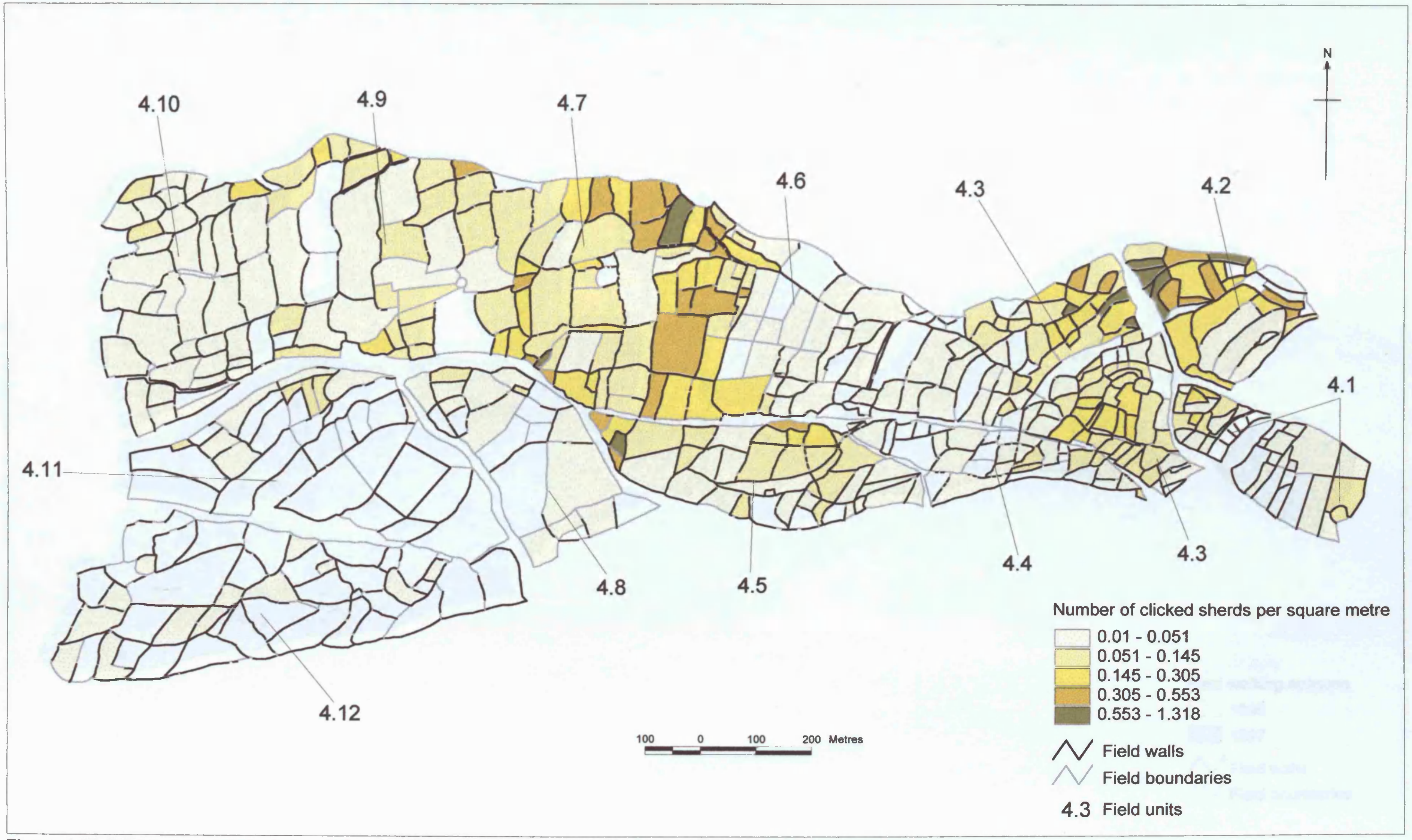

Figure 6.17 WF4.1- 4.12: 'clicked sherd' density distribution

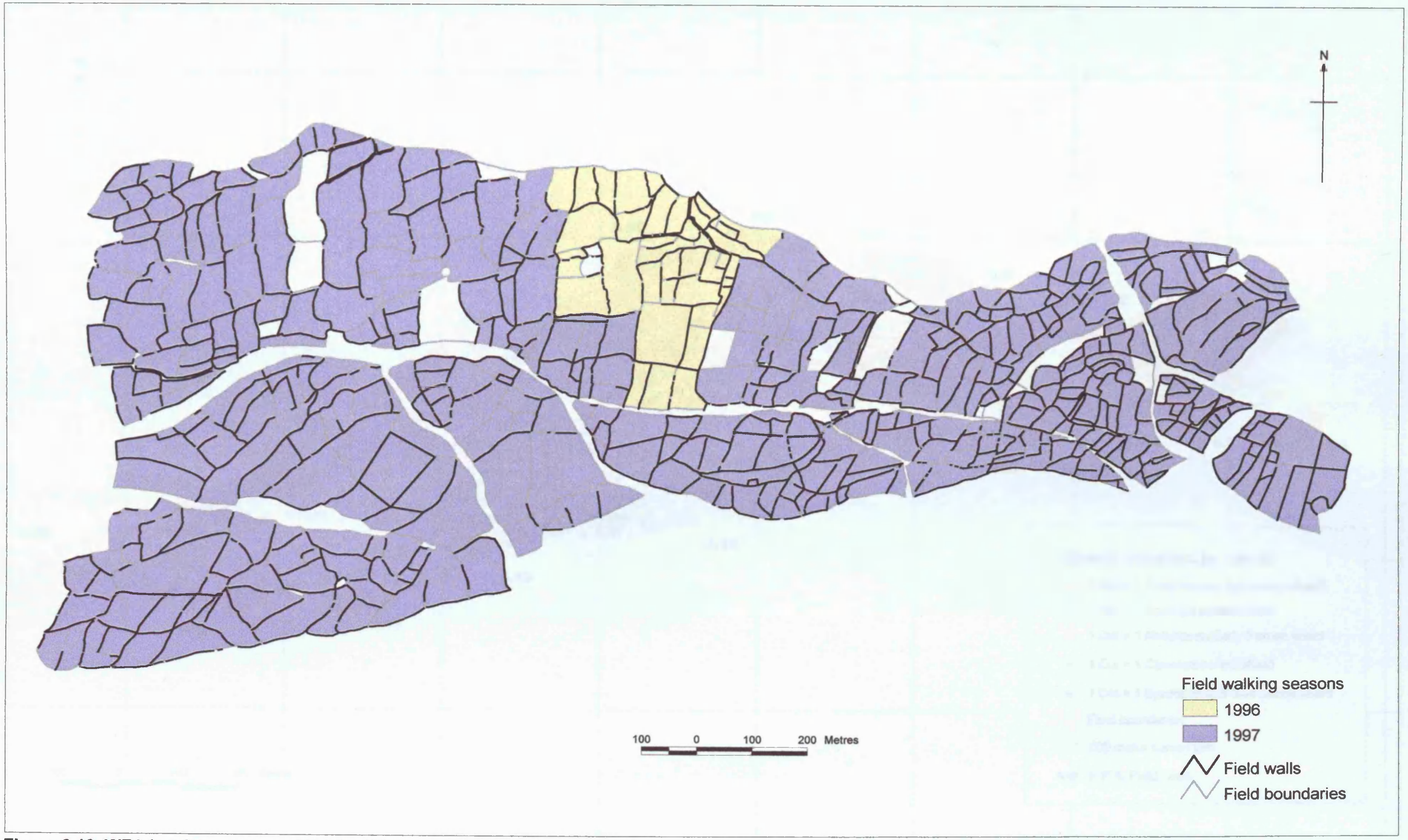

Figure 6.18 WF4.1- 4.12: seasons of fieldwalking

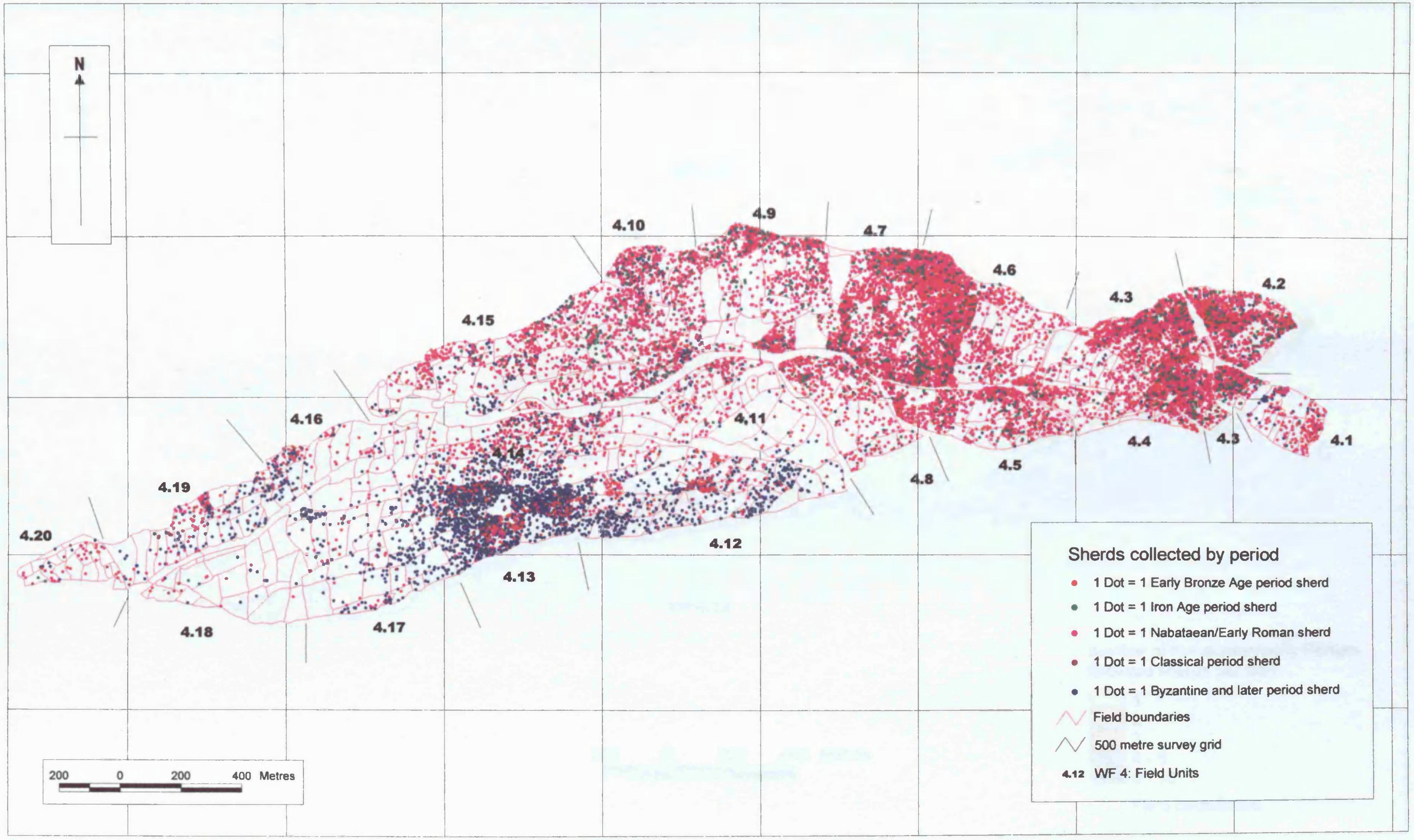

Figure 6.19 WF4: total distribution of dateable sherds

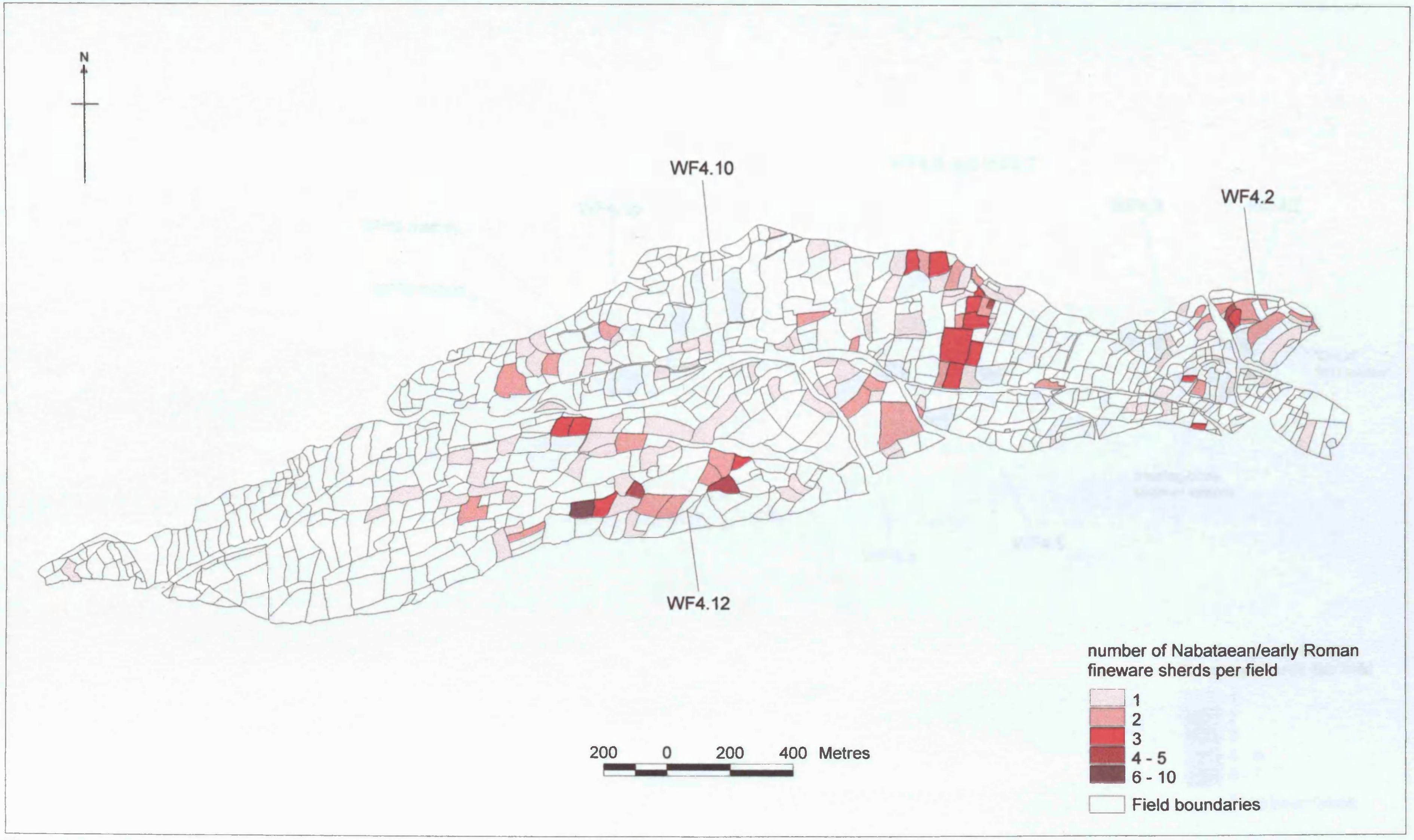

Figure 6.20 WF4: distribution of late Nabataean/early Roman fineware sherds

