1

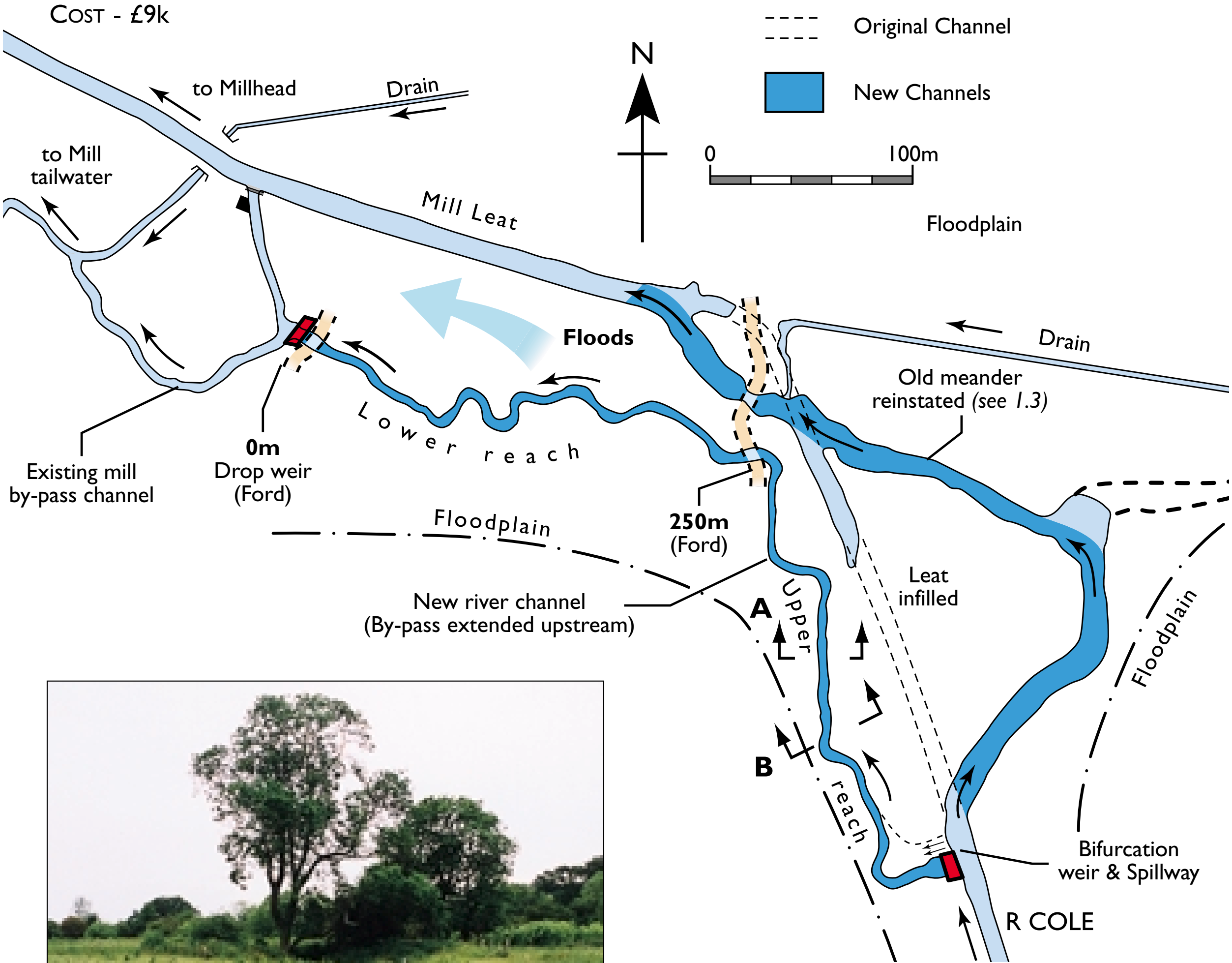
RESTORING MEANDERS TO STRAIGHTENED RIVERS

1.1 New meandering channel through open fields

RIVER COLE

LOCATION - Coleshill, (Oxon/Wilts border) SU 234935
DATE OF CONSTRUCTION - Autumn 1995
LENGTH – 500m
COST - £9k

Figure 1.1.1
PLAN OF UPSTREAM OF MILL



Lower reach in Summer – *August 1997*

DESCRIPTION

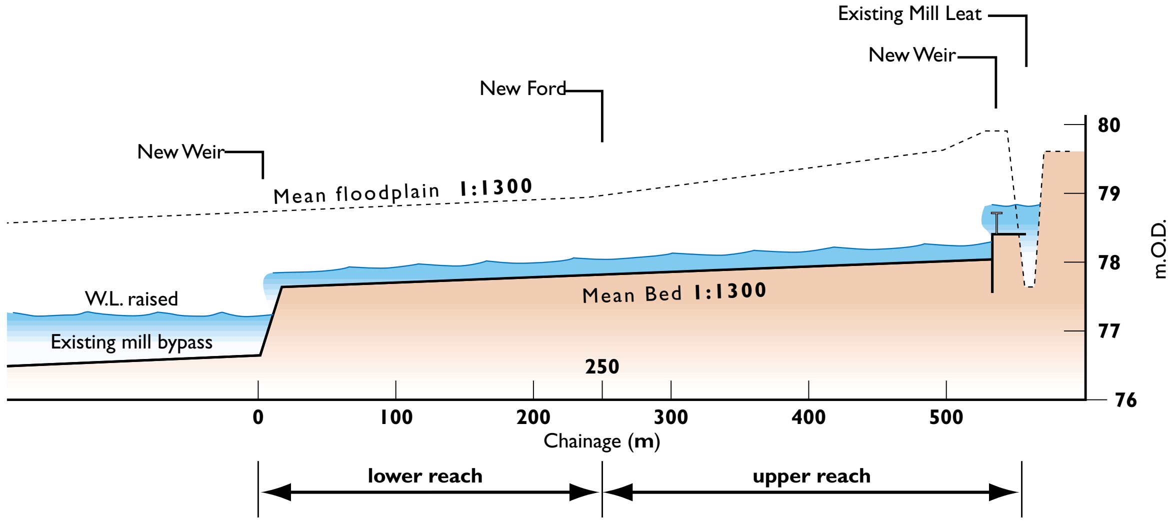
A new river course was created to introduce a reach of free flowing water to a floodplain that hither to featured only a slow flowing mill leat. An exisiting mill by-pass channel remained in operation and was incorporated into the new design by extending it as far upstream as practical to create the additional meandering channel that was required. The River Cole is now diverted from the leat to flow in the new channel, which is small in size, to ensure seasonal inundation of the adjacent floodplain.

