River Dee, Holt to Worthenbury, Wrexham and Cheshire

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Highlights

This GCR site, known as the 'River Dee meanders', is one of the most tortuous stretches of meandering channel on a major British river. The stretch crosses the fluvial/tidal transition and is a location at which the interaction of river and tidal processes can be observed in a relatively natural setting (Figure 3.33).

Upstream reservoir regulation of the river flow has caused a progressive change in the discharge regime over the past 50 years, and the downstream section of the stretch is also influenced by a backwater from the 11th century Chester Weir.

The restricted amount of management of the channel allows the river's response to these anthropogenic influences to be observed.

Introduction

Little scientific research had been undertaken on this stretch of the River Dee until Gurnell *et* al. (1993) were commissioned to undertake a hydrological and geomorphological study by the Countryside Council for Wales (CCW). Some of the detailed results of this work are summarized in Gurnell *et al.* (1994). A programme of research on the contemporary fluvial-tidal processes on this section of the Dee has subsequently been funded by the Leverhulme Trust (Gurnell, 1996, 1997a,b). The following account of the River Dee meanders site is based on information from the above publications.

The River Dee between Holt and Worthenbury is approximately 18 km in length along the channel centreline, and is located at the transition between the upstream, fluvially influenced river channel and downstream channel sections, that are additionally affected by a freshwater backwater during spring tidal cycles. The most downstream section of the reach also contains a permanent backwater from Chester Weir (located some 20 km downstream of the stretch). The stretch consists of a meandering planform with a highly sinuous course (the sinuosity, expressed as the ratio of total channel centreline length to the length of the axis of the meanders, is approximately 2 : 1). The stretch contains at least 16 major meanders with additional changes in direction, giving a major meander wavelength slightly in excess of 500 m. The average channel width is approximately 30 m (limits of normal winter water level) and generalized bedslope ranges from 0.00005 in the most downstream section to 0.00065 at the upstream end of the reach.

The adjacent floodplain contains a number of palaeochannels, indicative of past channel mobility. A comparison of the position of the national boundary between England and Wales in the downstream sector of the stretch, and the county boundary along the upstream sector, is further evidence of movement in the historical position of the channel. A more ancient course of the River Dee has been identified from borehole data, indicating the varying depth from the ground surface to bedrock. These data have been collated by the Environment Agency and can be used to describe a palaeovalley the course of which appears to diverge from the present course of the Dee in a large arc south from Llangollen, crossing the present valley north of Overton, and passing to the east of Holt. At some point in the Devensian late-glacial (estimates vary from 18 000 to 14 000 BP), this course would have migrated towards, or been relocated to adopt, the approximate present position of the channel. Nevertheless, an analysis of Ordnance Survey map (Gurnell *et al.,* 1994) and aerial photograph (Gurnell, 1997a) information suggests that, over the past century, the river channel has been surprisingly stable in its position. Furthermore, sedimentary and archaeological evidence suggests that the recent period of relative channel stability extends back two or three centuries.

Description

Although this stretch of the River Dee is of interest in the context of the long-term evolution of its valley, terraces, floodplain and channel, there are as yet few research results to provide detail with regard to these aspects of the site (Gurnell *et al.,* 1993). Research so far has concentrated upon contemporary processes and adjustments in the river channel over the past century. It has revealed a number of unexpected characteristics of channel morphology and mobility, which are elaborated below.

Detailed analyses of the character and changes in the channel's planform have been undertaken by extracting information from 1 : 10 000 and 1 : 10 560 scale OS maps (Gurnell *et al.,* 1994) and from aerial photographic coverage at approximately 1 : 10 000 scale (Gurnell, 1997a), and by analysing the information within a Geographic Information System (GIS). The use of very careful methods of data extraction and computer-based manipulation have been essential to ensure that subtle changes in the river's planform are separated from errors generated in transcribing and analysing the data (Downward *et al.,* 1994). The changing character of the cross-profile of the river channel has been assessed through the analysis of 122 cross-profile surveys undertaken by the Dee and Clwyd River Authority in 1973, and 36 re-surveys plus an additional 20 new cross-profiles surveyed in 1994–95. Field observation of the landforms has been used to confirm the analytical results and to interpret their process significance.

