5

Controlling River Bed Levels, Water Levels and Flows

5.1 Bifurcation weir and sidespill

River Cole

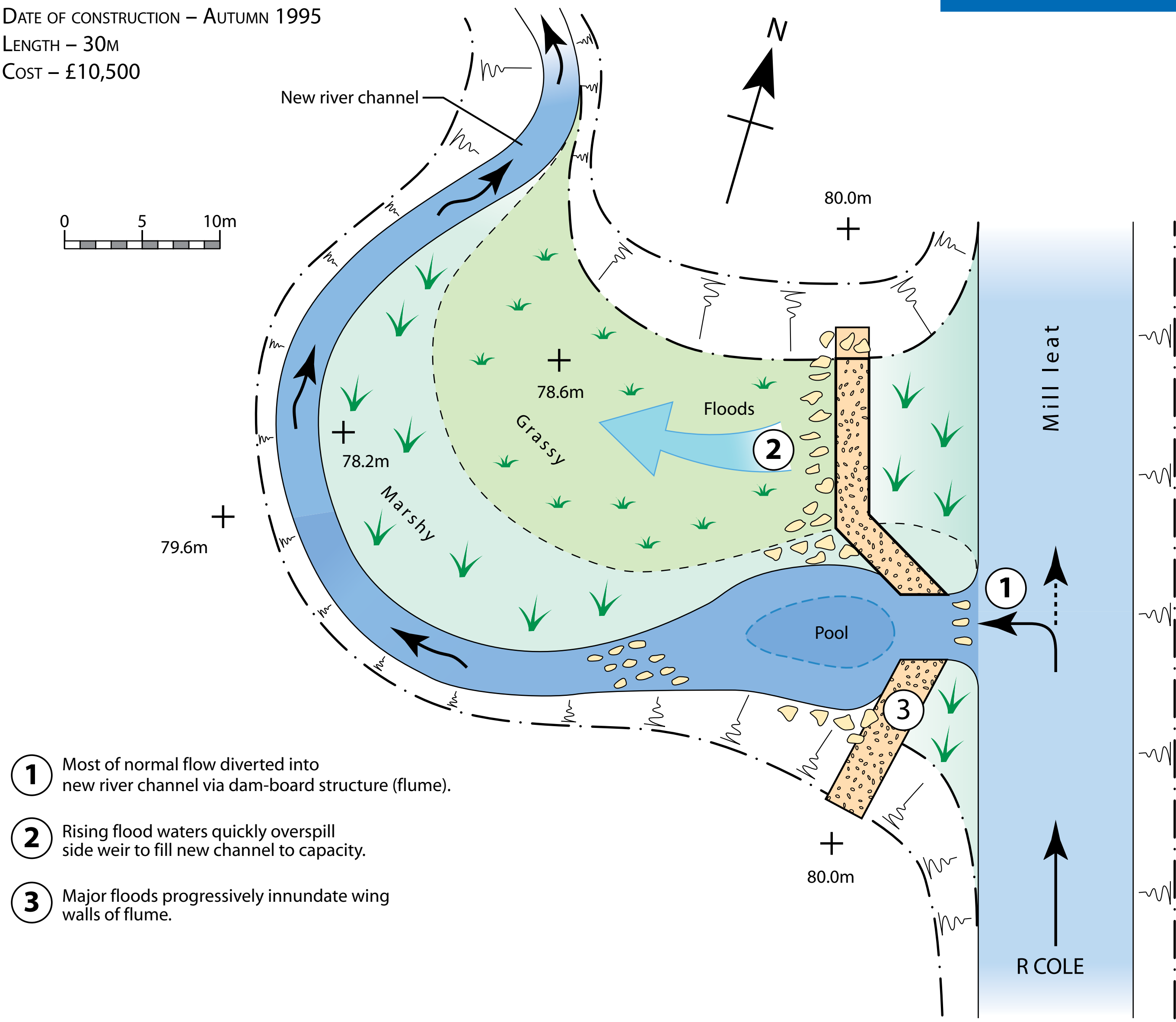
Location – Coleshill, Oxon/Wilts border, SU234935

Date of construction – Autumn 1995

Length – 30m

Cost – £10,500

Figure 5.1.1
Plan of bifurcation weir



Description

Most of the flow in the river needed to be diverted from the mill leat, where it is impounded at a high level, into a newly created, free flowing channel that branches from it (*see Technique 1.1*). A structure was needed to meet the following criteria:

- control the level and volume of water retained in the leat;
- control the volume of water diverted to the new channel;
- maintain stable structural conditions when inundated by floods;
- create a visually attractive feature with ecological value;
- safeguard flow to the new channel should the mill sluices be suddenly opened.

A further hydraulic requirement was that the new channel should have filled with floodwater via the new structure just before the mill leat itself overspilled at a point some 250m further downstream.

A designed 'high level' overspill exists here (at 79.2m) to initiate general inundation of the floodplain. If the new channel was only partially full at such time, then floodwaters would drop into it causing serious scour of the banks, risking breaching between the new channel and the leat.

These techniques were developed to suit site specific criteria and may not apply to other locations

Controlling River Bed Levels, Water Levels and Flows

Design

The normal range of summer/winter base flows weir over a pair of damboards housed in a simple concrete flume. The top level at which the boards are set was critically determined to give precise control over the division of low flow between the new channel (90%) and the mill leat (10%), as well as control of the water level in the latter. A free fall of water over the boards is necessary to achieve this.

The normal water level in the new channel is controlled by its longitudinal bed gradient, determined independently (*see Technique 1.1*), a water level differential of c. 0.6m usually exists across the structure. The new channel begins as a deep pool leading into a long sweeping bend. The pool is sustained by floodwaters passing through the flume.

A rock/gravel riffle was created at the downstream lip of the pool. The pool is lined with rock close to the structure to safeguard against underscour. Beneath the flume, a 0.2m diameter pipe ensures that at least a small flow of water continues should the level in the leat drop below the damboards.

Control weir (*location* ① *on plan*)

Figure 5.1.2
Elevation of downstream side of weir

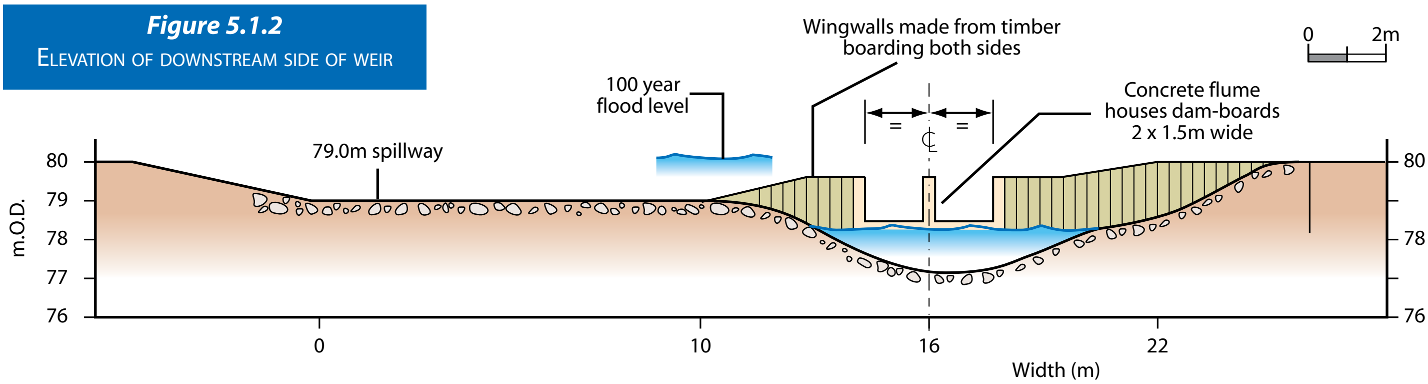
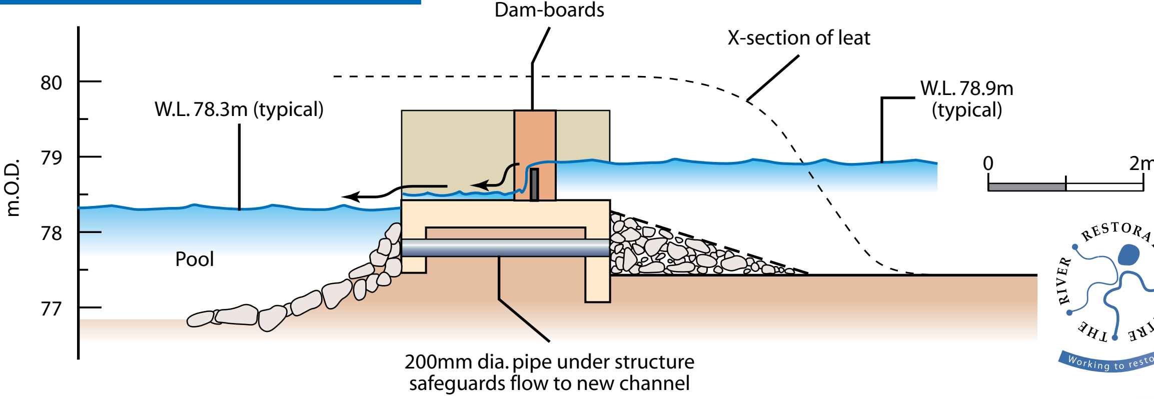


Figure 5.1.3
Section through dam-board structure



These techniques were developed to suit site specific criteria and may not apply to other locations

5

Controlling River Bed Levels, Water Levels and Flows

The hydraulic capacity of the flume is small (to suit base flows) so a 10m wide spillway is incorporated alongside to feed sufficient floodwater to fill the new channel. The crest level is only 0.1m above the normal water level in the leat so it operates frequently. Below the spillway, a large area of land is gently graded out towards the new channel which sustains marshy conditions around its inner margins. This low lying area is largely flooded before overspill occurs, ensuring a fairly smooth combining of floodwaters passing downstream. Water in the new channel rises quickly, ensuring the overspill is completely submerged (drowned) at an early stage of a rising flood, thereby further reducing scour potential.

The spillway is defined by two parallel lines of road kerbs infilled with stone/gravel (a small amount of rock is incorporated along the downstream edge of the kerb line where eroding eddy currents are strongest). Reeds growing upstream of the structure also help to ensure stability and improve 'natural' blending between hard and soft elements.

Wingwalls link the flume to the spillway, and to the adjacent banks of the leat, through a smooth transition of levels. Large floods will inundate these walls so they are designed as weirs in their own right. Two parallel lines of vertical wooden planking are joined via walings and tie rods, infilled with clay, and topped with stone/gravel. The wingwalls are thereby free-standing structures that simply abut the sidewalls of the flume.

The spillway and wingwalls form a 'natural' footpath and are linked over the flume by a temporary wooden bridge.

Subsequent performance 1998 – 2001

The structure has functioned exceptionally well and fulfils all design criteria. The complex configuration of channel and landforms combine with diverse patterns of flow currents to sustain a variety of habitat niches as well as an overall feature of landscape interest. Snipe are commonly seen probing the marshy areas intrinsic to the design. The National Trust (owners) plan to undertake landscape planting, and to provide a permanent bridge to further enhance the location. The abundance of fish in the new channel suggest that migration is ocurring satisfactorily.

Spilllway alongside bifurcation weir – April 1997

Flood filled channel downstream of bifurcation weir

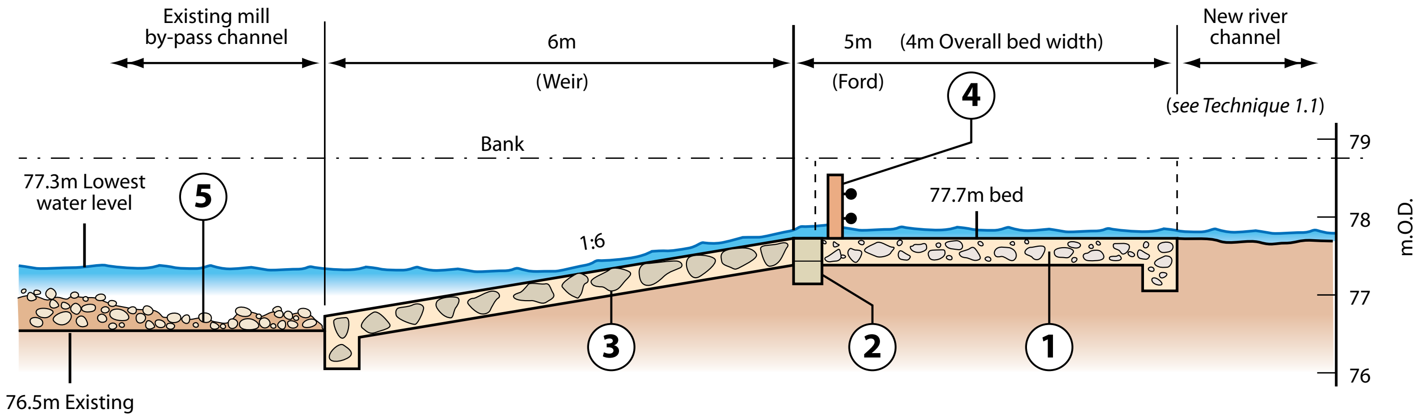
These techniques were developed to suit site specific criteria and may not apply to other locations

5 Controlling River Bed Levels, Water Levels and Flows

5.2 Drop-weir structures

River Cole
Location – Coleshill, Oxon/Wilts border, SU234935
Date of construction – Autumn 1995
Cost – Upstream drop-weir £2,800. Downstream drop-weir £2,500

Figure 5.2.1
Drop-weir on new river upstream of mill



1. Ford – 0.15m down densely graded stone over polythene membrane
2. Cut-off wall – concrete kerb blocks (incorporates membrane)
3. Weir – 0.3m down densely graded stone over filter membrane
4. Stock fence comprising two strained cables
5. Gravels deposited over existing bedof old mill by-pass

Description

New river channels that were created both upstream and downstream of Coleshill Mill have bed levels that are elevated c.1m higher than the bed of the existing channels into which they now flow (*see Techniques 1.1 – 1.2*). Measures were needed to stabilise the river geometry at both confluence points because of the sudden change in bed levels. Drop-weirs were built at each.

Weir and rock apron

These techniques were developed to suit site specific criteria and may not apply to other locations

Controlling River Bed Levels, Water Levels and Flows

Design

Drop-weir on new river upstream of Mill
Consideration was given to partially infilling the existing downstream channel (mill by-pass) with gravel to achieve a transition between bed levels at the confluence. Infilling would have been undertaken over a long reach but would still have been intrinsically unstable for some time. This option was discounted in favour of the secure fixed structure shown.

The river bed approaching the structure increases in width from 2.6 to 4m where it is stoned (**1**) to create a useful fording point; slopes of 1:8 are incorporated each side. This increase in bed width is necessary to maintain a shallow depth of water for a wide range of flows. A vertical wall of mortared pre-cast concrete kerbing blocks (**2**) defines the downstream edge of the ford. It serves to set a fixed profile right across the section, as well as reducing the risk of river water flowing underneath the structure causing it to collapse. Water flowing over the wall passes evenly down to the lower channel over a rock apron (**3**) at a slope of 1:6. During time of spate, downstream water levels rise more quickly than those upstream causing the structure to eventually submerge or 'drown', although not frequently.

A livestock fence was incorporated in the form of two wire cables strained along the crest line and up each side to field level. The cables are strong enough to withstand the pressure of floating debris that inevitably catches on such 'fences' in time of flood but they do not form an impenitrable barrier that otherwise arises if woven fencing is used.

Gabion weir and pool

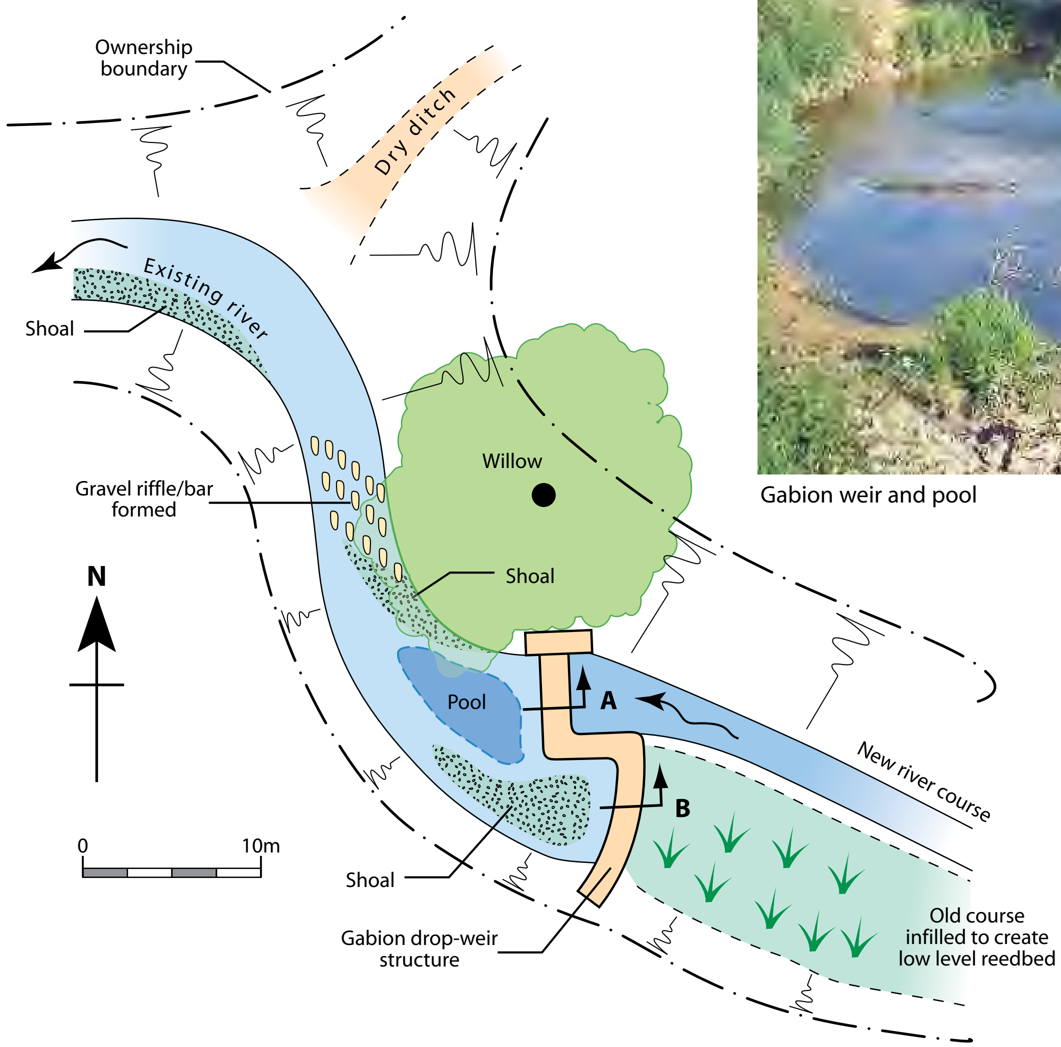


Figure 5.2.2
DROP-WEIR ON NEW RIVER DOWNSTREAM OF MILL

5

Controlling River Bed Levels, Water Levels and Flows

Drop-weir on new river downstream of Mill
The confluence of existing and new river is located at the downstream limit of land on both banks owned by the National Trust. No agreements had been reached with adjoining owners but the continuation of river restoration into the lower reach was regarded as a future possibility. A 'temporary' structure was therefore designed, albeit its existence may be long term. A particular feature of this confluence is a new reedbed that runs parallel to the new river course; it was created by partial backfilling of the old river bed (*see Technique 9.2*).

Figure 5.2.3
SECTION **A** THROUGH GABION DROP-WEIR

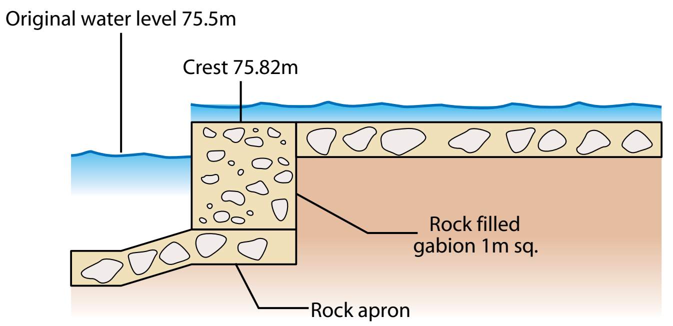
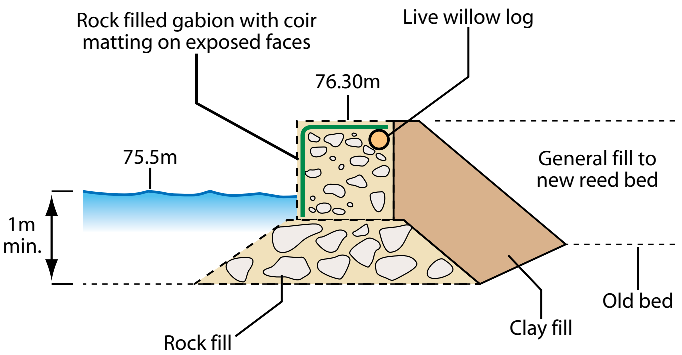


Figure 5.2.4
SECTION **B** THROUGH GABION DROP-WEIR



A wall of stone filled wire baskets (gabions) was built along the line shown to retain and secure both the new river bed and the new reed bed alongside it. The gabions at the reedbed are elevated above river levels and are visible, so coir matting was incorporated on exposed faces to attract vegetation and improve visual amenity. Two gabions, incorporating willow branches, form a short wall on the opposite bank.

A scour pool was expected to form below the gabion wall so larger rock was incorporated underneath the wall and the bed excavated to achieve a minimum water depth of 1m under normal flow conditions. The structure was expected to submerge fairly soon in a rising flood so no further revetment of river banks was undertaken.

Subsequent performance 1998 – 2001

Both have performed well benefiting from the formation of substantial gravel riffles just downstream which raised bed and tailwater levels reducing the overall drop described.

The lower confluence has been an outstanding success and the change in normal water levels at the structure is now barely discernable, but is marked by a change from fast flowing water in the new channel to a deep, still pool of water that precedes the riffle. The gabion structure is virtually hidden from view among the vegetation that has grown up within it.

The upper confluence structure has lost stone from the weir because the size used was below the 0.3m graded mix specified. The structure remains functional because the block wall is stable - numerous larger stones have settled out below it. The stone work was re-built in summer 1998.

Fish have migrated into each new channel suggesting that neither structure is a significant hindrance.

5 Controlling River Bed Levels, Water Levels and Flows

THE RIVER RESTORATION CENTRE
Working to restore & enhance our rivers

5.3 Restoring and stabilising over-deepened river bed levels

RIVER OGWEN AND NANT FFRANCON

LOCATION - 5km south of Bethesda, Gwynedd SH 641615
DATE OF CONSTRUCTION - Autumn 1998
LENGTH – 900m
COST - £48 000 construction, £8 000 flood model, £5 000 design

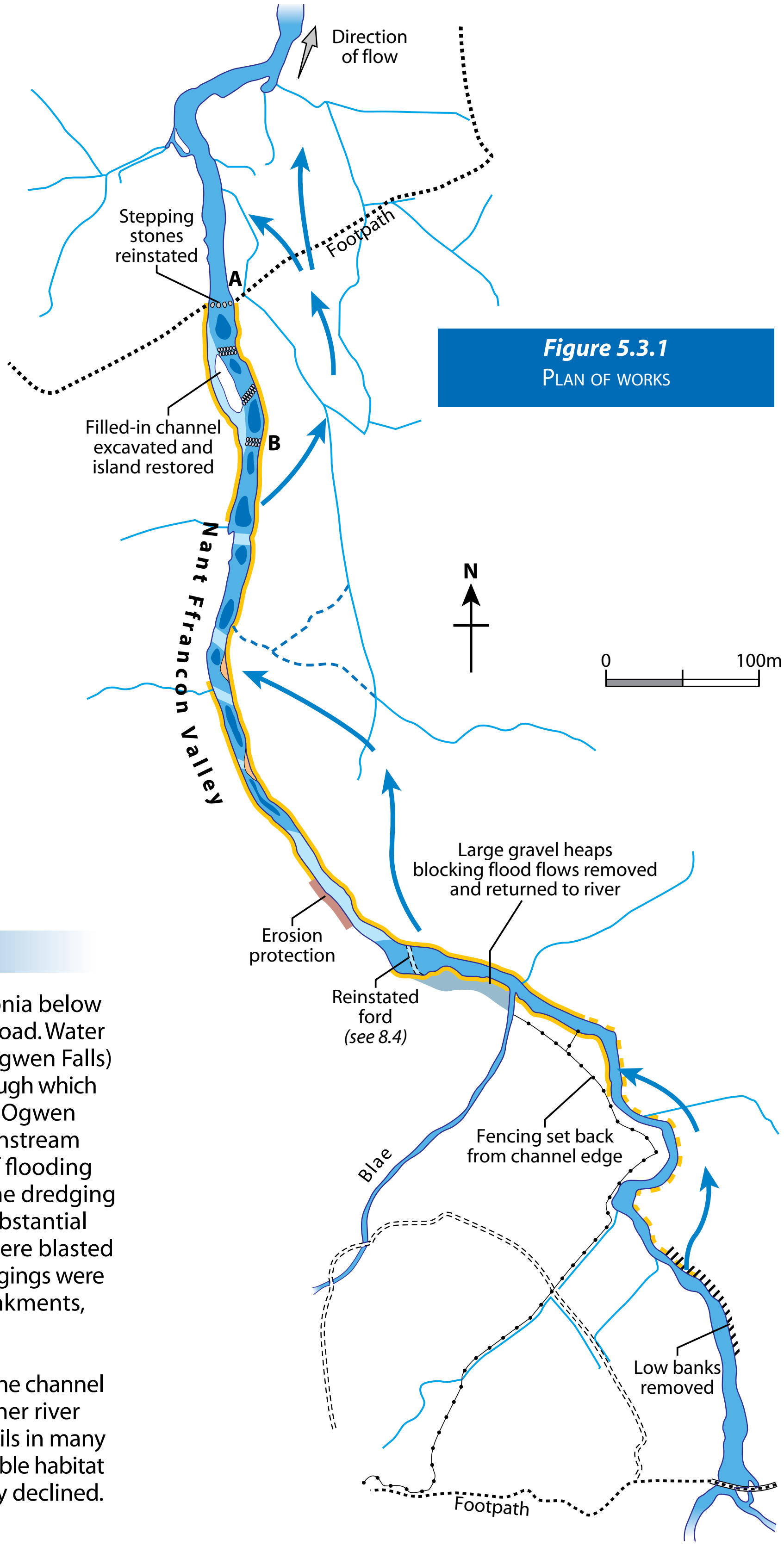


Figure 5.3.1
PLAN OF WORKS

Key

- **A – B** Boulder cascades
- Pool-riffle sequence re-installed
- Flood routes re-established
- Re-sectioned ditching
- Point bars restored
- Spoil heaps from 1969 scheme

Description

The Ogwen is in a mountainous location of Snowdonia below Llyn Ogwen (Lake Ogwen), alongside the A5 trunk road. Water from Llyn Ogwen cascades over Rhaeadr Ogwen (Ogwen Falls) down into the large glacial valley of Nant Ffrancon through which the Ogwen flows northwards. During the 1960s the Ogwen was deepened by dredging over a 4km length downstream of the waterfall. This was to reduce the frequency of flooding over the valley floor to improve livestock grazing. The dredging of the river proved to be difficult in places where substantial deposits of boulders were present. Rock outcrops were blasted at the lower limit of works at Pont Ceunant. Most dredgings were piled along the river banks forming irregular embankments, some were removed from site.

Over the succeeding 30 years the river responded to the channel deepening by flushing through virtually all of the finer river bed gravels and scouring both river bed and bank soils in many places. The reach became severely denuded of any stable habitat for flora and fauna and a once thriving salmon fishery declined. Flooding was still troublesome to farmers.

Controlling River Bed Levels, Water Levels and Flows

Deep channel and dredgings on bank at Blaen-y-Nant confluence

Restored bed levels and bank profile

An appraisal of the problem concluded that far too much floodwater was being conveyed in the enlarged channel and that it would be necessary to restore pre-works river bed profiles to correct this imbalance. Re-routing of more frequent floods over the floodplain fields would result from this, helping to sustain other desirable habitats.

Detailed designs were prepared and implemented for the upper 1km of the river, close to Rhaeadr Ogwen, after detailed consultation with the National Trust (landowners) and farmers.

Design

Stage I works (Figure. 5.3.1)
The figure shows the extent of restoration works undertaken. Figure 5.3.2 shows the longitudinal profile of the reach and highlights the extent of river bed restoration needed. The long profile was the most important design reference.

The profile of the floodplain fields clearly indicated strong post-glacial influences on the natural landforms. Downstream of chainage 0m the fields lie horizontal and comprise an old lake bed (*Figure. 5.3.2*). The fields rise steeply upstream to chainage 400m (at gradients of circa 1 in 100) but flatten to 1 in 600 upstream of this. The river dredgings along the steeply graded reach were predominantly glacial boulders and old Ordnance Survey maps indicated that an island in the river was once sustained at the same location.

It was therefore evident that a post-glacial 'dump' of large boulders at the island site was the primary control over the river bed levels and gradients, and the restoration of this feature became fundamentally important.

A boulder cascade (**A** to **B**) was designed comprising four drops of around 0.4m over a reach of 100m, giving an average gradient of 1 in 100 to parallel the natural field gradients alongside.

