

Using Shuttle Radar Topography to map ancient water channels in Mesopotamia

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The Shuttle Radar Topography Mission (SRTM) is currently producing a digital elevation model of most of the world's surface. Here the authors assess its value in mapping and sequencing the network of water channels that provided the arterial system for Mesopotamia before the petrol engine.

Keywords: Mesopotamia, Bronze Age, Sasanian, irrigation, digital mapping

Introduction

The literate and city-based polities of Sumer and Akkad in southern Iraq are widely regarded as among the earliest examples of successful city-based civilisation, and great strides have been made in understanding their archaeology, economy, literature and social conditions. Fundamental to the development of these societies was a network of water channels, which provided irrigation for the cultivation of food crops, and a means of transport of goods from city to city. Irrigation technology and access to a network of channels has therefore been recognised as a key component of the so-called 'Mesopotamian advantage' (Algaze 2001).

The seemingly flat terrain of the Mesopotamian lowlands is drained by the Tigris and Euphrates rivers, which form a system of branching and locally meandering channels. Deposition of fine sand, silt and clay both within and alongside the channels results in the aggradation of levees which gradually raise the rivers until they flow several metres above plain level on low ridges (Buringh 1957). The excavation of canals to divert irrigation water from the main river channels towards fields also results in levees. Formation processes are similar to those of riverine levees, but in addition, channel excavation and cleaning operations result in the up-cast of clean-out banks alongside. As a result of these processes, both natural and artificial channels become raised above plain level to form levees up to 5m or so in height, and up to several kilometres in width. With a gentle gradient of *c.* 1:10 000 to 1:15 000 towards the head of the Gulf, the plains appear virtually flat, and surface elevation appears to reflect the pattern of levee development. The excavation of new canals as well as the natural branching process of rivers has resulted in an immensely complicated network of natural, artificial and hybrid channels across the plains.

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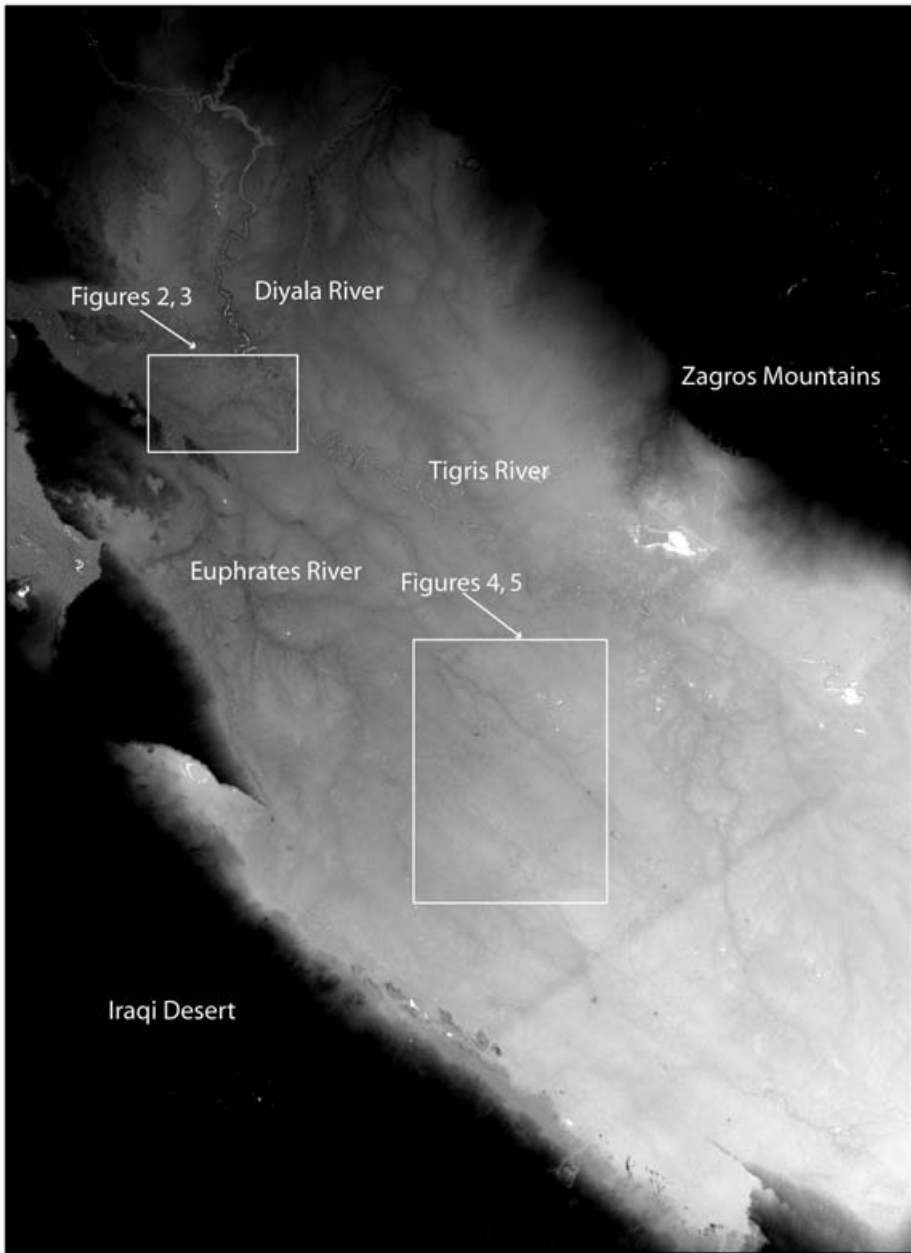
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Cuneiform texts have been used to indicate the changing geography of some of the channels over several millennia, and the levees are often visible from the air as low ridges, relict meanders or soil moisture marks, but the complexity of the Mesopotamian landscape makes it extremely difficult to disentangle their history. Despite recent advances (Cole & Gasche 1998; Verhoeven 1998), interpretation has been hampered by the lack of geomorphological data, maps and air photographs. As satellite imagery became increasingly available from the 1970s it has been possible to make general maps of channel systems of the Mesopotamian plains (Adams 1981), and the recent public release of CORONA satellite imagery has resulted in a flurry of new studies on landscapes in both Mesopotamia and beyond (Pournelle 2003; Hritz 2004). The digitisation of topographic maps of the Mesopotamian plains west of Baghdad has provided valuable supplementary micro-topographic data indicating the pattern of river levees and other channel systems (Cole & Gasche 1998). A still higher potential for interpretation has now been provided by the recently released data from the Shuttle Radar Topography Mission (SRTM), which takes the form of digital elevation models (DEM) for virtually the complete globe (Sherratt 2004).