Channel positional mobility

The channel planform has been surprisingly stable over the past century. Channel mobility has been lowest at the downstream end of the reach, increasing steadily in an upstream direction. Where channel movement has occurred, it has been mainly oscillatory in character, rather than indicating the channel migration that might be expected within a meandering river stretch. Where consistent channel migration has been identified, it has been predominantly towards the left bank in the central section of the stretch and towards the right bank in the upstream section. The predominant modes of channel planform change in the lower sections of the reach are either of no identifiable movement or reveal an oscillatory pattern. These spatial trends can be associated with decreasing stream power down the reach as a result of decreasing bed slope, and the increasing influence of the backwater from Chester Weir, and from high tidal levels overtopping the weir crest.

With the exception of six locally active sections, the total width of the floodplain, including the width of the active channel, across which the river has moved in the period 1876–92 is in the range 33–62 m. Since typical channel widths are in the range 20–45 m, total lateral movement beyond the width occupied by the active channel is less than half the present channel width along much of the river. The extent of lateral movement is significantly greater on meander bends (mean extent including the active channel, 55 m) than at points of inflexion (mean extent 46 m).

There appears to be a temporal pattern within the historical planform data, the most notable changes seeming to have occurred since 1949. There appears to have been an initial increase in channel position mobility and then a recent stabilization in channel position since 1979.

Variations in channel width

The active channel width is greater on meander bends than at points of inflexion. When these meander-scale variations in channel width are removed, an unusual spatial trend of downstream narrowing in channel width is identified. In addition, there appears to be a temporal trend whereby the channel has narrowed, particularly since the mid-1960s. The narrowing appears to have propagated downstream to the central portion of the reach by the mid-1970s, and to the downstream portion by 1992. This channel narrowing is thought to result from the closure of Llyn Celyn in 1965, which has resulted in significant changes in the river flow regime (Gurnell *et al.*, 1994).

Variations in the channel cross profile

Analysis of 122 surveyed cross-sections (Gurnell, 1997b) dating from 1973 has shown that the morphology of the river channel along the 18 km stretch changes in a clearly identifiable manner. Up to three minima in the width : mean depth ratio of the channel at individual cross-sections, identify levels with distinguishable morphologies the geometric properties of which exhibit clear downstream trends. In particular, the highest level (level 1: overtopping level) defines a channel which becomes narrower and deeper in a downstream direction, thus maintaining an approximately constant cross-sectional area. This complements the observations on downstream channel width narrowing from maps and aerial photographs. The lower two levels (levels 2 and 3) define channel cross-sections which increase in area in a downstream direction by maintaining an approximately constant width but an increasing depth. Level 3 is only consistently identified in the downstream sector of the 18 km stretch that is influenced by the Chester Weir backwater. Simple process modelling suggests that level 1 is adjusted to flows within the 1.5–2.33 year return period under the present flow regime, and that level 2 may be associated with the dominant discharge for sediment transport and its adjustment as a result of flow regulation. Upstream trends in the geometric properties of cross-sections to level 2 exhibit a distinct change in slope at the limit of the weir backwater, suggesting that the morphological impact of the dominant discharge for sediment transport under flow regulation is moderated by the backwater from Chester Weir.

There are statistically significant differences in the geometry of the river channel cross-sections between the upstream fluvially influenced sector, the central fluvial-tidal sector and the downstream fluvial-tidal-weir backwater sector.

Other spatial and temporal characteristics of channel change identified from aerial photographs, 1946–92

Distinct changes in bank vegetation cover have occurred, with an increase in tree- and shrub-lined banks from 31 to 61% in the upstream sector and 3 to 41% in the downstream sector of the stretch over the 1946–92 period. The timing of these increases in tree and shrub cover corresponds closely with the timing of observed channel narrowing. Field observations show that the development of willow/sallow/alder cover is associated with high bank sedimentation rates. The association of the development of tree and shrub cover with changing channel width is, therefore, likely to be extremely important in understanding channel change on this stretch of the Dee. Certainly, low-level depositional benches have been observed (in the field and on aerial photographs) to support the development of shrub and tree cover, but the direction of causality is unclear. The development of benches and other less-marked components of the channel cross-sectional morphology may result from a change in the sediment transport and deposition regime as a result of flow regulation, particularly since the mid-1960s. Thus, channel narrowing may result from deposition of sediments, which may then become colonized by shrub vegetation. However, it is possible that a change in bank grazing and management practices has allowed colonization of the banks by shrubs and trees, which has then trapped transported sediment during flood events, thus resulting in a narrowing of the channel.