DESIGN

Longitudinal profile (fig. 1.1.2)
The new mean bed gradient was set at 1:1300 to match the mean floodplain gradient. The bed elevation was set to give the shallowest channel

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

Figure 1.1.2
LONGITUDINAL PROFILE



possible whilst having just sufficient depth to contain summer spates. The resultant channel bed is elevated higher than the old mill by-pass, but is lower than the retained water level in the mill leat which feeds it. Drop weirs were therefore required at each end *(see 5.1 and 5.2).*

Whilst weirs are generally undesirable, the alternative of deeper channels was more so at this site. The drop at the downstream end was reduced in height as a consequence of introducing new meanders downstream of the mill; these raised normal water level in the existing mill by-pass to historic levels (*see 1.2*).

Alignment of channel (fig. 1.1.1)
The existing mill by-pass follows an ancient course of the River Cole. Remnants of its ancient course were

Upper reach at time of excavation – *October 1995*

Upper reach – *1998*

also evident in the fields between chainage zero and 250m, (lower reach), so the new channel was set to follow these at a fairly uniform depth of c. 1m. Upstream of ch. 250m the new channel deviates from any natural course because it had to be aligned roughly parallel to the mill leat which is unnaturally close to the edge of the floodplain. Land levels along this upper reach rise significantly above the average for the floodplain, hence the new channel is deeper. Meanders were set out to 'mimic' the natural form evident in the lower reach.

Cross-sections (figs. 1.1.3 – 1.1.4)
Section A shows a normal flow channel 2.6m wide by 0.8m deep - the geomorphology of the Cole indicates this to be the ideal size of channel. Because overall channel depth needed to exceed 0.8m *(fig. 1.1.2)*. The upper banks were graded back as flat as practical.

Section B shows a compatible asymmetrical profile introduced at each significant bend. The deepest bed level is cut below the mean bed gradient to introduce pools. The 1:1 batters on the outside of the bend were expected to steepen through natural channel adjustment.

Profiles on inside of meanders
Land levels were lowered to a depth of 0.8m above mean bed as shown on Section B. As all meanders are small in amplitude, no further shaping was undertaken; profiles were simply rounded off to give smooth transitions into Section A either side.
The profile was later modified *(see below)*.

Figure 1.1.3
SECTION A THROUGH SYMMETRICAL CHANNEL

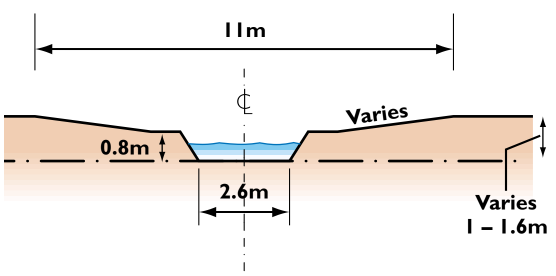
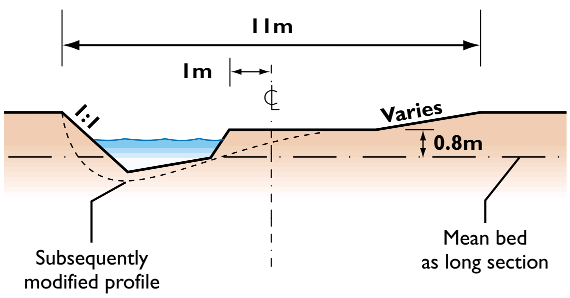


Figure 1.1.4
SECTION B THROUGH ASYMMETRICAL CHANNEL



SUBSEQUENT PERFORMANCE (1995/8)

The upper reach of the channel developed an intermittent bed substrate of gravel as well as small riffles of gravel below each meander. Limited supplies of gravel are derived from the clays exposed towards the bottom of the channel; none are carried down from the upper catchment. Additional gravels were imported to this reach one year after construction and 'seeded' into each pool for distribution by flood currents.

In the lower reach, where the new channel is less deep, gravels are less evident throughout. The drop weir at the lower end draws water noticeable faster as it approaches it. Downstream of this structure, the old by-pass channel has attracted substantial deposits of gravel, sand and silt derived from the new channel. These deposits are well sorted and have partially restored bed levels/profiles in the by-pass to historic levels, recreating variable flow depths.

The stiff clays in the river banks resisted erosion preventing cliffs from forming on the outside of meander bends where 1:1 batters were cut. Conversely, floodwaters were racing across the flat areas formed on the inside of each meander causing scour of the surfaces. The asymmetrical profiles were subsequently re-excavated as indicated on Section B.

Since these modifications the channel has performed satisfactorily in all respects; a good range of flow currents, substrates and bank forms are sustained throughout the year.

No planting, or seeding of the channel was undertaken. Natural colonisation is occurring slowly. The channel is unfenced allowing cattle access at low density under Countryside Stewardship prescriptions. Cattle have effectively grazed a proliferation of willow seedlings. Both aspects are being monitored.

The new meandering river course and the restored meander in the mill leat *(see 1.3) – July 1997*
Photo: Environment Agency

