Chapter 4 Fluvial geomorphology of north-west England

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Holocene fluvial development in north-west England

The river systems of north-west England fall into five main groups, the Mersey, Ribble, Lune and Eden drainage basins, and the radial drainage of the Lake District (Figure 4.1). Almost all have undergone a similar sequence of Late Pleistocene and Holocene development (Harvey, 1985a). With the exception of a small part of the Dane headwaters in the Mersey system, the whole area lies within the Devensian glacial limits and therefore was under glacial ice at the Devensian maximum (i.e. *c.* 18 000 BP). The Loch Lomond Readvance (*c.* 10 000 BP) affected only small parts of the Lake District mountain catchments (Sissons, 1980). The modern river systems were therefore initiated during the Devensian deglaciation between *c.* 18 000 BP and *c.* 14 500 BP, by which, approximately, the margins of the Lake District had become ice-free (Gale, 1985; Thomas, 1985; Vincent, 1985), and by implication when the regional ice sheet had melted from outside the Lake District, leaving still under ice only the Lake District valleys, and possibly the far north of the region within the limits of the disputed Scottish readvance (Thomas, 1985).

There then followed a period of periglacial activity, interrupted by warmer conditions during the Windermere interstadial, culminating in the intensely cold phase of the Loch Lomond stadial, before hillslope stabilization under an increasing vegetation cover took place in the Early Holocene (Pennington, 1970; Gale, 1985). Apart from sedimentation in estuaries, drowned as the result of the post-glacial sea-level rise (Tooley, 1985), there is little evidence of fluvial change during the early Holocene, other than incision into Pleistocene deposits (Ferguson, 1981; Harvey, 1985a). A relatively stable early Holocene landscape under an almost complete woodland cover must be envisaged, providing little sediment to what were presumably relatively stable rivers. However, for the later part of the Holocene, there is considerable evidence for fluvial change resulting from increased hillslope erosion as the woodland cover decreased, perhaps in part as the result of climatic deterioration, but increasingly under direct human impact.

Three major themes underlie spatial variations of Holocene fluvial activity in north-west England. These are: (1) the legacy from the Pleistocene; (2) the relative impact of climatically and human-driven environmental change during the Holocene; and (3) variations in the geomorphic sensitivity of the fluvial systems.

There are regional variations in the fluvial response to Late Pleistocene–Holocene climatic change. As the ice sheets melted during the Late Pleistocene, sediment was fed into proglacial river systems. Later incision into glacigenic sediments has left a legacy of fluvioglacial terraces along many of the main rivers. Within the small area subject to the Loch Lomond Readvance, glacial conditions again existed at the end of the Pleistocene and streams fed by these glaciers were proglacial. In that area there was a rapid transition from glacial conditions to temperate conditions in the Early Holocene, without an intervening periglacial period. Elsewhere in the upland areas, periglacial conditions persisted during the Late Pleistocene, with subsurface permafrost active, and hillslope scree and solifluction processes transporting sediment downslope, feeding what were probably braided river systems (Lewin, 1981b). Periglacial activity ceased at the beginning of the Holocene. In those areas which had been most heavily glaciated, it is probable that sediment, made available by glacial processes, continued to be supplied to the fluvial system for some time during the early Holocene until exhaustion of supply. Such paraglacial (*sensu* Church and Ryder, 1972) conditions have been described in western Scotland by Brazier *et al.* (1988), and probably occurred in the Lake District. Late Pleistocene fluvial conditions were spatially variable, with contrasts between proglacial, periglacial and paraglacial regimes. Each type of regime influenced the sediment availability for the postglacial fluvial conditions of the Holocene.