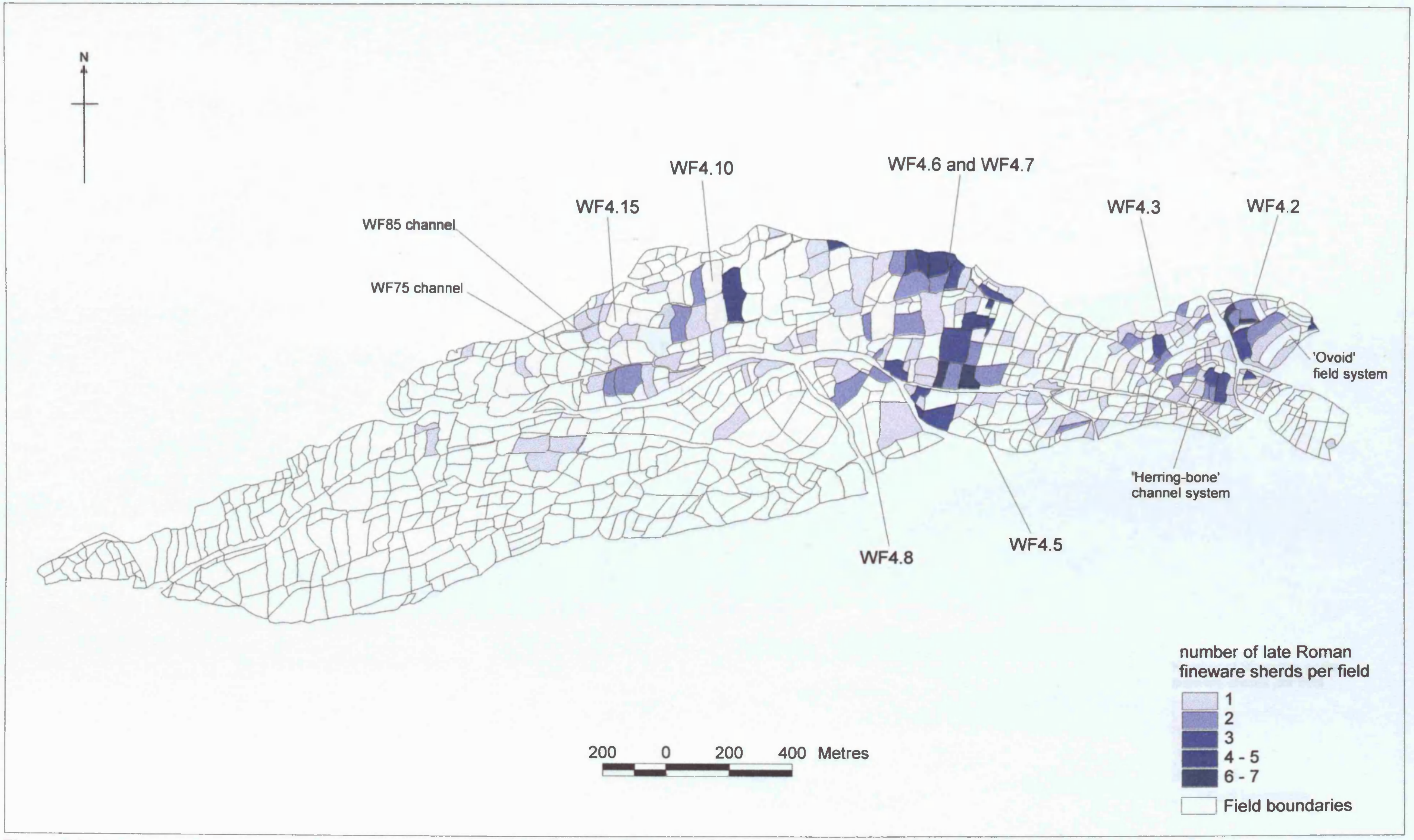

Figure 6.21 WF4: distribution of late Roman fineware sherds

Figure 6.22 WF4: distribution of Byzantine fineware sherds

Figure 6.23 WF4: distribution of late Byzantine/early Islamic fineware sherds

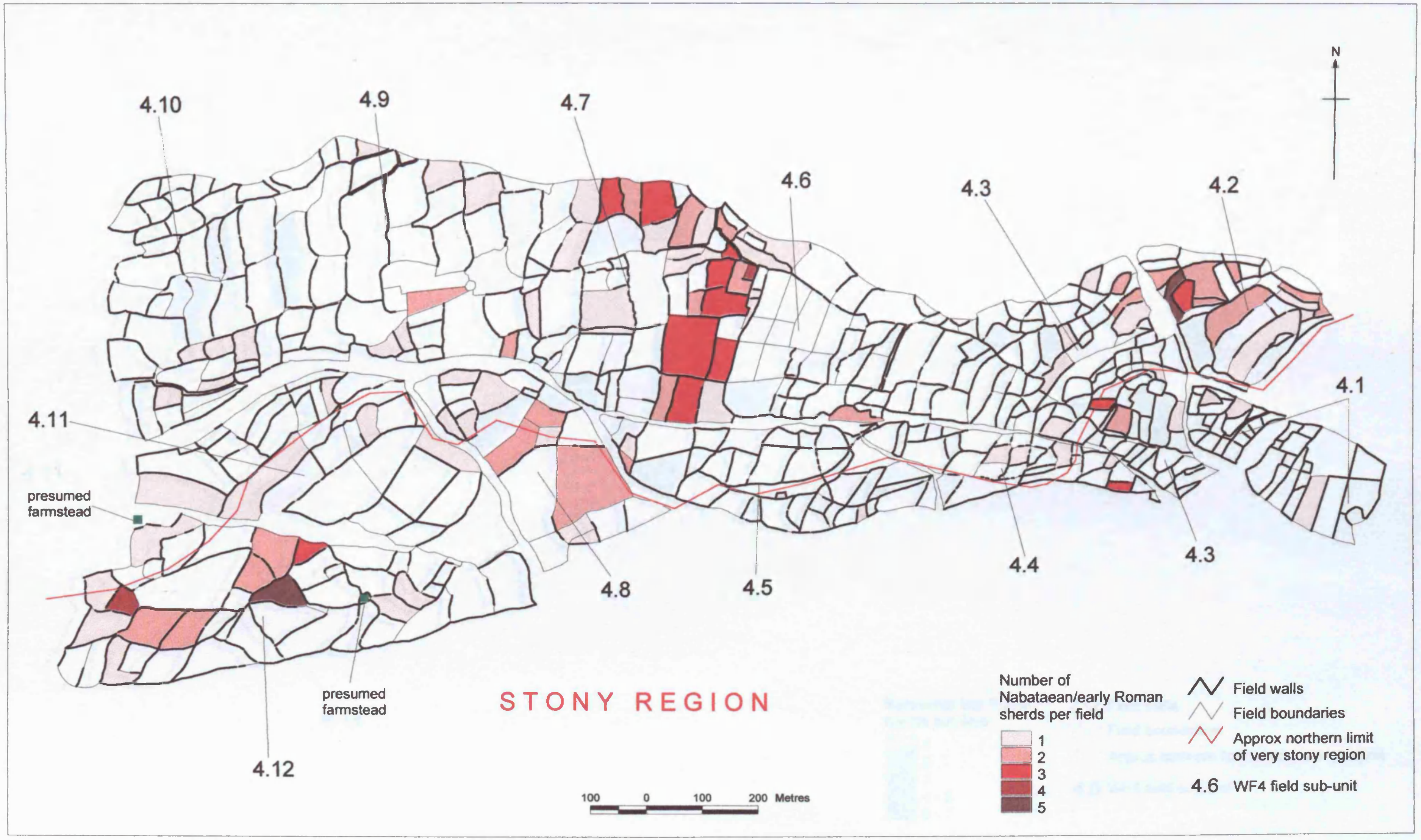

Figure 6.24 WF4.1- 4.12: Nabataean/early Roman fineware sherds in relation to walls

