1 Restoring Meanders to Straightened Rivers

1.5 New meandering channel replacing concrete weirs

RIVER MARDEN

LOCATION – Town centre at Calne, Wiltshire ST998710

DATE OF CONSTRUCTION – 1999

LENGTH – 100m

COST – not available

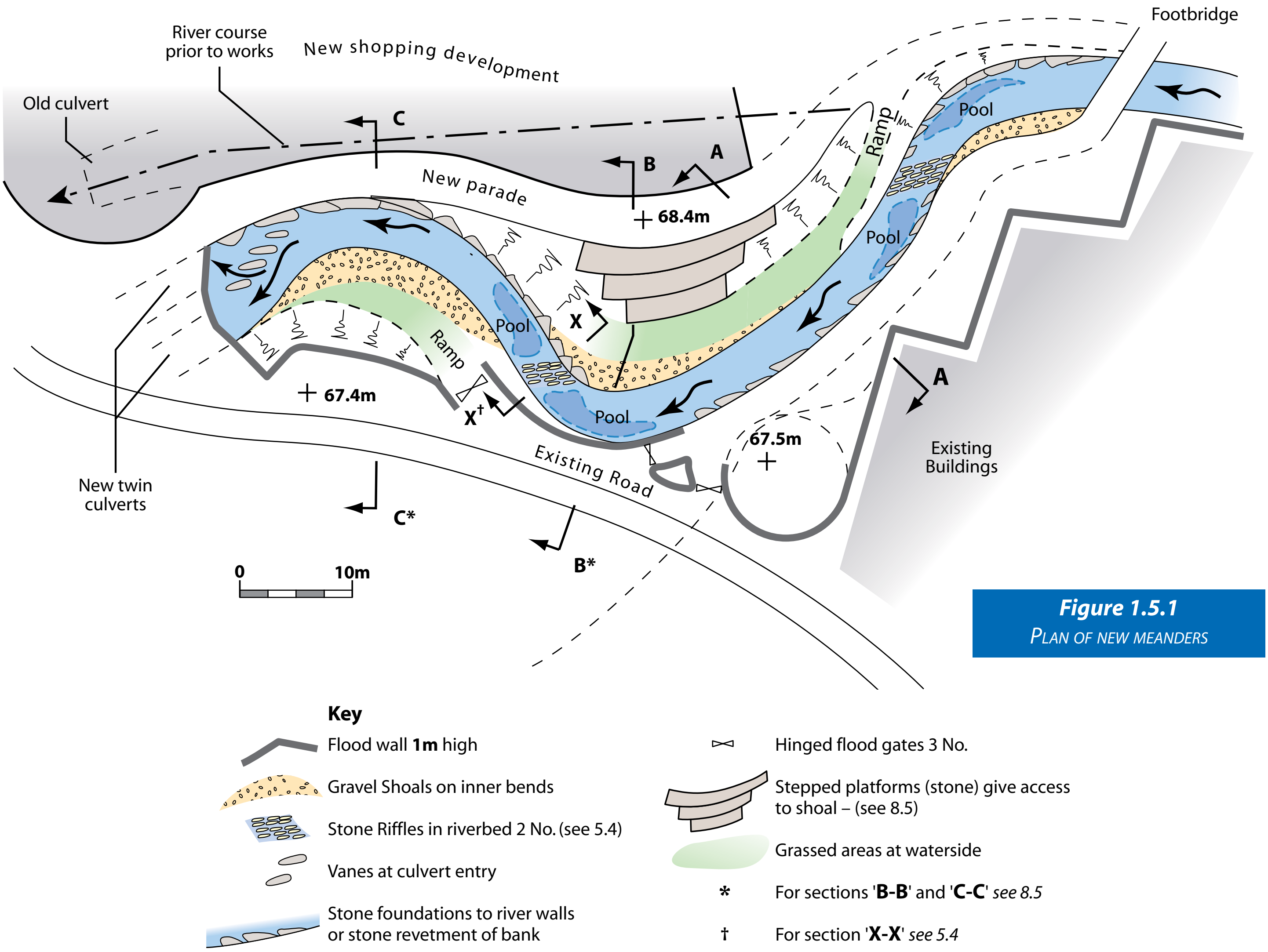


Figure 1.5.1
PLAN OF NEW MEANDERS

Description

A town centre factory had been demolished leaving a reach of river flowing through the site in a straight, concrete channel. The channel bed dropped vertically in two places forming weirs that barred the passage of fish and were unsightly.

Redevelopment of the site required that the river be diverted south of its existing course and that its character be improved to create an attractive public amenity. The site is prominently located in the heart of an ancient market town.

The diversion was undertaken in the form of a double meander such that natural geomorphological features including shoals, riffles and pools could be incorporated, as well as good public access to the waterside and a variety of sustainable attractive habitats for flora and fauna.

Earlier proposals to create an impounded, canal-like waterway were dropped in favour of the relatively free flowing river regime described.

Restoring Meanders to Straightened Rivers

Design

The diversion necessitated the re-siting of the upstream part of twin box culverts that carry the river under the main road. *Figure 1.5.1* shows the location of old and new culverts. The double meander route between the existing channel and the new culverts was optimised within the constraints of the existing and new buildings shown.

The gradient of the new river bed became 'fixed' between the culvert invert and the existing upstream level. *Figure 1.5.2* shows the resultant longitudinal profile with a mean bed gradient of 1 in 140. This gradient is much steeper than arises naturally on this part of the river with consequent high water velocities when the river is in flood.

Hydraulic modelling indicated velocities of up to two metres per second and flood levels up to 0.8m above adjoining roads and property. These hydraulic parameters meant that flood walls would be needed to contain the river and that erosion of the river bed and banks would need to be rigidly controlled.

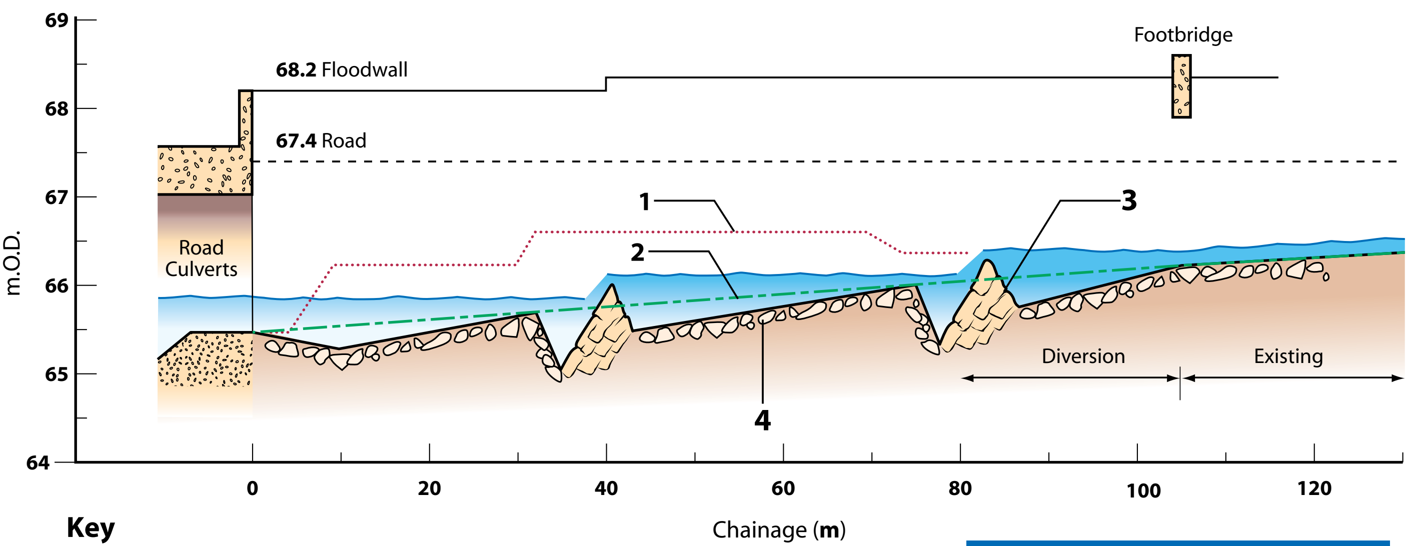
A design concept was needed that was sufficiently robust to meet these demanding hydraulic conditions but equally to meet the need for an attractive and sustainable environment.

The concept adopted was based on the premise that the gradient and alignment of the river were more typical of upland river locations where rock outcrops and gravel and cobble river bed substrates might be expected. Design of the many elements of the project began by developing a method of simulating stratified bedrock underneath the whole river diversion that would 'outcrop' to form river bank revetments, retaining wall foundations and river bed control cills.

Research was undertaken to select quarried rock that could be re-constructed on-site to simulate its natural characteristics. Purbeck Limestone from quarries at Swanage was chosen because it occurred in large, flat slabs of thickness between 0.1m to 0.9m. Slabs of rock could be laid securely, one above another, at consistent angles to recreate the 'dip and strike' of natural outcrops. The stone was sufficiently durable to withstand frost and could also be provided in cut building blocks for use in walls. Its colour and texture is similar to locally available Cotswold stone but its durability was much greater, an important factor in riverside locations.

The following lists the key locations where stone slabs were incorporated:

Within the foundations of all vertical riverside retaining walls
Slabs were laid at a consistent angle to project into and above the water creating the appearance of the walls being built on natural rock. Contrasting faces on opposite sides of the river were achieved by maintaining the 'dip' in the same direction i.e. smooth dip slopes one side and jagged escarpment faces on the other. As the river alignment approaches the culverts in the same direction as the selected dip-slopes, slabs were laid with the dip parallel to the retaining wall. This enabled a series of 'craggy' current deflectors to be incorporated into the foot of the wall.



Key

1. Original bed level – concrete channel with two drop weirs
2. New mean bed gradient at **1 in 140**
3. Two stone riffles built to stabilise river bed; pools upstream and downstream of each
4. Actual bed profile of gravel and cobble susbstrates

Figure 1.5.2
LONGITUDINAL PROFILE

Restoring Meanders to Straightened Rivers

Before:
View downstream towards culvert

Completion:
View of the new river course

At the bottom of earth slopes on outer bends liable to erosion
Slabs were laid exactly as above with consistent direction of dip and strike to revet these banks with varying faces depending upon the channel alignment of each location. See section A–A, figure 1.5.3 for aspects of both wall foundations and bank revetments.

Outcrops in the riverbed to create low cills
The steepness of the river bed gradient needed to be checked by introducing two low barriers of rock to resist any tendency of the bed to scour downwards. These are shown as feature 3 on figure 1.5.2. They are located just downstream of each meander bend where underwater bars of river bed substrate e.g. gravels would naturally accumulate in the form of riffles. The stonework on adjacent walls and river bank was linked across the bed with stone laid at the same dip slope. Technique 5.4 shows details of these. They incorporate a gently sloping downstream face, much like a riffle. This enables the easy passage of migratory fish to be achieved and creates a 'tumbling' water feature rather than a sharp fall.

Restoring Meanders to Straightened Rivers

Building stone in walls and for amenity surfaces
Dressed stone was used to face and cap all retaining walls and flood walls as well as the headwalls on the new road culvert. These headwalls were designed with curving arched soffits to give the appearance of an older stone bridge, hiding the unsightly concrete boxes that carry the water under the road. On the inner bend fronting the new development, large stone slabs were laid to create stepped platforms down to the waterside shoal (*see 8.5 for details*).

Vertical vanes in the river upstream of the new road culverts
The twin culverts create an artificially wide river channel at entry with the consequential risk of the culvert on the inside of the bend attracting excessive silt accumulations. Four upright slabs of stone were concreted into the river bed to induce a sustained flow of water towards the inner culvert without barring the natural tendency of flow towards the outer culvert. The slabs project a nominal 0.15m above normal water levels and serve as 'vanes' that effectively modify the water currents at all stages of river flow, including flood flows.

All of the stone features described effectively define a precise and stable course to the river which was essential in this tightly developed urban location. The creation of the river bed and waterside shoals was an equally important aspect of design since both had to be similarly stable as well as being able to sustain flora and fauna.

Geomorphological calculations were undertaken to determine size, shape and distribution of the river bed substrates that were to be introduced in the differing hydraulic conditions generated by the double meander channel configuration. Two sources of material were selected for use either singly or in combination.

Stone rejects from nearby limestone gravel pits were used on the river bed upstream of chainage 40m (the lower riffle) where water velocities were highest. Sizes ranged from 40mm to 200mm and shape varied between rounded gravels and cobbles to flat pieces of stone. Elsewhere 40mm graded and washed gravels were used where water velocities were less severe. This included the inner bend shoals where the public would have easy access. A mixture of both was used in intermediate locations simulating the natural 'grading' of bed substrates that would arise had they been carried and deposited by the river.

The design was completed to accommodate floodwalls and floodgates and a range of public access and amenity features as well as a comprehensive landscape planting scheme sympathetic to the riverine environment. The introduction of marginal aquatic plants, etc. along soft edges and within the numerous interstices of the rock outcrops was deferred until floodwaters has passed through the newly created reach of the river. This enables the river to modify and soften the engineered work thereby revealing the most appropriate plant species for the multitude of different habitat niches expected.

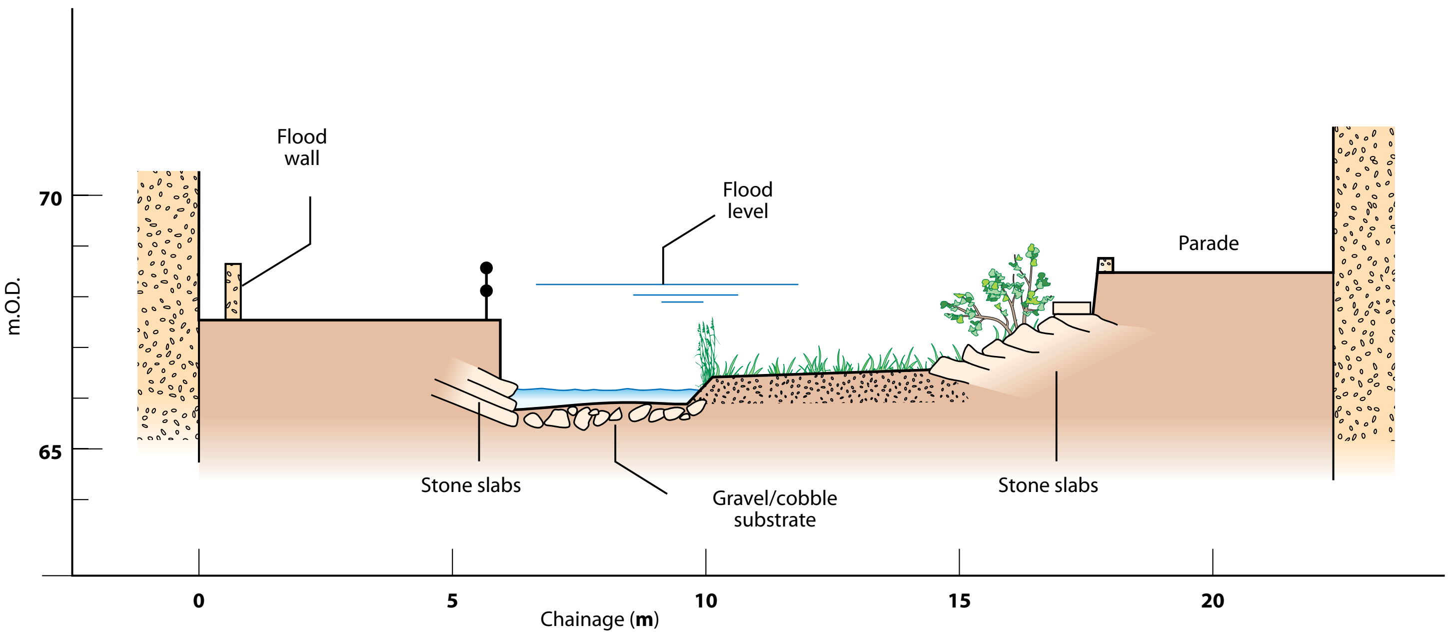


Figure 1.5.3
SECTION A THROUGH RIVER AND STONE SLABS

Restoring Meanders to Straightened Rivers

View of Section A (*fig 1.5.3*) on completion

View of Section A in November 2001

After: The new town centre in November 2001

Subsequent performance 1999 – 2001

The works have all remained remarkably stable bearing in mind that river bed substrates and shoal materials were all kept to minimum sizes, rather than 'over-sizing' to ensure stability.

The river has re-distributed some of the stone placed between the two riffles. This has created an additional riffle within the reach and the shoal at the front of the stepped platform has built up into an attractive, accessible beach.

The edge of the river channel between the two stone 'riffles' has slightly eroded along the un-revetted side. The latter can be easily controlled using pre-planted fibre rolls as part of the landscaping work and the former simply requires some gravel reject stone to be introduced into the soil that will then be grassed.

The four vanes at the culvert entry appear to be working well and sustain interesting current variations at low flows although some flood debris is attached to them. This debris is easily removed and is less problematic than it would be if it had entered the culverts.

The overall appearance of the riverworks is excellent and once the contractor finally clears the site and landscaping is completed it should naturalise well. Wildlife has occupied the site despite the intense building work with wagtails (*Motacilla spp.*), duck and fish being most obvious. The underwater rock and the sustained pools and faster flowing runs of water all promise to develop into valuable habitats.

Local comments are of young people enjoying 'messing about in the river' with no serious vandalism, partly due to the robustness of the design concept.

Original Information Provider:
RRC

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Restoring Meanders to Straightened Rivers

1.5 River Marden 2013 Update

River Marden	Medium energy, chalk
WFD Mitigation measure	Click Here to view details
Waterbody ID	GB109053022060
Designation	None
Project specific monitoring	None

The pools and shoals have remained fixed as designed and some redistribution of the bed gravels that were introduced has occurred. Whilst there has been some movement of bed material into the left hand culvert this has not been excessive (*see Figure 1.5.1*).

Great care was taken to ensure the risk of movement from bed material was reduced. As such a geomorphologist was involved during the design stages of the project. Although there was initial concern from the Environment Agency about the introduced gravels moving and causing a maintenance problem at the mouth of the culvert. This has been shown not to be the case.

The new meandering channel has performed well with no repair and little maintenance required. The grass area is part of the focal point for the town and was designed to allow access. It has therefore been mown for landscaping and amenity more than would be recommended to achieve ecological benefits.

The flood walls have not breached since construction. The photograph below illustrates the additional flood capacity provided by the scheme.

This was a relatively expensive project but this high level of investment has had a major impact in raising the image of the high street as witnessed by its central hub function and visitor attraction. It is used as a postcard image and the town's publicity material frequently features the scheme.

As a result of the project, there has been an increase in the diversity of aquatic marginal vegetation with brown trout (*Salmo trutta*) now inhabiting the river through the town centre.

The river in flood – the flood gates are closed and the much increased capacity protects the town centre – November 2012

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

Restoring Meanders to Straightened Rivers

The designed channel and shallow grassed slopes hold up well over the winter period – early 2006

Mown green river edge to allow public access in summer. Here the river's appearance is heavily managed as part of the aesthetics of the new town centre – 2010

Contacts

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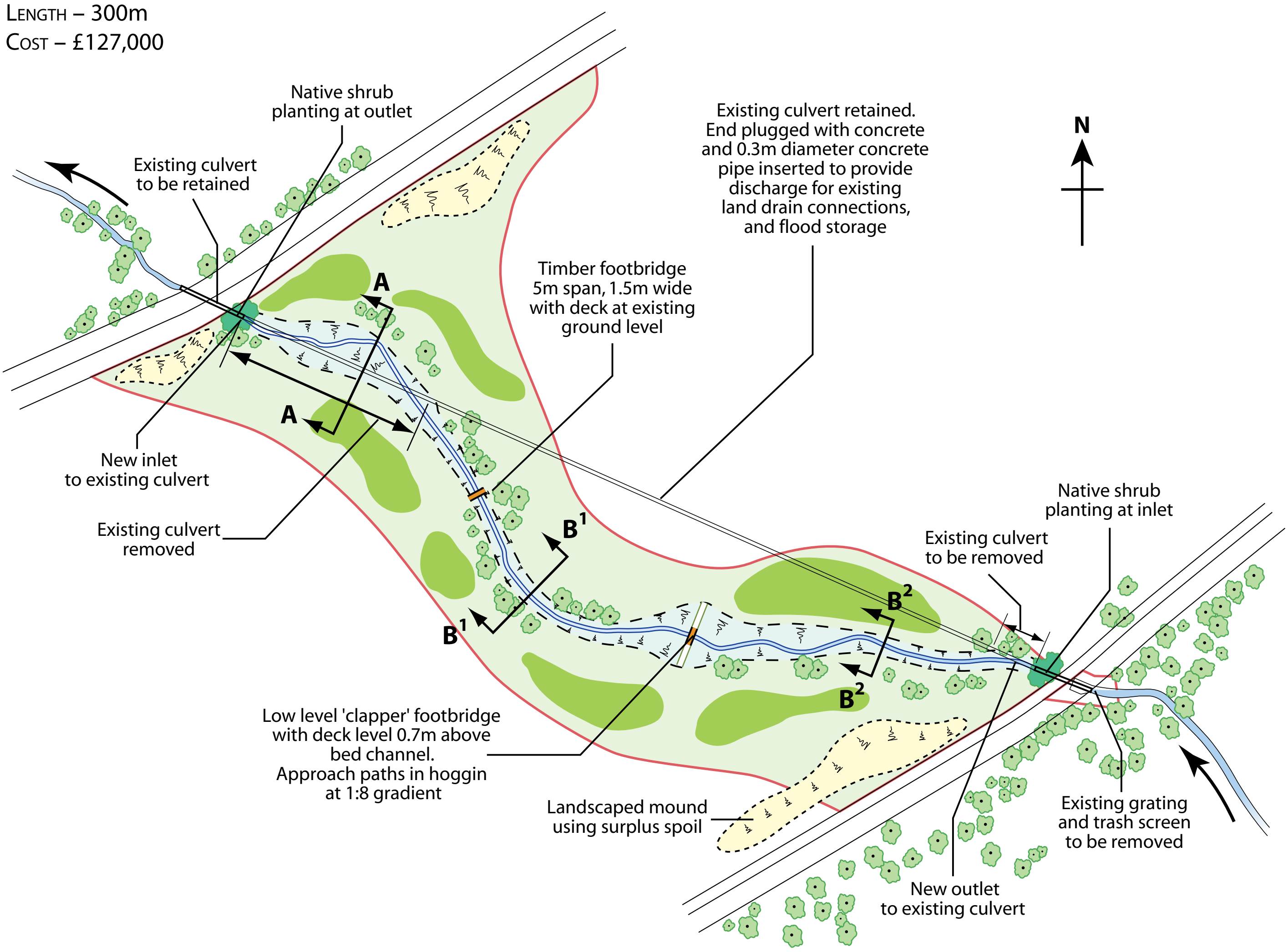
Restoring Meanders to Straightened Rivers

1.6 Opening up a culverted stream

River Ravensbourne
Location -Norman Park, Bromley TQ412674
Date of construction - March to June 2000
Length – 300m
Cost – £127,000

Figure 1.6.1
Plan of new channel



Description

The Ravensbourne is a spring-fed stream flowing from its source near Keston, on the north slope of the North Downs, northwards through Bromley, Catford and Lewisham to join the Thames at Deptford Creek. In many areas such as Norman Park the stream was confined within a culvert.

Culverting of small watercourses in urban and parkland areas has been common in the recent past. Burying the river was felt to reduce the flooding potential, minimise safety issues associated with open water and maximise land available for development or use as open space/playing fields. Little consideration was given to habitat loss, aesthetic and landscape appeal of rivers or the potential benefits of surface water storage.

The Ravensbourne flowed for 300m through a 1m diameter concrete-lined steel culvert. Smaller land drains, which had been ditches before the area was levelled to form the park, flowed into the culvert at intervals along its length.

Park access tracks and major services, including a gas pipeline and electrical supply cables, crossed the culvert at the north end and a water pipe and local electrical supply cables at the southern end.

Deculverting (daylighting) this section of the Ravensbourne provided an exciting opportunity to restore a more 'natural' stream with diverse in-channel and bankside habitats that link with Scrogginhall Woods just upstream. It also provides an interesting recreational facility for the local public.

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

Restoring Meanders to Straightened Rivers

View of headscreen prior to removal

'Daylighting' of the Ravensbourne

Design

Financial justification for the scheme was threefold: reduction in costly maintenance for a culvert, the removal of a trash screen that also required regular clearing and was a safety issue, and an increase in flood storage. There was also a positive environmental gain.

The culvert was severed and approximately 70m of the 300m long culvert was removed, isolating 180m of the remaining section. Two short lengths were left to maintain the existing access track and service crossings. As the culvert was ruler straight, simply excavating the watercourse and removing the concrete would produce a far from natural channel. In addition, culvert removal, backfilling and reshaping is considerably more expensive than plugging and digging an alternative, though longer, course.

The design of the river channel was based on the historical layout, fluvio-geomorphology, flooding considerations and present day use of the park (cricket pitches). To avoid being overly prescriptive, the design drawings were kept relatively simple. The conditions encountered on site meant the final course is slightly different from the design plan (*Figure 1.6.1*). Indicative cross sections were provided at key locations with the main objective always a shallow, safe, accessible bank (*Figures 1.6.2 and 1.6.3*).

The new channel varied in bank slope and bed width, but followed a smooth longitudinal bed profile. By then infilling with an excess of gravel, the stream was allowed to shape its new bed, rather than 'constructing' pools and riffles.

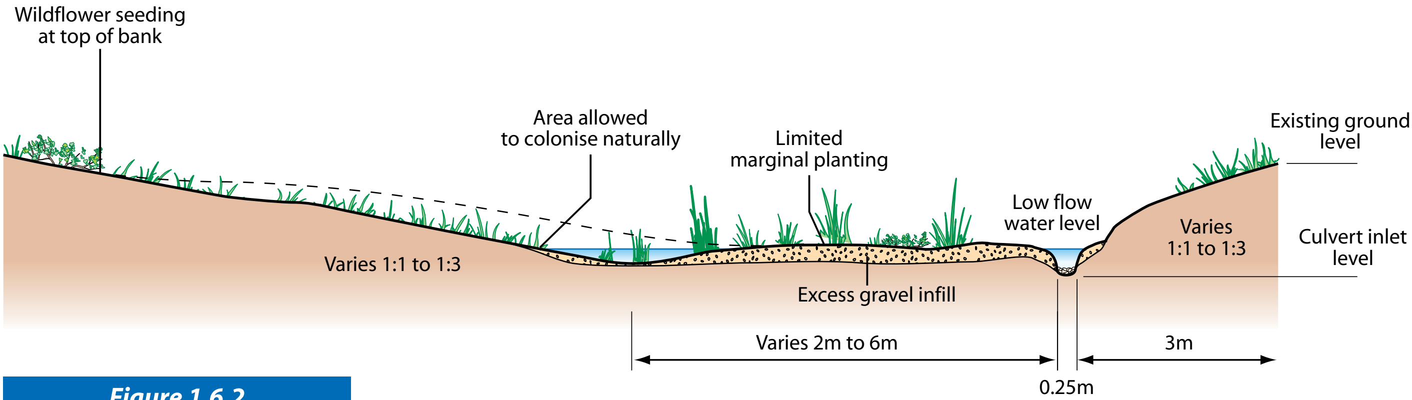


Figure 1.6.2
Section A through raised bed and marginal shoal

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Restoring Meanders to Straightened Rivers

Looking downstream at the shallow bank slopes. The severed culvert still visible

The new sinuous course and extent of wildflower seeding

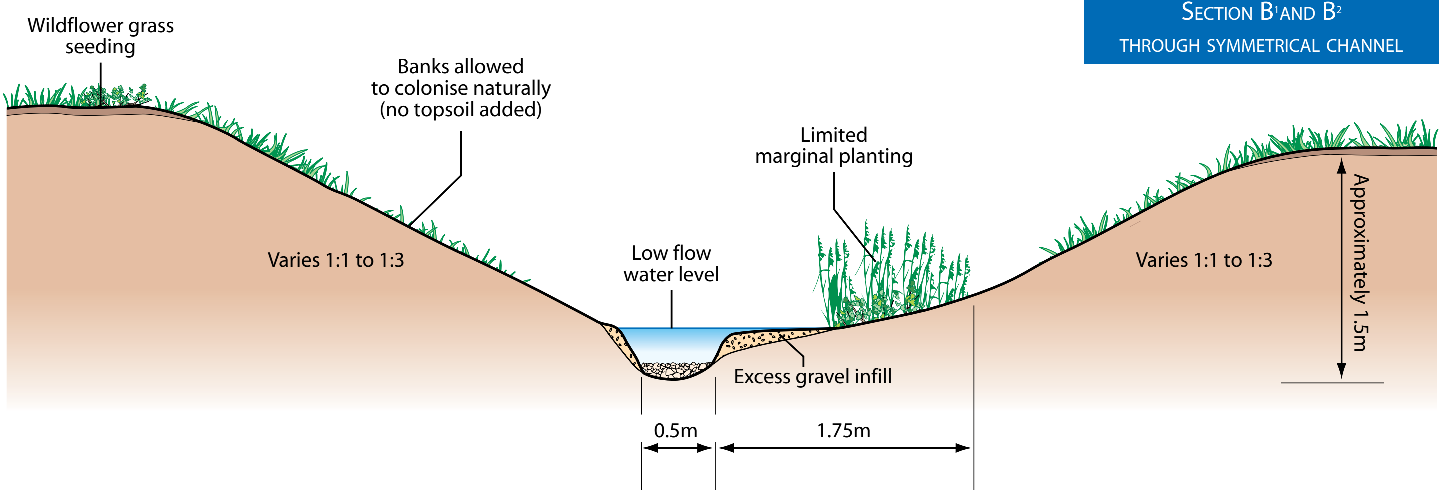
The new course is 12.5% longer than the culvert, sinuous, with varying bed and top-of-bank widths. A shallow (1:8 batter) 'beach' area, as a result of an exposed gravel lens, and new meanders (1:5 inside batters) form the focal points for access to the stream.

When considering this type of scheme, where the stream emerges and then re-enters a culvert, it is good practice to build in 'sediment traps'. These can take many forms and do not have to resemble deep holes or even be maintained once the site has stabilised. At Norman Park the channel was greatly widened at the downstream end of the works forming a damp gravely area which would act as a silt trap. This also allows the stream to find its own natural path within the confines of the overall channel width.

Spoil from the excavation remained on site, and the landscape architect located the mounds at either end of the new course, to ensure that they were subtle and blended into the park.

Two crossings have been constructed over the new channel, one a 'clapper' type bridge constructed of concrete (but looking like stone) and the other a timber structure. Both provide easy access across the stream and access to the water's edge is made possible along most of the course by shallow bank slopes.

Figure 1.6.3
SECTION B[1] AND B[2]
THROUGH SYMMETRICAL CHANNEL



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

Restoring Meanders to Straightened Rivers

Planting up the 'wet berm' area and shielding the culvert entrance with shrub planting

Topsoil was not replaced on the riverbanks in order to attain a low fertility substrate suitable for the natural colonisation of wildflowers and plants from upstream. A 'buffer zone' between the amenity grassland and the top of the bank was seeded with a low-density wildflower mix from an approved source. This creates a visually pleasing edge to the playing fields and provides a suitable seed source for the banks. On the river's edge native provenance marginal plants were carefully sourced from a local nursery. School children were involved in some of the marginal planting. Wildflower plugs were also planted. The culvert entry and exit were both screened using a variety of native shrub species.

Subsequent performance 2000 – 2001

The park users, particularly dog walkers, now see the open Ravensbourne as a focal point, circling the area and making use of the crossing points. Children and dogs play along the banks even though the site has still to mature.

The gravel bed has been redistributed by the flow creating riffles and pools (down to the clay bed in places).

Completion was celebrated at a launch ceremony in June 2000

The marginal planting is suffering disturbance from early use and may take longer than expected to establish a good cover, though this should eventually produce a good diversity of edge habitats. The wildflower plugs have been decimated by crows in search of worms. About a third were removed from the ground and died.

The planting scheme was designed as a balance between creating an instant impact for the local users and allowing the natural processes of colonisation to occur. Even so the local users have stated that they would have liked more immediate impact from the planting.

Intial invertebrate and fish surveys have shown little change, but this should improve with time as the site matures and the marginal and emergent vegetation develops.

The early success of the project can be attributed to the multi-disciplinary project team and the Partnership between the Borough Council and the Environment Agency.

