Environment Agency

Evidence

Appraisal of river restoration effectiveness: Shopham Loop case study

Report – SC070024/c

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Miranda Kavanagh

Director of Evidence

Executive summary

This report presents the findings of a second case study carried out as part of an appraisal of river restoration schemes designed to help achieve Water Framework Directive (WFD) objectives. The case study was one element of a study carried out as part of the broader Environment Agency project, 'Managing Hydromorphological Pressures in Rivers'.

The case study featured Shopham Loop on the River Rother in West Sussex which was restored in 2004. Historical modification of the River Rother for navigational purposes resulted in the creation of a canal cut at Shopham. Over the years, the former course of the river, a large meander loop, has become cut off and the canal cut has become the preferential course of the river. The restoration scheme involved:

- constructing an earth bund to prevent flow into the canal cut and reconnect the former meander loop
- creating a new inlet channel to the loop
- inlet and exit bed control
- lowering embankments
- installing bankside stock fencing
- creating a wetland scrape in the floodplain

Monitoring data indicate that the hydromorphology objectives relating to the width, depth and sinuosity of the channel had been met, though there were sampling limitations. A lack of monitoring data made it difficult to assess whether the objectives relating to sedimentation and flow velocity had been met.

The assessment against the biological objectives is inconclusive primarily due to the variation in the number of samples and season in which they were collected over the years and between sites, and the short timeframe over which monitoring has been undertaken. The information that is available indicated that the macroinvertebrate community is already at 'good' or better status in parts of the loop. Results also suggest that the conservation value of the species present is increasing and the habitat more favourable for the target fish species.

This case study has shown it is possible to reconnect this type of meander relatively easily and reasonable cheaply. This kind of restoration scheme is particularly sustainable because it restores the river back to its natural form and function, and therefore requires little or no intervention after restoration.

The report highlights a number of lessons learnt relating to scheme design and implementation, setting of objectives, monitoring approach and sharing experiences:

- The Shopham Loop scheme has highlighted the importance of understanding the history of the site in order to shape its future. Schemes should be considered in a strategic catchment based approach and ensure that there is an emphasis on restoring river processes and that pressures are addressed at a catchment scale
- There is a need for good quality data to help shape designs, but it is important that these data are appropriate and relevant to the scheme.
- The reuse of material was considered very beneficial and it is recommended that a similar policy is adopted for future schemes.

- Ecological improvement is likely to be the principle motivation for restoration schemes. It is therefore important to establish whether there are other pressures affecting the ecology which may mask or prevent ecological improvements from being realised.
- It is important to set project and monitoring objectives that can be assessed scientifically with replicated sampling and a before–after–control–impact approach. Future schemes should include monitoring that helps to assess the effectiveness of the restoration against WFD relevant objectives and allows time for the hydromorphological response of the river to the proposed measures, both spatially and temporally.
- Monitoring methods should be written clearly and records managed properly to ensure they can be replicated by different people.
- Use of routine monitoring data from across the catchment is essential to provide context for local changes and so help distinguish between responses to measures and macro-scale or longer term trends.
- Monitoring data should be collected over a sufficiently long time period so that the system has time to re-equilibrate. Each river system will be different and a degree of flexibility must be built in to the monitoring strategy to make best use of resources.
- Continued monitoring at Shopham Loop is recommended so that the trends that were beginning to develop can be monitored into the future. In addition velocity measurements and substrate observations are required to assess the impact of the restoration. Further analysis of mesohabitat data would be useful in examining the relationships between the macroinvertebrate community and habitat change.

The monitoring methods used in the case study are detailed in an accompanying report, *Appraisal of River Restoration Effectiveness: Shopham Loop Monitoring Report.* Two further reports present the findings from the primary case study involving the restoration of the Seven Hatches site on the River Wylye in Wiltshire and the monitoring methods used in that case study.

Contents

1 Introduction

This project forms part of a broader Environment Agency project, 'Managing Hydromorphological Pressures in Rivers', which seeks to provide guidance to practitioners on the management of hydromorphological and sediment pressures in catchments to aid the delivery of the Water Framework Directive (WFD). This study is one of many projects working towards improving our understanding of hydromorphology-ecology interactions and providing evidence to improve the confidence of the decisions we make.

This part of the project focuses on how we can assess of the effectiveness of river restoration schemes for the Water Framework Directive and transfer the lessons learnt. It uses the Seven Hatches river restoration scheme on the River Wylye as the primary case study (Environment Agency 2014a) and the Shopham Loop scheme on the River Rother as a secondary case study.

This report on the Shopham Loop restoration scheme presents findings from the scheme that may have broader application for those involved in river restoration. The report describes the Shopham Loop restoration scheme and considers the scale and transferability of the restoration techniques and whether the approaches can be effectively scaled up or down or applied across river types. The report discusses the scheme design and the lessons learned as a result of the scheme's implementation.

The information on which this report is based was gathered through discussions with Environment Agency staff involved in the restoration scheme at Shopham Loop.

1.1 Structure of this report

Section 2 presents the background to the restoration project including the baseline conditions and the project's aims and objectives.

Section 3 describes the preliminary studies, the main engineering tasks required to implement the scheme and the monitoring carried out post restoration. It also considers the lessons learnt and recommendations for future schemes.

Section 4 presents the WFD relevant objectives set as part of the project and makes an initial assessment of the hydromorphological and biological impacts of the scheme at the time of writing.

Section 5 provides brief conclusions and summarises the lessons learnt from the Shopham Loop scheme.

An accompanying monitoring report provides further details of the monitoring performed (Environment Agency 2014b). It describes the analysis techniques and interpretation of results used to assess the effectiveness of the restoration scheme against WFD objectives.

2 Shopham Loop restoration

The River Rother is 48 km in length, rising in Empshott, Hampshire, and flowing to Stopham in West Sussex where it meets the River Arun. Shopham Loop is located downstream of Coultershaw Bridge near Petworth (Figure 2.1).