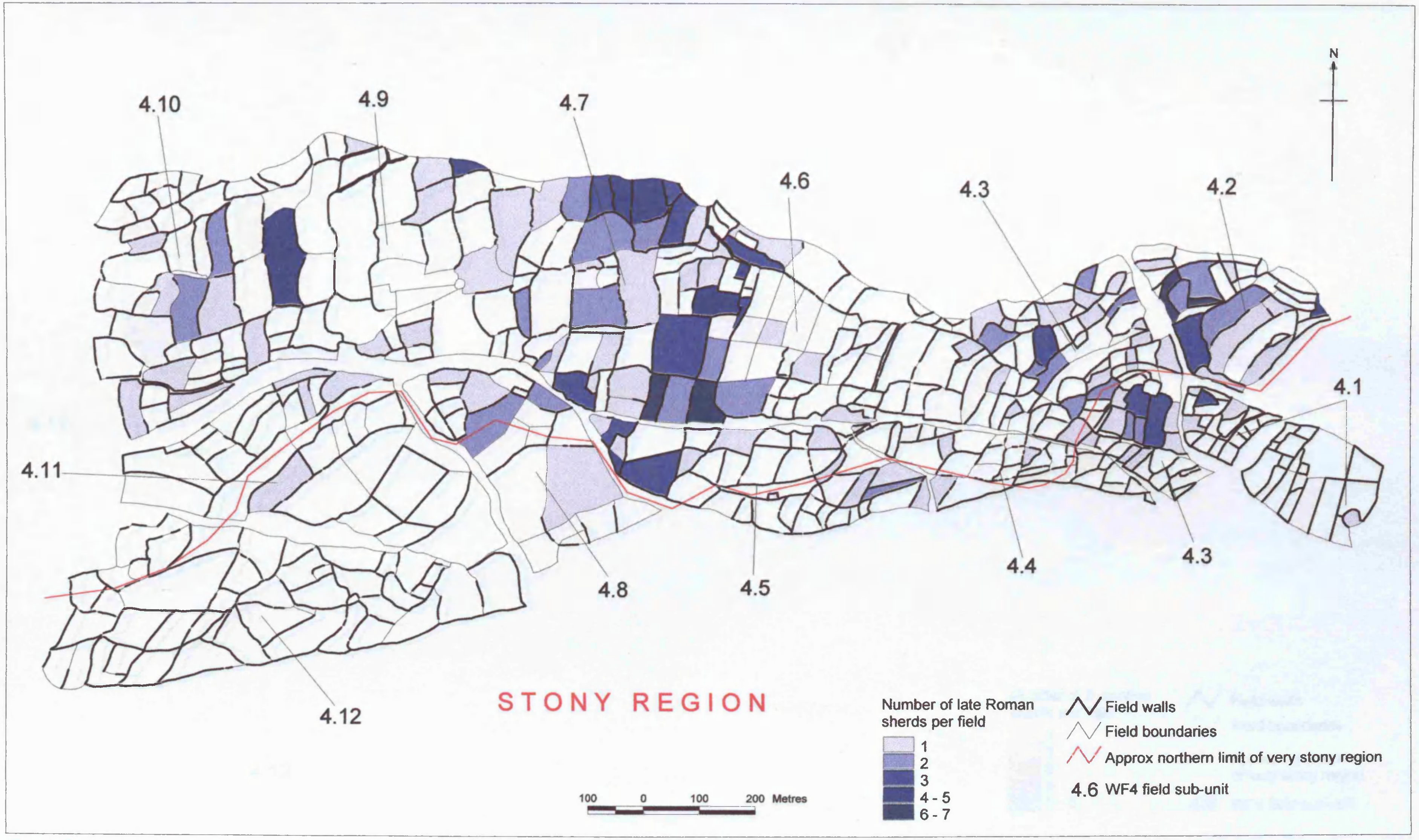

Figure 6.25 WF4.1- 4.12: late Roman fineware sherds in relation to walls

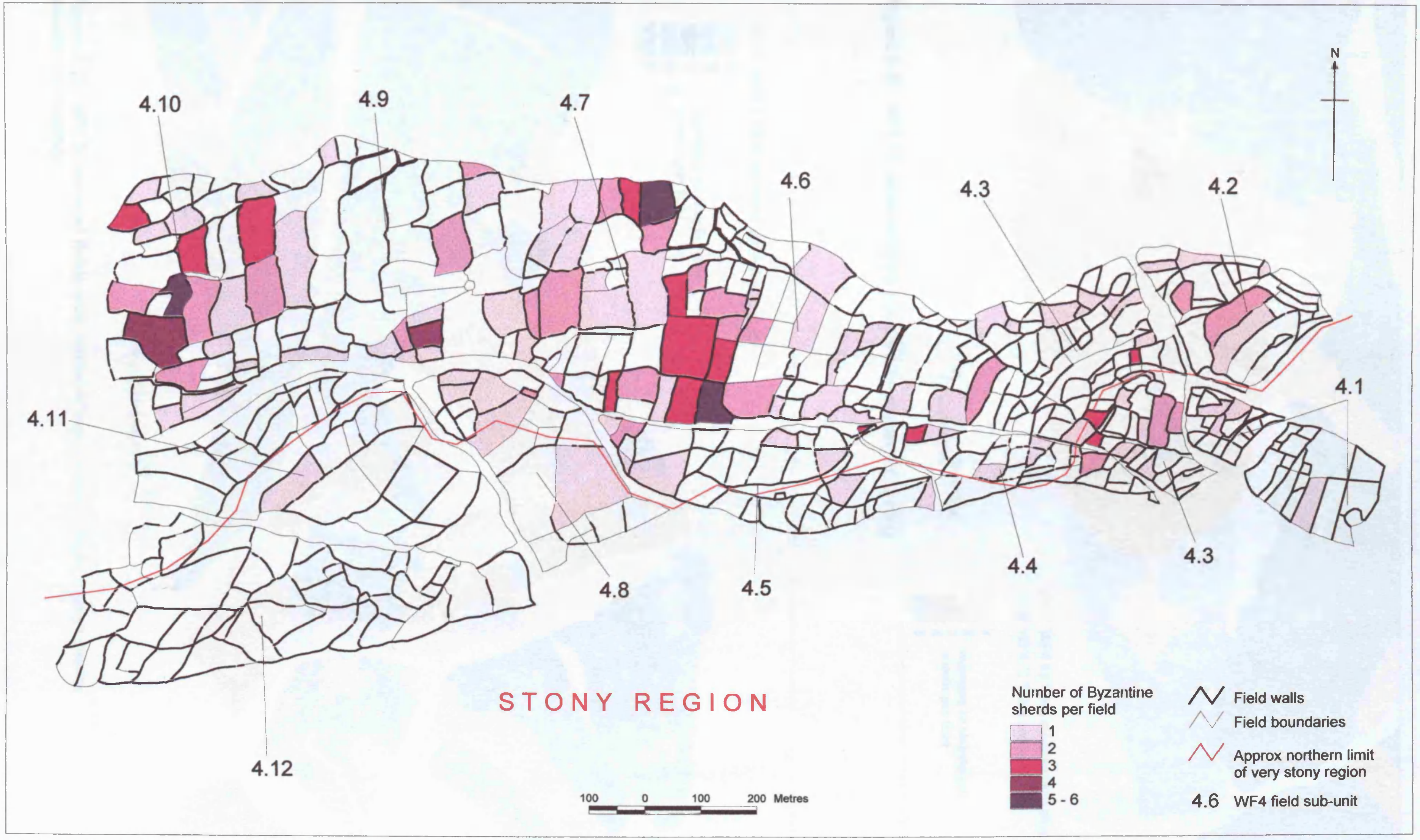

Figure 6.26 WF4.1- 4.12: Byzantine fineware sherds in relation to walls

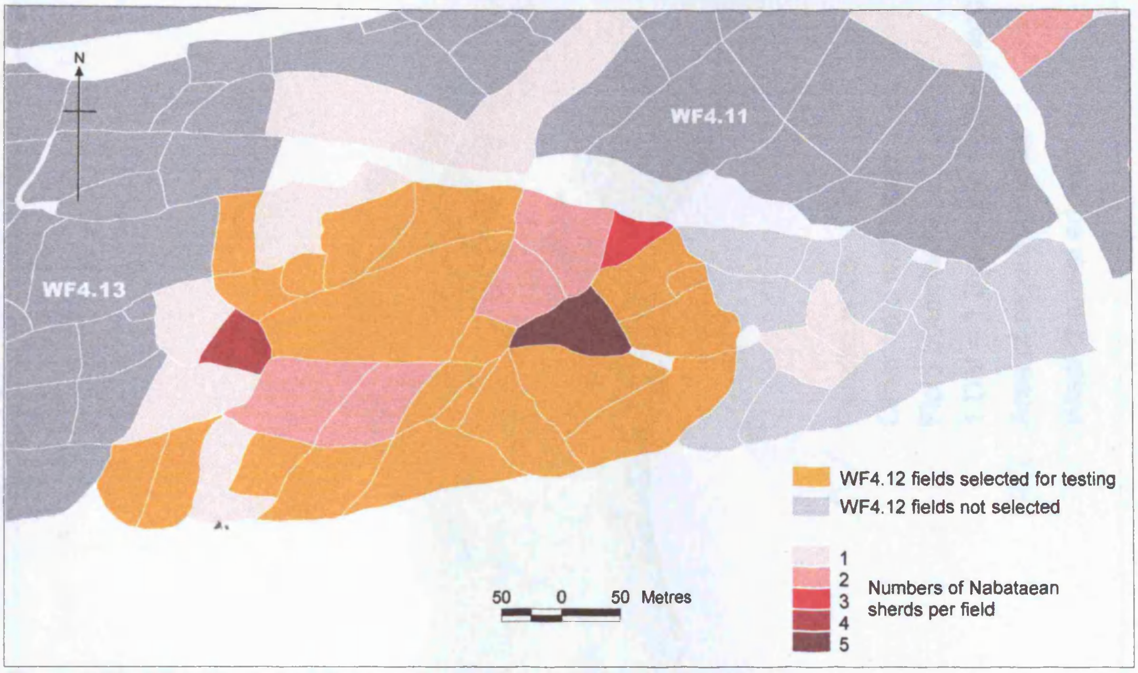

Figure 6.27 WF4.12: area of fields selected for statistical testing

Figure 6.28 WF4.3: terraced fields with relatively high number of late Roman sherds selected for testing

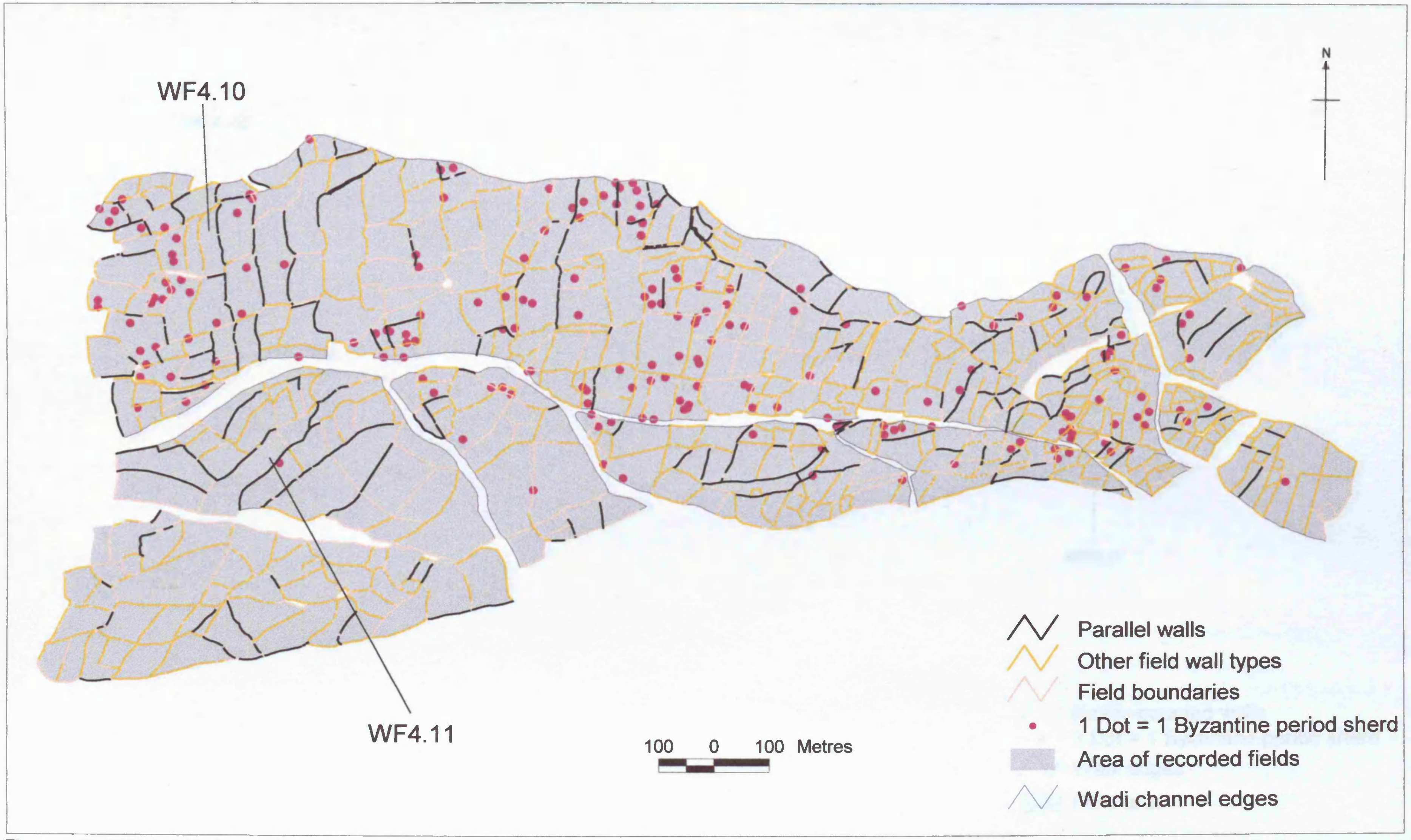

Figure 6.29 WF4.1- 4.12: the relationship of parallel walls and Byzantine fineware sherds