Shuttle Radar Topography Mission

The Shuttle Radar Topography Mission (SRTM), is a joint project between the National Imagery and Mapping Agency (NIMA) and National Aeronautics and Space Administration (NASA), one aim of which is to facilitate military, environmental and economic projects: *'The objective of this project is to produce digital topographic data for 80% of the earth's land surface (all areas between 60 degrees north and 56 degrees south Latitude), with data points located every 1-arc second (approximately 30 meters) on a latitude/longitude grid. The absolute vertical accuracy of the elevation data will be 16 meters (90% confidence) (<http://srtm.usgs.gov/Mission/missionsummary.html>)'*. In the case of the Near East, the available data is for 3-arc second intervals, or 90 metres. Although this will result in smaller and narrower levees being missed, larger features, which can be several hundred metres or more in width, tend to be readily picked up. The images were taken by means of radar interferometry in which two radar images are taken from slightly different locations so that differences between the images allows for the calculation of surface elevation, or changes in elevation (<http://srtm.usgs.gov/Mission/missionsummary.html>). The data from this mission is being released in sets over the coming years. A preliminary version for selected parts of the world has recently been made available for scholarly research.

The SRTM data comes in the form of a Digital Elevation Model (DEM) which can be opened and viewed as an image or a set of images depending on the size of the area of interest. Images consist of elevation points. For southern Mesopotamia the thousands of data points show relatively few errors, and if present, such errors would be registered at the sensor as a negative number. On the image, these points are clearly evident in comparison with the surrounding landscape. SRTM data is unprocessed and therefore there is no estimate of its statistical error, but where elevation points are available (such as on the summit of the mound of Nippur), estimates of its total height fall within $\pm 2-4\text{m}$. Figure 4 indicates the range of variation along a transect across a levee south of Nippur. When data is obtained in an unprocessed form, some processing is required. For example, the SRTM data for the