1

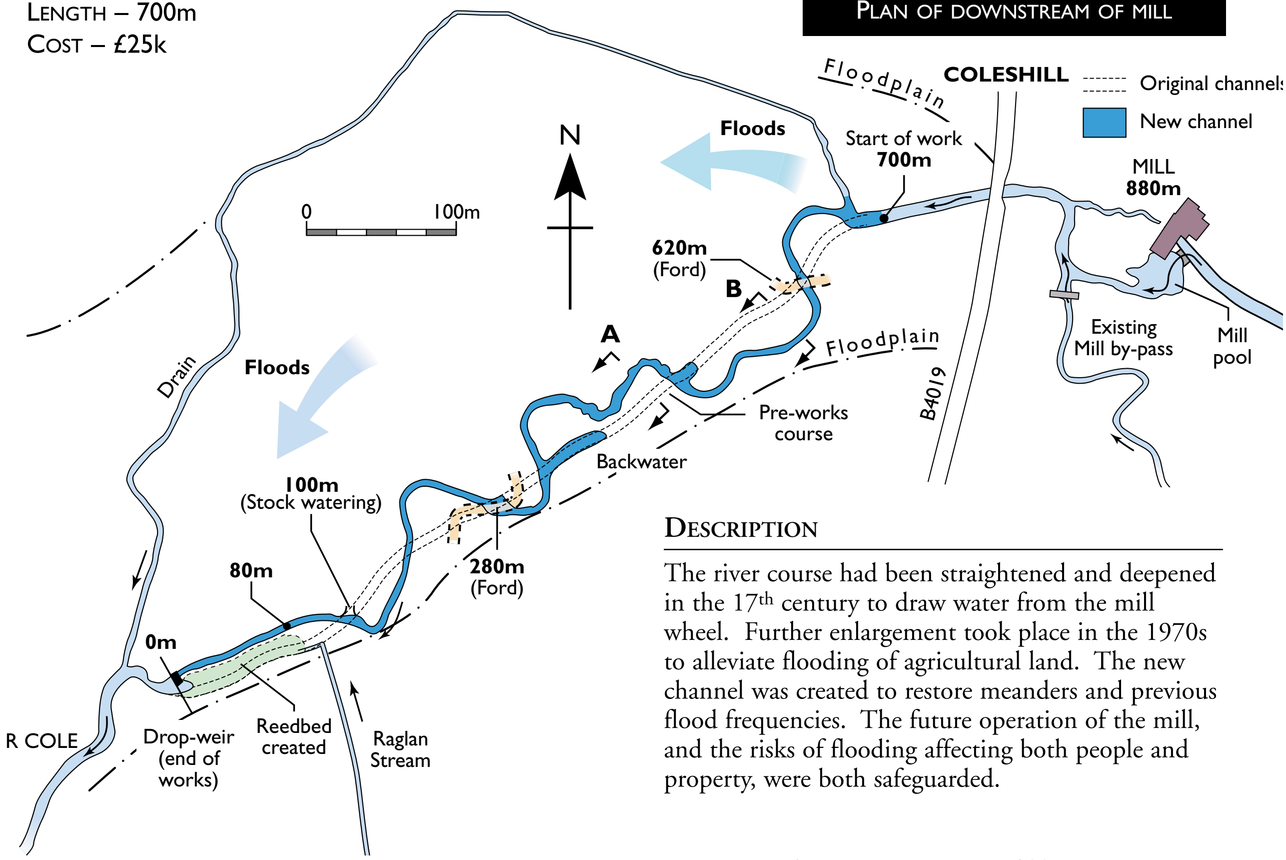
Restoring Meanders to Straightened Rivers

1.2 New channel meandering either side of existing

River Cole

Location - Coleshill, (Oxon/Wilts border) SU 234935
Date of construction - Autumn 1995
Length – 700m
Cost – £25k

Figure 1.2.1
Plan of downstream of mill



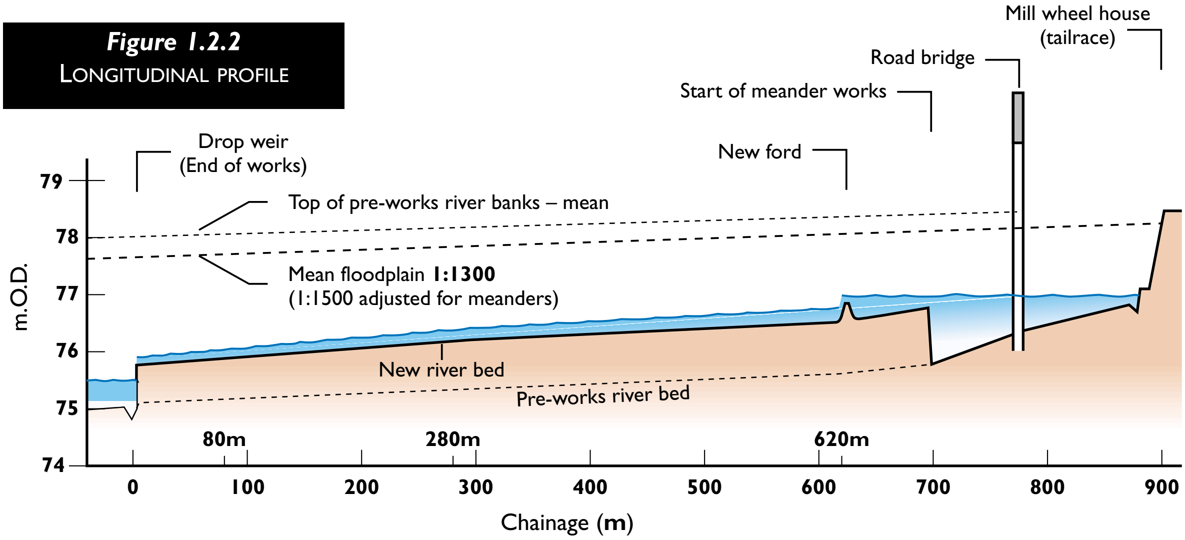
Description

The river course had been straightened and deepened in the 17th century to draw water from the mill wheel. Further enlargement took place in the 1970s to alleviate flooding of agricultural land. The new channel was created to restore meanders and previous flood frequencies. The future operation of the mill, and the risks of flooding affecting both people and property, were both safeguarded.

Aerial view of new meanders – *July 1996*
Photo: Environment Agency

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

Figure 1.2.2
LONGITUDINAL PROFILE



DESIGN

Longitudinal profile (fig. 1.2.2)
The elevation of the new river bed was raised by up to 1.0m, the maximum possible that still enabled water to flow freely from the old mill wheel tailrace. The bed gradient would ideally have paralleled that of the mean floodplain gradient (1:1300 straight; 1:1500 meandered) but was steepened to reduce the height of the drop structure needed at the downstream end of the reach. The actual bed gradients constructed are: chainage 0-280m at 1:740; 280-620m at 1:1000; 620-700m at 1:460; these equate to a mean of 1:700.

The raised bed enabled impoundment of water upstream of the works, restoring historic levels in the mill pool and the mill by-pass. A stone ford was built at ch. 620m to safeguard water levels against any downward scour of the new bed.

Channel before works – *1994*

New channel flowing into existing channel during construction – *September 1995*

Meanders during construction – *1995*

Alignment of channel (fig. 1.2.1)
Practical influences on the meander layout were the desire to retain several mature willows on the new river banks, and to maintain a sensible balance of land areas lost/gained either side of the old straight course. A geomorphological audit of the river, including a study of meander form evident in the downstream reach, finalised the layout. The relatively straight reach between ch. 0 and 80m avoided disturbing a fritillary meadow alongside and facilitated a riverside reedbed downstream of the Raglan Stream junction *(see Part 9)*. At ch. 280m the meander deliberately cut into rising ground just off the floodplain to provide a local cliff face c. 2.5m high.