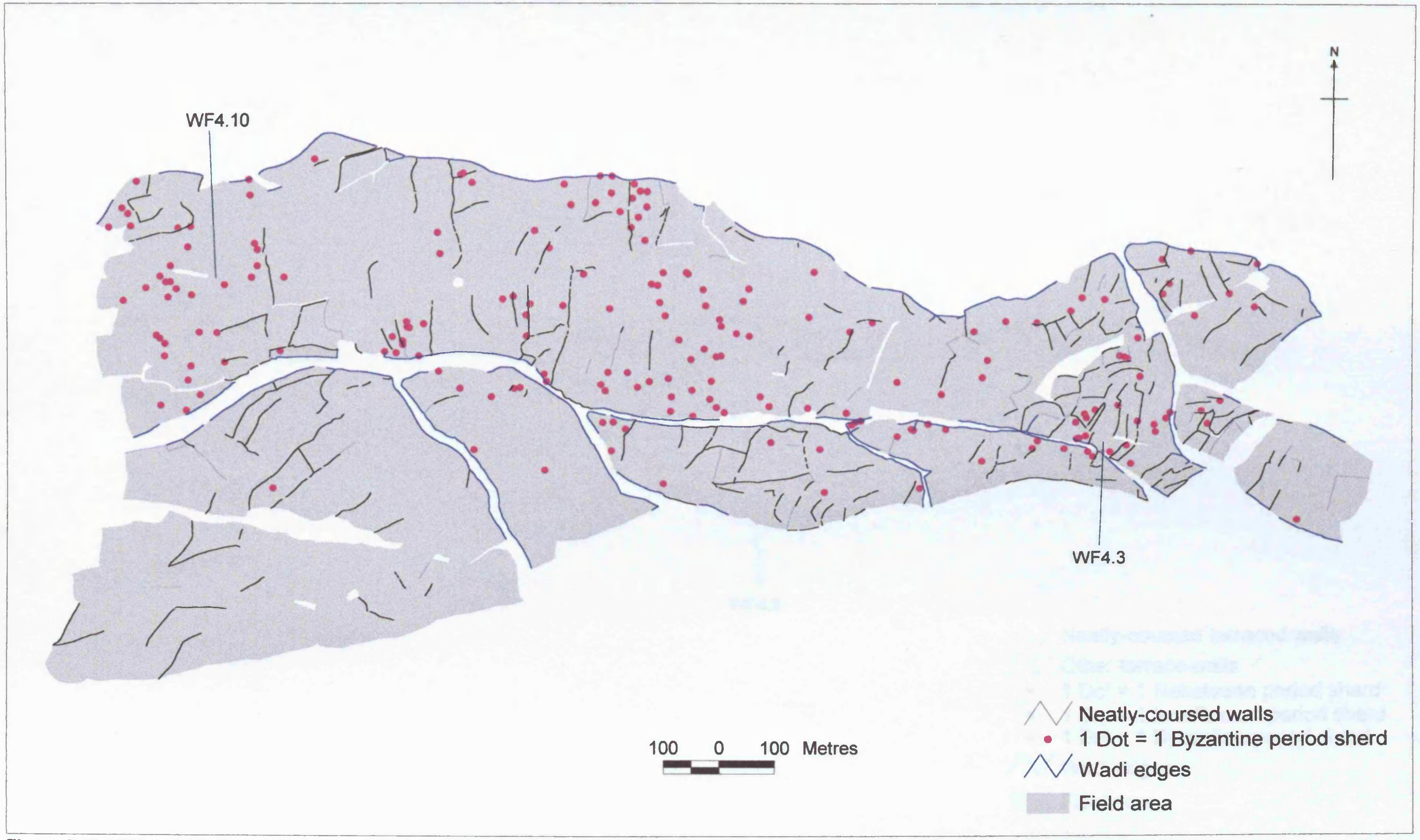

Figure 6.30 WF4.1- 4.12: the relationship of neatly-coursed walls to Byzantine fineware sherds

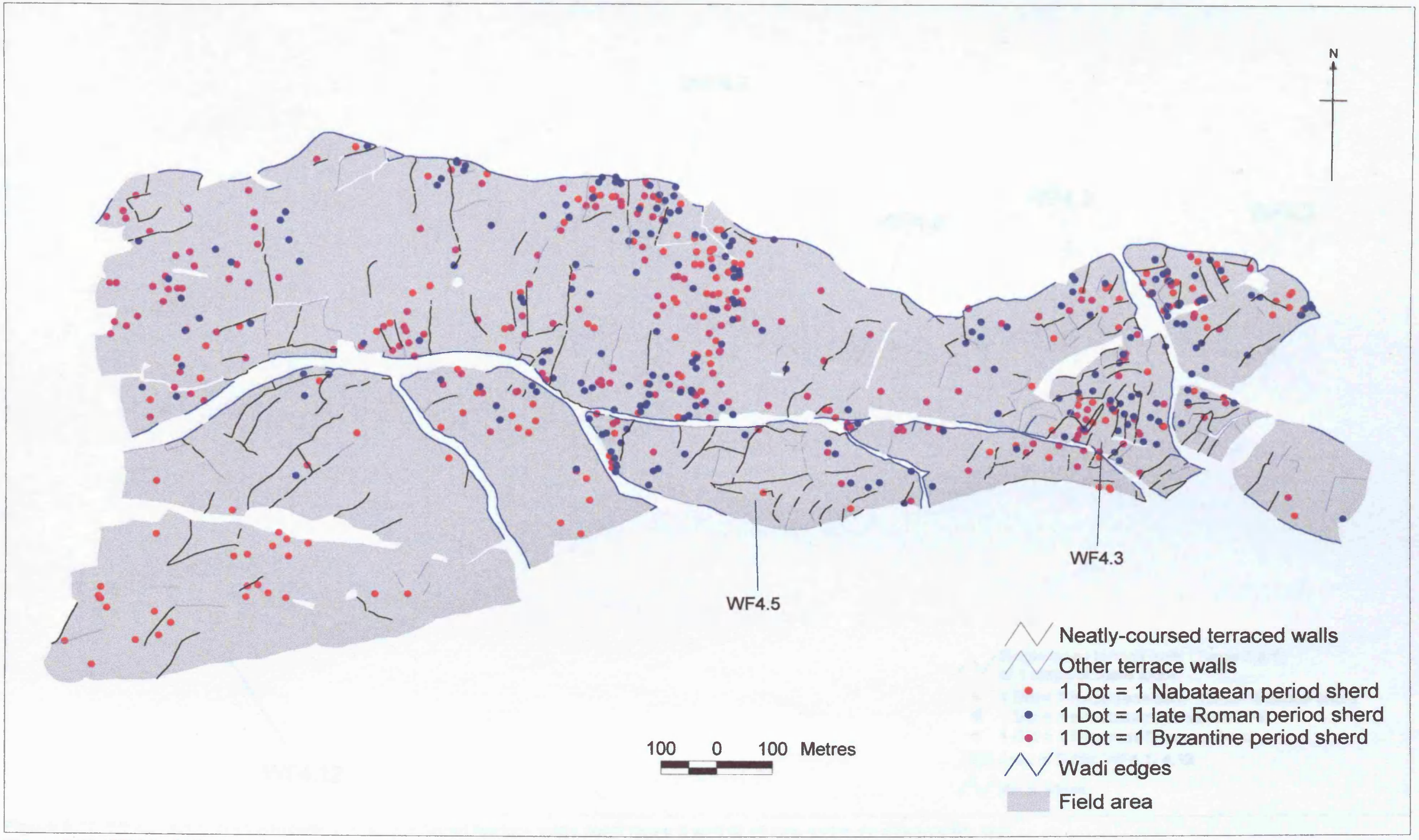

Figure 6.31 WF4.1- 4.12: the relationship of neatly-coursed terrace walls of all types to Nabataean, late Roman and Byzantine fineware sherds

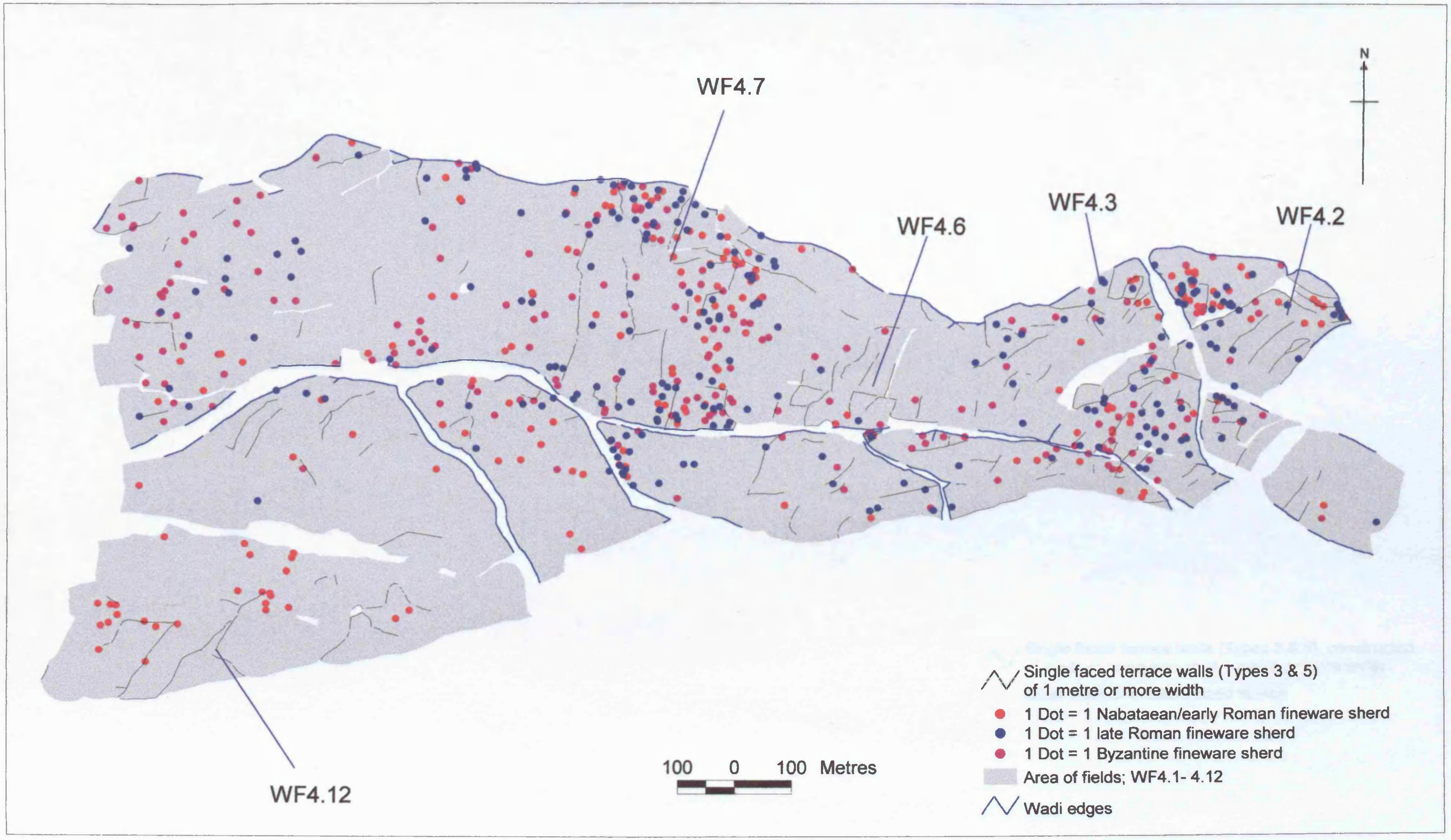

Figure 6.32 WF4.1- 4.12: the distribution of single-faced terrace walls (wall types 3 and 5) of one metre or more width and Nabataean/early Roman, late Roman and Byzantine fineware sherds