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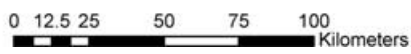
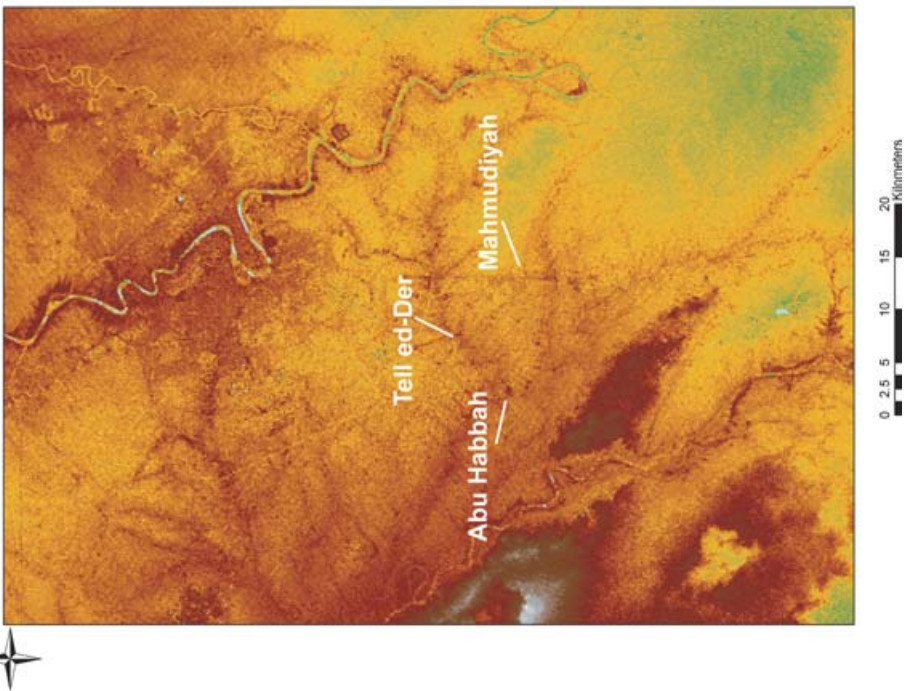
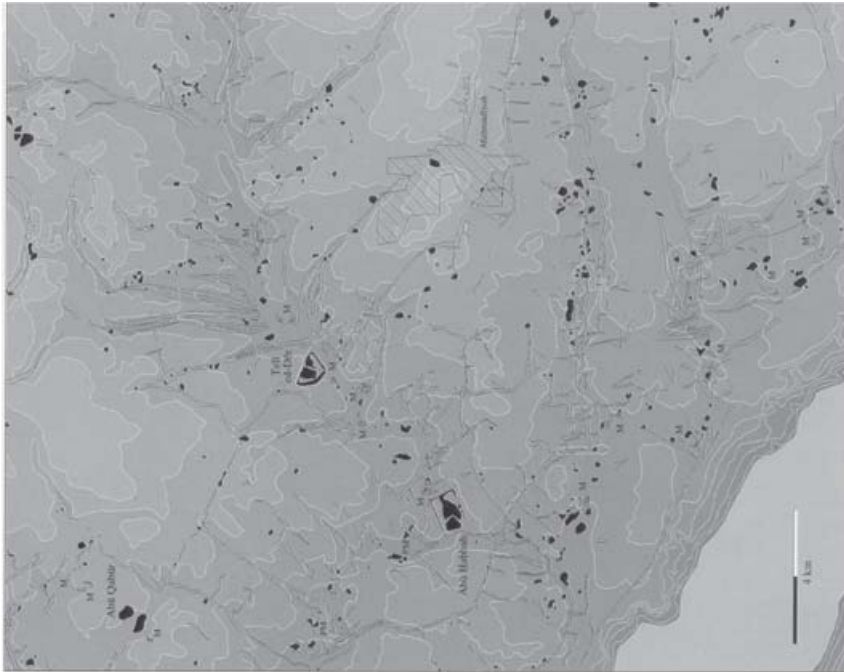


Figure 1. Pattern of levees (in shades of grey) representing modern and ancient channels on the southern Mesopotamia plains, derived from the Shuttle Radar Topographic Mission.

SRTM mapping in Mesopotamia



Figures 2 (bottom) and 3 (top) For legends, see facing page.

