Advisory Visit

River Manifold, Staffordshire

25th March, 2019

1.0 Introduction

This report is the output of a site visit undertaken by Tim Jacklin of the Wild Trout Trust (WTT) to the River Manifold near Longnor, Staffordshire, on 25th March, 2018. Comments in this report are based on observations on the day of the site visit and discussions with members of Derbyshire County Angling Club (DCAC).

This section of the River Manifold has been the subject of a previous WTT Advisory Visit (2007) and practical habitat improvement works by WTT and Trent Rivers Trust around 2008 – 2010. The habitat works were the subject of a scientific study of invertebrate populations (Everall et al., 2012). In 2011, a study was carried out by Loughborough University on behalf of Natural England, looking at the physical characteristics of rivers in the Upper Dove catchment, including the River Manifold (Rice & Toone, 2011).

Normal convention is applied throughout the report with respect to bank identification, i.e. the banks are designated left hand bank (LHB) or right hand bank (RHB) whilst looking downstream.

2.0 Catchment / Fishery Overview

The Manifold is a tributary of the River Dove, rising at Flash Head and joining the Dove at Ilam. The upper reaches flow over geology dominated by sandstones and undifferentiated silt/mudstones, predominantly of the Millstone Grit series and Bowland Formation; these rocks weather easily producing finer clastic sediments (cobbles, gravels, sand). Further downstream below Ecton, the geology is predominantly limestone, which is more resistant but soluble, producing classic karst features including subterranean drainage and dry valleys; this results in the river between Wetton Mill and Ilam being seasonally dry (Rice & Toone, 2011).

The catchment falls within the Peak District National Park. The Hamps and Manifold Valleys SSSI is located downstream of Ecton and the reach of river inspected falls outside of this (upstream) but within the SSSI Impact Risk Zones for planning purposes. Table 1 summarises the Water Framework Directive information for the River Manifold.

River	River Manifold
Waterbody Name	Manifold - source to conf R Dove
Waterbody ID	GB104028052891
Management Catchment	Dove – Dove Upper Rivers and Lakes
River Basin District	Humber
Current Ecological Quality	Overall classification of **Good** ecological status for 2016
U / S Grid Ref inspected	SK0935163438
D / S Grid Ref inspected	SK0955762146
Length of river inspected	~1500m in total

Table 1 Summary of Water Framework Directive information from https://environment.data.gov.uk/catchment-planning/WaterBody/GB104028052891

DCAC own the fishing rights on approximately 10km of the River Manifold between Longnor and Ecton Bridge, a section located on the sandstone geology. There are several different land owners along the fishery and land use is predominantly sheep and cattle farming.

The fishery is managed as a wild brown trout fishery and no stocking is carried out. Grayling are present in the Manifold, particularly downstream of Ecton, although their abundance is much reduced compared with previously recorded numbers (WTT Advisory Visit, River Manifold, Swainsley Fishing Club 2008) and anecdotal reports. No grayling have been recorded from DCAC waters in recent years.

River habitat improvement works were carried out on some sections of DCAC's Manifold fishery around 2008-10 by Wild Trout Trust and Trent Rivers Trust. The aim was to demonstrate more ecologically sympathetic techniques of reducing bank erosion (using brushwood and fencing out livestock), compared with the interventions commonly used by land managers (channel straightening; battering of banks using gravel/cobble from the river).

The reach of river inspected during the current visit can be divided into two sections of different character. The southerly, downstream section around

Ludburn Farm is more sinuous and meandering whereas the northerly section up to Windy Arbour Bridge is artificially straightened. Historic maps show the straightening of the latter section took place between 1801 and 1838 (Figure 1).

Straightening of the river has a profound impact on the quality of in-stream habitat and hence the fishery. Removing bends from the river steepens its gradient and leaves a shallow riffle/glide sequence with no deeper water pools, hence very few areas for adult trout to live. Because of this, the northerly straightened section of the river has poor habitat and would need a significant project (i.e. channel realignment, re-meandering) to restore it, which would rely upon buy-in from adjacent land owners/managers.

Although the channel straightening took place two centuries ago, interventions to maintain its straightness and control bank erosion are regularly carried out by adjacent landowners/managers. This was seen during both the 2007 and present WTT advisory visit (Photo 1 and examples in Section 3). This is particularly the case on the northerly straightened section, but examples were also seen on the Ludburn section, and there appears to be a gradual reduction in channel sinuosity and hence habitat/fishery quality (Appendix 1).

Bank erosion and human intervention to control it have evidently been a long-term issue in this locality and the fluvial audit (Rice & Toone, 2011) is recommended reading for a detailed assessment (Appendix 1 contains some relevant extracts). The present situation is complex, with conflicting aims of the different interests involved, differing ownership of land and fishing rights, no enforcement of regulations on in-river works, debate over the ongoing consequences of historic straightening and lack of an agri-environment subsidy framework that would support river restoration. Meaningful river habitat improvement in the straightened section of the Manifold requires interventions that are beyond the scope of an angling club working party.