Original Information Providers:
Trevor Odell
Julie Baxter

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Restoring Meanders to Straightened Rivers

1.6 River Ravensbourne 2013 Update

Morphological processes are now able to take place on this de-culverted stretch of the Ravensbourne. Erosion and deposition is occurring within the new meandering channel and flow variability has developed. Areas of fast flow are evident in the shallower riffles and there is slower flowing water at the margins where the water level is deeper. Within a month of the works being completed the gravel had been redistributed as expected. The river had exposed the clay subsoil and has now created a stable channel.

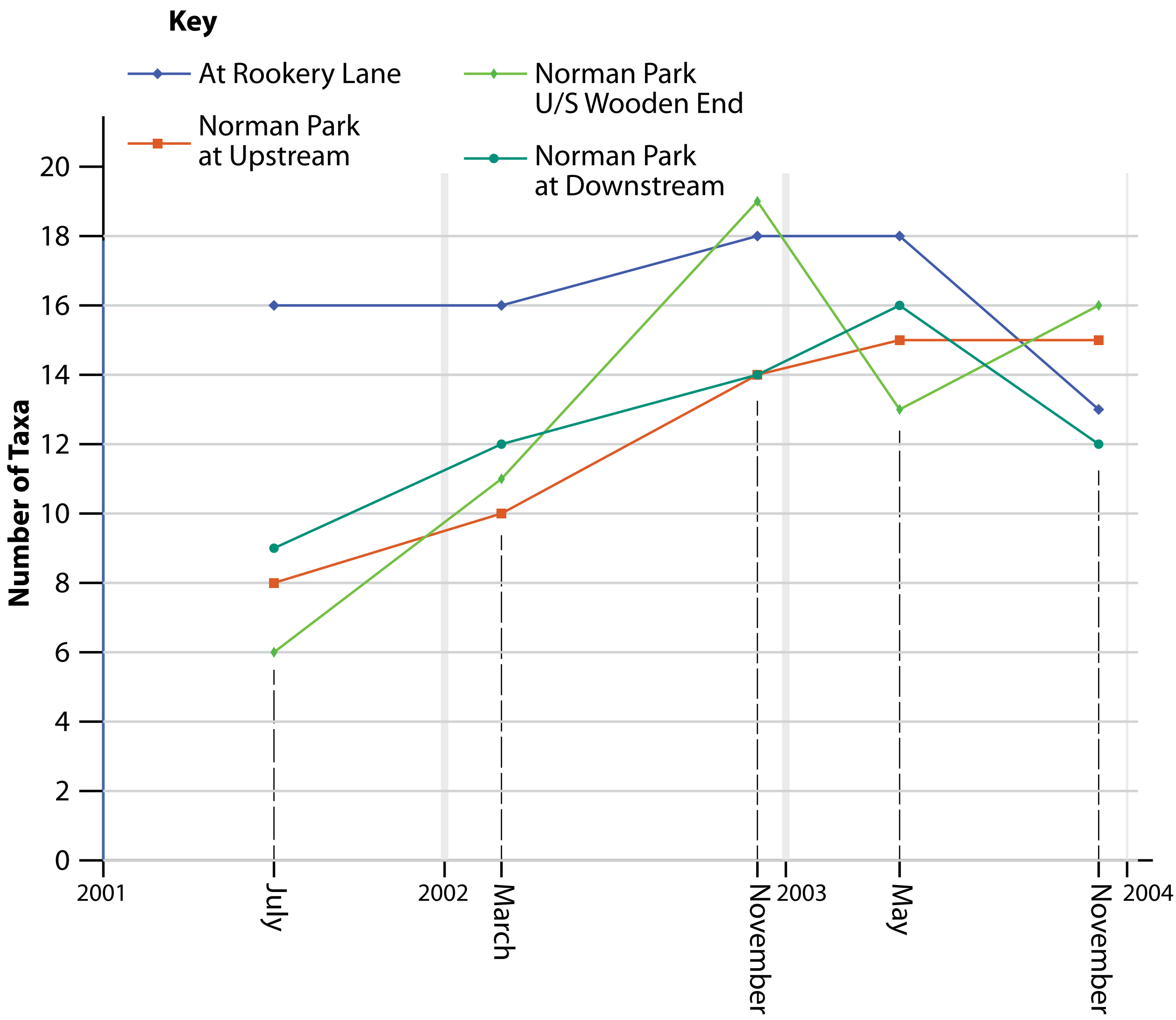
Opening up the culvert has reconnected the river to the floodplain. This provides an opportunity for floodwaters to be stored on the floodplain, reducing the flood risk downstream.

The park area is well used by local people for recreational purposes and a site visit and talk was given at a local school following the works.

River Ravensbourne	Low energy, gravel
WFD Mitigation measure	Click Here to view details
Waterbody ID	GB106039023260
Designation	None
Project specific monitoring	Macroinvertebrate

Effective narrowing of the channel, and asymmetric shallowing of the bed has occurred following restoration – 2012

Macroinvertebrate sampling was undertaken between 2001 and 2003 and this showed an increase in the number of taxa recorded following the works. Further sampling is planned for 2013 in order to compile a more complete dataset.



Changes in the number of invertebrates between 2001 and 2003.
By 2003 numbers for the control site (Rookery Lane) and the restored sites were similar demonstrating ecological improvement in the de-culverted stretch of the river.
(*River Ravensbourne, EA data*)

Contacts

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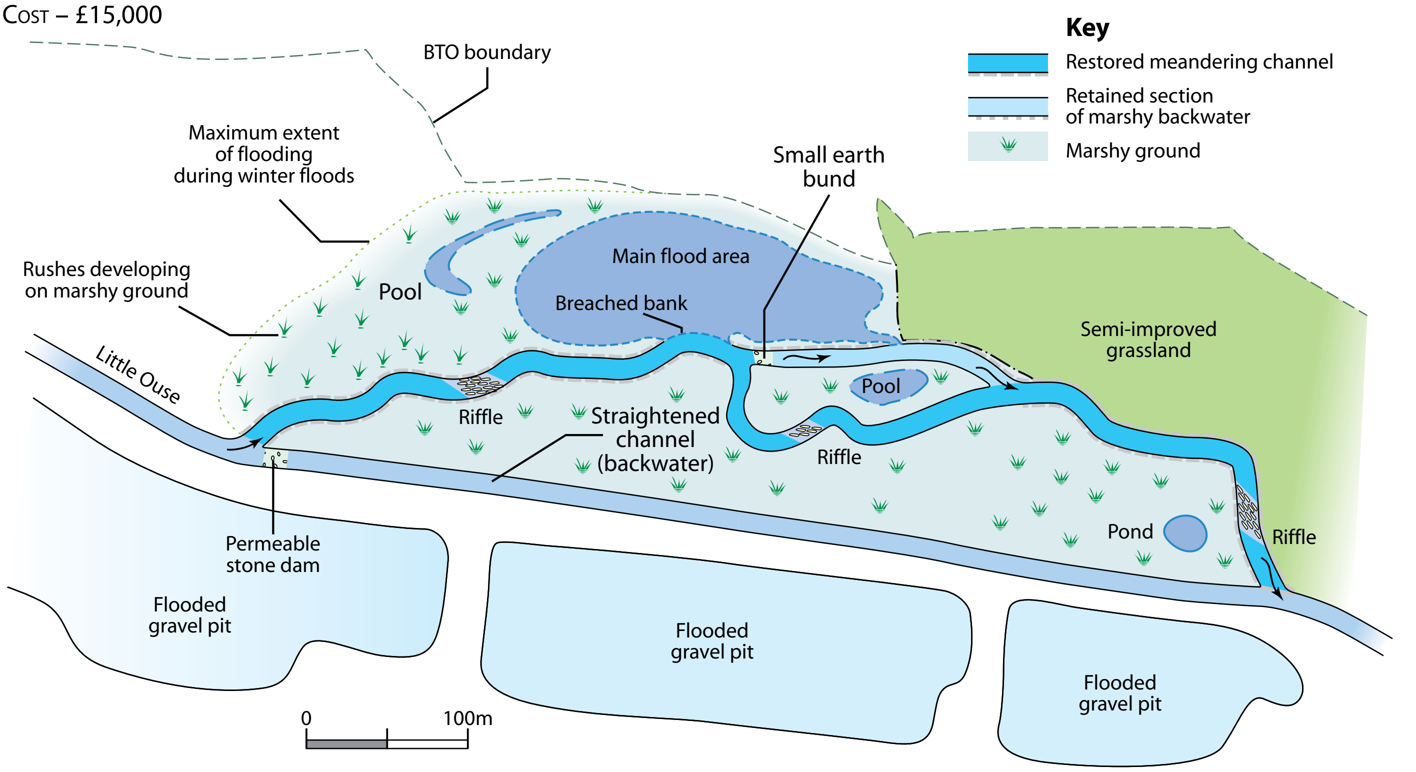
1

Restoring Meanders to Straightened Rivers

1.7 Reconnecting remnant meanders

River Little Ouse
Location - Thetford, Norfolk TL870812
Date of construction - 1994
Length – 900m
Cost – £15,000

Figure 1.7.1
Plan of meanders



Description

The Little Ouse is a low gradient river draining an area of mixed land use (forestry, dry grassland and arable). Sand and gravel extraction has taken place as part of a 30 year programme within the valley. This had lead to 900m of the river being bypassed by a new canalised channel.

Canalised course of the Little Ouse

In 1991, the site and adjacent land was purchased by the British Trust for Ornithology (BTO) to create a wetland bird reserve. BTO approached the Environment Agency to assist with restoring flows to the meandering course. The grassland on either side of the old course was beginning to dry out due to the lower water levels within the new channel, and resultant lack of connectivity between river and floodplain.

The new canalised course was straight, trapezoidal, circa 6m wide and 1-2m deep, with 3m dry, steep banks dominated by tall ruderals and grass. In-stream habitat was poor, macrophytes were confined mainly to the shallow margins, and the substrate was dominated by sand with some silt and gravel.

The old meandering channel remained as a damp depression, merely infilled at each end during the excavation of the new cut. By restoring flows to the old channel 900m of diverse river habitat incorporating deep pools, runs and riffles would be regained, in contrast to the uniform, slack and deep water of the canalised section. Additionally, the landowner was keen to see the land adjacent to the meanders flood, restoring the lost hydrological connection between river and floodplain.

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

Restoring Meanders to Straightened Rivers

Looking downstream along the old meanders

The marshy habitat that the isolated meanders provided would be lost through reconnection, so it was decided to retain and bypass a short 120m section of the old course. This would provide a refuge for plants and animals and a source for colonisation of the proposed wetland reserve.

Design

Assessment and design of the restoration scheme was kept simple and carried out 'by eye', since the old channel was still intact as a reedy, damp depression meandering through the valley bottom.

The old course was reopened by excavating the 'plug' material from the upstream and downstream ends of the meanders. Some tree work and minor regrading was carried out along the remaining length of the original course where necessary. The very small amount of spoil was spread within the immediate reach of the excavator. The restored Little Ouse now has an average channel depth and width of 1m and 8m, respectively.

Using a 50 foot (15m) reach dragline, a boulder and stone structure was placed into the river at the upstream end of the canalised reach (permeable stone dam on *Figure 1.7.1*), to raise the river level by 0.6m. This would ensure that approximately 90% of flow would be routed through the re-opened course.

The meanders needed to be 'unplugged' at both ends

The structure, 6m wide by 10m long by 2m high, was constructed using 1.5m by 1m prefabricated concrete blocks below a 0.75m depth of boulder sized limestone, surfaced with 0.25m of cobble sized limestone. The 'weir' was designed to be permeable to provide a sweetening flow to the canalised channel. Flows, where levels exceed the 2m crest, will overtop and discharge through the retained canalised 'flood relief' backwater channel.

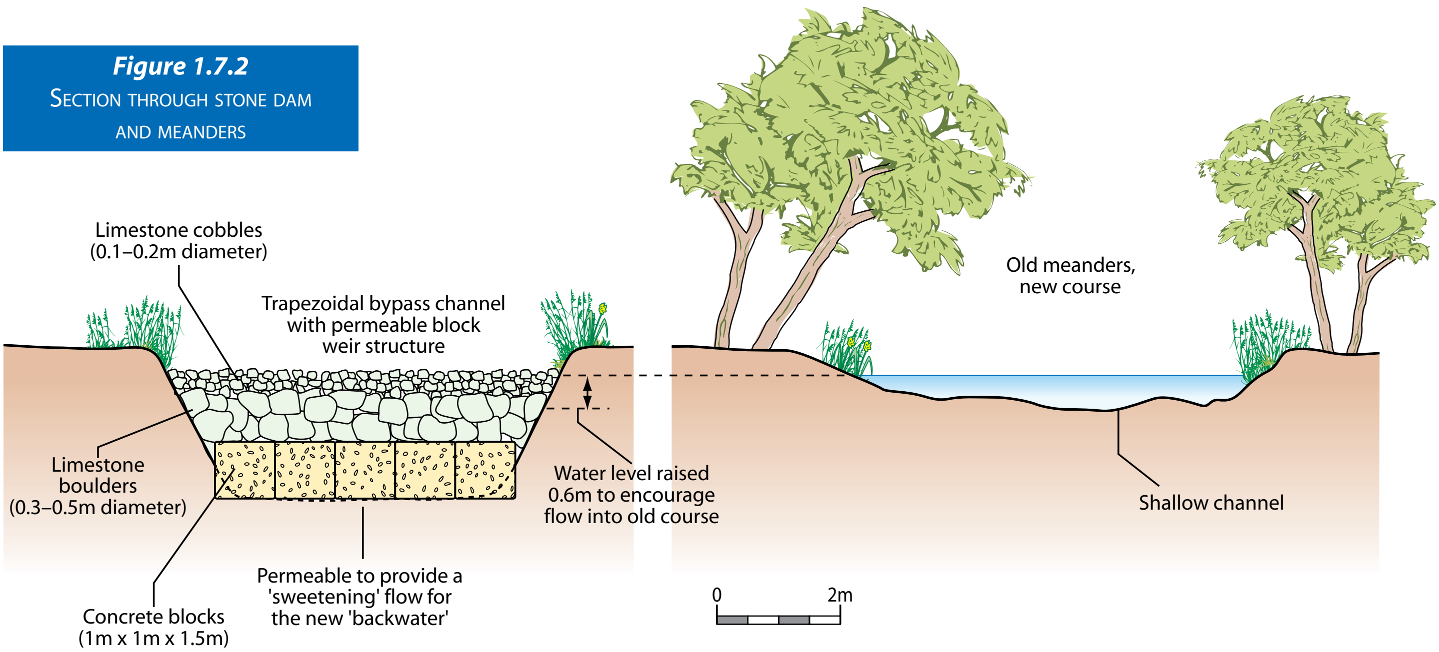
In the middle of the meandering reach a marshy backwater section was isolated with a bund and a sluice at the upstream end to protect the habitat from high velocity flood flows.

Sluice, bund and upstream flooding area

THE RIVER RESTORATION CENTRE
Working to restore & enhance our rivers

Restoring Meanders to Straightened Rivers

Figure 1.7.2
Section through stone dam and meanders



Subsequent performance 1994 – 2001

Surveys show that the meandering channel is sustaining a diverse aquatic invertebrate community, with stonefly (*Plecoptera spp.*), mayfly (*Ephemeroptera spp.*) and snail (*Gastropoda spp.*) species which are not present in the canalised section. Fish species such as chub (*Squalius cephalus*) and dace (*Leuciscus leuciscus*), also not found in the straight section, are using the reconnected reach as spawning and nursery habitat.

The re-establishment of marshland plants on this site has taken longer than originally anticipated. This may be due to a combination of factors, including an inadequate seed-bank, build-up of silt deposits, and prolonged inundation. However, wildfowl and waders have not been slow to use the greater areas of shallow standing water, including nesting pairs of lapwing (*Vanellus vanellus*).

After reconnection to the river

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

Restoring Meanders to Straightened Rivers

The restored Little Ouse

Sections of fencing have been erected along the meanders to restrict grazing and poaching by cattle, and to allow marginal plant establishment.

Some scour around the weir was discovered, due to overtopping in high flows. The length of the dam and a section immediately upstream has since been revetted to minimise further scour.

Original Information Providers:
Geraldine Daly
Chris Gregory

Flooding along meanders – Spring 1999

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Restoring Meanders to Straightened Rivers

1.7 River Little Ouse 2013 Update

© BTO Main breach along the meanders – 2002

© BTO Same bank reinforced using blue clay – October 2003

© BTO Breach of the reinforced clay bank – March 2004

River Little Ouse	Low energy, gravel
WFD Mitigation measure	Click Here to view details
Waterbody ID	GB105033043090
Designation	None
Project specific monitoring	Vegetation, Birds, Water level

High river levels resulted in scour of the more vulnerable sections of meanders causing breaches in the banks. These were repaired using clay in 2002, but subsequently failed and further breaches occurred. These were exacerbated by a fallen willow (*Salix spp.*) branch that deflected the flow.

In the context of this project, the original design was aimed at encouraging seasonal inundation on the floodplain to create suitable nesting habitats for waders such as lapwing, as well as providing winter wildfowl refuge. These unpredicted breaches have, instead, resulted in permanently ponded areas.

The increased regularity with which the floodplain is inundated, combined with the topographic variability of the floodplain, means that lower areas now remain permanently wet. At this site this is not acceptable. In other locations however, this could be deemed as providing additional habitats on the floodplain whilst working with natural river and hydrological processes. In addition the project has had positive benefits for the river. In flood flows fine silt is deposited on the floodplain resulting in a clean gravel bed.

Clay bunds and the subsequent implementation of staked-in pre-planted matting and pallets installed to prevent erosion of these highly vulnerable banks have not been successful. In the case of the latter measure, it is possible that cattle poaching exacerbated the destruction of the matting and pallets.

Monitoring of the vegetation has indicated that the banks greater than 0.35m in height have become well vegetated, indicating greater potential stability where overtopping is less frequent (i.e. time between floodplain flood events is designed to allow vegetation to establish). As a result a decision has been made to raise banks slightly from the original design. This is to ensure future over-topping only occurs when banks are stable and not vulnerable to erosion during the flood season. Young willow shrubs will be used to build up the banks to create 'living revetments'. Work will commence in September 2013 at an approximate cost of £6,000.

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

Restoring Meanders to Straightened Rivers

© BTO

Initial vegetation growth on pre-seeded coir matting – December 2005

© BTO

Erosion of the coir matting – April 2008

This project demonstrates the need to understand the specific characteristics and vulnerability of your site. Whilst lowering a bank to create a breach for floodplain reconnection is a positive idea, getting the height correct to enable vegetation to establish and create some stability between overtopping events is critical. In addition it has highlighted that monitoring the site can allow you to adaptively manage and enable you to resolve any initial issues.

Contact

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3

Enhancing Straightened River Channels

3.4 Radical re-design from uniform, straight channel to a sinuous, multi-channel river

RIVER ALT

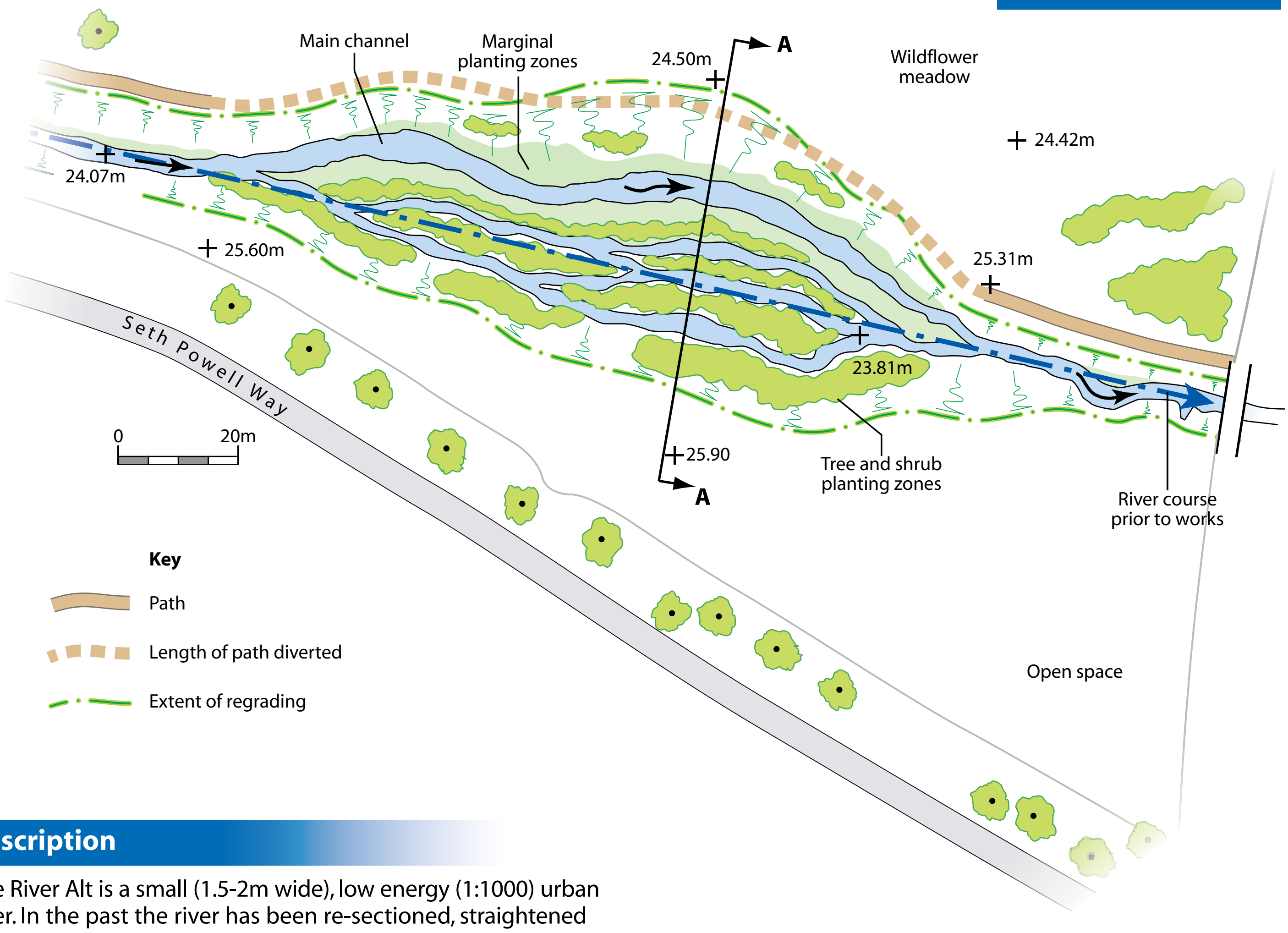
LOCATION – KNOWSLEY, LIVERPOOL, MERSEYSIDE SJ435927

DATE OF CONSTRUCTION – 1996

LENGTH – 140M

COST – £40,000

Figure 3.4.1
PLAN OF THE WIDENED BRAIDED CHANNEL



Description

The River Alt is a small (1.5-2m wide), low energy (1:1000) urban river. In the past the river has been re-sectioned, straightened and over-deepened. The rehabilitated section runs through an area of public open space having been previously realigned to follow the road edge, close to a housing estate. Improved water quality has resulted in fish returning to some parts of the system in recent years, but further improvements in wildlife value had been limited by the poor quality of the river habitat.

Consultation with local authorities, community groups and local schools took place during the design and construction phases. Options for rehabilitation were constrained by existing planning permissions on part of the site and the existence of a wildflower meadow. The provision of public access was a very important element in the design.

The river flows beside a road and was constrained within a trapezoidal channel. Dense bankside growth often hid the small watercourse. An existing footpath on the left bank was set back from the river. A result of disposal of excavated material from the original construction of the course, the immediate bank was at a higher level than the surrounding land, effectively shielding the river from view.

As the river course moved away from the roadside, it presented the opportunity to create a wide (up to 30m) floodplain within the confines of the channel. By doing so this could open up the view of the river by removing the existing 'raised' bank.

Trees, shrubs and marginal plant species

Trees at 2m centres	Shrubs at 1m centres	Marginals at ~ 4/m²
White willow	Common osier	Purple loosestrife
Ash	Goat willow	Yellow flag
Oak	Hawthorn	Water plantain
Alder	Blackthorn	Common club-rush
Gean	Hazel	Common reed
Bird cherry	Dog rose	Water mint
Eating apple varieties	Honeysuckle	Gypsy wort
	Dogwood	Water forget-me-not
	Bramble	Brooklime

Trees and shrubs all 1+1 bare root transplants 0.6m–0.9m, ratio of 2:1 shrubs to trees.
Random species groups of 3–5 trees and 5–7 shrubs.

Before:
The Alt, straight and steep sided

Bed dominated by silt

Design

The 1.5 metre 30 degree banks were excavated back on either side of the existing course, creating up to a 30m width of 'floodplain'. This work was carried out over 140m. The 'floodplain' comprises a 'main' channel and several braided channels separated by marginal berms. In order to achieve a matrix of channels, standing water and damp areas, interspersed by trees and shrubs, ground levels needed to vary. Due to the uncertainties of ground condition and in order to work with the natural conditions as much as possible, this was supervised on-site to avoid over-specification on the design drawings, and to allow for adjustments as necessary.

Bed levels were calculated from existing levels, constrained by a bridge at both ends and an outfall half way along the scheme. Fortuitously the bed level corresponded to a clay layer, making a good guide for the contractors. Working in the wet also provided a good guide to relative levels.

The existing channel was narrowed to form the deeper of the braids. The new 'main' course was about 25% larger and deeper than the braided channels to encourage the majority of low-flows along this route, and was located along the left bank, nearest to the footpath route. It was accepted that high flows would possibly alter this pattern and that such natural changes could take place due to the excess flood capacity within the new 'floodplain'.

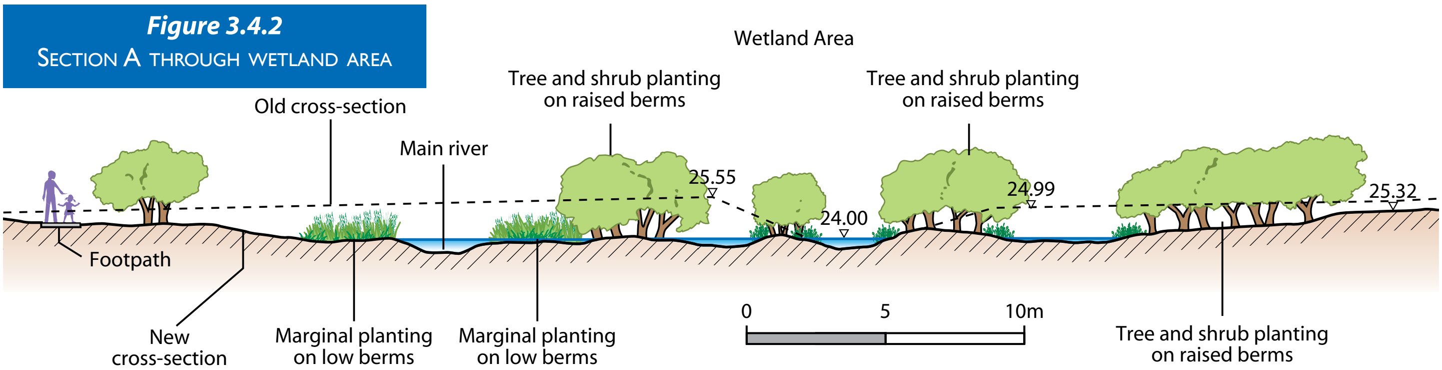
The excavated 'floodplain' area

The final bank profiles were as shallow as 1:25, connecting the low lying adjacent land by removing the existing raised edge. For a length of 50m the redirected footpath now cuts across the shallow bank slope bringing the public closer to the watercourse.

The shallow berms separating the braids and main course were planted with various riparian species rather than relying on natural recolonisation, as there was little natural seed source upstream. In addition on some of the higher berms willow was planted to provide extra cover. A native grass and wildflower mix was used for the banks.

Spoil disposal had to be addressed at an early stage to permit such a large (9000m^3) 'floodplain' excavation. The nearby school planned to build an earth bank to prevent illicit vehicle access to its playing fields. By using 6000m^3 from the enhancement works to help the school achieve this, the project avoided a potential doubling of costs.

Figure 3.4.2
SECTION A THROUGH WETLAND AREA



Subsequent performance 1996 – 2001

The planting has been successful, with the exception of some of the shrubs on the riverbank which were removed.

Though only indicative at this stage, on at least two occasions there has been a whole water quality class improvement between upstream and downstream on the site. Though not physically well suited to most fish, the number of sticklebacks (*Gasterosteus spp.*) has increased markedly.

Anecdotal evidence suggests that people are happy with the scheme. However, there is also evidence that some people were expecting something different.

When creating a wide, shallow and braided channel it is important to recognise the likely increase in urban rubbish deposited after flood events. If not properly managed this can seriously affect the success of the overall project, particularly from the public's viewpoint.

Original Information Provider:
Neil Guthrie

A good diverse vegetation structure has developed along and between the channel threads

3

Enhancing Straightened River Channels

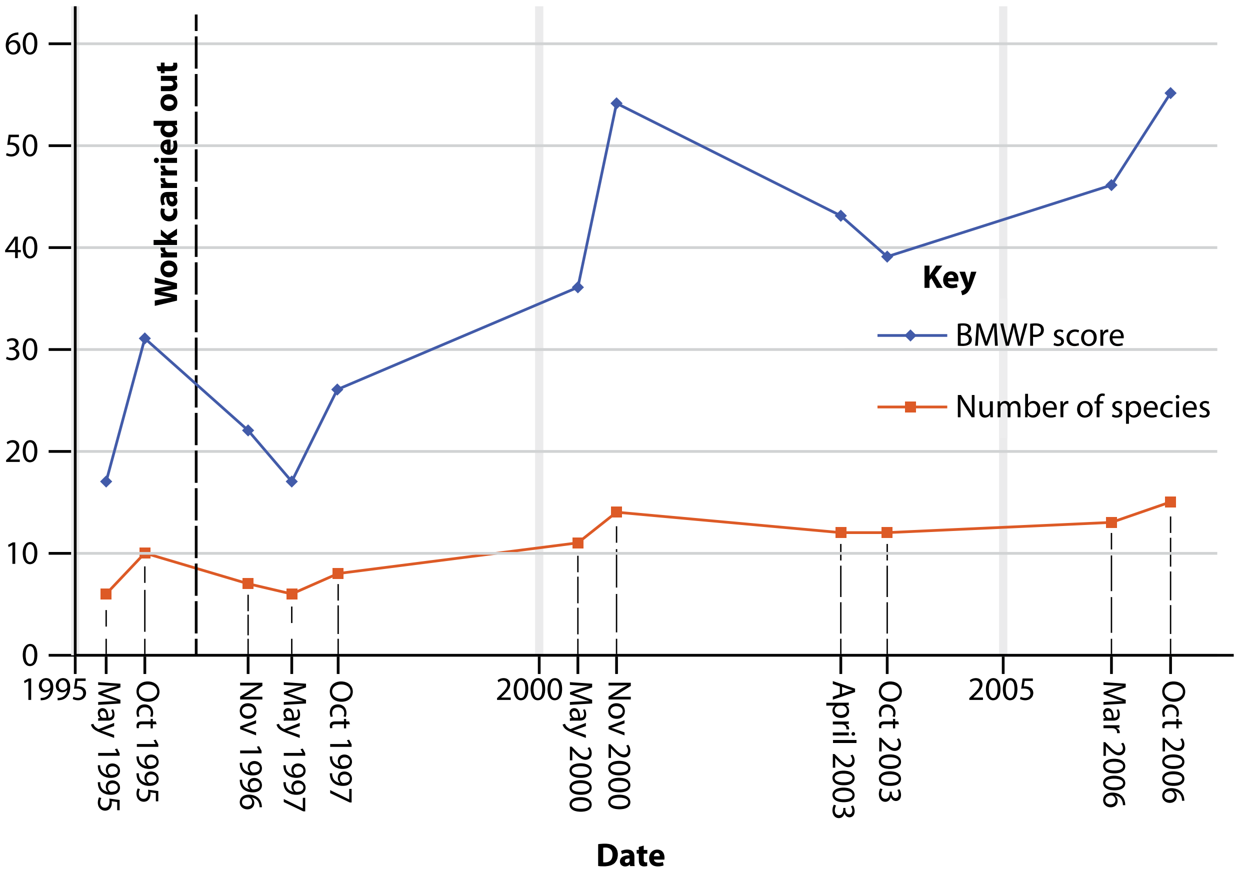
3.4 River Alt 2013 Update

River Alt	Low energy, clay
WFD Mitigation measure	**Click Here** to view details
Waterbody ID	GB112069060580
Designation	None
Project specific monitoring	Macroinvertebrate

The initial earthworks have led to access and recreation improvements along this stretch of the Alt. Common reed (*Phragmites australis*)has been able to develop reinstating a locally rare habitat and increasing the biodiversity potential of the river at this location. Biodiversity within the braided section of the channel has been limited by reedbed monoculture. The encroachment of the reedbed has reduced velocities thereby increasing siltation and reducing flow variation as a result.