Near East is not geo-referenced and it must therefore be registered in order to bring it into a GIS. Nevertheless, most SRTM imagery can be used with relatively little processing.

Mapping the channels

As is to be expected from a region with such a long history of channel development, the pattern of raised terrain revealed by the digital terrain model is complex (Figure 1). The pattern of interweaving and bifurcating levees represents the aggradation of sediments from both natural and artificial channel systems over at least 10 000 years. Confirmation of the quality of the SRTM data comes from the Sippar area (Abu Habbah on Figure 2), where the raw digital imagery can be compared with precise topographic data of the alluvial plain derived by a team from the University of Ghent from 1:25 000 maps, satellite images and field survey (Figure 3; Cole & Gasche 1998; Verhoeven 1998). Both show the same system of levees and channels, ranging in size from the main irrigation channel running past both Sippar and Tell ed-Der down to secondary distribution channels. The information from the DEM successfully captures both the height of the levee as well as the pattern of channel branches.

Sequencing

The relative locations of the channels and their associations with dated sites potentially provide evidence for the sequence in which they were in use. Some channels are oriented with the dominant slope of the plain, that is NNW-SSE, whereas others follow an orientation closer to east-west. The dendritic pattern of some levees appears to be a result of a process of bifurcation which can result either from the excavation of new canals from a trunk channel, or from the creation of new 'natural' channels by the spontaneous breaking of river banks along breaches created by humans or by natural agencies (i.e. avulsion: Jones & Schumm 1999; Verhoeven 1998: 192-8).

As argued by Jacobsen (1958) and Adams (1965), archaeological sites form alignments along the levees, and thus dated sites provide an indication of when a channel became active. Figures 4 and 5 show two distinct NNW-SSE levees in the vicinity of Nippur, both of which are followed by alignments of sites recognised and mapped by Adams (1981). In addition, a weaker alignment of sites is related to a more dispersed feature to the south-east of Nippur. In the case of the large levee to the north-east of Nippur (no. 1 on Figure 5), the associated sites, as indicated on the maps of Adams (1981), imply that there were two periods of occupation, the first in the Early Dynastic (early third millennium BC) and the second in the Sasanian period (early first millennium AD). It appears that the Early Dynastic levee was later adopted by a Sasanian channel which diverged from the older levee downstream. The second levee (no. 2 on Figure 5) accommodated Sasanian sites

Figure 2. Topography represented by SRTM data for the Sippar area south-west of Baghdad (levees are evident as brown ridges, Baghdad as the brown area on the Tigris to the NNE of Tell ed-Der).

Figure 3. Topography of the Sippar (Abu Habbah) area (see Figure 2). Based on 1m contour data derived from conventional topographic maps (from Cole & Gasche 1998 with permission).