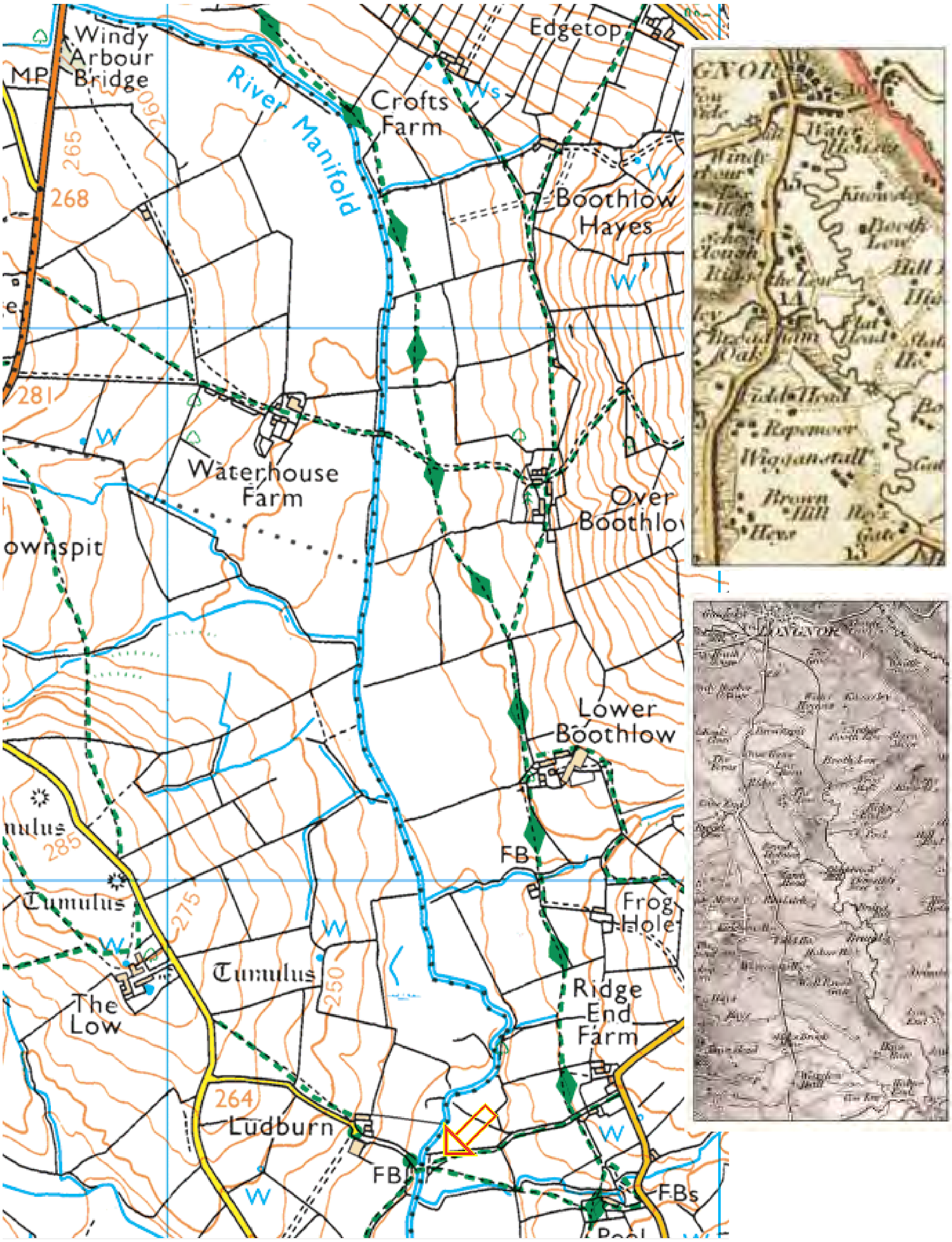


Figure 1 River Manifold between Windy Arbour Bridge, Longnor and Ludburn (flow north to south). Inset (top), extract from map of Smith (1801) showing sinuosity of the river. Inset (bottom) extract from Ordnance Survey First Edition 1838, showing straightened river (Rice & Toone, 2011).

Photo 1 October 2007. Example of unconsented channel straightening and gravel dredging downstream of Windy Arbour Bridge. This prevents the straightened channel from re-gaining sinuosity and better habitat.

3.0 Habitat Assessment

The photographs below run in an upstream direction from the d/s limit of the Ludburn beat; approximate grid references are given for each location. All photos are from this site visit (March 2019) unless otherwise stated.

Shortly after the installation of the brushwood shown in Photos 2 - 7, anglers' catches demonstrated the cover provided by the submerged branches was being utilised by numerous trout, especially juveniles; this has been recorded in similar circumstances elsewhere (e.g. Wye & Usk Foundation projects), where increases in abundance of 400%+ in juvenile salmonid numbers were attributed to the protection provided from goosander and cormorant predation. Three goosanders were observed during the present visit, so maintaining complex underwater cover and refuge for fish from predators is very important. To that end, it is recommended that the willows which have become established are laid over into the water, maintaining the living bank protection and increasing fish cover.

Photo 2 March 2009. View downstream towards the d/s end of the Ludburn beat, shortly after completion of brushwood installation and fencing.

Photo 3 March 2019, same view as above (NGR SK0953162178). More willow whip/stake planting here would be beneficial.

Photo 4 June 2009. First summer after brushwood installation and fencing. Site in first field downstream of Ludburn footbridge (Grid ref of tree indicated by arrow: SK0942962357)

Photo 5 March 2019, view as above. Fewer trees have established here compared with the site in Photos 2 & 3. Planting willow whips/stakes here is recommended to increase fish cover and bank protection.

Photo 6 January 2009. View downstream towards footbridge and DCAC signing-in box at Ludburn Farm, immediately after installation of conifer brash at the toe of the bank and fencing well back from the river. (NGR SK0947562521).

Photo 7 March 2019. The same view as above. The combination of brushwood bank protection and exclusion of livestock (fencing) has been successful, allowing planted willow cuttings to establish, stabilising the bank. The willows on the right bank should be laid over into the water (like hedge-laying). A living willow stake could be driven into the bank to hold the top ends down.

Photo 8 January 2009, upstream view from same position as Photo 7.

Photo 9 March 2019. Same location as Photo 8 (SK0949662539), downstream view. The Manifold is very dynamic, with sediment supply and transport (gravel bar formation) and bank erosion demonstrated by the above two pictures of the same location a decade apart. Rice & Toone 2011 discuss the cause and effect of these process (Appendix 1).