Minimal management has been undertaken since the project works and is limited to debris clearance at the road culvert downstream. As a result the wider area is heavily shaded by willow (*Salix spp.*) and alder (*Alnus spp.*) tree cover. Bramble (*Rubus fruticus*) is also dominant over much of the site. In 2012 Knowsley Metropolitan Borough Council (MBC) carried out improvement works on the riparian corridor and re-opened the choked braided side channels as part of the 'Knowsley 2020' project. Tree works on the over steepened banks immediately upstream of the site were also undertaken. The council has been advised not to plant further willow and alder trees but to use oak (*Quercus spp.*), hawthorn (*Crataegus spp.*) and hazel (*Corylus spp.*) as they are not likely to encroach as far into the reedbed.

The visual appeal of the site and the visibility of the River Alt as a feature at this location has been improved through the scheme. Knowsley MBC is undertaking further work to open up access to the riparian corridor and is currently installing a cycle way. Local residents were consulted through the North Huyton Neighbourhood Network for the 2012 works.



Changes to overall number and diversity of invertebrates at the downstream end of the site between 1995 and 2006.
(Stock Bridge Site, SJ 43210 92717. EA data)

Water quality and invertebrate sampling was undertaken between 1994 and 2006 and indicates that there has been an overall improvement in the number and diversity of macroinvertebrates at the site. Further to the improvements in water quality. noted in 2001, the Biological Monitoring Working Party (BMWP) scores shown below indicate that water quality downstream of the site has improved following the works. The BMWP uses invertebrates as biological indicators of water quality. A high BMWP score is indicative of cleaner water.

The technique used on the River Alt has been a catalyst to encourage similar thinking in the region. The site would have benefited from a tailored long term management plan.

One of the choked braided side channels – March 2012

Contacts

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Enhancing Straightened River Channels

3.5 Narrowing of an over-widened channel using low cost groynes

RIVER AVON

LOCATION - STRATFORD-SUB-CASTLE, SALISBURY, WILTSHIRE SU127327
DATE OF CONSTRUCTION - OCTOBER 1997
LENGTH - 125M
COST - £2,000 (EXCLUDING FENCING)

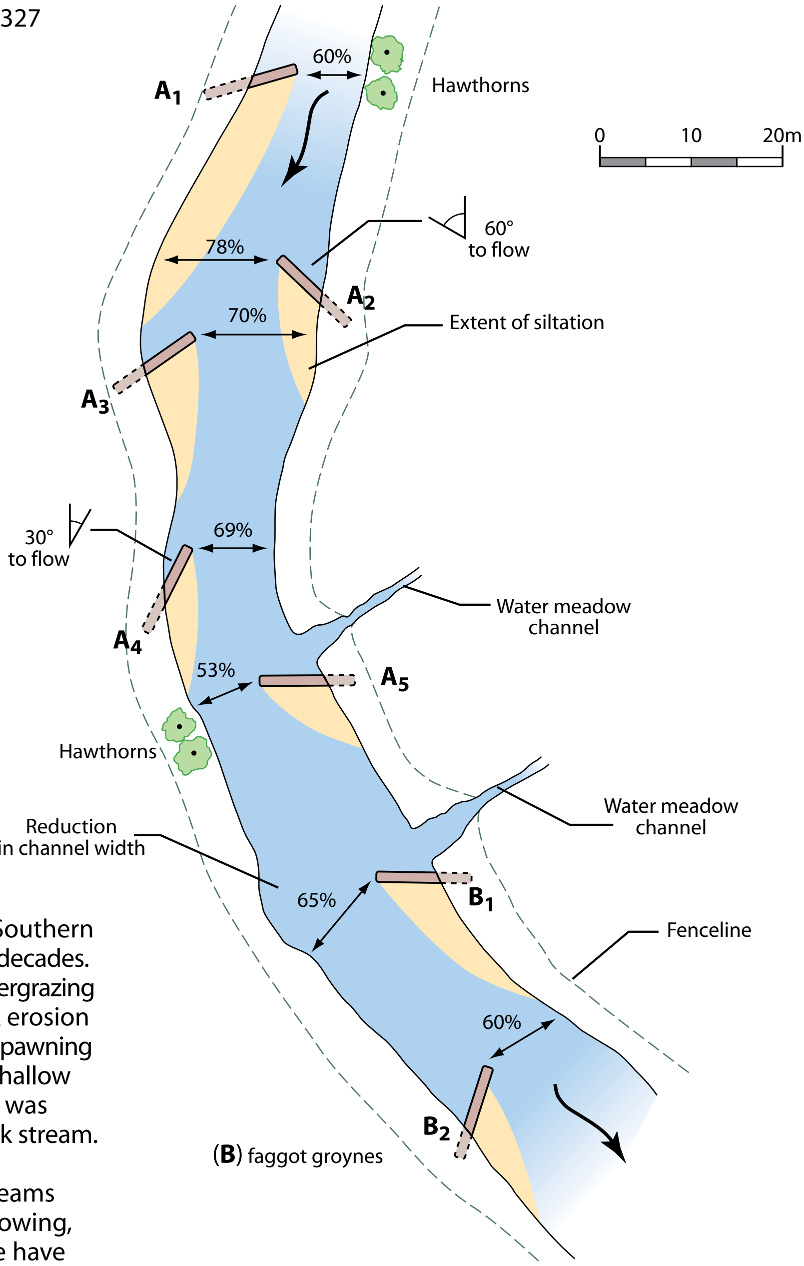


Figure 3.5.1
PLAN OF NARROWING WORKS

Description

The Wiltshire Avon, like many other chalk streams in Southern England has been severely degraded over the past few decades. Excessive stock of cattle in adjacent fields have lead to overgrazing and poaching of its banks resulting in extensive bank erosion and the accretion of sediment in downstream salmonid spawning gravels. The overall result has been the creation of a shallow over-wide channel with poor habitat diversity. This site was chosen because it represents a severely degraded chalk stream.

Recent habitat enhancement techniques on chalk streams have concentrated on modifying, and frequently narrowing, the channel to sustain increased flow velocities. These have involved bio-engineering methods such as the extensive use of willow (*Salix spp.*), loose brushwood and faggots to redefine specific channel characteristics. However, these techniques have proven to be costly, in the order of £30-£55 per metre of river (*see Techniques 3.1 and 3.2*). This project sought to evaluate an alternative technique to establish whether the same level of habitat diversity could be achieved using low-cost groynes comprised of different materials.

Different types of groyne construction were trialed. The expectation was that the groynes would 're-energise' the reach, providing variations in flow characteristics. Sediment being transported downstream would accumulate both upstream and downstream of the groyne and ultimately result in a 'natural' narrowing of the channel due to the settlement and accretion of transported material. Fencing of the river, preventing stock access would allow marginal plants to stabilise this new channel edge and lead to the creation of in–channel sinuosity and flow variation. Habitat diversity would follow as a direct consequence of the physical alterations and stock exclusion.

The total cost of the groynes was less than £2000, equating to a cost over the area of £11 per linear metre.

Enhancing Straightened River Channels

Completed chalk groynes

Design

The design concept incorporated the need to diversify the flow characteristics along the length of the river by installing upstream facing groynes at specific sites on the right and left bank. These were placed according to the on-site observations and an understanding of the flow dynamics of the river.

Construction of the first of the seven groynes in the 125m stretch commenced at the upstream limit of the site. The angle of groyne at the bank was decided by ascertaining the direction of flow (using a floating rope) and constructing at either 60° or 30° to this. The same method was used to construct each of the groynes. Final placement of the groynes was decided on site.

After marking out the area with pegs a JCB dug a trench 0.5m deep and 1-2m wide, with the excavated bed and bank material placed to one side. The trench was cut into the existing bank to anchor the completed groyne. The trench was then filled with either chalk or faggot bundles to provide reinforcement and stability and the excavated material from the original trench replaced on top.

Type **A** deflector – vegetation established

Figure 3.5.2
Section through chalk groyne

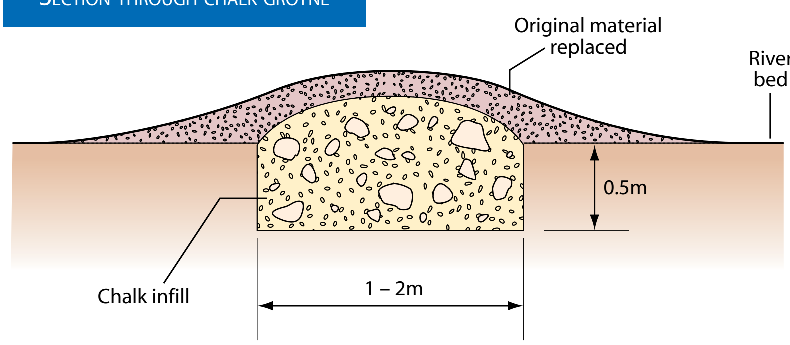
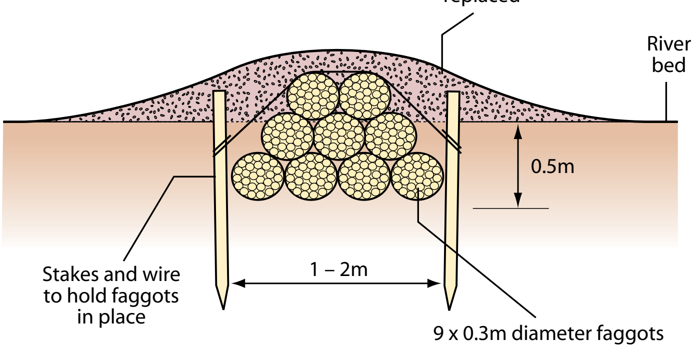


Figure 3.5.3
SECTION THROUGH FAGGOT GROYNE



During construction of the chalk groynes the chalk was rammed down with the JCB bucket. For the faggot groynes the stakes were hammered in by hand, and the JCB bucket was used to hold down the faggots whilst they were wired in place.

By progressing downstream it became apparent that each structure produced a visible 'silt line' marking the extent of slack water created by the groyne. This information was used to determine the positioning of the next groyne, to maximise the likely benefit accrued from each by avoiding overlap.

The finished groynes slope from the bank towards the channel centre so as not to encourage turbulence and erosion of the bank. Also the groynes were positioned facing upstream to ensure that the high flows passing over them were angled towards the centre of the river. This is an effective 'bank protection' and 'pool scouring' measure.

Subsequent performance 1997 – 2001

In narrowing the channel to approximately 60% the groynes have effectively increased velocities. Several structures have had some of the gravel surface eroded by winter flow, the material being deposited immediately downstream of the groyne forming shallow gravel riffles. The ends of the structures are areas of relatively high velocity: these areas have been utilised to great effect by both Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) for spawning.

The desired accretion of material up and downstream of the groynes began soon after installation was completed. Particle sizes indicate a good mix of fine silt and organic material to coarse sand and gravel. This habitat has been colonised by a variety of submerged and emergent vegetation and is providing excellent habitat for lamprey and cyprinid fish fry.

An initial concern, visual intrusion of the groynes, has been negated by the rapid siltation and colonisation by marginal plants naturalising the structures and stabilising the banks. There was no significant difference in the performance and stability of the chalk filled groyne compared with the faggot filled structures: the chalk groynes were however 37% cheaper to construct.

Pre and post-works monitoring was carried out to evaluate the success of the technique. Though the works budget was small it was felt that monitoring was sufficiently important to justify additional expenditure. Monitoring consisted of pre-works, one and three year post-works survey data on physical habitat and flow, fish population, macrophyte observations and macroinvertebrate community sampling.

Type **B** deflector before planting

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

Enhancing Straightened River Channels

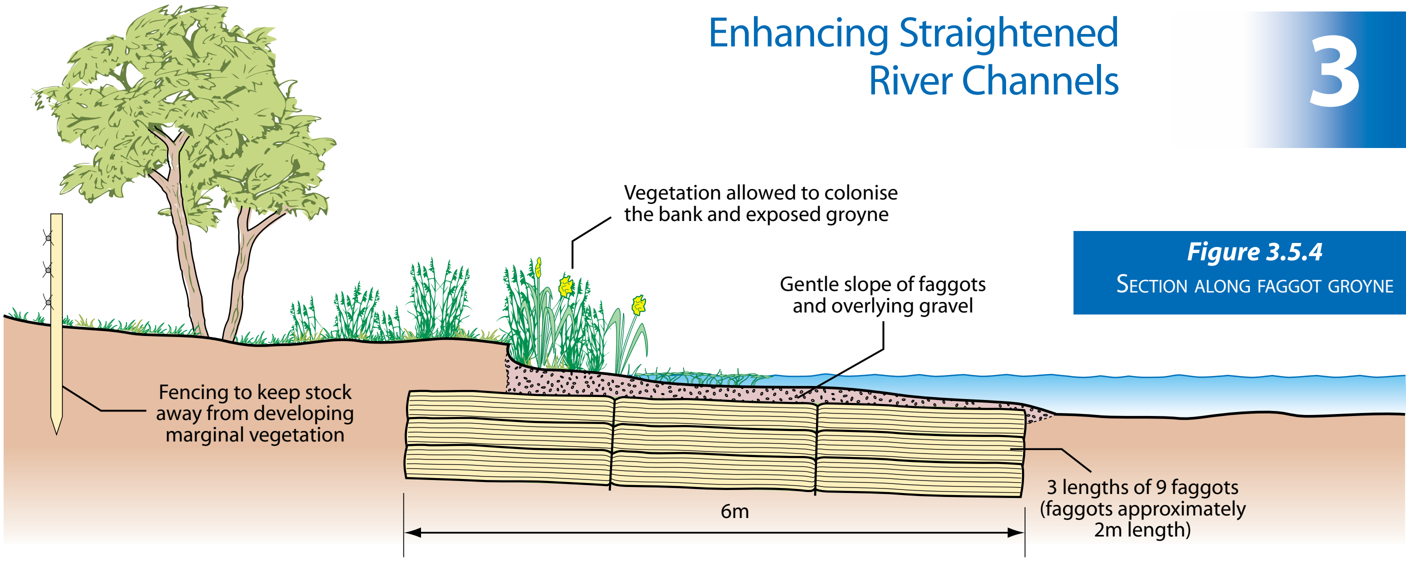


Figure 3.5.4
Section along faggot groyne

Results from this work indicated that the groynes in combination with the fencing increased marginal emergent and submerged macrophyte diversity, a change in substratum composition (a shift from silt and sand domination to gravel and pebbles), with the finer material being deposited in the slackwater areas. Macroinvertebrate diversity was not influenced by the rehabilitation work, and fish population density and diversity improved.

Original Information Providers:
Lin Davis
Allan Frake

Cattle poached, wide and shallow

Groynes in place already increasing flow diversity

Silt deposits were quickly colonised and the river narrowed

3

Enhancing Straightened River Channels

3.5 River Avon 2013 Update

River Avon	Low energy, chalk
WFD Mitigation measure	Click Here to view details
Waterbody ID	GB108043022350
Designation	SAC, SSSI
Project specific monitoring	Vegetation, Fish, Morphology

Initially the chalk and faggot groynes were equally effective. In the medium to longer term the faggot groynes were less effective, disintegrating over time. The chalk groynes remained in place enabling material to accrete up and downstream. In addition the velocities created at the in-stream end of the chalk groynes have been important for attracting salmonids to spawn in the areas just downstream.

The use of faggots was a trial element of scheme but, as they were more costly and less effective in the long term, they would not be recommended for use in future projects of this nature.

Detailed surveys were carried out before the works were undertaken and a long term survey (due to be completed in 2013) has been carried out post works outlining changes to the morphology, hydrology and ecology of the reach. The plant community has changed markedly from pre-restoration and the study aims to determine whether the community has reached a climax structure or is still changing.

Following the works rapid siltation occurred, resulting in channel narrowing. In the 2007 survey an approximately 30% reduction in channel width was observed compared to pre works. The variations in flow characteristics observed in 2002 remain the same.

Catch monitoring undertaken by Salisbury District Angling Club (SDAC) indicates further increases in salmonids and spawning. Fished by wading, the site is a valuable fishery with good stocks of brown trout and grayling (*Thymallus thymallus*).

Most of the reach was fenced to prohibit the entry of cattle into the channel. In addition, there has been the occasional need to trim back willows along the walkways to maintain access for anglers.

©Allan Frake

The narrowed channel – May 2007 (Arrow indicates location of 2012 photograph)

© SDAC

The site after 15 years showing the development of vegetation – November 2012

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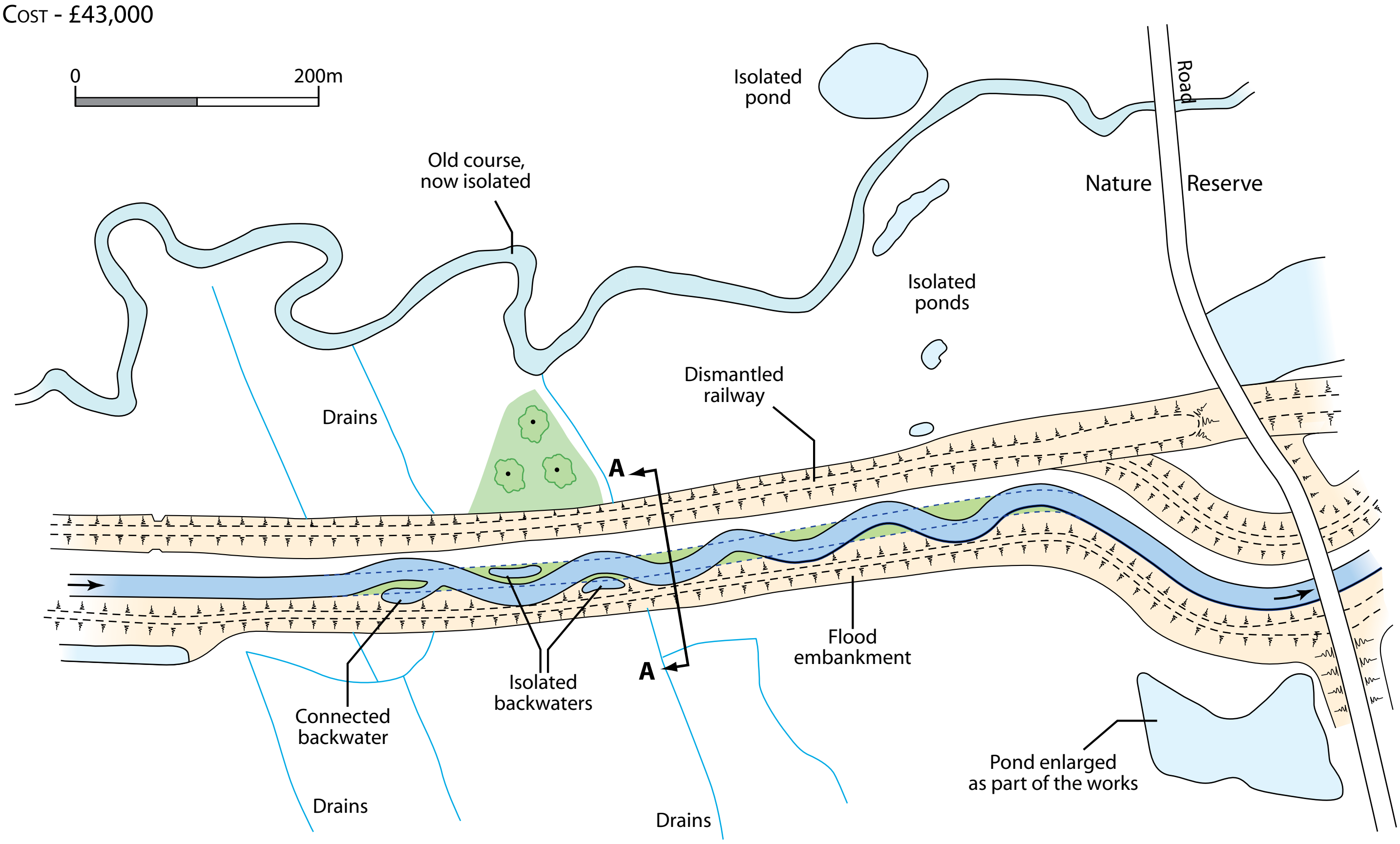
3

Enhancing Straightened River Channels

3.6 Creating a sinuous low flow channel in an over-widened river

RIVER DEARNE
LOCATION - MEXBOROUGH, WEST OF DONCASTER, SOUTH YORKSHIRE SE484012
DATE OF CONSTRUCTION - SUMMER 1995
LENGTH - 500M
COST - £43,000

Figure 3.6.1
PLAN OF SITE



Description

The lower River Dearne had suffered substantial changes to its natural gradient as a result of subsidence problems caused by deep mining operations. To alleviate this problem, a new, straight and featureless river was created in the 1970s to ensure efficient evacuation of floodwater. The design standard for the channel was calculated to be approximately 1 in 150 years (50% greater than required). The lack of physical diversity resulted in excessive emergent vegetation growth which extended across the channel and further impeded flow. Prior to the works, high terrestrial berms rose up to the flood banks. The river bed substrate was composed predominantly of nutrient-rich silt, overlaying some transported gravels.

Some of the subsided land adjacent to the abandoned old channel formed wetland habitat, which has subsequently been designated as a SSSI. However, the wildlife value of the canalised river was very low due to its physical uniformity, poor water quality and low gradient. Water quality began to improve in the 1980s due to mine closures and improved sewage treatment, and the river became valued as a coarse fishery. Its potential was however limited by the lack of in-stream physical habitat diversity, which left few opportunities for fish to spawn.

Meandering was not a viable option, and so the creation of a low-flow channel was deemed beneficial for all interests. A narrow channel would create a self-sustaining coarse substrate with greater water velocity, which in turn should reduce the extent of siltation and reed (*Phragmites spp.*) growth.

A scheme was developed which would maximise the present fishery and the wider spawning potential of the river by introducing sinuosity into the straight, over-widened channel. It would also demonstrate reduced maintenance benefits whilst having no detrimental effect on flood protection.

The proposed scheme was a drastic reduction in width, with a very sinuous course created by constraining the low-flow width by large boulders. The previous over-design of the straight course allowed for such work to be undertaken and still provide the necessary flood protection standards.

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

Enhancing Straightened River Channels

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River Dearne. Wide and straight, choked in summer

New sinuous reed-fringed course

Design

The sinuous low-flow channel was defined by placing stone in the river to form the 'inside' of each bend. Locally occurring magnesium limestone was chosen. The decision to armour was taken to provide a defined channel and to be removable in the event that flood defence concerns arose.

Placement was carried out by an excavator from within the channel as water levels only varied between 0.3m and 0.7m.

Work started upstream and looked initially to increase velocities in the first two bends to 0.5m/s, reducing the increase to near existing flows (approximately 0.2m/s) at the final bend.

In this way the narrowing of the low-flow channel was determined by a combination of estimating the reduction required and measuring the velocity after placement of the boulders.

Placement of limestone boulders and berm back-filling

Enhancing Straightened River Channels

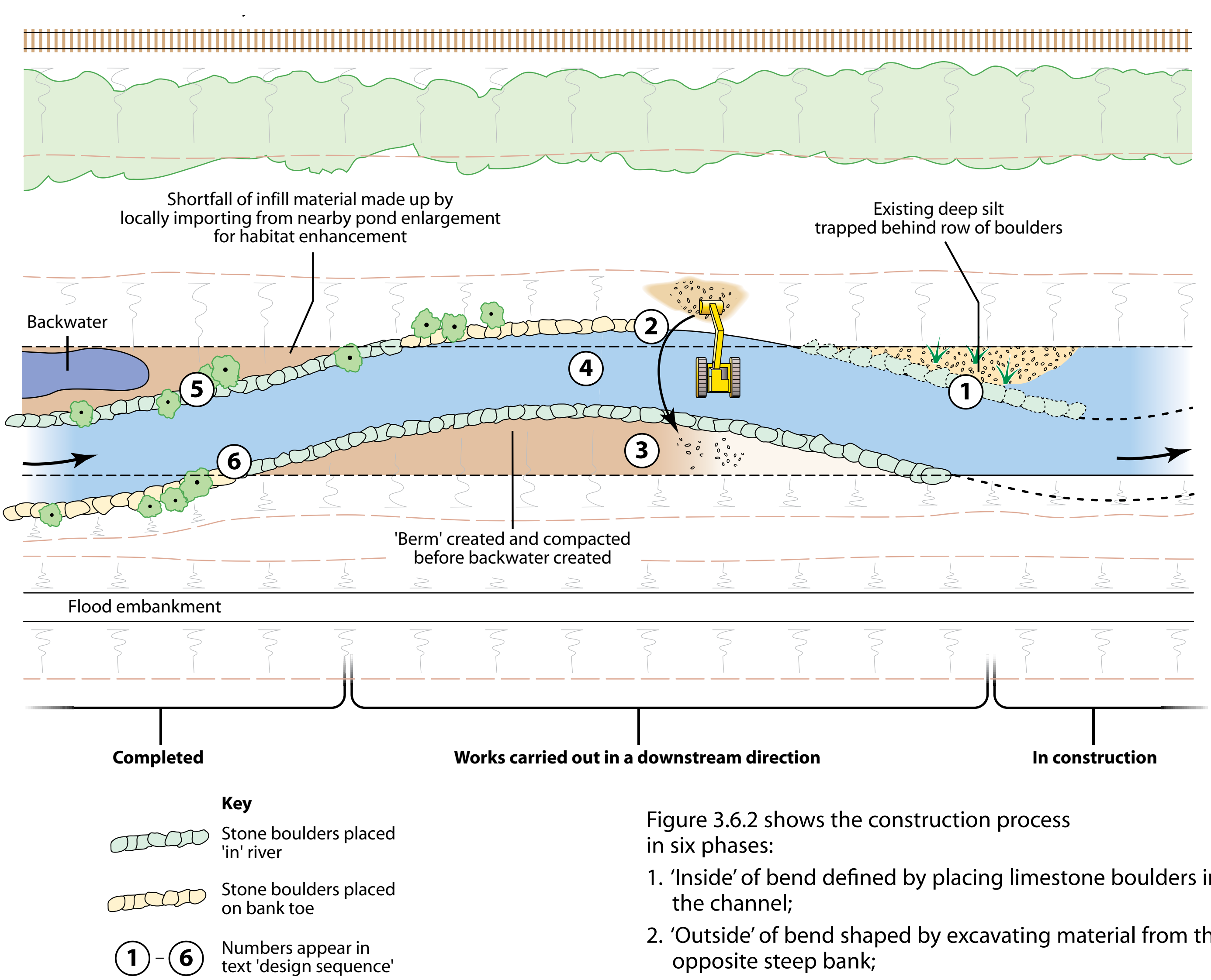
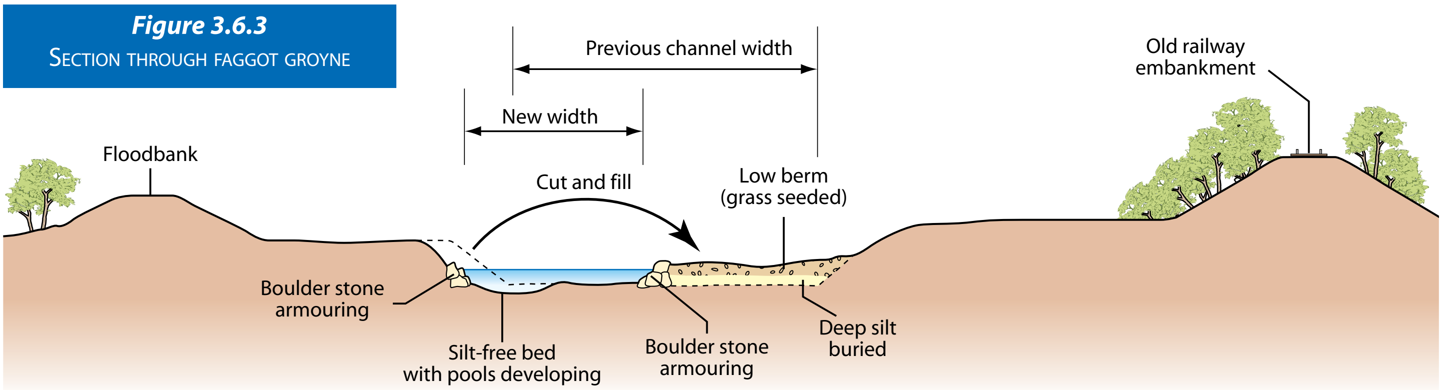


Figure 3.6.2
Plan of works

Figure 3.6.2 shows the construction process in six phases:

1. 'Inside' of bend defined by placing limestone boulders into the channel;
2. 'Outside' of bend shaped by excavating material from the opposite steep bank;
3. Material from 2 used to backfill the 'inside' bend forming a low berm;
4. Additional limestone boulder armouring placed on toe of 'outside' bend;
5. Backwaters excavated within the low berms created;
6. Berms and banks seeded with a grass mix and later planted with standard trees.

Figure 3.6.3
Section through faggot groyne



Enhancing Straightened River Channels

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Narrowing increased velocities and created riffles used for fish spawning

The low-flow channel included three small backwaters and scrapes, and the low berms were created at a variety of levels to enable the establishment of a range of riparian communities, from swamp to dry grassland.

The former 10m wide channel was narrowed by up to 5.5m in this way, but maintained flood capacity by equating cut and fill and ensuring that the in-channel structures were kept to a low level. The new low-flow berms, were designed to be submerged during floods.

The berms and banks were seeded as soon as the earthworks had been completed so that the root system would consolidate the new earth banks before winter floods. Seeding was completed by late summer and growth was well advanced before the end of the autumn. This also limited potential erosion through heavy rain.

Some transplanting of emergents from the channel was carried out, both in front of and within the rock armouring, to promote vegetation of the berm edge.

The successful completion of the first 500m section prompted a rapid implementation of a similar length in 1996/97.

Subsequent performance 1995 – 2001

By creating a sufficiently narrow low-flow channel the effect on the silty bed was immediate. Within two weeks of completion the majority of the silt had been cleared. Deposition of gravel and silt occurred rapidly on the inside of the bends with pools (up to 2m deep) having since developed at the apex. The silty areas have promoted the colonisation of marginal plant species.

Fisheries surveys since the works were completed show the beneficial effect of the scheme. Numbers of chub (*Squalius cephalus*), dace (*Leuciscus leuciscus*), barbel (*Barbus barbus*), roach (*Rutilus rutilus*) and gudgeon (*Gobio gobio*) have all increased, but more importantly there is now successful spawning and recruitment of juvenile fish.

The limestone was rapidly colonised by algae and lichen once in place and silt deposition between the stones allowed a variety of waterside plants, including reeds and sedges (*Cyperaceae spp.*) to quickly become established. By summer 1996 marginal reeds were beginning to grow and by autumn 1996 the reed growth had masked the armouring.

A small amount of erosion occurred in two areas, which were not protected. In one location rock armouring and willow (*Salix spp.*) planting was used to address this problem, but in the other the river was allowed to widen into a pool.

Live willow stakes were inserted along both banks and on the new berms to provide cover and supplement the self-set trees already establishing at the margins.

The two unconnected backwater pools dried out due to the hydraulic draw of the river through the loosely compacted fill material. To mitigate this effect upstream connections were made using 0.1m diameter plastic pipes.

Two years post-works, an audit of the scheme reported an annual saving of between £2,500 and £3,000 in reduced maintenance costs as a direct result of the work carried out.

Original Information Provider.:
Chris Firth OBE.