Cross-section (figs. 1.2.3 – 1.2.4)
Section A shows a normal flow channel 2.6m wide by 0.8m deep. The geomorphological audit of the Cole indicates this to be the ideal size of channel. Because actual channel depths were greater than 0.8m, the upper banks were graded back at shallow profiles.

Section B shows a compatible asymmetrical section introduced at each bend. The deepest bed level is below the mean bed gradient to ensure that pools are sustained.

Land profiles between meanders
These were all lowered by c. 0.4m to levels that approximated to the mean floodplain levels (*fig. 1.2.2).*

Figure 1.2.3
SECTION A THROUGH SYMMETRICAL CHANNEL

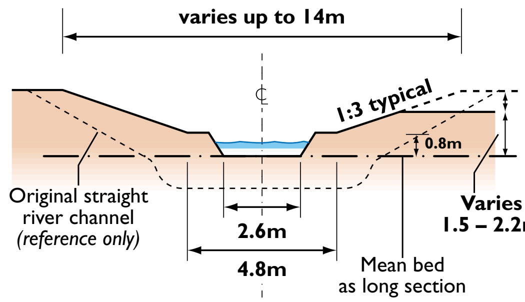
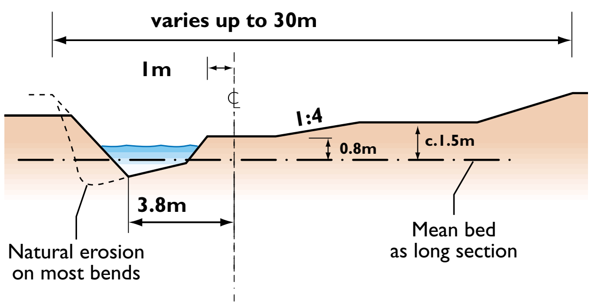


Figure 1.2.4
SECTION B THROUGH ASYMMETRICAL CHANNEL



This necessitated the removal of spoil deposited on the old river banks from the 1970s deepening works. The conveyance of flood flows across the meanders proved to be important in achieving the necessary hydraulic safeguards during 1 in 100 year flood conditions.

The old straight channel located within these areas was largely backfilled, although not completely (*see Parts 2 and 8* for details of backwaters, fords, stock watering points, etc that were incorporated).

SUBSEQUENT PERFORMANCE 1995/8

Spates of floodwater immediately following completion of the new channel led to rapid and extensive reshaping of the channel. Cliffs were eroded, pools were scoured and gravel riffles and sandy shoals deposited, all creating desirable natural features within the reach. Excess sediments built up immediately downstream of the works, helping to restore a further reach of the original over-deep channel. Since these initial adjustments, subsequent spates have satisfactorily sustained the regime described but at a much lower rate of change. Intervention has been limited to further flattening of the profile of the inside of the south side bend at ch. 280m. The river is largely unvegetated after two summers, although marginal vegetation is becoming established. A wide range of soil types are exposed in the channel and these account for the diversity of features that are now evident.

Diverse new channel – Two years after construction. – *March 1997*

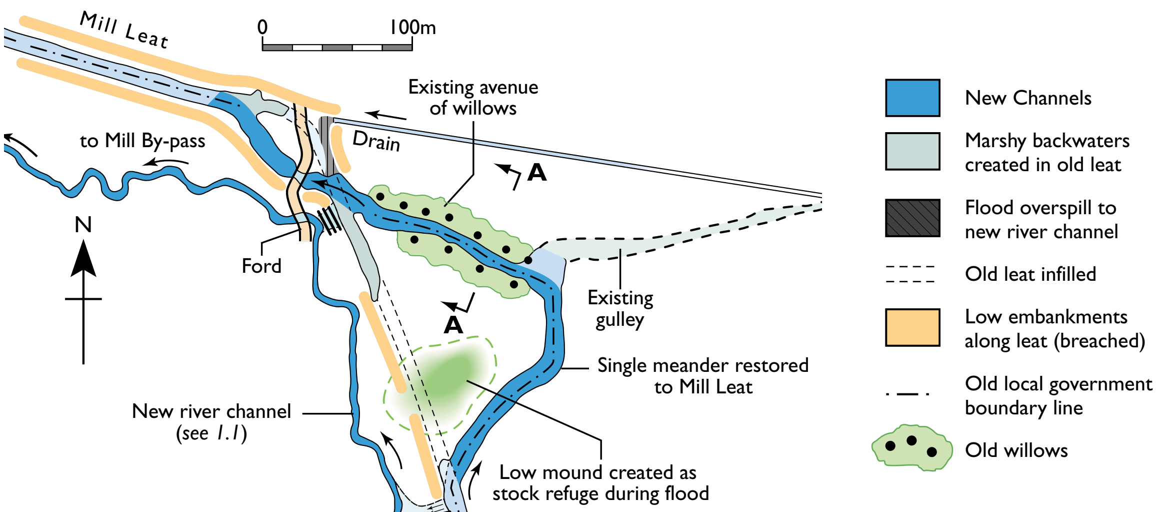
Natural cliff formation post works – *March 1997*

1.3 New meander in an impounded river channel

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1996
LENGTH – 300m
COST – £9k

Figure 1.3.1
PLAN OF MILL LEAT AND NEW MEANDER



DESCRIPTION

The mill leat is a straight, embanked channel built in the 17th century to store/convey river water for mill operations. It was modified in the 1970s to reduce the risk of flooding adjacent land. As part of the River Cole restoration project most of the river flow now by-passes the mill (and the leat) in a new meandering channel *(see 1.1)*. The leat was subsequently enhanced by restoring a single meander to its course.

DESIGN

Longitudinal profile
The existing river bed levels were retained throughout the new meander in order to maintain the historic depths of impounded water. Normal water levels were raised by c. 300mm to achieve this, involving replacing/repairing sluices at the mill in accordance with archived drawings retained by the owner, the National Trust. No embankments were reinstated on the new meander; water is free to spill into adjacent fields consistent with the overall river restoration objectives for this site.