Photo 10 Some saplings have established on the LHB here. These are providing good cover and should be left until larger before considering laying them over for cover (SK0951562574)

Photo 11 October 2007. Same area as Photo 10, illustrating the dynamic nature of the river. A complete change from a riffle to pool habitat has occurred (now impounded by the gravel bar in Photo 9).

Photo 12 Some of the overhanging willow branches on the RHB can be partially cut and laid along the bank here to provide cover and bank stability (SK0951562605); retaining some high cover will also be important to provide shade and reduce river warming.

Photo 13 Immediately u/s of Photo 12. Bank protection with woody material and living willow in-fill has successfully protected the bank. The sprouted willow could be coppiced and used to reinforce this area and elsewhere.

Photo 14 View u/s from SK0952062614. Apart from the pool in the foreground, this section is straight and shallow, with no deeper water to hold adult trout. The arrow indicates the area shown in Photos 15 and 16 below. This area may have been artificially straightened in response to bank erosion that was occurring (Photo 16).

Photo 15 Area indicated by arrow in Photo 14 (downstream view from RHB). Brushwood revetment and willow planting had been carried out here (shown by the line of willows). The area in front of the willows appears to have been filled with river sediments.

Photo 16 September 2008. The same area as Photo 15. If the river here was actively realigned and the above eroding area back-filled with river sediments, this illustrates the problem that this type of intervention poses to the fishery. The bends in the river where the erosion occurs is where deeper pools form, and these deeper pools hold adult trout. The straightening of the river and in-filling of bends with sediment leaves a shallow riffle/glide (Photo 14) with no areas for adult trout and little angling interest, devaluing the fishery.

Photo 17 Another site where channel straightening has probably been carried out, (NGR SK 09598 62656).

Photo 18 A deeper area at the head of the straight section in Photo 17. Hinging branches over to provide extra cover from the LHB is recommended.

Photo 19 Block failure erosion. Revetment with willow bundles may slow down erosion on sections like this and provide some fish cover, but livestock exclusion would also be required on low banks like this.

Photo 20 Rapidly eroding bank. Erosion may be slowed by stabilising the bank with brushwood and willow (see Photo 22), which would tend to focus the river energy into scouring the river bed and creating more depth; along with the woody cover, this would improve the fish holding capacity. Livestock exclusion would be ideal, but the use of thorn brushwood and willow may provide some grazing protection. Stopping bank erosion is not a possibility, nor desirable, but slowing it to improve habitat is.

Photo 21 Another cut-off meander, possibly as a result of the fallen tree (arrow) altering the river course.

Photo 22 Willow bank revetment approximately 10 years old has provided some bank stability and channel depth in front of it, creating a nice holding pool. These willows could be laid over to provide ongoing bank protection and cover.

Photo 23 September 2008. The same area as Photo 22 before the work was carried out – insufficient depth and cover to hold trout.

Photo 24 Meander bend at SK0946262886.

Photo 25 September 2008. The same bend as Photo 24. The arrows in each picture indicate the same tree, showing how far the river channel has moved in a decade.

Photo 26 Hard bank protection such as this does not reduce the shear stress caused by fast water, hence erosion tends to occur where the stone begins and ends, undermining it. Use of brushwood and willow is preferable as it absorbs the energy of the water, binds the bank with roots and provides good cover and habitat.

Photo 27 The very straight river channel which begins above the Ludburn section (at approximately SK0947162955) and continues to Longnor (c.2km). The straightening of the channel here dates to the early C19th (Rice & Toone, 2011), and is a fundamental reason for the generally poor habitat for adult trout (and hence fishery quality) throughout. Riffle and glide habitat predominate and there are very few deeper holding areas for adult fish.

Photo 28 Example of the use of river bed material to shore-up an eroding bank and prevent lateral movement of the river channel. Such activities are damaging to in-stream habitat and prevent the straightened river from re-developing meanders and better trout habitat; if the gravel disturbance is carried out during the fish spawning season (Oct – May), direct damage to fish eggs could be caused. For these reasons, such activities are governed by the Environment Agency's Environmental Permitting Regulations.

Photo 29 Typical section of the straightened channel, illustrating the lack of adult trout habitat.

4.0 Recommendations

- Liaise with the landowners alongside the sections of river where DCAC own the fishing rights. All works carried out by DCAC should be discussed and agreed with the relevant landowners, and ideally vice versa. The aim should be to persuade landowners not to carry out operations such as dredging of gravels and straightening of the channel, which are damaging to the fishery and also contravene environmental regulations. Wherever possible, work with landowners to exclude grazing livestock from the river and riverbanks.

- Maintain the livestock fencing that currently exists along sections of the river (around Ludburn). Replace the rotten posts and if necessary, use a fencing contractor. Whatever the causes of the excessive bank erosion seen during this visit, grazing of the banks makes it worse and the fencing is the fishery's biggest asset.

- Plant willow whips or stakes within the fenced sections of river (e.g. Photos 3 & 5) and elsewhere where they are likely to be inaccessible to grazing livestock. The quickest and easiest way of establishing willow trees is by driving short sections of freshly cut willow into the ground. This can be undertaken at any time of the year, but will have the greatest success during the dormant season, shortly before spring growth begins (ideally late Jan-March). Whips should ideally be planted into soft, wet ground so that there is a greater length within the ground than out of it, to minimise the distance that water has to be transported up the stem; 30-40cm of whip protruding from the ground is sufficient. Whips of 5mm-25mm diameter tend to take best, but even larger branches/stems can be used. If taking cuttings during the growing season, care should be taken not to leave excessive amounts of foliage on the whips as these greatly increase the surface area of the plant and can lead to their dehydration. Bushier willow species like sallows (*Salix caprea* and *S. cinerea*) are recommended over taller, faster growing species.

- On the section of river upstream of the footbridge at Ludburn, lay the willow along the RHB into the river margins (Photo 30). This technique can also be used elsewhere, where there are suitable trees present.