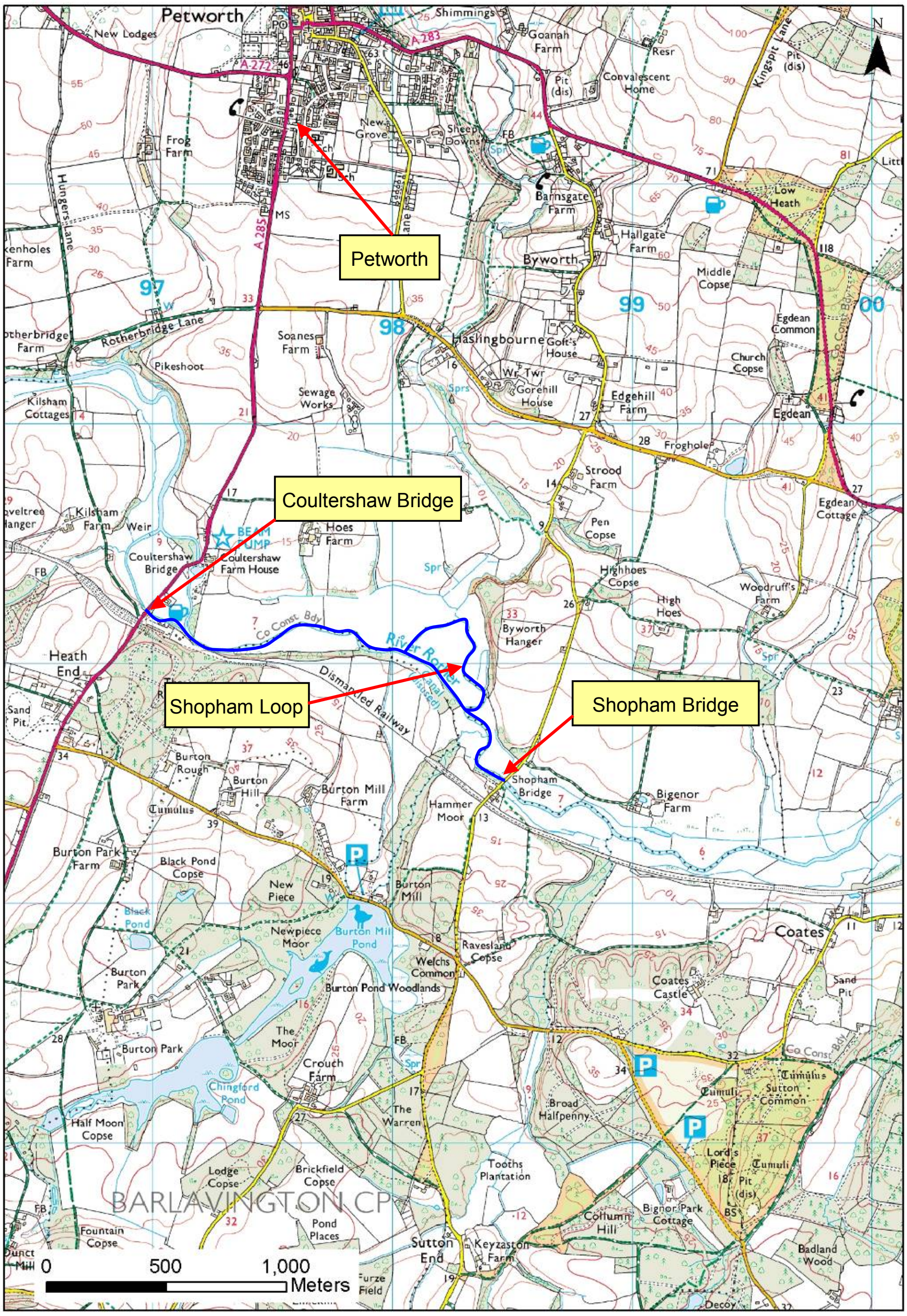


Figure 2.1 Location of Shopham Loop

2.1 Pre-restoration

2.1.1 Historical modifications

The original course of the River Rother followed the meander loop shown in Figure 2.2. In 1795 as a result of the Rother Navigation, a canal cut was created with a lock structure at the downstream end and a small weir at the upstream end of the meander loop. The majority of flow was intended to remain in the meander loop with the canal cut used as necessary. Consequently, the meander loop retained a well-defined channel over its entire length of 800 m and, until the mid-1930s, supported a healthy population of fish and other wildlife. When the navigation was rescinded by an Act of Parliament, the lock gates fell into disrepair and were eventually removed. The canal cut became the preferential course of the river with the longer course of the loop slowing conveyance and encouraging silt deposition, particularly at the upstream end.

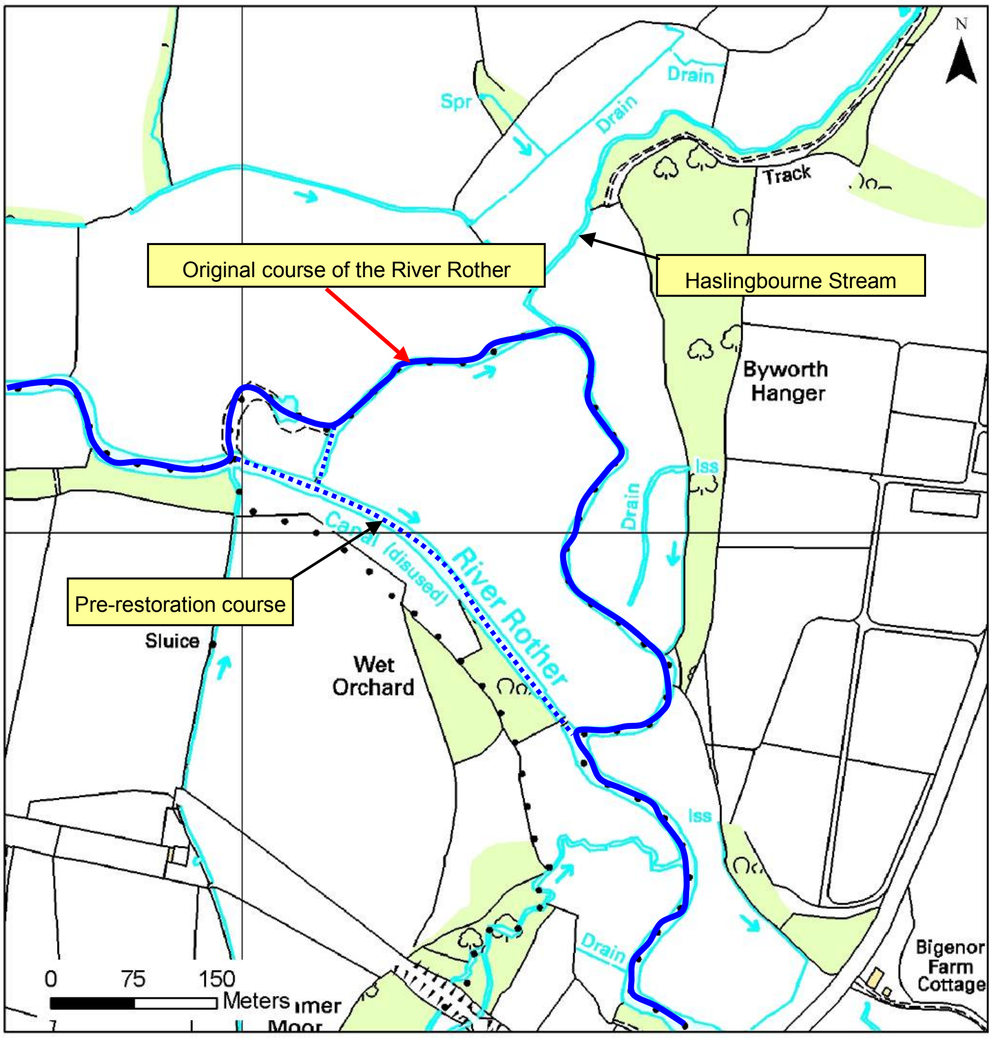


Figure 2.2 Map showing historical course of the river

2.1.2 Baseline conditions

After the canal became the preferential river course the loop only carried a small base flow from a tributary (Haslingbourne Stream) in its lower reach (Figure 2.2). Upstream of this tributary, the loop was normally dry, but carried floodwaters in high flow events for a short period of time. Over a number of years, the meander loop became cut off from the canal cut due to large deposits of sand and silt that were derived from the occasional flood flows (Figure 2.3).

Figure 2.3 Sand deposited in the upstream end of the meander loop

The meander loop was de-silted in 1996 by the Environment Agency as part of the Fisheries Action Plan to improve conveyance and enhance conditions for fish. However, this did not address the apportionment of flows causing the siltation.

There was little ecological value in the upstream end of the meander loop as a result of it being dry for much of the year. However, a wide range of fish was present downstream of the Haslingbourne Stream confluence. A survey in 1997 of 150 m of the meander loop found a variety of fish species including minnow, lamprey, gudgeon, fry, dace, roach and perch. A total of 1,474 fish were caught at a density of 3.93 fish per m^2.