Main channel and backwater
5 years on, Summer 2000

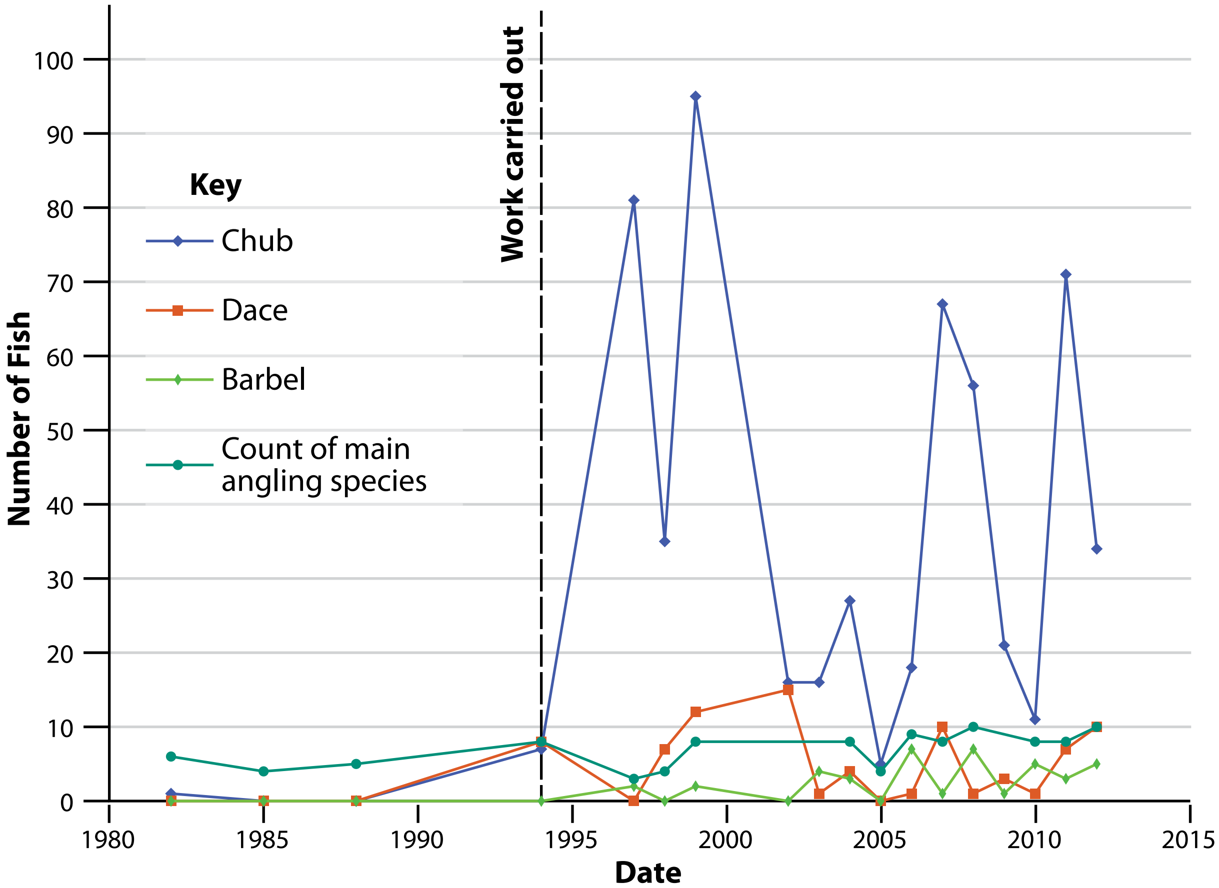
3

Enhancing Straightened River Channels

3.6 River Dearne 2013 Update

The narrowed channel has increased velocities and as a result sediment has been transported downstream, maintaining clean gravel spawning grounds in the restored reach. Anglers are happy with the results of the scheme and have commented on improved fish size in the area. Two particularly successful seasons for recruitment and spawning, 2010 and 2008, are cited as the reason for this. In 2012 a Barbel of over 10lbs was recorded at this site. Fish populations are monitored annually and both the number and diversity of fish species has increased following the works.

River Dearne	Low energy, gravel
WFD Mitigation measure	Click Here to view details
Waterbody ID	GB104027063173
Designation	SSSI
Project specific monitoring	Fish



Fisheries data showing changes in the count of species of anglers over time.
The data indicates improvement in the count of the main angling species and significant increases in the numbers of some individual species. (*Pastures Bridge site, EA data)*

Of the three backwaters created along the channel, two have now silted up and only operate in very high flows. The third was breached at its top end and has formed a secondary channel. This provides a relatively sheltered environment that anglers indicate holds fish fry under normal conditions. If the breach had not occurred it is highly likely that this backwater would also have silted up. Whilst the silted backwaters are not functioning as fish habitat as they were intended, they do have wider biodiversity benefits.

Main channel and operational backwater – October 2012

Occasional tree management continues to be necessary along the banks and involves pollarding of willows. When one section is cut, the adjacent section is left to ensure that some cover is always available.

The scheme has been successfully replicated at two upstream locations on the same watercourse. The use of similar backwater features located within the low flow berm areas were not included by the Rivers Trust at these sites, due to the risk of rapid siltation. Whilst the backwaters created for this scheme are not functioning as fish habitat, they have wider benefits to biodiversity and as such any Environment Agency schemes would probably still include them. This project has demonstrated the need to design accordingly depending on the desired aim of the backwaters. Building a maintenance plan would also be beneficial to address the likely siltation of backwaters.

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3

Enhancing Straightened River Channels

3.7 Replacing a concrete drain with a 'natural' channel

Yardley Brook
Location - Shard End, South-east Birmingham SP118198
Date of construction - March 1995
Length – 100m
Cost – £5,000

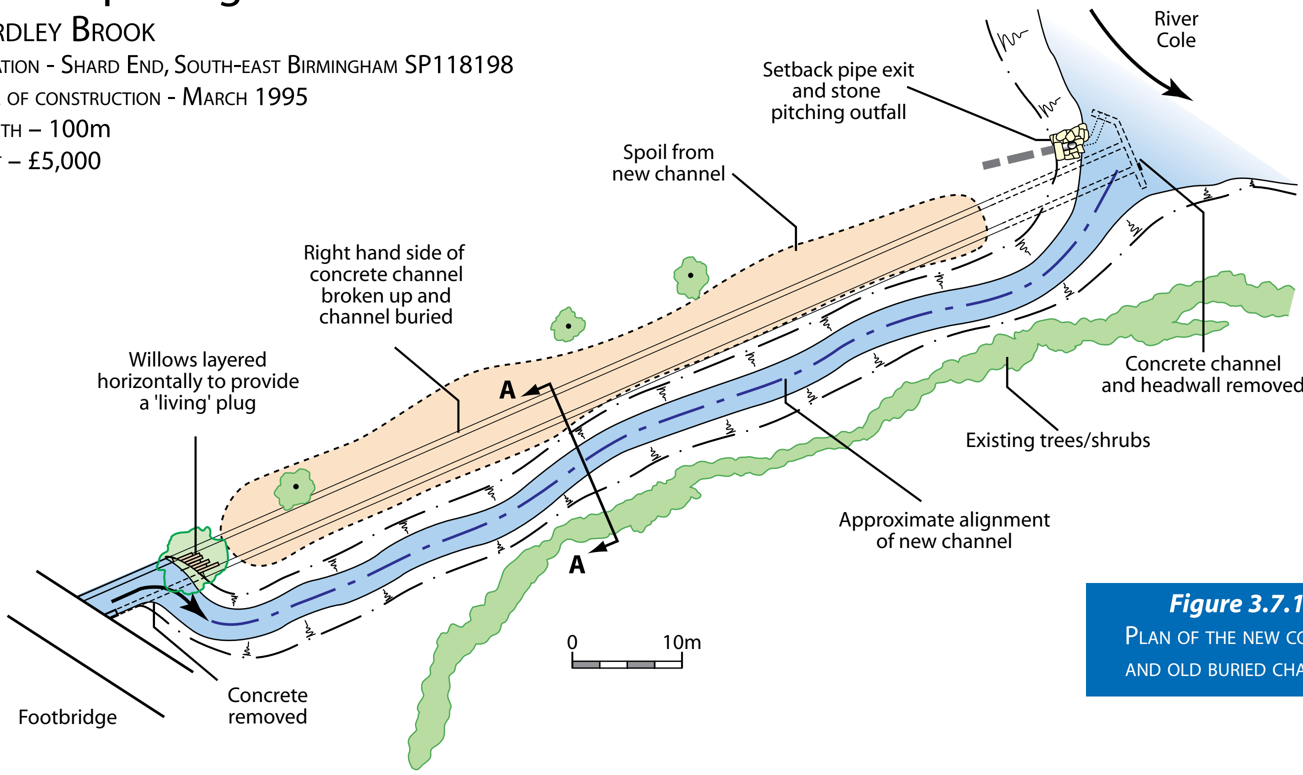

Figure 3.7.1
Plan of the new course and old buried channel

Description

Yardley Brook rises in south-east Birmingham and emerges from a culvert onto the floodplain of the River Cole in a concrete channel. The catchment is highly urbanised, with over 150,000 people living within 2km of the river. Urban run-off thus causes periodic poor water quality and significant litter. The brook itself is contained within an area of made-up ground which has been retained as public open space.

Originally a sewage outfall, the brook no longer needed to be contained in a concrete straight-jacket due to closure of the sewage works upstream in the late1960s. The brook is located within the Project Kingfisher area; a collaboration between local and statutory authorities and volunteer groups to achieve a substantial improvement in the wildlife quality of an 11km section of the Cole and adjacent land in Solihull and Birmingham.

Yardley Brook entering the River Cole before works

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

The brook was constrained in a concrete sleeve, offering no possibility for small-scale in-channel enhancement. Rehabilitation required removal of the brook from its 100m long concrete surround. Complete relocation, rather than removing the concrete, was the cheaper option.

Design

The lip of the concrete channel was broken up using an excavator, to ensure that once buried the remnant channel would not protrude above ground level. The broken concrete was pushed into the barely flowing channel.

Figure 3.7.1 shows the 100m sinuous channel that was excavated alongside the brook. The new course was excavated at a greater depth than the concrete channel bed. Previously the bed of the River Cole had been approximately 0.7m below the concrete outfall, as a result of deepening of the Cole over the lifetime of the concrete brook. A simple 'V' shaped channel was dug with sloping earth banks as it was decided that the brook could sufficiently shape itself. Over-specifying the design would not be cost-effective.

Concrete channel being broken up

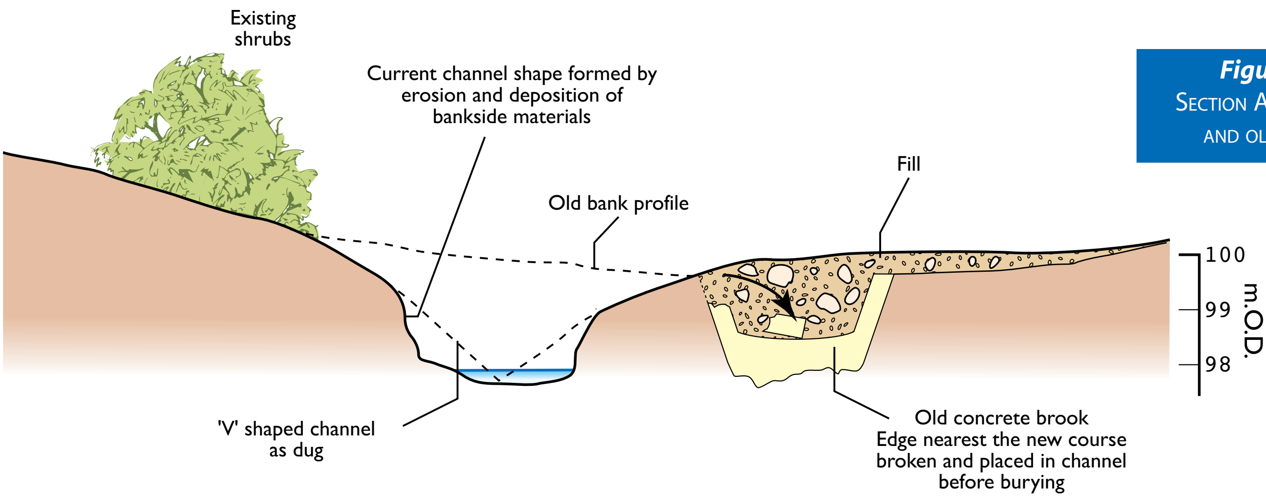

Figure 3.7.2
SECTION A THROUGH NEW AND OLD CHANNELS

3

Enhancing Straightened River Channels

The 'new' brook being excavated adjacent to the old channel. Spoil stockpiled

All spoil was stock-piled between the new and the old channel, and where this became too narrow, on the opposite bank of the old channel. This maintained the flow through the old drain and allowed all work to be carried out in the dry. Once completed, flow was diverted through the new course, and the old channel was filled using the spoil from the new.

At the upstream end of the 'new' brook the old course was blocked with rubble then plugged with live willows (*Salix spp.*) laid in during the in-filling process to form a growing plug.

The new confluence with the River Cole is on the site of the old outfall structure. The large (9m by 2m) concrete eyesore was removed and the mouth reformed to a more natural appearance. A number of large concrete blocks, remnants of failed bank protection works, were also removed. This concrete was broken up and buried nearby.

A drainage pipe that exited at the old outfall structure was given a new stone pitched headwall which is now well hidden by growth and difficult to discern.

The works took two weeks, one of which accounted for concrete removal and breaking-up. The end result is an apparently natural 2-3m wide channel.

Live willow plug

After – the new 'natural' Brook

Subsequent performance 1995 – 2001

Immediately following the diversion to the new channel a dramatic change in the habitat quality of the brook was achieved in terms of landscape, visual amenity and ecology.

After completion winter flows quickly began to 'develop' the kinds of natural channel features one would associate with a small brook. The 'V' shape quickly transformed through erosion of the loose fill material into a much more 'natural' channel 2-3m wide. This process has continued as the site matures.

The live willow plug has grown to secure the breakout point of the new brook. This area now blends in well with the general appearance of the brook and its self-set bankside trees and shrubs.

Six years on, Yardley Brook has developed 'natural' channel features in contrast to the concrete channel previously in place. The brook still suffers from periodic poor water quality due to the dense urban population that surrounds it.

The work was deemed so successful that a further concrete length of the main River Cole was removed in 1996-1997. This type of 'demonstration' site gives added confidence to others and reduces potential risks through valuable experience.

Original Information Provider:
Andrew Crawford

Six years on. Earth cliffs, gravel shoals and a diverse flow regime – April 2001

3

Enhancing Straightened River Channels

3.7 Yardley Brook 2013 Update

Following works a more natural bed profile has been created and natural processes are now able to take place. The more natural channel has created flow variability with areas of fast flowing water and slack water at the margins, where emergent vegetation is now growing. There are still major water quality issues, as a result of misconnections, which may be investigated in the future.

The project would have benefited from following the original plan, i.e. make a shallow V shaped cross section with the excavated material placed away from the bank. Instead the soil was piled up next to the channel making a much steeper V shaped channel. Erosion has removed much of the material which has contributed to raising the bed of the River Cole, at the mouth of the brook, by some 0.4m. In addition, as a result of the new channel having too steep a gradient in some places, a nick point started to move upstream exposing a sewer pipe. To remediate this, a layer of large gravel stones was laid on top to act as a check weir to prevent further erosion.

The live willow plug at the upstream end of the brook has continued to be very successful as a bioengineered bank stabilisation method.

Following this project similar work has been carried out on the main River Cole. Concrete was broken up, and where possible, removed from the channel immediately downstream of the confluence with Yardley Brook.

Yardley Brook	Medium energy, clay
WFD Mitigation measure	**Click Here** to view details
Waterbody ID	GB104028042502
Designation	None
Project specific monitoring	None

© Environment Agency

Yardley Brook flowing into Cole

© Environment Agency

Erosion exposing sewer pipe as nickpoint moves upstream

© Environment Agency

Yardley Brook flowing into the Cole. Riparian trees and vegetation have now grown up to stabilise the banks – February 2013

Contacts

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3

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

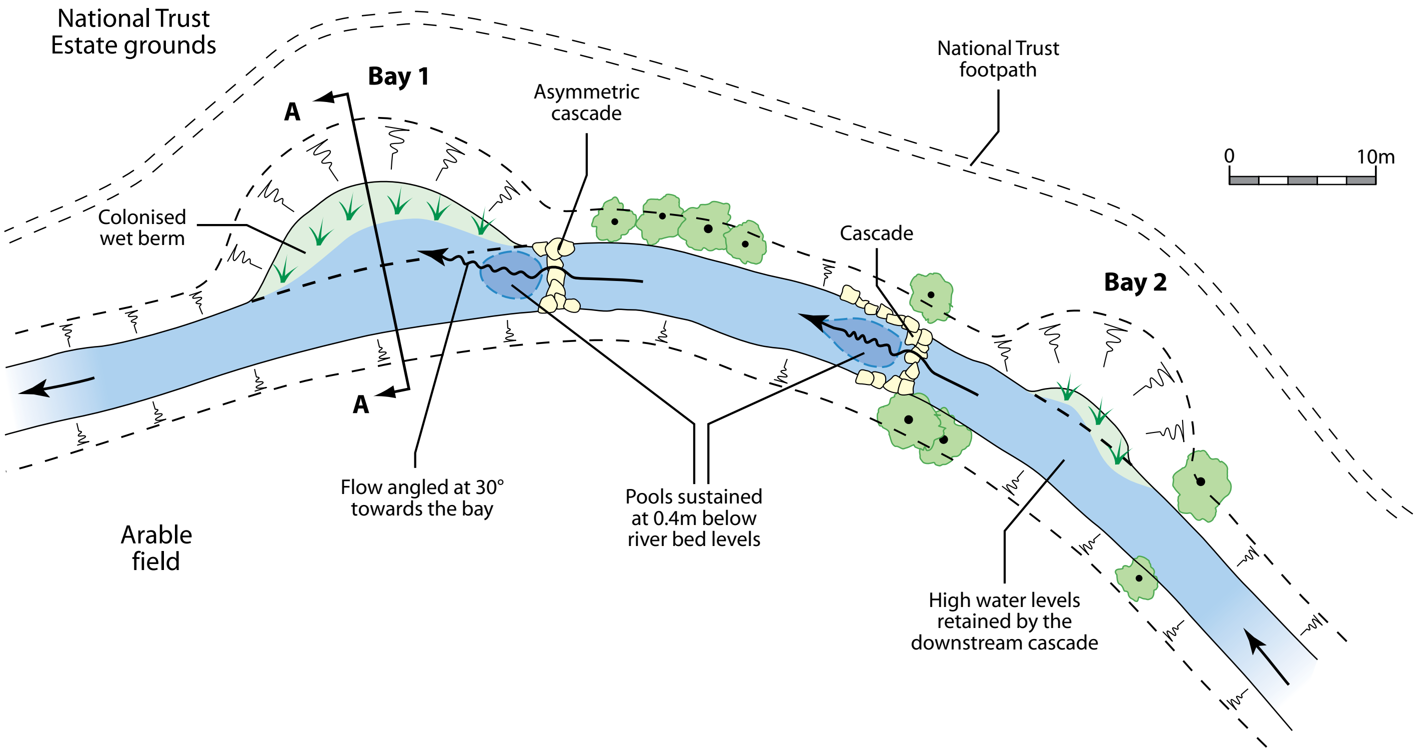
Enhancing Straightened River Channels

3.8 Creation of on-line bays

RIVER TALL

LOCATION - ARDRESS, NR. MOY, CO. ARMAGH, N. IRELAND. OS MAP 19, H916555
DATE OF CONSTRUCTION - JULY 1995 TO DECEMBER 1996
LENGTH - BAYS BETWEEN 10M AND 30M
COST - NOT AVAILABLE

Figure 3.8.1
PLAN OF SITE



Description

The Tall River is a main tributary of the River Blackwater, flowing through Co. Armagh. It is a slow flowing, low energy river within an agricultural catchment. The river had been subject to an arterial drainage scheme in the 1960s, which deepened and widened the river.

The 1.2km Tall River scheme was the first project within Northern Ireland to address the specific need to enhance the riverine environment, rather than being attached to a larger flood prevention scheme. The enhancement works were a part of a larger 'water recreation' scheme, developing footpath access along the river linking with footpaths already developed by the landowner, the National Trust. Due to landowner restrictions works could only be carried out on the National Trust owned right bank and in-channel.

The deepening resulting from the arterial drainage scheme meant that the river had lost its natural connection to the floodplain. It was felt that some kind of shallow slackwater habitat was needed. As creation of large backwaters was unacceptable to the landowner, the option of creating small 'bays' was considered. These bays would provide some shelter in high flows suitable for fish fry and invertebrates, and shallow margins should increase the macrophyte diversity within the reach.

Design

Four bays of differing sizes were excavated within the reach. Three of these were accompanied by upstream stone cascades, to generate turbulence and ensure that the bays remained 'open' rather than quickly silting up. The bays also incorporated a low ledge, just below summer water level to accommodate a variety of macrophyte species. *Figure 3.8.1* shows the two bays located at the downstream end of the enhancement reach.

The roughly semi-circular bays were excavated down to bed level where the bay meets the channel. This level is then followed back, rising to the low ledge level at the bay edge. The width of ledge varies with the size of bay.

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

Enhancing Straightened River Channels

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Downstream bays after less than a year.
Note: Bay 2 is already becoming choked with vegetation

From the ledge the bank rises at a batter shallower than the existing 1:1 bank (approx. 1:2 to 1:3). The batter angle varies with the difference between bed and bank top from 2 – 4m (*Figure 3.8.2*).

The stone cascades were constructed from 0.5m+ boulders formed into a rough 'loose' arc and dished in the centre. This configuration helps to direct the flow away from the potentially erodable banks. The bankside boulders are securely keyed into the sides. The loose construction allows water to pass through the structures, reducing the backwater effect at low flows whilst providing a good degree of turbulence.

Subsequent performance 1996 – 2001

The bays that had associated upstream boulder cascades have remained 'open' to differing degrees.

Upstream bays 3 and 4 (not illustrated)
These two bays are accessible to cattle and are used as drinking points. There is an element of poaching at the water's edge, but the stocking densities are low enough not to be of concern. Grazing maintains a cropped but diverse macrophyte margin.

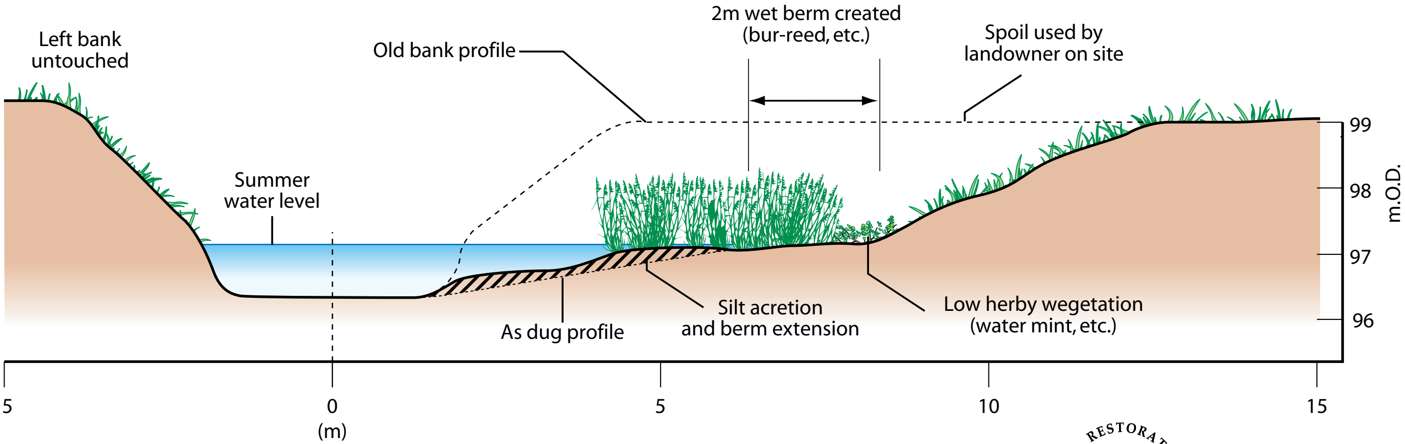

Figure 3.8.2
SECTION A THROUGH BAY 1

Bay 1 showing the angle of flow keeping the bay 'open'

The smaller of the two (bay 3) is sustained by the turbulence generated by its cascade and is cleared of loose silt during high flow events. The larger (bay 4), 30m in length, is too large to remain silt free and has developed shallow margins. Both cascades have excavated deeper pools adjacent to the bays.

Downstream bays 1 and 2 *(Figure 3.8.1)*
Cattle are excluded from the lower reach and, as a result, the more vigorous emergent vegetation, such as bur-reed (*Sparganium spp.*), is dominating.

Bay 1 is similar in size to bay 4 but is able to retain its open nature due to the positioning of its cascade. The flow of water over the boulders is angled into the bay, approximately 30 degrees offset from the main channel. This directional flow is helping to maintain the bay at low and high flows.

Bay 2 rapidly silted up and colonised with emergent vegetation, spreading well into the main channel. The cascade for this bay was placed downstream, resulting in increased water levels from the backwater effect created. This has reduced flow velocity and now acts as a silt trap, promoting silt deposition and vegetation growth.

The success of these bays on the River Tall seems to be determined by:

- adequate velocity, turbulence and direction of flow;
- sizing and shaping of the bay;
- grazing of the colonising vegetation.

Original Information Provider:
Judith Bankhead.

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

3

Working to restore & enhance our rivers

Enhancing Straightened River Channels

3.8 River Tall 2013 Update

A repeat River Corridor Survey (RCS) carried out two years after the works showed an increase in emergent vegetation and macrophyte diversity. The bays are inundated at high flows, acting as a fish refuge, however due to siltation these may be becoming too shallow. Following the creation of stone cascades a greater variation in flow characteristics has been observed.

The success of the bays varied depending on the presence, or otherwise, of a structure deflecting water into them. If the project was to be carried out again, more consideration would need to be given to either the location of the bays within the overall flow regime of the river, or be designed to include a deflection structure that would maintain flows into the bay. Additionally, the site would have benefited from a long term management plan, particularly for tree planting.

The scheme has been used as an early demonstration site within Northern Ireland which effectively communicated the concept of implementing restorative measures on rivers to both senior management and wider stakeholders. The works demonstrated the need to design in harmony with the rivers natural processes and hence some of the measures implemented worked better than others. Similar projects have since been undertaken including the successful creation of vegetated berms on the Ballee Burn and the creation of shallow bays at Ecos Centre, Ballymena.

River Tall	Low energy, clay
WFD Mitigation measure	**Click Here** to view details
Waterbody ID	10611
Designation	None
Project specific monitoring	Vegetation

Bay 2, looking downstream. Heavily vegetated – May 2012

Bay 2, looking downstream – March 2006

Contacts

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3

Enhancing Straightened River Channels

3.9 Introducing gravel to inaccessible reaches

RIVER CHESS
LOCATION – BLACKWELL HALL, LATIMER, BUCKINGHAMSHIRE SU980997
DATE OF CONSTRUCTION – 1994/95
LENGTH – 250M
COST - NOT AVAILABLE

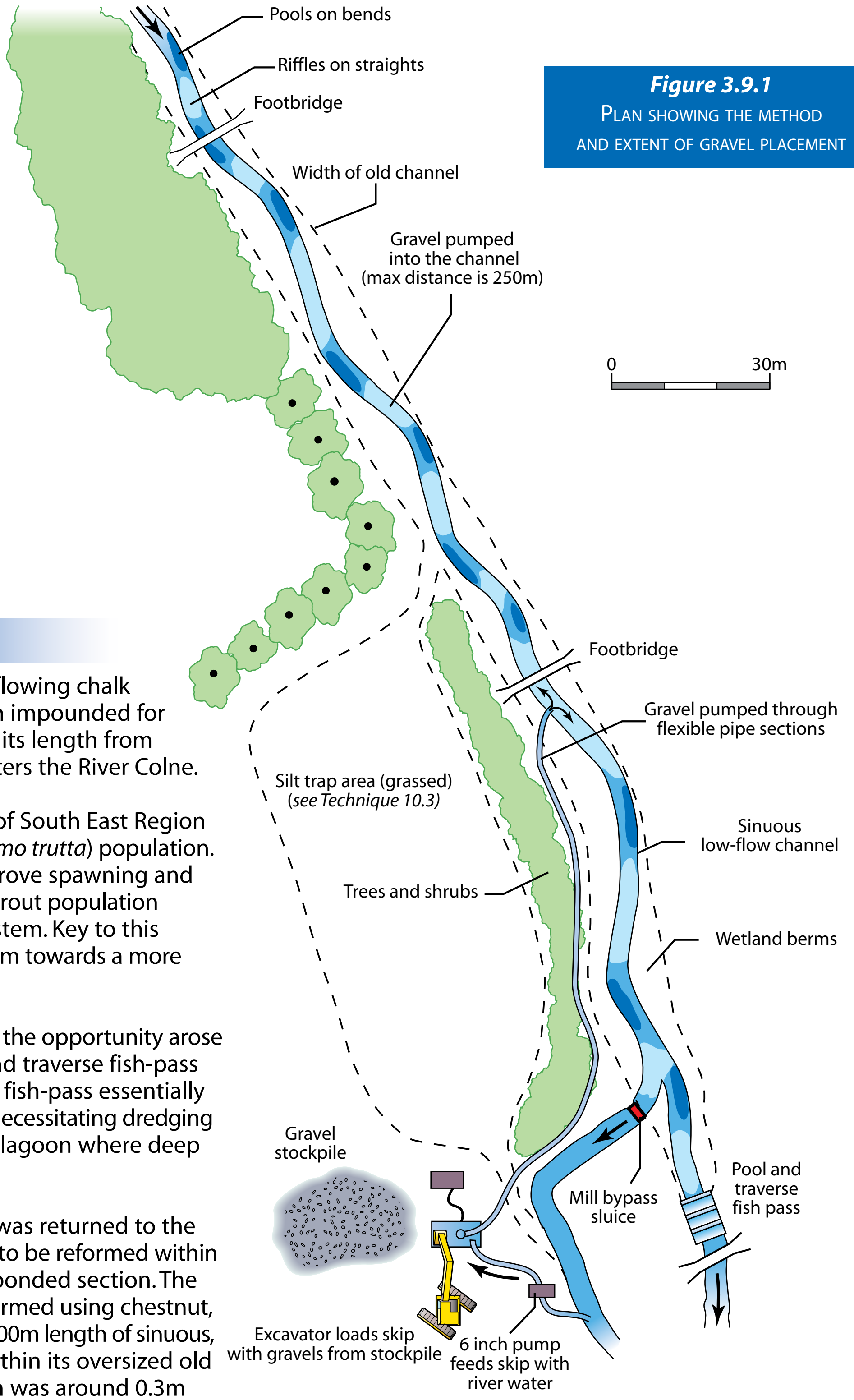


Figure 3.9.1
PLAN SHOWING THE METHOD AND EXTENT OF GRAVEL PLACEMENT

Description

The River Chess, naturally a shallow fast flowing chalk stream with a good gravel bed, had been impounded for milling purposes at various places along its length from Chesham to Rickmansworth where it enters the River Colne.

It is one of the few rivers in the NE Area of South East Region to have a self-sustaining brown trout (*Salmo trutta*) population. A long-term strategic objective is to improve spawning and holding conditions for the native brown trout population and restore free passage through the system. Key to this objective is the rehabilitation of the stream towards a more natural gravel-bed chalk stream habitat.

In 1993, at the request of the landowners, the opportunity arose to replace an old mill weir with a pool and traverse fish-pass to restore fish passage. Building the new fish-pass essentially lowered the upstream water level by 1m, necessitating dredging and re-profiling of the exposed wide silt lagoon where deep silt had accumulated (*see Technique10.3*).

By lowering the weir sufficient gradient was returned to the river to enable a narrow sinuous channel to be reformed within the previously deep, over-widened and ponded section. The narrowed new course of the Chess was formed using chestnut, ash and birch faggoting. This resulted in a 300m length of sinuous, narrow, fast flowing river, meandering within its oversized old channel. The sustainable, desirable depth was around 0.3m with an undulating gravel bed.

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

Enhancing Straightened River Channels

View of the wide dredged section, gravel being placed within the low-flow channel

As a result of the previous management of the river, the Chess had been gradually denuded of its gravel bed. Imported gravels were introduced into the stream by pumping. This method of placement overcame the imposed restrictions associated with conventional plant access to privately owned land and disturbance of woodland and bankside vegetation.

Design

The gravel material specified was well-graded 5–25mm gravel, which closely resembled the grading found downstream. The poor accessibility meant a novel approach was used to place the gravel material.

- At the site compound a submersible pump powered by a diesel generator was placed in a skip located near to the river.
- Using a six inch pump the skip was filled with river water.
- An excavator loaded the stockpiled gravel into the skip.
- The gravel was then pumped along a 250m flexible pipe and fed into the new low-flow channel where specified.