Photo 30 Laying trees into the water to provide excellent cover for trout. Inset: detail of partial cut to retain the tree and keep it alive.

- Consider installing bank protection / fish cover (e.g. Photo 6) in areas such as Photos 19 and 20. Use thorn brash to deter grazing and incorporate living willow bundles (or stakes/whips).
- Continue with the invertebrate monitoring being carried out under the Riverfly Partnership's Anglers' Riverfly Monitoring Initiative (ARMI).

Prior written Environment Agency (EA) consent may be required for some of the above recommended works.

5.0 Making it Happen

The WTT could help via a Practical Visit (PV). PV's typically comprise a visit where WTT Conservation Officers will complete a demonstration plot on the site to be restored.

This enables recipients to obtain on the ground training regarding the appropriate use of conservation techniques and materials, including Health & Safety, equipment and requirements. This will then give projects the strongest possible start leading to successful completion of aims and objectives.

Recipients will be expected to cover travel and accommodation (if required) expenses of the WTT attendees.

There is currently a big demand for practical assistance and the WTT has to prioritise exactly where it can deploy its limited resources. The Trust is always available to provide free advice and help to organisations and landowners through guidance and linking them up with others that have had experience in improving river habitat.

We have produced a 70 minute DVD called 'Rivers: Working for Wild Trout' which graphically illustrates the challenges of managing river habitat for wild trout, with examples of good and poor habitat and practical demonstrations of habitat improvement. Additional sections of film cover key topics in greater depth, such as woody debris, enhancing fish stocks and managing invasive species.

The DVD is available to buy for £10.00 from our website shop http://www.wildtrout.org/product/rivers-working-wild-trout-dvd-0 or by calling the WTT office on 02392 570985.

The WTT website library has a wide range of materials in video and PDF format on habitat management and improvement: http://www.wildtrout.org/content/library

6.0 Acknowledgement

The WTT would like to thank the Environment Agency for supporting the advisory and practical visit programme in England, through a partnership funded using rod licence income.

7.0 References

Everall, N. C., A. Farmer, A.F. Heath, T.E. Jacklin & R.L. Wilby (2012) Ecological benefits of creating messy rivers *Area*, Royal Geographical Society (with the Institute of British Geographers). doi: 10.1111/j.1475-4762.2012.01087.x

Rice, S.P. & J.A. Toone (2011) Fluvial Audit of the Upper Dove Catchment. *Report for Natural England by Centre for Hydrological and Ecosystem Science, University of Loughborough*.

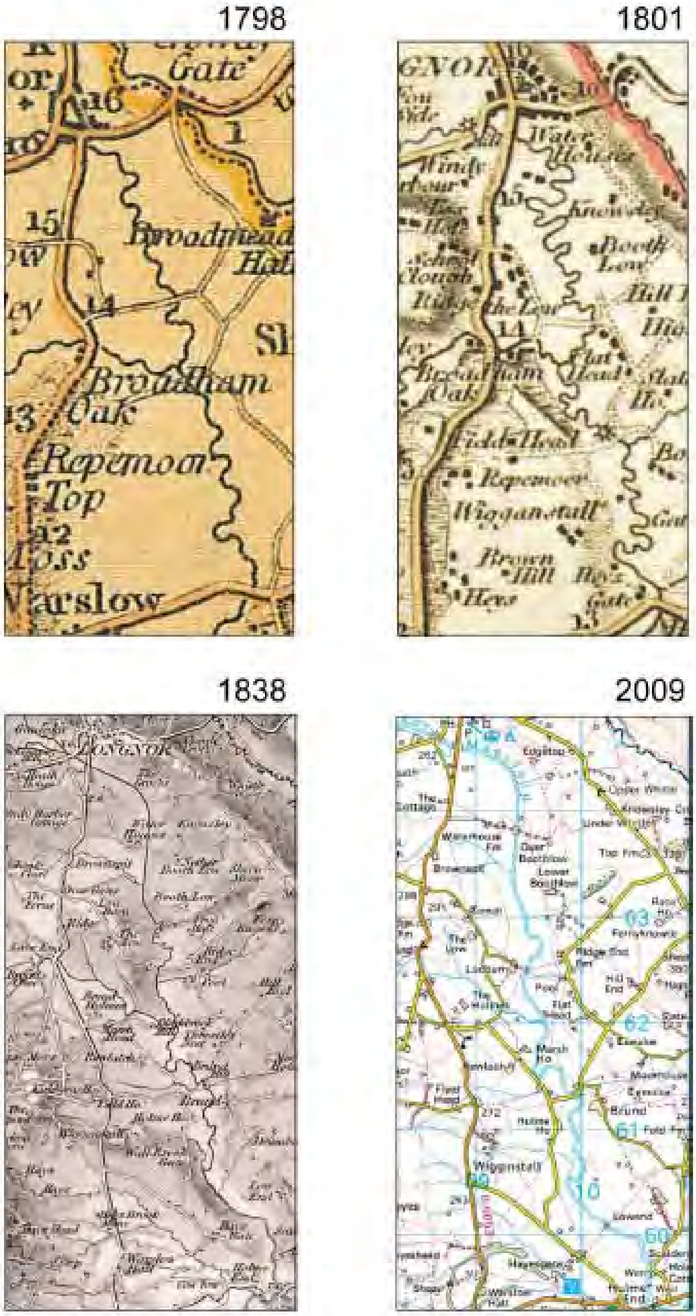
8.0 Disclaimer

This report is produced for guidance; no liability or responsibility for any loss or damage can be accepted by the Wild Trout Trust as a result of any other person, company or organisation acting, or refraining from acting, upon guidance made in this report.