Before the restoration scheme the canal cut carried all the flow except in large flood events. Despite an existing embankment, floods would often break bank on both sides of the cut, spilling onto the adjacent floodplain.

Geomorphological conditions in the canal cut were uniform, with laminar flow, although some gravel substrate existed upstream of the old lock that provided potential spawning habitat for fish. Overhanging trees were also present along the reach providing areas of shading.

2.1.3 WFD catchment context

The environmental objectives for the River Rother are outlined in the South East River Basin Management Plan (Environment Agency 2009). Shopham Loop is located in the Western Rother water body (GB107041012810). The water body at the time of this study had ‘poor’ ecological status. Full details of the condition of the water body and mitigation measures are provided in Table 2.1. The status for fish is ‘poor’, macroinvertebrates ‘good’ and macrophytes ‘good’. All supporting elements are classified as in ‘high’ status – including ammonia, dissolved oxygen, pH, copper and zinc – except phosphate which is ‘moderate’ status.

Other pressures likely to be impacting on the biology and hydromorphology of the river Rother include widespread sedimentation due to changing farming practices and the predominance of sandstone. In addition, groundwater abstraction, and barriers to river continuity have been identified as issues in the catchment (Environment Agency Water Body Summary Sheet for Western Rother).

Table 2.1 Full details of water body GB107041012810

Water body ID	GB107041012810
Water body name	Western Rother
Current overall status	Poor (very certain)
Status objectives	Good by 2027
Hydromorphological designation	Not designated a heavily modified water body
Biological elements	Fish: currently poor Invertebrates: currently good Macrophytes: Good Phytobenthos: Good
Hydromorphological supporting conditions	Quantity and dynamics of flow: does not support good (quite certain) Morphology: supports good
Mitigation measures	None

Source: Environment Agency (2009)

2.2 Aims and objectives

2.2.1 Original aims and objectives

The Shopham Loop restoration scheme was not implemented as part of the Water Framework Directive but was selected as a site to carry out restoration works because of the degraded nature of the meander loop through siltation and the opportunity it presented to reinstate the former course of the river as highlighted in the Rother Fisheries Action Plan.

The aim of the scheme was to improve the environment by:

- restoring 1 km of degraded watercourse and its interaction with the floodplain
- restoring natural river processes to benefit biodiversity
- safeguarding, enhancing and diversifying the fishery of the lower River Rother catchment
- preserving historical river structures associated with the Rother navigation

The project was funded by Natural England (through the Higher Level Stewardship Scheme) and the Environment Agency (Fisheries, Recreation and Biodiversity and

Flood Risk Management). It began in 2000-2001 with a feasibility study, followed by design in 2003 and construction in 2004.

2.2.2 Water Framework Directive relevant objectives

The Shopham Loop restoration scheme was not implemented specifically to meet the requirements of the Water Framework Directive. This project therefore developed objectives relevant for the Water Framework Directive which could be used to measure the success of the restoration scheme. These objectives were set according to the SMART system (Specific, Measurable, Achievable, Realistic and Time-bound).

The hydromorphological objectives were developed by considering the pre-restoration issues within the reach in relation to the quality elements identified in the WFD:

- hydrological regime
- river continuity
- morphological conditions

The likely response of the quality elements to the specific restoration measures was assessed. The issues identified, the relevant restoration measures and the description of the expected hydromorphological response are outlined in Table 2.2. Draft objectives were then set based on the expected hydromorphological responses.

Table 2.2 Expected hydromorphological responses resulting from restoration scheme

Hydromorphological quality element	Description of the problem	Relevant restoration measures	Description of expected hydromorphological change
Hydrological regime			
Quantity and dynamics of flow	Historical channel alteration for navigation (which fell into disrepair) combined with changing catchment land use led to the silting up of a meander loop on the River Rother and subsequent river diversion.	Reconnection of meander loop and creation of riffles as bed fixes at each end of the loop. Creation of bund preventing splitting of the flows Retention of backwater habitat	Increased flow diversity Continued function of canal cut as backwater with increased water levels and flushing during peak events
River continuity			
Continuity providing for migration of aquatic organisms and sediment transport	Flow diversion and siltation problems reduce the biodiversity and fisheries quality of the site.	Reconnection of meander loop	Continuity reinstated

Hydromorphological quality element	Description of the problem	Relevant restoration measures	Description of expected hydromorphological change
	Canal gate debris may have obstructed fish passage. Decreased length of river habitat		
Morphological conditions			
Channel patterns	Canal cut was a uniform, straight channel with low morphological diversity.	Reconnection of meander loop Cross-sectional design	Meander planform and cross-sectional design will encourage localised variability in channel width and depth.
Width, depth variation	Canal cut was of uniform width and depth except when gate debris occurred.	Reconnection of meander loop	Increased morphological diversity leading to localised creation of width and depth variations
Flow velocities	Channelisation may have increased flow velocities while quantity and velocity of flow was exceptionally low in the loop.	Reconnection of meander loop	Increased flow diversity due to creation of riffles and meanders
Substrate conditions	Siltation is a major issue at Shopham Loop.	Reconnection of meander loop Reconnection of the river with the floodplain above Shopham Loop on the left hand bank Embankment design to recreate the effect of the lock gates, prevent flows taking the quickest route and retain the backwater	Decreased siltation due to higher flow velocities within the river Sediment deposited on the floodplain once out of bank More areas of gravel substrate in new riffle

Hydromorphological quality element	Description of the problem	Relevant restoration measures	Description of expected hydromorphological change
Structure and condition of riparian zone	Lack of trees and riparian vegetation causing a lack of shelter and shading around Shopham Loop Lack of marginal and aquatic vegetation due to the depth and uniform cross section and flow of the river	Fencing to allow trees to establish and to replicate some of the habitat in the canal cut (continuous fencing on one bank only).	Increased height of vegetation Increased coverage of vegetation Improved riparian structural integrity Areas of shelter and shading in the river to provide habitat for aquatic species

The hydromorphological and biological WFD relevant objectives developed for the Shopham Loop site are presented in Table 2.3 together with the type of data that can be used to assess them. An assessment of the impact of the restoration scheme on these objectives is provided in Section 4.

Table 2.3 WFD relevant objectives

Objectives	Data to be used to assess objectives
Hydromorphological	
• Increased morphological diversity (based on width, depth and sinuosity and in-channel features) • Increased sinuosity • Increased variation in depth and width • Increased variability in velocity and diversity of flow types • Development of diverse bedforms • Increased height and coverage of riparian vegetation • Reduced sedimentation within the Loop	• Channel cross-sections • Long profile • Visual assessment of flow types from physical biotope mapping • Hydrological modelling • Macrophyte data • Mesohabitat mapping
Biological	
Macrophytes	
• Increased percentage cover of macrophytes • Increase in macrophyte species diversity in relation to faster flows	Macrophyte data

Objectives	Data to be used to assess objectives
and decreased siltation	
Macroinvertebrates	
• Increase in macroinvertebrate species diversity • Increase in species preferring faster flows (LIFE) and an increase in the proportion of sediment-sensitive invertebrates (PSI) • Good or better biological status of macroinvertebrates in the loop • Increase in conservation value (CCI)	• Species diversity • Lotic Invertebrate index for Flow Evaluation (LIFE) • Proportion of sediment-sensitive invertebrates (PSI) • River Invertebrates Classification Tool (RICT) • Biological Monitoring Working Party (BMWP) • Average score per taxon (ASPT) • Community Conservation Index (CCI)
Fish	
• Increased diversity and abundance of native fish species e.g. roach, perch, eel, carp) • Changed age structure of fish communities (increased presence of juvenile fish) • Floodplain • Restoration of floodplains through increased connectivity	• Electric-fishing data

3 Details of restoration scheme

3.1 Introduction

An appraisal and feasibility study at Shopham Loop by the River Restoration Centre (RRC) in 2001 identified the preferred restoration option as blocking off the canal cut with an earth bund, thus diverting the river flow into the loop with associated de-silting and reprofiling of Shopham Loop.