During the later part of the Holocene there is evidence for increased fluvial activity, following the low level of fluvial activity of the Early Holocene, in the form of increased lake sedimentation rates (see Gale, 1985), aggradation of younger Holocene river terrace sediments, and tributary junction alluvial fans (see Harvey, 1985a). These changes followed climatic deterioration from the mid-Holocene Atlantic climatic optimum (Musk, 1985), and may have been in part a direct response to climatic change or the consequence of climatically induced vegetation change. However, there is increasing evidence of human-induced stress on the geomorphic system during the later Holocene. In the recent debate on the relative influence of climatic and human causes of Holocene fluvial change, there is evidence for the influence of both sets of factors (Ballantyne, 1991a). A number of studies, based on upland northern Britain, have stressed the importance of the effects of climate on flood incidence, and the adjustment of river systems to flood sequences (e.g. Macklin and Needham, 1992; Macklin *et al.,* 1992a,c; Passmore *et al.,* 1992; Rumsby and Macklin, 1994). Others have stressed the importance of sediment supply, and hence the influence of human-induced erosion on fluvial activity (e.g. Harvey *et al.,* 1981; Hooke *et al.,* 1990; Harvey, 1992a; Tipping and Halliday, 1994). It may well be that in proximal upland sites, where coupling between hillslope sediment sources and the channel system is strong (Harvey, 1992a, 1994), the impact of variations in sediment supply is high; hence the potential for response to human-induced erosion. In piedmont reaches (*sensu* Newson, 1981) variations in stream power may be more important, therefore these larger rivers may be more responsive to a climatically induced flood signal. Both factors have almost certainly influenced Late Holocene fluvial geomorphology of northwestern river systems, and interactions between the two may account for spatial variations between mountain, upland, piedmont and lowland environments.

Holocene fluvial response to environmental change also depends on the sensitivity of the system (Brunsden and Thornes, 1979), and on its nearness to geomorphic thresholds (Schumm, 1977), especially to the threshold of critical power (Bull, 1979), relating actual stream power to that required to transport the sediment supplied. These conditions may be modified by time lags (Brunsden and Thornes, 1979) and by coupling within the system (Harvey, 1992a, 1994). The fluvial systems most susceptible to environmental change are high-energy systems, draining steep catchments in areas of the most severe climates, either those prone to severe winter conditions, or those susceptible to high-magnitude floods (Harvey, 1985a, 1986; Newson, 1992). Again there are contrasts between the mountain, upland, piedmont and lowland river systems in the north-west.

Geology, relief and hydrology

The themes outlined above set the context for the development of the modern river systems, but other factors have influenced their style of development, of which geology, relief and hydrology are the most important. The influence of geology is both direct, through its influence on sediment calibre, and indirect, through its influence on relief. There is a strong contrast between the upland and lowland areas (Johnson, 1985a,b). The uplands include areas of folded Lower Palaeozoic rocks, volcanics in the central Lake District, and compact but fissile sedimentary rocks in the Howgill Fells and Lake District margins (Broadhurst, 1985). Elsewhere the uplands comprise less strongly folded Carboniferous strata, of two types of terrain. The first is on gently dipping Carboniferous Limestone in the Lake District margins and, together with the overlying Yoredale series of limestones, sandstones and shales, in those western parts of the central and northern Pennines that are drained by the headwaters of some northwestern rivers. The second is on the folded sandstone and shales of the Forest of Bowland, the Rossendale upland and the northern and western margins of the Peak district, drained by northwestern rivers (Broadhurst, 1985).

In the lowland areas, Upper Carboniferous rocks occur in west Cumbria, the central Lancashire lowland and lowland Lonsdale, but the main lowland areas, the Cheshire/Lancashire plain and the Vale of Eden/Solway lowland, are underlain by Permo-Triassic marls and sandstones. Except in the mid-Cheshire ridge and in parts of the Vale of Eden, bedrock is generally covered by a blanket of Quaternary sediments (Longworth, 1985; Worsley, 1985).

Within the upland areas the overall relief has been accentuated by glacial erosion (Johnson, 1985b). In most cases the rivers follow pre-existing valley systems, but there are numerous examples of glacial diversions of the drainage (King, 1976; Harvey, 1985a). In the lowlands the modern river system is in most cases totally new, developing on a glacial depositional surface, although often inherited from glacial meltwater channel systems (e.g. Knowles, 1985).