Pumping apparatus in operation

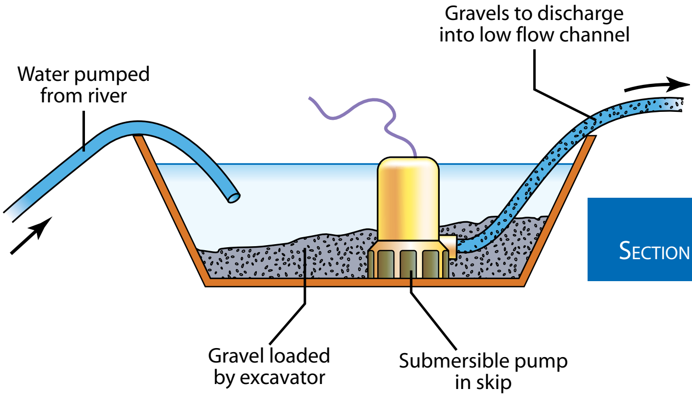


Figure 3.9.2
SECTION THROUGH PUMPING APPARATUS

Gravel pumping in operation

Four years on
– gravel shoals and deeper hollows remain

Using this approach the contractor was able to place the gravels economically and without having to remove existing valuable trees and shrubs. By introducing the gravel it was possible to shape the bed, recreating pools on the bends and riffles on the straight sections (*see Technique 5.5* for more detail on bed raising).

Subsequent performance 1995 – 2001

Some redistribution of gravel has occurred locally, forming deeper hollows and bars.

Original Information Providers:
Steven Lavens
Chris Catling

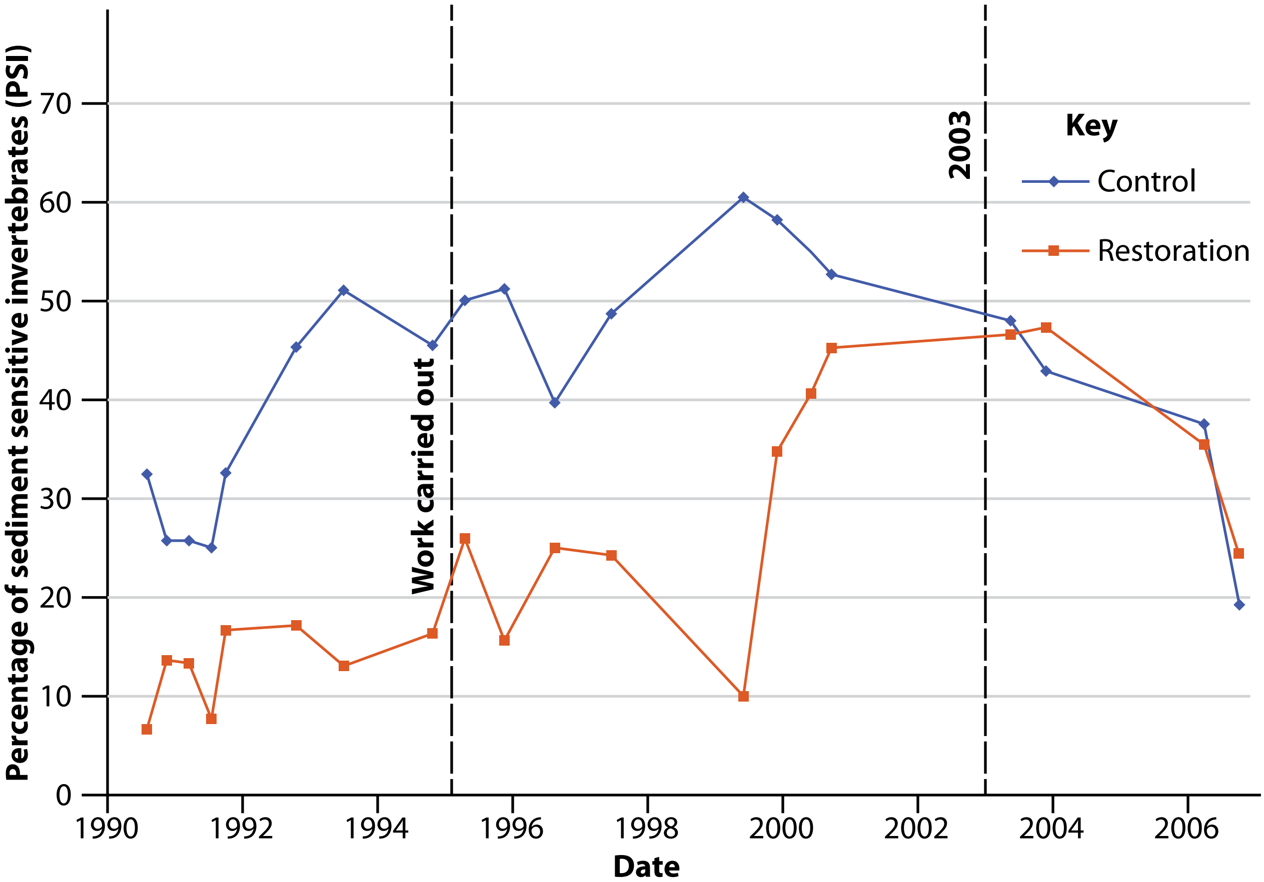
Enhancing Straightened River Channels

3.9 River Chess 2013 Update

The works have successfully created diversification of flow, from moderate velocities in deeper glides, to fast flowing water over the gravel riffles. There has been some localised redistribution of gravel but the narrowed channel remains silt free. Very clean gravel is now present where before the substrate was entirely silty. The variety of gravel sizes has provided a range of niche habitats and has encouraged the establishment of submerged macrophytes such as water starwort (*Callitriche heterophylla*).

Post project invertebrate monitoring demonstrates an increase in the Percentage of Sediment sensitive Invertebrates (PSI) at the restoration site. This gradual increase to levels similar to the control reach by 2003, indicates a cleaner substrate.

River Chess	Low energy, chalk
WFD Mitigation measure	**Click Here** to view details
Waterbody ID	GB106039029870
Designation	None
Project specific monitoring	Invertebrates



Increases in the number of silt sensitive species.
By 2003 the restored reach had achieved a similar invertebrate community to the upstream control site.
(*Blackwell Hall site, EA data*)

Enhancing Straightened River Channels

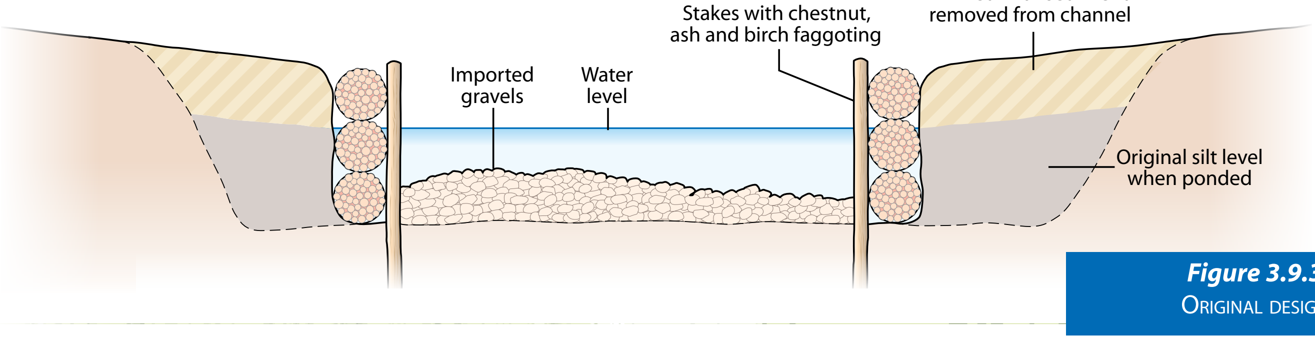


Figure 3.9.3
ORIGINAL DESIGN

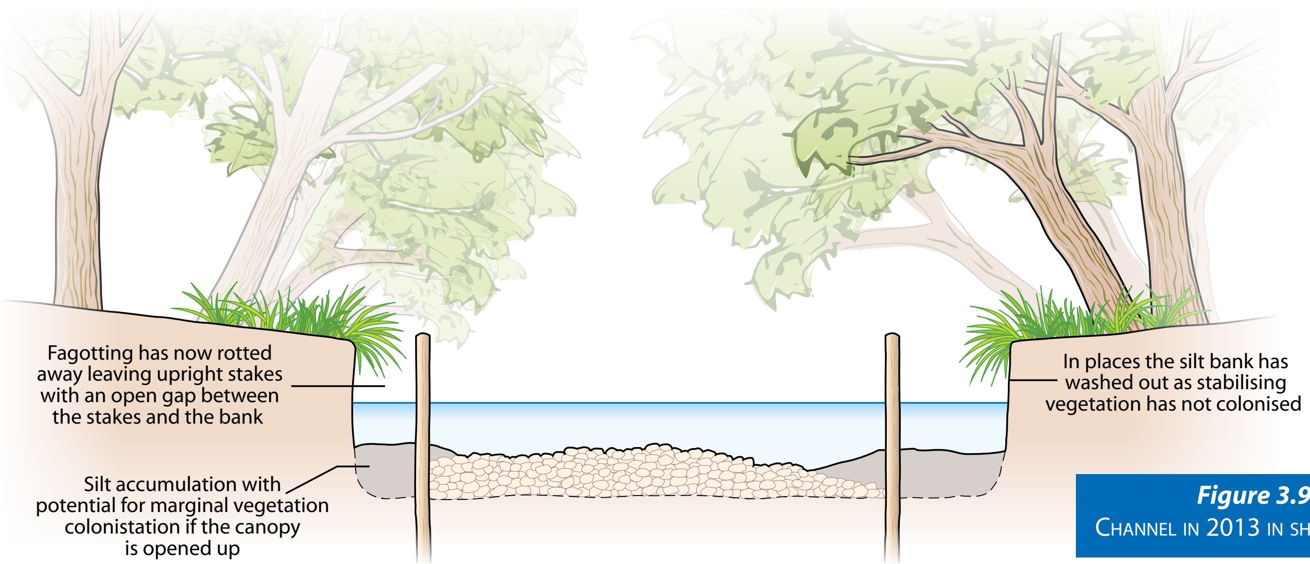


Figure 3.9.4
CHANNEL IN 2013 IN SHADED REACHES

Looking downstream the lines of posts visible with no vegetation behind them – 2013

Silt accumulation behind the posts – 2013

Channel narrowing on the River Chess was successful where the channel is not shaded by trees – 2013

© RRC

The mechanism by which the channel was narrowed has had mixed success.

The use of faggots to define a channel edge relies on a strong growth of marginal vegetation to bind the decaying faggot deadwood, any silt they accrete and the earth/silt bank held behind them.

The works to the 300m dredged section was carried out sympathetically to minimise the need for disturbance to the woodland. However, by not having to carrying out any tree works to these densely shaded parts of the reach, the over-shading has restricted vegetation colonisation and stabilisation of the retained-silt edge. In these reaches the faggots have decayed and in some places the bank edge has eroded (highlighted by the remaining line of posts).

The reduced velocities, resulting from the influence of the banks and the posts, are still acting to attract silt towards the stream's edges. Even now, tree work to open up the canopy to allow sufficient light penetration to aid vegetation colonisation of these silty margins, also helping to protect the eroded edge.

This highlights the need for a clearly defined approach to using biodegradable material (faggots, coir, jute, etc.). They are generally a short term solution that rely on planted or colonising vegetation to take over the stabilizing role that they initially provide. It is therefore critical that the intended vegetation is locally available (in situ or close by) and has sufficient light and growing seasons to establish strongly.

Contacts

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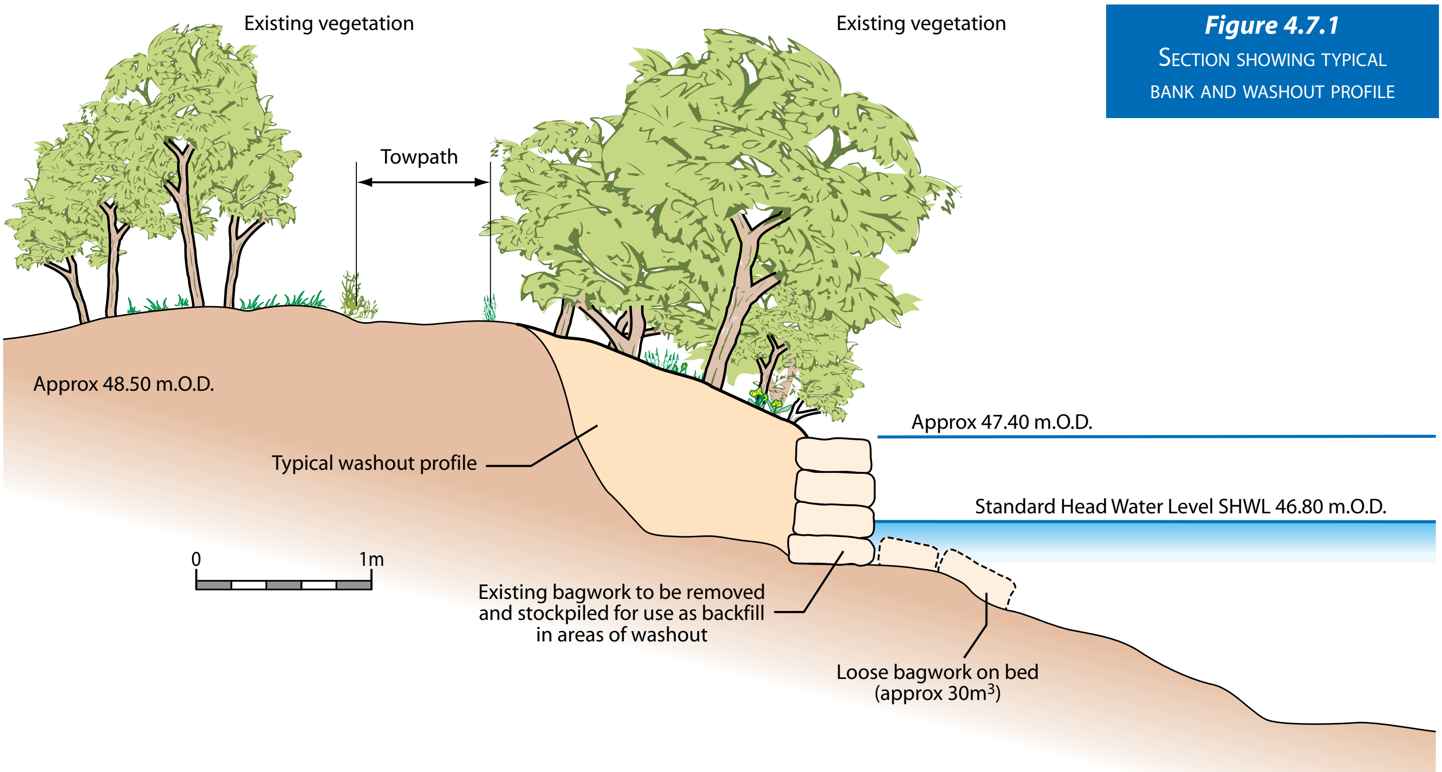
4

Revetting and Supporting River Banks

4.7 Bank revetment using low steel sheet piling and coir rolls

River Thames
Location - Clifton Lock Cut, Oxfordshire SU 544944
Date of construction - September 1996
Length – 140m
Cost – £45,000

Figure 4.7.1
Section showing typical bank and washout profile



Description

For centuries the River Thames has been heavily managed for the purposes of flood defence and navigation. In its lower reaches the river is restricted and controlled by weirs and locks. Various techniques of bank revetment are used along its banks including steel sheet piling and/or concrete bagwork. Boatwash is a major concern where more natural softer engineered banks exist. In addition, sections surrounding locks and 'artificial' lock cuts experience a degree of rapid drawdown and changes in velocity in association with lock usage.

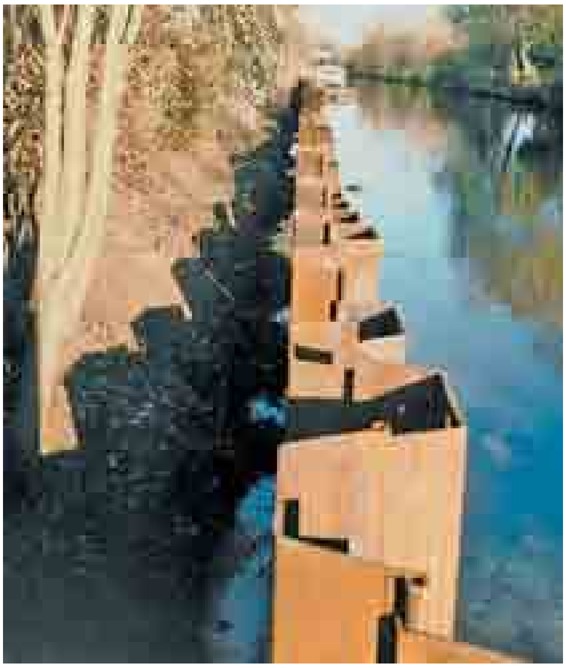
Sheet piling has the benefit of good structural integrity with a proven lifespan and can retain vertical banks. Concrete bagwork, similarly, has a proven lifespan and can be used in conjunction with near vertical bank faces. However, both these offer little benefit to wildlife in terms of habitat value and do not address landscape or aesthetic issues.

At Clifton lock cut the old concrete bagwork revetment was beginning to disintegrate and allow wash-out of the unprotected bank back towards the towpath. The reinstatement was initially to be sheet piling which would be visible above water level, continuing the existing run of high sheet piling and bagwork that protects the lock.

As an alternative, a more visually acceptable solution was proposed which would add habitat value to the reach. This design incorporated the structural integrity of sheet piling (to

Failed section of bagwork at Clifton Lock Cut

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



Initial sheet piling after bagwork removal, over existing trees

allow continued maintenance dredging) with an above-water 'soft' approach promoting vegetation growth. The sheet piling was carried out using a land based crane with floating pontoon to support the piling frame, thus reducing the degree of trimming and removal of existing bankside vegetation.

Design

The three vertical zones referred to in previous revetment techniques are considered below:

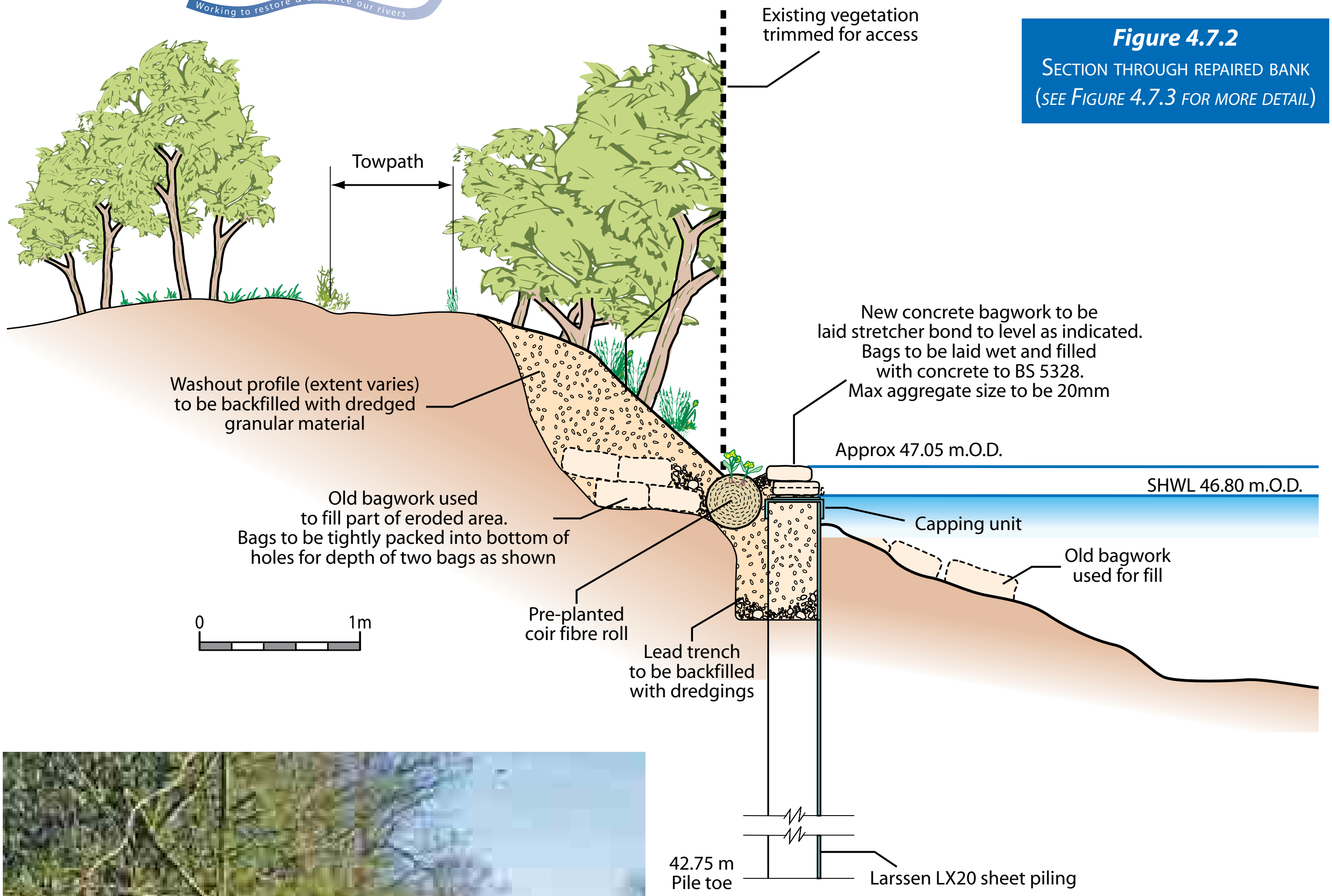
Below water
The old bagwork was removed to be used as backfill. To ensure stability at the toe of the bank, short sections of sheet piling were driven to below water level. The piling was capped with an inverted steel channel section with mesh welded to the top to prevent movement of the above two courses of new bagwork, ending just below 'standard head' water level (*see Figure 4.7.3*).

Water's edge
The sheet piling and bagwork was backfilled with the old bagwork and dredgings from the channel, then capped with a pre-planted (pond sedge, reed canary-grass and iris) coir fibre roll. The dredgings were stockpiled and allowed to de-water before being used as backfill.

2 layer capping bagwork and tie-in to existing sheet piling

Revetting and Supporting River Banks

Figure 4.7.2
SECTION THROUGH REPAIRED BANK
(SEE FIGURE 4.7.3 FOR MORE DETAIL)



The roll provides both retention of the backfill, preventing wash-out, and a medium for reedy marginal vegetation establishment. The vegetation, when established, provides an effective natural defence against boatwash, habitat for bankside wildlife and is visually more pleasing.

In addition, 0.05m diameter UPVC 'mammal' pipes were incorporated between the lower level bagwork at 1.5m intervals.

Upper bank
The upper slope was formed from imported topsoil and covered with a biodegradable fibre mat to protect and retain the sloping surface. The mat was used along most of the reach, a necessity due to the timing of the works with little opportunity of vegetation establishment before high winter flows. The matting was pinned to the slope using wooden pegs, rising to the retained shrubline. The bank was not seeded to allow natural re-vegetation.

Transition from the existing high sheet piling and bagwork wall is achieved by stepping down the bagwork to tie into the new 2 layer system. At the upstream end the return piling runs 1.2m into the bank.

Flax mat secured, planted coir rolls installed and voids backfilled

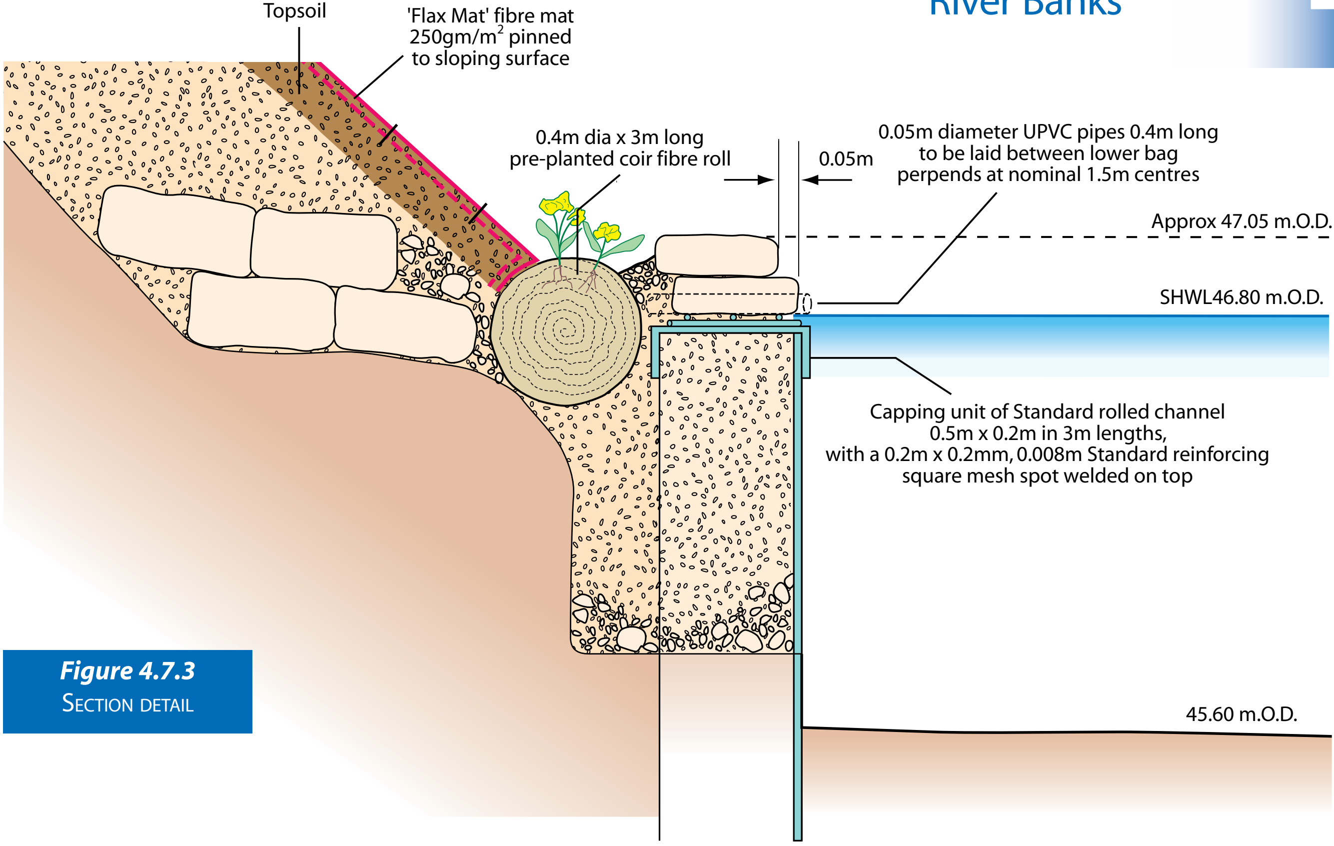


Figure 4.7.3
SECTION DETAIL

Vegetation establishment after 18 months

Subsequent performance 1995 – 2001

The revetted bank showed no signs of erosion and appears quite 'natural'. The emergent species planted in the reed rolls have established well, forming a dense marginal fringe.

The fibre matting protected the slope well and has since almost completely degraded allowing re-vegetation of the upper slope. In areas this has taken a number of years, possibly due to the steepness of some sections and a dry summer after completion. The growing root system of the retained shrubby vegetation helped to bind the backfilled bank and provide extra stability.

Some minor tree maintenance has been carried out along the towpath where it has begun to restrict access to, and views of, the river. In-channel dredging work (removal of displaced material) has also been undertaken since completion, with no adverse impact to the bank.

Original Information Providers:
Lesley Sproat,
Martin Luker.

4

Revetting and Supporting River Banks

4.7 River Thames 2013 Update

The introduced bagwork has settled (soil and silt has solidified) and is standing up well to wash caused by passing boats. Where there is sufficient light there is good vegetation growth and numerous plant species have successfully established. However, in some areas lack of maintenance means riparian vegetation has overgrown, restricting some views of the river from the towpath. The minor tree work carried out along the towpath has since ceased and it is suggested that the scheme may have benefited from a tailored tree maintenance schedule.

This technique has been recommended by the Environment Agency for use along the River Thames and similar managed navigation systems.

River Thames	Medium energy, clay
WFD Mitigation measure	Click Here to view details
Waterbody ID	GB106039030334
Designation	None
Project specific monitoring	None

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Vegetation growth has established and the bagwork has remained intact – August 2013

Contacts

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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 SH641615
Date of construction - Autumn 1998
Length – 900m
Cost - £48 000 construction,
£8 000 flood model, £5 000 design

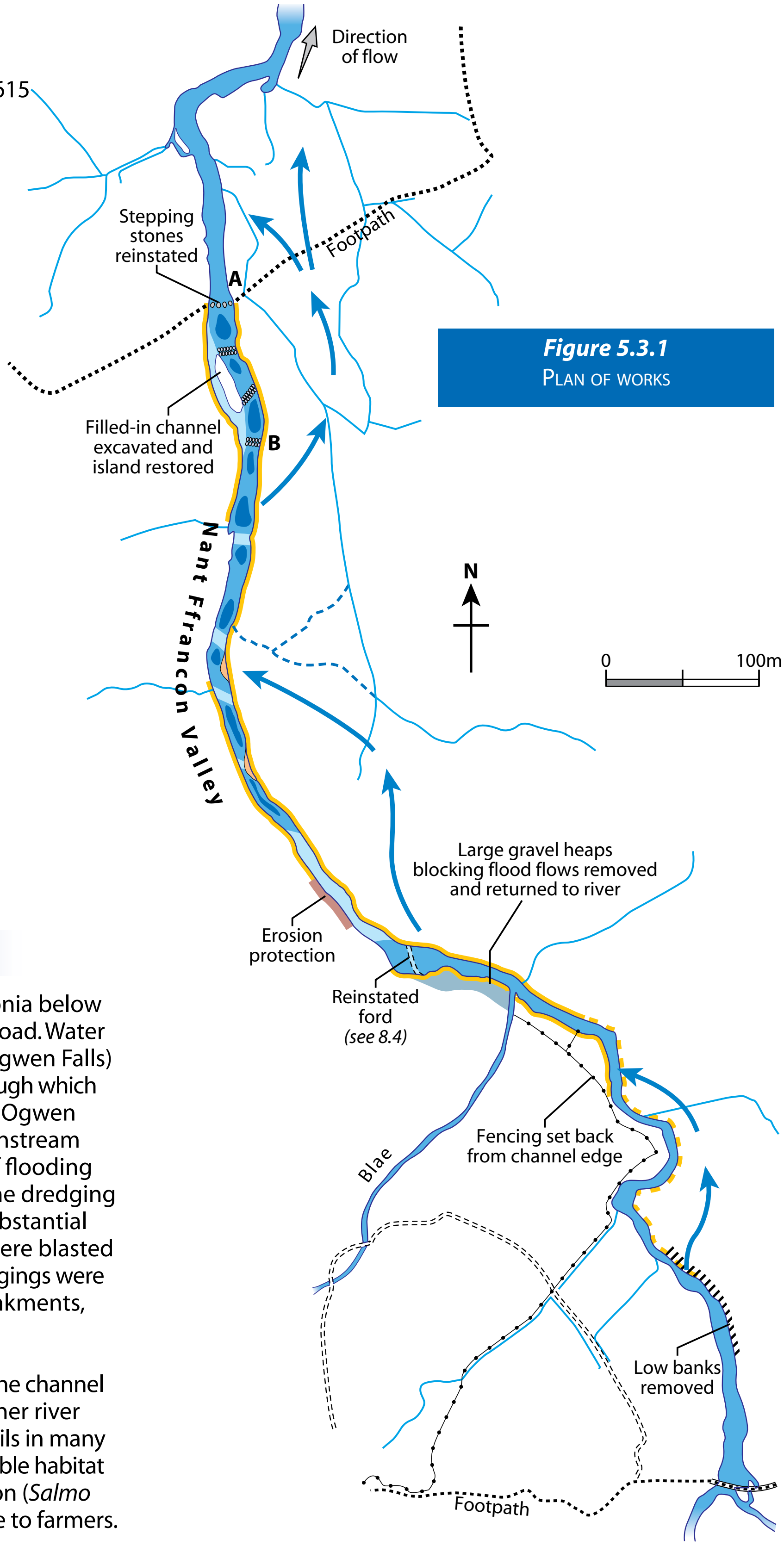


Figure 5.3.1
Plan of works

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 Atlantic salmon (*Salmo salar*) 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.