The following sections outline the preliminary studies and the engineering required to achieve the restoration. The information is adapted from the outline design report produced by the RRC and through discussions with Environment Agency personnel.

Figure 3.1 shows the site pre-restoration and identifies the features referred to below. Figure 3.2 is an aerial photo showing the site post-restoration and the implemented restoration measures. The two figures are at the end of section 3.4.

3.2 Preliminary studies

3.2.1 Geomorphology

A geomorphological assessment of the preferred option for restoration was made to:

inform the design of the restored meander loop

predict the geomorphological response to the proposed restoration

The outcomes of the assessment are summarised below.

Channel planform

The proposed planform alignment of the meander loop was selected from historical and existing Ordnance Survey (OS) mapping and from site visits. Although filled with deposited sand and silt, the meander loop, was still clearly visible, making this the most sensible route for restoration of the reach and simple in terms of excavations and channel works.

The historic course of the river at the upstream end of the meander loop was also evident from the OS mapping as being the local government boundary line (Figure 3.1). After consulting county archaeologists, reconnecting this section of the channel was ruled out due to the presence of two ancient navigation structures. The former course was also considered excessively sinuous compared with other parts of the River Rother (Darby 2007).

The pre-restoration connection between the Rother and the meander loop was at too tight an angle and was therefore not incorporated into the restoration scheme. A new alignment was designed (Figure 3.2) that provides a non-abrupt transition between the Rother and Shopham Loop and which avoids the features of archaeological interest.

Channel cross-section

The meander loop had retained a well-defined channel but discharge and sediment input had increased due to:

- increased urbanisation
- a change in agricultural practices since the canal was constructed from permanent pasture to maize and salad crops in the upstream catchment

It was felt necessary to reflect these changes in the cross-sectional design of the meander loop. The appropriate cross-section for the meander loop channel was estimated by referring to existing cross-sections of the loop and comparing these with the smallest of the cross-sections from different sections of the river. The smallest cross-sections were indicative of where the least engineering had been undertaken and therefore what the natural cross-section of the river was likely to be. The cross-sectional dimensions determined from this process and from geomorphological estimates from channel cross-sections performed in 2002 are given in Table 3.1.

Table 3.1 Cross-sectional dimensions

Parameter	Dimension
Bank top width*	12 m
Mean bed/bank gradient	1 in 1200 (0.08%)
Mean channel depth	2 m

Notes: * The bank top width was later reduced to 11 m due to the presence of two ancient stone buttress walls on either bank of the loop where it joins the Rother just below the lock site. These are just 9.5 m apart and were assumed to be old bridge supports and representative of the historic width of the loop channel.

The bed topography model developed by Bridge (1992) was used to determine the shape of the channel likely to be sustained within these parameters. Bridge's model is based on a number of parameters derived from the planform shape and roughness of the channel. The output consisted of 42 cross-sections over the full length of the loop with a satisfactory variation in channel shape to achieve the varied and diverse flow regime and channel form. However, it was not considered practical to create this number of cross-sections when implementing the scheme. The cross-sections derived from Bridge's model were therefore rationalised to just two trapezoidal cross-sections – one symmetrical and one asymmetrical – that closely matched the predicted shapes at the extreme outer bends and along the straight reaches. As it a result it was necessary to create transitions between the two design profiles during construction.

3.2.2 Hydraulic modelling

Hydraulic modelling of the outline design using a one-dimensional hydraulic model, ISIS, was carried out before the scheme was implemented. The model was calibrated by modelling the pre-restoration flow in through the canal cut and comparing the results with measured data at known discharges. The pre restoration situation was modelled using cross-sections provided by Halcrow and flows from approximately 2 km downstream of Shopham Loop. When the model had been calibrated satisfactorily, the new cross sections from Bridge's model (see above) were added to the model and the canal cut removed.

3.3 Scheme elements

3.3.1 The canal cut

Flow into the canal cut was prevented by construction of an earth bund just upstream of the old lock structure. The bund is located here because it leaves a long reach of the canal cut with a reasonable depth of still, ponded river water that remains connected to the Rother. This not only retains the historic character of the cut but also provides backwater habitat for fish.

The earth bund was constructed to a height that prevents overtopping in flood events. The existing earth embankment was also increased to the same height. The rationale for this was that water levels in the canal would rise rather than flow, causing silt deposition in the cut rather than in the downstream catchment. In addition, degradation of the existing embankment would have continued due to scour when floodwaters overtop. The bund and the embankment were constructed to 8 m above ordnance datum (AOD) to prevent frequent overtopping.

3.3.2 New inlet channel to the loop

As described previously, it was not considered appropriate to reconnect the original course of the river at the upstream end of the meander loop due to features of archaeological interest and the high sinuosity in the reach. A new inlet channel was therefore created (Figure 3.2) between the pre-restoration connection and the historical course. This channel was excavated at an appropriately gentle angle to reduce the tendency for turbulent flows as the river flows into the meander loop. This reduces the likelihood of eddying flows depositing sand material at the upstream end of the canal, thus cutting it off from the river.

3.3.3 Inlet control

An inlet bed control was needed to ensure the bed of the loop did not erode down to the depth of the upstream canalised section of the Rother (Figure 3.2). The bed control was combined with the creation of a fording point across the loop channel and a riffle feature for the benefit of in-stream habitat. The riffle feature was formed of compacted sandstone and then surfaced with flint gravels from the nearby Fittleworth Quarry.

3.3.4 Exit from the loop into the Rother

Bed control was also required at the downstream end of the meander loop to prevent headward recession due to the lower levels in the canalised downstream river. This was achieved by driving sheet piles across the width of the channel, approximately 1 m downstream of the bridge abutments. A blanket of compacted sandstone was placed across the bed width from the downstream confluence of the loop and the canal cut for 10 m upstream. The stone material has created a riffle, providing habitat for fish and other aquatic organisms. The control also fixes and prevents scouring of the foundations of the old bridge abutments (Figure 3.2).

Lowering embankments

To enable floodwaters to spill out onto the floodplain more naturally, sections of the raised levees were lowered. The lowered levels replicate the natural conditions at their locations and allow water to inundate the floodplain earlier. The location of these works is illustrated in Figures 3.1 and 3.2.

3.3.5 Bankside stock fencing

The Leconfield Estate owns the land on the left hand bank of Shopham Loop and the Barlavington Estate owns the land on the right bank. On the left- hand bank a continuous fence has been erected approximately 10 m from the banktop. Although this is encouraging the establishment of riparian vegetation, livestock can access the buffer strip via the ford. On the right-hand bank, the majority of the channel is accessible to livestock, although short sections have been fenced off around the loop, coinciding with areas of newly planted and established trees.

3.3.6 Wetland scrape in floodplain

A floodplain scrape was created as part of the restoration scheme, though this formalised an existing depression rather than excavating an entirely new feature. The scrape was designed with areas of drawdown although a deeper ponded area was included to store water at all times of the year and to provide habitat for fish and macroinvertebrates.