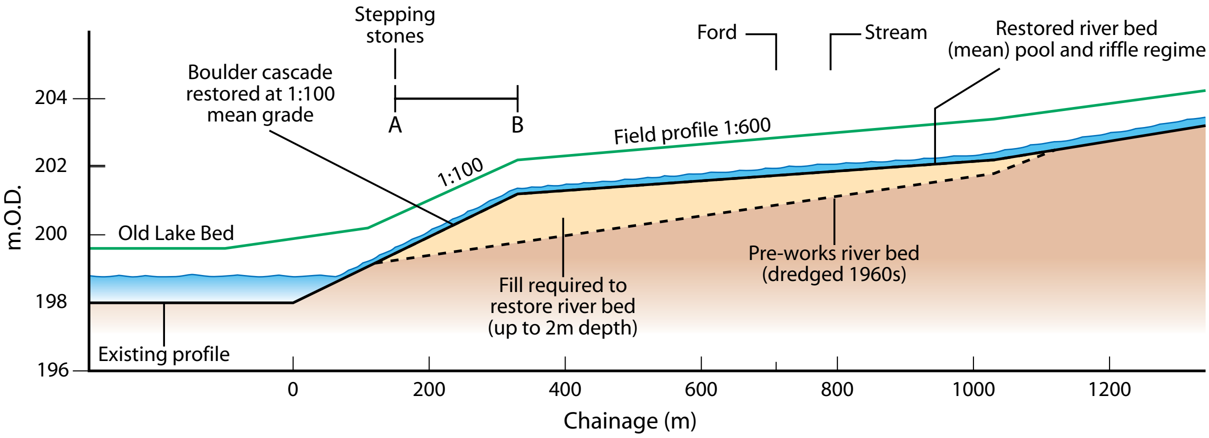
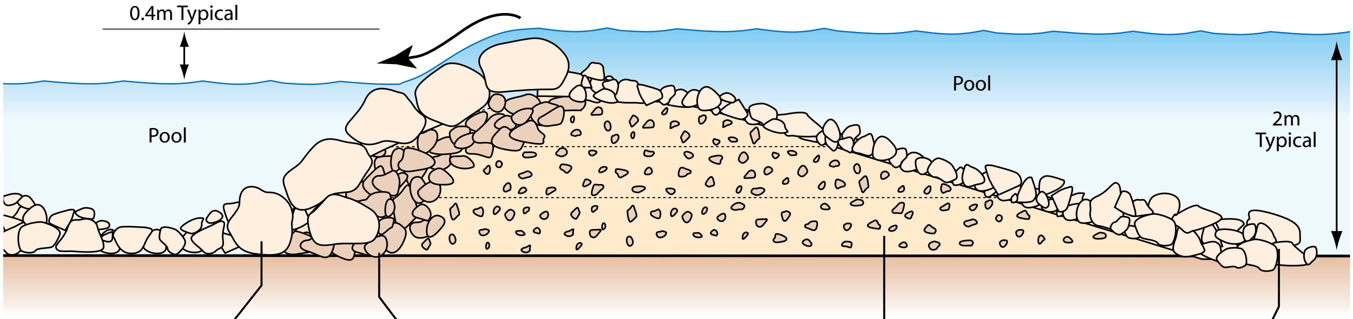


Figure 5.3.2
LONGITUDINAL PROFILE

5

Controlling River Bed Levels, Water Levels and Flows

Figure 5.3.3
Section through a cascade



Old maps were studied to determine the planform, which included the secondary channel that formed the island. Trial digs were undertaken to determine the historic bed elevations and thus the crest level of the upper cascade. It was concluded that river flow around the island was probably a seasonal feature so the bed elevation here was kept marginally above restored river water levels consistent with site investigations.

The design for each of the four elements of the cascade is detailed in Figure 5.3.3. Boulders face-up more general fill in a structured way. Construction comprised a series of 'lifts' undertaken whilst the river was flowing over the works. Each lift comprises a line of selected boulders that are backed up by a layer of mixed cobbles and gravels that are sufficiently large not to eventually wash out through the interstices between boulders. Behind this 'filter' layer a further layer of more clayey gravel fill was placed. The structure was built up in successive lifts to achieve a 'wedge' shaped profile that is sufficiently stable to impound water upstream. An armouring layer of rocks was finally dropped over the general fill. All material was carefully sorted from the original dredgings.

Restored island

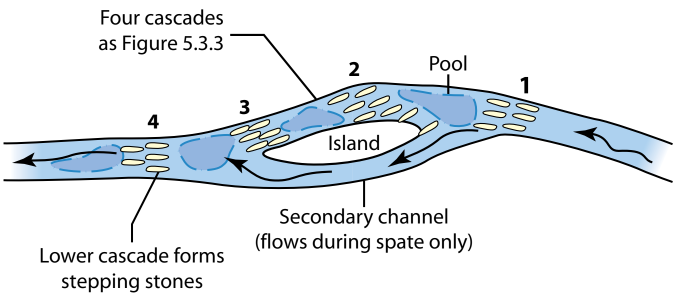
Restoration of boulder cascade, stepping stones and braided channel

These techniques were developed to suit site specific criteria and may not apply to other locations

Controlling River Bed Levels, Water Levels and Flows

Lower 'stepping stone' cascade

Figure 5.3.4
PLAN OF CASCADES



The lower cascade was the smallest of the four so was readily adapted to restore a series of large stepping stones recorded on Ordnance Survey (OS) maps. The effect of restoring the cascade was to impound the upstream reach of river to a water depth of 2m. Ideally this upper reach would have been completely backfilled to the 1 in 600 gradient shown on Figure 5.3.2. but insufficient material was available for this because dredged gravels had been removed from site.

The practical alternative to full bed restoration was to concentrate the material available into a series of individual cascades along the upstream reach. These took a similar form to the main cascade but the downstream slopes were much flatter to simulate 'riffle' characteristics rather than true cascades. The upper of these 'riffles' at chainage 700m took the form of a long diagonal ford which restored a feature recorded on old OS maps – (*see Technique 8.4 for details of this ford*).

Flatter 'riffle' cascade with upstream pool

The remaining gravels and clayey gravel dredgings on site were all utilised to enhance the riffle/pool sequence that was created in the upper reach. Some runs of gravel bed were introduced near to the ford and shoals were built on the inside of bends.

A major erosion site downstream of the ford was reinstated using the willow mattress technique featured in this manual in *Technique 4.2*. The willow used was a species found locally (grey willow type) which sprouted well initially but has subsequently been grazed by livestock, although it has held firm.

The re-routing of floods overland was investigated by a combination of hydraulic modelling and close scrutiny of precise ground topography. It was found that by removing 'embankments' of dredgings at key locations floods would follow patterns that left open routes for retreat of livestock to 'high' ground, and that traditional lambing fields were the least prone to floodings. This was a critical element of discussion with farmers.

Subsequent performance 1998 – 2001

The works have transformed the visual appearance of the river from a deeply incised, canalised waterway to a shallower, wider regime that displays many more dynamic features as water tumbles over and between boulders into long pools and runs. Severe flooding during the succeeding two winters has not caused any significant structural damage to the restoration works and flood patterns overland are as predicted.

Improvements in the biodiversity of the reach and in the salmon fishery are being monitored by the Environment Agency. Early indications of the monitoring are all positive, but of particular note is the extent to which migratory fish are utilising the river rather than simply passing through to reach the limited spawning gravels that had survived the dredging works close to Rheaedr Ogwen.

Work is now in hand to progress further stages of works building upon the confidence gained from the success of stage I. This success was particularly useful in gaining financial support for the much wider 'Wetlands for Wales' project that has since been launched.

Original Information Providers:
Bryan Jones
Elfyn Jones
RRC

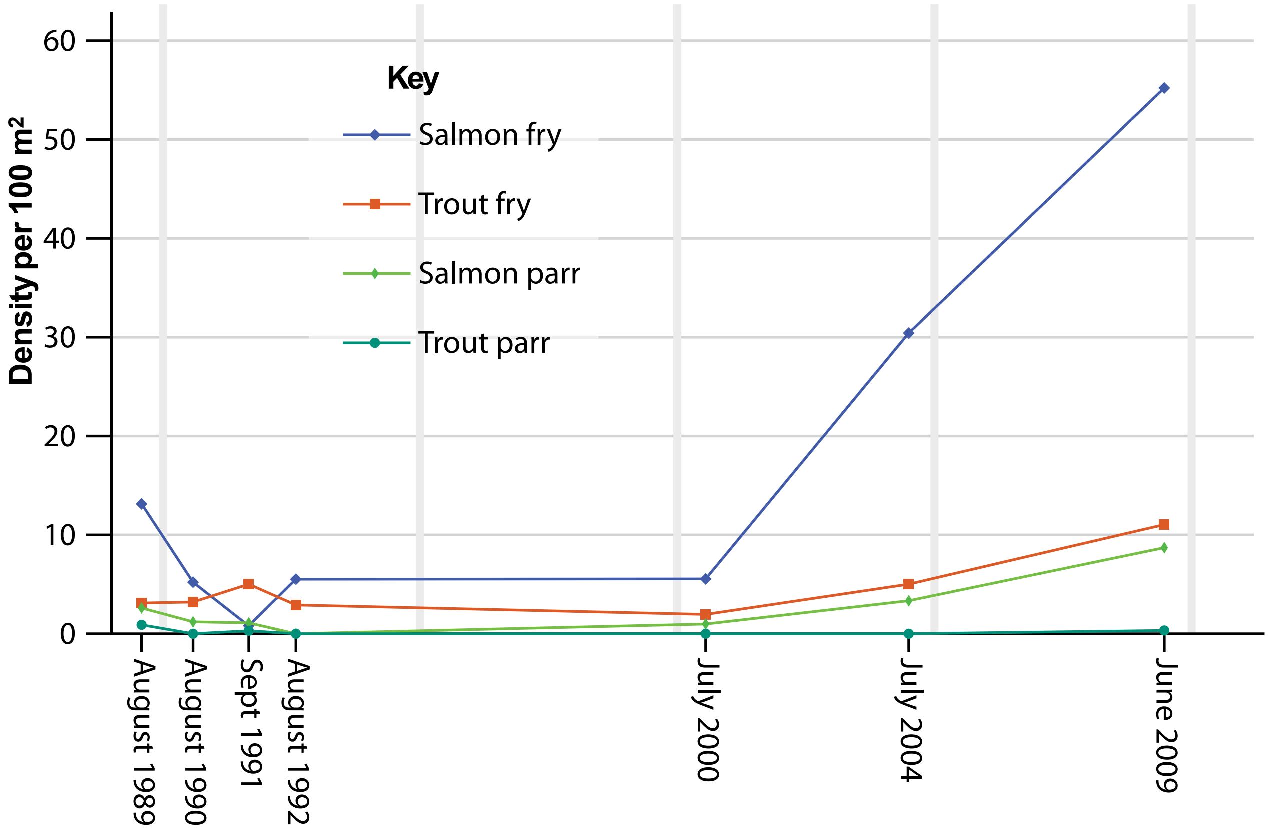
5.3 River Ogwen 2013 Update

River Ogwen	High energy, gravel
WFD Mitigation measure	Appropriate channel maintenance strategies and techniques e.g. minimise disturbance to channel bed and margins
Waterbody ID	GB110065054160
Designation	None
Project specific monitoring	Fish

No negative consequences of raising the bed level have been observed, however there were some stability issues between point A and B (*see Figure 5.3.1*). Bank slumping occurred in this location as a result of incorrect water levels in the design. Boulders were put in above this section to increase the water levels and this has reduced the slumping. These remediation works cost approximately £10,000. The longitudinal profile has remained stable with no significant morphological adjustment. In addition a greater variation in flow characteristics has been observed compared to the previously very uniform condition. Both factors indicate the success of the scheme.

Fisheries monitoring has demonstrated an improvement in salmonid recruitment. In particular a significant increase in the density of Atlantic salmon (*Salmo salar*) fry has been recorded (*see Figure 5.3.5*). Whilst continued monitoring of fish has been undertaken, no other ecological data has been surveyed in relation to this scheme. Fencing has been installed on the right bank and this has now vegetated up as a result.

Figure 5.3.5
Fisheries data showing a significant increase in the density of Salmon fry following the restoration works in 1998. No data post 2009



Restored bed levels and bank profile.
Right bank vegetated as a result of fencing.
November 2012.

Contacts

Huw Jones, Natural Resources Wales
huw.jones@naturalresourceswales.gov.uk, 01248 484076

5

Controlling River Bed Levels, Water Levels and Flows

5.4 Simulated bedrock outcrops

RIVER MARDEN

LOCATION - TOWN CENTRE AT CALNE, WILTSHIRE ST 998710
DATE OF CONSTRUCTION - 1999
LENGTH – 100m
COST – NOT AVAILABLE

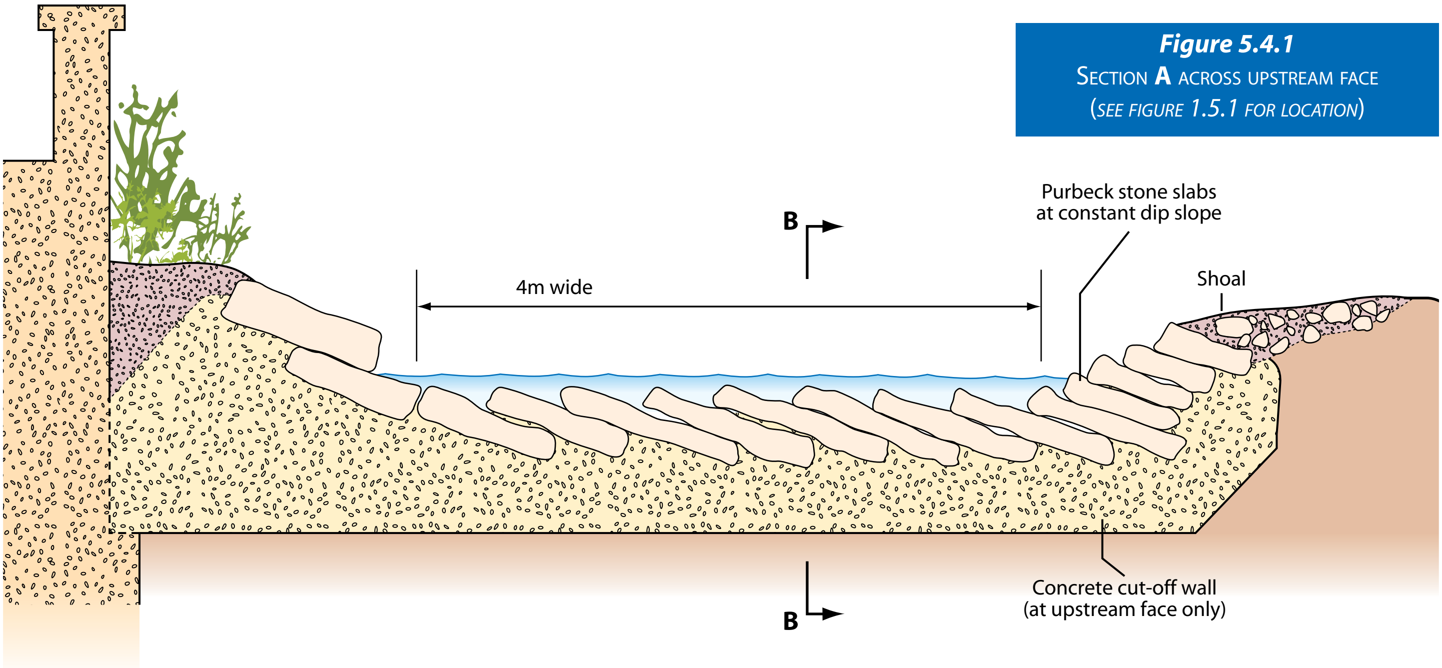


Figure 5.4.1
SECTION **A** ACROSS UPSTREAM FACE
(*SEE FIGURE 1.5.1 FOR LOCATION*)

Simulated rock outcrop with downstream pool

Description

A straight, concrete lined, section of river channel was diverted and restored in the form of a double meander. *Refer to Technique 1.5* for a plan and full description of the project.

The bed of the restored meandering channel needed to be stabilised against scour because of its steep gradient (1 in 140 mean) and the consequential high water velocities that exceed 2 metres per second during flood conditions. Two simulated rock outcrops were built into the bed to provide stability.

Design

The influence of the two rock outcrops can clearly be seen in *Figure 1.5.2* (*see Technique 1.5*); the longitudinal profile of the restored reach. The mean bed gradient is modified by projecting the outcrops above this profile and creating deeper pools both upstream and downstream of each. The purpose of the outcrops is to 'fix' the bed at two points thus checking any tendency of the river bed to scour deeper and to wash away the stone substrate introduced over the underlying clays. A varying hydraulic regime is created in keeping with the aims described for the project (*see Technique 1.5*).

The design of the rock outcrops is the subject of this technique.

Flat slabs of Purbeck limestone had been selected for a variety of purposes throughout the site and for use in the two outcrops. The slabs needed to be laid with a constant angle of dip and needed to provide a gently sloping face over which the water would tumble down to the lower level. A practical method of arranging the slabs needed to be developed; the outcome is shown in *Figures 5.4.1 and 5.4.2.*

Controlling River Bed Levels, Water Levels and Flows

5

Firstly, the upstream row of slabs was laid carefully to line and level in a bed of concrete. The concrete secures the required crest level along the tips of the slabs and also forms a cut-off wall that prevents water from flowing under the structure which can otherwise cause collapse. The angle of dip and the thickness of individual slabs determine the size of the jagged 'notches' created along the crest. Slab thickness of between 0.1m and 0.15m were found to be best suited. The slabs are extended upwards into each bank to become part of the revetments indicated on the site plan (*see Technique 1.5*).

Successive rows of stone were then laid parallel to the above, working down the slope, with the final row being stepped down to a level below any likely scour depth. These rows were all bedded in gravel reject stone to introduce flexibility to the lower structure and to improve the opportunity for plants to root between the stones, e.g. *Ranunculus*.

The random nature of stone slab size and thickness meant that a certain amount of selection was needed to achieve a reasonably tight fit where each abuts another, but this was not unduly critical. The structure is sufficiently robust and flexible to ensure security without resorting to the use of concrete or mortar in joints. Each outcrop was built in a day by three men and a machine for lifting.

Subsequent performance 1995 – 2001

The structures have achieved the main purpose of stabilising the river bed against scour without any problems. The appearance is excellent and will improve once vegetation is established between the stone slabs.

The effect of the jagged notches created by laying the stones at an angle is to generate an audible tumble of water over the whole structure. The concentration of flow down these irregular notches is likely to prove helpful to the passage of fish.

Original Information Provider:
RRC

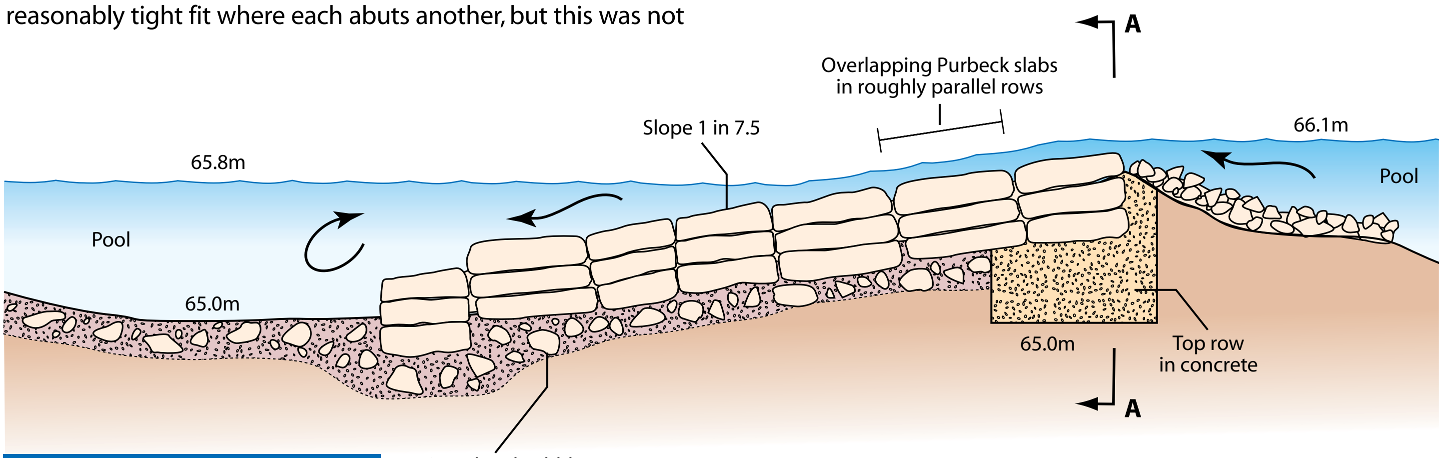


Figure 5.4.2
SECTION **B** THROUGH CENTRE LINE

The outcrops provide stability to the bed and banks as well as aesthetic interest

5

Modifying River Bed Levels, Water Levels and Flows

5.4 River Marden 2013 Update

The simulated bedrock outcrops have proved to be fully functional in stabilising the channel section and profile. They also provide considerable diversity of flow velocity and direction and have resulted in an increase in habitat diversity.

Careful selection of bed material which were in keeping with the local conservation setting has been integral to the long term success of the project. This bed material sizing and selection was guided by the Geodata Institute of Southampton University. Additionally the contractors were briefed by the consultant and landscape architecton how to lay the stones following strata lines to ensure that the installation was carried out using the best possible method.

Whilst the design drawings remained a useful reference tool it was the combination of the 'hands on' site explanation, both before and during construction, together with morphological expert judgement which proved the most beneficial. This approach ensured that the aims and objectives of the scheme were effectively communicated and the scheme was successfully implemented.

The scheme is an excellent example of urban river restoration achieved to a high standard within a conservation area.

River Marden	Medium energy, chalk
WFD Mitigation measure	Increase in-channel morphological diversity Managed realignment of flood defence Removal of hard bank reinforcement/revetment, or replacement with soft engineering solution Remove obsolete structure Set-back embankments (a type of managed retreat) Retain marginal aquatic and riparian habitats (channel alteration) Sediment management strategies (develop and revise) which could include: substrate reinstatement, sediment traps, allow natural recovery minimising maintenance, riffle construction, reduce all bar necessary management in flood risk areas Operational and structural changes to locks, sluices, weirs, beach control, etc Preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone
Waterbody ID	GB109053022060
Designation	None
Project specific monitoring	None

© NPA

River Marden riverside access – 2012

Contacts

Paul Jolliffe, Nicholas Pearson Associates (NPA)
paul.jolliffe@npaconsult.co.uk, 01225 445548

5

THE RIVER RESTORATION CENTRE
Working to restore & enhance our rivers

Channel Enhancement

5.5 Raising river bed levels

RIVER UPPER KENNET

LOCATION - RAMSBURY, WILTSHIRE, SU28317152
DATE OF CONSTRUCTION - 2ND OCTOBER – 20TH OCTOBER 2000
LENGTH – 210m
COST – £12, 000 – £14, 000 FOR CONSTRUCTION AND REINSTATEMENT WORKS ONLY†

† The cost of £14,000 did not cover design, surveys, administration and consents. The work was carried out by an experienced local river keeper and not a commercial contractor.

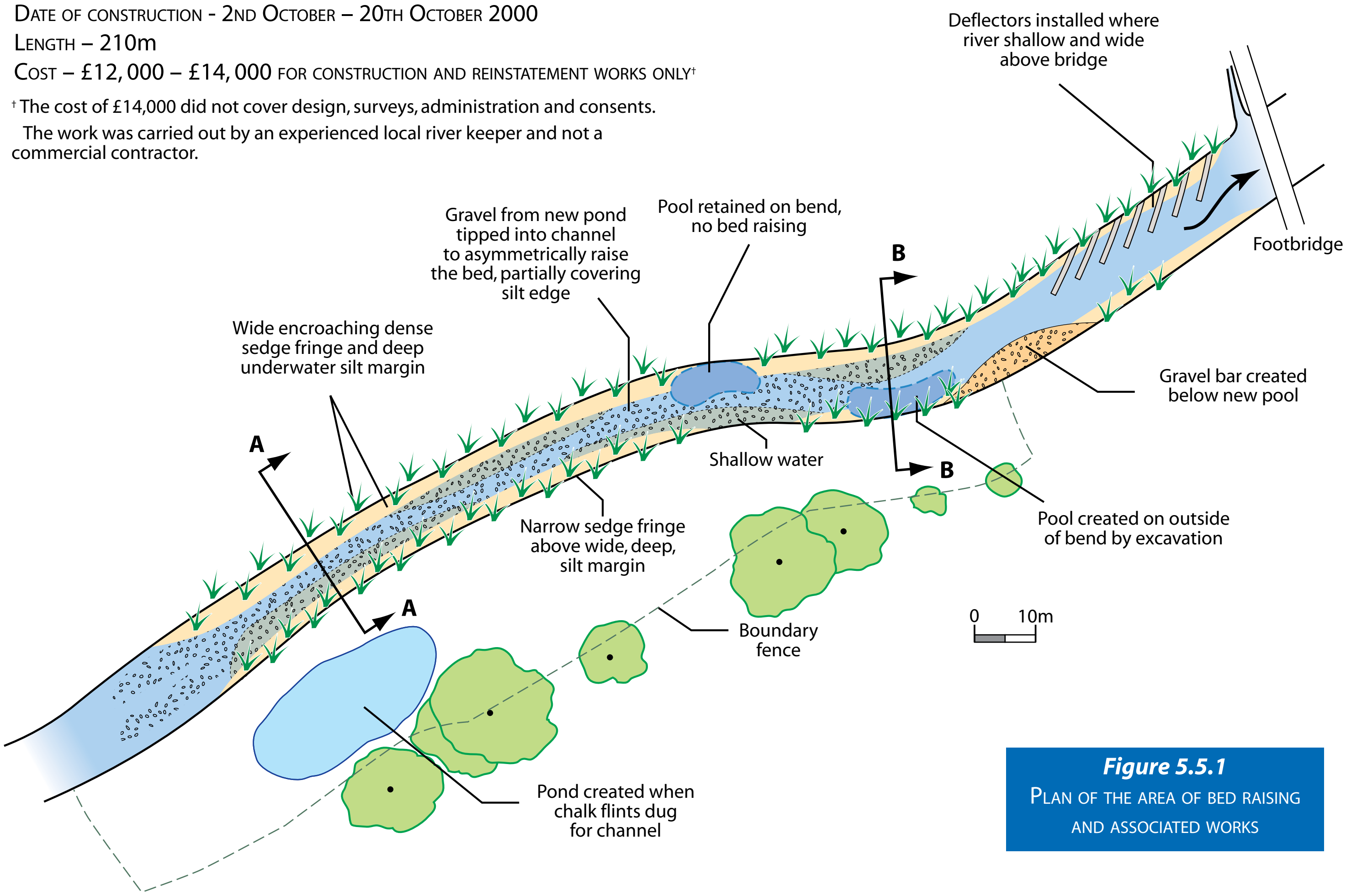


Figure 5.5.1
PLAN OF THE AREA OF BED RAISING AND ASSOCIATED WORKS

Description

The Upper River Kennet is a chalk river (Habitat Action Plan interest) under European Regulations and notified under UK legislation as a Site of Special Scientific Interest. Despite its designation, the river exhibits interesting contrasts in habitat quality. Some stretches support pristine chalk river characteristics (beds of abundant *Ranunculus* (Water-crowfoot) and clean gravels suitable for sustaining wild brown trout populations). However, past management works, ranging from mill impoundments to more recent dredging activities, have resulted in over-widened, over-deepened, sluggish stretches that are prone to silt deposition and lack gravel or crowfoot.

The site is a secondary channel of the Kennet, the probable natural course of the river prior to splitting into a leat to feed a mill. The channel had been widened and deepened many decades ago, but did not recover its natural characteristics. However, it did exhibit some signs of self-narrowing where marginal sedge had spread into the channel and accreted

Before restoration – sluggish deep water with encroaching sedge

These techniques were developed to suit site specific criteria and may not apply to other locations

significant silt shoulders. Despite this development, the channel remained too wide to sustain fast water currents and even in mid-channel the bed was subject to deep silt accretion.

A common approach to achieving self-sustaining habitats in enlarged degraded rivers is to narrow the river bed width and thereby concentrate flows within a defined low-flow channel. However, where the river also has a history of deepening, this may simply lead to the formation of a very constricted, deep course. To restore a more appropriate width to depth ratio, bed raising may also need to be considered (*see Technique 1.2 for further discussion on selecting the appropriate cross section*).

A 210m stretch upstream of Ramsbury was re-configured, primarily through raising the bed. The channel bed was raised asymmetrically to ensure that there was a narrow low-flow course and shallow edges to encourage marginal vegetation encroachment.

As the Kennet is a chalk stream the predominant flow is derived from groundwater, so major fluctuations in water level and velocity are much less than in rivers fed primarily by surface water. Consequently, a more flexible approach can be adopted for the location of gravel materials to raise the bed, as there is less risk of subsequent mass re-distribution.

Detailed flow modelling was a key element to determine the effects of the works under low-flow and flood conditions, for land drainage consent and to allay potential landowner concerns.

Design

Throughout, bed levels were raised to leave a maximum water depth of 0.5m at low water level (based on the Q_{90} discharge level - the level at which flows are exceeded 90% of the time). At this discharge, the margins of the channel would have a depth of <0.1m. The Q_{90} flow was indicative; the desire was to ensure that under very low flows the bed-width would be constricted to sustain at least some clean gravel at all times. The maximum depth of 0.5m at Q_{90} was based on a target reference width and depth.

Work was scheduled to commence in early October when river flows are usually at an annual low, approximating to Q_{90}. Prior to undertaking work, stakes were placed in the river to mark this level as a guide to the contractor during the gravel placement process. This was especially important since water levels would change if silt entrapment measures had needed to be installed downstream (on standby but not needed).