Alignment (fig. 1.3.1)
The pre-existence of the meander was evident in two ways. A shallow, muddy depression between a short avenue of old willow pollards, branching off the leat, delineated part of an old river channel. A study of old maps indicated that an historic local government boundary line passes between the willows, continuing in a clear meander line that rejoined the leat further upstream. This line was adopted as the centre line of the new meander because of the strong precedence.

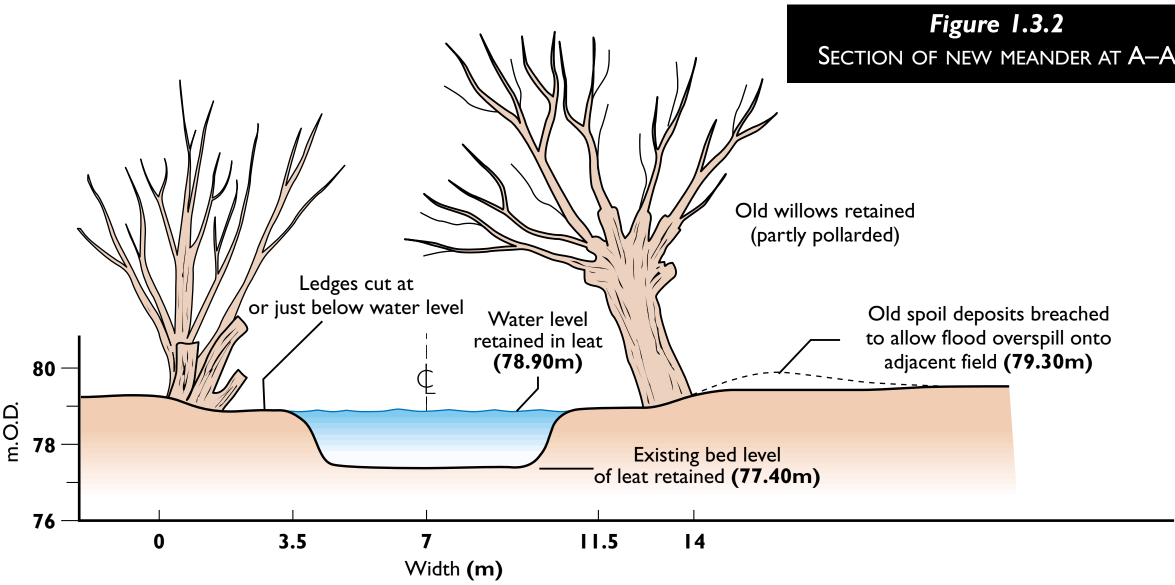
Cross-section (fig. 1.3.2)
The width of channel between bank tops was selected to retain the willows. The resulting dimensions closely matched the top width of the remaining mill leat, so was confirmed as suitable. The existing leat cross-section displayed wide ledges at, or about, normal water level that were cattle trodden either side of a deep, relatively clear, central channel. The new cross-section mirrors this configuration.

Profiles within the meander
The way in which flooding of surrounding land had been designed to occur makes livestock escape or rescue difficult. In mitigation, land levels within the new meander were raised locally in a gentle mound creating a refuge in times of flood.

SUBSEQUENT PERFORMANCE 1996/98

The new meander is visually striking between the willows; swans nested on the spit of land between the new and old channel where a quiet backwater has been created. Sheep are seen to favour the mound, being the 'highest and driest' ground in the area regardless of flooding. Marginal plants are satisfactorily establishing on the ledges each side of the newly created channel.

Figure 1.3.2
SECTION OF NEW MEANDER AT A–A



Remnant of meander – pre-works – January *1996*
(shallow water held temporarily after heavy rain/flooding).

Re-excavated meander
– Autumn *1997*

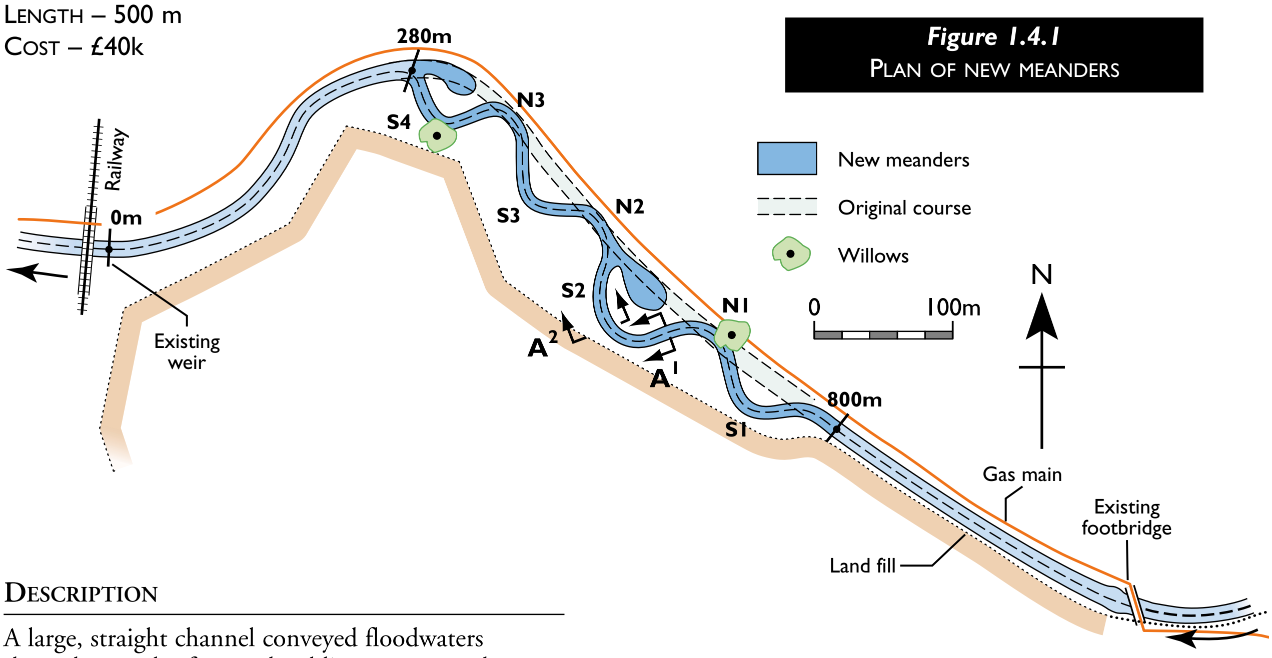
Restoring Meanders to Straightened Rivers

1.4 New meanders to one side of existing channel

River Skerne

Location – Darlington, Co Durham, NZ 301160
Date of construction – Autumn 1995 to Spring 1996
Length – 500 m
Cost – £40k

Figure 1.4.1
Plan of new meanders



Description

A large, straight channel conveyed floodwaters through a reach of grassed public open space that was bordered by housing and old industrial landfill. A new meandering river that partially incorporated the existing channel was created to the south side. The risk of flooding, affecting people and property, was safeguarded.