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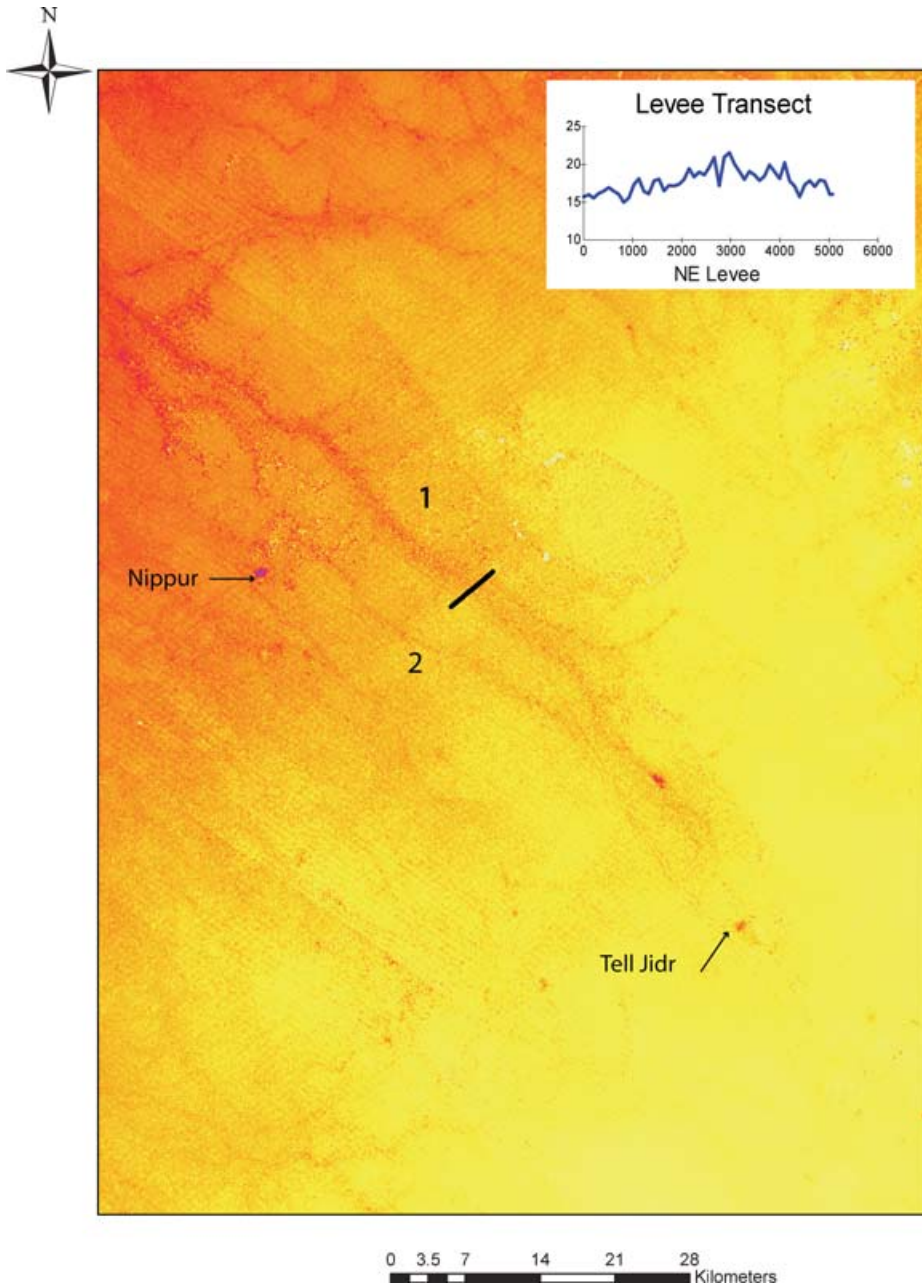
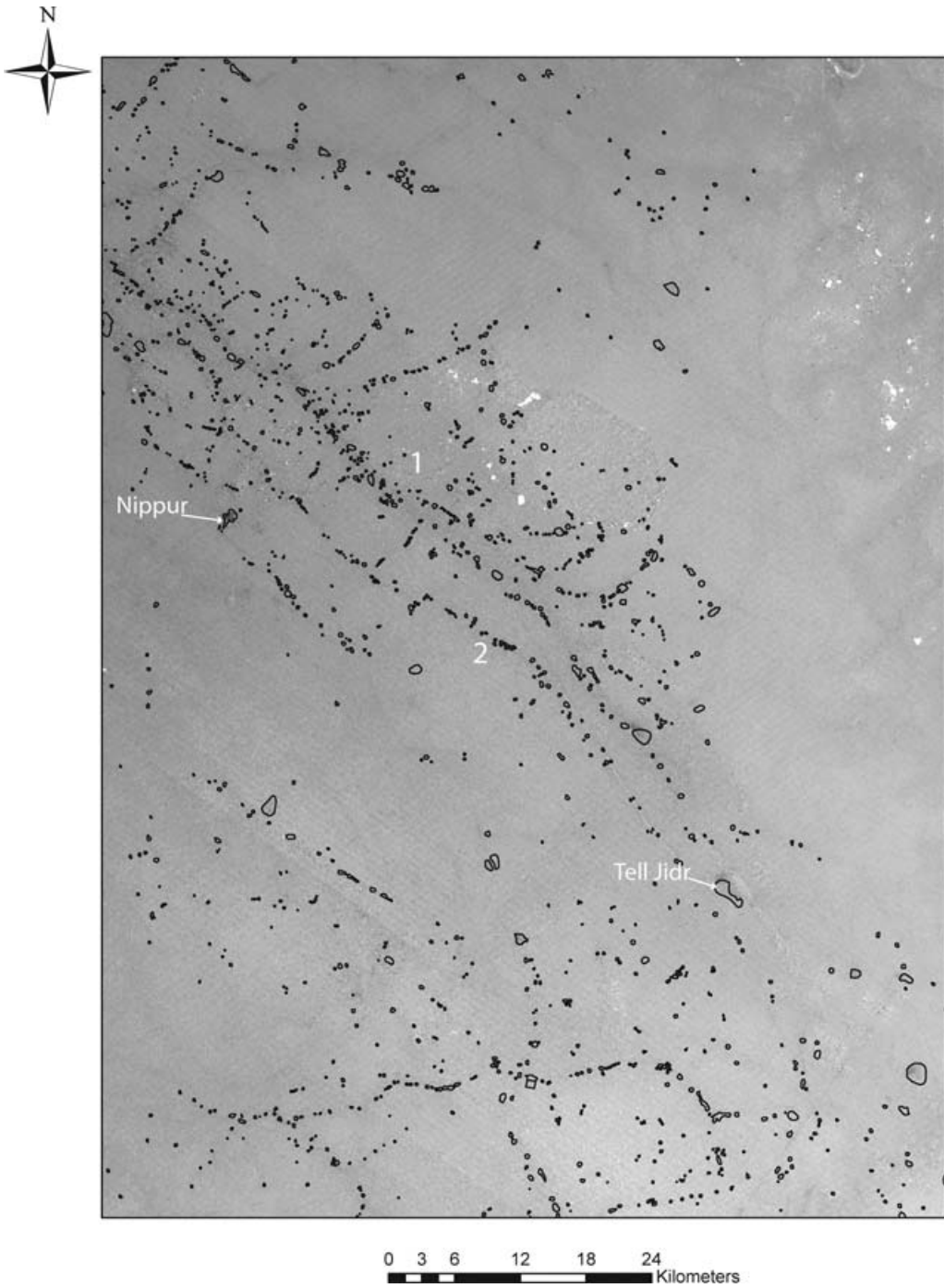