Gravel placement may influence or be influenced by fluctuating water levels

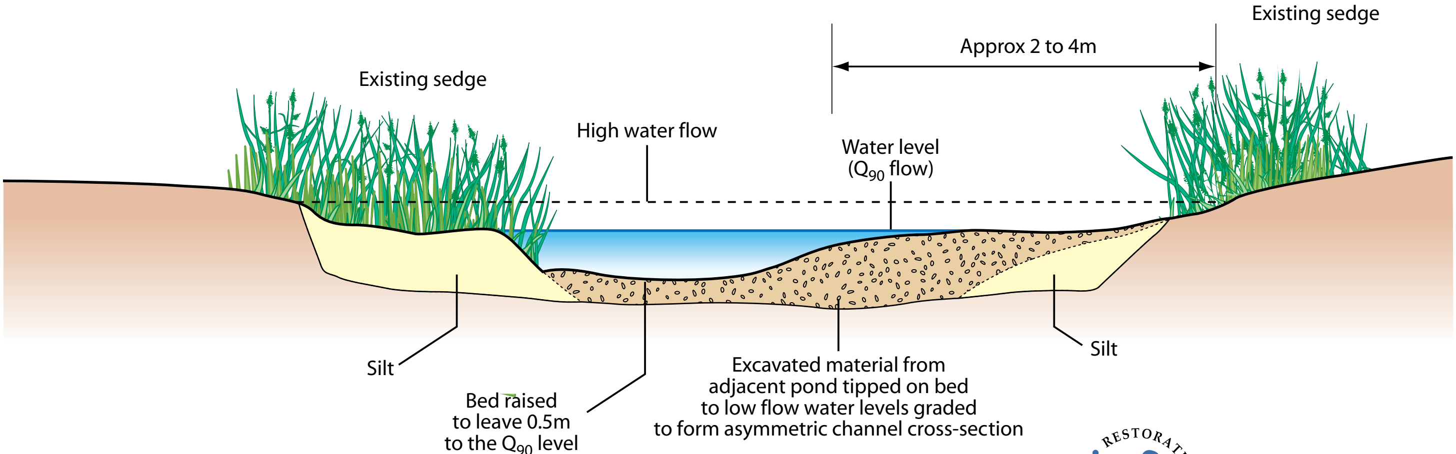
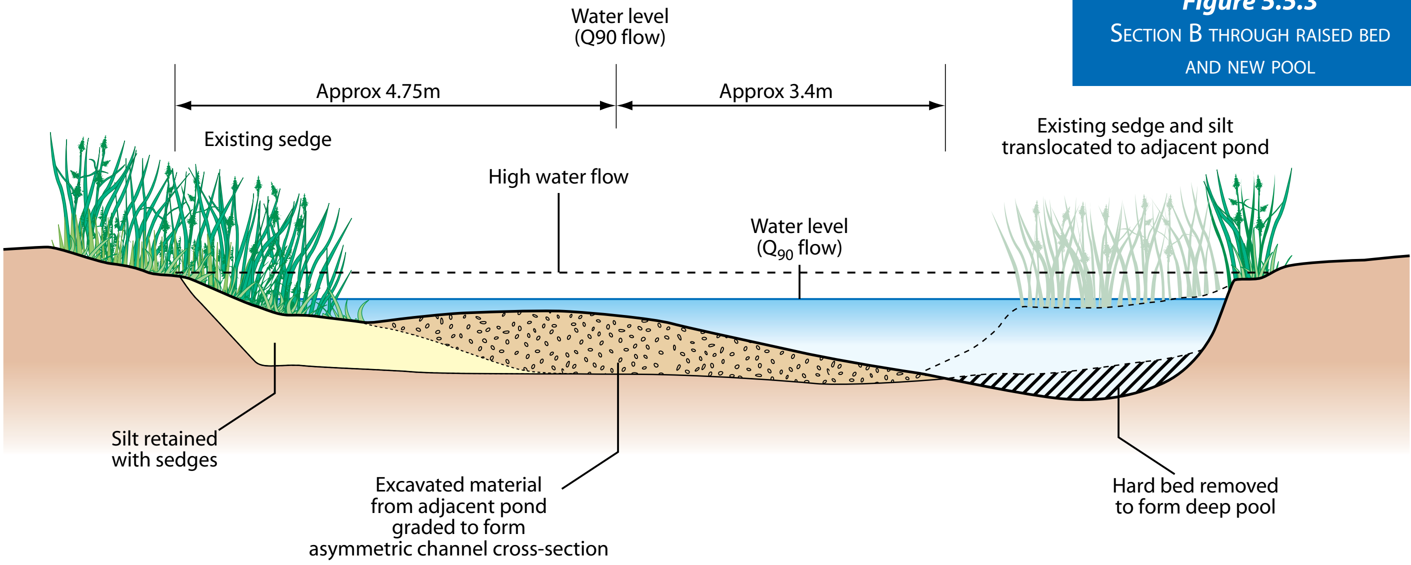


Figure 5.5.2
SECTION A THROUGH RAISED BED AND MARGINAL SHOAL

5

Channel Enhancement

Figure 5.5.3
SECTION B THROUGH RAISED BED AND NEW POOL



The material used to shallow the channel depth was chalky and gravel flints. Where possible it is advisable to use material from the immediate area to reflect the type of bed that would have been present under natural conditions. Here the gravel fill was excavated from the floodplain by the creation of an adjacent pond on the right bank. The suitability of the material was checked beforehand by the inspection of machine-excavated trial pits. Infill material was predominantly a mixture of gravels and flints varying in size from 0.02m to 0.01m, with <5% coarse sand and minimal silt. A few larger flints were also present.

Flinty gravel used to narrow and raise the river bed

Topsoil and overburden were first stripped and stored before the gravel was dug out and transported by dumpers to the river bank. Representative cross sections were produced as references for the placement of material so that a degree of sinuosity was created under low flow.

The contractor followed the drawings and had the advantages of both knowing the river stretch well and having been involved in the final design. Regular on-site supervision was provided by an experienced team member.

The works length can be divided into three sections.

A. *Straight with marginal sedge on both sides*
   Cross section A (*Figure 5.5.2*) is a typical section across this reach. Silt colonised by sedge represents up to half of the total channel width.

New pond with early growth, showing the gravelly nature of the floodplain material

Gravel has been used to shallow and narrow the remaining open water channel by up to a half, with the shallower margins finishing just below the Q_{90} level. The remaining low flow channel is raised to within 0.5m of the Q_{90} surface.

These techniques were developed to suit site specific criteria and may not apply to other locations

A few months after completion, the raised bed evident

Gravel has been used to shallow and narrow the remaining open water channel by up to a half, with the shallower margins finishing just below the Q_{90} level. The remaining low flow channel is raised to within 0.5m of the Q_{90} surface.

B. *'S' bend with some marginal sedge*
The outsides of each bend are enhanced with a pool, the first by retaining existing very deep water, the second by dredging the silty sedge margin (material then used to provide marginal substrate in the new pond). Cross section B (*Figure 5.5.3*) shows the asymmetric section with fill material for this latter scenario. To ensure the pools are sustained by scour, the inside of bends had gravel deposited on them to simulate natural point bars.

C. *Straight, wide and shallow section*
After exiting the bends the channel widens. Significant narrowing is expected to naturally develop as sedge encroaches from the bank and entraps newly accreted silt. This narrowing process has been enhanced by the addition of deflectors (up to 5m in length and facing upstream), installed to help to deflect flow into mid-channel and accelerate silt deposition between the deflectors (*see Technique 3.1 for further discussion of deflectors*). Here deflectors were chosen due to the shallower and wider nature of the channel, and the limited access requiring hand installation.

The associated pond, from which material was won, was re-profiled to give shallow margins and bank slopes. It was planted with emergents excavated from the channel, and additional native wetland species.

Subsequent performance 2000 – 2001

Work was only completed in October 2000, prior to very high flows. Evidence after one year indicates that the reduction in channel size has not resulted in any bank erosion, and that the gravel has stayed predominantly in place. Minor local changes in gravel composition have occurred, with less fines in the low-flow channel.

The re-configured channel has restored typical chalk stream habitat, establishing a self-cleansing gravel bed suitable for *Ranunculus* to establish and for wild brown trout spawning.

During subsequent high flows the full (circa 10m) channel width will be occupied by water, yet under Q_{90} flows the channel width will narrow in most places to less than half of this, maintaining a cleaning velocity to keep the new gravels free of silt.

Original Information Providers:
Nick Lutt
Mike Crafer
Kevin Patrick

5

Modifying River Bed Levels, Water Levels and Flows

5.5 River Upper Kennet 2013 Update

River Upper Kennet	Medium energy, chalk
WFD Mitigation measure	Restore/Increase in-channel morphological diversity Preserve and, where possible, restore historic aquatic habitats Sediment management strategies (develop and revise) which could include: substrate reinstatement, sediment traps, allow natural recovery minimising maintenance, riffle construction, reduce all bar necessary management in flood risk areas
Waterbody ID	GB106039023172
Designation	SSSI
Project specific monitoring	None

Improved management of the sluice has helped to control water levels, but has not been sufficient to enable the river to scour all silt from the bed. It did provide sufficient added energy upstream to enable narrowing and edge habitat enhancements to be far more effective. In some locations the use of post and wire deflectors did not work well. The wire rotted away after two to three years, leaving a series of posts in lines and now most are both ineffectual and unsightly. However in other locations they are invisible where sedge encroached rapidly from the edge.

The river narrowing and bank stabilisation aspects of the scheme have created much more natural channel profiles. Areas of faster flowing water have developed in the main channel with local backwaters at the margins. Marginal vegetation has developed creating additional habitat.

Bed-raising has improved in-channel character and reconnection to the floodplain.

© Alconbury Environmental

Effective narrowing of the channel and asymmetric shallowing of the bed has occurred following restoration – 2011

Contacts

Nigel Holmes, Alconbury Environmental Consultants
n.holmes3@btinternet.com, 01487 822020

Reference material – Click here

These techniques were developed to suit site specific criteria and may not apply to other locations

5

Modifying River Bed Levels, Water Levels and Flows

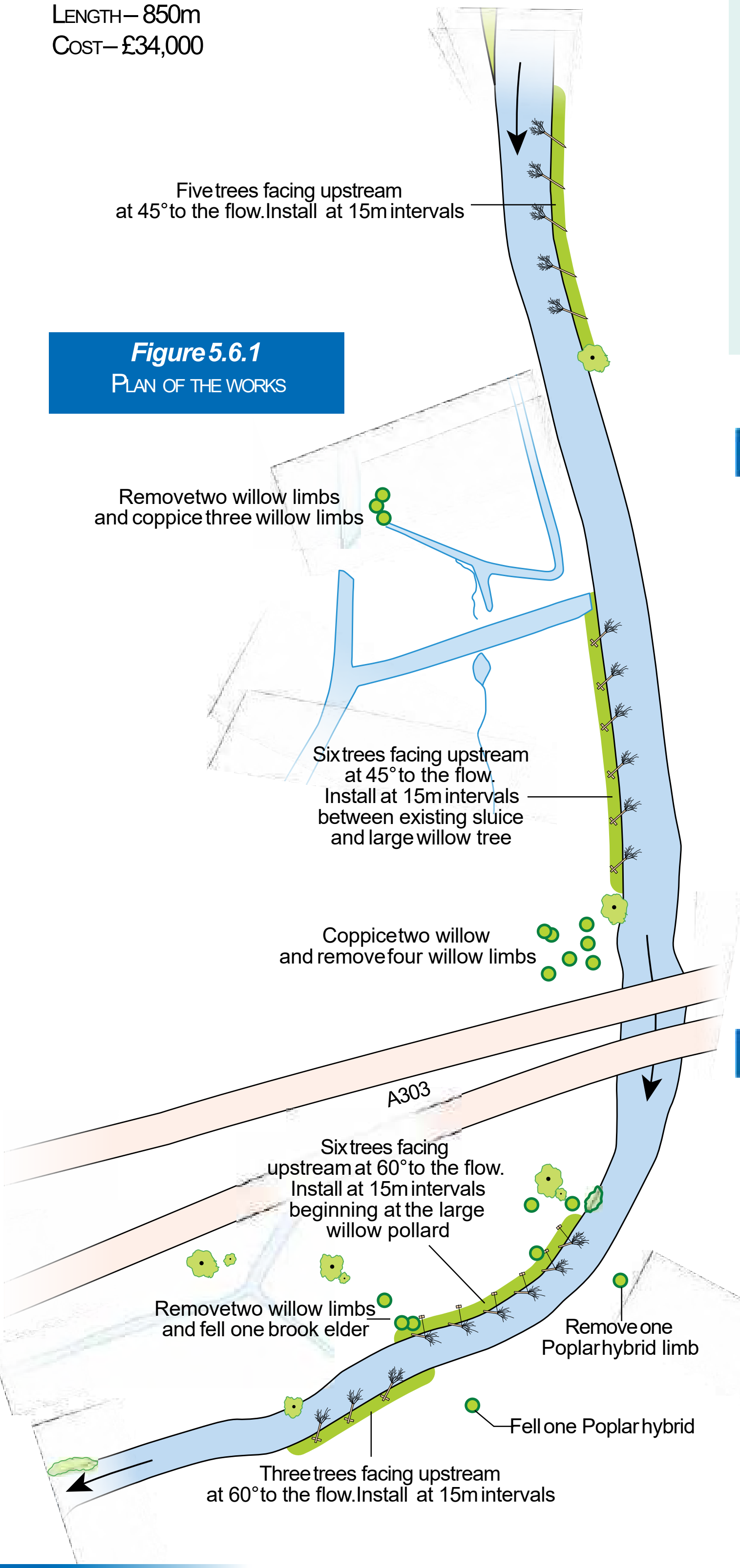
5.6 Fixing whole trees into the river bank for flow diversity

River Avon

Location - Amesbury, Wiltshire. SU15834257
Date of construction - September 12th – mid October 2008
Length – 850m
Cost – £34,000

River Avon	Low energy, chalk
WFD Mitigation measure	Restore/increase in-channel morphological diversity Preserve and, where possible, restore historic aquatic habitats
Waterbody ID	GB108043022350
Designation	SAC, SPA, SSSI
Project specific monitoring	Fixed point photography, habitat mapping, RRC rapid assessment method

Figure 5.6.1
Plan of the works



Description

The River Avon STREAMEULIFE project aimed to reinstate physical form and diversity, creating dynamic chalk stream habitats that are sustained by the river's natural flow regime. This particular technique was to introduce woody material (whole trees) to create a diversity of morphology and flow, particularly for SAC species such as bullhead (*Cottus gobio*), brook lamprey (*Lampetra planeri*), Atlantic salmon (*Salmo salar*) parr and the characteristic water crowfoot (*Ranunculus*) community.

As a result of historic dredging and siltation there was a lack of suitable gravel substrate for migratory salmonids to spawn on and there was a need for a shift from a uniform bed with silt-dominated substrate, to gravel and cobbles.

Though the site was within a well wooded corridor, the river had little in the way of bankside trees and the resultant lack of woody material input, along with historic dredging, had contributed to the lack of physical habitat diversity in the river.

Design

Large whole trees were installed on the left and right bank either side of A303 over a disrtance of 850m (*see Figure 5.6.1*).

Trees large enough to extend approximately 7m into the channel were used to reduce the free flowing width by 35%–50%. This reduction in high flow conveyance was deemed to be acceptable at this site following hydraulic modelling. The trees were placed at 45 – 60 degree angles, facing upstream to deflect overtopping flows towards the centre of the channel.

Modifying River Bed Levels, Water Levels and Flows

Three different fixing techniques were used. Initially a crucifix design was used but, where the bank was very soft, an alternative anchoring technique was utilised. Where there were water vole (*Arvicola amphibius*) colonies, or the riverside path had to be kept intact, a staking technique was used to avoid cutting a slot and disturbing the bank or path.

Crucifix Method

Firstly a cross-shaped trench was excavated. Then the tree to be placed in the stream was attached to another shorter section of timber using a mortise and tenon joint and high tensile wire (*see Photograph 1*), forming a crucifix shape. Finally the completed structure was lifted, using a long reach excavator, placed into the excavated trench (*see Photograph 2*) and then backfilled.

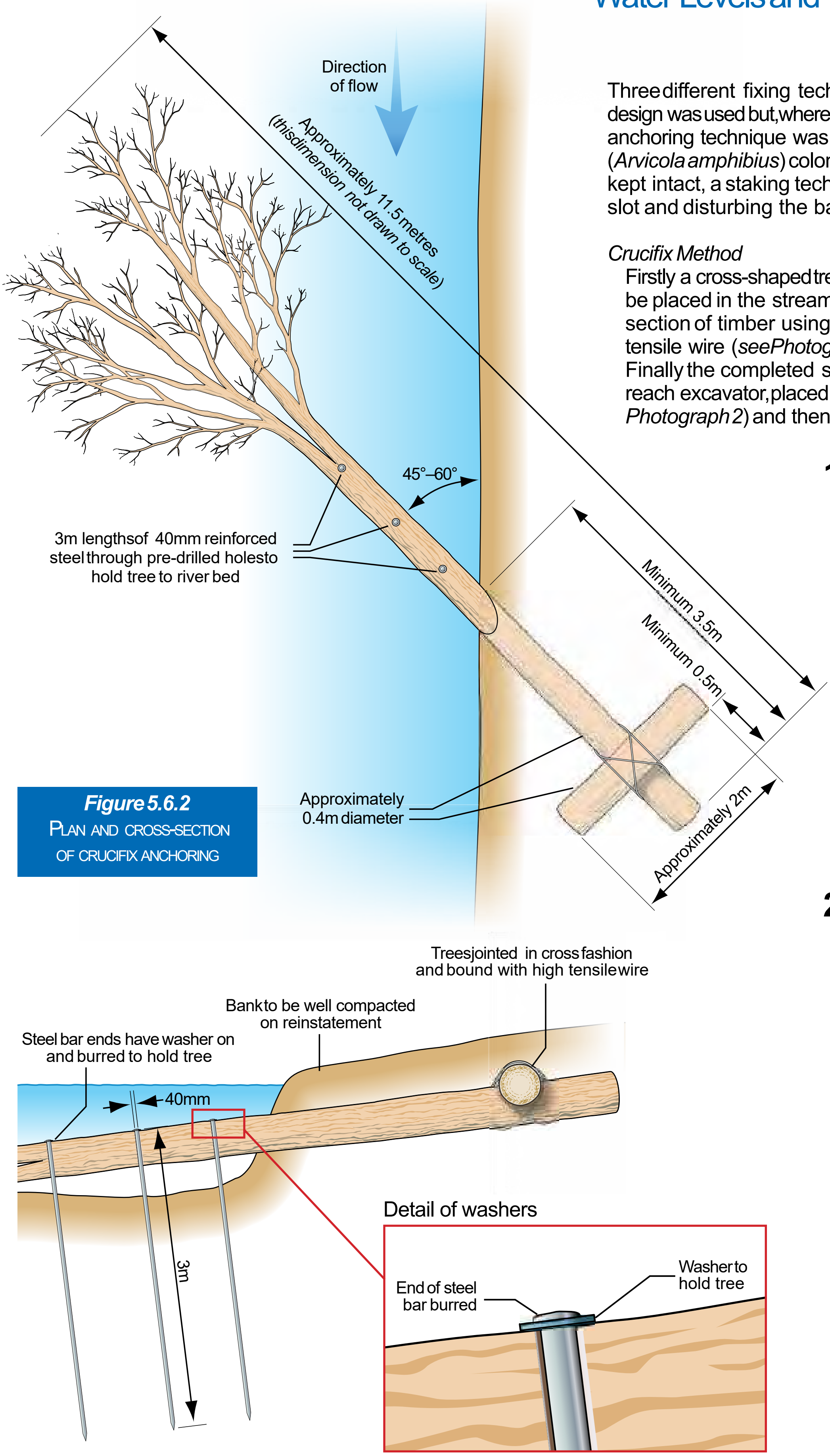


Figure 5.6.2
PLAN AND CROSS-SECTION OF CRUCIFIX ANCHORING

1

© Natural England

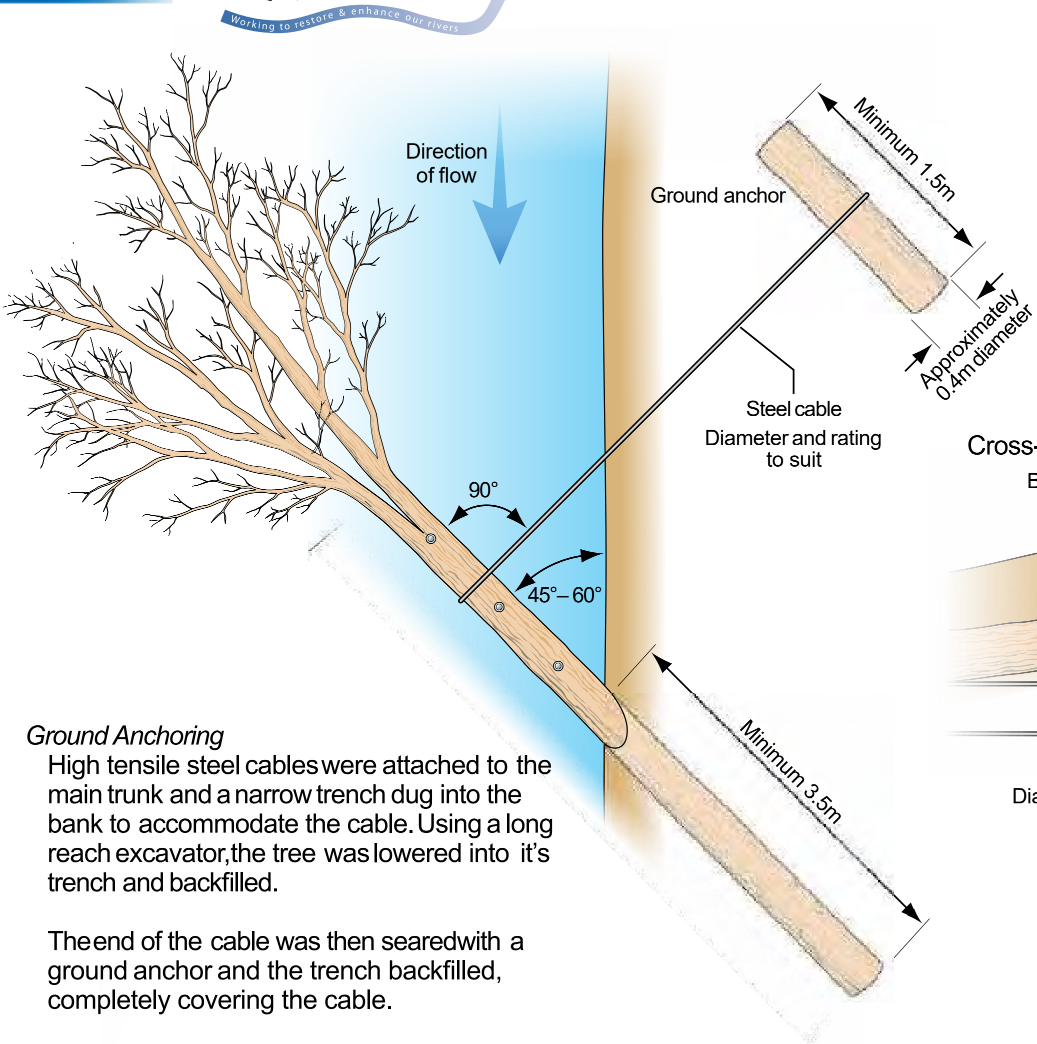
2

© Natural England

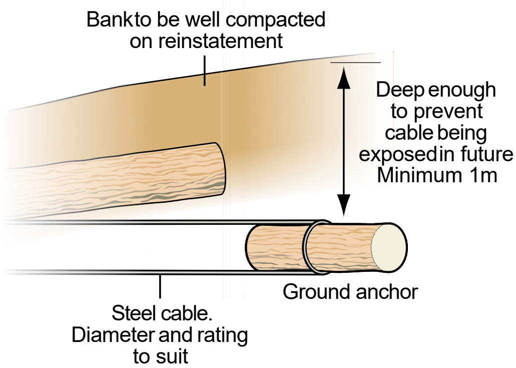
THE RIVER RESTORATION CENTRE
Working to restore & enhance our rivers

Modifying River Bed Levels, Water Levels and Flows

Figure 5.6.3
PLAN AND CROSS-SECTION OF GROUND ANCHORING



Cross-section of ground anchor



Ground Anchoring

High tensile steel cables were attached to the main trunk and a narrow trench dug into the bank to accommodate the cable. Using a long reach excavator, the tree was lowered into it's trench and backfilled.

The end of the cable was then seared with a ground anchor and the trench backfilled, completely covering the cable.

Staking

This was used where the river banks were soft. The end of the tree trunk to be used was sharpened and then pulled horizontally into the bank (using the long reach excavator), embeded by approximately 2 metres.

In all cases the trees were pinned to the river bed with 3m long, 40mm diameter reinforced steel bars to ensure that they did not move or pull free from the bank. Holes were drilled into the trunk before it was placed in the river. The structure was then pinned into place by the excavator bucket, pushing the bars through the pre-drilled holes into the river bed to a depth of 2m. The steel bars were a requirement to get flood defence consent for the work. However, understanding of how much achoring is required has improved.

PHOTOGRAPH OF STAKING METHOD

© Natural England

The sharpened end of tree trunks being pushed 2m horizontally into the bank using a long reach excavator – 2008

These techniques were developed to suit site specific criteria and may not apply to other locations

Subsequent performance

Reach-scale mapping of all sites was undertaken including fluvial audit, physical biotope mapping, river corridor survey and repeat photography. Results showed that the installation of woody material has created greater flow variability. There are now areas of marginal dead water and faster flowing water creating more varied habitat. Sediment accumulations are now concentrated at the channel margins rather than on the channel bed along the main flow path. This is keeping the gravel bed clean for spawning habitat and provides silty marginal habitat for brook lamprey.

The dominant vegetation remains similar to that observed prior to restoration. Additional species were observed in 2009, including water crowfoot (*Ranunculus spp.*), watercress (*Cruciferae spp.*) and water mint (*Mentha aquatica*). The low gradient and deep channel remains a limitation on the extent and diversity of macrophyte growth within the channel.

The aquatic plants are annually managed by cutting throughout the River Avon catchment. The fishing club initially reported problems for their weed cutting boat, so in some reaches 1.5m to 2m was cut off the outer ends of the submerged trees. In other places they have been trimmed where they protruded above water level to reduce snagging of fishing lines and the cut weed.

Wide slow flowing channel lacking flow variability – August 2008

Trees installed on the right bank. Submerged with branches just protruding out of the water – January 2009

One year later, wood deflectors are collecting rafts of weed and providing shade, cover and habitat. Silt has been deposited between the deflectors.

Marginal plants are now starting to establish in the silt narrowing the channel – July 2009

Contacts

Jenny Wheeldon, Environment Agency/Natural England Adviser, formerly Avon STREAM Project manager
Jenny.Wheeldon@naturalengland.org.uk, 0845 6003078

Reference material – Click here

5

Modifying River Bed Levels, Water Levels and Flows

5.7 Felling and placing trees for habitat and flow diversity

RIVER BURE

LOCATION - BLICKLING ESTATE, NORFOLK. TG161301

DATE OF CONSTRUCTION - PHASE 1 - NOV. 2008
- PHASE 2 - NOV. 2010

LENGTH – 300m

COST – APPROX. £5,000 (INCLUDING STAFF WAGES, CHAINSAW FUEL AND VOLUNTEER EXPENSES)

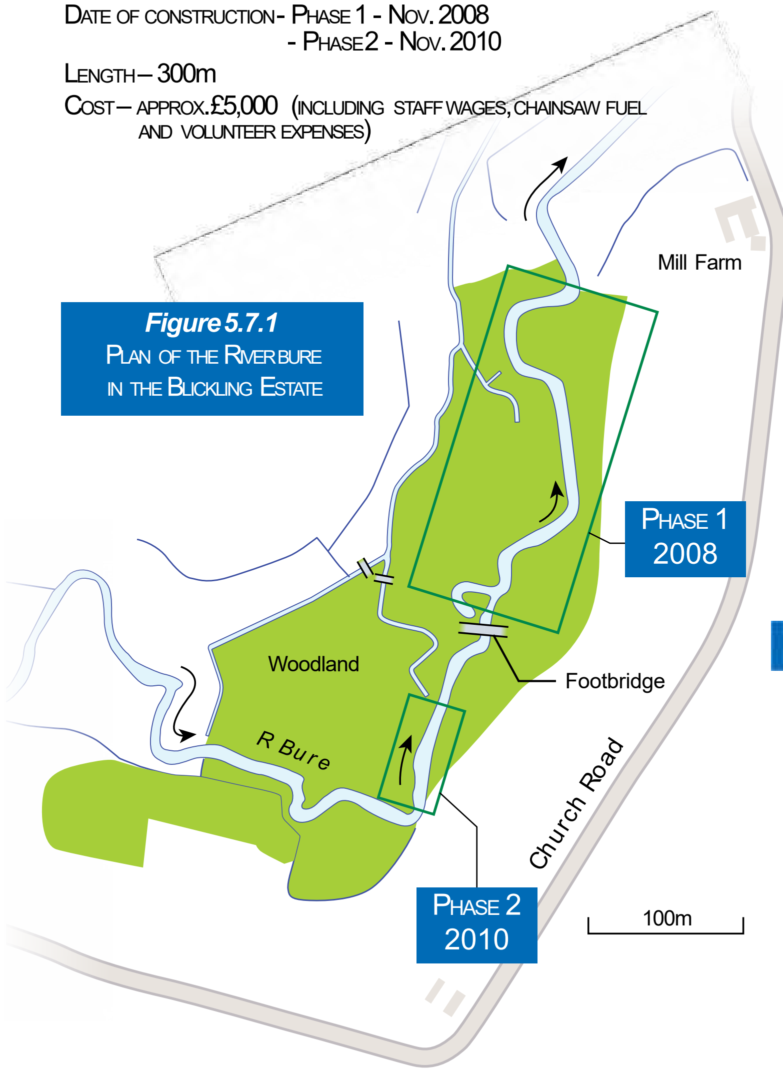


Figure 5.7.1
PLAN OF THE RIVER BURE IN THE BLICKLING ESTATE

River Bure	Low energy, gravel
WFD Mitigation measure	Increase in-channel morphological diversity Preserve and, where possible, restore historic aquatic habitats
Waterbody ID	GB108049007170
Designation	SAC, SPA, SSSI
Project specific monitoring	Fish, macroinvertebrates, plants, sediment transport and distribution, flow velocity, substrate characteristics,

Description

The aim of the project was to re-establish the natural river processes interrupted by past management and to provide morphological, hydrological and habitat diversity. The project was completed in two phases. The project was low cost, used on-site materials and had minimal impact on the riparian zone.

The River Bure at Blickling National Trust Estate had been historically altered for milling and, more recently, meanders were cut off at the end of the 19th century. The local channel gradient is moderate (between 1 in 300 and 1 in 800) and the river has a gravel bed with a significant overlying silt layer in an over-widened channel. The river is flashy, prone to high flows during and after heavy rain especially in the winter. The riparian and adjacent land is well wooded, with alder and willow carr and remnants of ancient woodland.

Woody material (entire trees) was felled into the channel in as natural a form as possible to increase flow variability. It was envisaged that the trees would either create scour or trap mobilised silt and sediment. Marginal deposition would eventually vegetate and stabilise creating a faster flowing, narrower channel with clean gravel substrate.

Design

There was no formal desk-based design process for this technique beyond the broader planning of the improvement of the river reach. Rather, an intuitive approach was used in the field, as near as possible forming natural features with natural materials.

Flow diversity was achieved by felling whole trees in to the river channel and leaving them in situ as much as possible. Generally the selected trees were those which were leaning over the water already which were likely to eventually fall into the river. An application for Flood Defence Consent was submitted to the Enviroment Agency detailing this approach. The proposed works were accepted as in this particular location it was determined that there was no increase in flood risk to adjacent properties.

As a channel had to be kept open, some repositioning was made with the use of a small hand winch. Often a second felled tree pinned down one already lying in the water, so it was not always necessary to stake the trees to keep them in place. It was necessary to stake some of the trees. 1.5m peeled and pointed stakes were used to wedge the butt end of the felled trees until the tree became waterlogged. It was envisaged that a certain amount of movement of trees would occur in flood events.

The site was intended to remain dynamic adjusting to natural processes. The remaining riparian tree cover will continue to contribute fresh woody material. Due to the relatively low cost, materials used and support of the landowner it would be fairly simple to move the trees if problems arose, so there was scope to be bold with the works.