Design

Longitudinal profile (fig. 1.4.2)
The original mean bed gradient of 1:1300 paralleled the mean bank gradient at a depth of c. 2.4m.

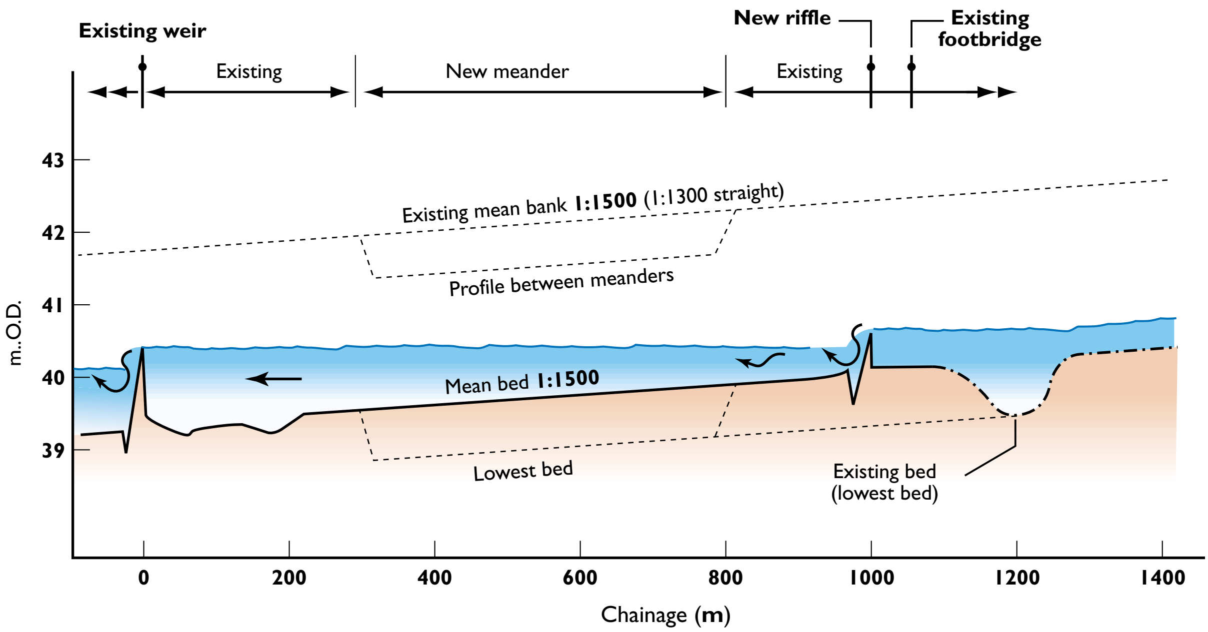
Meander excavation – Autumn *1995*
Photo: Northumbrian Water/AirFotos

The new mean bed gradient and level matches the existing but flattens to 1:1500 because of the increased length created. Bed scour around each meander was expected to reach c.1m depth as observed at an exisiting bend at ch. 1200m. This is shown as 'lowest bed' on the long section 1m below mean bed. Conveyance of floodwaters across the new meanders was facilitated by a general lowering of inter-meander land levels by c. 0.6m. This also enhanced water storage aspects of the 1 in 100 year flood hydrograph, attenuating the peak flow downstream.

Normal water levels in the reach are controlled by an existing weir at ch. 0m, but the effect of this diminished at ch. 900m where the original straight channel was retained and enhanced. Enhancements included an artificial rock/gravel riffle at ch. 1050m shown on the long section (see *Part 3).*

Alignment of channel (fig. 1.4.1)
The lateral extent of meandering is constrained between a gas main, running closely alongside the north bank of the old course, and landfill tipped to within 10 to 50m of the south bank. Bends S4 and N1 were located to retain two mature willows on the banks. The remaining meanders are set out between and checked against geomorphological criteria to finalise the layout. High flows in this channel and

Figure 1.4.2
LONGITUDINAL PROFILE



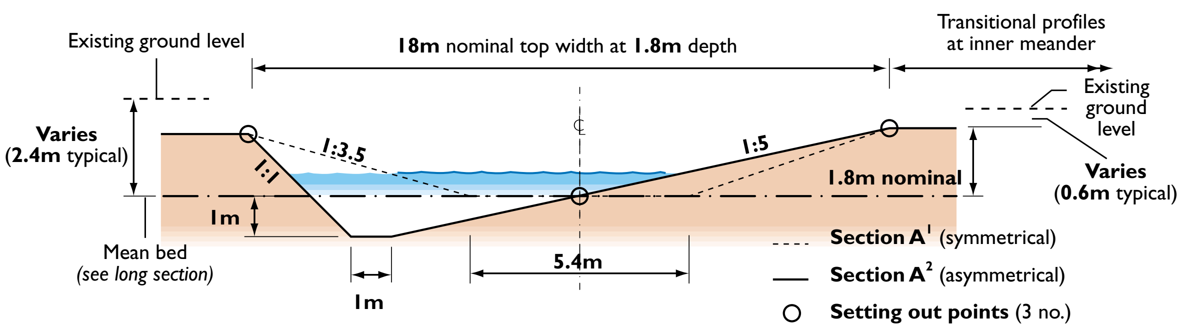
other constraints precluded any possibility of 'mirroring' historic meander patterns that were sustained by entirely different hydraulic criteria.

Cross-sections (fig. 1.4.3)
Because of continuously varying vertical depths described for the longitudinal profile, the design needed to be simplified. Two sections (symmetrical and asymmetrical) were developed based on mean depth (1.8m) and mean top width (18m). These applied to two points only on each meander - intermediate profiles required a continuous transition between them. The asymmetrical section allows for 1m of scour at each bend described above.

A variation of the pair of sections shown was developed for bends **S1** and **S4**. A horizontal ledge at normal water level was incorporated around the inside of each to simulate the effects of natural shoaling.