Appendix 1 – Extracts from Rice & Toone, 2011

Figure 6.6 Straightening of the River Manifold downstream of Longnor

Extracts from four maps which isolate the date of straightening to sometime between 1801 and 1838: Yates' 1798, Smith 1801, OS first edition 1838, OS 1:50 000 2009.



is associated with a reduction in the frequency of bedrock exposure in the channel bed and banks. Together these factors represent a reduction in lateral constraint that is associated with greater lateral movement and thence bank erosion downstream to Lud Well.

Large proportions of the upper reaches of the Dove from Hollinsclough through to Hartington have fencing that is located on the terrace edge above the channel entrenchment or adjacent to the channel. This reduces the potential for aggravation of bank erosion by livestock and, with the exception of localised poaching (Section 4.3), there appears to be relatively little direct pressure on the river banks associated with stock.

On the *River Hamps*, bank erosion is dominated by fluvial processes. The hotspot between Onecote and Ford is driven by flows impinging on meander bends aiding the scour of bank faces. Banks are unprotected, and in the absence of riparian vegetation they are relatively unstable. The apparent incision through this reach also acts to over-deepen the channel and further destabilise the banks.

On the *River Manifold*, bank erosion is accomplished by a wider variety of processes at a greater number of sites. In addition to direct fluvial erosion, sub-aerial weathering and bank retreat by mass failure are more common. Bank erosion in the first of these hotspots, between Thick Withins and Harding's Booth (reaches 4, 5 and 6), is driven by important right bank tributaries which add water and sediment to the channel (Pyeclough and an unnamed tributary downstream) which promotes lateral channel movement where bars are constructed and the channel adjusts to its new water and sediment regime. Bank erosion in this hotspot is aggravated by the presence of livestock on the channel margins. Most of the banks are unprotected by fencing and grazing occurs to the bank top.

The second hotspot segment stretches from Windy Arbour Bridge to Haysgate above Hulme End, covering reaches 12, 13, 14, 15 and 16. In reach 12, the straightened reach south of Longnor to Ludburn, it is probable that fluvial bank erosion has increased as a consequence of reduced planform roughness (the channel is straight, not sinuous), channel steepening and consequently greater river bank shear during high flows. Moreover, straightening was accompanied by incision which has over-deepened the channel, destabilising the banks and probably further accelerating bank erosion, especially along the right bank (Figure 6.9a).

However, this reach is the least unstable of all of the hotspot reaches with only 21% of the audited length affected and only 16 sites of observed bank erosion. This suggests that the impact of straightening on bank erosion processes has not been too significant. Indeed, if the naturally sinuous reaches elsewhere along the Manifold are a useful analogue, the amount of bank erosion promoted by straightening may be less than would be expected if the river had been left in its natural, sinuously meandering course. Perhaps of greater concern, especially since the straightening would be very difficult to reverse, is that bank erosion is aggravated by livestock poaching of bank surfaces, especially where local access sites or inlets within the bank are used by cattle to access the river (Figure 6.9b).

In the lower part of reach 13 and upper part of reach 14, over a total distance of approximately 190 m, and starting 85 m upstream of Blake Brook confluence, the right bank of the Manifold is subject to significant mass failure (Figure 6.9c, d). Bank failure here is the most continuous and intense observed anywhere in the catchment and is a highly significant source of fine-grained sediment. Large numbers of cantilever failures line the toe of the river bank and tension cracks are apparent on the bank top. Undercutting of the banks by fluvial erosion, especially of the poorly consolidated gravel layer, is probably a precursor to most of these failures. The mechanism of failure and the saturation of the banks suggest that there may also be a groundwater influence through this channel section, perhaps associated with the Blake Brook catchment.

In Reach 16, bank erosion is again extensive, with long runs of channel affected by mass failure (Figure 4.4a), fluvial erosion (Figure 6.9e) and subaerial weathering (Figure 6.9f). The banks here are a composite of coarse gravel overlain by finer, consolidated, overbank sands. Erosion of the bank toe gravels leads to undercutting and cantilever failures. The fields bordering this reach are not entirely fenced and grazing occurs right to the edge of the channel. Whatever the underlying cause of the bank erosion, this grazing certainly adds pressure by precluding riparian vegetation development, direct trampling and livestock surcharge. The channel is notably sinuous in this reach and the bank erosion is focused, as anticipated on the outside bends of point bars.

Some general comments about bank erosion on the Manifold are warranted. Comparison of Figure 4.3 which maps total length of bank erosion per reach and Figure 4.15 which maps total bar surface area per reach, reveals that the reaches of the Manifold most affected by bank erosion also exhibit extensive in-channel bar deposits, particularly reaches 6, 12, 13, 14, 15 and 16. There are other reaches where there are a lot of bars but little bank erosion (e.g. reach 9), but all of the reaches where bank erosion is extensive contain large bars. This highlights the symbiotic relationship between bar development and bank erosion in alluvial rivers. On the one hand, bank erosion supplies both fine and coarse, bar-building sediment to the channel which might imply that bars are a product of bank erosion. On the other hand, bar construction forces lateral shifts in the channel thalweg, increasing flow impingement and therefore causing local erosion, as is especially evident in meander bends where point bar construction forces erosion of the outer bank. This process implies that bar construction is the cause of bank erosion, rather than the product of it.

This issue is relevant for trying to unravel the causes of lateral instability through these reaches. On the one hand one can suggest that voluminous coarse sediment supplies and associated deposition might be responsible for causing the severe bank erosion. A possible source of this sediment is the straightened reach below Longnor which we have suggested may act as an efficient conduit for sediment transfer from the upper catchment (Section 6.1, above) and which would have acted as local source of material, during and after its construction. That the Ludburn reach (reach 13) exhibits some evidence of aggradation, supports this idea. However, on the earliest available maps, which pre-date the straightening of reach 12, reaches 13 -16 are already highly sinuous and evidence of long-term instability abounds in the floodplain. In this case, it seems unlikely that deposition of excess sediment downstream of reach 12 can be the ultimate cause of the middle Manifold's lateral instability. So, while it is possible that the straightening has acted to exacerbate a naturally unstable situation, it is not possible to say that the straightening is responsible for the current bank erosion.

consistent with the generally finer nature of the bed materials. This does not mean that the Dove has higher bed load transport rates or that annual sediment fluxes are greater, only that the particles making up the bed tend to move during lower magnitude flows.