Modifying River Bed Levels, Water Levels and Flows

1 Select trees which are already leaning over the water and are likely to eventually fall in the river.

2 Fell them so that they remain attached to the stump (often referred to as 'laying' or 'hinging') or so that part of the trunk stays on the bank. Allow branches to penetrate the river bed to increase the stability of the tree and to prevent the tree from rolling or being mobilised by the flow.

3 Modify the position if necessary to maintain an open channel if the felled tree blocks the flow. If absolutely necessary, prevent movement with a 1.5m stake.

Once the wood is waterlogged it will become less prone to movement at low to medium flow events. However, significant flood events may still cause major re-working and movement. Similar schemes elsewhere have used tethering to prevent downstream movement of placed woody material.

4 Fell more than one tree on top of each other to provide a greater mass to the structure and give a dense web of branches.

© Gemma Harvey (QMUL)

These techniques were developed to suit site specific criteria and may not apply to other locations

5

Modifying River Bed Levels, Water Levels and Flows

Subsequent performance

Up to 2013 the technique has had no negative outcomes and no adaptive management has been necessary. There is a possibility that some of the material may move so the site is visited by the National Trust countryside staff a few times a year, especially after high flows, to see if there are any issues. So far no significant movement has occurred, despite significant flooding which occurred in March 2013.

There is scouring of fine sediment and exposure of gravel in areas where the structures have concentrated flow. The movement of sediment and the colonisation by marginal plant species around the wood structures can be seen. These observations appear to support effective narrowing of the over-widened channel and an increase in physical habitat complexity.

This technique has caused a local change in attitude to in-channel woody material in that requests from the fishing club to remove trees that have fallen in to the river have all but ceased. Instead the request is to modify their position so as not to block the river. This also has a benefit through reduced management costs from not having to use large machinery to lift or winch trees out of the river.

Pre-works monitoring was only undertaken for the second phase (2010) and consisted of flow velocity, substrate characteristics, fine sediment distribution, bed topography and aquatic plants. An upstream wood-free section has also been similarly monitored. Repeat surveys have been undertaken in 2010, 2011 and 2013. Results will be published at a later date as part of a PhD thesis. The project team has committed to continuing the survey work to enable critical evaluation of the works.

© Dave Brady

Before – Over widened silt laden channel

© Dave Brady

After – With narrowed channel and vegetated berms where silt has built up downstream of the felled trees – 2012

Contacts

Dave Brady, National Trust
dave.brady@nationaltrust.org.uk, 01263 731994

Gemma Harvey, Queen Mary University London
g.l.harvey@qmul.ac.uk, 020 7882 2722

Murray Thompson, National History Museum
murray.s.thompson@gmail.com

Carl Sayer, University College London
c.sayer@ucl.ac.uk, 020 7679 0517

Reference material – Click here

These techniques were developed to suit site specific criteria and may not apply to other locations

5

Modifying River Bed Levels, Water Levels and Flows

5.8 Gravel reworking to restore a low flow channel

River Darent
Location - Hawley Manor, Kent, TQ55207213
Date of construction - September 2005
Length – Approx. 250m
Cost – £1,800

River Darent	Low energy, chalk
WFD Mitigation measure	Increase in-channel morphological diversity Preserve and restore historic aquatic habitats Sediment management strategies (develop and revise) which could include: Substrate reinstatement, Sediment traps, Allow natural recovery minimising maintenance, Riffle construction, Reduce all bar necessary management in flood risk areas
Waterbody ID	GB106040024222
Designation	None
Project specific monitoring	Invertebrates, vegetation

© Alconbury Environmental

Over-widened channel prone to low flows. Little or no marginal or submerged vegetation – July 2005

Description

The River Darent in the Dartford area has been heavily modified over many years, including changes to channel planform, the implementation of land drainage schemes and abstraction, leading to an over widened channel. Prior to restoration this section of river, two miles upstream of Dartford, was very uniform with a shallow gradient. The natural substrate is dominated by gravel but had become overlain by silt. Flow and habitat diversity was limited with negative impacts on fish and macroinvertebrate communities.

The aim of the project was to demonstrate that the processes that sustain a healthy chalk stream could be restored and the habitat protected during drought periods. This was to be achieved in a cost-effective way by re-working the in-channel gravels to form a low flow channel. The restoration work contributed to Chalk Rivers Biodiversity Action Plan (BAP) targets and complemented the implementation of the Darent Action Plan (1992).

Before (top), during (middle) and immediately after (bottom). The low-flow channel now occupies approximately 50% of the previous bed, supporting an improvement in flow depth and velocity – September 2005

© Alconbury Environmental

Modifying River Bed Levels, Water Levels and Flows

Figure 5.8.1
SEQUENCE OF GRAVEL REDISTRIBUTION AND PLANTING

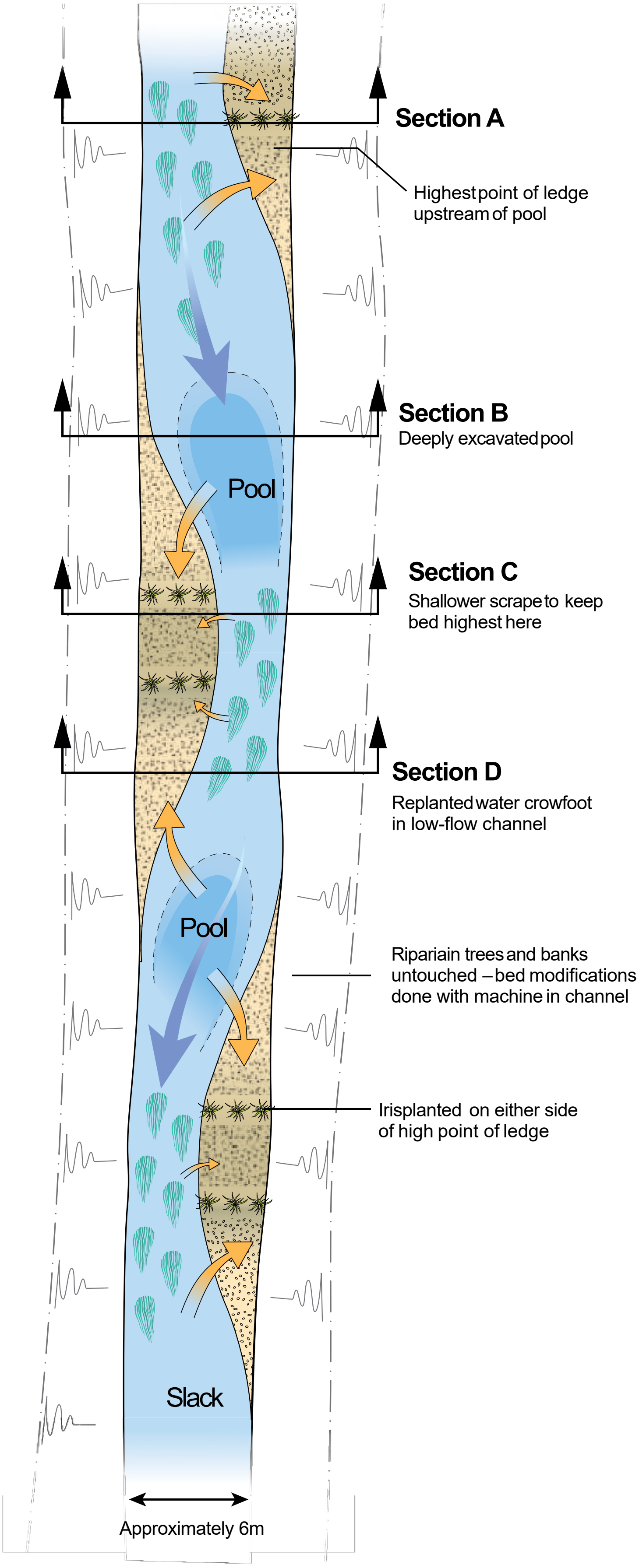
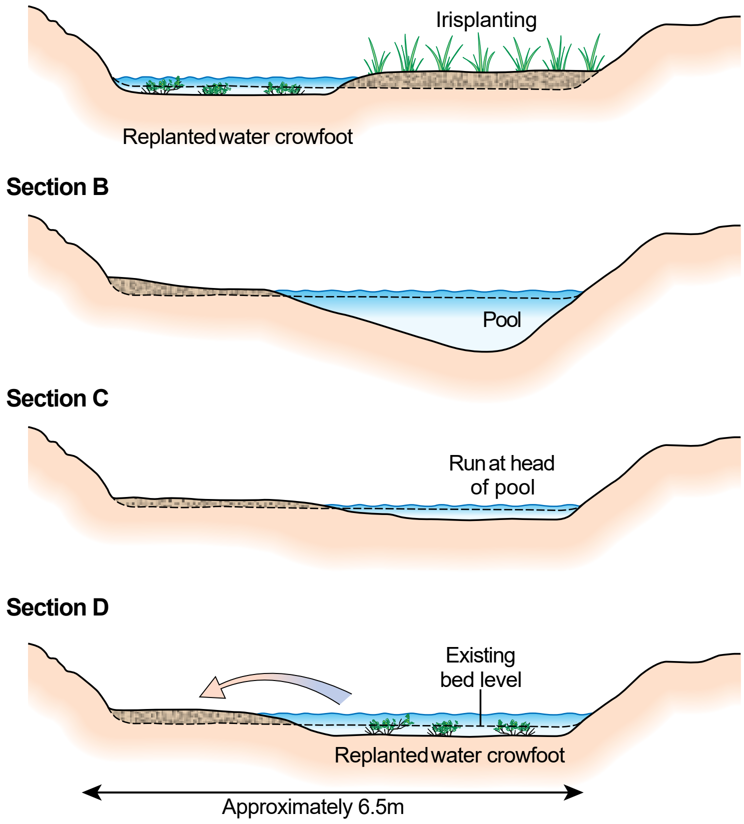


Figure 5.8.2
INDICATIVE CROSS SECTIONS



Design

All of the bed modifications were carried out from within the channel, so that the banks and trees were left untouched. The channel was re-profiled using a long reach excavator creating a sinuous channel, with pool and riffle sequences, still within the confines of the original channel.

The excavator accessed the river where there were suitable gaps between trees and the creation of gravel berms at these points enabled the excavator to exit the river without damaging the completed work.

A low flow channel was created by moving small amounts of gravel in a meandering path. Part of the bed was kept at a higher elevation to create a sequence of riffles.

In other areas more significant quantities of gravel were redistributed enabling pools to be created. Pools, spaced at approximately 20m intervals, were designed to be self-cleaning. Gravels were placed upstream of each to narrow the flow and increase velocity to induce scour in these pools.

The whole of the construction phase was supervised by the designer who was on site throughout the work and provided instructions to the excavator driver.

Existing bankside trees with large root systems acted as natural deflectors and provided a variety of marginal habitat. A small amount of planting was carried out, including water crowfoot (*Ranunculus spp.*), yellow flag (*Iris pseudacorus*) and purple loosestrife (*Lythrum salicaria*). The water crowfoot was sourced locally from the Darent.

Subsequent performance

Photographic evidence shows that the in-channel features created as a result of the works have been maintained over the subsequent seven years and are still present. However, no detailed morphological assessment has been undertaken. Clean gravels can be seen throughout the reach and the low flow channel, pools and riffles provide improved fish habitat.

Comparison of pre and post-works invertebrate monitoring, using the Proportion of Sediment-sensitive Invertebrates (PSI) method, demonstrates an overall improvement in the composition of species indicative of good chalk stream habitat conditions. A significant increase in the numbers of less silt tolerant species, for example blue-winged olive mayfly (*Ephemerella ignita*), has been observed along with a decrease in more silt tolerant species, for example caddis fly (*Trichoptera spp.*). This supports the observations that the blanketing silt has been replaced by well oxygenated clean gravel. Further invertebrate monitoring is scheduled to be carried out at this site, and others on the Darent, in spring and autumn 2013.

Vegetation surveys were completed pre and post-works (2004 and 2008) using the Mean Trophic Rank (MTR) method. Successful establishment of the vegetation that was planted was observed. Dense areas of reedmace (*Typha latifolia*) fringe the river and a good proportion of water crowfoot was recorded in the channel following the works. These observations were supported by an improvement in the MTR score from 35 to 42.

Additionally, the work has provided a more attractive riverscape and as a result Dartford Borough Council is currently working to improve the standard of footpath access adjacent to the river.

This scheme represents a good example of a small scale, low cost technique. The scheme also demonstrates the value of having an expert on site during construction and what can sometimes be achieved within a day.

5 years on the channel is narrower and more sinuous. Vegetation, both submerged and riparian, has established well – May 2010

Contacts

Tom Cook, Environment Agency (*South East*)
tom.cook@environment-agency.gov.uk, 08708 506506

Nigel Holmes, Alconbury Environmental Consultants
n.holmes3@btinternet.com, 01487 822020

5

Modifying River Bed Levels, Water Levels and Flows

5.9 Replacing an armoured bed with boulder step-pools

Inchewan Burn

Location – Birnam, near Perth, Scotland NO017405
Date of construction – September – November 2007
Length – 100m
Cost – £100,000

Inchewan Burn	High energy, gravel
WFD Mitigation measure	Restore form and function (channel and channel migration zone) Remove structure (culvert, bank protection etc) Make flow regimes more natural
Waterbody ID	150290
Designation	None
Project specific monitoring	Hydraulic habitat, fish

Description

The Inchewan Burn is a tributary of the River Tay SAC and flows through the village of Birnam. The upstream section retains much of its natural character, though in a heavily forested valley. The catchment is steep and flashy which has caused flooding in Birnam in the past.

In the 1970s the village was bypassed by the A9 trunk road, which runs alongside the main Edinburgh to Inverness railway. At this location a 100m reach of the burn was realigned and channelled between the supports for the road bridge. The channel was stabilised using concrete, gabion baskets and a stepped Reno Mattress base. These wire structures had begun to break down and became a barrier to Atlantic salmon (*Salmo salar*), a feature of the Tay SAC. In low flow conditions this reach had no surface water flow, with all water flowing through, rather than over, the loose stone and wire. This heavily degraded reach was restricting access to 3km of good spawning habitat upstream, though a steep natural chute restricts upstream fish movement until high flows.

Close up of the degraded Reno Mattress base – 2007

© A.Pepper

© RRC

Before restoration works showing complete failure of the wire structure and no surface flow – August 2006

Although the bed could be replaced, work on the banks was still heavily constrained as they provide structural foundations for the A9 (the concrete right bank) and support to the re-graded steep left bank (a three tier gabion wall).

The aim of the scheme was to recreate a boulder step-pool bed to mimic the natural upstream character of the burn, and so improve fish passage for salmon.

These techniques were developed to suit site specific criteria and may not apply to other locations

Design

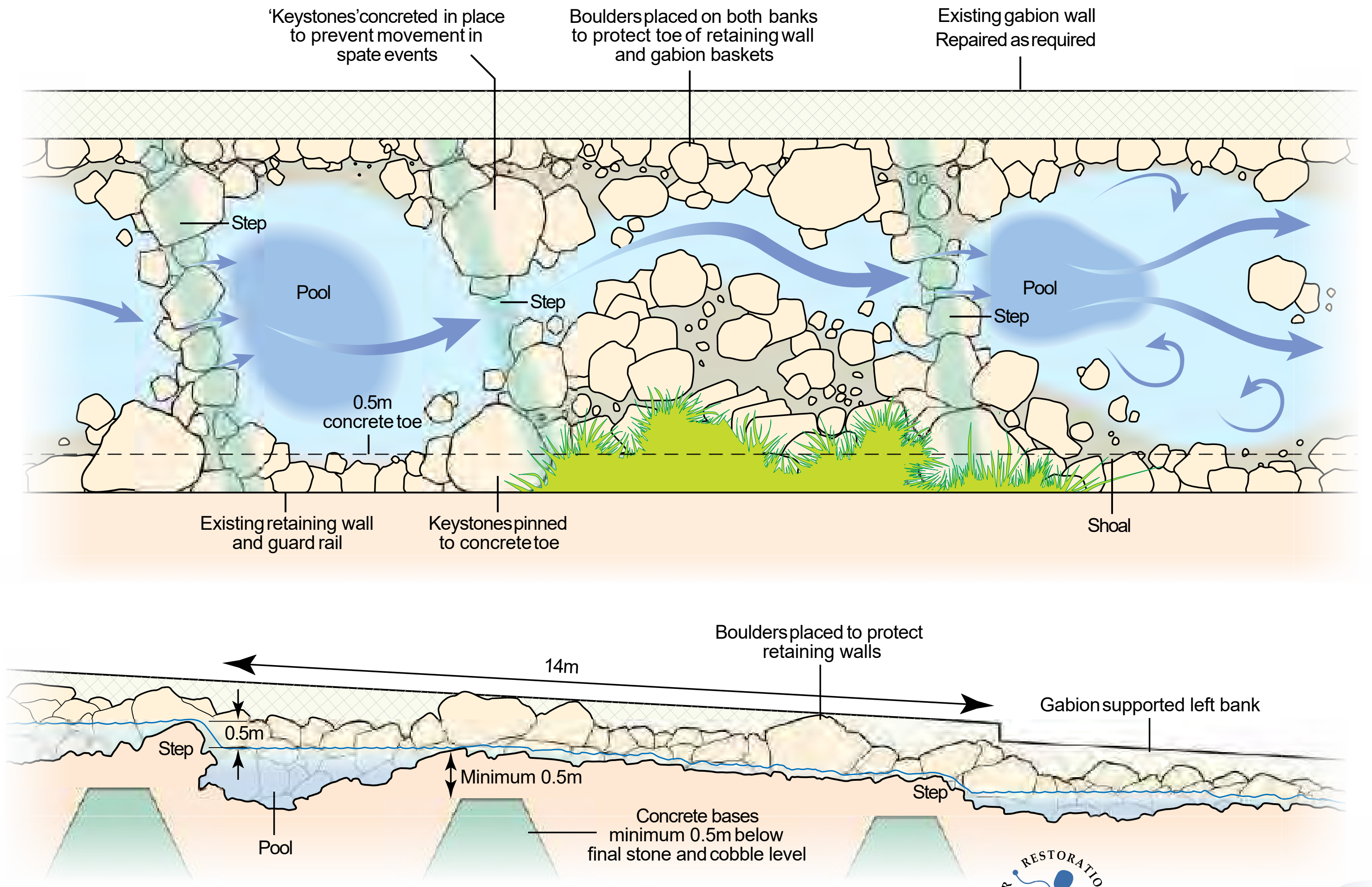
The method statement for the works was a simple concept based on utilising the gradient of the degraded reach (1 in 14) to form a series of step-pools, replicating as closely as possible the upstream bed form (*Figure 5.9.1*).

A schematic of the reach illustrating the repeat step and pool features (all varying in boulder arrangement) helped to guide the contractor. Further guidance was provided using the upstream reference site to aid discussions with the RRC and the supervising local ghillie.

© RRC

The natural channel, a few hundred metres upstream, showing the variable step-pool configuration formed by large boulders – November 2005

Figure 5.9.1
SCHEMATIC OF STEP-POOL SEQUENCES AND LONG PROFILE



Modifying River Bed Levels, Water Levels and Flows

This meant that the contractor only had minimal fixed dimensions (the number of steps, step drop and distance between steps) to guide the placement of boulders, and the instruction to make it resemble the upstream template reach as far as possible.

First, the wire from the disintegrating mattressing was removed. The cobbles that had been transported downstream were retained for reuse. The work was carried out during a dry period, with all of the low flow in the burn routed through a 0.5m diameter pipe.

The large boulders required for the bed were sourced from local field stone piles. These were lowered in to the burn and placed using a system of levers and pulleys. The largest (0.5 tonne) were used as 'keystones', mimicking the upstream channel where the largest boulders were integral to the step features, retaining the smaller interlocked boulders (the 'step') behind them.

The high gradient meant that there was a need to ensure that the keystones did not move. For this reason, a buried concrete base and steel pins were used to fix the most critical bed elements. Where concrete was to be used to bed-in the steps, it was specified to be buried at least 0.5m below the stone and cobble base to ensure that it remained unseen (*Figure 5.9.1*).

© SEPA

Wire from mattresses in bed removed. The stone was retained to use in the new step-pool system – 2007

© SEPA

Excavating for the concrete base to bed the larger boulders – October 2007

© SEPA

Steel pins in the concrete retaining wall toe awaiting boulder placement – 2007

The vertical concrete right bank (i.e. the road bridge footing) was constructed with a 0.5m wide toe which had previously been hidden beneath the wire mesh bed. This stepped ledge needed to be hidden by the new works (for aesthetic reasons and to prevent undercutting) and therefore provided a secure foundation for locating a number of the keystones. The boulders and concrete ledge were both drilled and the boulders then fixed in place with resin and steel pins.

Modifying River Bed Levels, Water Levels and Flows

5

© RRC

Immediately after completion – December 2007

Beneath the A9, five years after – May 2012

© RRC

Boulders were also placed along the gabion basket left bank retaining wall, partly to hide the gabions but also to protect them from the abrasive throughput of bed material which had destroyed the Reno Mattress base.

The restoration works were coordinated and supervised by the local ghillie, and funded by Transport Scotland, with input from RRC, SNH, SEPA, Scottish Native Woods and Perth & Kinross Council.

Subsequent performance

In December 2007, the local ghillie observed salmon, sea trout and brown trout (*Salmo trutta*) swimming through the reconstructed section of the burn and upstream once more. The work has made a dramatic improvement to the aesthetics of the reach, which is appreciated by regular users of a footpath close to the river bank.

Monitoring by the University of Stirling in 2009 compared the hydraulic habitat and fish density in the unmodified upstream reach with that of the restored reach. This showed that hydraulic habitat had been successfully restored and that juvenile salmon and brown trout were colonising this reach. However, passage upstream was being impaired by the shallow masonry culvert bed beneath the railway.

The success of the scheme was in part a result of basing its design on the upstream reference reach. This provided a visual template for restoration which could be easily understood as a 'shared vision' by the design engineers, stakeholders and contractor.

© RRC

The restored reach mimicking the step pool configuration of the upstream reach – May 2011

Contacts

Jock Monteith, Salmon fishing services
jock@salmon-fishing-scotland.com, 07968145033

Martin Janes, River Restoration Centre
rrc@therrc.co.uk, 01234 752979

Reference material – Click here

THE RIVER RESTORATION CENTRE
Working to restore & enhance our rivers

5 Modifying River Bed Levels, Water Levels and Flows

5.10 Creating 'natural' features in a heavily engineered flood scheme

RIVER VALENCY

LOCATION - BOSCASTLE, CORNWALL SX10009123
DATE OF CONSTRUCTION - 2007/8
LENGTH – 300m
COST – NOT KNOWN (PART OF A £6.3M FLOOD RISK MANAGEMENT SCHEME)

River Valency	High energy, gravel
WFD Mitigation measure	Preserve and, where possible, restore historic aquatic habitats Operational and structural changes to locks, sluices, weirs, beach control, etc
Waterbody ID	GB108049007170
Designation	None
Project specific monitoring	Fish

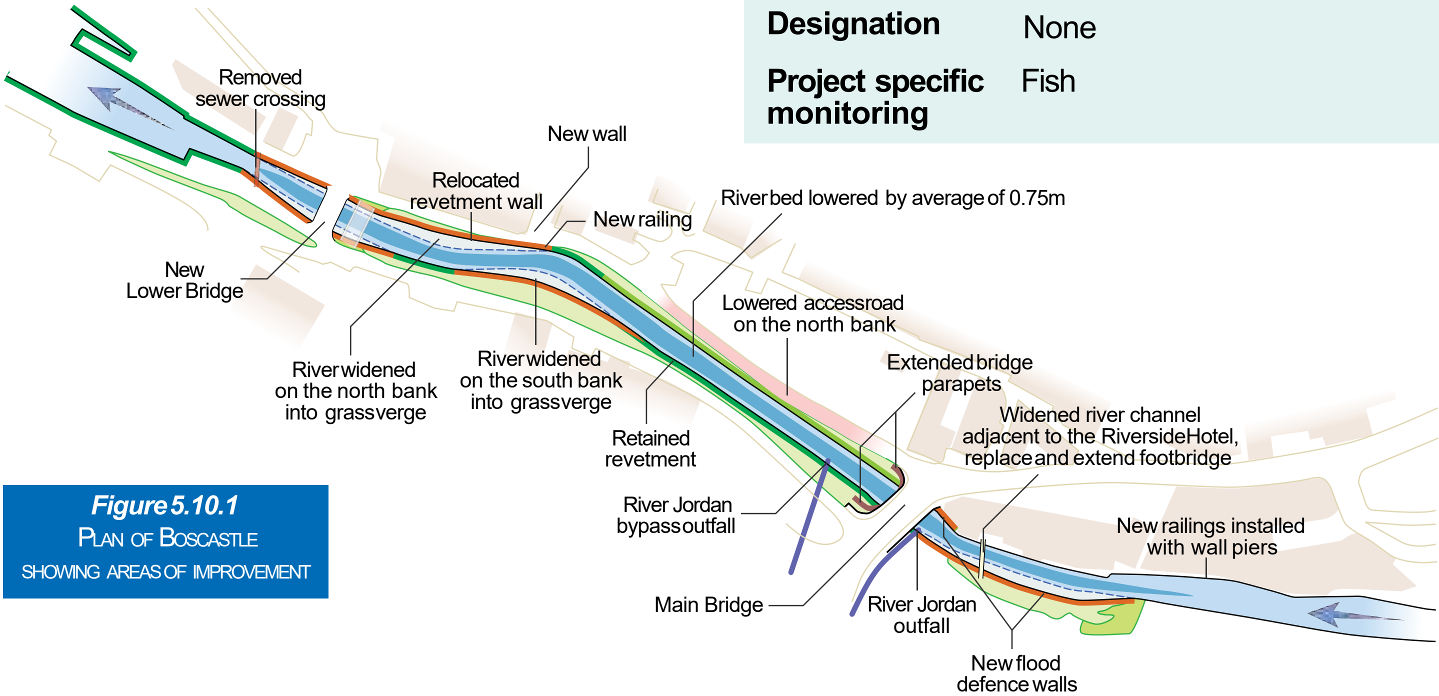


Figure 5.10.1
PLAN OF BOSCASTLE SHOWING AREAS OF IMPROVEMENT

Description

Boscastle village is located in a steep sided and narrow valley through which the River Valency flows down to the harbour. In 2004 an intense storm centred over the small wooded catchment caused massive erosion of sediment and river-side trees. This, combined with high flows, inundated the village with water and debris causing extensive damage.

The village is of great historic value and is a main attraction for visitors to North Cornwall. The river itself is the centrepiece of the village. The process of Enviromental Impact Assessment (EIA) and landscape appraisal led to the best enginering design that would deliver the multiple flood risk, landscape and environmental objectives.

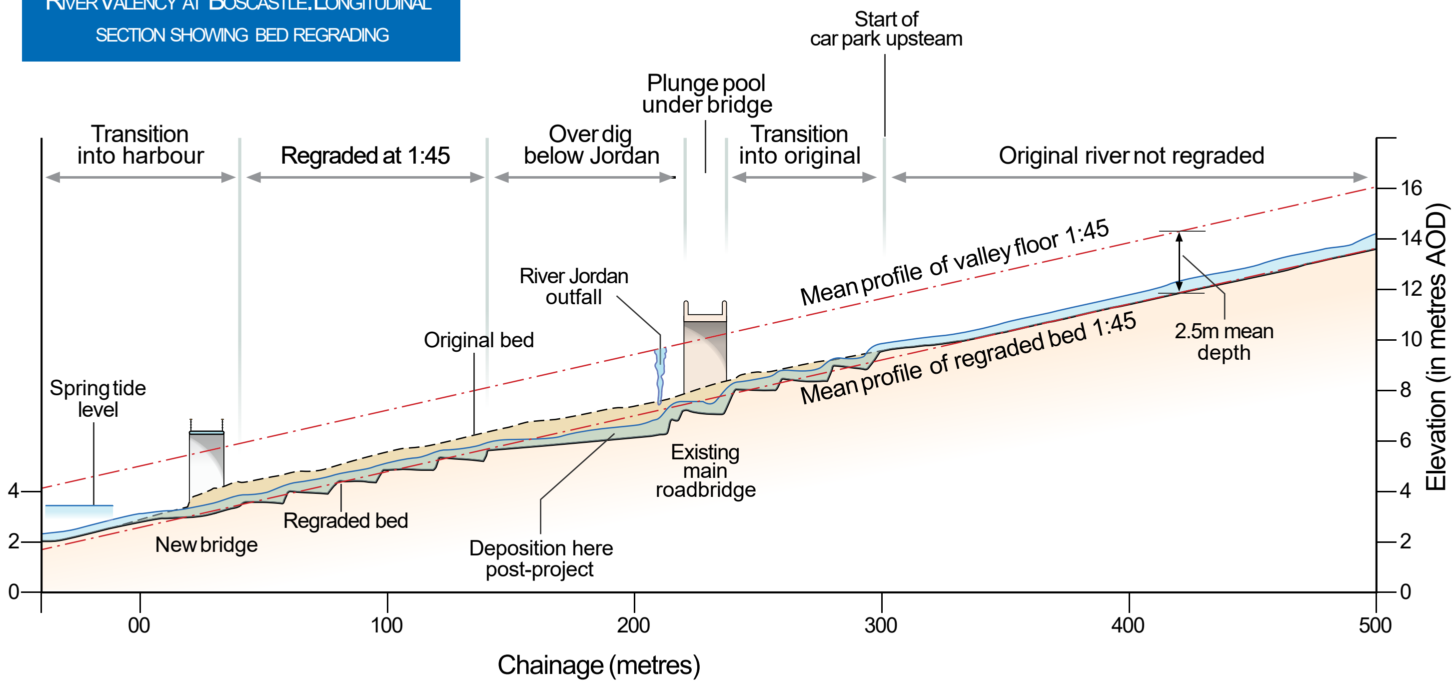
Enlargement of the river channel offered the only viable way to reduce flood risk and improve the flood capacity and sediment conveyance of the river. The scheme aimed to demonstrate 'best practice' in achieving this sympathetically, so avoiding a deep geometrically uniform channel. The channel was designed in such a way that it simulated the natural features found higher up in the undisturbed reaches of the river by engineering features into the excavated bedrock.