3.4 Implementation

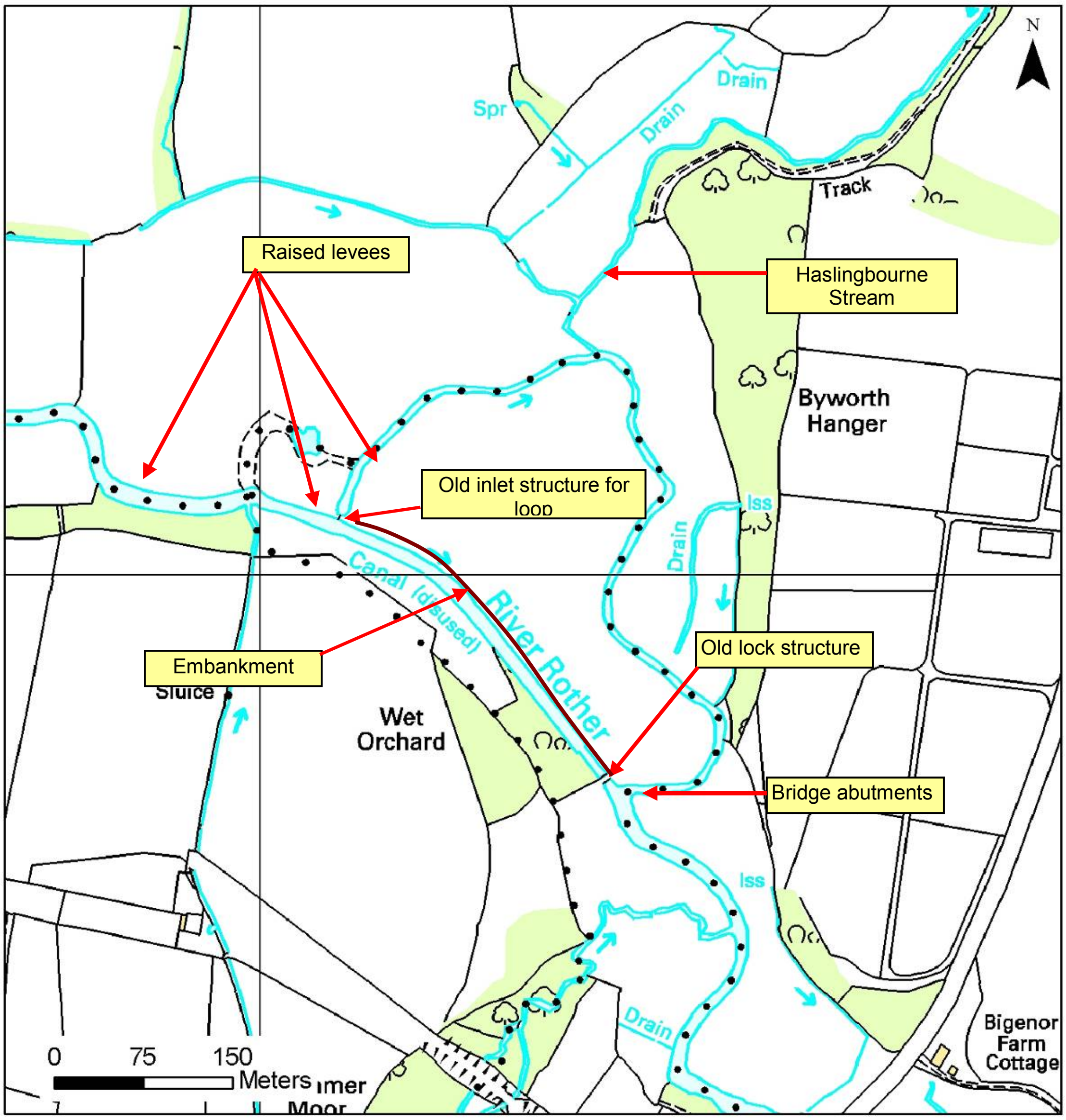
The restoration scheme was implemented in 2004 by staff from the Environment Agency's Operations Delivery team.

In order to carry out de-silting and reprofiling works to the meander loop in dry conditions, the Haslingbourne Stream was diverted along an existing ditch line that follows the Byworth Hanger wood (Figure 3.2). On completion of the restoration works, the newly excavated Haslingbourne Stream channel was only partially infilled to provide ponds and cattle drinking points.

An important aim during the construction phase was to minimise resource use and to maximise the sustainability of the project. Activities onsite such as diversion of the Haslingbourne Stream and works to the meander loop provided large quantities of clay, sand and silt. To achieve an appropriate material for construction of the bund, the sand and clay were mixed (67% sand to 33% clay) and allowed to drain prior to use. As the embankments would have small head pressure acting on them they were constructed using sand, silt and clay (67% sand/silt and 33% clay/silt). The structures were designed to have maximum width and shallow backslopes to ensure stability from grazing animals and control of the hydraulic gradient. The construction of the bunds and embankment resulted in no net export or import of materials.

The sandstone material required for the bed fixing at the upstream and downstream ends of the loop was sourced from the nearby Fittleworth Quarry.

The design elements of the restoration scheme cost approximately £15,000–20,000 and the construction approximately £90,000.



Raised levees
Haslingbourne Stream
Old inlet structure for loop
Embankment
Old lock structure
Bridge abutments
Drain
Spr
Drain
Track
Byworth Hanger
Iss
Drain
Canal (disused)
River Rother
Sluice
Wet Orchard
Iss
Drain
Bigenor Farm Cottage
0 75 150 Meters
N