Figure 4. Topography derived from SRTM for the area south of Nippur showing levees as an orange trace (represented on Figure 1 by box).

(Adams 1981: fig. 45), although an earlier period of use is suggested by the presence of occasional Kassite (late-second millennium BC) sites along this levee.

Indicative of the sensitivity of the radar images is their ability to pick up the topographic profile of the third river drain (pale line immediately west of Tell Jidr, Figure 5), which was



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Figure 5. Topography derived from SRTM for the area south of Nippur with sites derived from 'Heartland of Cities' (Adams 1981) superimposed.

dug during the late 1980s to conduct drainage waters through the central plains. It is also possible to compute cross profiles of the levees themselves to demonstrate their elevation as well as the range of variation of topographic values (Figure 4).

Although in most parts of the Mesopotamian plains sites tend to be aligned along levees as well as following down the hydrological gradient, in the northern areas some site alignments appear less orderly. In such areas, site alignments conflict with the general gradient to follow up and over levees (Cole & Gasche 1998). Whereas in the former case the aligned sites presumably must have been associated with a single water channel, in the latter case either the alignment of sites might be coincidental or, a later levee might have crossed over an earlier alignment of sites which followed an earlier, perhaps buried, levee. One advantage of the DEM data is that it will enable archaeologists to recognise such contradictions between levees and settlement patterns, with a view to further investigation.

On a larger scale, SRTM imagery has the potential to help unravel the relative contributions of the Euphrates and Tigris rivers to the development of early irrigation systems. For example, in the plains north of Baghdad, a Tigris palaeo-channel of pre-medieval date is well known from air photographs and old maps (Adams 1965: fig. 4), and is also evident on the SRTM images. Relict levees which continue this alignment to the south of Baghdad might therefore represent a continuation of this palaeo-channel. Alternatively, they may indicate the deposits of a combined Tigris-Euphrates course, or the easternmost distribution channels of the Euphrates.

The complexity of the channel patterns of Mesopotamia illustrates some of the problems that Mesopotamian communities, as well as later Sasanian and Islamic engineers, had to contend with. The images demonstrate how, as levee systems developed, the resultant topographic complexity must have made later canal construction and water engineering increasingly difficult. For example, some older levees may have acted as dams which constrained the main flow of water down towards the Gulf. As a result, it would not always have been possible to dig canals according to optimal principles of engineering, and rather it would have been necessary to avoid, by pass or dig through pre-existing features. Not only would this have inhibited canal design and contributed to the overall work load, by restricting the flow of water, waterlogging would have been exacerbated thereby contributing to salinisation and associated decreases of production.