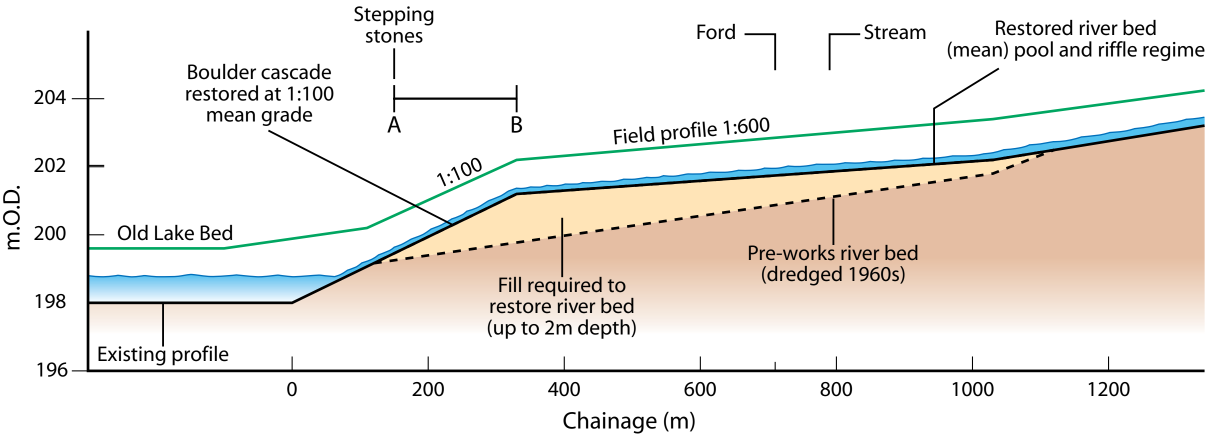
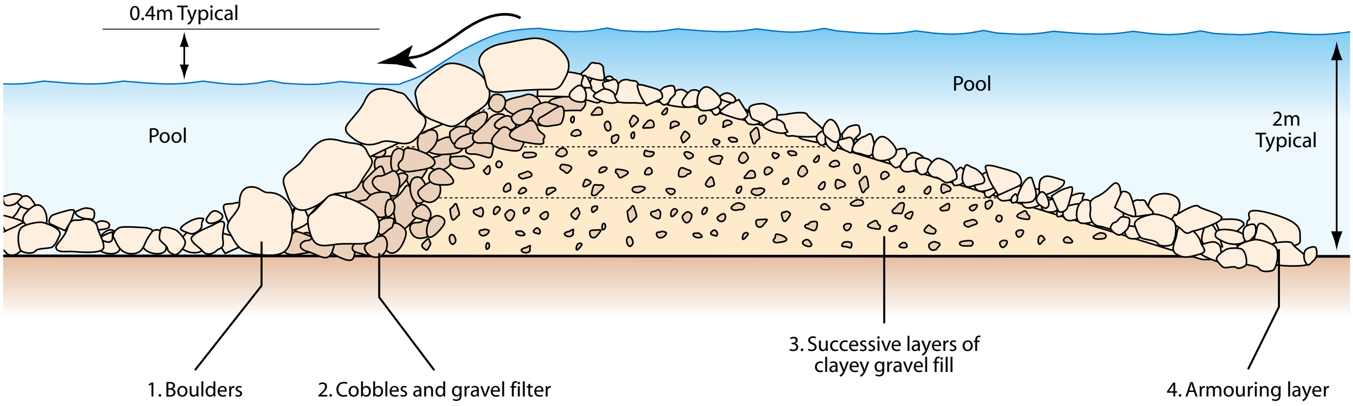


Figure 5.3.2
LONGITUDINAL PROFILE

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.

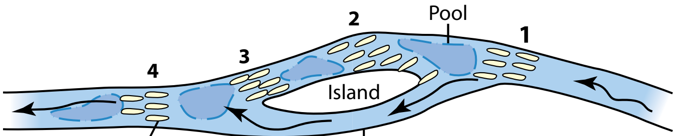
Restored island

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

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 (*Salix spp*.) 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

Controlling River Bed Levels, Water Levels and Flows

5.3 River Ogwen 2013 Update

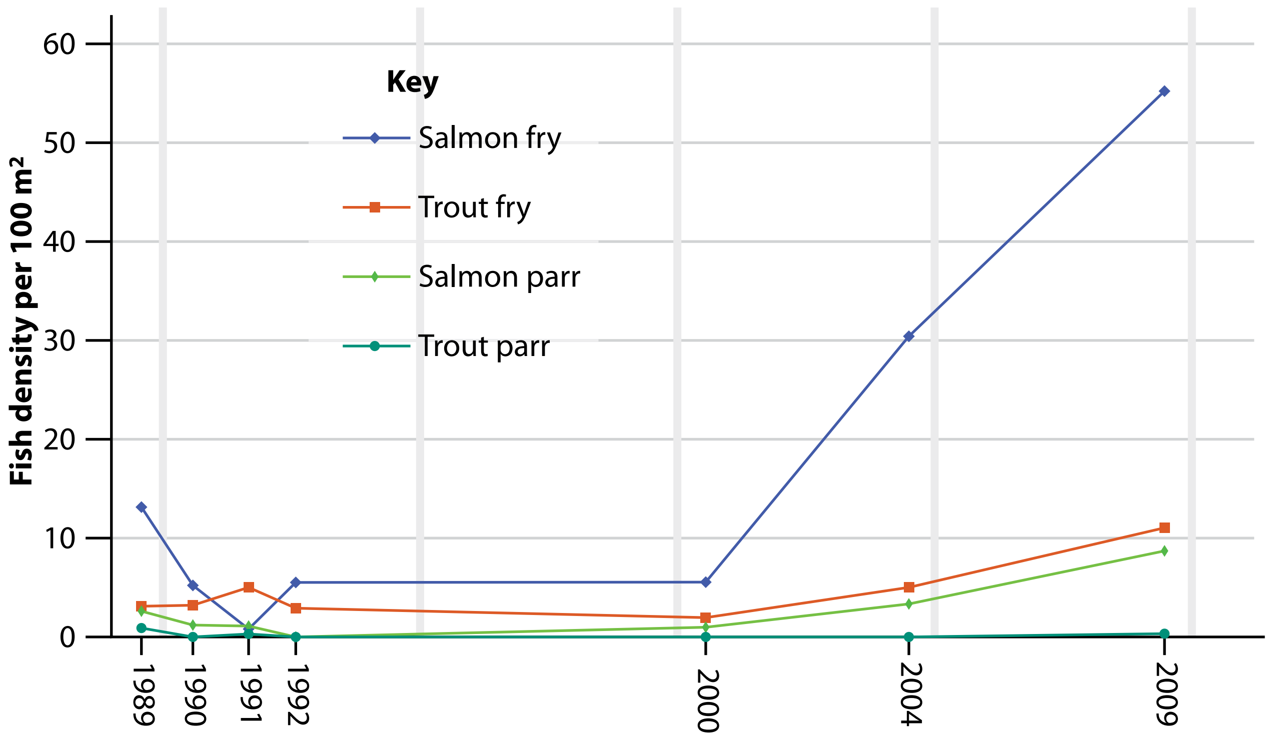
River Ogwen	High energy, gravel
WFD Mitigation measure	**Click Here** to view details
Waterbody ID	GB110065054160
Designation	None
Project specific monitoring	Fish

No negative consequences of raising the bed level have been observed., The longitudinal profile has remained stable with no significant morphological adjustment. A greater variation in flow diversity 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 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.

Some adaptive management was required around five years after completion. The boulder cascades settled more than was anticipated such that the 'island' feature was rarely an island. Additional boulders were installed to raise the cascade levels closer to the original design levels. The degree to which slumping and settlement of placed bed material (even boulders) neds to be carefully considered when attempting to restore bed levels. The remediation works cost approximately £10,000.

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



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

Controlling River Bed Levels, Water Levels and Flows

5

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

Contacts

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Modifying River Bed Levels, Water Levels and Flows

5.4 Simulated bedrock outcrops

RIVER MARDEN

LOCATION - TOWN CENTRE AT CALNE, WILTSHIRE ST998710

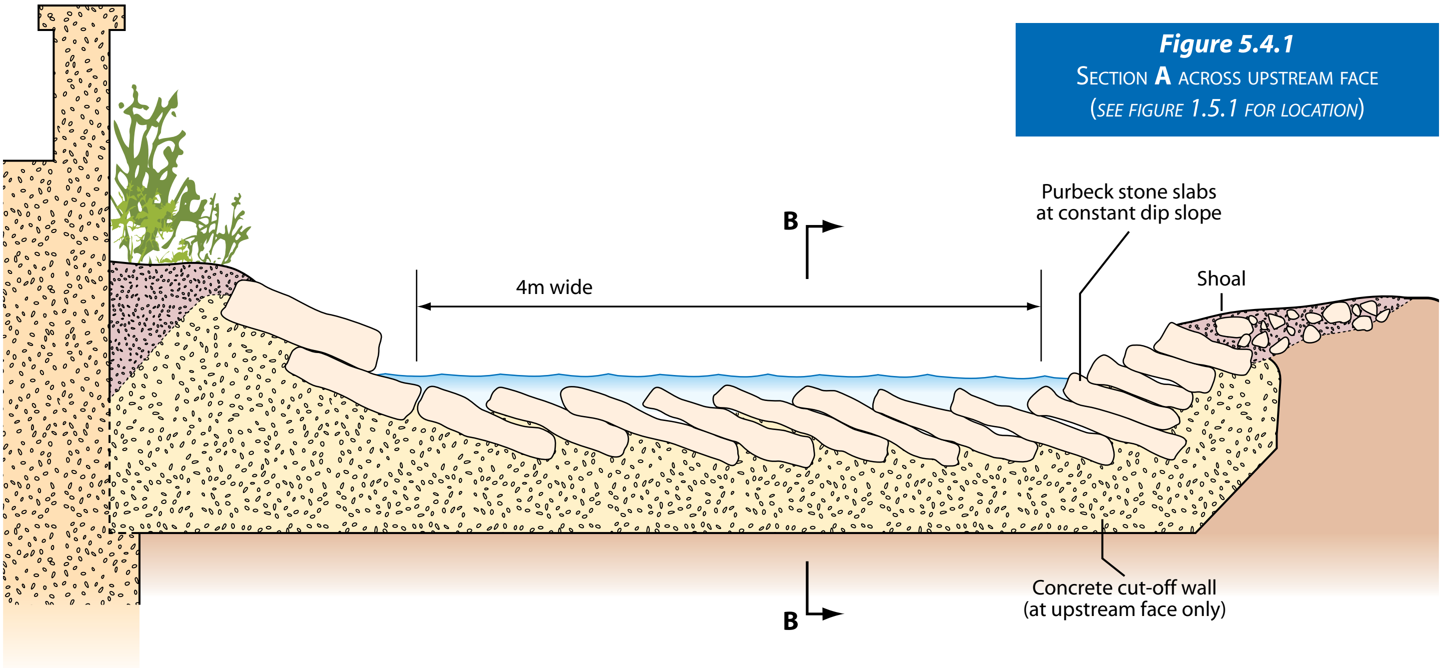
DATE OF CONSTRUCTION - 1999

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.*

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.

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 1999 – 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

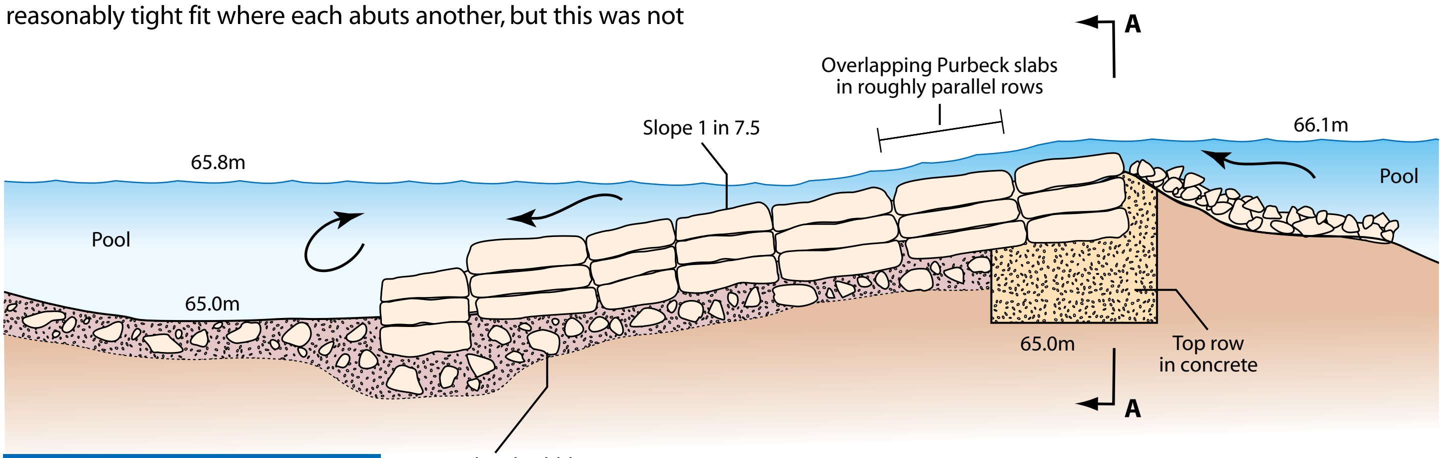


Figure 5.4.2
SECTION **B** THROUGH CENTRE LINE

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

River Marden	Medium energy, chalk
WFD Mitigation measure	Click Here to view details
Waterbody ID	GB109053022060
Designation	None
Project specific monitoring	None

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 riverside access – 2012

Contacts

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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

5.5 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.

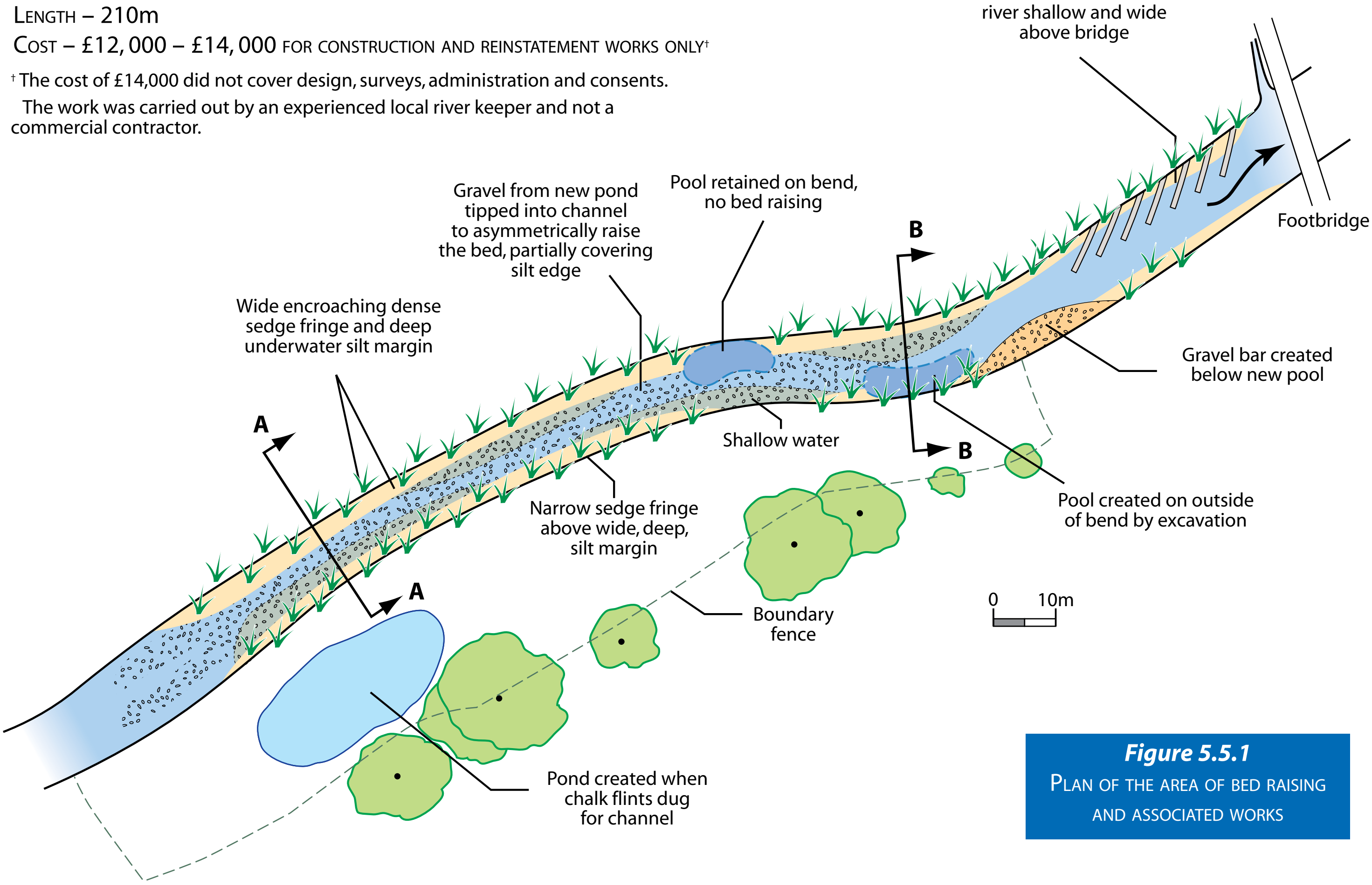


Figure 5.5.1
PLAN OF THE AREA OF BED RAISING AND ASSOCIATED WORKS

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 water crowfoot (*Ranunculus spp.)* and clean gravels suitable for sustaining wild brown trout (*Salmo trutta*) 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 water 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 (*Cyperaceae spp.*) had spread into the channel

Before restoration – sluggish deep water with encroaching sedge and accreted 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

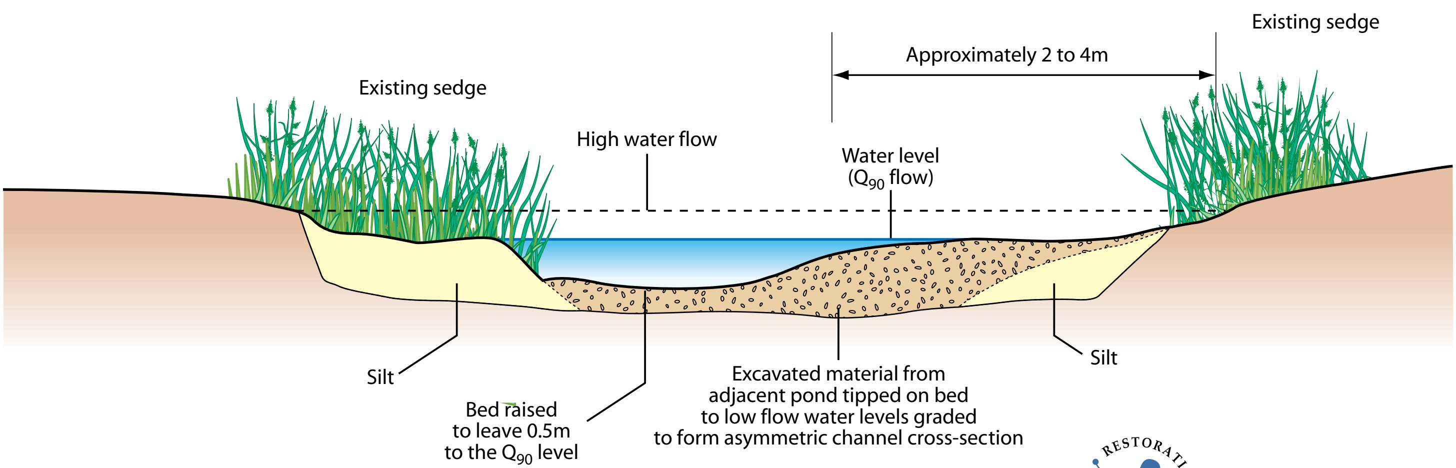
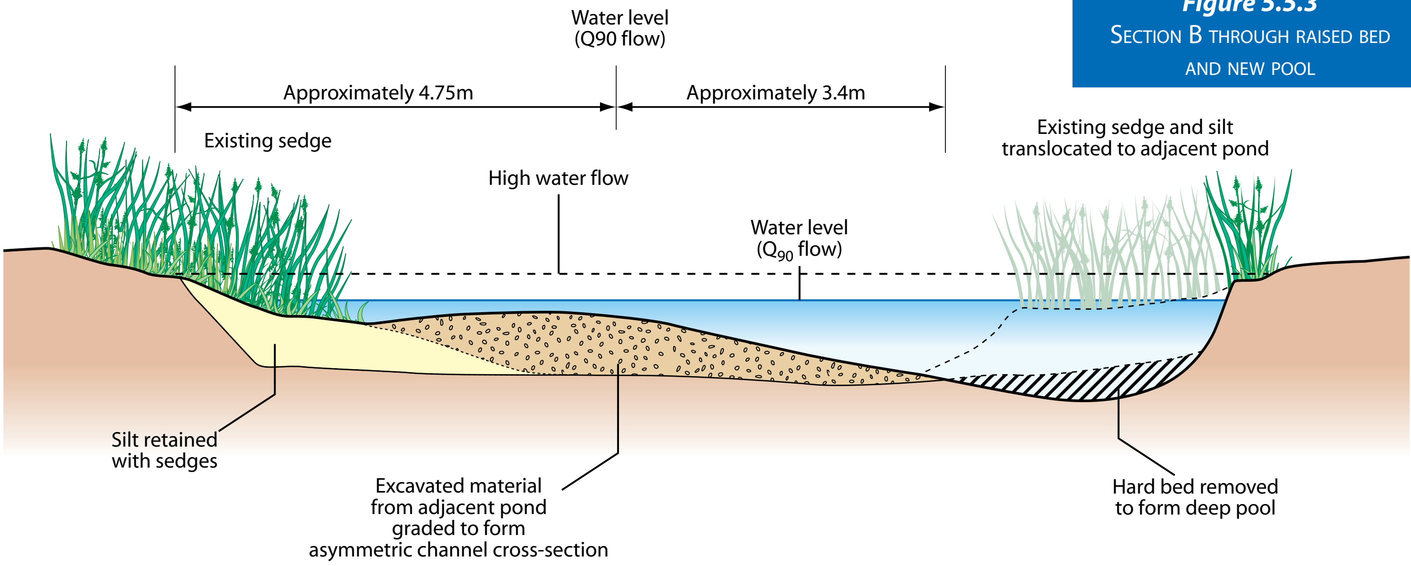


Figure 5.5.2
SECTION A THROUGH RAISED BED AND MARGINAL SHOAL

Modifying River Bed Levels, Water Levels and Flows

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.

   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.

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

A few months after completion, the raised bed evident

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 water crowfoot 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	Click Here to view details
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.

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

Contacts

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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

6.3 Removing and setting back floodbanks

LONG EAU

LOCATION - MANBY, LINCOLNSHIRE TF407863
DATE OF CONSTRUCTION - MAY – JUNE 1995
AREA – 16ha
COST – £60,000

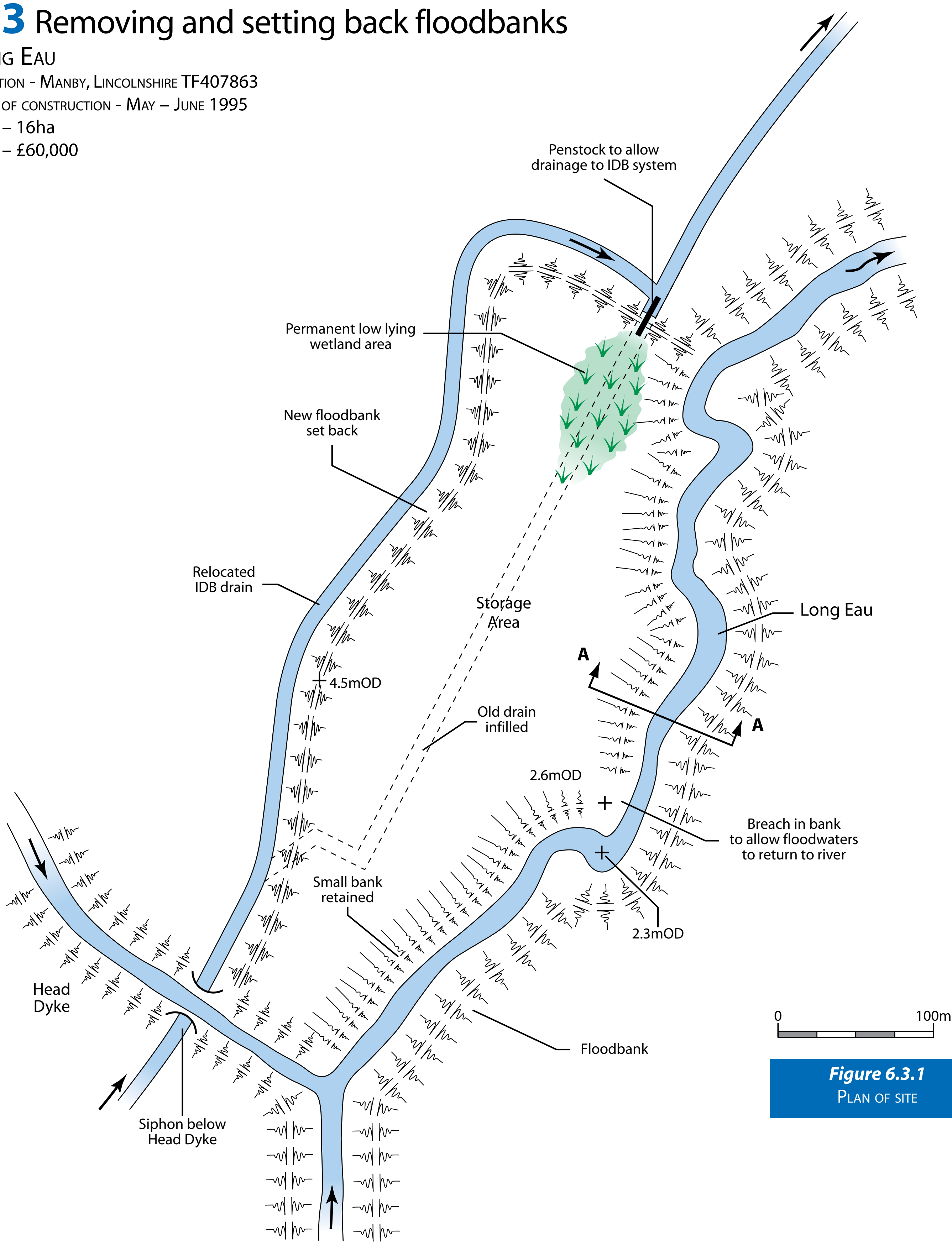


Figure 6.3.1
PLAN OF SITE

Managing Overland Floodwaters

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.

6

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

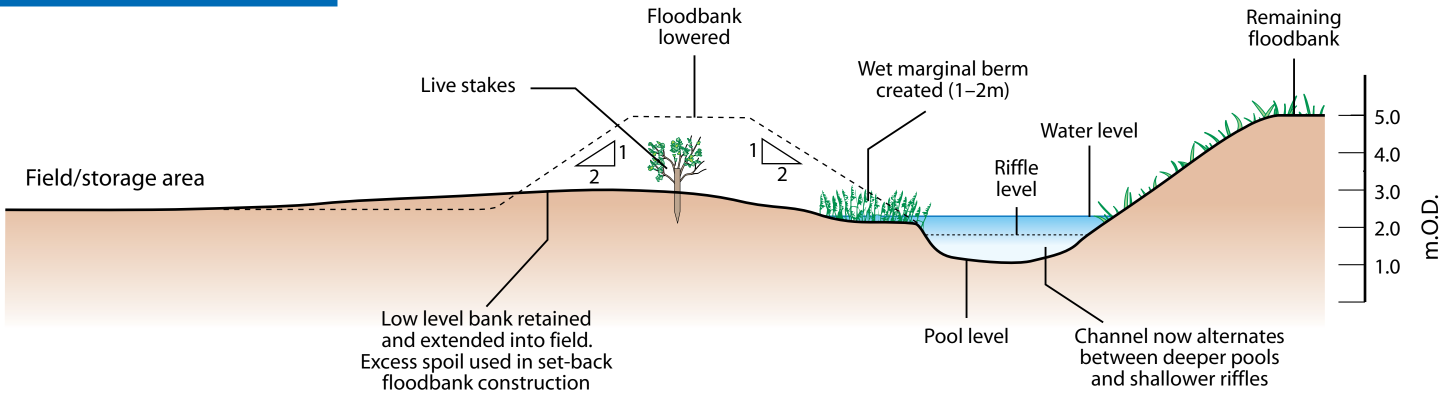
Water will spill onto the site from the Long Eau when levels reach 2.6m above OD and has reached a maximum of 4m above OD. Levels are then reliant on conditions in the Eau subsiding and, depending on the intensity of the event, have been retained for two or three days. Below the Eau level of 2.6m, 75% 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

Figure 6.3.2
SECTION A THROUGH FLOODBANKS



Berm at section A after 4 years

6

Managing Overland Floodwaters

6.3 Long Eau 2013 Update

River Long Eau	Low energy, clay
WFD Mitigation measure	Click Here to view details
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

7 Creating Floodplain Wetland Features

7.2 Floodplain wetland mosaic

River Thames

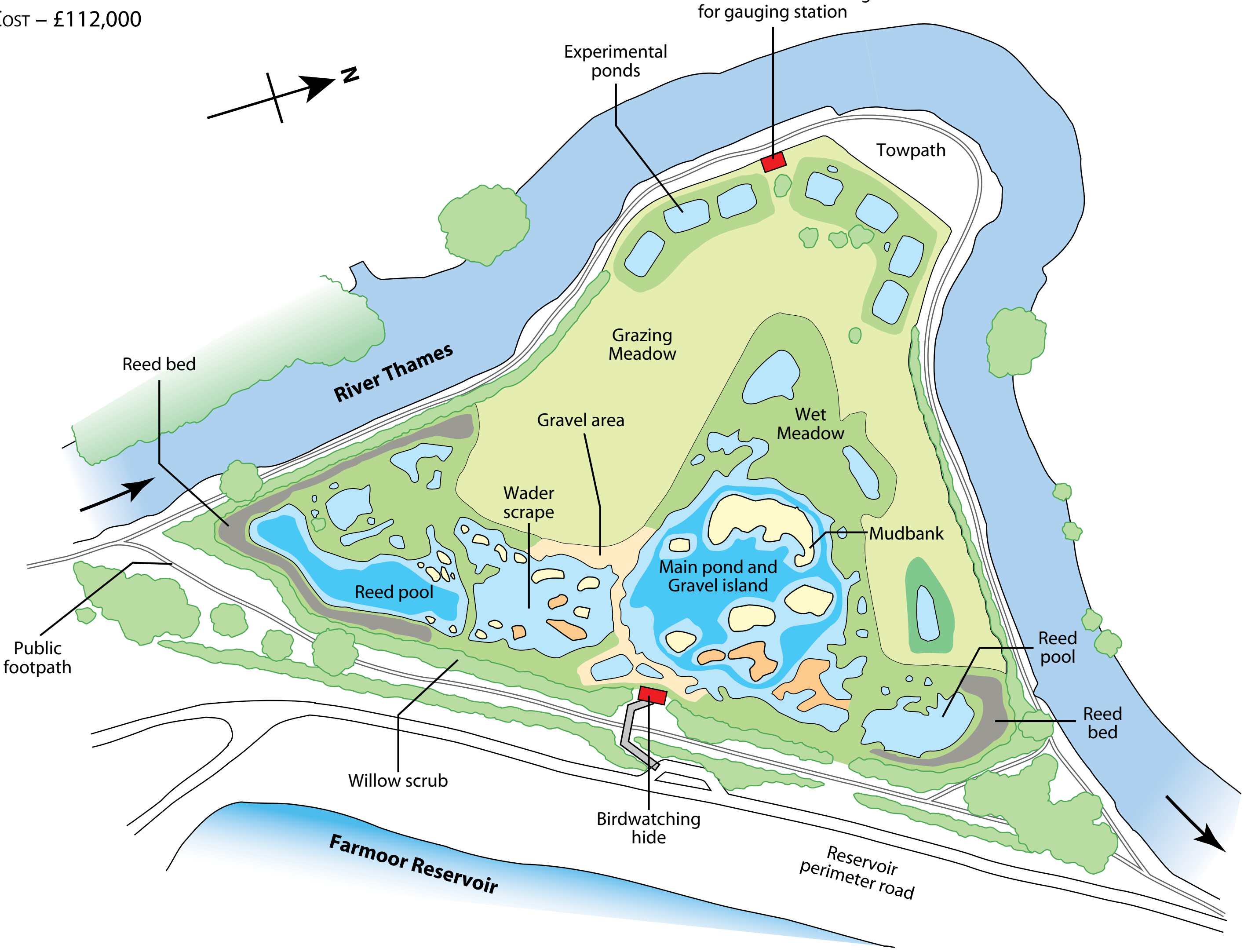
Location - Pinkhill Meadow, Farmoor Reservoir, Oxfordshire SP 439067

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.