Figure 3.1 Shopham Loop pre-restoration

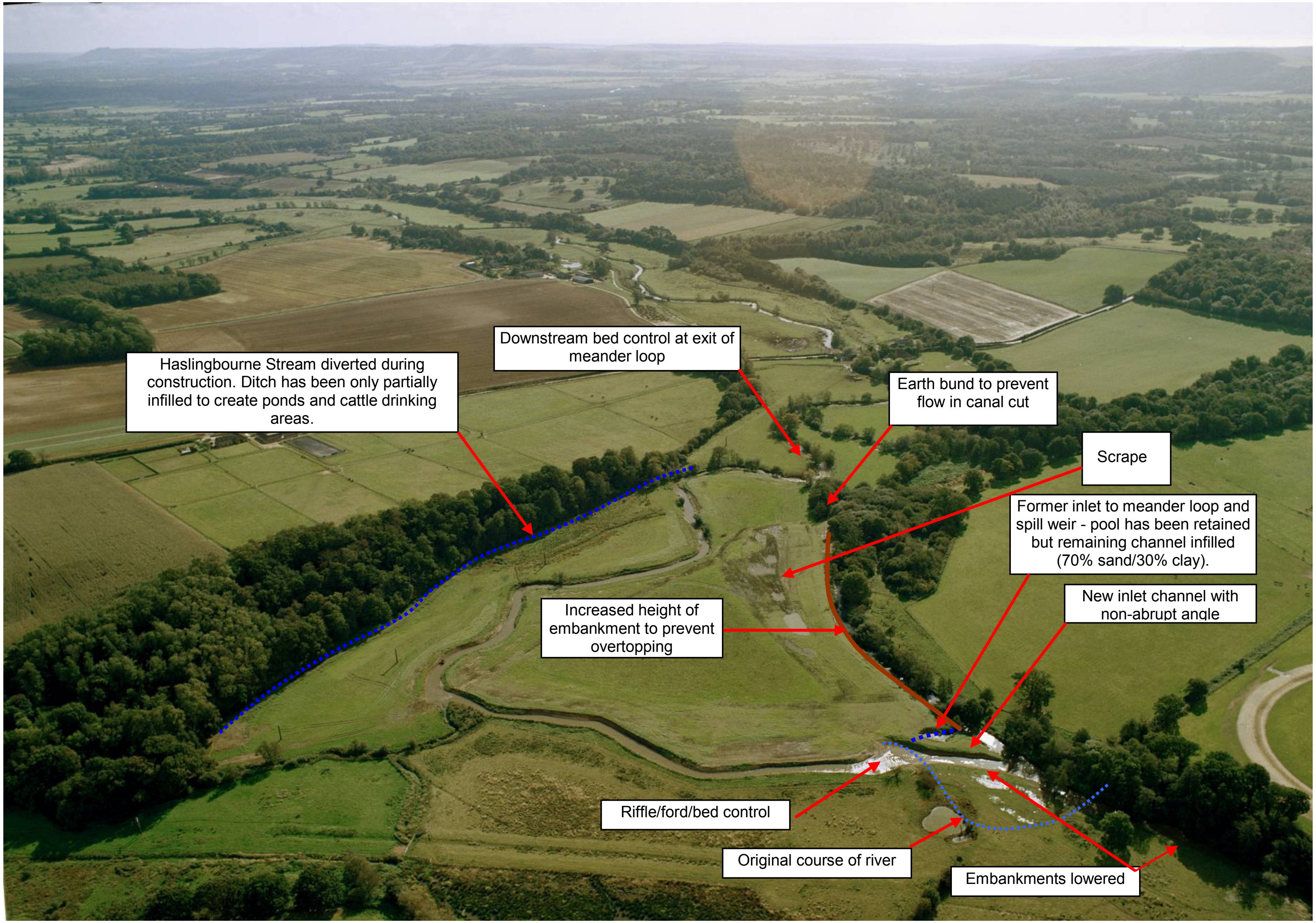


Figure 3.2 Aerial photograph of the site post restoration

3.5 Photographic record of restoration scheme

The photographs below were taken before, during and after restoration. They highlight the degraded condition of the meander loop prior to restoration and the extent of the on the channel cross-section. Photographs of other features of interest such as the riffle at the upstream end of the site are also included.

Figure 3.3a shows the meander loop prior to restoration, with minimal flow. However the original course of the river is clearly evident. Figure 3.3b shows the same section of the meander loop immediately after restoration and Figure 3.3c shows it three years after restoration. Post-restoration, the channel has been widened and the cross-section is trapezoidal in shape (Figure 3.3b). Following reconnection of the meander, the banks are becoming vegetated and natural slumping has occurred on the outside of the meander bend (Figure 3.3c). These processes are helping to increase morphological diversity and indicate that the system is functioning naturally.

(a) **(b)** **(c)**

Figure 3.3 Meander loop (a) pre-restoration, (b) immediately post-restoration and (c) in 2007 three years post-restoration

Figure 3.4 shows the upstream end of the meander loop before restoration and indicates the extent to which sand deposition had cut off the meander. The riffle created at the upstream end of the meander, which is acting as a bed control to prevent headward recession, is shown in Figure 3.5.

Figure 3.4 Upstream end of meander loop showing sand deposition and lack of flow pre-restoration

Figure 3.5 Riffle/ford at upstream end of the meander loop post-restoration

Figures 3.6, 3.7 and 3.8 show the canal cut pre-restoration, during construction of the bund and post-restoration respectively. The bund was constructed just upstream of the old lock and consists of sand and clay excavated from the meander loop and the Haslingbourne Stream.

Figure 3.6 Canal cut pre-restoration

Figure 3.7 Construction of bund in canal cut

Figure 3.8 Canal cut acting as a backwater (post-restoration)

3.6 Monitoring

The River Restoration Centre and Environment Agency carried out monitoring at the site before and after restoration work as shown in Table 3.2. Monitoring was carried out to assess the success or failure of the techniques used such that the lessons learned could assist with future restoration schemes. The monitoring was designed to be an integrated and holistic assessment sensitive to changes in geomorphology, hydrology and hydraulics, and the ecology within the channel.

The accompanying monitoring report (Environment Agency 2014b) provides further details of the monitoring and analysis underpinning the results and conclusions presented in this case study report. Readers are recommended to read the monitoring report for a more detailed technical explanation of the methods and techniques employed.

Table 3.2 Pre-and post-restoration monitoring at Shopham Loop

Dataset	Details	Location	Date
Pre-restoration			
River Rother cross-sections (design)	17 cross-sections through the River Rother	From Coultershaw Bridge to Shopham Bridge	2002
Shopham Loop cross-sections	14 cross-sections around loop	Entire loop	2002
River Rother longitudinal cross-section	Longitudinal section along the River Rother	From Coultershaw Bridge to Shopham Bridge	2002
Shopham Loop longitudinal cross-section	Longitudinal section along the loop	Downstream of Shopham Lock bridge to upstream of Shopham Lock weir	2002
Macroinvertebrate data	One-minute kick samples: 42 samples taken from 12 mesohabitats	Loop and canal cut	2002
Post-restoration			
Water level data	Water level measurements from three locations	Just upstream of the loop, within the loop (downstream of Haslingbourne Stream) and near Shopham Bridge	January 2006 onwards
Fish data	Electric-fishing	Shopham Loop	2005, 2006, 2007 and 2009
	Fish survey	Floodplain scrape	2006 ,2007 and 2009
	Survey of larvae	Loop and canal cut	2005
	Electric-fishing	Canal cut	2009
	Fry netting	Canal cut	2009
Macroinvertebrate data	One-minute kick samples in mesohabitats (cobbles, gravel, sand, woody debris, deep play, shallow clay)	Loop only (not canal cut) Various locations depending in location of mesohabitats	2005, 2006, 2007 and 2009
Macroinvertebrate data	Five fixed locations (three-minute kick samples)	Shopham Loop	2006, 2007 (all sites) and 2009 (one site)

Dataset	Details	Location	Date
Macrophyte data	Macrophyte surveys: the loop was divided into 100 m sections and records of species present and estimated coverage recorded	Shopham Loop	2005, 2006 and 2007
Environment Agency macroinvertebrate monitoring stations	Macroinvertebrate samples	Shopham Bridge and Selham Bridge*	Shopham : 1989 to 20012 Selham: 1975 to 20013
Cross-sections	Cross-sections on the Rother and the loop	2005: two on the Rother, 24 on the loop 2006: three on the Rother, 19 on the loop 2009: three on the Rother, 23 on the loop	2005, 2006 and 2009
Flow monitoring data	Three locations: Fittleworth, Hardham and Iping Weir. NB Fittleworth is not reliable at out-of-bank flows	Fittleworth: ~17 km downstream of loop Hardham: 20 km downstream of loop Iping Weir: 7.5 km upstream of loop	1995 to 2009
Physical biotope mapping	Around the loop		2009

Notes: * The 'control' site for the case study – an Environment Agency macroinvertebrate monitoring station upstream of Shopham Loop.

4 Hydromorphological and biological response

4.1 Expected response following preliminary studies

The geomorphological and hydraulic assessment predicted the following hydromorphological response.

The newly excavated channel can be expected to sustain a good range of desirable physical features including cliffs, pools, bars and riffles.

Sands and silts that are carried into the loop can be expected to flush right through the loop without significant deposition. This is because flow speeds in the loop will generally be higher than those in the Rother. Some sand will be deposited on the inside of meander bends, but this is not considered an adverse response.