Finally, the connectivity of River Dove's sediment transfer system is severely modified in the lower reaches, through the Dales, by a large number of small weirs (=116), each of which acts as a sediment trap. Weir density is much greater on the Dove than on the Manifold, reaching 19 weirs per kilometre. Natural connectivity is also restricted through the Dales by extensive stone-built bank reinforcement which precludes lateral movement and therefore access to stores of sediment in remnant pockets of floodplain and to hillslope sources including talus aprons.

7.2 River Manifold

In contrast to the Dove, the middle reaches of the Manifold are not entrenched and, from approximately Thick Withins to Hulme End, the channel wanders freely across a widening floodplain that supplies a considerable amount of fine and coarse sediment to the channel. In contrast to the Dove, flow energy is expended on bank erosion rather than bed incision. Eight reaches, that form two 'hot spot' segments are particularly notable for the extent and intensity (in terms of volumes of sediment supplied) of bank erosion (sections 4.2 and 6.2)

Throughout these hotspot segments, banks are composites of silty-sandy and gravel-cobble material. Former meander loops and relict channels visible in the field and on aerial photography confirm the evidence from historical map analysis (Section 6.2) that the Manifold has a long history of lateral channel instability that extends beyond the two-hundred years of our historical analysis. This long history of recycling alluvial sediments laid down by the river, has ensured and continues to ensure a supply of both course and fine sediment to the river.

Tributaries are also an important source of sediment to the Manifold. Eleven tributaries or drains appear to be significant sources of sediment including, Pyeclough Brook,Oakenclough Brook, Blake Brook, Warslow Brook and Hoo Brook. These supply coarse gravels and cobbles as well as fine sediment and are one of the major reasons why the Manifold's bed materials are notably coarser than those of the Dove (Section 5.3)

Our analysis in Section 4.2 indicates that further sediment is supplied by coupling to hillslope bluffs, particularly between Thick Withins and Longnor Wood. In general, because the valley wall constitutes the river bank for considerable lengths of the upper part of the Manifold, natural weathering of the bare and friable rock face and scour of debris collecting at the foot of bluffs, supplies a significant amount of fine sediment to the channel. Poaching is also significant along this part of the river and is, overall, slightly more important on the Manifold than the Dove (Section 4.2). This may, in part, reflect the lack of entrenchment along the Manifold such that cattle are able to access the channel more easily.

More abundant supplies of sediment are reflected in the larger number and area of bars on the Manifold compared to the Dove. Approximate total bar volumes calculated from field survey measurements are 10180 m^3, 2757 m^3 and 2323 m^3 for the Manifold, Dove and Hamps, respectively (Section 4.3, see caveats therein). However, the sediments stored in the bed of the river and on these bars appear to be generally less mobile than on the Dove, suggesting that relatively frequent bankfull flows are insufficient to move much sediment and that larger floods than bankfull are required to move appreciable bed material (Section 6.2).

With regard to the connectivity of the sediment system, weirs are present but less of a problem along the lower reaches of the Manifold than on the Dove. However, a road crossing at Harding's Booth, two large weirs at Longnor and weirs upstream of Hulme End do interrupt sediment movement in the middle and upper reaches.

7.3 River Hamps

Sediment supply on the Hamps is dominated by bank erosion and tributary drainage with relatively little sediment supplied by hillslope coupling to bluffs or by poaching. Bank erosion is most severe at one hotspot between Onecote and Ford (reach 5) where the channel appears to be incising, perhaps in response to sediment retention behind weirs on the major tributary that enters the Hamps' right bank near Onecote Grange and two low dams on the mainstem. The total length of erosion here is 967 m or 36% of the audited reach length. The Hamps is notable for the dense, herbaceous riparian vegetation along the river banks in the upper reaches which may help to minimise erosion there.

Sediment storage in bars is relatively limited along the Hamps, with the lowest frequency of the three rivers (= 8 km^{-1}). We did not examine the Hamps system in as much detail as the Manifold or Dove, but the lack of bed material along the upper reaches, at least in some part, may reflect the presence of two low dams in reach 2 (Figure 7.1). These have been significant barriers to sediment transport in the past and will continue to supply fine sediments trapped behind them for some time. Both dams appear to be associated with the mine at Mixon. Downstream of Ford, bars are well-developed and there is an amount of coarse sediment in the channel akin to the developed bars seen on Manifold.

Figure 6.7 Reduction in sinuosity in the Ludburn reach of the River Manifold (1845-2009)