Creating Floodplain Wetland Features

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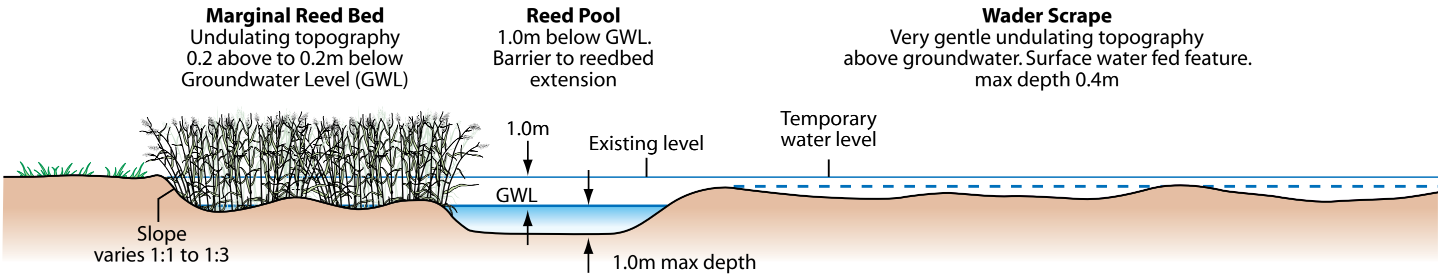


Figure 7.2.2
INDICATIVE SECTION THROUGH REED POOL

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

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

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 100m^2). 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.

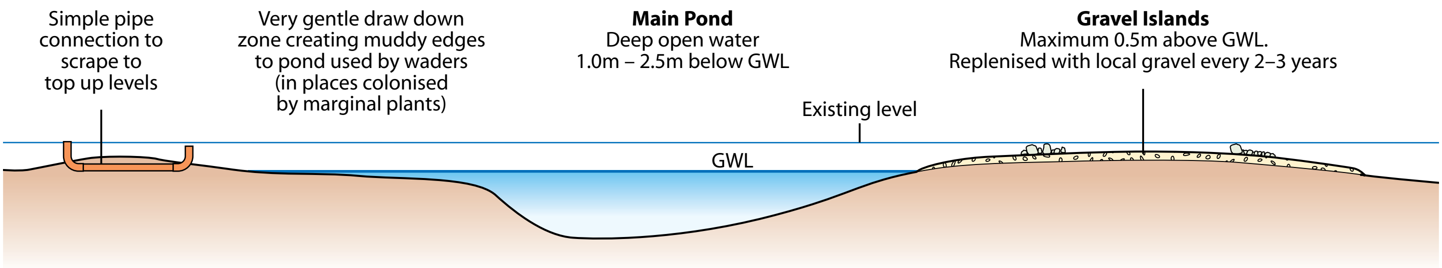
Gravel islands and margins
Created over an area of 0.1ha, these provide nesting habitat for Little Ringed Plover and Common Tern. The gravel was carefully selected from a local source to ensure a good size distribution, important for some nesting birds. Selectively placed cobbles and boulders also provide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

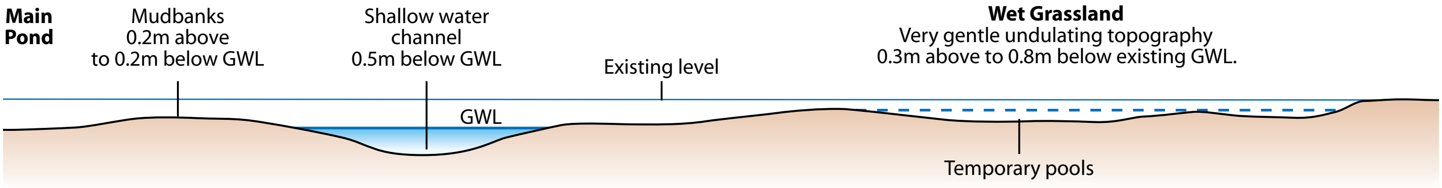
Reedbeds
Two linear reedbeds, totalling over 250m in length, were excavated along the eastern edge of the site. Shallow trenches were dug and planted with pot grown Common Reed. These serve as a boundary to human disturbance from adjacent footpaths and provide valuable nesting and foraging habitat for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

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.

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	Click Here to view details
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 (*Typha latifolia*) occurred in the 5 years following the works to prevent initial domination by this species. Invasive species, in particular New Zealand Pygmyweed (*Crassula helmsii*), 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.

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

Contacts

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

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

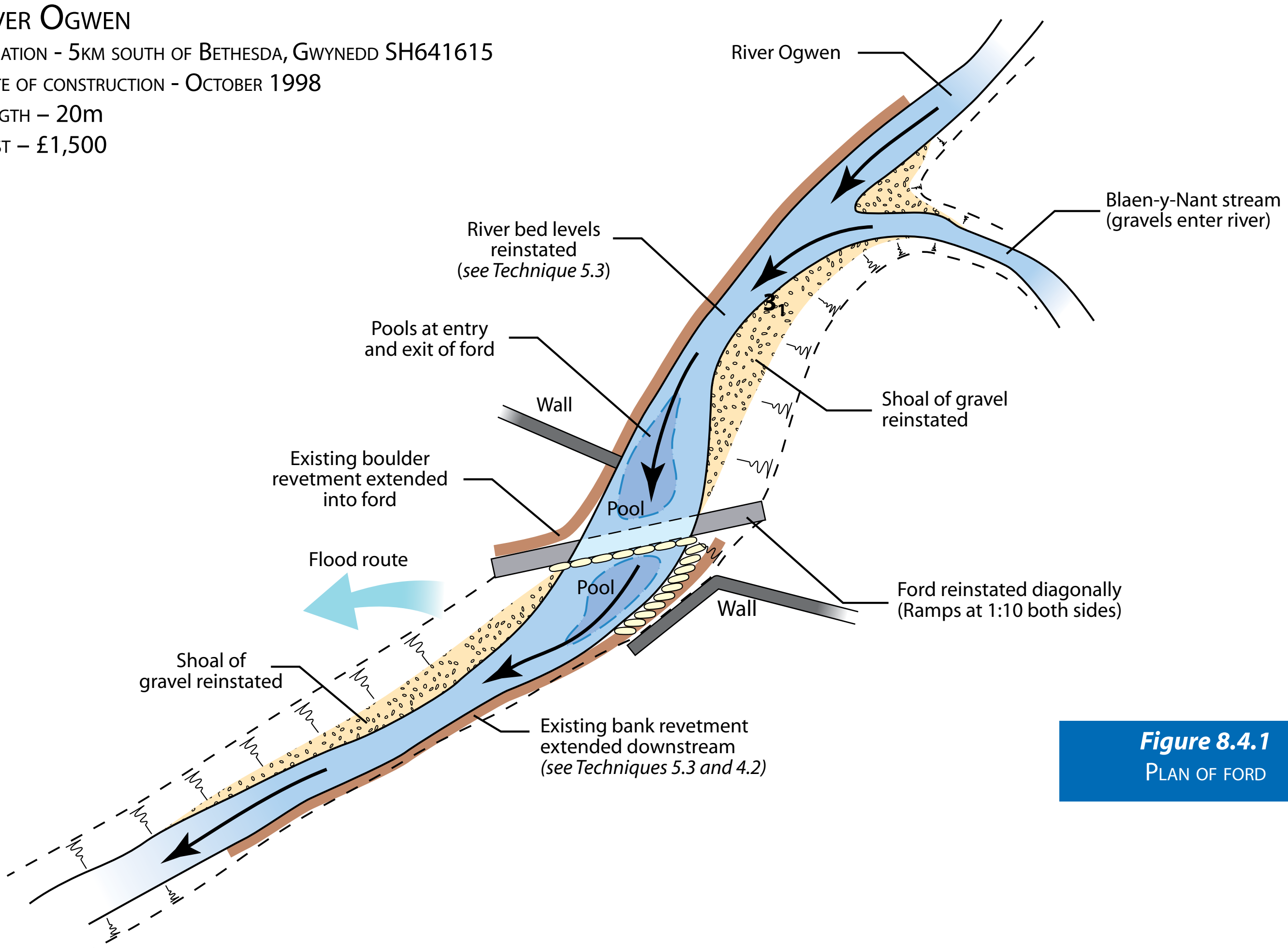

Figure 8.4.1
Plan of ford

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

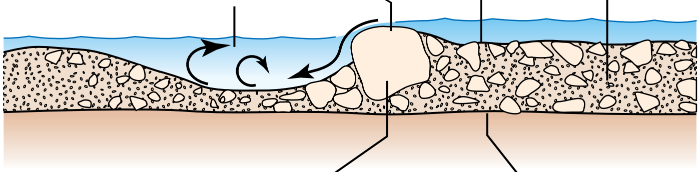

Figure 8.4.2
SECTION THROUGH FORD

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	Click Here to view details
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

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8

Providing Public, Private and Livestock Access

8.5 Urban riverside access

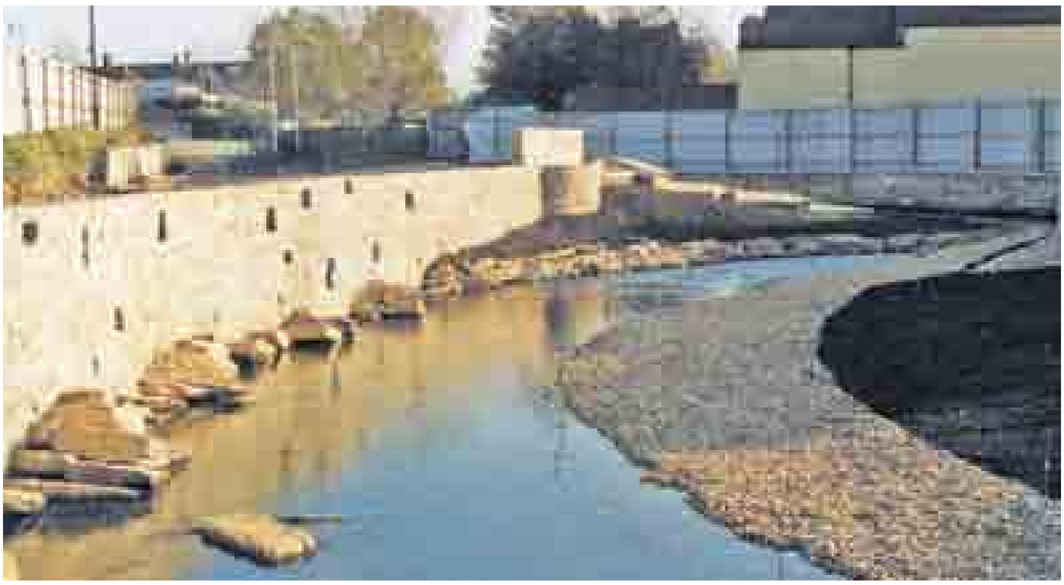
RIVER MARDEN
LOCATION - TOWN CENTRE AT CALNE, WILTSHIRE ST998710
DATE OF CONSTRUCTION - 1999
LENGTH – 100m
COST – NOT AVAILABLE

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

Providing Public, Private and Livestock Access

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 fronts 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.

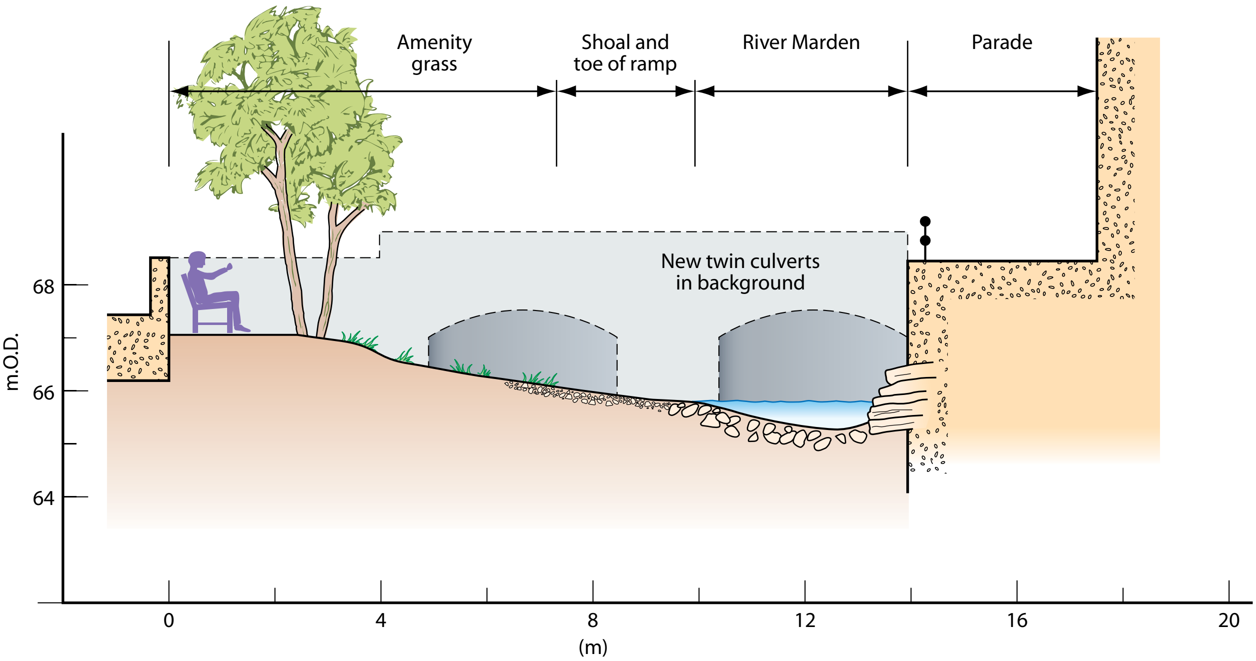
View showing the lower part of the accessible new river course – November 2001

8

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*)



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

Providing Public, Private and Livestock Access

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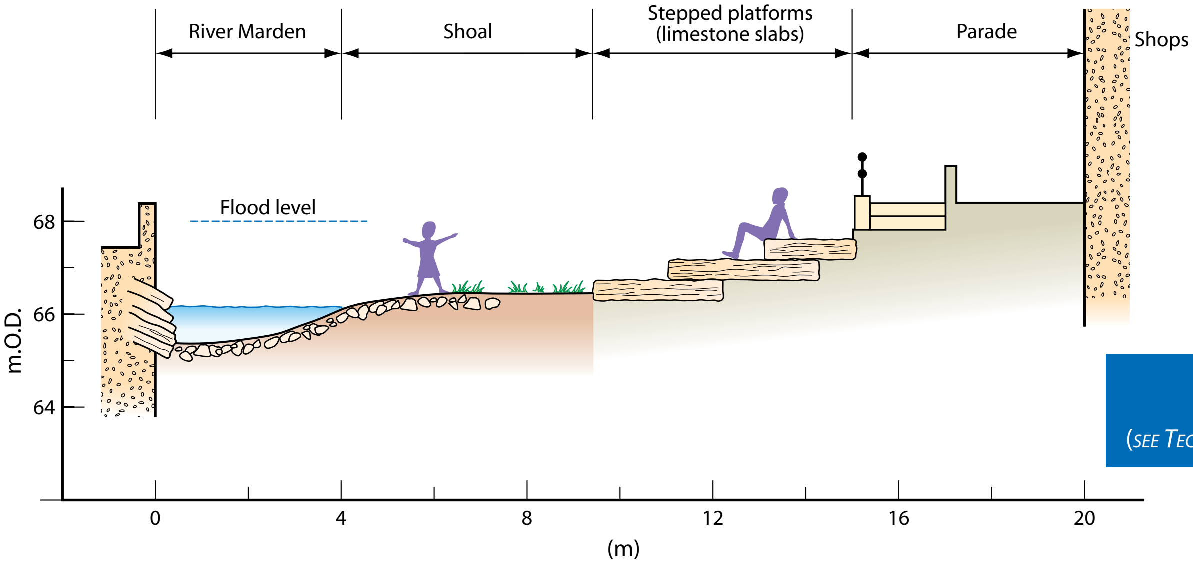

Figure 8.5.2
Section **B**
(see Technique 1.5 for location)

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

8

Providing Public, Private and Livestock Access

8.5 River Marden 2013 Update

River Marden	Medium energy, chalk
WFD Mitigation measure	Click Here to view details
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. Flood gates at access points are closed during high flow events to ensure public safety.

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 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

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River Marden riverside access – 2012

Contacts

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10

Utilising Spoil Excavated from Rivers

10.3 Cost-effective silt removal from an impounded channel

RIVER CHESS

LOCATION – BLACKWELL HALL, LATIMER, BUCKINGHAMSHIRE SU 980997

DATE OF CONSTRUCTION – 1994/95

AREA – CIRCA 3000M2

COST – NOT AVAILABLE

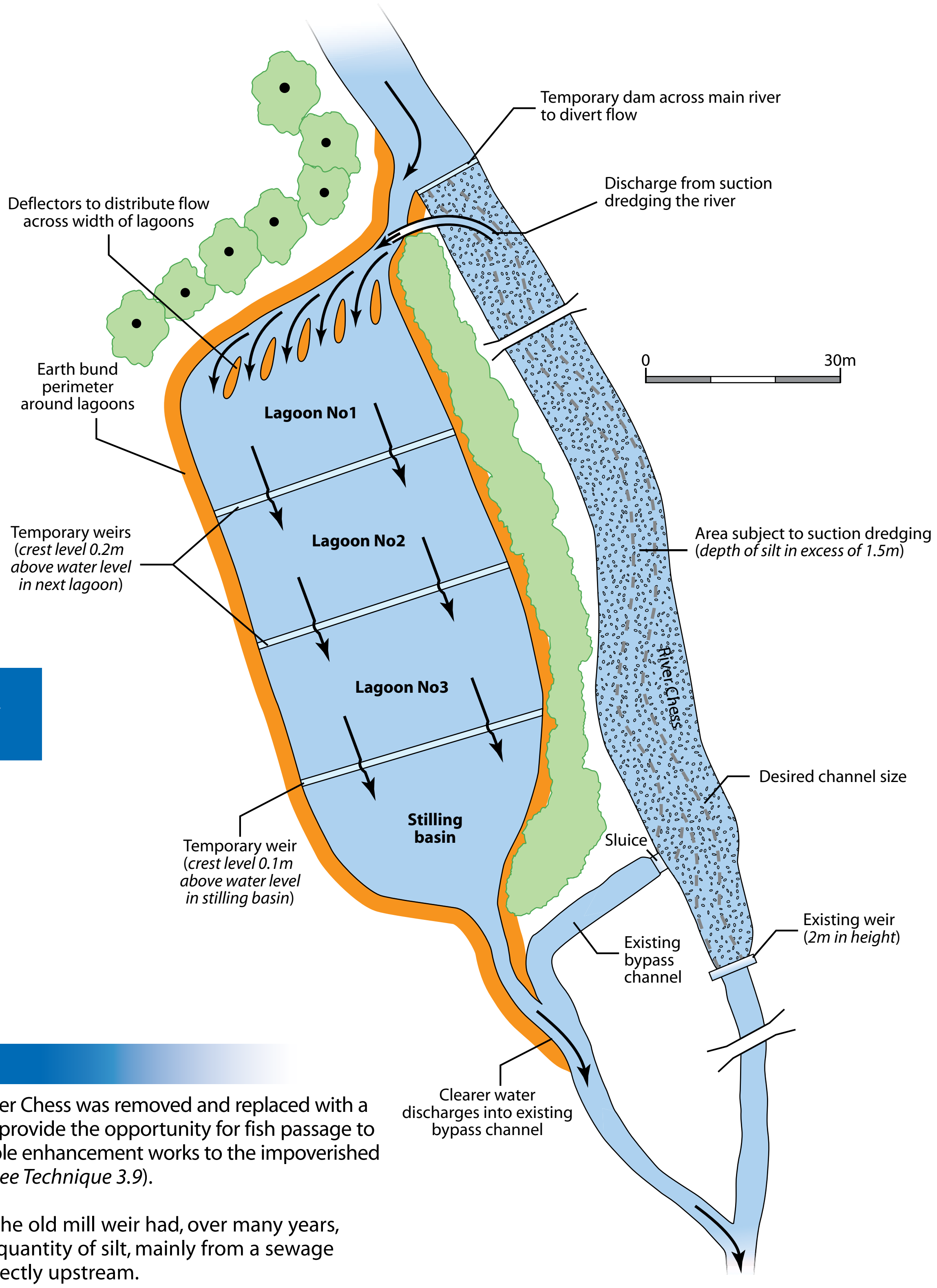

Figure 10.3.1
PLAN OF TEMPORARY SILT TRAP LAGOONS

Description

A mill weir on the River Chess was removed and replaced with a fish-pass. This would provide the opportunity for fish passage to be restored and enable enhancement works to the impoverished channel upstream (*see Technique 3.9*).

The channel above the old mill weir had, over many years, accumulated a vast quantity of silt, mainly from a sewage treatment outfall directly upstream.

Utilising Spoil Excavated from Rivers

Mill weir and replacement fish-pass

Dredging and re-profiling of the wide silted lagoon behind the weir was carried out in association with the fish-pass works. Prior to the implementation scheme, the water company relocated its effluent outfall downstream of the site.

By lowering the water level, sufficient gradient was returned to the river to re-form a narrow sinuous channel within the previously deep over-widened and ponded section. The impounded channel size needed to be drastically reduced, both in width (8m to 2m) and in depth (in places silt was up to 1.5m deep).

To achieve this the accumulated silt retained by the old weir had to be removed. In order to avoid moving spoil off-site the dredged material was incorporated into an adjacent grass field. Removal off-site of such material is often expensive and, if sent to a landfill site, unsustainable.

Design

Using an excavator a series of low bunds were constructed in the adjacent field. The earthworks followed the fall in land levels to allow gravity flow. These bunds formed three shallow lagoons and a stilling basin. The first lagoon incorporated deflectors to ensure an even distribution across the width of the lagoon. The lagoons were separated by low temporary earth weirs (*Figures 10.3.2 and 10.3.3*).

The silted river was temporarily dammed and de-watered via the old mill bypass sluice. The river was diverted via a bunded inlet channel through the 'silt-trap'. To remove the large volume of saturated silt, suction dredging was used, the discharge being pumped into the first lagoon. The silt laden river water proceeded through the 3 lagoons depositing its silt load before ultimately rejoining the existing bypass channel.

Retention time within the silt-trap was approximately 2-4 hours. In this way $1300m^3$ of excavated and suspended material was removed from the stream. The area of field used was circa $3000m^2$ resulting in a maximum increase in height over the field of circa 0.2m.

The silted lagoons were allowed to de-water for 1 month and the temporary weir materials (tarpaulin and sandbags) removed. The silt and earth bunds were then flattened and graded into the field. The surface was hand raked and the whole area grass seeded with a meadow mix.

Main Photo (*Top right*): Exposed silt, looking towards mill weir.
Inset above left: Dredged. Inset above right: 4 years later

10

Utilising Spoil Excavated from Rivers

Lagoons and stilling basin – February 1995

Lagoons, stilling basin and overspill – March 1995

Retained silt load – April 1995

As a grass field 4 years later

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

Utilising Spoil Excavated from Rivers

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Figure 10.3.2
Typical section through lagoons

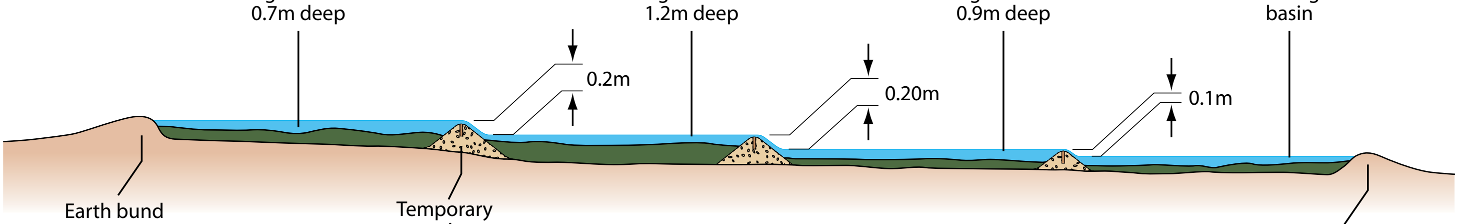
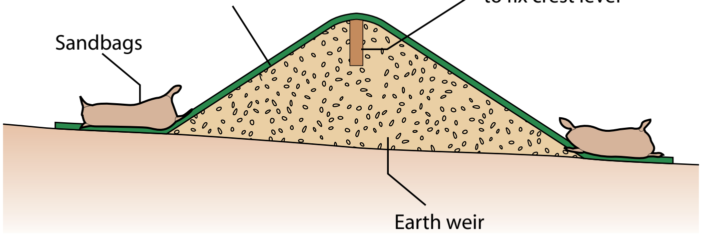


Figure 10.3.3
Typical detail of temporary weirs



Dewatering. View from inlet channel – April 1995

Graded, harrowed and seeded – June 1995

Subsequent performance 1995 – 2001

Now fully grassed over, the field is not noticeably out of character. Indeed it appears to be a normal field.

Where sufficient gradient exists and loss of floodplain storage capacity is not affected or is not an issue, this technique for de-silting may be a suitable alternative to removal off-site.

Original Information Providers:
Steven Lavens
Chris Catling

10

Utilising Spoil Excavated from Rivers

10.3 River Chess 2013 Update

A RRC visit in 2013 confirmed that the site continues to function as a normal field, further demonstrating the benefits of using this technique where this is a necessary requirement. In some areas the vegetation is dominated by nettles (*Urtica spp.*), however this is not uncommon where there is a large amount of silt as nutrient levels are high.

River Chess	Low energy, chalk
WFD Mitigation measure	Click Here to view details
Waterbody ID	GB106039029870
Designation	None
Project specific monitoring	None

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The field 18 years after works – 2013

Contact

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

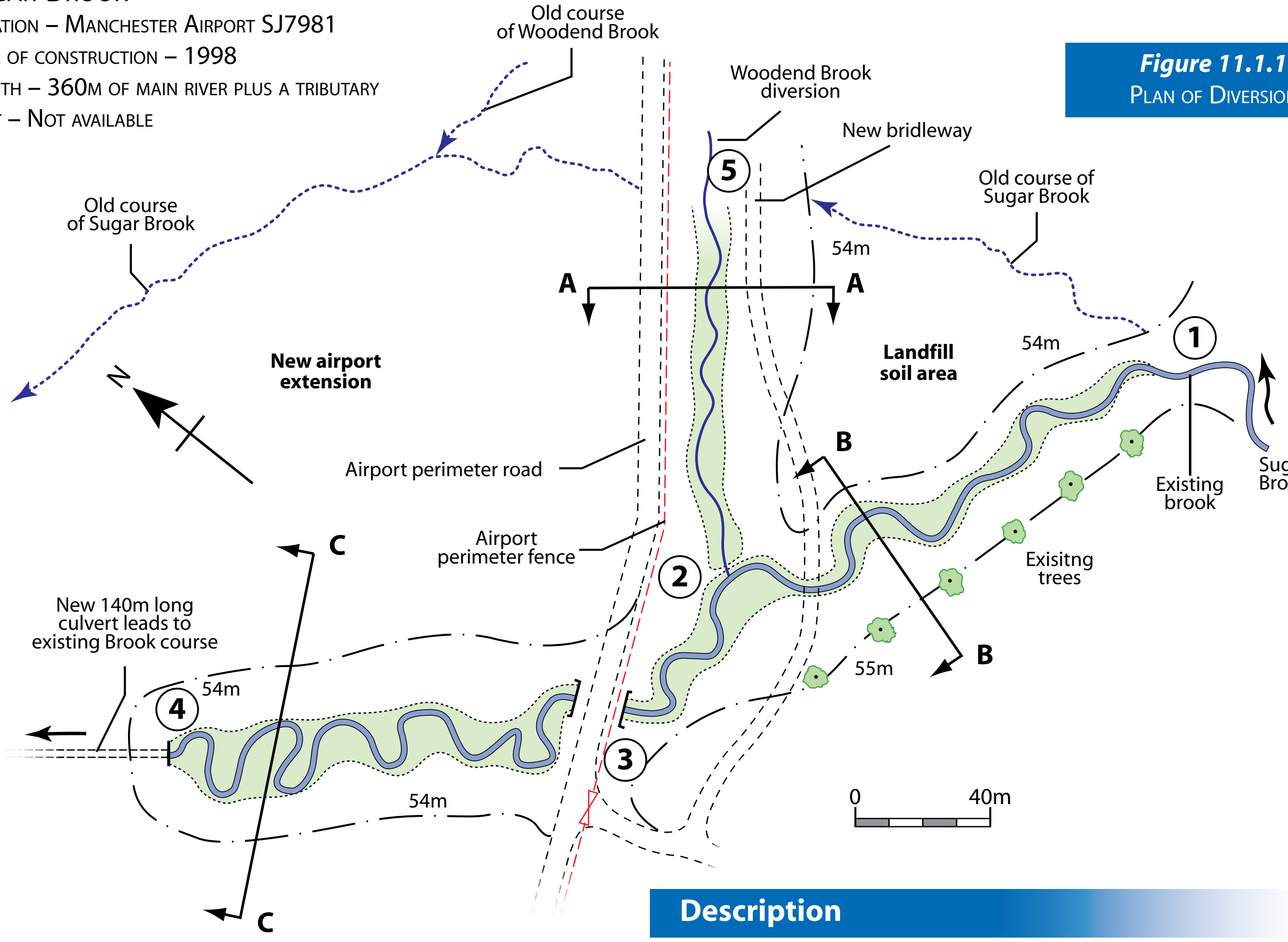
11 River Diversions

11.1 Diversion of a River Valley

Sugar Brook

Location – Manchester Airport SJ7981
Date of construction – 1998
Length – 360m of main river plus a tributary
Cost – Not available

Figure 11.1.1
Plan of Diversion



Key

Contours at 54/55m indicating top edge of new valleys created

Indicates extent of relatively flat valley floor (floodplain) with small incised channel meandering through

1. Start of Sugar Brook diversion
2. Woodend Brook confluence
3. Perimeter road culvert
4. Airport culvert
5. Start of wetland on Woodend Brook

Description

The construction of a second runway at Manchester Airport required the back-filling of a 350m long reach of Sugar Brook, and its valley, to bring ground levels up to the required elevation for the runway, the runway approaches and marginal safety grasslands. Rather than place the entire reach in a buried culvert the brook was realigned over a 500m long reach that reduced the length of culvert involved to 140m where it unavoidably passed under the runway approaches and lighting strip. The remaining length of the diversion, some 360m, was constructed as an open watercourse.

A small tributary stream, Woodend Brook, was similarly affected and needed to be diverted into the realigned Sugar Brook. This was achieved entirely in an open watercourse further avoiding culverting.

Figure 11.1.1 shows the previous route of the two watercourses and the route of the diversions to the south that take them clear of the airport perimeter fence towards the new culvert under the airport approaches (airport culvert). This culvert reconnects directly to the existing Sugar Brook course at its exit. The length of the diversion equalled the length that it replaced, thus maintaining the same overall bed gradient.

River Diversions

Sugar Brook before culverting, a reference site for the new channel

Many issues arose in the design of the watercourse diversions, but perhaps of greatest significance was the depth to which excavations needed to be taken to achieve the required bed levels. The new bed falls fairly uniformly at about 1 in 200 gradient between existing bed levels of Sugar Brook at each end of the 500m diversion. In contrast to this, the ground levels along the diversion route increased in elevation to heights of over 5m above the new bed. Channel depth of this magnitude (5m) far exceeded the natural channel depth of approximately 1m that are typical of Sugar Brook, so a novel approach to design was essential.

The diversion presented an opportunity to recreate the natural features found on unmodified reaches of the brook.