The hydrology is dominated by high rainfall and low evapotranspiration in the uplands (Ward, 1981). The major rivers have high discharges per unit drainage area when compared with other English rivers (Harvey, 1985a; Newson, 1981) and, because of the steep terrain and generally impermeable bedrock in the upland catchments, tend towards a flashy regime with a high short-term variability. An exception to this pattern are the Lake District rivers downstream of the major lakes, where the flow is naturally regulated by storage in the lake basins. On all the rivers there is a low seasonal variability. Floods may occur at any time of the year; in the steep headwaters summer storms are important, but on the main rivers major floods tend to result from heavy cyclonic rain, particularly in autumn and winter, or occasionally from heavy rain and snowmelt (Newson, 1981; Harvey, 1985a).

Fluvial landforms and processes in north-west England

The fluvial geomorphology of north-west England reflects the influence of the factors outlined above on the developing fluvial system during the Holocene. In the Lake District, within the Loch Lomond stadial limits and in valleys occupied by Late Devensian valley glaciers, glacial erosional and depositional landforms are fresh. The river system is young. Steep bedrock channels and gorges through glacial erosional terrain alternate with alluvial reaches through the intervening basins. These alluvial reaches often have braided channels or wide shallow single-thread gravel-bed channels, and some may have been dominantly aggradational since deglaciation. Where rivers enter lake basins there are well-developed lakehead deltas and small steep fan deltas from tributary streams (Hay, 1926). Sediments within these forms probably span the whole period since deglaciation.

Within the Lake District, Late Pleistocene glacial erosional forms and depositional forms have been largely unaltered during the Holocene. Locally, there has been incision by ravines in areas of more resistant bedrock, and by gully development in softer rock areas. These erosional forms fed sediment to debris cones and alluvial fans at the slope base, but so far in the absence of research on these forms in the Lake District, they cannot be definitively ascribed to either the Late Pleistocene or the Holocene, or ascribed to paraglacial or strictly post-glacial conditions.

In other upland areas, Late Devensian solifluction transported debris to the lower parts of the hill-slopes into which the modern streams are now incised (Harvey, 1985a). The overall trend since the Late Devensian has been one of incision (Ferguson, 1981). Where the incising rivers encountered bedrock, small gorges were created, but elsewhere the incision was punctuated by river terrace formation, including major Late Devensian terraces, and minor Late Holocene terraces. In several areas, notably in the Howgill Fells and the Forest of Bowland, the periglacial hillslopes have been deeply dissected by gully erosion during the Holocene (Harvey, 1985a; 1992a). These gully systems, now largely stabilized, fed sediment to debris cones and alluvial fans at slope-base and tributary junction sites, often grading into low river terraces (Harvey *et al.,* 1984). Hillslope gullying and associated fan deposition in these areas appear to be almost wholly Late Holocene (Harvey *et al.,* 1981; Harvey and Renwick, 1987; Harvey, 1992a), in response to human-induced vegetation changes, especially during the 10th century AD. There are smaller areas of more recent active gully erosion (Harvey, 1974, 1992a), contributing sediment to the modem stream system, and influencing modern channel styles (Harvey, 1977, 1987a, 1991; Harvey *et al.,* 1979).

Many of the modern alluvial channels in the uplands tend to be fairly stable, single-thread, locally meandering gravel and cobble-bed channels. On some, sediment transport rates are high (see Newson, 1981; Newson and Leeks, 1985), and where sediment inputs are high the channels tend to be wide and shallow, less stable, and locally braided (Hitchcock, 1977a,b; Thompson, 1986, 1987; Harvey, 1991).

In the piedmont and lowland areas, Late Pleistocene to Holocene incision again predominates, with river terraces dating from the Late Devensian and the Late Holocene. There is no clear-cut evidence of terraces relating to the early part of the Holocene. In the lowest, estuarine river reaches, sedimentation has been dominant, especially in relation to the Flandrian sea-level rise (Tooley, 1985). In interfluve areas the landscape is dominantly a Late Pleistocene, glacial or fluvioglacial landscape, with little or no evidence, apart from incised tributary streams, of Holocene landform development. Human-induced soil erosion related to woodland clearance, for which there is a growing body of evidence (see Hooke *et al.,* 1990), appears to have been diffuse, and, although producing valley floor sedimentation, did not produce a suite of recognizable erosional hillslope forms.