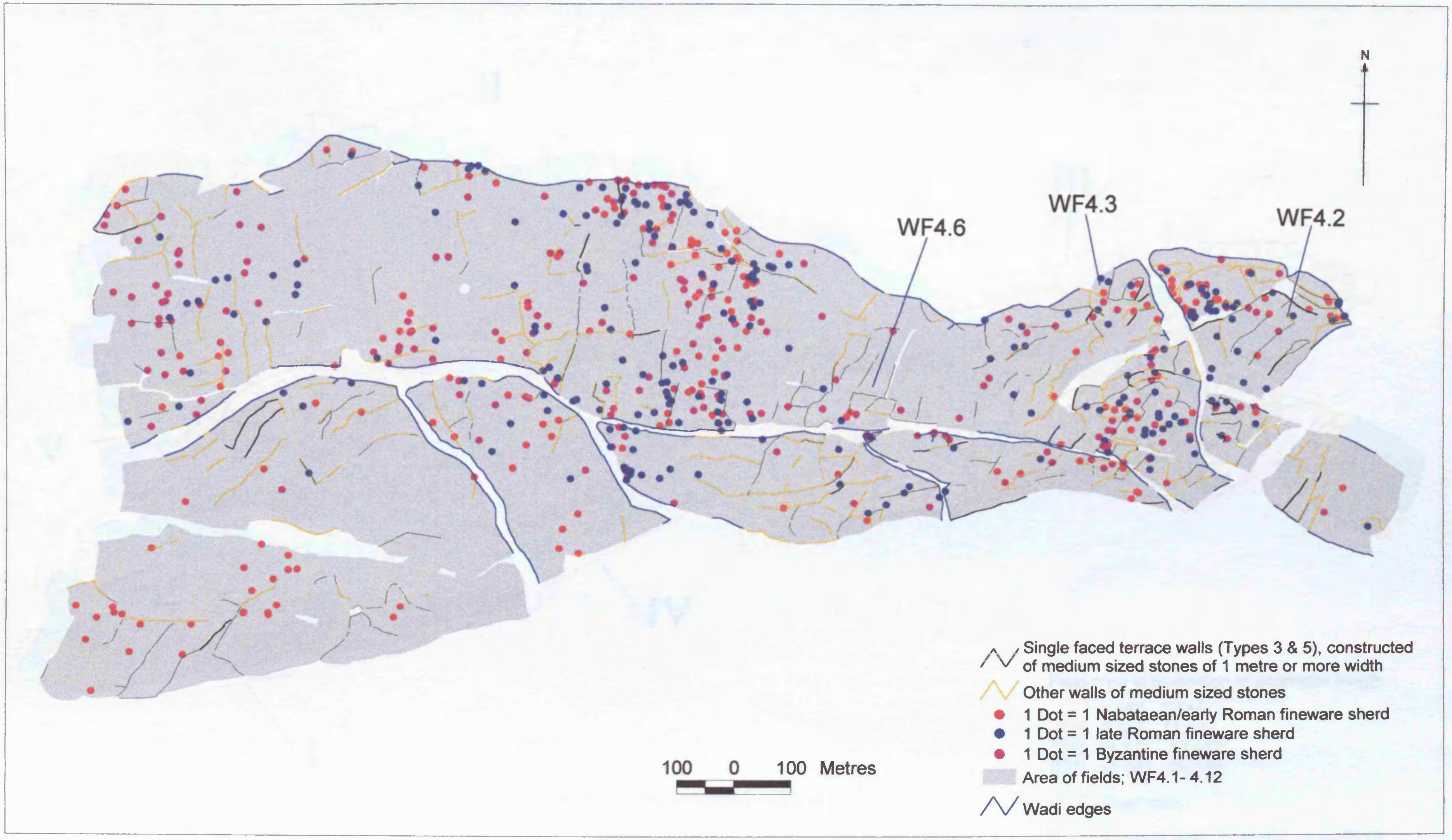

Figure 6.33 WF4.1- 4.12: the distribution of single-faced terrace walls (wall types 3 and 5) constructed of medium sized stones of one metre or more width and Nabataean/early Roman, late Roman and Byzantine fineware sherds

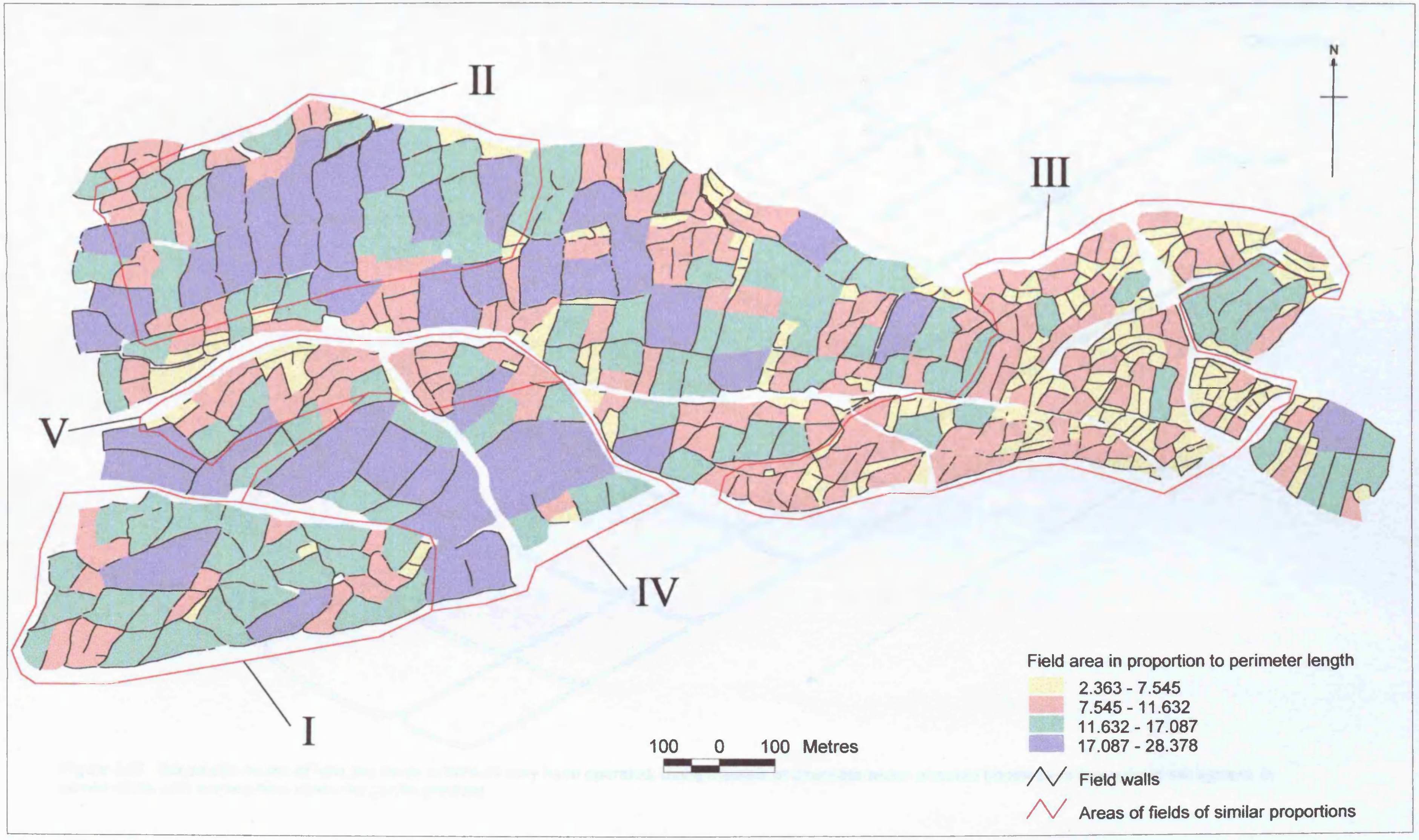

Figure 6.34 WF4.1- 4.12: the relative proportion of field area to perimeter length

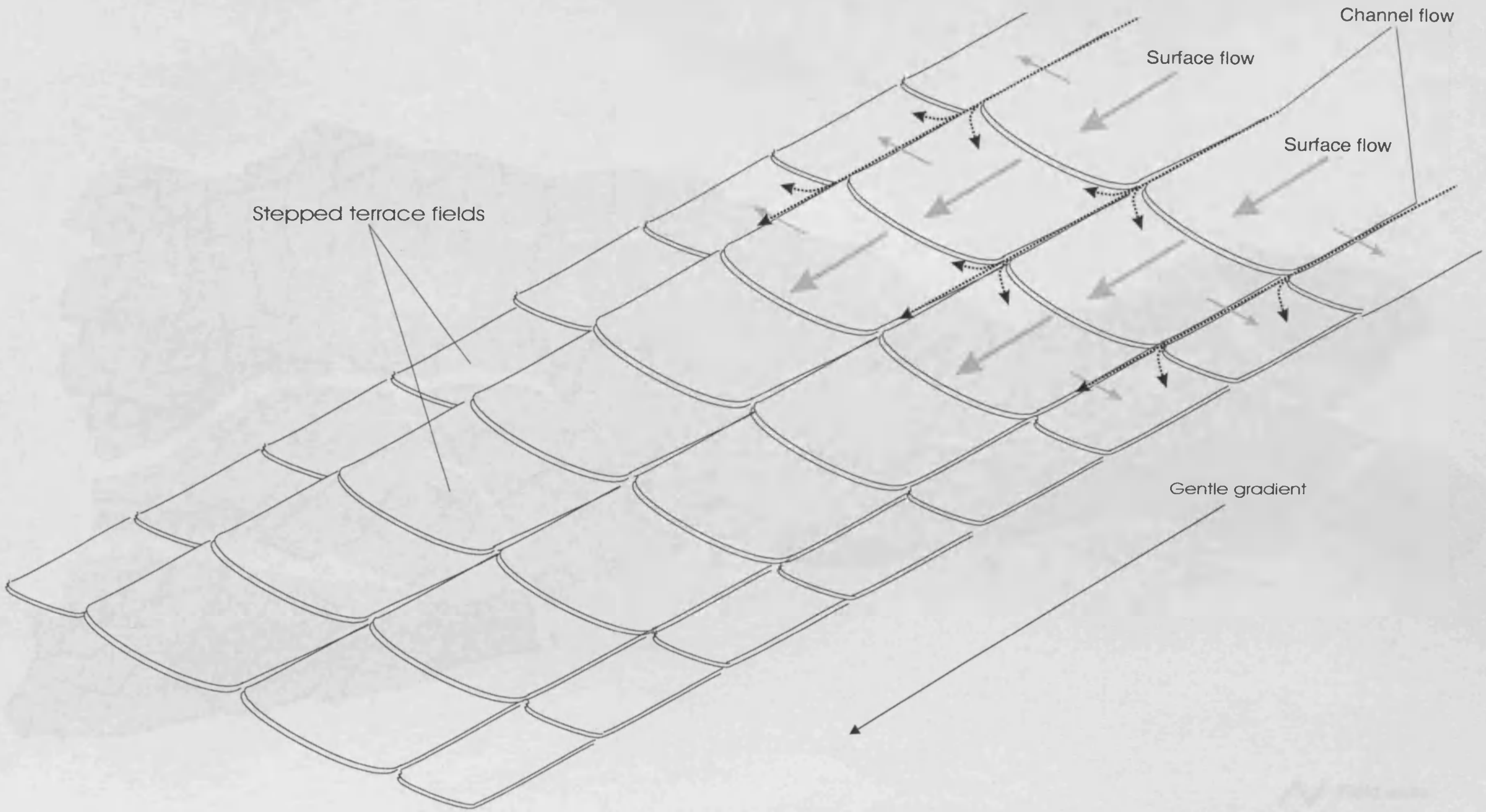

Figure 6.35 Schematic model of how the fields in WF4.10 may have operated, using a series of channels which directed floodwaters throughout the system in combination with surface flow down the gentle gradient