© Halcrow

Natural cascade and pool upstream of Boscastle – 2006

These techniques were developed to suit site specific criteria and may not apply to other locations

Figure 5.10.2
RIVER VALENCY AT BOSCASTLE. LONGITUDINAL SECTION SHOWING BED REGRADING



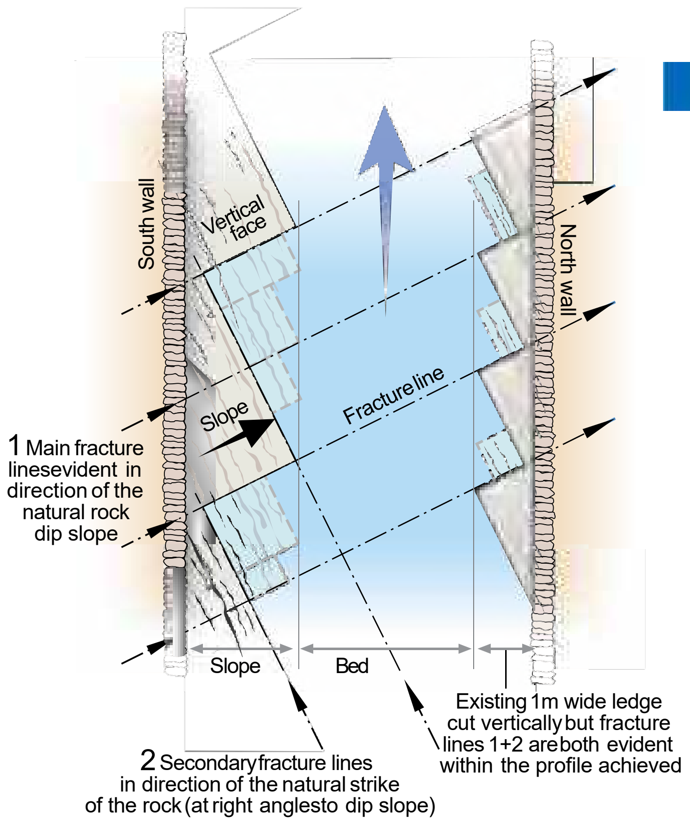


Figure 5.10.3
SIMPLIFIED PLAN OF THE RIVER CHANNEL SHOWING THE EFFECT OF NATURAL FRACTURE LINES WITHIN THE ROCK BREAK

Design

A detailed topographical survey of the longitudinal profile of the river was an important design tool. This enabled a new, lower bed gradient to be superimposed onto the original one, giving the 'best fit' with the levels upstream and downstream of the reach.

The natural valley slope at Boscastle is 1 in 45 and the channel bed upstream of the village has a depth of approximately 2.5m. Extending this channel depth down through the village to the harbour, the longitudinal section showed the original bed to be typically 1 metre higher. This helped to explain the loss of capacity through the village and its propensity to flood. Bed regrading to this 2.5m depth profile was therefore considered feasible (*Figure 5.10.2*).

The design of the cross section and longitudinal profile of the lowered bed involved close study of the natural characteristics of the rock visible in the upper river and in the harbour. The rock featured strong bedding planes that typically dip from left to right bank, angled downstream at about 45°. It had vertical fracture lines as well as regular intrusions of much harder quartz. Concept drawings were provided to show how the rock was to be removed. An engineer worked closely with machine operators to obtain the desired result of the left side sloping with the dip and the right side vertical along the fractures. Both sides were zig-zagged to stay within the 'character' stone retaining walls.

5

Modifying River Bed Levels, Water Levels and Flows

© Halcrow The low flow course had to be entirely excavated to best mimic millennia of erosion of a hard rock bed.

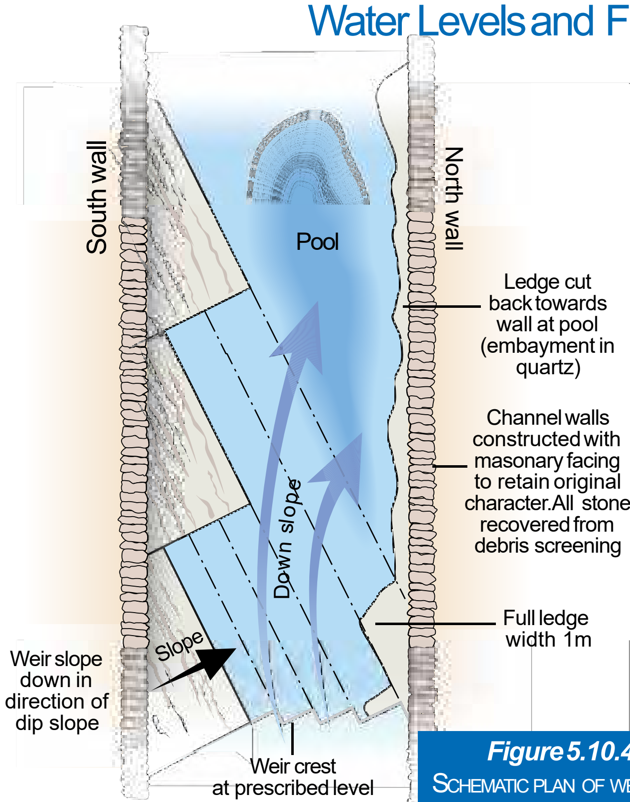


Figure 5.10.4
SCHEMATIC PLAN OF WEIR AND POOL IN QUARTZ STRATA

Understanding the geology and morphology of the river was critical to the design. This avoided the potential problems that can arise if the rock is broken out in a way that does not mimic the natural structure. For example simply cutting to a uniform profile could trigger subsequent collapse as the river erodes the rock back to a naturally stable profile.

Cascades with pools below were formed along the bed with nominally 0.2m drops at 9m intervals to approximate the 1 in 45 gradient. Excavation was only undertaken under the supervision of an experienced river engineer, enabling every aspect of the final topography to reflect the specific nature of the rock in situ as it was worked. The alternative of trying to detail the bed profile for the contractor would have been impractical.

Deepened channel using natural fracture lines within the bedrock. Retaining walls becoming vegetated

© Halcrow

These techniques were developed to suit site specific criteria and may not apply to other locations

Subsequent performance

The re-profiled river has performed well during the years since completion. The excavated profile has remained stable, as have the individually sculpted cascades, pools and embayments. Within the latter a good diversity of flow characteristics provides niche habitats, with some gravel in sheltered eddies as well as small beaches. It is also visually attractive, enhanced by the sound of the cascading water. This contrasts markedly with the flat, featureless river bed that existed before.

© Halcrow

Gravel beaches have formed within the bedrock channel

A single negative aspect has been the excessive deposition of stony sediment at one location. This is where the bed was significantly cut down below the optimum mean bed gradient of 1 in 45, to provide greater flow capacity where an overspill culvert of a tributary stream, the River Jordan, enters (*See Figure 5.10.2*). Bed material has simply filled this over-deepened pool to bring the bed back up to the 1 in 45 mean. Consequently there are no rock features in the bed here. This outcome was foreseen and this 'pool' had been designed such that the excess fine deposits would remobilise during flood flows, thus

© Halcrow

River Jordan outfall. The over-deepened pool has clearly filled with large stone sediment – October 2008

restoring channel capacity when required. As an additional part of the scheme, large sediment is now intercepted upstream of the village, but an intermediate reach has scoured clean and it is this larger material that has filled the pool. This is planned to be removed to see whether or not subsequent, finer sediment will remobilise as intended.

The project demonstrated that visual references for the contractor were essential, in the form of site visits and first hand explanations. This helped the design consultants and contractor to understand the complexity of the project's requirements.

Observations suggest that the key objectives of lowering the bed to provide greater flood capacity whilst creating a functioning and visually attractive landscape have been achieved. Electrofishing surveys carried out two years after completion found Atlantic salmon (*Salmo salar*) and other migratory fish such as eel (*Anguilla anguilla*) had navigated to the upper catchment.

Contacts

James Burke, Environment Agency
james.e.burke@environment-agency.gov.uk, 08708 506506

Halcrow, lead design consultants
01392 444252

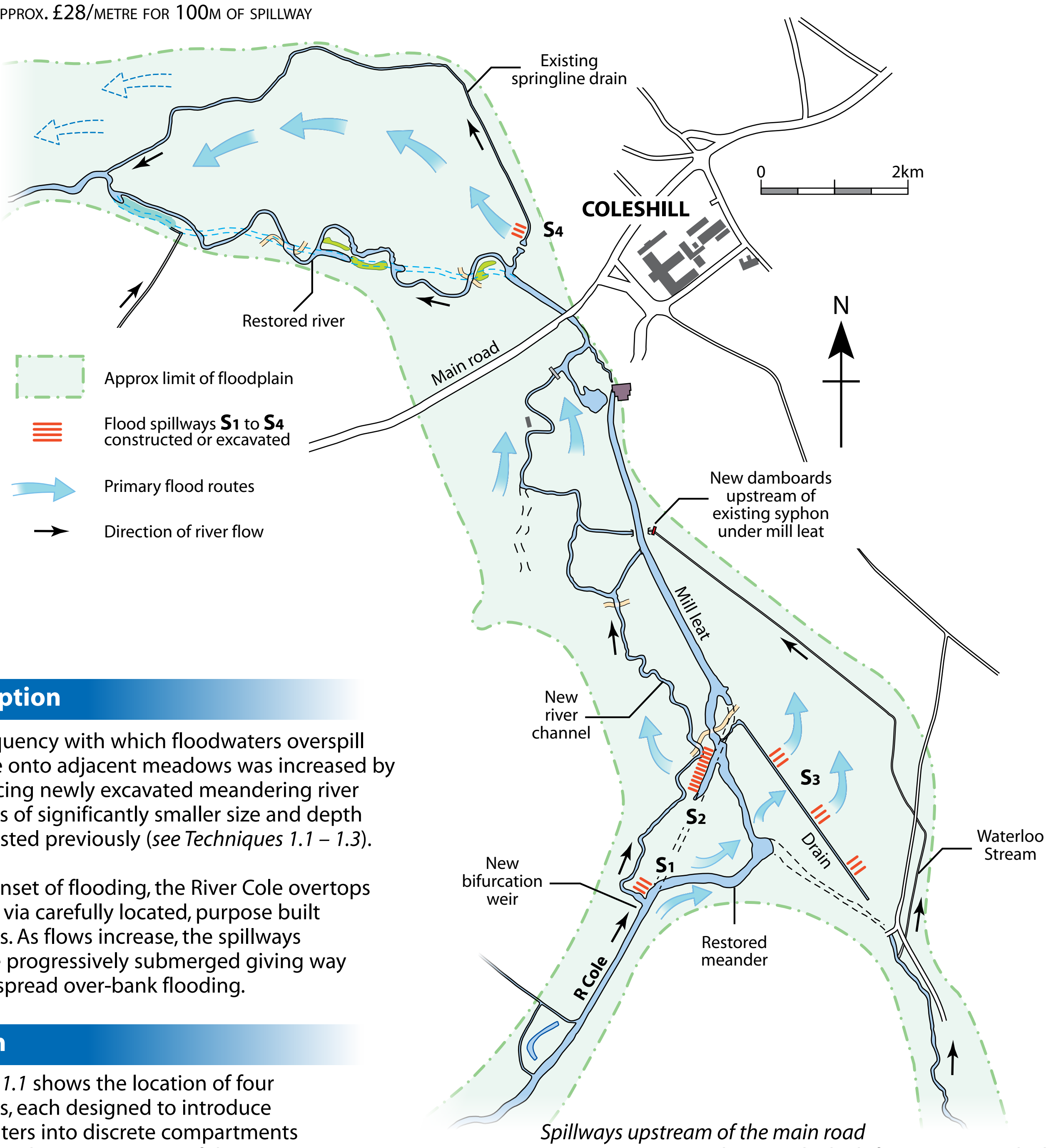
Reference material – Click here

6 Managing Overland Floodwaters

6.1 Floodplain spillways

River Cole
Location - Coleshill, Oxon/Wilts border, SU234935
Date of construction - Autumn 1995
Area – 50ha
Cost – Approx. £28/metre for 100m of spillway

Figure 6.1.1
Plan of Flood Routing



Description

The frequency with which floodwaters overspill the Cole onto adjacent meadows was increased by introducing newly excavated meandering river channels of significantly smaller size and depth than existed previously (*see Techniques 1.1 – 1.3*).

At the onset of flooding, the River Cole overtops its bank via carefully located, purpose built spillways. As flows increase, the spillways become progressively submerged giving way to widespread over-bank flooding.

Design

Figure 6.1.1 shows the location of four spillways, each designed to introduce floodwaters into discrete compartments of the floodplain. Upstream of the main road three spillways (**S1** to **S3**) operate with incremental rises in river level and flow. Downstream of the main road a single spillway (**S4**) introduces water to the right bank meadows. Flood waters pass under the road via the river bridge and two existing flood culverts set at field level.

Spillways upstream of the main road
Spillway **S1** is located alongside the bifurcation weir which feeds water into the newly excavated river channel (*see Technique 5.1*).

The spillway operates early on in a rising flood and is sized such that the new channel fills to bankfull in advance of any overspill elsewhere.

Spillway **S2**. Flood flows indicated by the arrows overtop the spillway, merging with the new channel (not visible)on the Great Eau at Withern

Spillway **S2** begins to operate only after **S1** has filled the new channel with water. Water spilling over **S2** passes directly into the new channel causing it to overflow its banks and initiate field flooding. Scour of the overspill is minimal because this design ensures floodwaters from both **S1** and **S2** merge without excessive turbulence.

The level at which **S2** is set is critical; it is 300mm lower than the floor of the mill further down river, to ensure floodwater is diverted away from the mill. In practice, **S2** replaced an unsightly concrete cascade weir built at the mill to protect it from flooding. The cascade has been boarded off and will be infilled once the performance of **S2** is proven to be satisfactory.

The length and longitudinal profile of **S2** was also critically determined, by hydraulic modelling, to ensure sufficient flow of floodwater down the valley to avoid worsening 1 in 100 year flood levels for isolated properties on the fringes of the floodplain. The crest has a compound profile which is surfaced in stone over the lower part.

Spillway **S3** is a previously existing low embankment alongside a field drain built to prevent water in the leat backing up the drain and overspilling into a large meadow to the east. In 1995, when the main project works were completed, no modifications to this embankment were made. Subsequently, it was verified through observation that floods rarely overtopped the embankment, so in 1998 the crest was lowered at several locations, just sufficient to gain the flood frequency desired. The only escape for floodwaters entering the meadow is via a ditch and syphon pipe under the leat. Water levels build rapidly due to this 'throttle', creating a floodlake. The embankment low spots created are all elevated 100mm higher than the crest level of **S2** so that flooding of compartments arises incrementally giving the farmer time to react if livestock are present.

Spillway downstream of the main road (Figure 8.2.2)
Spillway **S4** is located alongside a spring line drain that discharged to the river. The drain was firstly blocked with soil well back from the river to help keep the meadow damp. The redundant length of drain between the river and the staunch was then modified to carry floodwaters from the river out onto the floodplain. This was neccessary because the land alongside the river is higher than the general field levels, thereby delaying the onset of natural flooding. The drain modifications overcome this problem.

6

Managing Overland Floodwaters

Spillway **S2** in flood

Spillway **S4**. Floodwaters spilling into field gully.

The drain was enlarged to increase its flow capacity and the bank level at the overspill point, lowered to form spillway **S4**. The spillway is located close to a natural gully that meanders down through the floodplain fields and probably marks an ancient river course. The spillway was completed by shallow excavation of the field to extend the gully right up to the bank of the drain.

An access bridge was built over the drain using two 1m diameter pipes, sized to allow reasonable volumes of floodwater to pass through. The top of the crossing was kept up at the prevailing river bank level so that livestock could be evacuated, after flooding commenced via the nearby spillway **S4** (*see Technique 8.2.*)

Subsequent performance 1995 – 2001

The hydraulic performance has closely matched the predictions of the hydraulic model, which were conservatively judged to avoid excessive summer flooding when hay or livestock are in the fields. Experience of flood levels during the two summers post construction led to the slight lowering of levels at S3, described above, as well as a similar degree of lowering at S4.

The stone surfacing of S1 and S2 suffered localised scour damage which was rectified by partial reconstruction, taking greater care to ensure the predominant stone size (200mm) was evenly distributed and well compacted into turfy soil that quickly generated root and sward binding. Level pegs were driven near **S2** so that its designed crest could easily be checked for trampling by cattle or erosion by water.

6 Managing Overland Floodwaters

6.2 Profiling of land between meanders

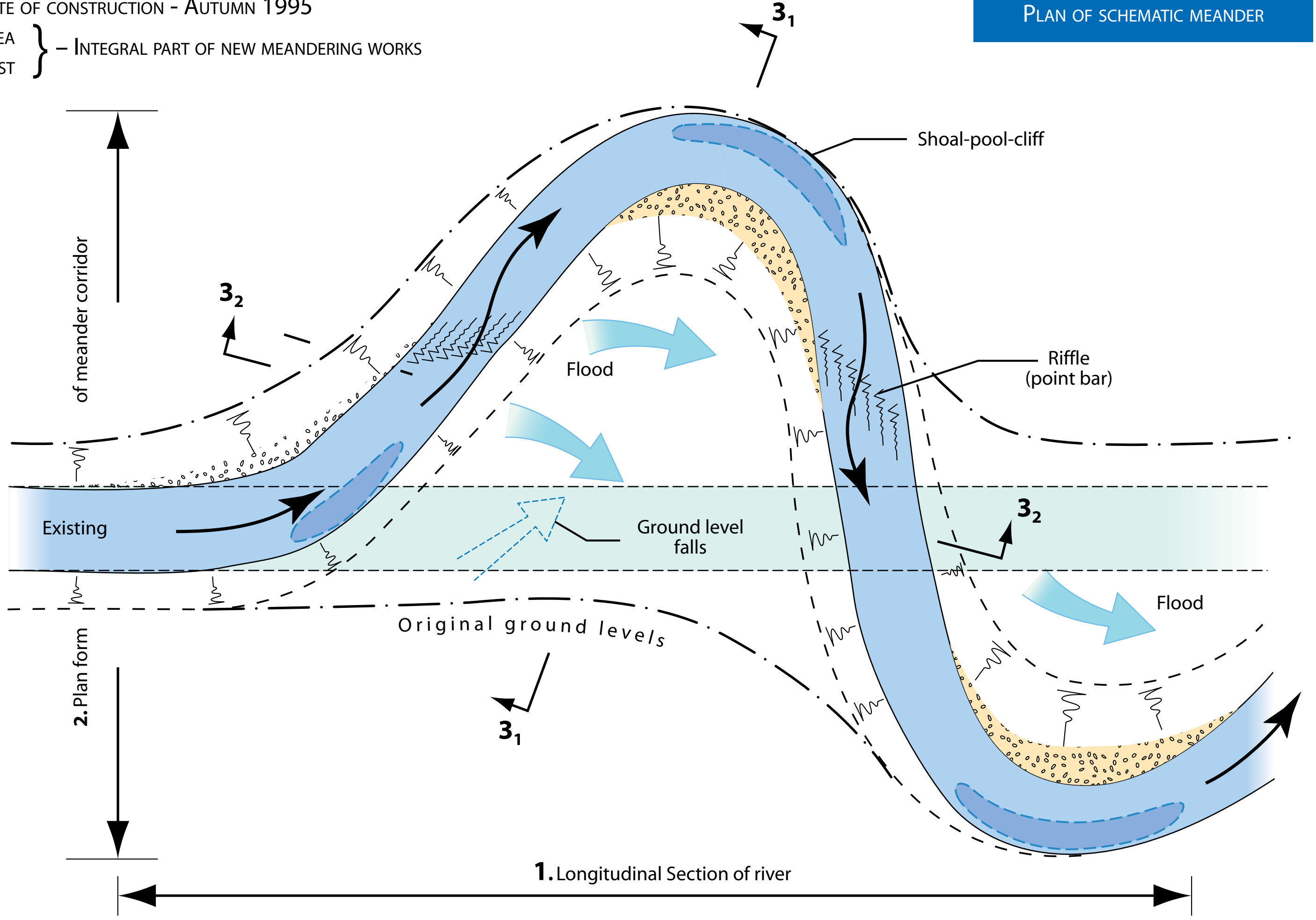
Rivers Cole and Skerne

Location - Coleshill, Oxon/Wilts border, SU234935
– Darlington, Co Durham, NZ301160

Date of construction - Autumn 1995

Area } – Integral part of new meandering works
Cost

Figure 6.2.1
Plan of schematic meander



Description

The creation of new meandering channels required a design that reflected the hydro-geomorphological processes that naturally lead to meander formation. The natural geometry of meanders is complex, but certain basic principles were followed at both the Cole and Skerne sites to develop simplified designs that could be implemented using conventional excavation plant.

The creation of the new meanders reflected this process by including reprofiling of land within the meander corridor. If this was not done, and works were limited to simply excavating a sinuous channel, then erosive forces would have been un-naturally high, due to the confinement of the river, until such time as the river had itself adjusted to the more balanced form depicted.

Design

Figure 6.2.1 depicts an idealised meander where the outer bank is eroding and the inner bank accreting, thereby generating a slow migration of the meander down the river valley. This fundamental process means that the profile of the land within the meander naturally results from deposition during successive floods, and that it will usually be markedly different from the generally flat profile of the wider floodplain.

The design of meanders at the sites is fully explained in *Techniques 1.1* to *1.4*. This involved the sequential determination of the following dimensional details:

1. The mean longitudinal bed profile of the whole reach;
2. The alignment of meanders in plan;
3. The variable channel cross-sections to suit 1 and 2 above;
4. The profile of the land within the meanders.

These techniques were developed to suit site specific criteria and may not apply to other locations

Managing Overland Floodwaters

Figure6.2.2
Section $3_1 - 3_1$

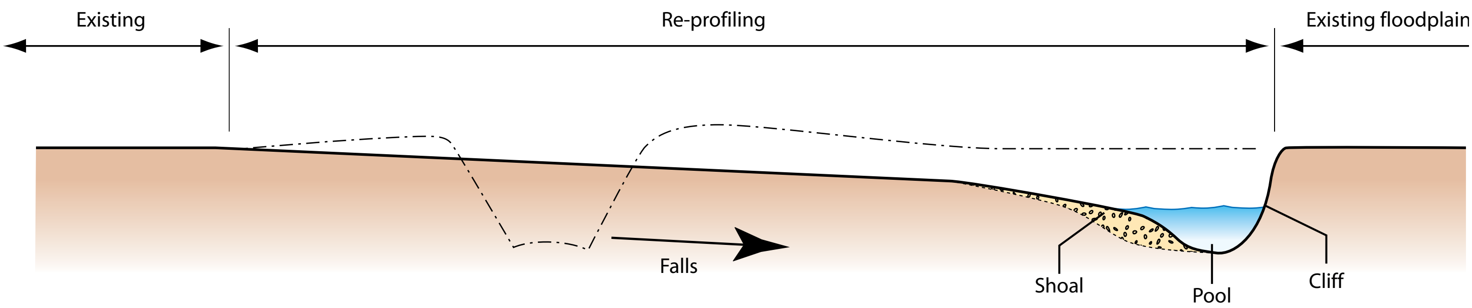
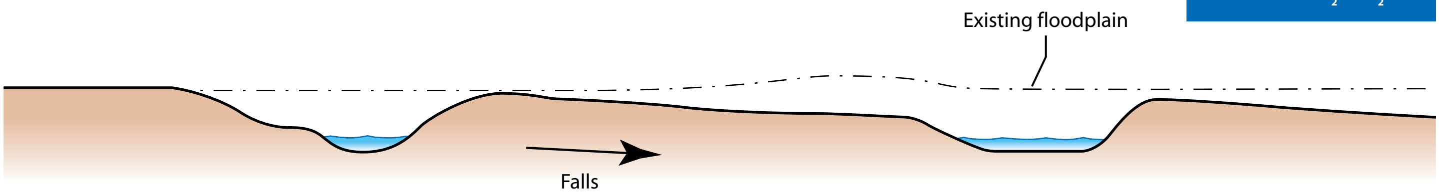


Figure6.2.3
Section $3_2 - 3_2$



The aim of 4 (re-profiling) was to integrate the other three aspects (bed, bank and plan form) creating a sustainable river corridor. The extent and nature of re-profiling was influenced by the way in which floods would pass between successive meanders before reaching water levels that gave rise to general over-bank flow onto the wider floodplain.

The conveyance of floodwaters between meanders proved to be a significant factor in achieving the necessary hydraulic capacity of the river.

The two most important aspects of re-profiling are indicated in the two cross-sections (*Figures. 6.2.2 – 6.2.3*) and summarised below:

- Gradually falling levels laterally across the meander profile merging into a shoal-pool-cliff profile at the apex (*see Technique 3.1*);
- Gradually falling levels longitudinally between the start of the meander and the return leg (*see Technique 3.2*).

This approach ensures that submergence of the meander in a rising flood will commence at the return leg, starting where shoal deposition is most active and progress back towards the entry bend. This pattern of submergence generates flow currents that are complex and varied but are generally smooth. This contrasts with the turbulent conditions that ariseif re-profiling is not undertaken.

Other practical benefits of re-profiling in this way include a safer environment for people and livestock. Easy access down to the waterside is intrinsic to the design, and the risk of being trapped by floodwater suddenly cutting straight across the meander is greatly reduced.

The formation of sustainable pools, riffles and cliffs in the locations indicated on the plan is similarly an intrinsic feature of these design principles.

Subsequent performance 1995 – 2001

Although the principles of the design were well understood, their full application was compromised for a number of reasons, including underground services, although every meander, at both locations, was subjected to re-profiling to some degree. It was evident after the first winter season that some further re-profiling was desirable to get much closer to the idealised form described (*see Technique s 1.1 – 1.2*).

The re-profiling has proved to be a very important aspect of the design, the best example being the largest meander on the Skerne where a backwater is incorporated (*see Technique 2.1*).

6

Managing Overland Floodwaters

6.3 Removing and setting back floodbanks

Long Eau

Location - Manby, Lincolnshire TF407863
Date of construction - May – June 1995
Area – 16ha
Cost – £60,000

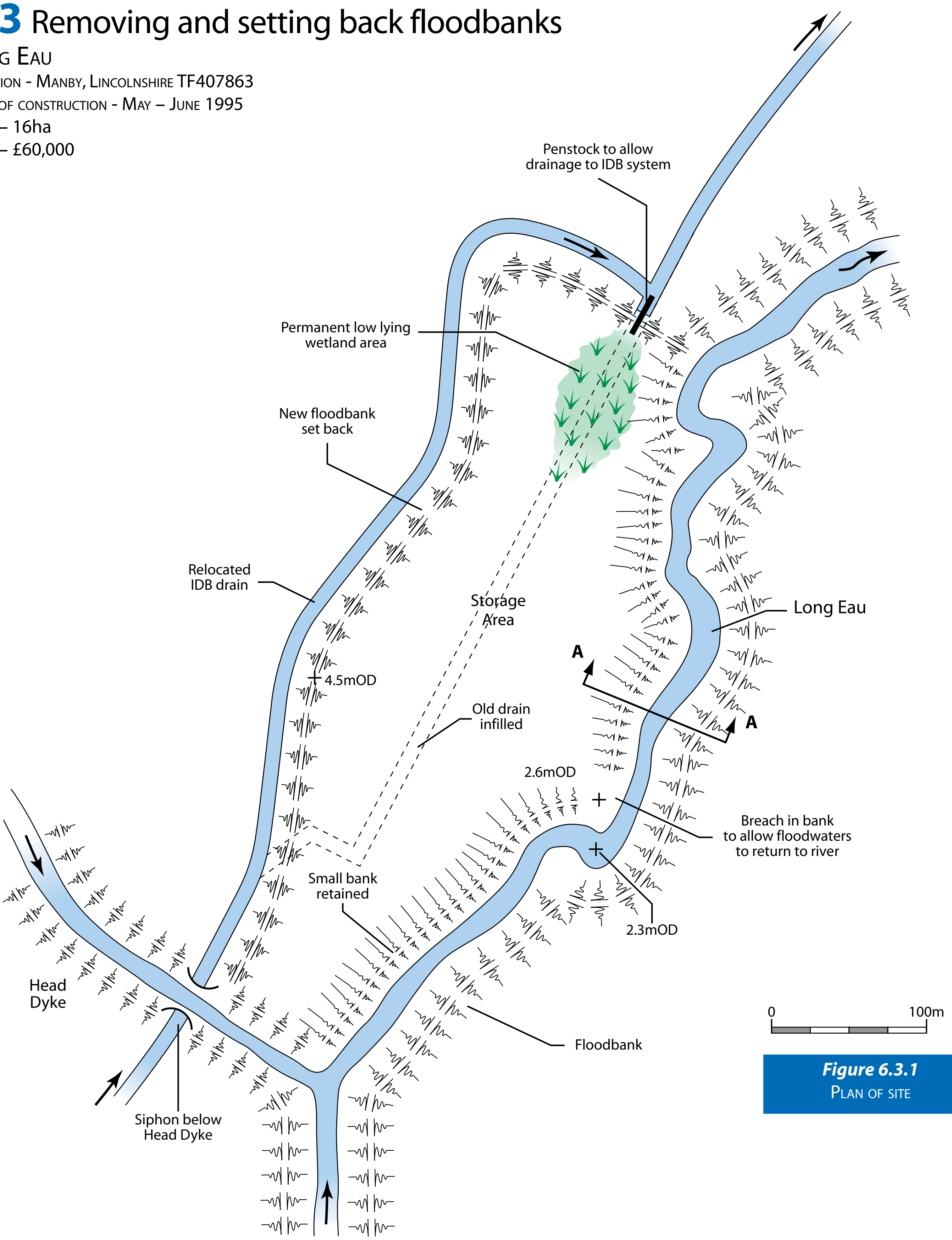


Figure 6.3.1
Plan of site

These techniques were developed to suit site specific criteria and may not apply to other locations

Managing Overland Floodwaters

6

Removal of the left floodbank and marginal berm creation on the Great Eau at Withern

Description

The Great and Long Eau drain large areas of predominantly agricultural land. Both rivers have been heavily modified and embanked to increase capacity to protect the surrounding land, and both are high-level carriers relative to the surrounding land. Regular dredging to maintain capacity has removed any natural substrate.

Three sites were chosen along the Long and Great Eau to demonstrate improved flood protection standards through a process of setting back floodbanks previously located along the riverbank. At each site the floodbank was removed and a flood storage area created on adjacent land. The site selection process also took into account the opportunity to combine floodplain restoration with river channel enhancement and marginal habitat creation.

Landowner support was key to the implementation of the schemes, and some form of financial incentive was essential to landowner support. Farming and Wildlife Advisory Group (FWAG) and the Countryside Commission helped landowners successfully enter into the Countryside Stewardship Scheme, to gain compensatory funding of a total of £60,000.

Relocating the IDB drain and set-back floodbank

Apart from in the upper reaches, the majority of the Long Eau has little gradient and is virtually bereft of any habitat structure. There is little contact with the previous floodplain as the river has been deeply dredged, and seasonal over-topping cannot occur due to high floodbanks.

Design

Long Eau – Manby

The left floodbank was lowered to just above ground level, so still retaining a low embankment. The field-side slope was widened and flattened to 1 in 10 as this would now act as an overspill. The river-side bank was also re-profiled, sloping gently down to a wet berm up to 2m wide where marginal plants could establish.