The present day river channels in the piedmont and lowland areas are generally meandering channels. Those on piedmont rivers, fed by upland sources, tend to be active (see Knighton, 1972; Mosley, 1975a,b; Hooke and Harvey, 1983; Hooke, 1984a,b; 1986, 1996) whereas the lowland meandering channels tend to be stable (see Harvey, 1985a).

The recent human impact on the fluvial systems of north-west England has been considerable, especially in the Mersey basin. Numerous upland catchments have been impounded, water is abstracted and diverted, channelization has taken place in urban areas, and some streams and rivers are grossly polluted (Walling and Webb, 1981). Fortunately, the most extreme effects are restricted to the central part of the Mersey basin. However, this does underline the need for conservation of the more important sites elsewhere in north-west England.

Fluvial geomorphology GCR sites in north-west England

The sites described below have been selected for the GCR to be representative of fluvial conditions throughout the Holocene to the present day in north-west England. By definition, the final list of GCR sites includes only those of national importance, but also considered in this discussion are other sites of regional rather than national significance. This discussion is subdivided into mountain (Lake District) sites, upland sites, piedmont and main river sites. No truly lowland sites are included. Estuarine areas are also excluded.

Mountain areas

Three sites in the Lake District have the potential for inclusion in the GCR: Langstrathdale, Wasdale and Buttermere. All show features of an immature Holocene fluvial system adjusting to a relatively recently deglaciated mountain environment. Langstrathdale Beck is a large mountain river with bedrock reaches exhibiting small gorges and waterfalls, alternating with alluvial reaches exhibiting braided channels. The site includes the presumed downvalley limit of Loch Lomond stage glacial ice (Sissons, 1980). Also included are undated post-glacial hillslope gullies and debris cones. The Wasdale site exhibits a rich variety of mountain fluvial forms (Boardman, 1988): erosional forms including gullies, ravines and incised bedrock channels, and depositional forms including debris cones, alluvial fans, braided river channels, a lake-head delta and several fan deltas issuing into Wasdale Lake. The best developed fan deltas in England occur at the Buttermere site, which also includes a range of smaller scale debris cones. There has been no published work on these features since Hay's (1926) work.

Several other sites in the Lake District, though not proposed for the GCR, exhibit a fine range of mountain fluvial features. Upper Eskdale (GR NY20), is a mountain river with bedrock and alluvial reaches, similar to Langstrathdale. Oxendale (GR NY20), a tributary at the head of Langdale, is a steep mountain catchment in glacial erosional terrain, with bedrock-controlled channels, gorges and waterfalls in the upper reaches, and postglacial stream terraces, small alluvial fans and boulder/cobble bed reaches downstream. Another site of regional importance is at Aira Beck (GR [NY 3 1], [NY 3 2], [NY 4 1], [NY 4 2]), at the position of a major glacial drainage diversion, showing a spectacular waterfall and bedrock channel leading to a large fan delta where the beck issues into Ullswater. Surprisingly, there is little recent research into Holocene fluvial landform development in the Lake District, although there has been some work on modern and recent processes (see Newson and Leeks, 1985; Carling, 1987a).

Upland areas

Outside the Lake District three important upland sites have been selected for the GCR, two in the Howgill Fells and one in the Forest of Bowland. The two in the Howgills, at Carlingill and Langdale/Bowderdale, represent a superb suite of Holocene fluvial landforms and zones of current erosion and deposition. They are both important sites for research. The Carlingill site has features associated with stream capture (see King, 1976; Harvey, 1985a), including waterfalls and incised gorges, but more importantly a superb suite of Holocene hillslope gully systems, alluvial fans and stream terraces (see Harvey, 1985a, 1992a; Harvey *et al.,* 1984). There are also gullies active at present where erosion processes have been monitored for over 25 years (Harvey, 1974, 1977, 1987a,b, 1992a; 1994; Harvey and Calvo-Cases, 1991; Harvey *et al.,* 1979). The Langdale and Bowderdale valleys also include important Holocene sites, particularly gully systems and alluvial fans (Harvey, 1992b,c; Harvey *et al,* 1981), which have provided the basis for one recent PhD thesis on Holocene soils and geomorphology (Miller, 1991). Another reason for inclusion is that they preserve the effects of a major flood (Harvey, 1986), including channel pattern changes and excellent examples of alluvial fan and debris cone deposition (Harvey, 1986, 1991; Wells and Harvey, 1987).