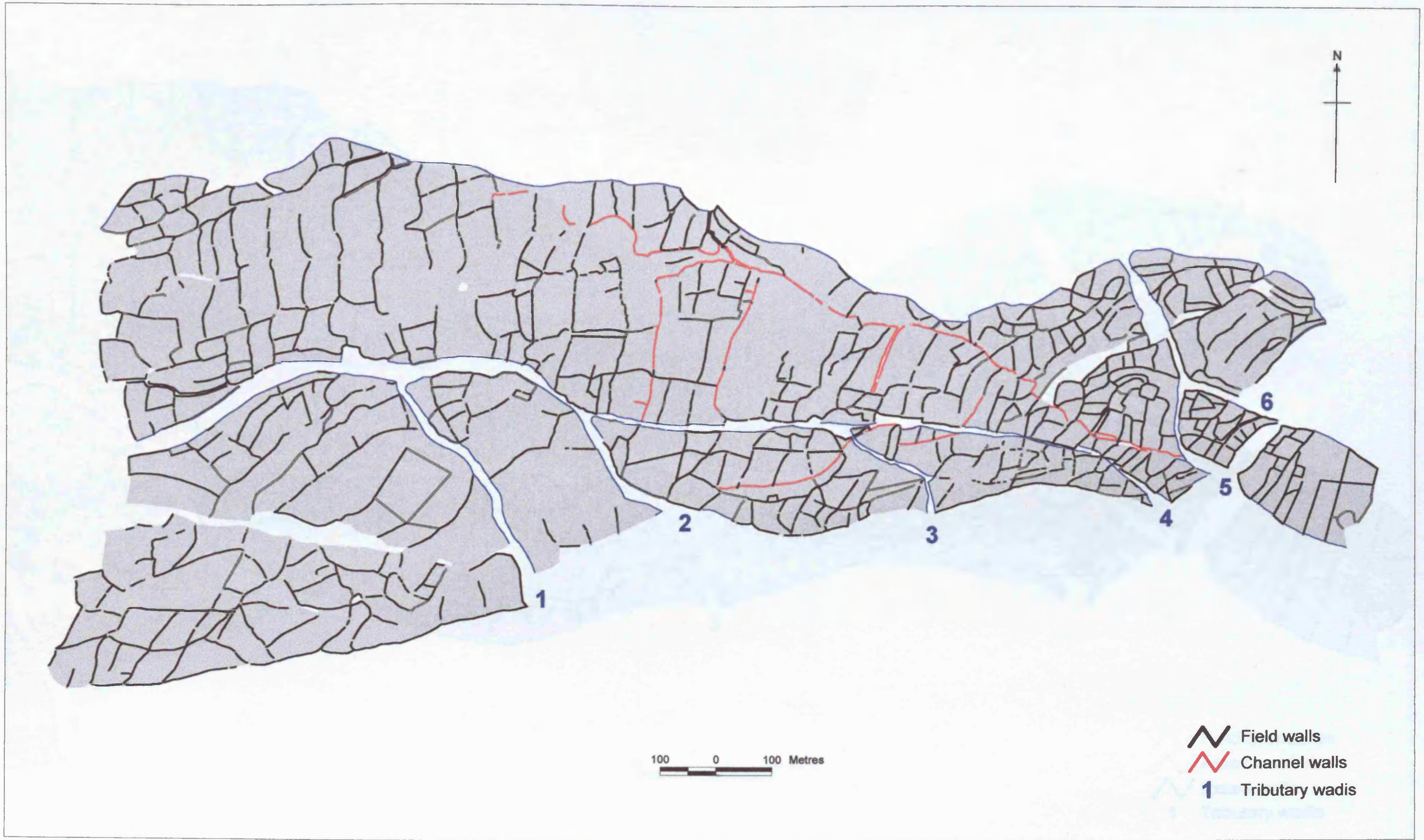

Figure 6.36 WF4.1- 4.12: remains of channel networks within units WF4.1 to WF4.9

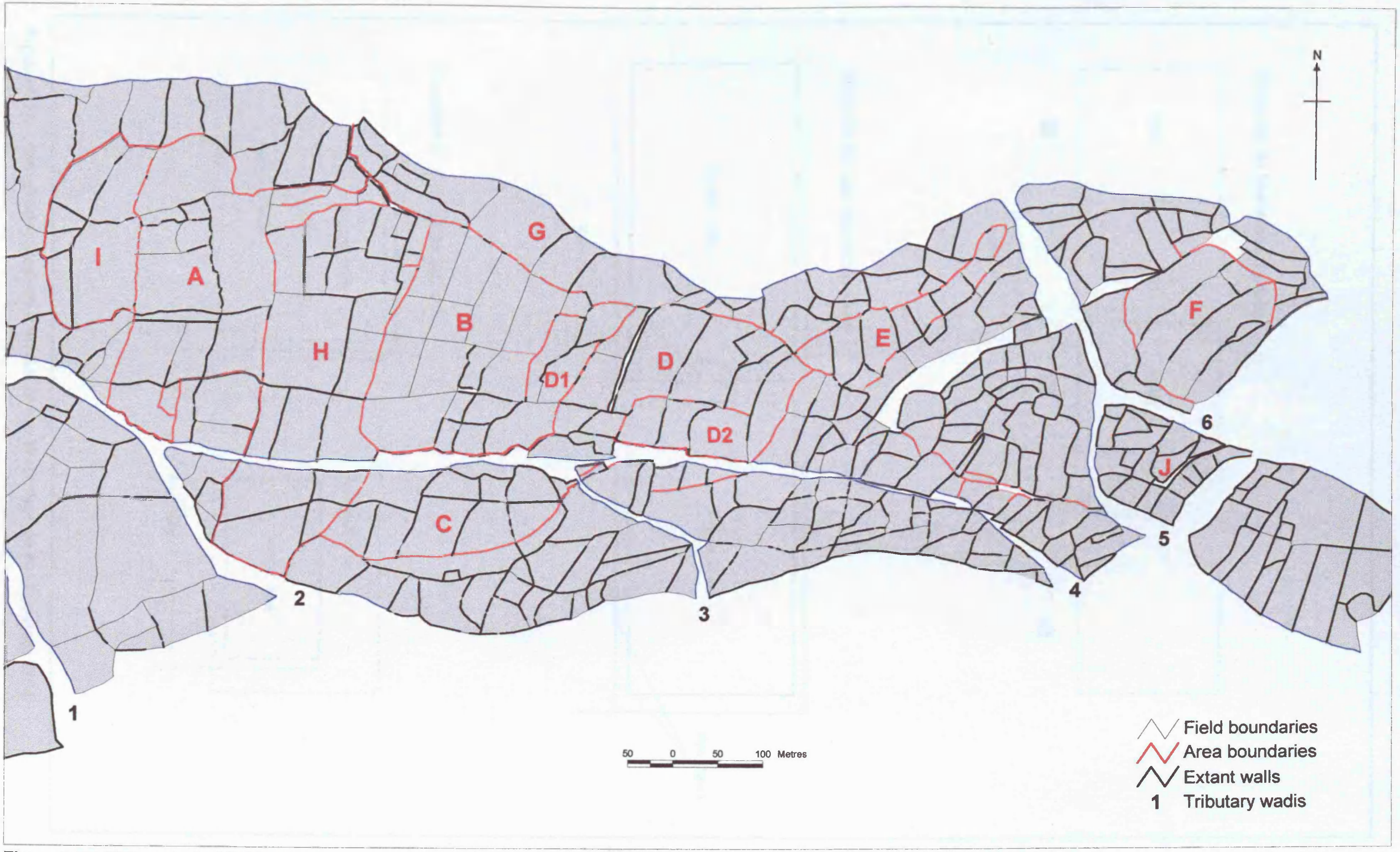

Figure 6.37 WF4: selected field groups

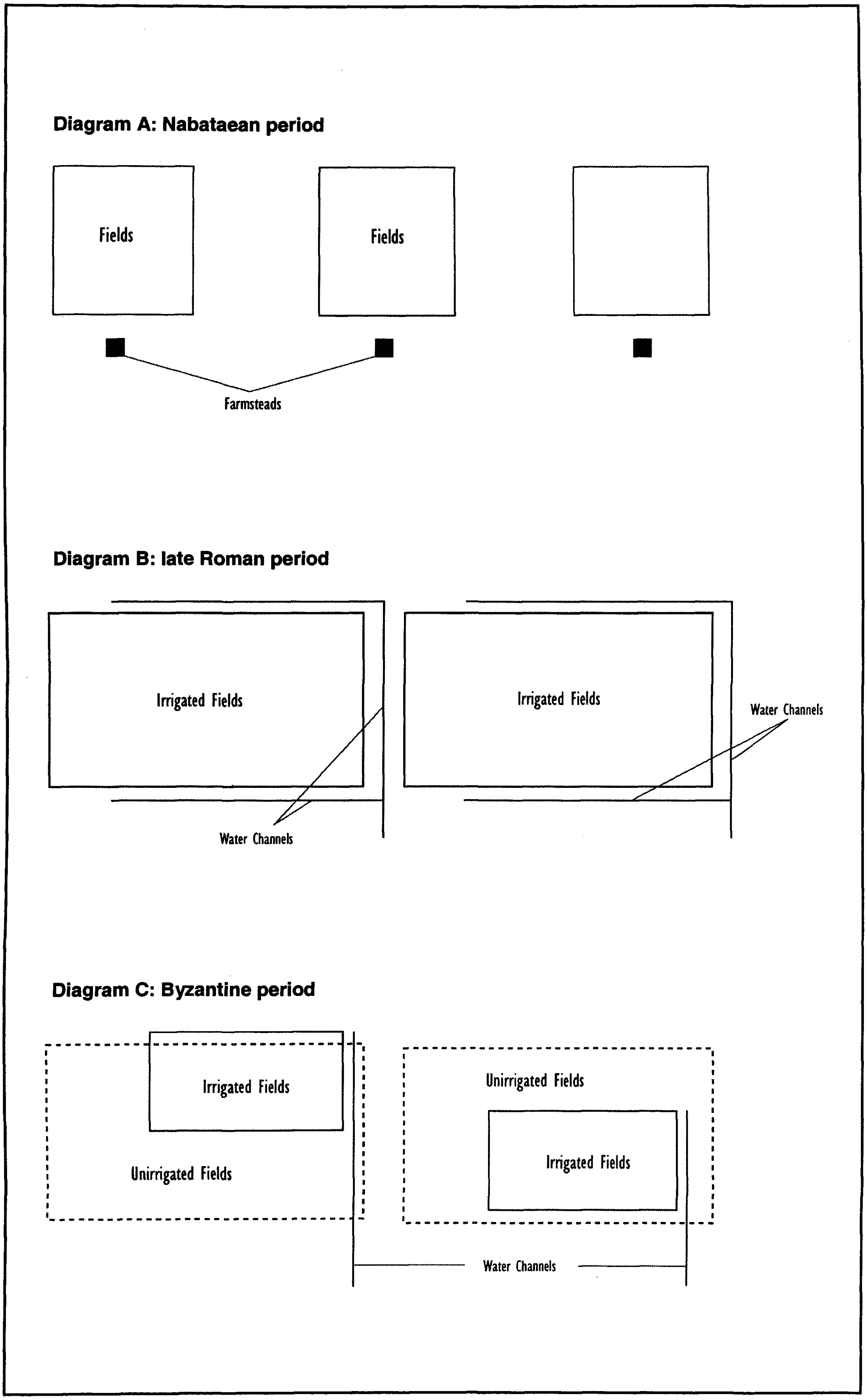

Figure 6.38 Simple development model of the Wadi Faynan field system WF4

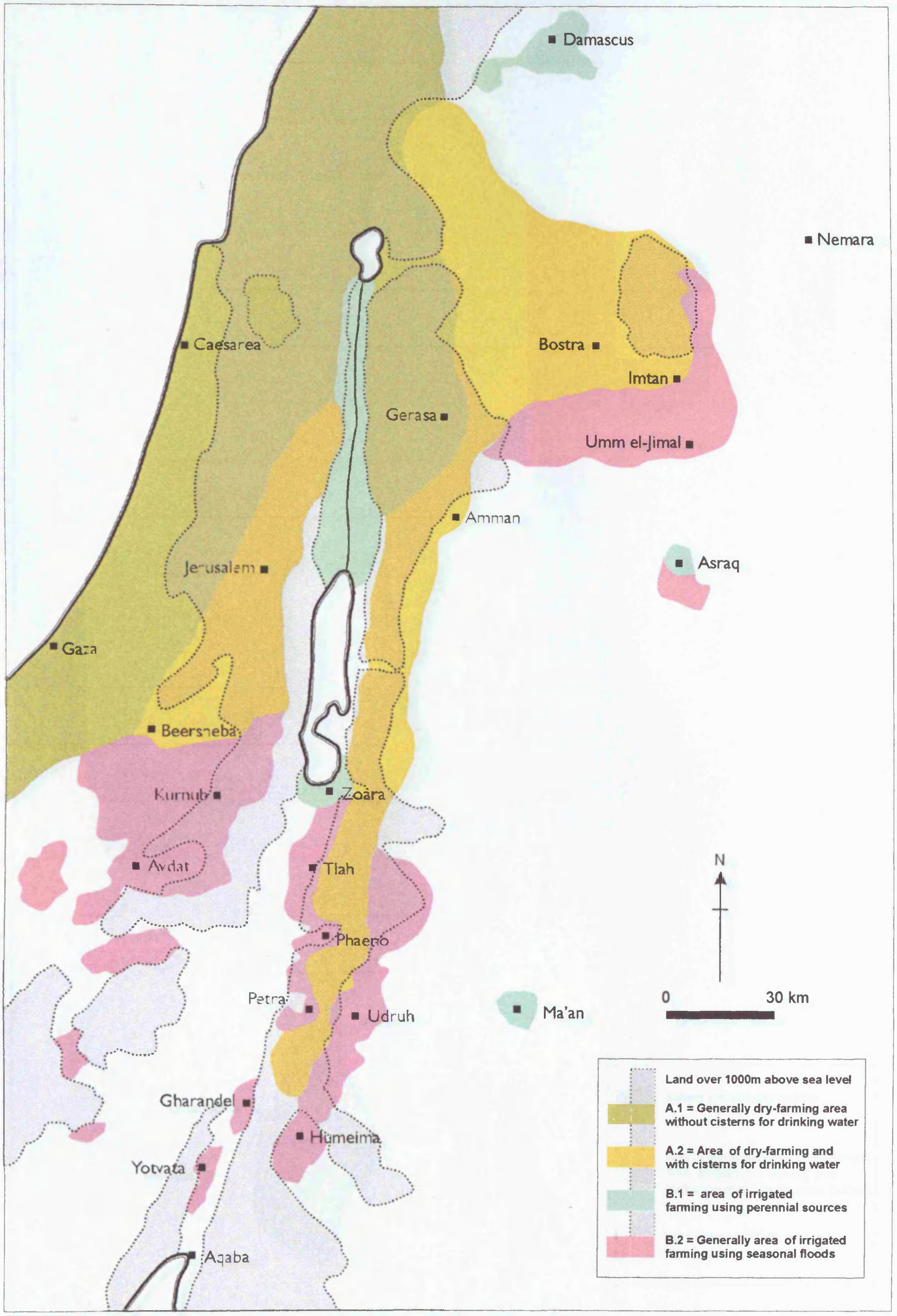