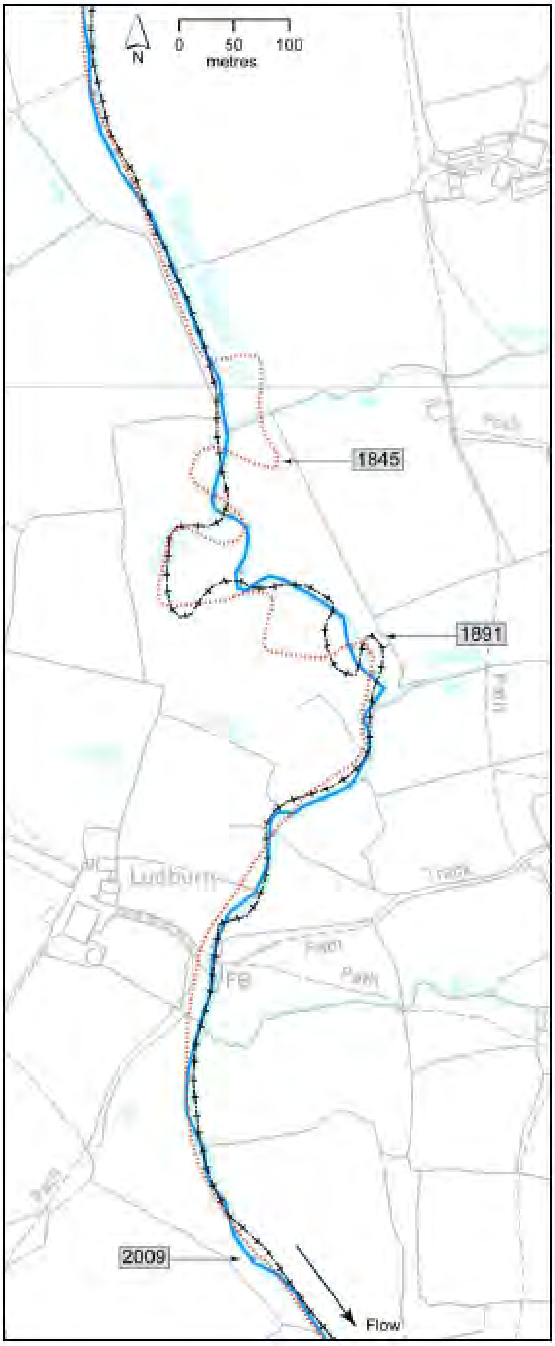
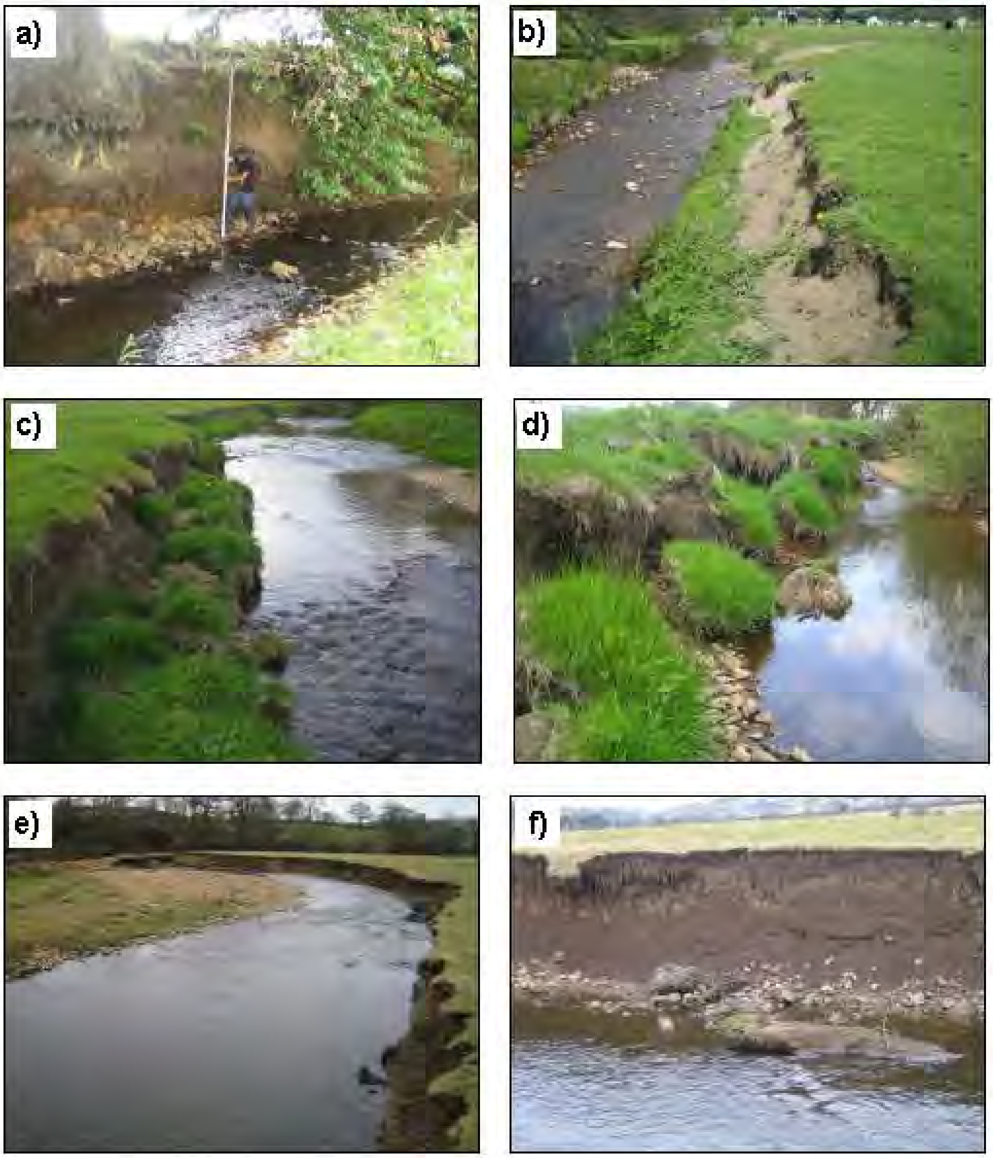


Figure 6.9 Bank erosion features in hotspot two on the River Manifold

a) Incision, associated with historical straightening of reach 12 downstream of Windy Arbour bridge, has resulted in over-steepening of the right channel bank which is unstable. Stability is improved by the root networks of mature riparian trees, but these trees are now undercut so their role is increasingly tenuous. The bank is approximately 4 m high. b) Bank erosion is aggravated in reach 12 by livestock poaching of bank surfaces. c) Mass failure typical of severe bank erosion in reaches 13 and 14. Note that the failed blocks extend along the toe of the bank as far as the eye can see. d) Removal of coarser but unconsolidated gravels at the base of some of the banks in reaches 13 and 14 (foreground) is probably a precursor to these cantilever failures. e) Long runs of erosion characterise the banks in reach 16 where (f) subaerial weathering of thick overbank sands is an important source of fine sediment.