Another interesting upland site in the Howgills, although not a GCR site, is at Cautley (GR SD69). This site contains a range of glacial erosional and depositional landforms, and periglacial landforms as well as Holocene gullies, alluvial fans and terraces.

The Langden Valley, in the Forest of Bowland, is included in the GCR because of a good dated record of Holocene erosion and deposition preserved in alluvial fan and terrace sediments (Harvey and Renwick, 1987). The modern channel is one of the most mobile and best-developed, cobble-bed braided channels in northern England (Wilcock, 1967a, 1971; Hitchcock, 1977a; Thompson, 1985, 1986). This valley has provided a field base for several doctoral theses (Wilcock, 1967b; Wilkinson, 1971; Hitchcock, 1977b; Thompson, 1984; Miller, 1991).

Piedmont and main river sites

Only one piedmont or main river site is selected for the Fluvial Geomorphology of North-West England GCR Block, the River Dane at Swettenham, Cheshire. This is an important site for piedmont fluvial geomorphology, with a well-developed set of dated river terraces that contains an excellent record of the fluvial sequence from the Late Devensian to the present day (Hooke *et al.,* 1990). The modern channel is little disturbed by human activity, and exhibits a fine suite of active meanders that have developed since dissection of the youngest terrace at some period prior to 1840 AD (Hooke and Harvey, 1983). Research continues on fluvial processes and morphology of this channel (Hooke, 1996).

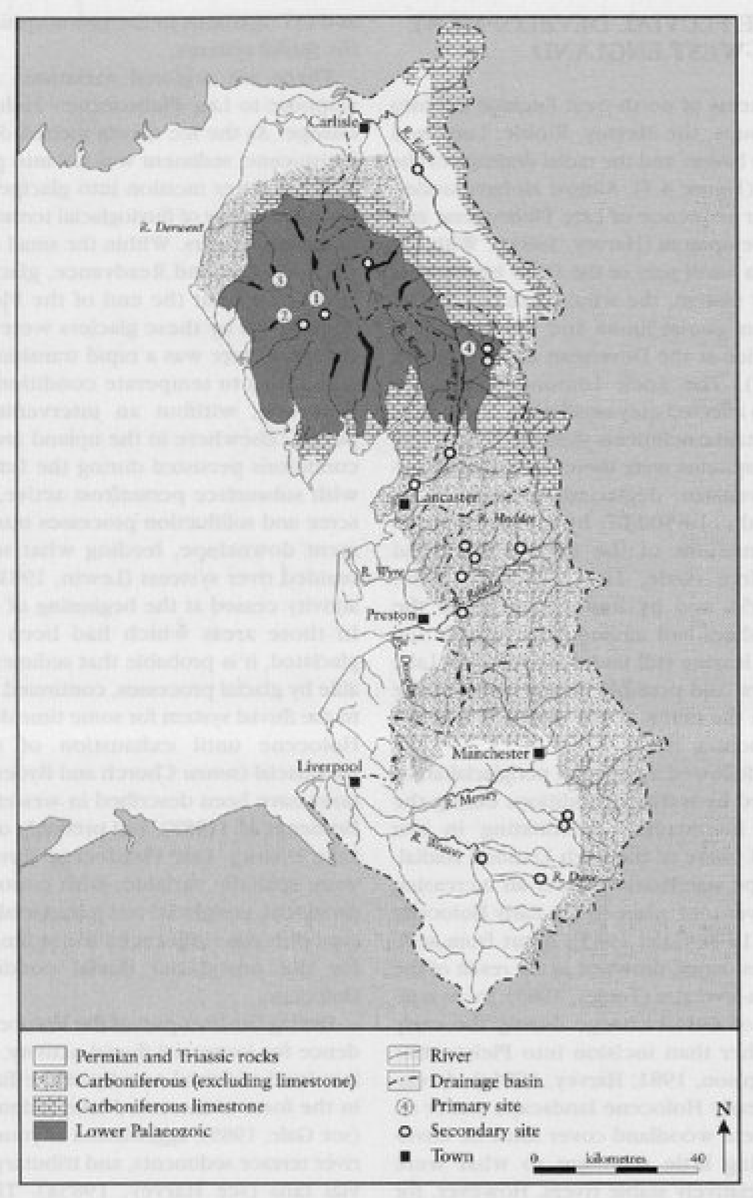
In addition to these GCR sites there are a number of other regionally important piedmont and main rivers in the northern and central part of the area, namely the Eden, the Lune and the Ribble, which each show differing styles of Holocene river development, illustrated by the following four sites. The River Eden at Armathwaite (GR [NY 5 4]), forms a deeply incised gorge reach, with a channel locally in bedrock and locally braided. Upstream of the gorge the river meanders through a wide flood-plain, and downstream there is a dominantly meandering channel within a narrow floodplain, set below postglacial terraces. The River Lune at Arkholme (GR [SD 5 6]), near the confluence with the Greta, is a channel poised close to the meandering/braided threshold (Thompson, 1984), that has shown frequent changes over the past *c.* 100 years. The mobile channel in a fairly wide floodplain exhibits excellent sedimentary bar features. Lower downstream the River Lune at Caton (GR [SD 5 6]) has a wide gravel-bed channel forming large unconfined meanders. Towards the Crook of Lune bedrock gorge, the floodplain becomes narrower and increasingly confined between terraces. The River Ribble at Balderstone (GR [SD 6 3]), has confined meanders as the result of Holocene incision, with arcuate terraces on the insides of the bends.