The 2100m^3 of spoil from the bank removal was used to fill in an Internal Drainage Board drain that ran through the centre of the proposed storage area. This had to be re-routed behind the new 'set-back' floodbank to maintain the integrity of the upland and lowland drainage system. Material excavated from the construction of the new drain was used to form the new floodbank, set back from the river by up to 300m. The new bank is large due to the volume of material that needed to be excavated to re-route the IDB drain. The new embankment is constructed of clay with slopes of 3:1 to a height of 2.5m to 2.7m above the adjacent ground level. This gives a designed crest level of 4.5m above OD with a crest width of 3.5m minimum. The volume of material used for the embankment was 18,500m^3.

The River Restoration Centre — Working to restore & enhance our rivers

Managing Overland Floodwaters

View along the trapezoidal right bank of the Long Eau

View from the new embankment across the restored floodplain showing wintering wildfowl – January 1999

Water is designed to spill onto the 16ha site from the Long Eau when levels reach 2.6m above OD, just 0.3m over their normal retained level. This floods progressively outwards from the old course of the IDB drain, which represents the lowest levels within the area. This low spot remains damp for much of the year, the downstream end forming a permanent wet scrape/shallow pool.

The project team and landowner were keen to avoid prolonged springtime surface inundation by floodwater trapped in low lying pockets and not returning to the river. Where such areas were evident the bank was lowered locally to allow drainage back to the river as river levels subsided, as well as into the area as levels rose. As the water depths lower through gravity drainage and evaporation a penstock can be accessed by the landowner to discharge water to the IDB system to allow the grass sward to recover for early summer grazing.

Long Eau - Little Carlton and Great Eau - Withern

Similarly, upsteam at Little Carlton the floodbanks were removed and set back, and at Withern the natural rise in slope was used to contain floodwaters without the need to replace the bank. As with Manby both sites included work on the floodplain and river's edge, creating scrapes, reedbeds, berms, riffles and, where suitable, exposed cliff faces.

Subsequent performance 1995 – 2001

Initial hydrological modelling indicates significant local benefits, including an increase in the standard of protection over a 3km stretch of the Long Eau at Little Carlton and at Manby.

Long Eau, Manby

Water will spill onto the site from the Long Eau when levels reach 2.6m above OD and has reached a maximum of 4m above OD. Levels are then reliant on conditions in the Eau subsiding and, depending on the intensity of the event, have been retained for two or three days. Below the Eau level of 2.6m, 75% of the washland will retain water to a depth of up to about 0.5m. This can remain for 3-4 months providing ideal conditions over the winter months for dabbling and grazing ducks such as widgeon, teal, gadwall and mallard.

Waterfowl and waders have increased on the floodplain. Lapwing and redshank have bred on the site. Flocks of over 60 redshank and snipe, curlew, ruff, common and green sandpiper are amongst the birds that use the washlands in the winter.

Original Information Provider:
Phil Smith

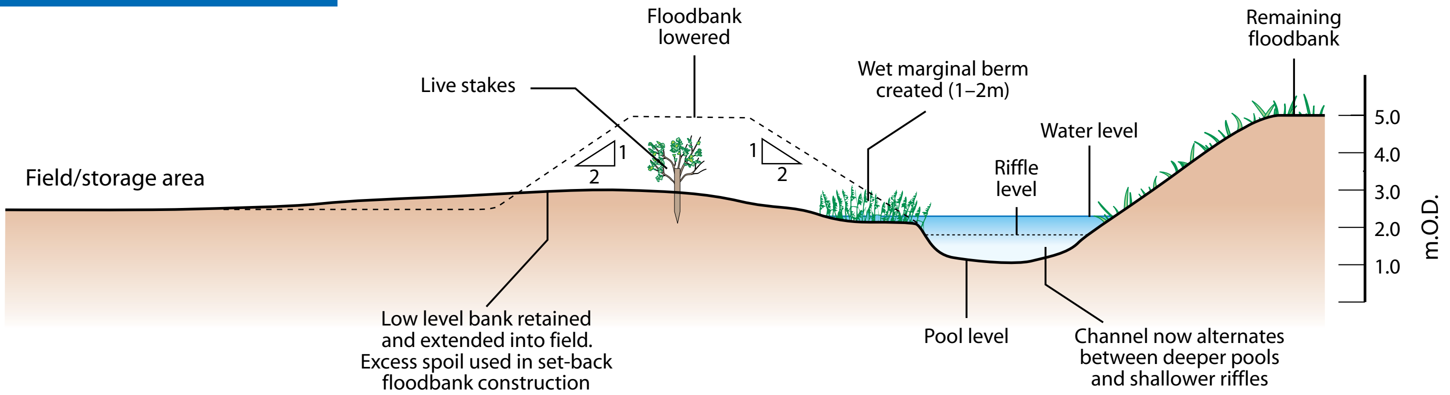
Floodplain, penstock and permanent wetland area – October 2001

These techniques were developed to suit site specific criteria and may not apply to other locations

Managing Overland Floodwaters

6

Figure 6.3.2
SECTION A THROUGH FLOODBANKS



Berm at section A after 4 years

6.3 Long Eau 2013 Update

River Long Eau	Low energy, clay
WFD Mitigation measure	Set-bank embankments (a type of managed retreat)
Waterbody ID	GB105029061670
Designation	None
Project specific monitoring	None

The downstream flood peak has been reduced as water spills out into the floodplain and is held in the storage area. As the land was previously used for arable farming, the drainage at this site was good. This meant that initially water retention in the storage lagoon was limited. Progressively, with more frequent flooding and a change to the grazing regime, water has been retained for longer periods.

The scheme has coped well with recent floods, with some water successfully retained from winter through to the spring, and there is no evidence of negative impacts upstream or downstream. This has provided confidence to reduce vegetation management within the adjacent reach.

Initially the farmer (landowner) was disappointed that the storage area reduced the area available for grazing. However, he was able to work this into his livestock management plan and is now happy with the situation.

Wetland habitat has been created and wildfowl continue to be attracted to the site. Although not part of the original plan, a public access bird hide has been created by the landowner and this is well used by bird watchers.

This site provides a good example of the benefits of working with natural processes, and the Environment Agency has successfully used the same technique on other sites. A farmer upstream has used a similar technique, and has also seen an increase in overwintering and breeding wildfowl and waders.

There were complications in construction due to the diversion of the IDB drainage system which made the project expensive. Future projects should try to avoid this.

Floodplain, penstock and permanent wetland area 11 years on – August 2012

Contact

Caroline Tero, Environment Agency (*Anglian*)
caroline.tero@envrionment-agency.gov.uk, 08708 506506

6.4 Breaching a flood bank to reconnect active floodplain processes

BURN OF MOSSET

LOCATION - FORRES, MORAY, SCOTLAND NJ04955727
DATE OF CONSTRUCTION - 2008
LENGTH - 500M
COST - £100,000

Burn of Mosset	Medium energy, gravel
WFD Mitigation measure	Restore form and function (channel and channel migration zone) Restore form (floodplain) Make flow regimes more natural Riparian planting
Waterbody ID	23021
Designation	None
Project specific monitoring	Annual & reactive

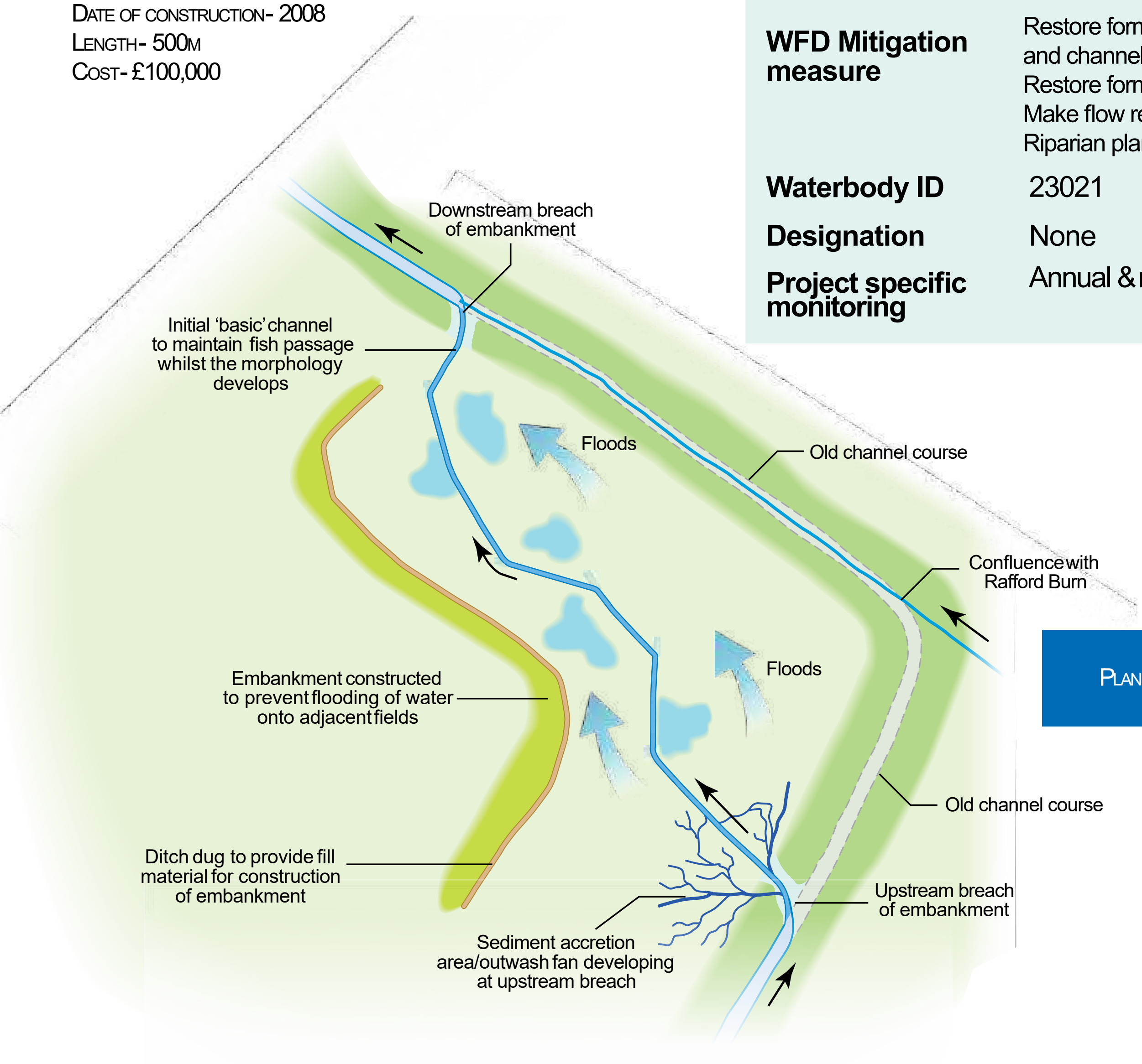


Figure 6.4.1
PLAN VIEW OF THE SEDIMENT ACRETION AREA

Description

The Burn of Mosset is a small but geomorphologically active gravel-bed stream that drains an area of 49km². It flows northwards through the town of Forres before entering Findhorn Bay. Forres has had a long history of flooding from the burn, with six events causing serious property damage and disruption within the last 50 years.

A new Flood Alleviation Scheme (FAS) included the construction of an upstream earth fill embankment dam designed to allow for discharges up to 8.5 m³/s to flow through Forres, with excess floodwater temporarily stored behind the dam.

This upstream storage area, the focus of this case study included an extensive natural sediment accretion zone. It has a large capacity to store sands and gravels and also retain large woody material. This will reduce the risk of sediment blockage or damage of the dam control structure from sediment or large wood respectively.

The implementation of this natural sediment accretion zone replaced the need for a conventional sediment trap as part of the wider FAS.

Managing Overland Floodwaters

6

The work aimed to create a mosaic of river and floodplain habitats by allowing active river processes to develop a multi-threaded (anabranched) system together with floodplain wet woodland features.

Prior to the work, the burn was a degraded perched watercourse and flowed around the edge of the field (*see Figure 6.4.1*), with dredged spoil deposits used to build the flood embankments, thus disconnecting the burn from its floodplain area.

Design

Two breaches of the existing embankments (*see Figure 6.4.1*) were created to allow flow to spill out across the floodplain. Their locations were selected using LiDAR imagery to identify low areas of land suitable for the course of the temporary "basic" channel, which was constructed to ensure that there was no interruption in migratory fish passage.

The overall aspiration was to then allow natural processes to develop a multi-thread watercourse. Initially the upstream breach in the bank was set to maintain 80% of the lower flows in the existing channel, and protected using thirty tonnes of locally sourced granite placed within the breach opening. This was to ensure that species within the existing channel could continue to use the available habitat whilst the new watercourse continued to develop.

A low embankment was constructed parallel to the new channel close to the site boundary (*see Figure 6.4.1*). this was to protect adjacent fields outside the area of the burn management works from flooding. Material was won from digging a small ditch which avoided the need to import fill over very soft ground.

Tree planting was undertaken as part of the scheme to encourage the development of wet woodland. Only tree species native to eastern Scotland and of local provenance were selected for planting including: common alder - *Alnus glutinosa* (25%); silver birch - *Betula pendula* (25%); sessile oak - *Quercus petraea* (25%); rowan - *Sorbus aucuparia* (15%); and goat willow - *Salix caprea* (10%).

Whips, between 0.45m and 0.6m in length were planted, as these tend to establish well and grow more quickly than more mature specimens. The whips were planted in clumps of three to five of the same species, spaced at two metre centres, with a planting density to allow for some failures. Mesh guards were not installed to protect the whips since there was a risk they would be washed off during a flood event and could pose a hazard to wildlife. Additionally, there was concern that any mesh could have introduced man-made debris into the natural environment downstream.

The upstream breach two years post construction: widening of breach and gravel deposit to the left; abandonment of the old course on the right (blue arrow=new route.red arrow=old route) – 2010

© Scot Avia

Sediment accretion area/outwash fan has developed at the upstream breach – July 2011

Subsequent performance

Approximately one year after the banks were breached in September 2009 the channel experienced an estimated 30m³/s flood flow (of the order of a 1 in 10 year event). The stone protection at the upstream breach was partially washed out, as anticipated. The breach enlarged such that the majority of the flow was diverted along the new route after the flow subsided. The result was rapid development of river features, including the formation of an outwash fan (*see Figure 6.4.1*). Some ecological degradation has occurred in the short term, as the old channel is now dry except during very high flow events.

The flow interacted with woody material situated in the widened upstream breach causing erosion on the right bank of the original channel. Measures were taken to mitigate against further erosion on th eopposite bank, since any breach occurring at this location could result in flooding of a significant area of valuable grazing land. Small scale on-going adaptive management is predicted to be necessary in the short to medium term until this modified river system becomes better established.

The wet woodland habitat remains in the early stages of development but has already attracted a diverse range of flora and fauna (especially birds). Many of the unprotected whips were eaten by deer soon after being planted; it is hoped that this floodplain feature will naturally recover over time.

Managing Overland Floodwaters

© Royal Haskoning

Channel development. The acretion area is storing woody material and river sediments – March 2012

© Royal Haskoning

The material used to construct the low embankment was soft peat. The consistency of the material was subsequently found to be insufficiently resilient to avoid damage during flow events that spilled into the wider flood storage area. Minor breaches occurred in two locations along the embankment, which now allow water to flow in to the low area on the boundary of the site.

Overall this scheme illustrates what can be achieved when working with natural sediment transport processes in flood storage zones. In 2010, the Saltire Society of Scotland in association with the Institution of Civil Engineers awarded the Forres FAS its 'environmentally sustainable construction' commendation.

Contacts

Matthew Hardwick, Royal HaskoningDHV
matthew.hardwick@rhdhv.com, 01733 334455

Paul Winfield, Royal HaskoningDHV
paul.winfield@rhdhv.com, 01392 441376

Carina Oliver, Royal HaskoningDHV
carina.oliver@rhdhv.com, 0131 56122296

Reference material – Click here

7

Creating Floodplain Wetland Features

7.1 Floodplain scrapes

River Skerne
Location - Darlington, Co Durham NZ301160
Date of construction - Autumn 1995 (in meanders), May 1996 (at Rockwell)
Number – 2 excavated; 1 in backfilled chanel
Cost – £1,000 each for excavation

Completed spring-fed scrape

Description

The term 'scrape' is used to describe a shallow pond that forms in a natural lowspot in a floodplain. Scrapes are sometimes dry during the summer unless they are fed by springs. The most common reason for their occurrence is probably the historic migration of a river across a floodplain leaving only partially filled channels behind but there are many other reasons. Scrapes afford off-river habitat for plant and animal species dependent on their unique characteristics, including frogs and newts.

Three new scrapes were formed on the Skerne floodplain. The first two were located within the meanders of the newly realigned river (*see Technique 1.4*) and the third within Rockwell Nature Reserve, alongside the main east coast railway line (*see key plan preceding the technique section*).

Design

Scrapes within meanders
The south side of the floodplain is partially overfilled with industrial waste contained within a clay bund. Clean water was observed to be seeping from the toe and to be sustaining a lush growth of grass (mown) all year round. A scrape was excavated within this area of low artesian water pressure so that full advantage could be taken of the opportunity to introduce a significant wetland feature to the floodplain (*Figure 7.1.1*).

The irregular shape fits comfortably within the limited area available and the depth has been limited to 0.3m in the interest of public safety, as well as to suit the emergent and marginal aquatic vegetation sought. The side slopes are very shallow for similar reasons. No overspill was built. In very wet periods excess water seeps towards the river over the grassed area alongside.

On the north side of the new meanders the old, straight, river channel has been infilled in places. Immediately downstream of the first meander (entry bend) infilling was profiled to leave a shallow depression, intended to attract surface water from the adjoining parkland, thereby creating a small wetland feature during the winter.

Both scrapes were subsequently planted by organised parties of local school children. Species included Ragged Robin, Loosestrife, and Meadowsweet that were grown from seed as part of a school project linked to an English Nature series of freshwater guidance publications.

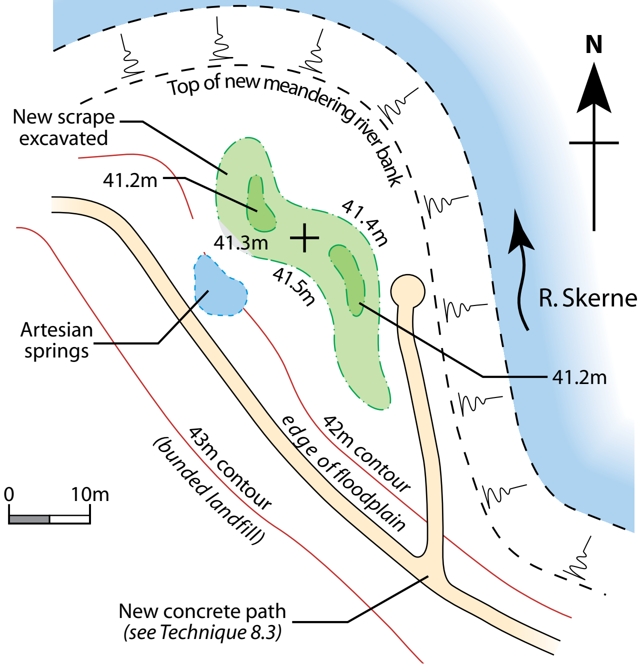
Scrape at Rockwell Nature Reserve
The reserve is a well-established wetland site where several ponds and scrapes have been excavated in an area of low artesian ground water pressure sustained by rising ground alongside. Great crested newts are a protected species found in the reserve. The area of the reserve nearest to the river was, however, marred by piles of dumped soil and rubble that have overgrown with less desirable ruderial plants.

These techniques were developed to suit site specific criteria and may not apply to other locations

Creating Floodplain Wetland Features

7

Figure 7.1.1
PLAN OF SCRAPE WITHIN MEANDER FED BY GROUNDWATER



View of Rockwell scrape site after removal of rubble piles

Comparitive view of Rockwell scrape after work completed

Some piles were cleared from site and the ground taken down to expose historic floodplain soils, although these were found to be interspersed with deposits of dumped foundry sand. These sands were also evident throughout the restored floodplain, marking Darlington's industrial history of iron works.

Working closely with the local Wildlife Trust, a new scrape was then excavated and the spoil removed from site. The scrape is about 50m^2 in area and slopes gently down from one side to a maximum depth of 1m where it returns steeply to ground level forming a small cliff that is overhung by pre-existent willow carr.

Subsequent performance 1995 – 2001

Both scrapes excavated within artesian ground water areas have proved to be very successful, sustaining wetland habitat year round and providing visual interest to previously unremarkable areas.

The scrape formed in the backfilled river course has not been successful, although it does collect water occasionally. This has not been sufficiently frequent, or prolonged, to establish any wetland plants. The scrape has been colonised by the same species of grass and wild flowers sown around it, but they are weakened as a result of occasional waterlogging. It is arguably a nuisance in this public open space since it provides no discernible ecological or amenity benefits.

It is reasonable to conclude that for floodplain scrapes to provide worthwhile ecological value they are dependent upon a reasonably reliable source of groundwater or surface water, albeit most are intrinsically seasonal features that do not have to be wet for more than 6-9 months of the year.

Surprisingly both duck and moorhen spend time on the artesian fed scrape within the meanders where they are highly visible from the new path built alongside (*see Technique 8.4*).

7

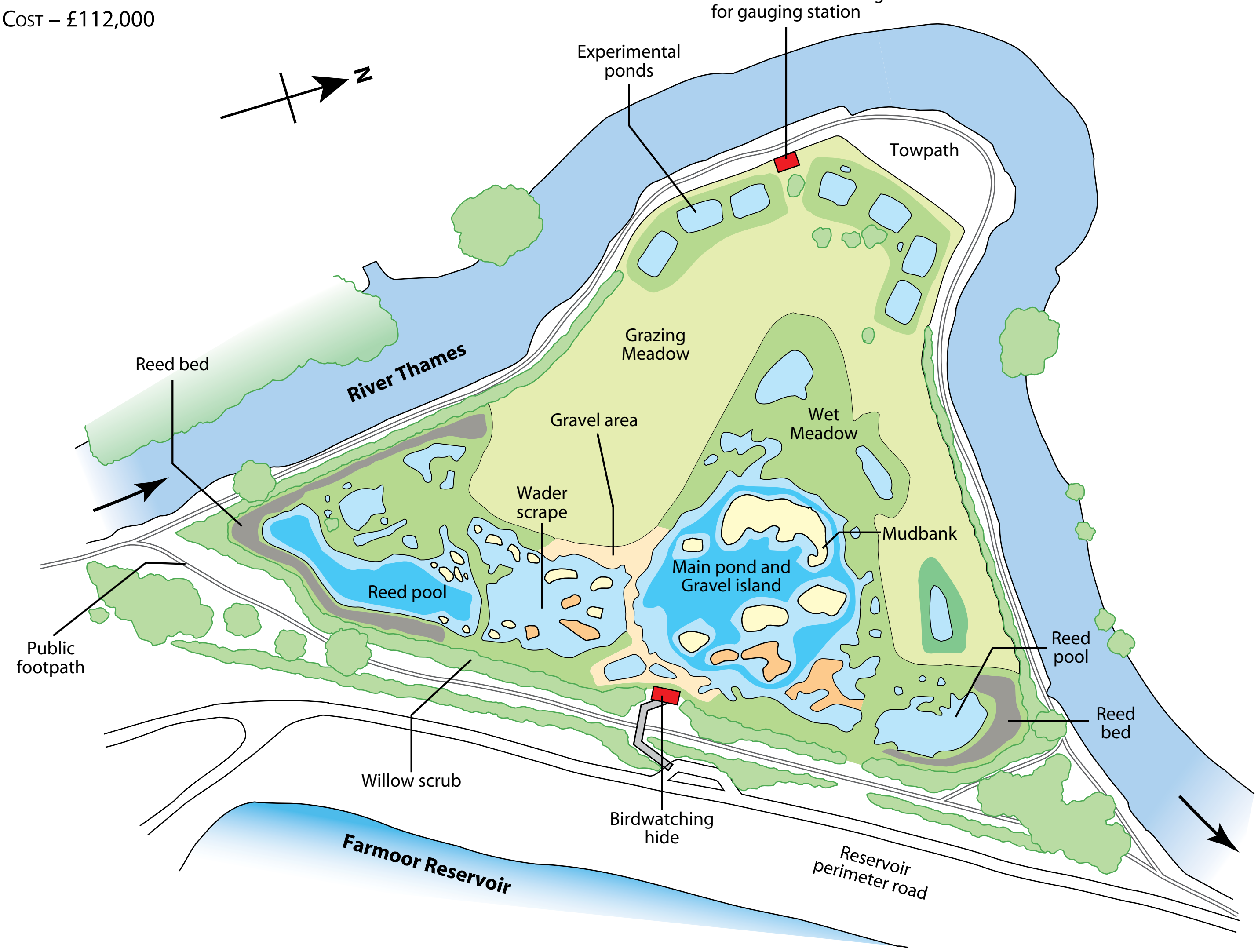
THE RIVER RESTORATION CENTRE
Working to restore & enhance our rivers

Creating Floodplain Wetland Features

7.2 Floodplain wetland mosaic

River Thames
Location - Pinkhill Meadow, Farmoor Reservoir, Oxfordshire SP 439067
Date of construction - June 1990, December 1991
Length – 1.5ha
Cost – £112,000

Figure 7.2.1
Plan of Pinkhill Meadow



Description

Pinkhill Meadow is located in a 4 hectare meander of the River Thames at Farmoor Reservoir. In a detailed landscape assessment of the reservoir site in 1988 the meadow was identified for its potential for wetland creation. Few areas of wetland had survived agricultural improvement in this part of the Upper Thames Valley. Approximately 1.5 hectares of the meadow still had a valuable relic meadow flora including species such as Adders Tongue, Great Burnett and Pepper-Saxifrage.

The aim of the scheme was to complement the river and the reservoir habitats by restoring the floodplain wetland within the meadow which had been largely disturbed during reservoir construction.

A key objective was to restore habitat for breeding waders and wildfowl, notably redshank, and to create a place where people could experience a wide variety of wetland wildlife at close quarters and enjoy a more "natural" floodplain landscape.

The project was a collaboration between the landowners (Thames Water) and the National Rivers Authority (NRA), advised by Pond Action.

A concept plan for the site was prepared from the landscape appraisal and developed into the detailed design, incorporating the project objectives with the site constraints.

These techniques were developed to suit site specific criteria and may not apply to other locations

Creating Floodplain Wetland Features

7

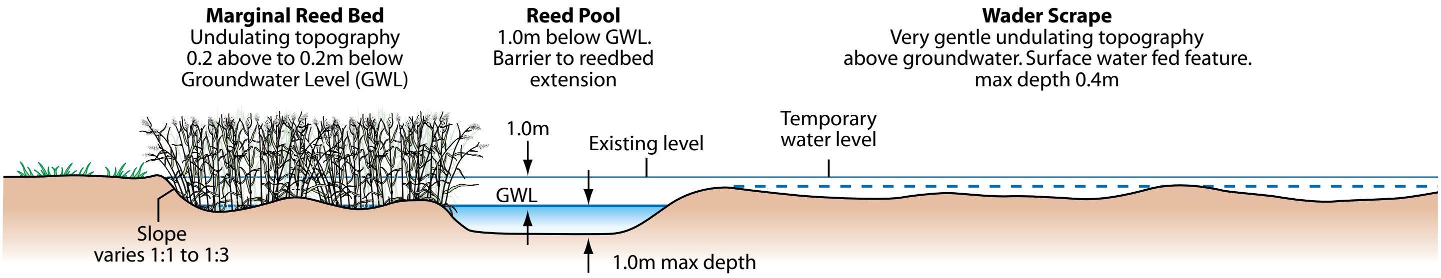


Figure 7.2.2
INDICATIVE SECTION THROUGH REED POOL

Design

A concept plan for the site was prepared from the landscape appraisal and developed into the detailed design, incorporating the project objectives with the site constraints.

The mosaic of over 40 ponds and pools was designed to maximise the topographical, and hydrological diversity of the site. This included specific creation of individual waterbodies with a wide range of maximum depths and permeability, and low angle, undulating drawdown zone areas to encourage wetland plant diversity.

Two phases of excavation were undertaken, the first in June and July 1990 and the second over the winter period in 1991/2. By phasing the works it was possible to better understand the detail needed for the more complex works in the second phase.

Excavation was based on detailed landscape design drawings provded by the NRA landscape architect, and firmly led by close project management and continuous on-site supervision from key members of the project team. In this way the inexperienced machine operator was able to achieve the very subtle variations in topography in relation to water levels. The 20,000m^3 of excavated material was carefully graded into a low hill near the adjacent Pinkhill Lock, but outside of the floodplain. This was then planted with trees and shrubs and sown with a wildflower seed mix.

In phase 1 four waterbodies were created; the main pond, wader scrape and two reedbed pools. In phase 2 the existing waterbodies were extended, added to and re-profiled to create areas of shallow water, wet meadow, mudflat and temporary pool habitat.

Observations of the phase 1 works provided valuable detail for the improvements undertaken in phase 2. Observations of actual as opposed to design water levels in the pools were used to refine the new excavation levels, marginal areas and undulating contours of the wet meadow. The location of the mudflats was also based on the usage of the various areas of the site by different bird species.

Key features created:

Deep water
The main pond is up to 2.5m deep and covers an area of just under 0.5ha and was excavated down into the gravel aquifer. The size and depth increases the diversity of habitats and isolates the several islands reducing the likelihood of predation of bird nests. The depth also ensures open water and from a management viewpoint it also restricts the complete colonisation by marginal wetland plants.

Shallow-water areas and edges
These areas were designed to between 0.3m below and 0.1m above normal water levels. As the main pond level will fluctuate by about 0.3m, reflecting groundwater levels, these areas are important to retain shallow slopes at the water's edge.

Wader scrapes
– February 1992

7

Creating Floodplain Wetland Features

Main pond, pool and reedbed creation – February 1992

Temporary ponds and pools
The site also includes small temporary pools, some isolated and some bordering the larger waterbodies. Sizes vary from a few square metres to the larger two semi-permanent ponds (approximately 100m²). These transient ponds are designed to dry out in drought years (two or three times since excavation) and provide a habitat with low fish predation, benefiting many aquatic invertebrates and some amphibians.

Wader scrape
A 400mm maximum depth shallow pool was formed within the alluvium overlaying the gravel aquifer and the water level controlled by means of a connecting pipe to the main pond. This feature provides extensive muddy margins for feeding waders and Teal, particularly during autumn migration.