While the weirs may well have been present for a long time and have a natural, even appealing appearance, in places, they remain effective barriers to natural geomorphological function and are therefore problematic. With the weirs in place there is no possibility of moving the river towards a more favourable geomorphological condition. Removal of some or all of the weirs would be a first step toward trying to regain a more natural geomorphology of cleaner substrates, natural pool-riffle morphology and throughput of coarse sediments.

However, simply removing the weirs will not necessarily produce the desired effects unless that process was seen as part of a broader set of interventions. In particular: (1) the stone-built bank reinforcement is an additional constraint that would need to be tackled in order to maximise the chances of regaining some form of natural morphological behaviour; (2) there is limited coarse sediment supply to the river from upstream, so that re-coupling the river to its hill-slope sediment sources within the dales is important for coarse sediment recruitment and would require consideration; (3) elevated fine sediment supply from the upstream catchment is a potential constraint on success. Tackling these issues requires a holistic, catchment scale approach, especially in relation to (2) and (3). It would be challenging to accommodate (1) and (2) without compromising current recreational activities within the dales.

Moreover there are significant risks associated with decommissioning the weirs and a thorough risk analysis would be prudent. For example, the weirs are important for providing hydraulic heterogeneity that is almost certainly important for the recreational fishery. This would be degraded by weir removal and, although it would be ultimately replaced with a better heterogeneity driven by a natural morphology, there would be some time lag before this was achieved. Weir removal would have significant downstream effects: for example, mobilisation of large quantities of fine sediment, which will almost certainly contain high levels of organic nutrients and non-organic pollutants derived from the upstream catchment. Equally there will be upstream effects; for example, removal will effectively increase the slope of the river through the Dales which may instigate incision or lateral instability in the upstream reach to Hartington as well as within the Dales themselves. In addition, by removing the weirs and therefore reducing the residence time of water within the Dales, there is the potential for natural dewatering into the underlying karst, as occurs on the Manifold below Wetton Mill.

An integral part of any risk assessment would have to be scenario modelling of the manner in which the weirs were to be decommissioned (timing, sequence, number...). Small dam decommissioning has become a significant project in North America in the last decade and much about best practice could probably be learned by a thorough examination of published experiences from there and elsewhere in Europe. Ideally, planning would proceed with a thorough programme of measurements to ascertain the current morphological and hydrological situation. It would then rely on appropriate numerical modelling of the river to investigate different scenarios of decommissioning and allow reasoned predictions of the likely outcomes for different strategies in terms of the morphological impacts within the reach as well as upstream and downstream of it.

8.3 Bank erosion

Bank erosion is widespread in the upper and middle reaches of the River Dove, the upper and middle reaches of the River Manifold and in the middle reaches of the River Hamps. Particularly intensive bank erosion, that affects long stretches of river bank and produces large volumes of sediment, is apparent through the middle reaches of the River Manifold, between Thick Withens and Hulme End in two 'hot spot' segments (Section 4.2).

The 'hotspots' identified in Section 4.2 correspond to those reaches that have demonstrated historical planform instability (Section 6.2). This implies that the contemporary dynamic is not unusual, which in turn suggests that the current rates of bank erosion through the middle reaches of the Manifold may not be "excessive", "unnatural" or "accelerated". It is, of course, impossible to reach any firm conclusion about this in the absence of suitable data. Knowing whether bank erosion is "accelerated" requires comparison of lateral rates of bank retreat between a historical period and a contemporary period, which are both unavailable in this case. What we can say, however, is that the historical evidence shows that the channel has always been highly sinuous with active meander migration and cut-off processes and it is likely, therefore, that these reaches have always experienced relatively high rates of bank erosion.

It is notable that in several reaches of the Manifold and Dove where we observed the most bank erosion we also observed a lack of fencing, with grazing to the bank top along large portions of these reaches and relatively high levels of poaching (Figure 4.7; reaches 5 and 12 on the Manifold, reach 12 on the Dove). While we think it is inevitable that grazing and drinking livestock almost certainly aggravate existing bank erosion, it is not our view that they are the fundamental cause of bank erosion except in very local cases. If a management aim is to minimise bank erosion as a means of limiting fine sediment delivery to these rivers, then fencing off bank tops and encouraging establishment of natural riparian vegetation will remove the livestock impact and be beneficial without causing any obvious problems (see comments above regarding fine sediment management). However, it is also likely that such measures will not stop bank erosion, which is a natural consequence of the rivers' meandering nature.

This, in turn, leads to a final point regarding bank erosion and lateral instability on these rivers: it is highly unlikely that bank erosion can be 'solved', nor is it desirable to do so, given the importance of channel sinuosity and the sediments supplied by bank erosion for channel hydromorphology and therefore ecological integrity. Fencing off livestock from the river banks, encouraging riparian flora and expanding soft- or bio-engineering interventions will help to minimise fine sediment delivery from bank erosion and slow rates of bank retreat. Such measures might then yield ecological benefits by reducing the fines content of river bed sediments. However, the aim should not be to stop bank erosion, which would be futile and unwise.

8.4 Other issues

Poaching

We did not examine disturbance of the catchment land surface away from the immediate river corridor, which may be a significant source of fine sediments via the catchment's augmented drainage system (below). However, we did note sites of poaching at riverside locations. Despite the visual impact of heavily poached sites, poaching is present along only a very small proportion of each river (less than one percent) and its catchment scale impact may therefore be relatively limited. It is notable, however that individual occurrences tend to cluster together (for example, through reach 6 on the Manifold and reach 6 on the Dove) which may reflect variations in land management practices between properties. Importantly, local concentration of poaching, for whatever reason, probably means that there is a cumulative local effect at the