Three smaller rivers, all within the Ribble system, together with Langden Brook (see above), illustrate the range of channel pattern types on the margins of the Forest of Bowland. The River Hodder at Burholme Bridge (GR [SD 6 4]) is a cobble-bed piedmont river with a wide shallow, but relatively stable channel. There is a partly dated, very clear terrace sequence here (Harvey and Renwick, 1987). Skirden Beck near Bolton by Bowland (GR [SD 7 4]) has mobile tortuous meanders that exhibit recent cutoff bends (Thompson, 1984). There are also terraces towards the confluence with the Ribble. The River Loud near Longridge (GR [SD 6 3]) is really a lowland river, fed entirely by a drift catchment, but is unusual in that it becomes more of a piedmont stream downstream, as it receives 'upland' tributaries. Upstream the channel is highly sinuous, but stable, and has hardly changed its pattern over the past 100 years (Thompson, 1984).

Three sites on meandering piedmont rivers in Cheshire are of regional importance, and complement the GCR site on the Dane at Swettenham. Further downstream the River Dane at Northwich (GR [SJ 6 7]), has an active meander belt of tortuous meander bends, including recent and imminent cutoffs. Two small streams to the north of the Dane, the River Bonin at Mottram Bridge (GR [SJ 8 8]) and the smaller River Bollin Dean at Batley Bridge (GR [SJ 8 8]) both show documented, well-developed, active, tortuous meanders (Knighton, 1972; Mosley, 1975a,b; Hooke, 1996). Both have a post-glacial history of terrace development, although that on the Bollin is clearer and better exposed.

The seven sites described below are of national importance for demonstating the Holocene development of British fluvial systems, as well as modern fluvial processes and morphology.

References



(Figure 4.1) A location map showing the fluvial geomorphology GCR sites in the north-west England GCR Block. 1 Langstrathdale (potential GCR site); 2 Wasdale (potential GCR site); 3 Buttermere and Crummock Water (potential GCR site); 4 Carlingill Valley; 5 Langdale and Bowerdale; 6 Langden Brook; 7 River Dane.