It was predicted that the restored meander loop would be subjected to erosional and depositional processes that would modify its shape. The rate and extent of the changes will depend on the strength and nature of the soils present. However, the predicted physical changes are an essential part of creating a naturally functioning system and should not be viewed as detrimental.

Some downstream impact was predicted because the loop discharges water into the existing deep pool below the old lock. It is predicted that the pool will be maintained as it is at present, although sand deposition is expected where the flow regime is altered by changes in the flow direction. It is anticipated that a few new bankside shoals and underwater bars may form for a short distance downstream of the loop.

The new entry channel feeding water into the loop, combined with freer access to the floodplain here, provides a better hydraulic passage than the existing arrangement and encourages the settling of fine sediment on the floodplain rather than in the channel.

Mean river flow speeds in the restored loop during flood will be up to twice as fast as those currently experienced, thus reducing deposition of sands to an acceptable level.

4.2 Observed hydromorphological response

Detailed information on the hydromorphological responses of the scheme is presented in the accompanying monitoring report (Environment Agency 2014b). The following sections summarise the hydromorphological objectives which the scheme has contributed towards meeting.

- **Increased sinuosity.** The restoration measures have increased the sinuosity of the River Rother by extending the total channel length. Although it is likely that small-scale changes in the sinuosity have occurred since restoration due to erosional and depositional processes, it has not been possible to detect these changes from the information available.

- **Increase variation in width and depth.** The depth of the channel has increased and the width has decreased. There appears to be greater variation in width and depth in the main River Rother rather than in the Shopham Loop, but the loop system is likely to still be adjusting to the increased flow that it now conveys.

- **Increased variability in velocity and diversity of flow types.** The installation of bed controls at the upstream and downstream ends of the loop has created gravel riffles which display fast, shallow flow – conditions that were not present in the loop pre-restoration.

There are insufficient data to:

- assess whether more diverse bedforms have developed
- quantify any changes in velocity
- assess whether the rate of sedimentation has decreased

It is therefore not possible to assess whether the expected changes have occurred.

4.3 Biological

Detailed information on the biological response to the restoration scheme is presented in the accompanying monitoring report (Environment Agency 2014b). The following sections summarise the analysis of biological monitoring data.

4.3.1 Macrophytes

Analysis of macrophyte survey data indicates that percentage cover may have increased between 2005 and 2007, though this is based on visual estimation of coverage along a 100 m length. Percentage cover is likely to have increased due to the gradual establishment of species in response to the increased flow conveyed around the loop.

4.3.2 Macroinvertebrates

Results show that species diversity was highest prior to restoration and then declined rapidly immediately following restoration. This is likely to be a result of disturbance to existing habitats during implementation and in response to the changing flow conditions throughout the loop. Since 2005, species diversity has increased but has remained lower than the pre-restoration level. The increase in diversity is likely to be attributable to the development of a wider variety of habitats as the river re-naturalises and adjusts to its new course.

Analysis of LIFE scores shows that family and species LIFE and PSI scores increased in Shopham Loop between 2002 and 2009. This increase was greater than that at the Selham Bridge 'control' site, suggesting that improvements may be attributable to the restoration scheme.

Analysis of CCI scores shows that the macroinvertebrate population in Shopham Loop is of higher conservation value than in 2002. The CCI score at Selham Bridge decreased between 2002 and 2007, suggesting that the increase in the loop may be attributable to the restoration scheme.

Analysis of RICT outputs can help to explain what is driving the macroinvertebrate community composition. Based on ASPT score alone, the loop transects score either 'good' or 'high'. Based on the number of taxa (NTAXA), only some areas of the loop are attaining 'good' or 'high' status. This suggests that water quality is not a limiting factor for invertebrate community composition, because the ASPT Ecological Quality Ratio (EQR) is steady at either 'good' or 'high'. The variation in NTAXA could be due to habitat or sampler effort which could change with water depth. Very deep water can affect the sampling and could, in theory, decrease the number of taxa found without compromising the ASPT value. Another likely explanation is that, if the habitat is shifting and changing, this would inhibit the number of taxa found without compromising the ASPT too much as long as there was some acceptable quality habitat within the transect area. This variability suggests that the loop was still 'bedding in' in 2007.

A review of the WFD status of macroinvertebrates for the study water body and surrounding water bodies is presented within table 4.1 (data was obtained from the Environment Agency's Catchment Planning System accessed March 2014). The results show a consistently high status for the study water body and high or good status in surrounding water bodies. The results show a consistent pattern of high and good status with occasional records of moderate status. This supports the observation of the high conservation value of the macroinvertebrate community within Shopham Loop.

Table 4.1 Macroinvertebrate status

	study WB	upstream					downstream
	GB107041012810	GB107041012800	GB107041012770	GB107041013010	GB107041012760	GB107041012760	GB107041017950
2009	good	moderate	high	good	poor	poor	good
2010	high	good	high	good	no data	no data	good
2011	high	good	high	good	no data	no data	high
2012	high	good	high	no data	no data	no data	high
2013	high	good	high	good	no data	no data	moderate

4.3.3 Fish

Species diversity results show that diversity has increased since 2005, peaking in 2007 before declining slightly in 2009. Although pre-and post-restoration results are not directly comparable, they do suggest that the habitat in Shopham Loop has become more favourable for bullhead, brown trout, sea trout, chub and eel as a result of the restoration works.

Populations of lamprey fell from 64 in 1997 to none in 2009, possibly as a result of decreased sedimentation in the loop. These results are also likely to be attributable to the fact that lamprey are often only drawn from the substrate on the second or third passes when electric-fishing. Consequently they are likely to be under-recorded on the annual single run survey. The creation of the backwater is likely to provide more suitable conditions for lamprey, but a lack of data collection makes it impossible to ascertain whether the habitat is being used.

The most commonly occurring species in each survey year are bullhead, dace, chub, eel and brown trout, indicating that Shopham Loop provides favourable habitat for these species.

Populations of sea trout increased from none in 1997 to 26 in 2009, indicating an improvement in habitat for this species. This is possibly due to the gravel riffles providing spawning areas and also because the deep and fast flow in the loop provides good holding water for sea trout.

Results of surveys on the floodplain scrape show that the diversity of species present has increased since 2006. Populations of three-spined stickleback decreased from a thousand in 2006 to seven in 2009. However, populations of bream increased from 15 in 2007 to 315 in 2009. The 2013 netting contained a large number of non native sunbleak which were removed and destroyed after the survey. With the benefit of this confirmed identification it is probable that the previous survey in 2010 also contained sunbleak which were misidentified as juvenile dace. The large number of juveniles present within the scrape indicated the importance of such features in providing habitat and refuge from washout in high flows.

The canal cut is providing suitable habitat for a range of fish species including perch, rudd, tench, pike, eel and bream. A large number of roach fry were netted at the upstream end of the canal cut, which is a positive indication given that observed roach catches are consistently less than expected in the catchment.

A review of the WFD status of fish for the study water body and surrounding water bodies is presented within table 4.2 (data obtained from the Environment Agency's Catchment Planning System access March 2014). The results support the belief that a large amount of washout of juvenile coarse fish occurs on the Western Rother and is compounded by numerous structures on the river that do not allow these displaced individuals to return upstream.