Analysis of six sets of aerial photographs has also shown differences in the extent of in-channel bars and overbank deposition along the stretch. The central sector, which is not affected by the Chester Weir backwater but is the most upstream sector influenced by tides, has by far the greatest area of exposed depositional bars per unit channel length. This reflects the changing channel form downstream (the downstream channel is deeper and narrower, thus providing a smaller channel area within which bars can be mapped), but it is also probable that the hydraulic disturbance of the tides interrupts sediment transport through this sector and that as a result sediment is deposited. Thus this sector of the study stretch appears to play an important role in the storage and transfer of sediments from the river system to the sea. The extent of post-flood overbank deposition of sediment from one set of photographs also identifies the same central tidally influenced sector as experiencing more extensive bank and floodplain deposition of sediment than the other sectors. There also appears to be a change in bank depositional processes through the study stretch, with a transition from 14% of channel cross-sections experiencing deposition on both banks in the upstream fluvially influenced sector, to over 40% of sections experiencing deposition on both banks in the remainder of the stretch (influenced by hydraulic disturbances as a result of tidal and/or weir influences). Detailed field studies are required to define precisely the processes responsible for the change, but field observations were used by Gurnell *et al.* (1993) to suggest a transition from upstream bank processes dominated by fluvial erosion and deposition, to downstream hydrologically dominated bank failure and backwater-dominated plastering or draping of sediments across the bank face.

It is likely that this transition in bank deposition processes associated with the fluvial–tidal transition and the backwater from Chester Weir, coupled with changing rates of sediment deposition resulting from flow regulation and enhanced sedimentation under the influence of bank vegetation change, are the key factors in explaining spatial and temporal variations in the morphology of the River Dee meanders over the past 100 years.

Interpretation

Although at first sight, the geomorphological attraction of the River Dee meanders focuses on the tortuous planform of the river channel, and the expectation that such a meandering course is likely to be associated with active migration and cut-off processes, detailed research has revealed a far more fascinating and unexpected story. The relatively unmanaged form of the river in this stretch provides numerous clues concerning the interactions between fluvial and tidal processes and the anthro-pogenic influences of reservoir flow regulation and weirs on river channel form.

In the context of the past 100 years, the decreasing planform mobility and channel narrowing in a downstream direction are unusual observations, which can be explained by the interaction of fluvial–tidal flow regulation and weir influences. The complexity of these interactions is reflected in the cross-sectional form of the channel, and in field observations of the association of properties of channel form with bank sediments, erosion and failure processes. The relatively unmanaged nature of the stretch allows these subtle properties of the channel planform and cross-section to be identified, and also allows the interaction between bank processes and bank vegetation cover to be elucidated.