Conclusions

SRTM is mapping the detailed pattern of ancient channels in Mesopotamia, showing the complexity of the interwoven and possibly superimposed systems. By allowing the observer to examine the plains as a single comprehensive unit, the SRTM images enable features of the alluvial landscape to be traced across a very broad geographical extent. This, combined with the capability of pinpointing subtle landscape features, gives this new data source immense value at both large and small scales.

Especially clear are the substantial and long-lived levees that traverse the central portion of the alluvium. These have been identified through archaeological survey, and can now be traced by virtue of their topography on the DEM. For example, the early Dynastic levee

east of Nippur is a distinct and recognisable feature along which archaeological sites form a distinct alignment.

In addition to their value in tracing channel patterns, the SRTM data reveal the palimpsest of multi-period levees. These have the potential to be used for the reconstruction of sequences in which features with earlier sites aligned along them are apparently overlaid by levees associated with later sites.

The complex network of bifurcating and dendritic channel systems suggests how riverine and irrigation-induced sedimentation have contributed significantly to the aggradation of the northern part of the plain. This contrasts with the southern plains where levee systems are less pronounced, and where the southern alluvium has received considerably less sediment than areas in the north (Reichel 1997; Wilkinson 2003). This confirms earlier suggestions by Adams (1972) that the bulk of sedimentation occurred on the northern plains, which would account for the lack of visibility of prehistoric sites in such areas. The identification of the palaeo-channels, confirmed by more detailed studies, will help disentangle some of the knottier problems of the ancient historical geography of Mesopotamia.

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References

- ADAMS, R. McC. 1965. *Land Behind Baghdad*. Chicago (IL): University of Chicago Press.
- ADAMS, R. McC. 1972. Settlement and Irrigation patterns in ancient Akkad, in M. Gibson (ed.) *The City and Area of Kish*: 182-208. Miami, Coconut Grove (FL): Field Research Projects.
- ADAMS, R. 1981. *Heartland of Cities*. Chicago (IL): University of Chicago Press.
- ALGAZE, G. 2001. Initial social complexity in southwestern Asia: the Mesopotamian advantage. *Current Anthropology* 42: 199-233.
- BURRINGH, P. 1957. Living conditions in the lower Mesopotamian plain in ancient times. *Sumer* 13: 30-46.
- COLE, S.W. & H. GASCHE. 1998. Second and First Millennium B.C. rivers in northern Babylonia, in H. Gasche & M. Tanret (ed.) *Changing Watercourses in Babylonia. Towards a Reconstruction of the Ancient Environment in Lower Mesopotamia*: 1-64. Ghent: University of Ghent/Chicago (IL): Oriental Institute.
- HRTITZ, C. 2004. The Hidden Landscape of Southern Mesopotamia. *Akkadica* 125: 93-106.
- JACOBSEN, T. 1958. Summary of a report by the Diyala Basin Archaeological Project, June 1 1957 to June 1 1958. *Sumer* 14: 79-89.
- JONES, L.S. & S. SCHUMM. 1999. Causes of avulsion: an overview. *Special Publications of the International Association of Sedimentology* 28: 171-8.
- POURNELLE, J. 2003. *Marshland of Cities: Deltaic landscapes and the evolution of early Mesopotamian civilization*. Unpublished PhD thesis, Department of Anthropology, University of California, San Diego.

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- REICHEL, C. 1997. Changes in the plain levels of Babylonia and the Diyala region from 6000 BC onwards: a view from excavated sites. Paper presented at the 44th Rencontre Assyriologique Internationale, Venice, July 1997.
- SHERRATT, A. 2004. Spotting tells from space. *Antiquity* 78: <http://www.antiquity.ac.uk/projgall/sherratt/>.
- VERHOEVEN, K. 1998. Geomorphological research in the Mesopotamian floodplain, in H. Gasche & M. Tanret (ed.) *Changing Watercourses in Babylonia. Towards a Reconstruction of the Ancient Environment in Lower Mesopotamia*: 159-245. Ghent: University of Ghent/Chicago (IL): Oriental Institute.
- WILKINSON, T.J. 2003. *Archaeological Landscapes of the Near East*. Tucson: University of Arizona Press.