The water body in which Shopham Loop is located is extensive and highly variable, which is reflected within the ecology. There are a range of reasons for failure a series of measures are needed to address the multiple pressures. This will include some morphological restoration, improving fish passage and sediment management, (Environment Agency, 2013). Specific measures to improve the fishery have been considered on a catchment scale within the Western Rother Fisheries Action Plan (Environment Agency, 2002). These include partnership projects with the River Trust to create additional backwater/refuge areas on the river to attempt to counteract the washout of juvenile coarse fish.

Table 4.2 Fish status

	study WB	upstream					downstream
	GB107041012810	GB107041012800	GB107041012770	GB107041013010	GB107041012760	GB107041012760	GB107041017950
2009	poor	good	moderate	no data	moderate	moderate	high
2010	moderate	high	good	no data	moderate	moderate	high
2011	poor	good	good	no data	moderate	moderate	high
2012	poor	high	good	no data	good	good	high
2013	poor	good	moderate	no data	moderate	moderate	good

5 Conclusions and lessons learnt

5.1 Conclusions

The River Rother has been modified historically for navigational purposes, resulting in the creation of a canal cut at Shopham. Over the years, the former course of the river, a large meander loop, has become cut off and the canal cut has become the preferential course of the river.

The restoration scheme has reconnected the former meander loop, created a backwater in the canal cut and a wetland scrape in the floodplain. This was achieved by installing a bund in the canal to divert water around the loop.

In terms of hydromorphology, the objectives relating to the width, depth and sinuosity of the channel have been met, although sampling limitations restrict the certainty of the results. Assessment of the objectives relating to sedimentation and flow velocity is either limited or not possible due to a lack of monitoring data.

The assessment against the biological objectives was inconclusive primarily due to the variation in the number of samples and season they were collected over the years and between sites, and the short timeframe over which monitoring took place. The information that is available indicates that the macroinvertebrate community was already at ‘good’ or better status in parts of the loop. Results also suggest that the conservation value of the species present was increasing. Although pre-and post-restoration results are not directly comparable, they do suggest that the habitat in Shopham Loop has become more favourable for bullhead, brown trout, sea trout, chub and eel as a result of the restoration works.

There are numerous examples in the south of England where rivers have been canalised and this has often resulted in cut off meanders. This project has shown that it is possible to reconnect these meanders relatively easily and reasonable cheaply. The full benefits of the Shopham Loop scheme have yet to be realised, but it is anticipated that there will be significant benefits to morphological diversity, with biological enhancements occurring in response.

This sort of restoration scheme is particularly sustainable because it restores the river back to its natural form and function, and therefore requires little or no intervention after restoration. The reuse of materials evident in this project can be replicated elsewhere, ensuring that resource use is also sustainable.

Lowering of the levees has reconnected the river with the floodplain, encouraging flooding on the left-hand side of the floodplain. This has encouraged disposition of sand and silts on the floodplain, although the quantities were not assessed as part of the monitoring project.

In more recent years there has been a shift in approach to river restoration with more focus upon restoring riverine processes on a more catchment scale rather that localised restoration measures. The Government have adopted a catchment-based approach to the management of fresh water and transitional water bodies, in recognition of the many factors which affect water quality DEFRA (2013). This approach aims to integrate land and water management in a sustainable way to balance environmental, economic and social demands at a catchment scale.

Schemes such as Shopham Loop which reconnect old river channels are part of this strategic consideration of processes and when used in conjunction with other measures should improve the hydromorphological processes within catchments. Given the small scale of this restoration scheme (880m) within a water body extending 59.41km the further restoration measures planned within the Fisheries Action Plan are likely to be needed to improve fishery status at the water body scale.

5.2 Lessons learnt

5.2.1 Design and implementation

The Shopham Loop scheme has highlighted the importance of understanding the history of the site in order to shape its future. By doing this, the features of archaeological interest were preserved and the new channel was designed based on the historical dimensions of the river.

Acquiring help from those with experience and expertise in similar schemes can save a large amount of time, money and effort.

There is a need for good quality data to help shape designs, but it is important that these data are appropriate and relevant to the scheme. Excessive data collection can delay the scheme and incur unnecessary costs, so if the risks of the scheme are low, then it is important to be brave with decisions and data.

The clay, silt and sand acquired during works to the meander loop and the diversion of Haslingbourne Stream were used to construct the bund and to raise the embankment. This reuse of material was considered very beneficial and it is recommended that a similar policy is adopted for future schemes. Importation of materials was minimised and no material was transported offsite for disposal.

There is a need to consider restoration schemes in a strategic catchment based approach and ensure that there is an emphasis on restoring river processes and that pressures are addressed at a catchment scale.

5.2.2 Objective setting

Allowing time to consider the likely hydromorphological response of the river to the proposed measures, both spatially and temporally, helps to set realistic objectives and to design a more suitable monitoring strategy. Historic hydrological and geomorphological data are useful, if available, but simply looking at rainfall, topography, geology and the size of catchment can give an indication of whether the river has high or low hydraulic energy to cause geomorphological change.

Ecological improvement is likely to be the principle motivation for restoration work. It is therefore important to establish whether there are other pressures affecting the ecology which may mask or prevent ecological improvements from being realised. River basin management plans are a useful starting point and can help establish an ecological baseline against which improvements can be measured.

Making objectives specific reduces the likelihood of achieving an objective while causing a harmful environmental response. For example, an increase in the percentage cover of undesirable species would rate as a success for an objective of increased macrophyte cover, but if the objective was specific to *Ranunculus,* it would not. Following the SMART method should help with this and make subsequent measurement easier.

5.2.3 Monitoring

It is important that post-restoration monitoring has clear objectives and is linked to the objectives of the restoration scheme. Future schemes should include monitoring that helps to assess the effectiveness of the restoration against WFD relevant objectives. To obtain statistically meaning results it is recommended that replicated sampling is undertaken and a before–after–control–impact approach is followed.

Monitoring methods should be written clearly and records managed properly to ensure they can be replicated by different people.

The method used in this project to measure cross-sections was successful. However, it is imperative that cross-sections are directly comparable by ensuring repeat measurements are taken at the same locations. This can be easily achieved using a global positioning system (GPS).

In addition to the monitoring already undertaken, detailed monitoring of velocity and substrate is required to assess the response of the river to restoration works in terms of flow dynamics and sedimentation.

Use of routine monitoring data from across the catchment is essential to provide context for local changes and so help distinguish between responses to measures and macro-scale or longer term trends.

Monitoring data should be collected over a sufficiently long time period so that the system has time to re-equilibrate. Each river system will be different and a degree of flexibility must be built in to the monitoring strategy to make best use of resources.

5.2.4 Sharing experiences

It is essential that the results of the assessment of restoration schemes are communicated and shared to improve the evidence base and to establish what restoration techniques work in which situations and which monitoring techniques work. It is equally important that to understand where schemes have been unsuccessful.

Several information resources are dedicated to sharing information about restoration schemes. These include:

- the National River Restoration Inventory (http://www.therrc.co.uk/rrc_nrri.php) held by the River Restoration Centre
- the RESTORE wiki (http://riverwiki.restorerivers.eu) established as part of an EU Life project dedicated to communicating river restoration experiences across Europe

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List of abbreviations

ASPT	average score per taxon
BMWP	Biological Monitoring Working Party
CCI	Community Conservation Index
EQR	Ecological Quality Ratio
LIFE	Lotic Invertebrate index for Flow Evaluation
mAOD	metres above Ordnance datum
NTAXA	number of taxa
OS	Ordnance Survey
RICT	River Invertebrates Classification Tool
RRC	River Restoration Centre
SSI	sediment-sensitive invertebrates
WFD	Water Framework Directive

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