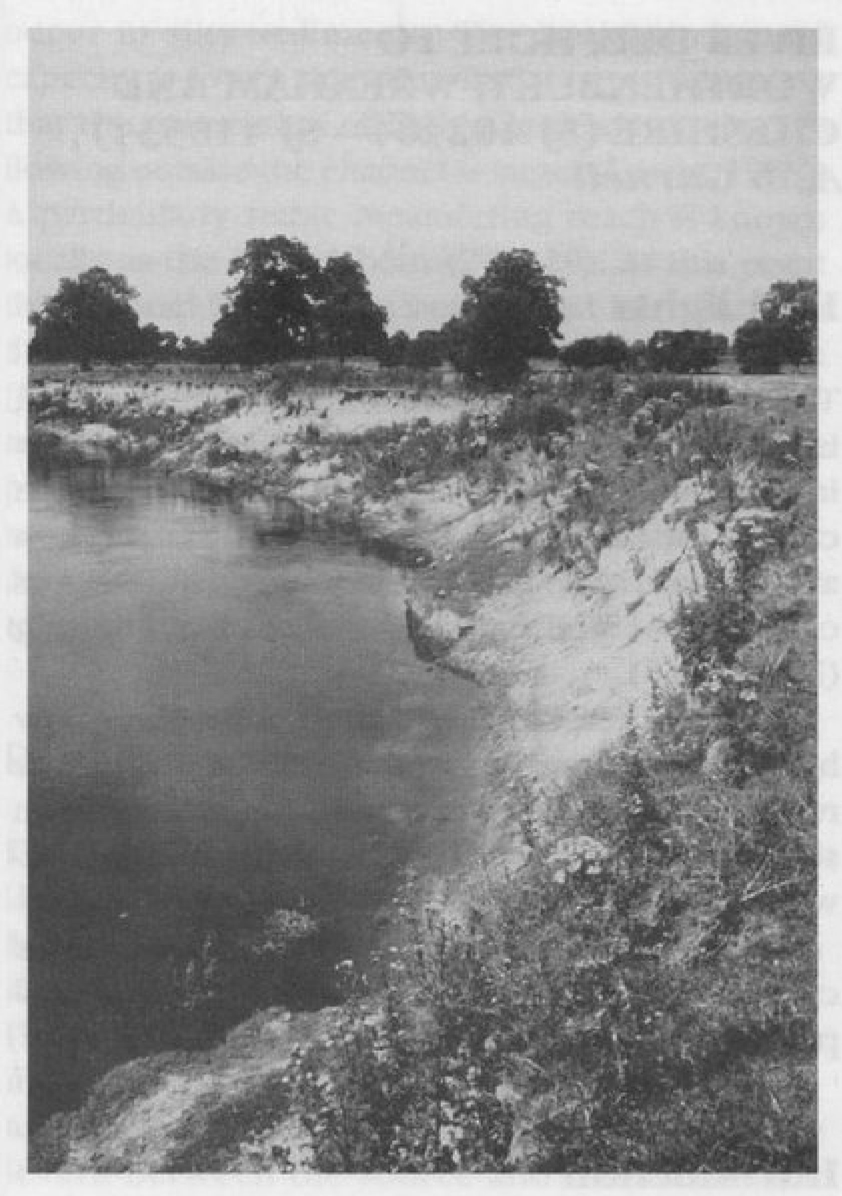
It is clear from the presence of palaeochannels and the evidence of mismatches between county and national boundaries and the current channel position, that the river has been more mobile in the past. The reconstruction of detailed Holocene fluvial sequences is a major undertaking which has yet to be addressed for this site. However, the preliminary observations presented in Gurnell *et al.* (1993), and based upon archaeological and sedimentary evidence, suggest a period of relative channel stability over the past two or three centuries. If it is the case that significant overbank deposition leading to cutoff infill ceased from some time around 1700 AD, then the possibility arises that the recent historical evolution of the system has been increasingly and significantly influenced by human modification, including progressive flow regulation.

Thus the original conservation interest in this site as an example of lowland tortuous meanders has now been supplemented by its importance as a site influenced by weir-controlled flows in different parts and affected by changes in the discharge regime due to regulation in the catchment. A complex spatial and temporal sequence of morphology and subtle instability has been identified, and is associated with unusual processes of bank adjustment.

Conclusion

This site comprises a tortuous meandering channel and a floodplain with some relict channels, which together with circumstantial evidence of boundary positions imply high mobility of the channel. However, recent research has shown that the channel has become more stable in planform in the past few centuries, but that morphology and stability do vary down through the reach. The behaviour is related to the varying influence of river discharge, tidal flows and weir backwater effects, which result in complex bank erosion and sedimentation processes. Potential exists for further study into the nature of these adjustments, and also into the Holocene evolution of the floodplain.

References



(Figure 3.33) The outer bank of a meander of the River Dee, between Holt and Worthenbury. (Photo: S. Campbell.)