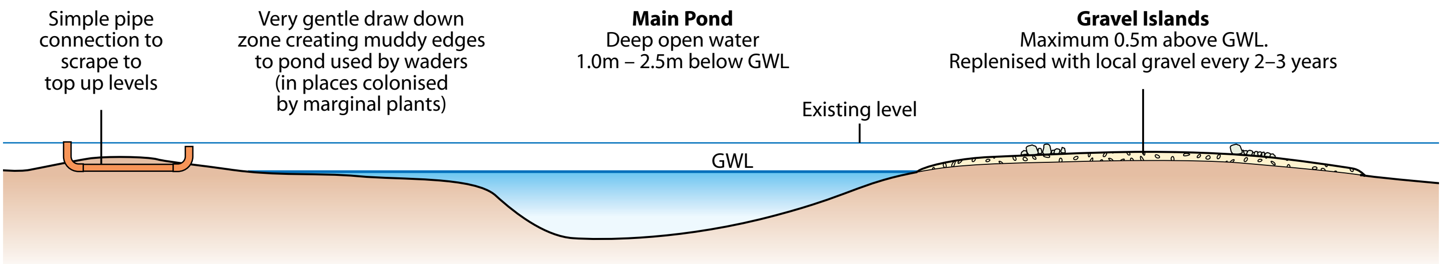
Gravel islands and margins
Created over an area of 0.1ha, these provide nesting habitat for Little Ringed Plover and Common Tern. The gravel was carefully selected from a local source to ensure a good size distribution, important for some nesting birds. Selectively placed cobbles and boulders also provide some cover.

Mudflats and islands
These were created by excavating into the alluvium. Gentle slopes of 1:20 minimum provide feeding and nesting habitats for wading wildfowl, but also created a more open habitat suitable for some marginal wetland plants.

Undulating wet grassland
Small variations in topography were engineered to create an undulating meadow with water levels close to the surface (between 0.1m and 0.2m above normal water level). This marshy/tussocky Rush and Sedge dominated area was designed to provide feeding and nesting areas for waders, particularly Redshank and Snipe.

Reedbeds
Two linear reedbeds, totalling over 250m in length, were excavated along the eastern edge of the site. Shallow trenches were dug and planted with pot grown Common Reed. These serve as a boundary to human disturbance from adjacent footpaths and provide valuable nesting and foraging habitat for wetland birds such as Reed Warbler and Water Rail.

Figure 7.2.3
INDICATIVE SECTION THROUGH MAIN POND AND GRAVEL ISLANDS

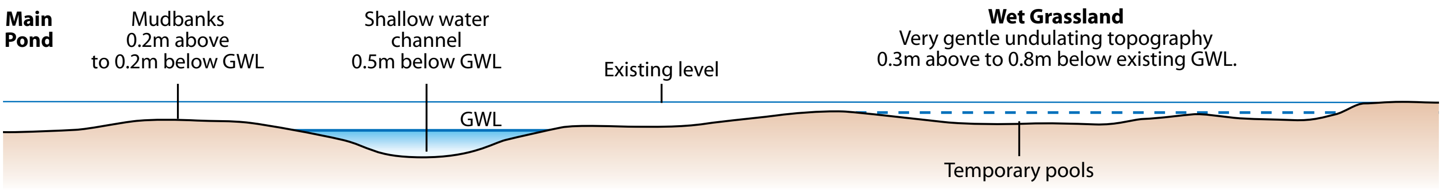


These techniques were developed to suit site specific criteria and may not apply to other locations

Creating Floodplain Wetland Features

7

Figure 7.2.4
INDICATIVE SECTION THROUGH WET GRASSLAND



Scrub
A double row of mixed shrubby Willow (incorporating some Hawthorn, Blackthorn and Dog Rose) forms a 4m wide hedge at the eastern edge of the site linking adjacent areas of reed, meadow, hedges and woodland. As with the reedbed the presence of the hedge also helps to mitigate the disturbance of the nearby footpath, as well as sustaining a rich insect population and providing over-wintering cover for frogs, toads and newts. The scrubby character is to be retained by staggered coppicing on an annual basis ensuring a permanent screen is maintained.

Subsequent performance 1995 – 2001

Continuous post-project appraisal was carried out on this site for the first 5 years after construction and the results showed that this small wetland creation scheme quickly acquired an extremely rich wildlife community.

In these 5 years over 20% (over 60 species) of all Britain's wetland and aquatic plant species colonised the site. In the main pond alone the plant community was one of the richest recorded in ponds in the county. Similarly 22% (over 150 species) of Britain's macroinvertebrate species were recorded on the site, including 12 breeding species of dragonfly.

Breeding wader densities have been very high, in one year up to 100 pairs/km^2 equaling that of grazing marsh and other important British wader habitats. In 1993 and 1994 two pairs of Little Ringed Plover bred, representing 15% of Oxfordshire's breeding population. Unfortunately the site was too small to sustain such densities and the plovers have not returned since 2000.

As a result of the commitment of the partners and the continued appraisal of the site's development some minor and major modifications have been funded in every second or third year between 1992 and 2002.

These have included:
- managing gravel islands;
- scraping new mudflats;
- creating new pools;
- doubling the size of the main reedbed;
- annual coppicing and thinning of the willow scrub.

A key reason for the huge success of Pinkhill, in terms of its pond creation, is the combination of three critical factors for creating biologically high quality sites:
- good water quality;
- high degree of landscape connectivity to other wetlands;
- complex mosaic design.

Original Information Providers:
Richard Hellier
Ponds Conservation Trust

Aerial view of site – 3 years after – October 1995

7

Creating Floodplain Wetland Features

7.2 Pinkhill Meadow 2013 Update

River Thames	Medium energy, clay
WFD Mitigation measure	Preserve and, where possible, restore historic aquatic habitats
Waterbody ID	GB106039030333
Designation	BAP Priority Ponds
Project specific monitoring	Macrophyte, Macroinvertebrate, Wetland birds

The Pinkhill Meadows project has been extremely successful in demonstrating that high biodiversity clean water ponds can be created. The concepts at Pinkhill have been applied extensively in the Million Ponds Project and in UK biodiversity policy.

Four monitoring pools have been regularly surveyed since works were completed. These have indicated that rich macrophyte, aquatic macroinvertebrate and wetland bird assemblages have been created, with rapid colonisation following project works. Following colonisation, the site is now in the top 10% of pond sites in the UK for aquatic macro invertebrates, supporting approximately 20% of all UK wetland plant and macroinvertebrate species.

Removal of Bulrush (*Typhalatifolia*) occurred in the 5 years following the works to prevent initial domination by this species. Invasive species, in particular New Zealand Pygmyweed (*Crassulahelmsii*),are a recent concern. Management of the site has changed over time – sometimes left abandoned for a time and, at others, focussed on specifically. Costs for this have been modest with a lot of the work carried out by volunteers. The reintroduction of grazing in 2008 has been welcomed as a management technique to open up marginal areas and prevent further encroachment of reeds. Maintaining grazing is identified as a priority.

© RRC

Main pond and gravel island continue to provide favourable habitat for wetland species – August 2013

Contacts

Alastair Driver, Environment Agency
alastair.driver@envrionment-agency.gov.uk, 07836 600868

Pascale Nicolet, Pond Conservation
p.nicolet@pondconservation.org.uk, 01865 483694

These techniques were developed to suit site specific criteria and may not apply to other locations

8

Providing Public, Private and Livestock Access

8.1 Fords and stock watering point

River Cole
Location - Coleshill, Oxon/Wilts border, SU234935
Date of construction – Autumn 1995
Length – 4 fords and 1 watering point
Costs – Fords £1,000 each. Watering point £1,000

Stock watering point at ch. 100m

Description

Two new fords and a stock watering point were created in the restored reach of the river downstream of Coleshill mill. Upstream of the mill two new fords were created (*see Part 1, Figures 1.1.1 – 1.1.2*). Each ford enables livestock to cross the river easily, as well as doubling as a drinking place. Those upstream of the mill are also used by farm vehicles and those downstream form part of an equestrian trail. Although all are similar in concept the configuration of each is significantly different to take advantage of local topography.

Design

Downstream of mill
All three features were created at locations where the old, straight river course was crossed by the newly excavated meandering course. Each is formed within the old backfilled river course where the soils are loose and susceptible to erosion. Rather than protecting the banks with revetments, each was set back from the true line of the new river by incorporating stoned access ramps (1:6 or flatter) to form either a ford or a stock watering point. As the new river bed at each point is filled to circa 1m above the old bed this too needed to be protected with stone surfacing.

Stock watering point at ch. 100m (Figure 8.1.1)
Located at ch. 100m just downstream of a sharp bend in the new river course where a fast flowing riffle of gravel was expected to form. This hydraulic condition, combined with the careful contouring of the adjacent river banks, helps to avoid the risk of siltation that all too often renders watering points useless. The post and rail fencing around the ramp is tied into bank top fencing on either side, as well as across the river, to form a secure field boundary point.

The river fencing comprises a single heavy wire cable strained tightly across on a diagonal line (*see photograph above*). The extra length of the diagonal renders the cable less likely to form a complete blockage of the river if floating debris becomes snagged on it. The angle of the diagonal is aligned to direct turbulence caused by its presence towards the mouth of the watering point, further reducing the risk of siltation.

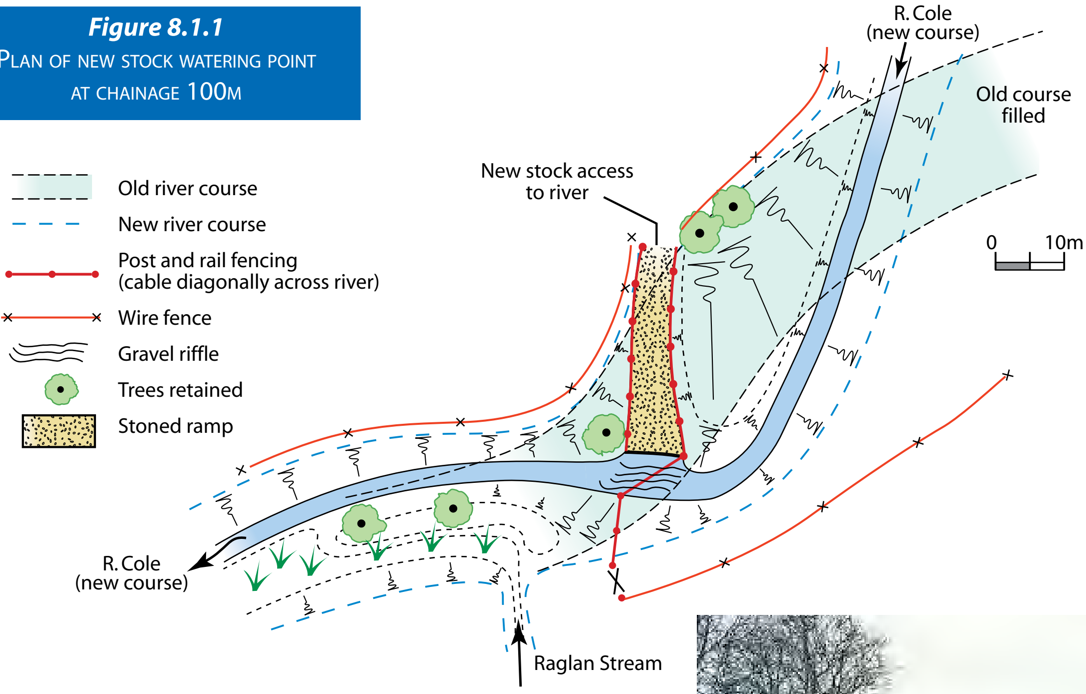
The ramp, its upstream flank, and the river bed are all formed over compacted fill, and flat surfaces are covered with stone over a filter fabric.

These techniques were developed to suit site specific criteria and may not apply to other locations

Providing Public, Private and Livestock Access

8

Figure 8.1.1
Plan of new stock watering point at chainage 100m

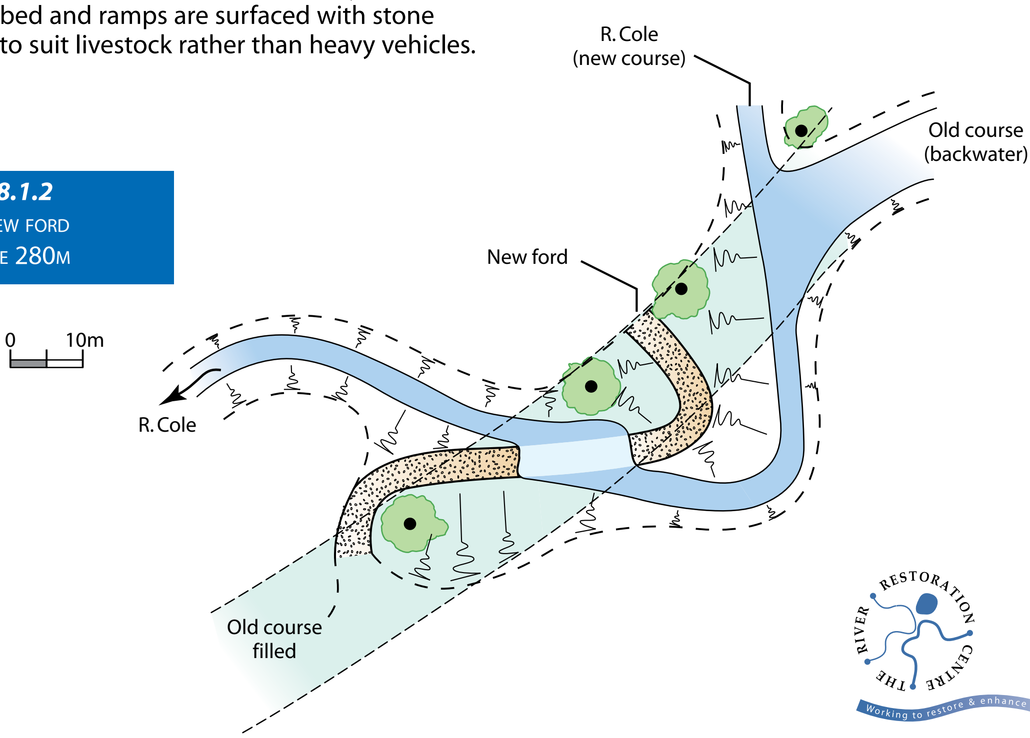


The ford at ch. 280m (Figure 8.1.2)
Aligned between three mature trees on the old river bank to create an 'S' shaped feature, it crosses the new river bed on a long diagonal (circa 15m compared with the typical bed width of circa 3m). The position of this diagonal approximates to the likely position at which a self-sustainable point bar of gravel would form, because of the sharp bend just upstream.

Most of the ford is formed within the old backfilled river channel, which is carefully contoured to create smooth transitions with undisturbed ground on both sides of the river, as well as with the root levels of the three trees and with the newly excavated channel. The river bed and ramps are surfaced with stone over a filter fabric to suit livestock rather than heavy vehicles.

Ford at ch. 280m

Figure 8.1.2
Plan of new ford at chainage 280m



8

Providing Public, Private and Livestock Access

The ford at ch. 620m (Figure 8.1.3)
This ford incorporates an old bankside willow on one side and crosses the new river course tangentially. This is not a natural gravel deposition point in the river (unlike the examples above) so the ford needed to be artificially strengthened if it was to remain in position. Another reason for strengthening was that the ford helps to avoid the risk of the new river channel down-cutting at this vulnerable point (*see Technique 1.2*).

The ford was formed to provide an 'overwide' river bed (circa 6m compared with circa 3m typical) and was elevated above the mean bed by circa 0.3m. This configuration was necessary to ensure that the normal river base flows 'weir' over at shallow depths so that it remains passable without being unduly sensitive to small increases in flow. During floods, the ford is completely 'drowned' and has no significant effect on water levels.

The old river bed was infilled to a depth of 1m and reinforced with a 0.4m thick layer of 0.15m sized stone that was run-out downstream to provide a gently sloping 'riffle' effect. The ramps each side were sloped at 1 in 6 and smoothly contoured into the bank lines of both old and new channels, as indicated in the figure. This contouring resulted in flat bank slopes that did not need revetting, although largely formed within fill.

Upstream of the mill
Two fords are incorporated into the new meandering river channel excavated in undisturbed ground throughout its length.

Ford at ch. 0m
This is integrated into a new drop weir and is fully described in *Technique 5.2*. The ford is not essential to the restoration project but given the small cost additional to the building of the weir it represents a worthwhile extra for the tenant farmer.

Ford at ch. 250m
The ford is shown diagrammatically in *Technique 2.2, Figure 2.2.1*. Its purpose is to provide vehicular access across the river in conjunction with the nearby crossing over the mill leat (*see Technique 8.2*). The ford is configured as a point bar located downstream of a sharp bend in the river. It crosses the river diagonally such that the ramp on the inside of the bend could take the form of a natural shoal of gravel that gently rises up to field level, mimicking the geomorphology of upland rivers where point bars and shoals of gravel often serve as crossing points. Because there is no significant bed load of gravel in the River Cole, the bar and shoal had to be artificially created using crushed stone and aggregate.

Equestrian ford at ch 620m

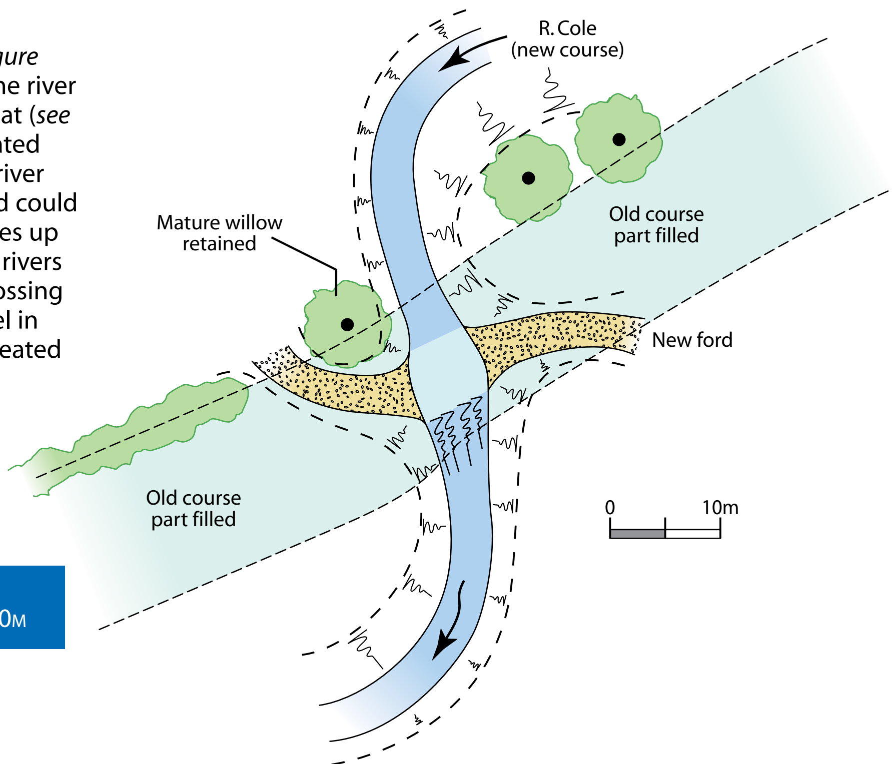


Figure 8.1.3
PLAN OF NEW FORD AT CHAINAGE 620M

These techniques were developed to suit site specific criteria and may not apply to other locations

The ramp on the outside of the bend was simply graded up to the new crossing over the leat and its flanks were contoured to form smooth transitions with the river banks on both sides. A flood spillway on the side of the mill leat is located near to the ford (spillway **S2** *see Technique 6.1*) so the hydraulics at the location are fairly complex. The bank contouring needed to reflect this by ensuring that all slopes were flatly graded and rounded off to minimise the risk of scour damage from turbulence during high flows.

Subsequent performance 1995 – 2001

All of the structures described have established well without the need for any adjustments or maintenance. This is particularly important since each is designed to be sustainable within the natural hydraulics of the new river channel.

Despite the commonality of the design concept, each is individually configured to take advantage of local conditions and this is evident in the variety of visual interest and habitat diversity that has resulted. Of particular note, water crowfoot is thriving in the tailstone of the equestrian ford and ch. 620m.

The fords and stock watering point downstream of the mill were created in preference to forming reveted river banks and have proved to be a practical option. As the marginal cost differences of this approach are small it should be worthy of consideration at other similar locations.

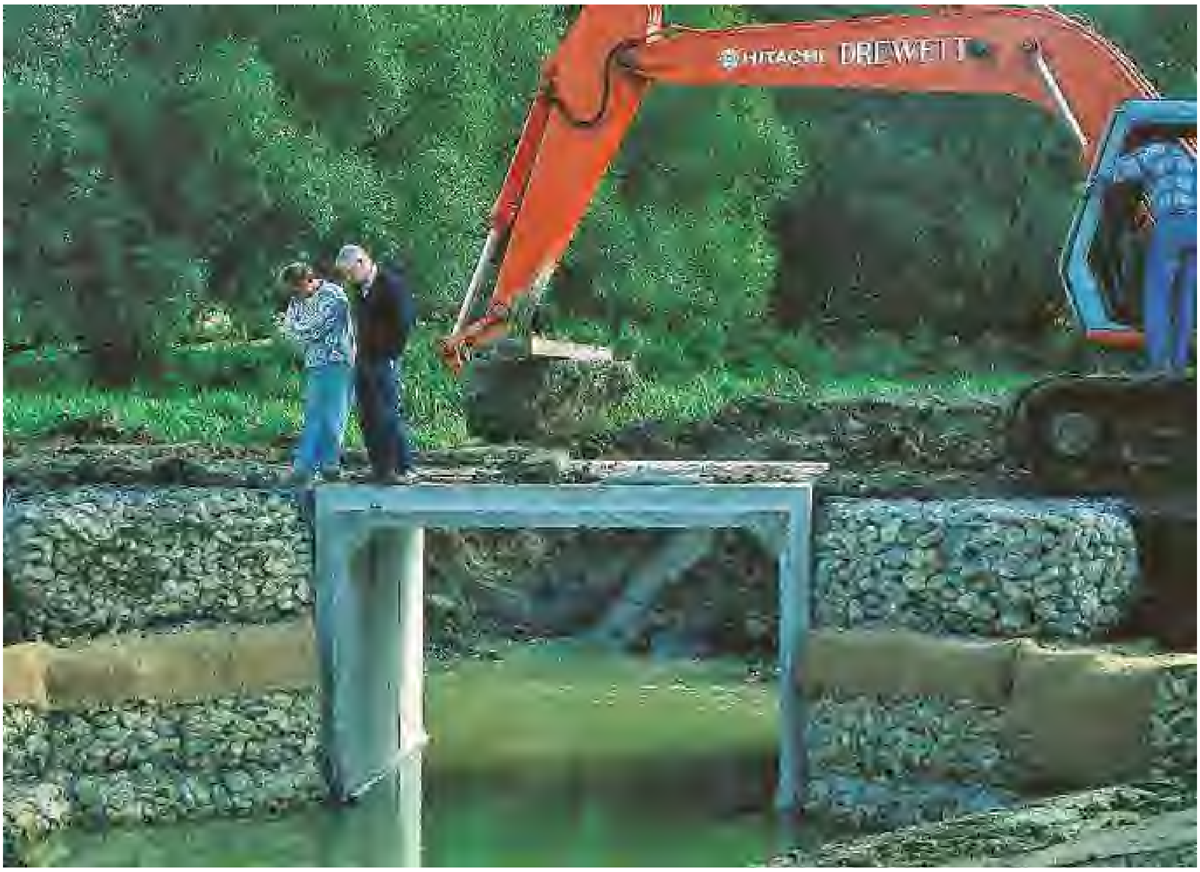
Vehicular ford upstream of mill at ch. 250m

8

Providing Public, Private and Livestock Access

8.2 Watercourse crossings

RIVER COLE
LOCATION - COLESHILL, OXON/WILTS BORDER, SU234935
DATE OF CONSTRUCTION – AUTUMN 1995
COSTS – CONCRETE CULVERT £8,700
– STEEL CULVERT £3,000



New concrete culvert crossing under construction

Description

Two new crossings were required to suit farm vehicles and river maintenance plant. The design needed to be functional but at the same time to be visually acceptable without incurring excessive additional costs to achieve this balance. The use of readily available pre-fabricated materials was favoured, since this typified the practice of most farmers and landowners who need such crossings - the aim was to demostrate easily replicable and cost effective design concepts.

One structure crosses the circa 10m wide mill leat, and the other a newly enlarged drain feeding floodwaters from the main river channel out onto the adjacent meadows (*see Technique 6.1 for description and location*).

Design

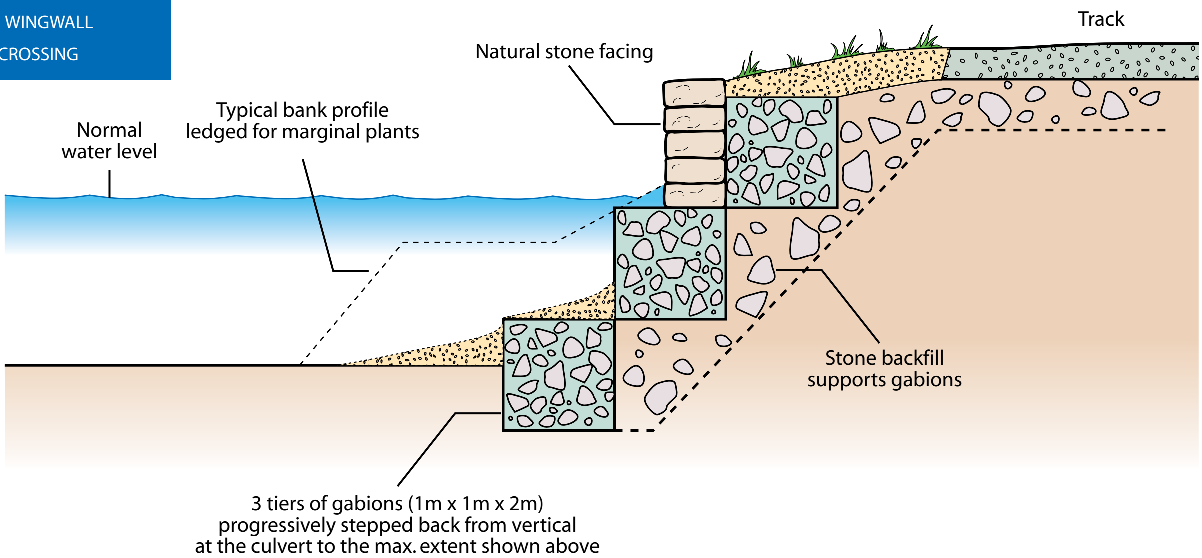
Mill leat crossing (Figure 8.2.1)
The structural elements comprise a pre-cast concrete box culvert 3m wide and 2.1m high that is flanked at each corner with stone filled box gabion wing walls. This arrangement is functionally satisfactory but is most unsightly so great care was taken to detail the wing walls such that visual amenity and habitat potential were improved.

Three tiers of gabions were needed to achieve the full wingwall height from invert to track level. The lower two were set just below the retained water level in the mill leat where they are permanently out of sight. These two layers were set out in plan to follow a 90 degree curve creating a wider river cross-section than the culvert. They were progressively stepped back from the vertical to create a ledge at the top of the first tier.

These techniques were developed to suit site specific criteria and may not apply to other locations

Providing Public, Private and Livestock Access

Figure 8.2.1
Section through wingwall of box culvert crossing



Completed 'bridge'

The upper tier followed a similar curve but was continuously stepped back sufficient to allow a stone wall to be built around the front face - this wall is the only visible element and it is decorative rather than structural. By stepping back the gabions the sloping river banks adjacent could be brought smoothly into line with the gabions and also accommodate an underwater ledge for aquatic marginal plants. The combination of marginal plants and stone walling are intended to draw the eye away from the concrete box which is a relatively minor feature of the overall visual aspect evident in the photo.

8

Providing Public, Private and Livestock Access

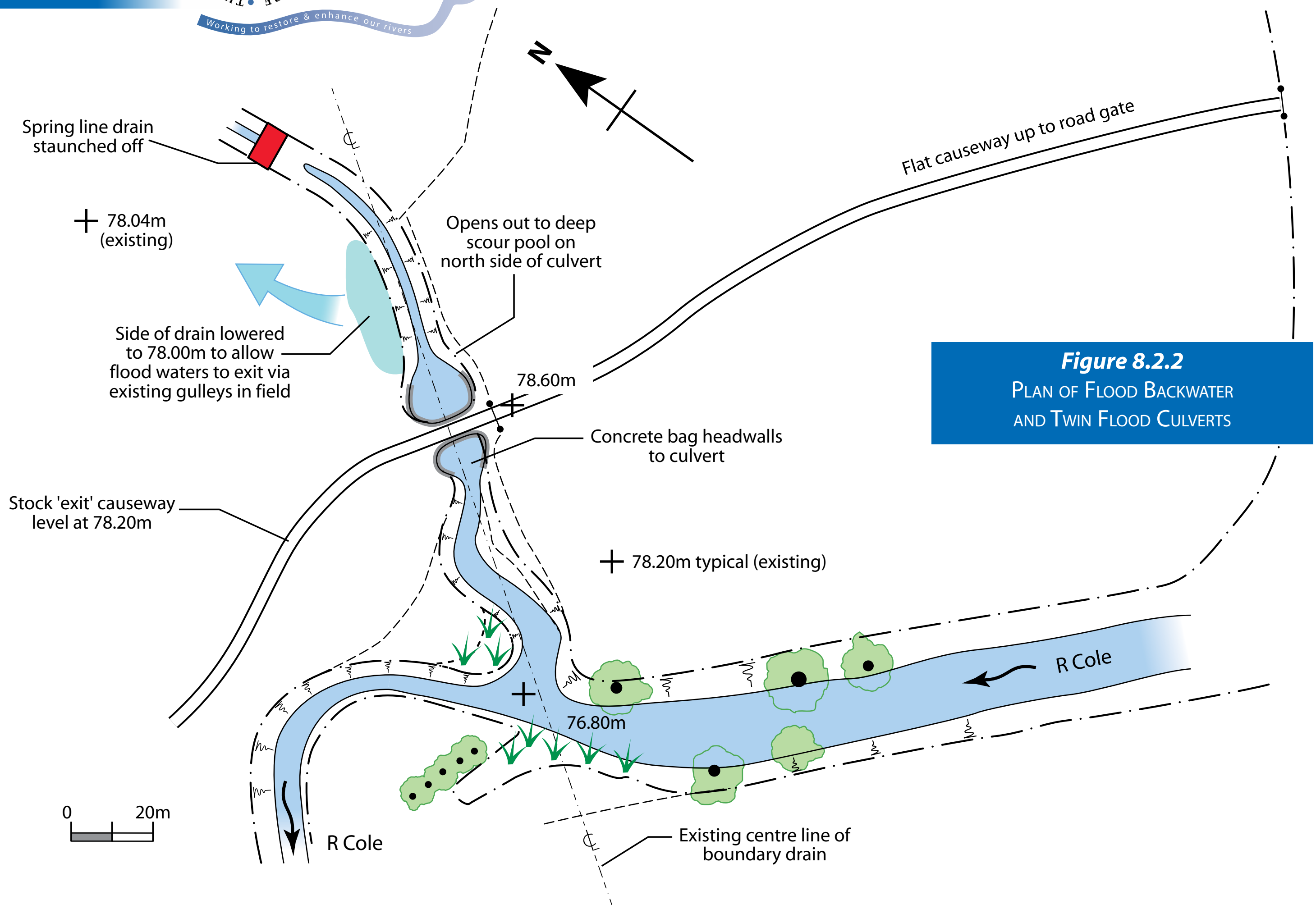


Figure 8.2.2
Plan of Flood Backwater and Twin Flood Culverts

Flood drain crossing (Figure 8.2.2)
This crossing is located downstream of the main road adjacent to spillway S4 (*see Technique 6.1 for plan and details of the drain*).