Design

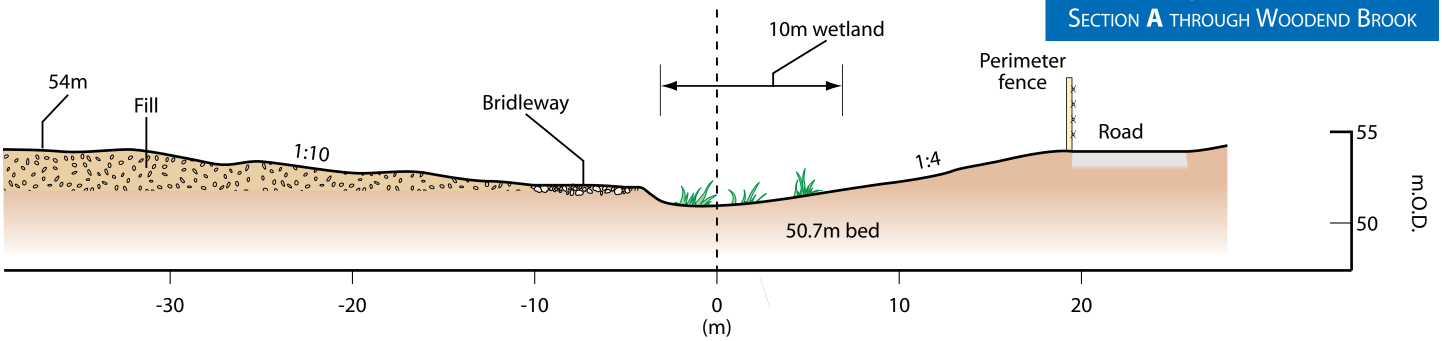
A preliminary outline design prepared at the planning permission stage indicated a slightly sinuous channel that was trapezoidal in cross-section over its full depth and lacked any of the detail and refinement needed to mimic the natural character of Sugar Brook. This approach aimed to achieve the least possible excavation width and set new bank tops around which various roads, paths and a surplus spoil disposal site were all positioned and linked to the subsequent planning permission. This resulted in an unduly narrow 'approved' corridor of land within which to achieve the detailed design of the diversion.

A trial excavation at the upper end of the diversion reach was undertaken to test the outline design. This was shown to be completely inappropiate. Apart from its deep 'canyon-like' appearance, the predominant clay soils could not be relied upon to remain stable at the depths of excavation involved. Undercutting of the toe of the slopes could be expected to accelerate collapse of the high banks.

A new approach to design was needed which recognised that the formation of the valley within which the brook naturally flows involved different geomorphological processes than those that sustain the small watercourse that is incised within the floor of the valley. Inspection of the undisturbed reach just downstream of the airport demonstrated a narrow rounded valley formed during glacial retreat with a fairly flat bottom of more recent fluvial sediments through which the brook course meandered. Cross-sectional templates were taken from this reference reach and used to design the new valley.

The approach to detailed design thus involved treating the diversion as a diversion of the valley of Sugar Brook and not as a channel diversion. If an acceptable valley form could be achieved then the creation of a small meandering stream within its floor became a relatively straightforward task.

Figure 11.1.2
SECTION **A** THROUGH WOODEND BROOK



Woodend Brook

Creating the New Planforms
Figure 11.1.1 shows the top edge of the newly created valleys of both Sugar Brook and Woodend Brook along contours of between 54 and 55 metres O.D. with a top width of between 30 and 50 metres. The relatively flat valley floor of each is also indicated at widths of between 10m and 20m.

The meandering plan form of Sugar Brook, which is cut into the valley floor by up to 1m only, was strongly influenced by templates of meander patterns elsewhere on the brook (*Figures 11.1.3 and 11.1.4*). Woodend Brook does not feature an incised course in the new floor but has been encouraged to form a wetland across its full width of around 10m (*Figures 11.1.2*). Natural channel incision is expected to develop slowly.

Valley Profiles
The manner in which the new valley side slopes were shaped was carefully excavated to mimic natural profiles which vary from concave, where ancient soil slips have arisen, to convex, where they have not. The mean slope associated with concave (slipped) profiles is likely to be flatter than when convex, creating desirable variations and mild sinuosity when looking down the valleys. Compound slopes involving both concave and convex slopes were also incorporated. Three cross-sections A, B and C indicate these variations which are also apparent on the photographs.

Sugar Brook looking upstream

Figure 11.1.3
SECTION **B** THROUGH SUGAR BROOK
UPSTREAM OF CONFLUENCE

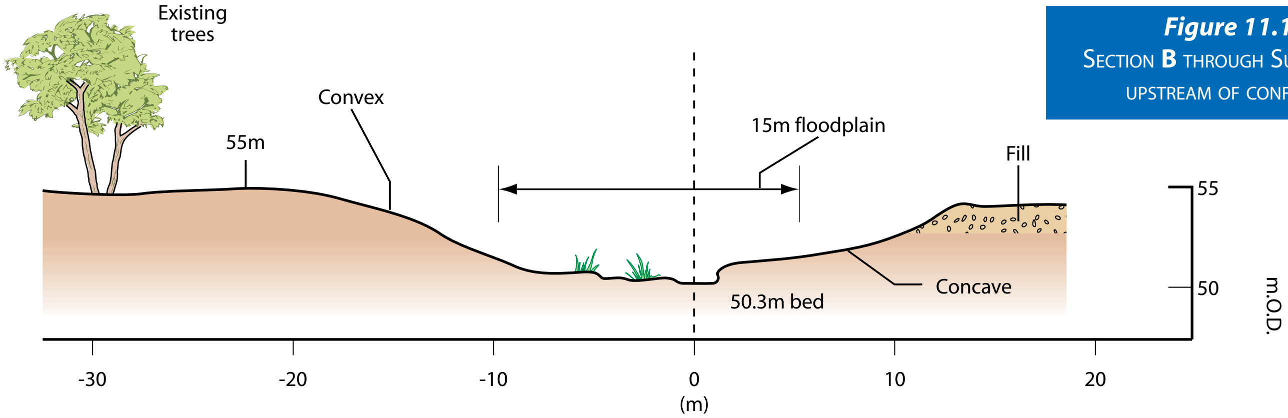
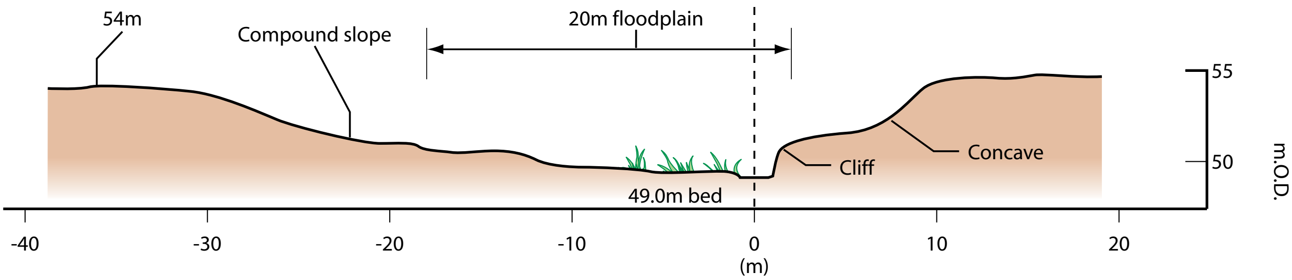


Figure 11.1.4
SECTION C THROUGH SUGAR BROOK DOWN-STREAM OF CONFLUENCE



Sugar Brook Valley below confluence – September 1999.

The river valley vegetation is developing well – November 2001.

Subsequent performance 1995 – 2001

The River Channel
This was meandered down the valley floor following the design principles described elsewhere in this manual (*see Techniques 1.1, 6.2*). Cliffs, riffles, pools and shoals were all initiated within the excavated channel profiles, but it was expected that rapid changes would arise during subsequent flood periods. The aim of the design was to create a channel form that anticipated the type of regime that was appropriate whilst leaving it to the stream to adjust to a reasonably stable form over succeeding years.

Extensive marginal and bankside planting was undertaken as part of the planning permission and a monitoring programme was set up with the first survey in 1999, one year after construction.

Although the extent to which the form of the newly created valley could be naturalised is severely constrained by spatial limits relating to the early planning decisions, its overall appearance is good. It is certainly far better than the trapezoidal profiles envisaged at the start, which suggests that the concept of river valley diversion, rather than channel diversion, is one that needs to be taken up early in similar circumstances.

An MSc study in 2000 (M Guy, University of Nottingham) found that considerable geomorphological activity is occurring on the channel, with active erosion and deposition patterns. It appears that the channel is still adjusting to reach dynamic equilibrium but is comparable with the undisturbed stretches of the stream.

As part of a post project monitoring scheme baseline information was compiled using water quality, benthic invertebrate data, topographical and river corridor surveys. In the first year, monitoring results of the aquatic planting confirmed all species planted had begun to establish, but a short term abundance of annual watercress (*Nasturtium officinale*) was influencing low flow characteristics. Some self-seeding willow (*Salix spp.*) and alder (*Alnus spp.*) are already evident along the riparian channel.

No significant changes in water chemistry have been recorded, with the exception of fluctuating suspended solids during construction and very high flows. Within two years, the benthic invertebrate fauna of the new channel comprises almost all taxa found in the original. The remaining high scoring rare taxa have yet to return (*MSc dissertation 2001 Z. James*). Manchester Airport plc continues to monitor the site.

Original information providers:
Karen Williams
Pam Nolan
Malcolm Hewitt
RRC

11

River Diversions

11.1 Sugar Brook 2013 Update

Sugar Brook	Low energy, clay
WFD Mitigation measure	Click Here to view details
Waterbody ID	GB112069061350
Designation	None
Project specific monitoring	Macroinvertebrates

Looking upstream from the footpath bridge – March 2007

© RRC

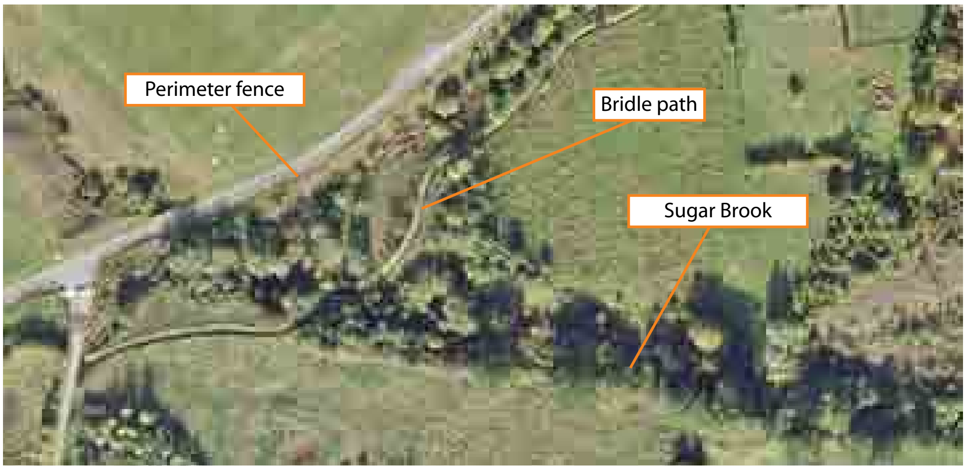
© RRC Looking upstream from the footpath bridge – July 2013

The self sown willow and alder mentioned in the 1998 – 2001 subsequent performance have now grown into a dense cover of trees. The photograph taken in 2007 shows the saplings growing along the bank and the more recent photograph taken in 2013 indicates that the channel is now completely shaded by this tree cover.

Invertebrate surveys were carried out in 2000 and 2013. Whilst the BMWP score has increased, there is not enough data to ascertain whether this increase is due to improvement in water quality related to the channel naturalising after the initial realignment.

The channel would benefit from some sympathetic tree thinning to allow at least some daylight to penetrate through to the channel.

Aerial photograph of Sugar Brook showing dense tree cover



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

11

River Diversions

11.2 Clay Lined River

River Nith

Location - West of New Cumnock, Ayrshire NS5412
Date of construction - April – September 2000
Length – 3km
Cost – £3,300,000

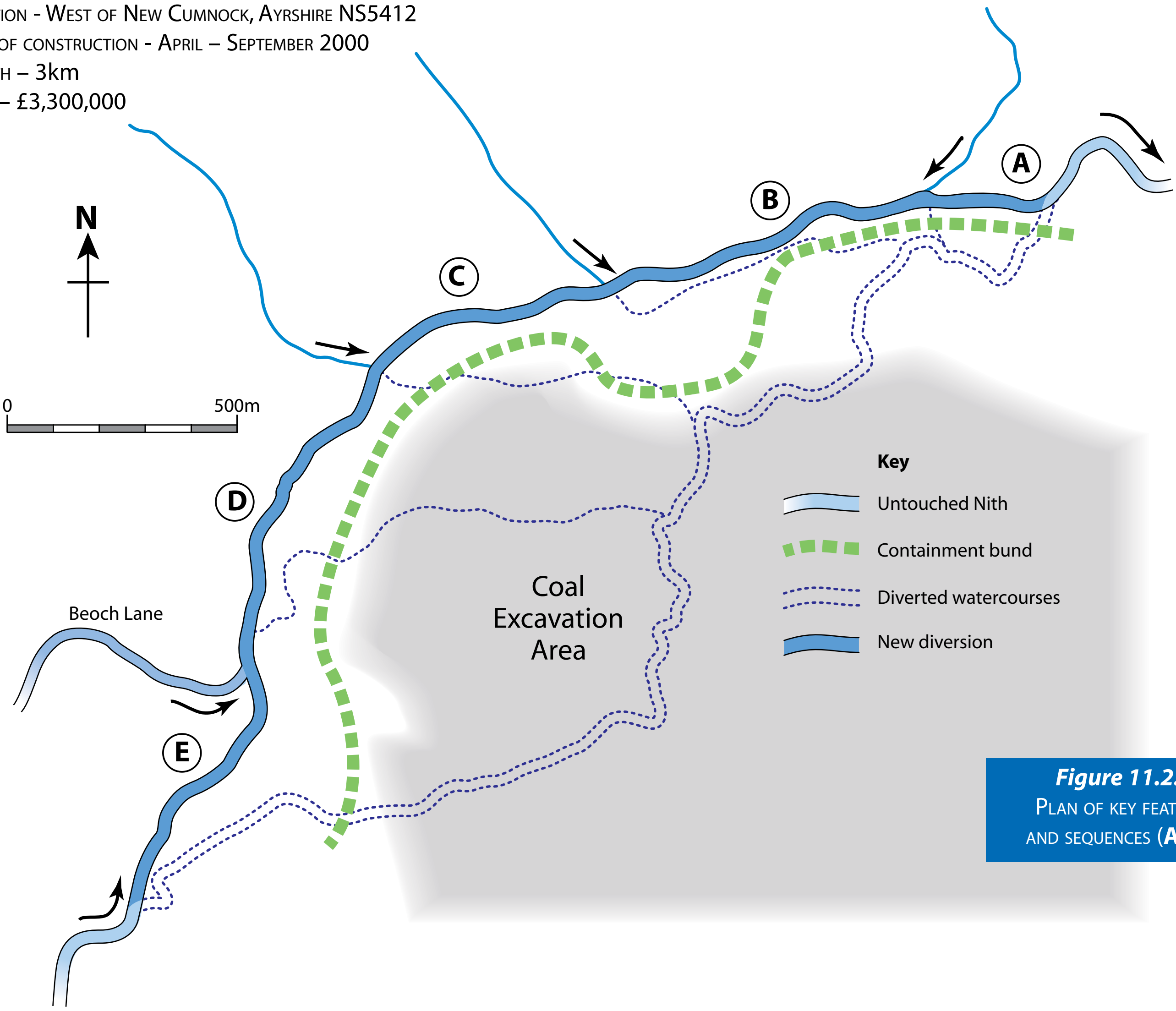


Figure 11.2.1
Plan of key features and sequences (**A – E**)

Description

The River Nith rises at around 500m above ordnance datum (AOD) in the uplands of south-west Scotland and is an important salmon and trout fishery. It drops sharply within 7km to meander through a wide grazed valley floor at only 220m AOD. The Nith has a mixed gravel, pebble and boulder bed, with stable and eroding earth cliffs, a common feature of the banks.

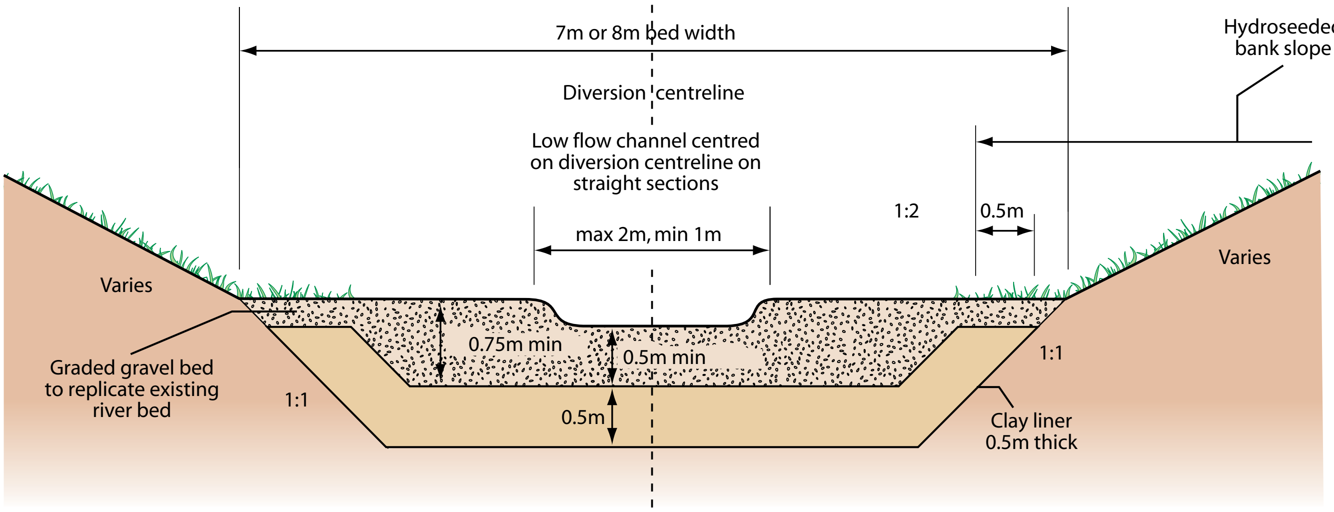
In 2000 an existing adjacent open-cast coal site was extended requiring the permanent diversion of a 3km reach of the River Nith, Beoch Lane and three tributaries. The whole floodplain site covers an area of approximately 3km^2.

The route of the diversion was restricted to a narrow corridor through areas of highly permeable strata and previous mine workings. In places the channel would need to be lined to prevent the river flowing below ground. In addition, to stop floodwater and ground water entering the opencast area, a containment bund, with an integral slurry wall constructed down to bedrock, was built between the new river channel and the coal excavation area.

The design flood standards adopted were the Mean Annual Flood for the river channel itself and the 1 in 50 year return period flood for the river corridor. Detailed hydraulic modelling established the diversion channel route and cross sections as well as the extent of flood protection measures required.

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

Figure 11.2.2
TYPICAL SYMMETRICAL CROSS-SECTION



Description

A clay lined two-stage channel profile was adopted incorporating suitable run-pool-riffle sequences modelled on those in the existing river channel. Construction materials, including the 0.5-1m thick clay liner, river bed gravels and boulders, riffles and bund material, scour protection and in-stream features all came from the adjacent opencast excavations. It was anticipated that the new channel could match the length of the old one, but ultimately a reduction of 10% was necessary.

Figure 11.2.1 shows the diversion channel to the north of the floodplain, with the containment bund protecting the opencast area. Works progressed from A to E upstream, enabling the tributaries and burn to be progressively captured by the new channel. These flows were used to wash silt from the new channel, then intercepted by temporary settlement lagoons at the confluence prior to controlled discharge to the Nith. On completion, flow from the River Nith itself was intercepted above point E and allowed to flow through the new channel.

The key components of the design are shown in *Figures 11.2.2 to 11.2.5* and include:

- a channel, between 0.5 and 1m deeper than the required depth, was excavated;
- along 80% of the diversion length a clay liner was compacted to form a barrier between the river flow and the permeable ground below. A very detailed specification was provided to the contractor regarding the quality of material, and the method of compaction;
- overlying the clay the new bed was formed from mixed cobbles, boulders, and gravels. Many thousands of cobbles and boulders, many of them covered in plant growth and harbouring invertebrate life, were carefully transplanted from the existing Nith and the captured tributaries to assist with the colonisation of the new channel;

Shaping the new channel within the clay lining

River Diversions

The 'constructed' run-pool-riffle sequence

- a 1-2m wide depression was formed to create the low-flow channel, centrally on straight sections and towards the outside on bends (*Figures 11.2.2 and 11.2.3*);
- precautionary stone rip-rap was placed on meander bends to maintain the designed planform;
- The bare banks were immediately hydroseeded with a grass mix to reflect the grassy moorland surroundings to maximise vegetation cover before the onset of winter.

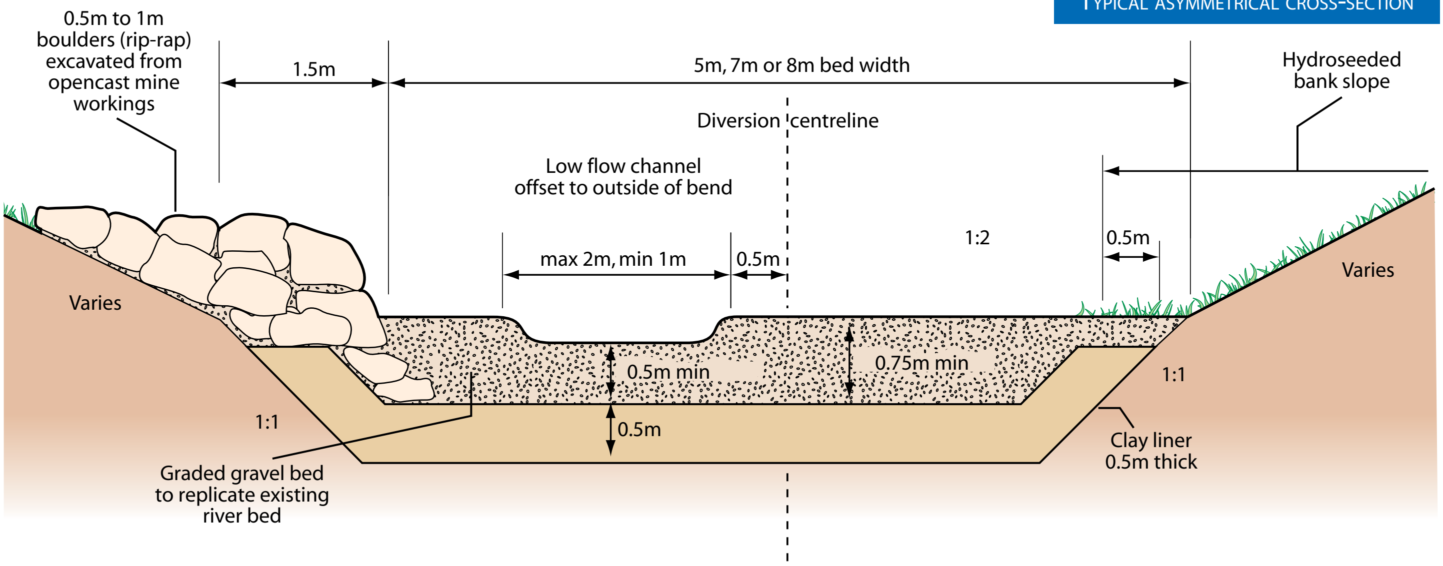
Run-pool-riffle sequences were constructed by over-excavating the ground where the pools would be located. When forming the bed, cobbles and boulders were pushed into the graded gravel upstream of the pool, forming a raised bed and a central faster 'run' of water entering the pool.

Some natural erosion of the riverbank was accepted, though the design aimed to restrict the lateral migration of the river outside the clay liner. To further stabilise the banks planting was undertaken, including reeds and grasses along the water margins, and alder (*Alnus spp.*), ash (*Fraxinus spp.*) and willow (*Salix spp.*) alongside the rip-rap.

An extensive programme of electro-fishing was undertaken to transfer fry, parr and other life stages of fish from the length to be diverted to assist with colonisation of the new channel.

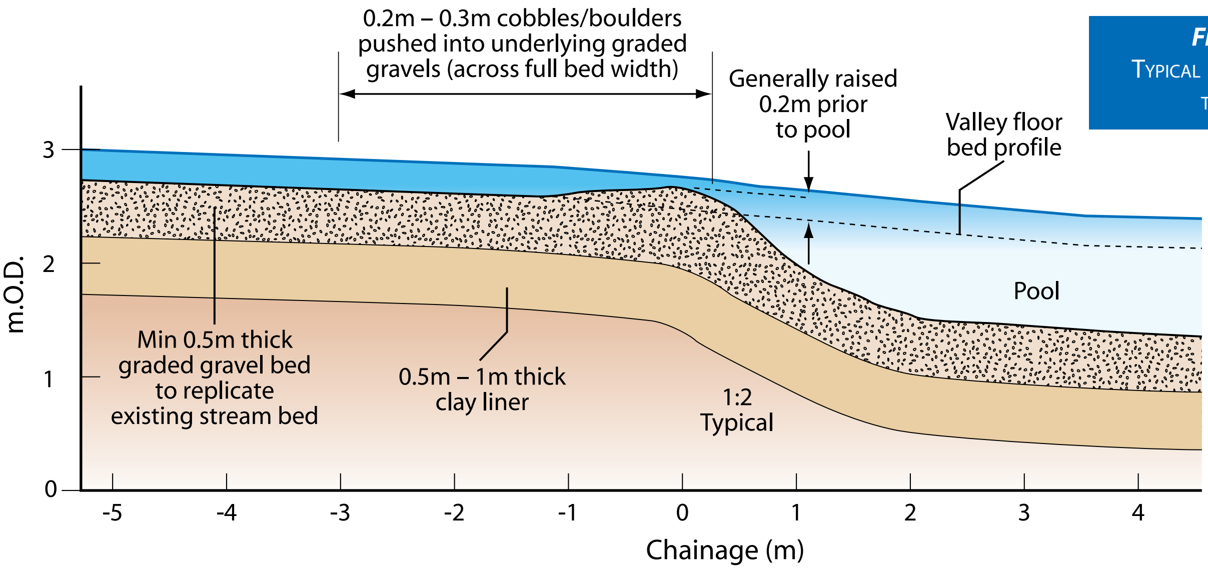
A matrix of wetland and other habitats was established in the new corridor with the intention of creating suitable habitats for a variety of wetland and grassland birds, otters, (*Lutra lutra*) insects and amphibians.

Figure 11.2.3
TYPICAL ASYMMETRICAL CROSS-SECTION



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

Figure 11.2.4
TYPICAL LONGITUDINAL SECTION THROUGH POOL



One year on and natural redistribution of in-channel sediments is helping to 'soften' the engineered channel

Subsequent performance 1995 – 2001

The ongoing biological and geomorphological performance of the diverted channel is being monitored under a PhD programme at the University of Stirling, sponsored by those sharing responsibility for the construction. A complete picture of the success of the project will only be possible following several more years of monitoring but the signs after twelve months are encouraging.

Recovery of the plant and benthic invertebrate communities is progressing well, although some species still remain low in abundance and others, found in the natural river, are absent from the diversion. This relates to low mobility and poor habitat and food availability due to the lack of vegetation. Fish have successfully recolonised the new channel, and the scheme has been hailed a success by the District Salmon Fisheries Board. Some additional planting is to be undertaken along the river-banks to provide in-stream shelter.

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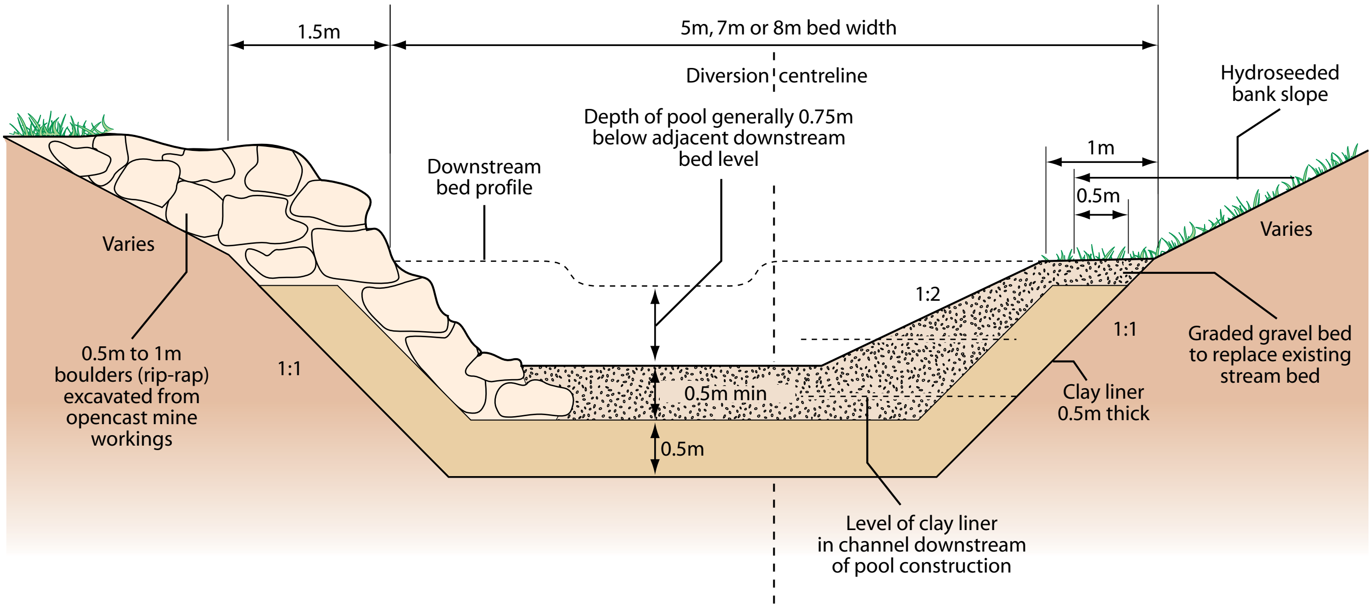
Figure 11.2.5
Typical pool construction



The overwide channel and plentiful bedload gives the river scope to shape its bed

River Diversions **11**

The rip-rap is still very evident but the in-river form is developing well

During a 1 in 10 year flood event the channel planform remained stable with only minor bank erosion. Channel change was most apparent near tributary junctions; dynamic reaches in natural rivers. The bed material was mobilised, as it was in natural reaches up and downstream, and as a result the constructed low-flow channel was replaced by a natural thalweg. The movement of the bed material resulted in some reaches becoming shallower, and the creation of point bars not in the design, increasing diversity of water depths and velocities.

Sorting of the bed material has deposited finer material on the inside of meander bends, resulting in a more natural appearance than immediately following construction. Minor bed level and bank adjustment is anticipated as a result of further high flows, in the same way as would occur in a natural river, but this will not threaten the integrity of the diversion.

The works have an eight-year maintenance period that will encompass annual inspections and reporting of any erosion control and/or replanting works deemed necessary.

Original Information Providers:
Mark Welsh
Gordon Cartwright
RRC

11 River Diversions

11.2 River Nith 2013 Update

River Nith	High energy, gravel
WFD Mitigation measure	Click Here to view details
Waterbody ID	GBNI1NB030307129
Designation	None
Project specific monitoring	Macroinvertebrate, Fish

The diverted channel had a wide riparian corridor. However, there was not enough channel sinuosity, and back water habitats were created which were out of character with the natural form of the river. In places the gradient was over steepened which, after the first floods, caused some headward erosion in one of the tributaries, the Dalgig Burn. In addition, bank erosion, slumping and some erosion in tight meander sections occurred. The eroded material was deposited in the lower gradient sections downstream, almost filling the channel in places. While it did create some additional habitat diversity, it was not planned. Problems with erosion were addressed by placing more boulders into the channel. This was fairly cheap to do due to the proximity of material to the site (mining by-product) and the machinery that was available.

Following works, trees and shrubs started to colonise the banks and an increase in macroinvertebrates and fish was observed. Successful recovery of macroinvertebrate richness and abundance was recorded and after 12 months there was a 90% recovery over the whole channel. After 2 to 3 years there was little discernible difference in species composition between the impacted and control sections.

Major changes

In 2004 the channel was moved again, roughly along the course of the original, because of a commercial decision to extend coal mining activities. This allowed the channel design to incorporate lessons from the former project's successes and limitations.

The channel realigned in 2004 after 7 years. Marginal vegetation has established and natural morphological processes are taking place – August 2011

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Reference material – Click here

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