Profiles within meanders (see 6.2 and 2.1)
As well as the general lowering of land levels described above, considerable profiling was specified to ensure inundation in time of flood was progressive from the downstream leg back towards the start of each meander. Similarly, special consideration was needed to ensure the safe 'submergence' of backwater features prior to general overbank flow. The safety of

Figure 1.4.3
SECTION THROUGH NEW MEANDERS



people during rising floods is of particular importance at this urban location. Exceptionally, land within bend **N1** could not be significantly re-profiled as a high voltage cable passes underneath.

SUBSEQUENT PERFORMANCE 1995/8

The newly meandered channel has proved to be stable under frequently occurring flood conditions. The most vulnerable banks, located where bends are incorporated into the backfilled course, are supported by revetments (*see Part 4*), but elsewhere the indigenous clays have resisted erosion. Sands, silts and mud have deposited as shoals where eddy currents arise around the inner margins of bends and the deeper pools created around the outside appear self-sustaining. Diverse flora and fauna have rapidly colonised the many different features of the new course and local people enjoy relatively safe access to the waters edge.

Completed meanders – Summer 1997

Looking downstream towards large backwater – February 1997

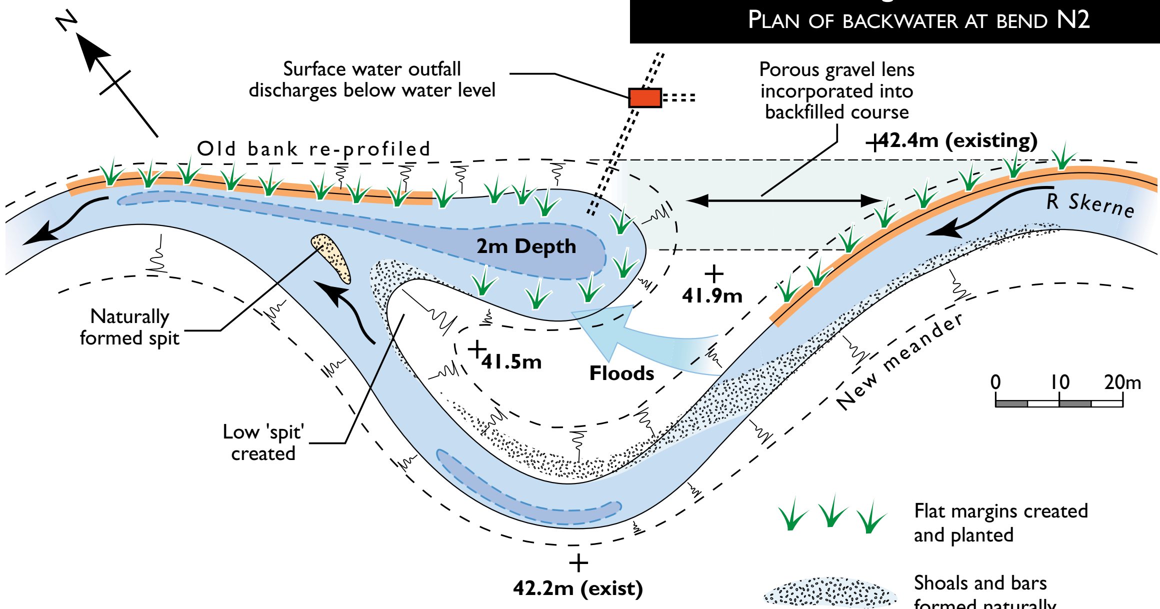
2

ENHANCING REDUNDANT RIVER CHANNELS

2.1 Creation of backwaters

RIVER SKERNE
LOCATION - Darlington, Co. Durham NZ 301160
DATE OF CONSTRUCTION - Autumn 1995
COST - £3k

Figure 2.1
PLAN OF BACKWATER AT BEND N2



DESCRIPTION

The creation of a new meandering river course, to one side of the existing straight channel, rendered short sections of the latter redundant. At two such sections the old channel was only partially backfilled. The unfilled lengths were enlarged to form backwater areas that are connected to the downstream leg of the new meanders.

DESIGN

The redundant lengths of channel were trapezoidal in section and needed to be enlarged and reprofiled to achieve their full ecological potential. Both were similarly designed - the largest is shown in figure 2.1.

A normal water depth of 2m was needed in the centre to prevent emergent plants from occupying the whole water area. Conversely, shallow depths around the sides were needed to encourage both marginal and emergent plants. The margins also provide a natural safety buffer against children accidentally reaching deep water.

Development of a series of cross-sections to provide the variable depths led to the plan form shown, which is typically 'onion' shaped. The top width is greatest where the excavation is deepest. The effect is exaggerated further by widening the shallow ledges adjacent to the greatest depths.

The hydraulic design of the meander ensures progressive submergence of the backwater during floods. Figure 2.1 indicates the way in which the land between the backwater and the river channel is profiled to ensure that the downstream leg (and the backwater) submerges before floods flow directly across the meander corridor. Floods sweeping over the backwater flow on downstream, merging with the main river flow. The complex currents that result at this stage affect the patterns of sediment deposition at the junction of the backwater with the main river channel. Large eddies inevitably arise, and these can easily cause sediments to settle out right across the junction, eventually closing it off from the river completely. The floodwater currents passing through the backwater help to reduce this risk; it was anticipated that a shallow spit of sediments would form, but not complete close the backwater. The formation of such a spit was reflected in the profiling of the land at the junction.

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

Following excavation and final profiling, the flat shallow ledges were intermittently planted with appropriate species sufficient to encourage their spread. A major surface water outfall was also located within the backwater after reconstruction *(see 9.1)*.

A final feature of the backwater is a simulated lens of gravel incorporated into the backfilled original straight channel. Such lenses can occur naturally during the formation of meanders. The purpose of the artificial lens is to encourage a small flow of river water to seep through to the backwater at all times. The amount of flow is dependent upon the difference in water levels between the backwater and the upstream river, which in this location is very small.

SUBSEQUENT PERFORMANCE - 1995/8

The backwaters are a strikingly successful feature of the project. They not only add to overall visual amenity but attract much bird life because of the diversity of habitats especially at the junctions. People are attracted to the backwater to feed the birds which further encourages them. The eddy currents anticipated are much in evidence, and have led to the natural formation of the small spit highlighted. This is a desirable feature that should help to maintain deep water because of the narrowing effect and increased velocity.