Figure 7.1 A schematic map of the prevalent farming systems of the Classical period

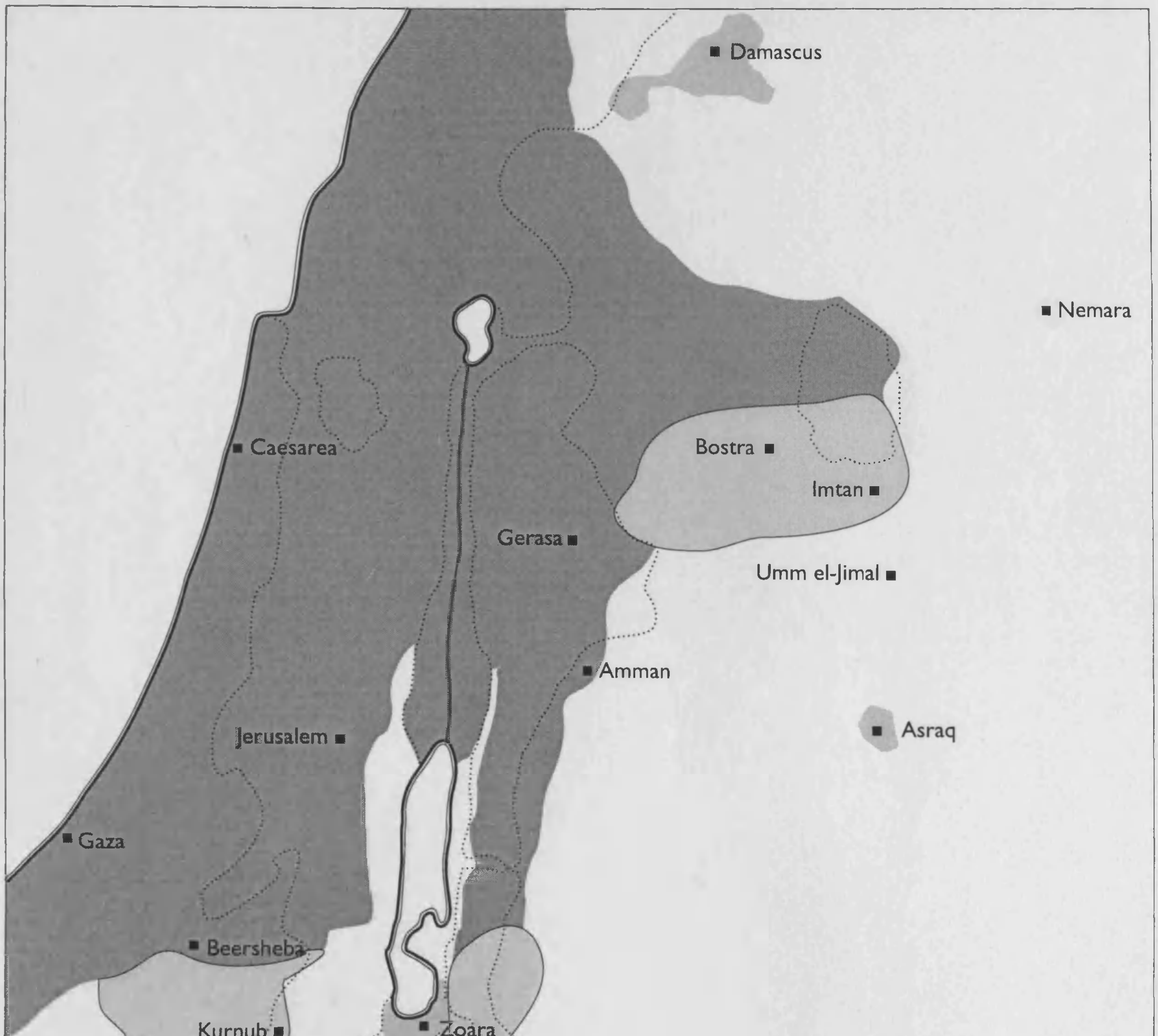

Figure 7.2 Main areas with some evidence of new Nabataean/early Roman period settlement

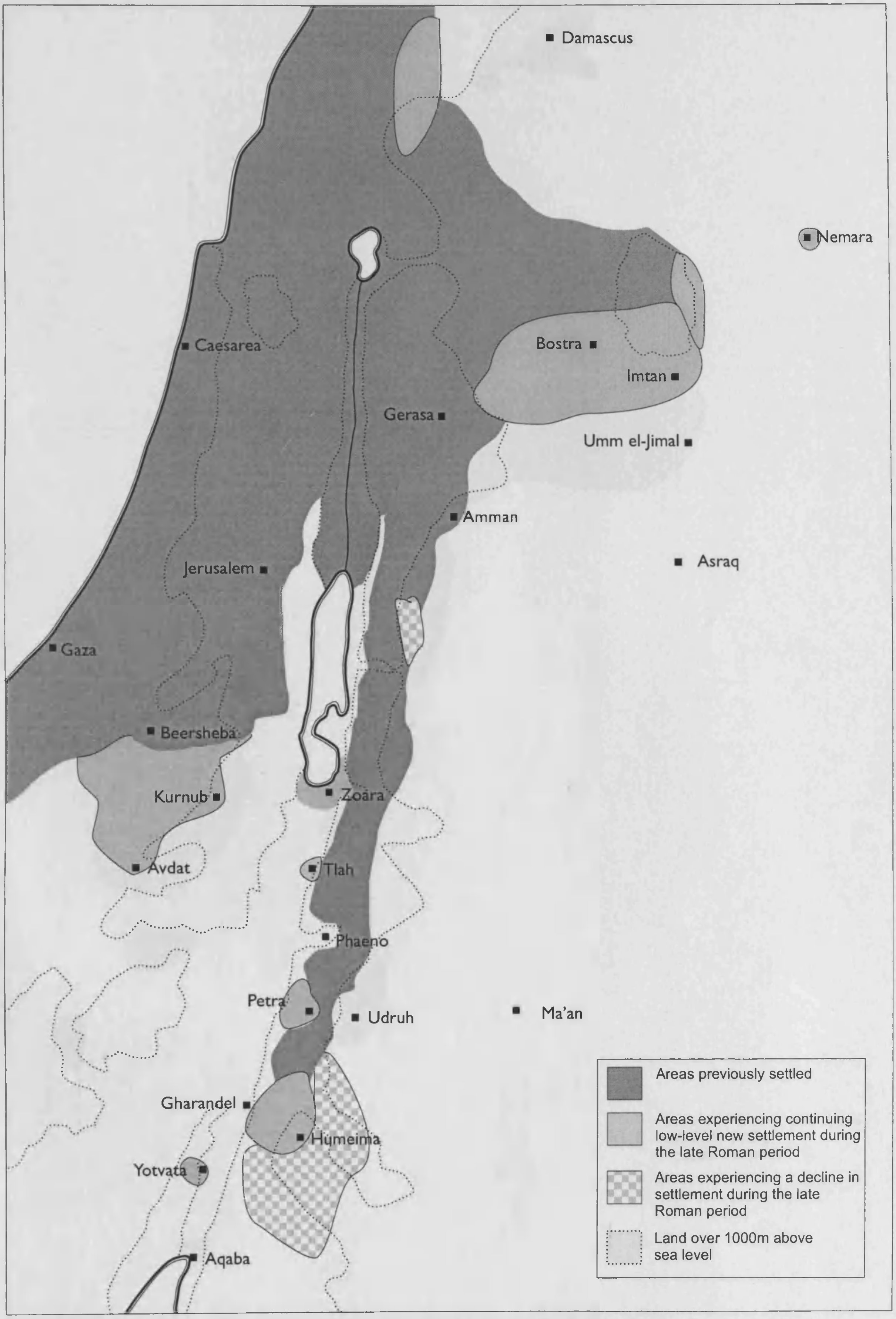

Figure 7.3 Main areas with some evidence of settlement change during the late Roman period