The flood drain is only 1m deep and two pipes of this diameter were needed to provide sufficient area to pass floodwater. Corrugated galvanised steel pipes were selected by the contractor; they are readily available and easy to install. When laid side-by-side they measure about 2.5m across, which is wider that the drain. The design of the headwalls at both ends, therefore, needed to form a smooth transition between the 'over-wide' pipes and the relatively narrow trapezoidal channel.

Concrete filled hessian sandbags were used to achieve this complex geometry. Another consideration was that the pressure of floodwaters passing through the pipes might produce high velocities and turbulence

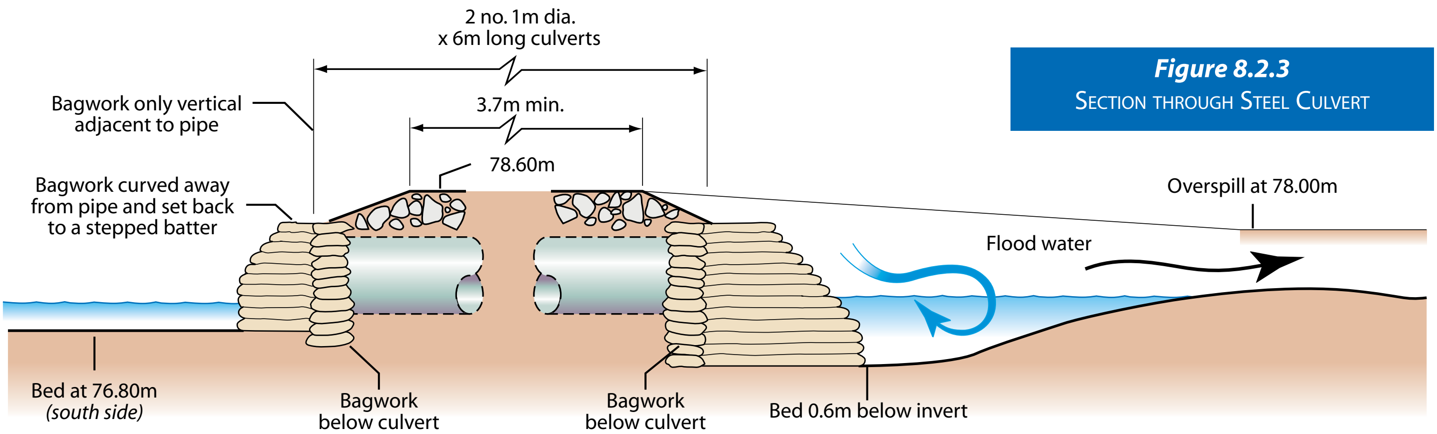


Figure 8.2.3
Section through Steel Culvert

These techniques were developed to suit site specific criteria and may not apply to other locations

Providing Public, Private and Livestock Access

8

The bagwork is built vertically across the face of the pipes and then curved gently outwards through 90 degrees or more with a slowly increasing batter until it merges smoothly into the sloping banks of the drain. The slopes are achieved by stepping the bagwork rather than laying it flat on the banks; the ledges thus formed attract silt and plant growth. The height of bagwork was curtailed close to the level of the pipe soffits.

Concrete bagwork is a versatile method of achieving complex shapes and it can rapidly take on a reasonably aesthetic appearance. This is because the concrete is invariably less dense than pre-cast or poured concrete alternatives and therefore provides a suitable surface for a variety of vegetation. The hessian rots away in a year or two, but in the short term it attracts silts which help to establish vegetation, particularly if the hessian is not impregnated with preservatives.

Subsequent performance 1995 – 2001

Both crossings have functioned entirely satisfactorily and present a reasonably attractive appearance within their respective settings.

The design is deliberately utilitarian in concept to demonstrate that even the most basic engineering materials, such as steel and concrete, can be enhanced at little extra cost.

Clear span bridges of good design are generally preferable in all respects to culverts but the additional cost involved could not be justified at Coleshill where short culverts afforded adequate flow area with little risk of problems caused by blockages.

Flood drain crossing seen from bank of R. Cole.
(bagwork wing walls incomplete)

Providing Public, Private and Livestock Access

8.3 Access paths suitable for disabled users

RIVER SKERNE
LOCATION – DARLINGTON, CO DURHAM, NZ301160
DATE INSTALLED – JUNE 1997
LENGTH – CONCRETE PATH 1000M X 1.8M, BITMAC PATH 225M X 2.5M
COST – CONCRETE PATH £55,000, BITMAC PATH £43,000

Concrete footpath and meanders

Description

Prior to the restoration project formal paved access alongside the river was very limited but was found by survey to be high on local peoples priorities for improvements. Two separate paths were included at the locations indicated on the project plan that precedes the techniques section of this manual.

The first passes along the south bank of the river where new meanders were created (*see Technique 1.4*) and links an existing footbridge at Hutton Avenue with a new footbridge near the railway line. A smooth concrete path was built after discussion with the Fieldfare Trust. The Trust is concerned with access for all but has special knowledge of disabled peoples' needs.

The second links an existing high level path bordering housing at Albert Road with the historic Skerne railway bridge that is featured on the UK £5 note. The path drops down to pass under Albert Road and then runs along the north bank of the river. It will form part of a future cycleway through Darlington and is built in bitumen macadam (Bitmac).

Design

Concrete Path
Designed to enable wheelchairs and pushchairs to pass freely, the gradients and surface of the path were such that all users would have easy passage. Resting/passing areas were placed approximately every 100m in positions affording interesting views of the site. The route was determined by the gradient of the land, the extent of winter floodwater and suggestions from the Fieldfare Trust. A proprietary concrete material and surface finish was selected to provide a smooth non slip footing and low maintenance. A buff colour was chosen to blend with the surroundings once weathered.

To intercept rain water running down from the adjacent slopes gravel drains were placed under the path and in others they were positioned alongside the path. A 0.1m layer of crushed stone was laid as standard but where vehicle crossing points were designated, extra stone was used to accommodate the extra loading. Coloured concrete (0.075m min.) was poured and the surface finished in the prescribed pattern.

Bitmac Path (Figures 8.3.1 – 8.3.2)
A great deal of preliminary work was needed before the path could be laid, including:

- revetment of the river bank either side of the bridge;
- retaining walls alongside a gas main and contaminated landfill;
- lowering land levels;
- lowering of manholes.

Providing Public, Private and Livestock Access

8

The route was designed as a combined footpath and cycleway and runs down a grassy slope, beneath Albert Road bridge and along the riverside to Skerne Bridge. Several safety features were incorporated:

- where the ground slopes away steeply, a small mound was placed on the downward side to restrict cyclists to the path;
- riverside hand railing either side of the bridge at the bottom of the slope;
- cycle barriers were placed at the bottom of the slope to slow cyclists as they pass under the bridge;
- the width of path allows wheelchairs to pass;
- level resting areas at intervals down the slope.

Drainage was important. To accommodate this, there is a fall of 50mm across the 2.5m wide path and a longitudinal gulley drain to collect run off from the slope above.

Bitmac footpath towards Skerne Railway Bridge

Subsequent performance 1995 – 2001

Both paths have proved to be extremely popular with all sections of the community and are used by different social groups throughout the day. Initial fears that the paths might become motorcycle tracks have not materialised, probably because they are 'policed' by so many pedestrians. Seating has been requested by older people wishing to rest and view the riverlife nearby.

Drainage of rain water from adjacent slopes proved critical and some remedial works were needed to clear occassional puddles and associated silts that muddied the path.

Figure 8.3.1
Plan of riverside path to Skerne Railway Bridge

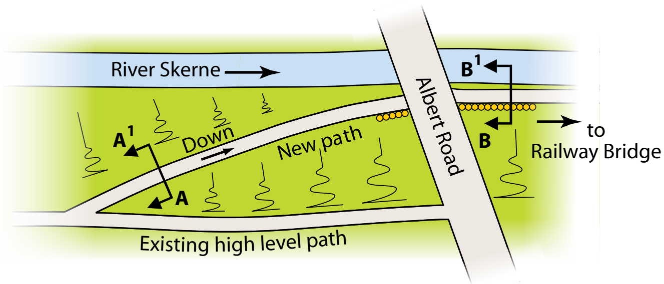
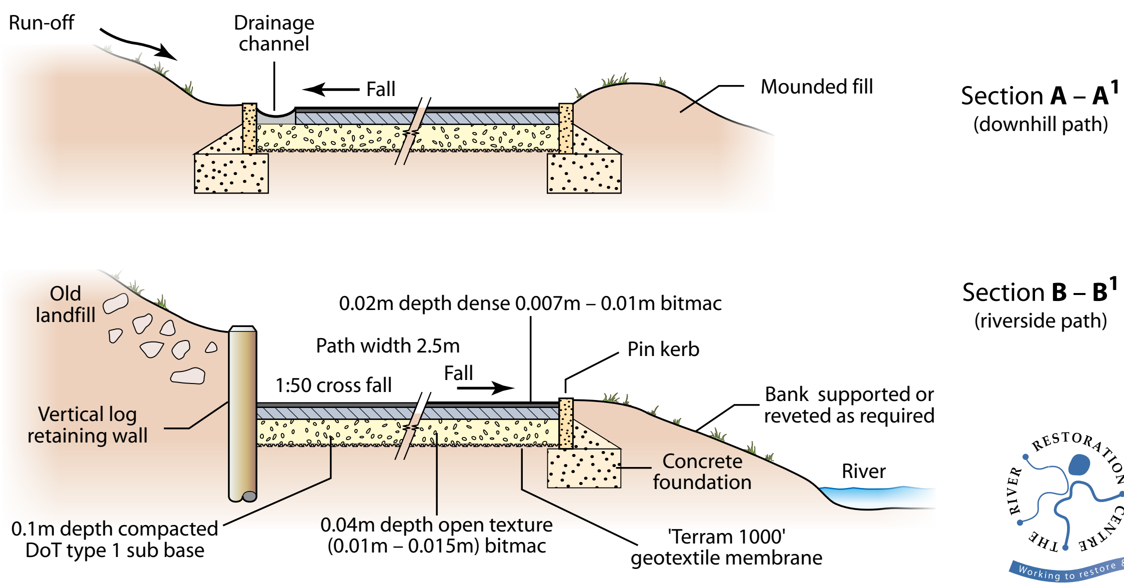


Figure 8.3.2
Section through riverside rath to Skerne Railway Bridge



8

Providing Public, Private and Livestock Access

8.4 Restoring a ford as a stock and vehicular crossing point

RIVER OGWEN

LOCATION - 5KM SOUTH OF BETHESDA, GWYNEDD SH641615

DATE OF CONSTRUCTION - OCTOBER 1998

LENGTH – 20m

COST – £1,500

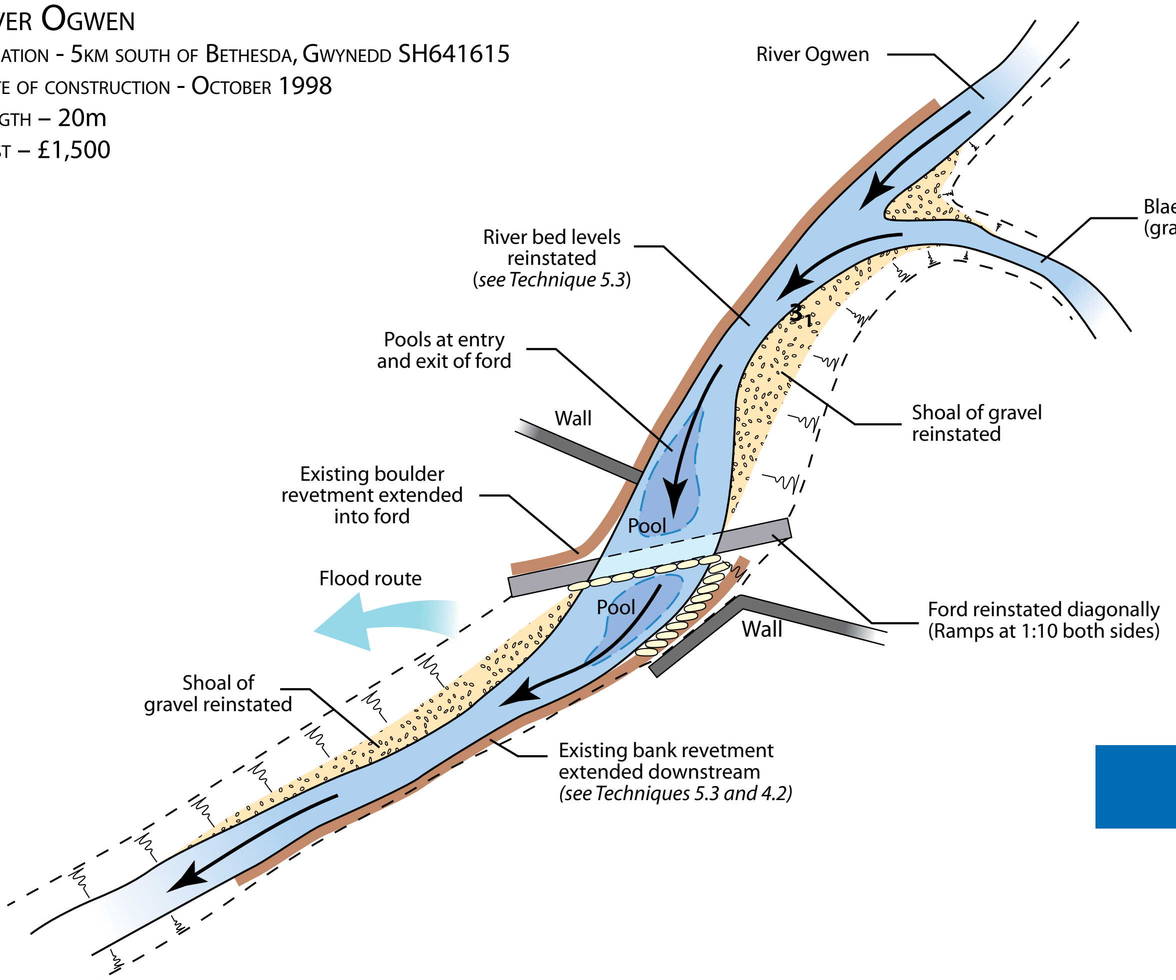


Figure 8.4.1
PLAN OF FORD

View across the deepened river at the old ford location

These techniques were developed to suit site specific criteria and may not apply to other locations

Providing Public, Private and Livestock Access

8

Description

The ford was built as part of comprehensive restoration of the river bed after deepening by dredging in the 1960s (*see Technique 5.3* for full details and a location plan). The ford forms one of a series of fixed points that stabilise the bed at its restored level.

Old Ordnance Survey maps indicated a ford had existed prior to dredging but it had been removed during these works; see photo of conditions pre-restoration. The farmer was keen for the ford to be restored as a stock and vehicular crossing point.

Design

The practicalities of sustaining a ford at this location demanded an understanding of the hydraulic and sediment patterns that would exist after the river bed had been raised by about 1m as part of the river bed restoration works. The river conditions at the approach and exit would be important factors. The length of the submerged part of the ford needed to be at least 20m i.e. twice the normal width of the river, in order to ensure that normal water depths were 'fordable', typically 0.3m or less. Approach ramps on both sides needed to be flatly graded at about 1 in 10 to suit vehicles and should blend with natural bank profiles rather than be severely cut into them. The overall length of the ford, between bank tops, needed to be 40m to meet these requirements. This compared with just 15m between bank tops for the natural channel.

Study of the old maps indicated that the original ford was broadly of the dimensions that were needed but it was still necessary to form a view on why it was sustained by the river and did not narrow through sediment deposition making it unusable. It was well known that many fords constructed at inappropriate sites become unusable due to rapid siltation.

The ford is located between two opposing bends in the river alignment such that shoals of gravel naturally accumulate on the inside of each. The two shoals would typically be joined by an underwater bar of gravel aligned diagonally across the channel. The natural cross-section of the river, drawn across this diagonal bar and up the flat shoal profiles each side, would roughly match the ford profile needed. The sustainability of the shoals and the bar of gravel would depend upon continuing inputs of material to the river. The tributary stream located just upstream (Blaen-y-Nant) was known to be the primary source

The restored ford, shoals and riverbed

8

Providing Public, Private and Livestock Access

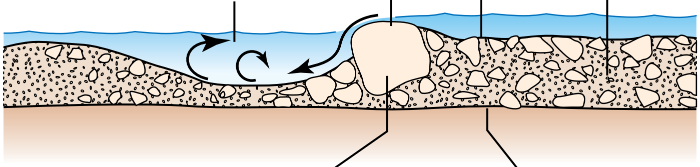


Figure 8.4.2
Section through ford

of sediment on this reach of river. It was therefore concluded that a diagonal ford aligned between the opposing bends was sustainable and that it would be typical of the natural fording points adopted by farmers on many gravel bed rivers where similar geomorphology arises. It was necessary to develop the design of the ford in accordance with these principles.

It was decided to define the downstream edge of the submerged length of ford with a line of glacial boulders as shown on *Figure 8.4.2*. This provided the stable bed level that needed to be defined as part of the overall river bed restoration. It was not possible to completely restore the river bed elevations with gravel due to lack of suitable material (*see Technique 5.3*), so the new ford might have washed downstream if the profile had not been fixed by the boulders. They also ensured a clear route across the river remained visible between the ramps on each side. The gravels that were available from previous dredging operations were utilised to restore the two important shoal profiles upstream and downstream of the ford. The river bed was also fully restored with gravel upstream and downstream of the ford with particular attention to the profiling of pools and runs that naturally form at opposing bends (*see Figure 8.4.1*).

Downstream crest defined by boulders

A potential threat to the stable profile needed at the ford was the 'migration' of the bends through erosion of the outer banks of each. Serious erosion had arisen further downstream of the ford site but old river bank revetments were evident at the site and upstream of it. Existing revetments of small boulders were repaired and consolidated into the ford. The erosion downstream was repaired using the willow mattress technique featured in this manual (*see Technique 4.2*).

The location of two solid stone walls on opposite banks of the river were a further consideration. The routing of overland floodwaters down the valley would clearly be interrupted by these opposing walls with all flow being concentrated between them coincident with the location of the ford (*see Figure 8.4.1*).

Careful study of the topography of the adjoining fields indicated that the natural flood route involved overtopping the bank on the right side of the ford (looking downstream). This bank was carefully graded to blend with a discernible 'gulley' down the field such that floodwater passing between the two walls could easily escape out onto the natural floodway again without causing undue stress at the ford. The arrow on *Figure 8.4.1* indicates this important floodway.

Subsequent performance 1995 – 2001

The entire configuration of the ford, shoals, pools and runs has proved to be sustainable, with the ford in regular use by the farmer.

The visual appearance of the ford is excellent as it has sympathetically blended into its location and is not intrusive in any way.

This success is attributed to the care taken to understand the underlying river geomorphology and the sympathetic adaptation of this in both the historic context of the site and that of the wider river restoration project.

Original Information Providers:
Bryan Jones
Elfyn Jones
RRC

8

Providing Public, Private and Livestock Access

8.4 River Ogwen 2013 Update

River Ogwen	High energy, gravel
WFD Mitigation measure	Appropriate channel maintenance strategies and techniques e.g. minimise disturbance to channel bed and margins
Waterbody ID	GB110065054160
Designation	None
Project specific monitoring	None

The ford remains in good condition with minimal disturbance to river morphology and has not required any repairs to date (March 2013). The ford is used occasionally by the tenant farmer who crosses the river in this location with his tractor.

Just upstream of the restored ford there is another crossing point that is used more frequently by both the farmer and the National Trust. Whilst it is not a purpose built ford it is easier to use as the river is wider and shallower at this point and the ground on both sides of the river is more stable for driving a vehicle on.

Fencing was put in along the river bank as part of a Tir Gofal (Agri-environment scheme for Wales) requirement in early 2000. In addition willow spiling was installed just downstream of the ford location to protect the banks from erosion and this has worked well.

The ford remains stable with the boulders used for the downstream crest remaining in position – February 2013

Contacts

Sarah Mellor, National Trust
sarah.mellor@nationaltrust.org.uk, 01492 860123

Dewi Roberts, National Trust
dewi.roberts@nationaltrust.org.uk, 01248 600954

8

Providing Public, Private and Livestock Access

8.5 Urban riverside access

RIVER MARDEN
LOCATION - TOWN CENTRE AT CALNE, WILTSHIRE ST 998710
DATE OF CONSTRUCTION - 1999
LENGTH – 100m
COST – NOT AVAILABLE

The river and weirs before reconstruction

Description

A straight, concrete-lined, section of river channel was diverted and restored in the form of a double meander. *Refer to Technique 1.5 for a plan and full description of the project*.

The inner part of each meander is configured as a gravel shoal. People enjoy being close to the river at such locations although the opportunity to do so in a town centre location is rare. This technique is concerned with the means by which people are afforded safe access to the shoals. In addition, the Environment Agency required occasional access for maintenance plant, particularly to the twin road culverts at the downstream end where flood washed debris may accumulate.

Gravel margins and seeded soil form the shallow banks opposite 'rocky' walls

These techniques were developed to suit site specific criteria and may not apply to other locations

Design

The meander configuration effectively divides the reach into two parts for access purposes. The lower part comprises the meander approaching the road culverts where access is from the south side. The upper part comprises the meander fronting new retail development where access is from the north side.

Access on the lower part
A gently sloping ramp was achieved by aligning this parallel to the course of the river channel thereby maximising the distance over which a drop of circa 1.5m could be incorporated. The ramp blends smoothly into the shoal and falls at 1 in 12.5 at its steepest. *Figure 8.5.1* indicates the profile of the inner bend and shoal. The upper part of the ramp is reinforced against wear and tear with limestone block paving. Purbeck limestone was used extensively throughout the project (*see Technique 1.5*). Grass is seeded between the paving blocks ensuring a good blend with the grassed areas around the shoal.

Access on the upper part
A gently sloping ramp was again built parallel to the river course at about 1 in 12.5. This ramp gives access to a 20m long section of waterside that is flat and is within 0.4m of normal water level. Dense marginal aquatic vegetation will front this short reach. The reach leads into the shoal fronting the development.

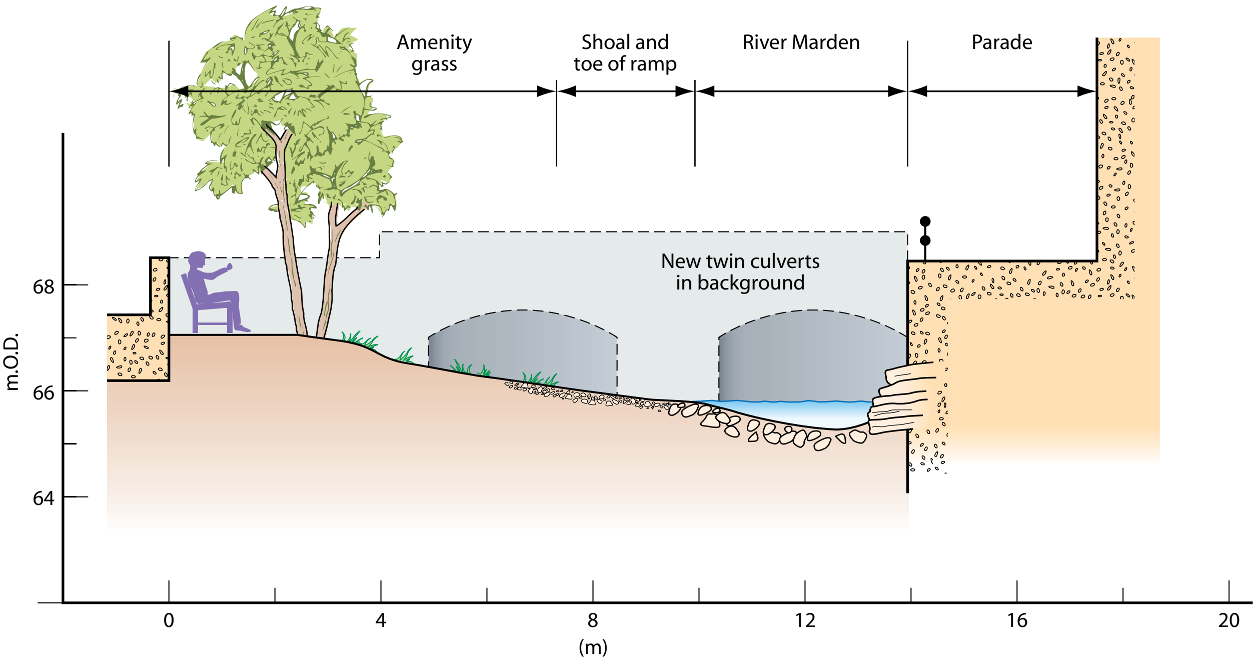
The inner bend that fronts the retail development is shown as a cross-section in *Figure 8.5.2*. Three wide steps surfaced in slabs of Purbeck limestone form the riverbank. These 'stepped platforms', as they have come to be called, are up to 1.5m wide and provide informal seating areas for people at the riverside. The steps give direct access to the shoal and are integrated into the parade that fronts the new retail area.

View showing the lower part of the accessible new river course – November 2001

Providing Public, Private and Livestock Access

Seating and gentle grass and gravel slope to water's edge

Figure 8.5.1
Section C (see technique 1.5 for location)



Providing Public, Private and Livestock Access

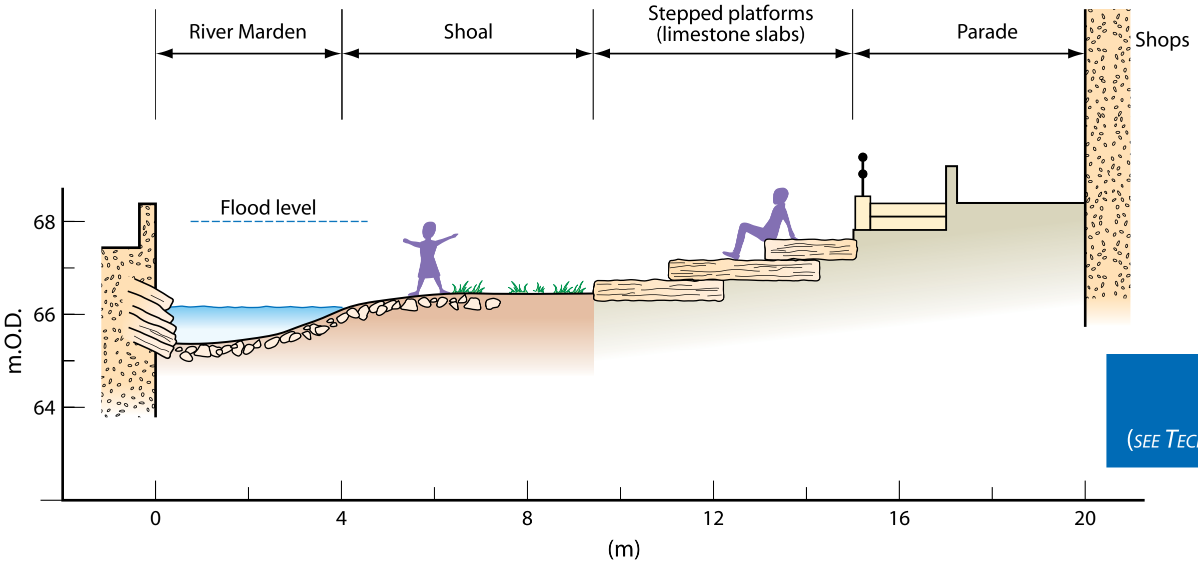


Figure 8.5.2
Section **B**
(see Technique 1.5 for location)

Stone steps leading down to grass and gravel shoal

Subsequent performance 1995 – 2001

The public will not have full access to the river until the retail development work is completed during 2001 but the overall appearance of the access provision is inviting and safe during normal river conditions.

During times of flood all of the features described will be submerged. Some cleaning of silt and debris is anticipated but should not be onerous.

The overall concept of maximising the opportunity for access to the waterside within the whole river channel and floodway is expected to work well.

Original Information Providers:
RRC
Richard Vivash

The River Restoration Centre
Working to restore & enhance our rivers

8

Providing Public, Private and Livestock Access

8.5 River Marden 2013 Update

River Marden	Medium energy, chalk
WFD Mitigation measure	None
Waterbody ID	GB109053022060
Designation	None
Project specific monitoring	None

The river access, which was a key project design, has proved popular. The reach is now an attractive and interesting feature of the town centre environment, serving as the centrepiece for the town's annual charity duck race. The restoration scheme has won several design awards including a Civic Trust Commendation in 2003. It appears to have addressed both aesthetic and biodiversity issues and is well used by the local people.

The town centre rejuvenation was welcomed following the demolition of the Harris Bacon factory in 1984. Denis Robson, chairman of Castlefields Canal & River Park Association(CARP) stated "*The Calne now has a beautiful 'natural' flowing river that is a delight to visit. By any measure this is a very successful project*".

The scheme is an excellent example of urban river restoration, providing public access and amenity to a scheme which has utilised working with natural processes to achieve flood risk management benefits.

The scheme was initially maintained by Wiltshire County Council. Since being transferred to the responsibility of Calne Town Council (circa 2009) the level and extent of maintenance of the planting has been significantly increased, although this has led to many native shrubs being replaced by with ornamental species. Ideally the native species should be retained wherever possible to give a more natural marginal and riparian zone.

The annual charity duck race – 2010

© NPA

© NPA

River Marden riverside access – 2012

Contacts

Paul Jolliffe, Nicholas Pearson Associates (NPA)
paul.jolliffe@npaconsult.co.uk, 01225 445548