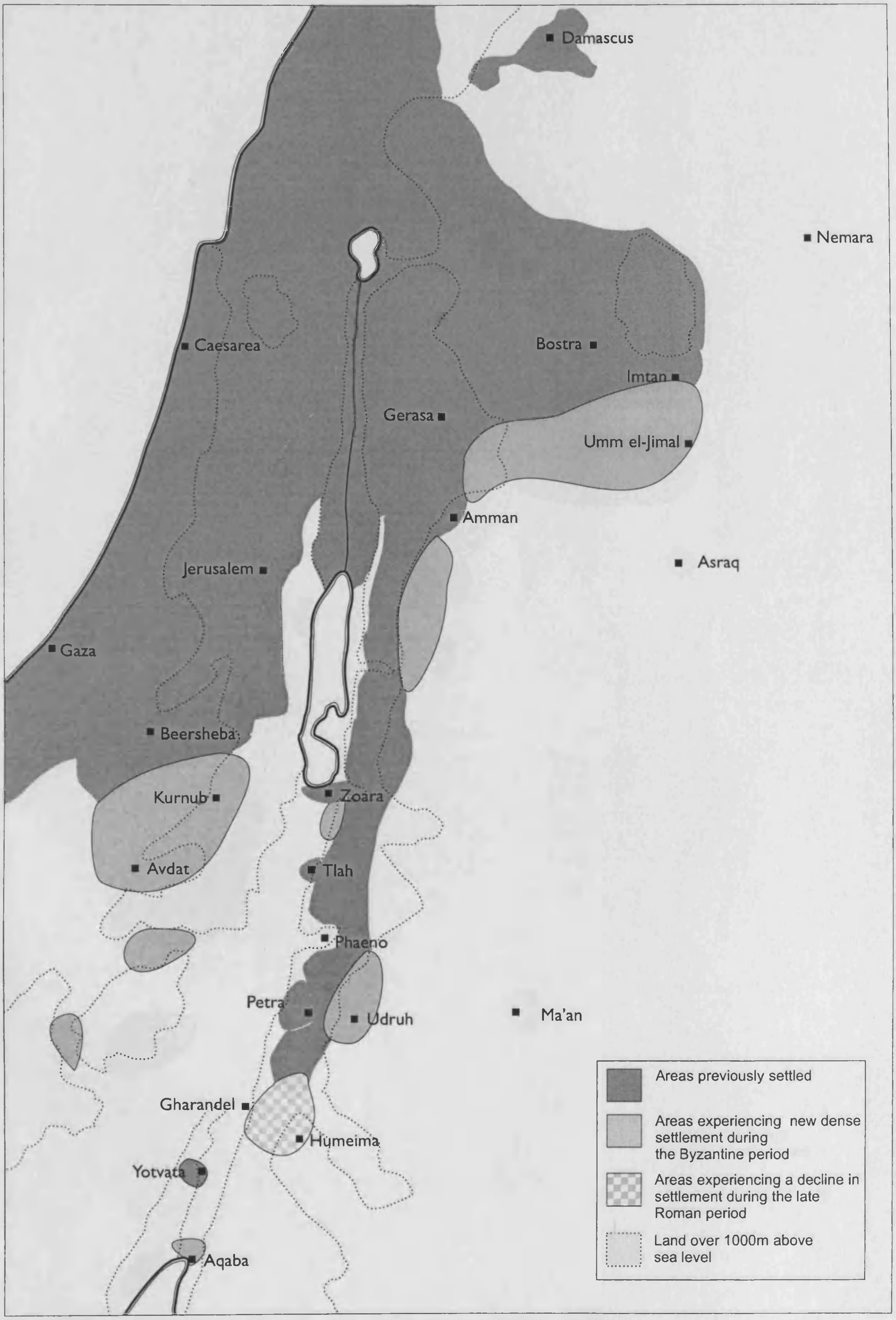

Figure 7.4 Main areas with some evidence of settlement change during the Byzantine period

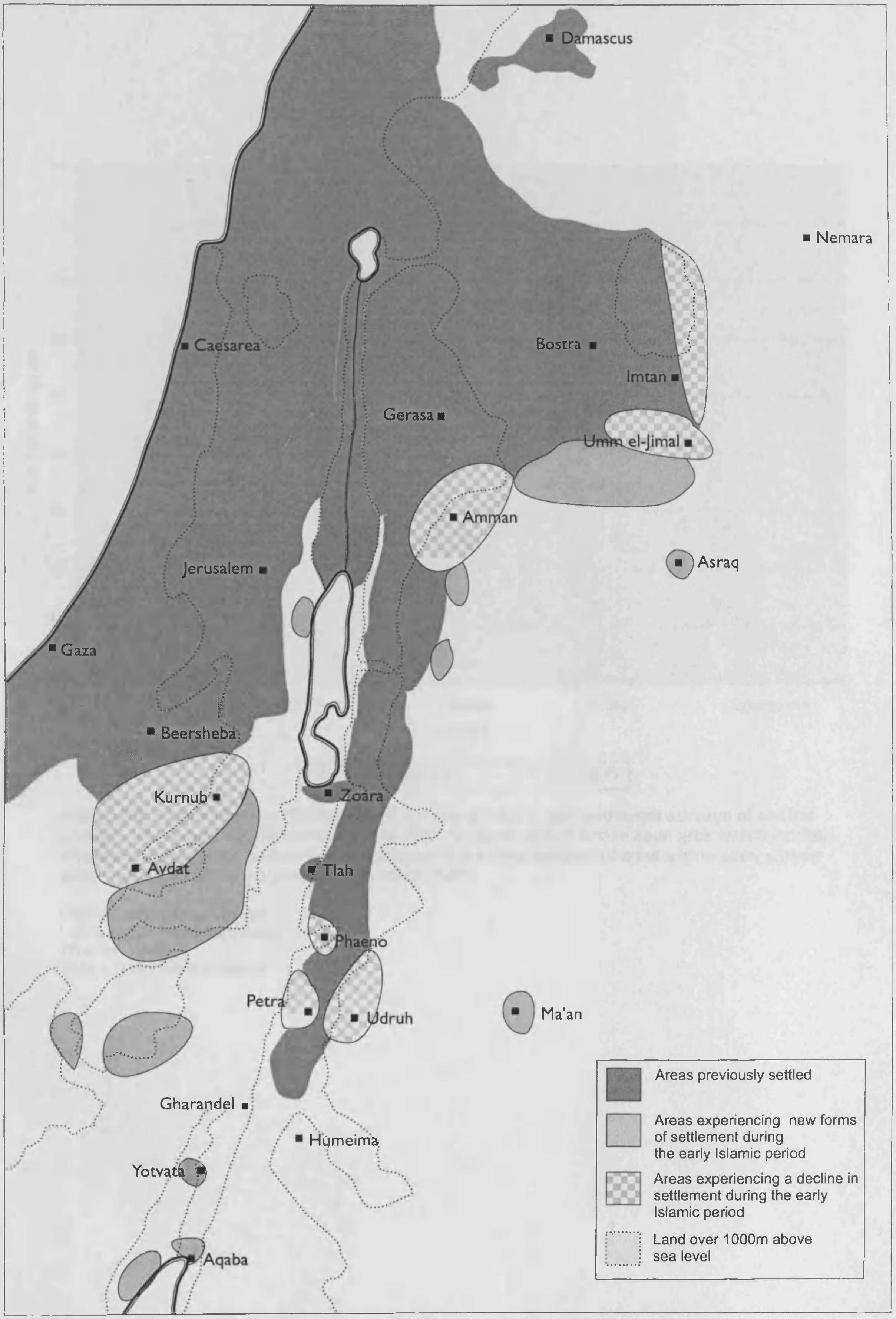

Figure 7.5 Main areas with some evidence of settlement change during the early Islamic period

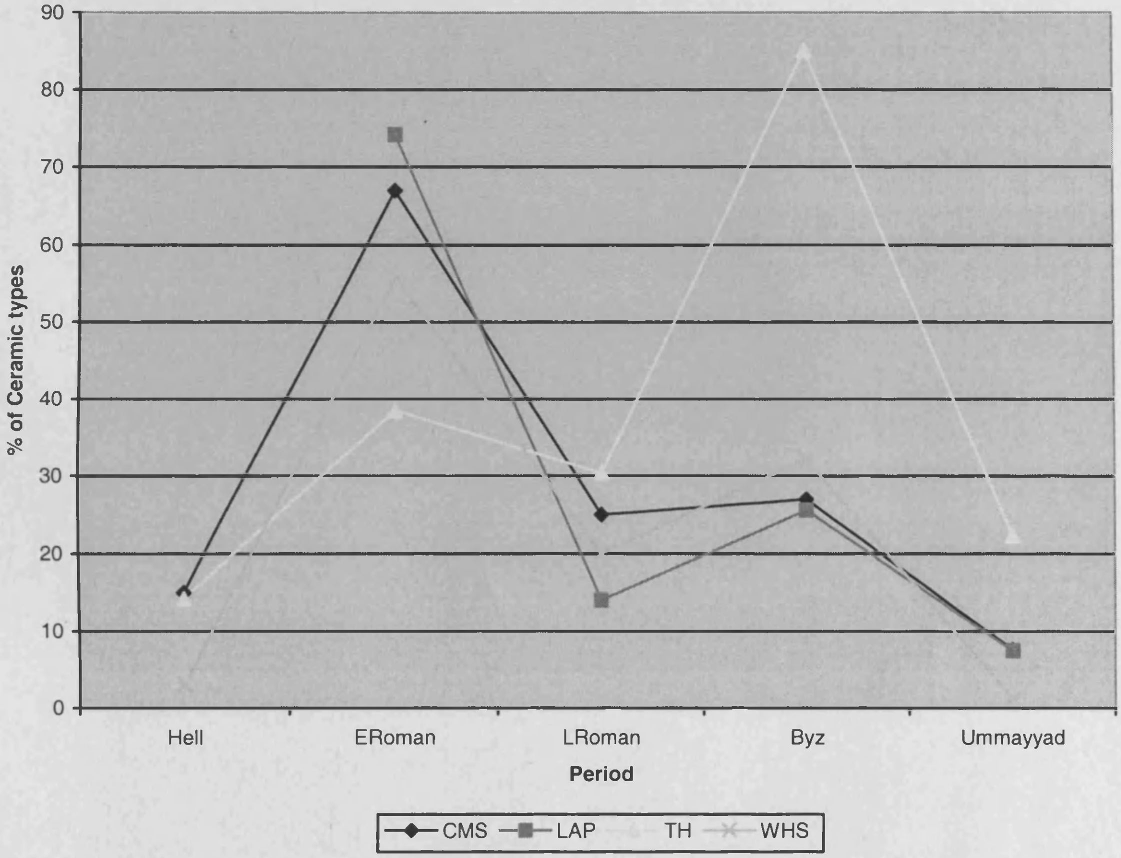

Figure 7.6 Graph showing the combined results of four major landscape surveys of central Jordan. The graph shows the number of sites for each period and in each area which exhibit sherds of a particular period as a percentage of the total number of sites within each survey area. (using information provided in Parker 1992).

CMS = Central Moab Survey
LAP = Limes Arabicus Project
TH = Tell Hesban
WHS = Wadi el-Hasa Survey