Large Backwater – *November 1996*

2

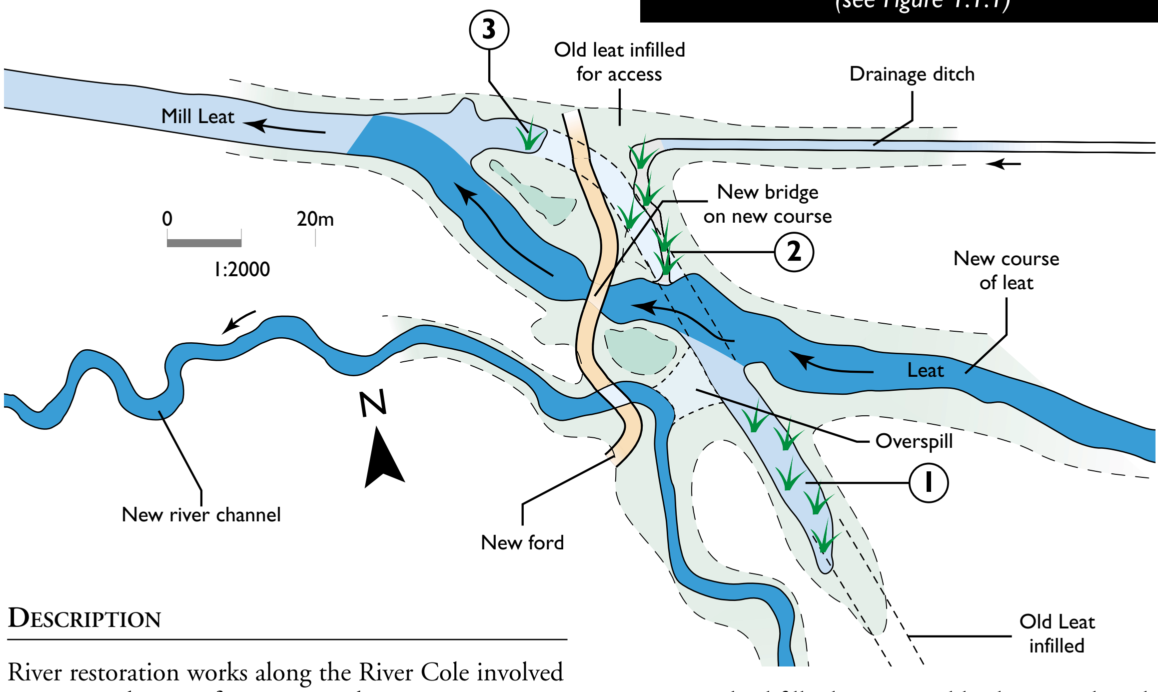
ENHANCING REDUNDANT RIVER CHANNELS

2.2 Creation of backwaters

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995
COST – No direct costs but additional spoil carted to landform area

Figure 2.2.1
BACKWATERS AT 1, 2, 3 DELINIATE COURSE OF LEAT PRIOR TO NEW BRIDGE AND NEW MEANDER IN LEAT
(see Figure 1.1.1)



DESCRIPTION

River restoration works along the River Cole involved re-routing the river from its straight course into new meandering channels *(see 1.1 – 1.3)*. Remnants of the old river course were incorporated into the overall restoration as backwaters at 3 locations and as a bay at another location.

DESIGN

Each feature created is uniquely different, but all are based upon the common principle of only partial backfilling. This also avoids the need to revet or support backfill where it would otherwise abut the new channel.

Backwaters on mill leat (fig. 2.2.1)
A new bridge was built 'in the dry' before completing the diversion of the leat and backfilling the old course *(see 8.2)*. Backfilling was limited to providing a link to the new bridge, leaving the lengths denoted **2** and **3** on the figure open to the river. Backwater **2** is linked to a drainage ditch which backs up with river water when the leat rises, creating a reversal of flow into other parts of the drainage system, which in turn contributes to the seasonal flooding of fields. The bed of this backwater has been raised to just below normal water level to sustain a marshy aquatic habitat. In contrast, backwater **3** remains as open water with marginal ledges and willows.

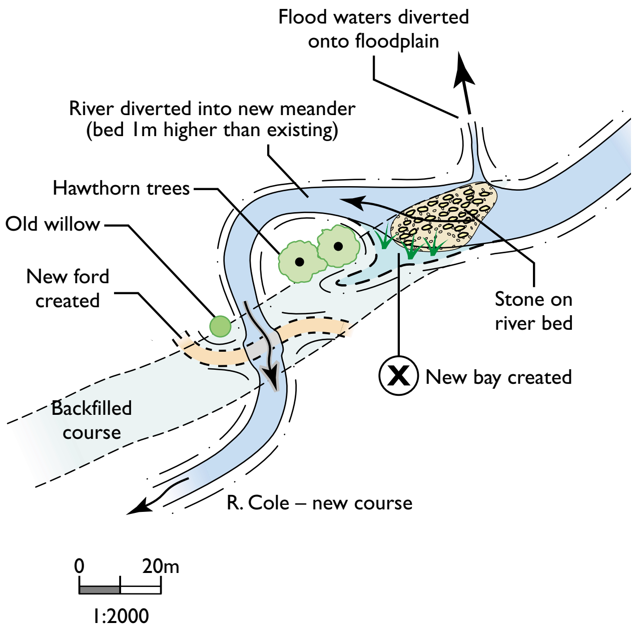
Backwater **1** was created after excavating a new meander in the leat *(see 1.3)*. It is an unfilled length of the old leat which was enhanced by removing the embankment from the left side so that rising floodwater could overspill to merge with floodwaters in the new river channel adjacent to it.

Backwater **1**

New bay at start of lower meanders (fig. 2.2.2)
The new meandering channel is smaller than the existing channel upstream and its bed is elevated c. 1m higher. As a result, water in the upstream channel is impounded and slow moving which contrasts with a marked increase in velocities within the new channel. The design of the junction of the old and new channels reflects these hydraulic conditions. The risk of downward scour of the new bed was alleviated by backfilling the existing channel bed where it abuts the new and adding a layer of stone to create a secure transition. To complete the diversion, the old channel was backfilled in a manner that created a small marshy bay within which the slower moving floodwaters approaching the new meander can eddy freely before entering it. This was preferable to complete backfilling and having to revet the fill to resist erosion.

Opposite the bay, an old drainage ditch entered the river. This was incorporated and enlarged to enable floodwaters to pass freely from the river out onto the lowest part of the floodplain, remote from the main river course. As a further safeguard against downward erosion of the new river bed, a stone ford was created 80m downstream where the new channel crosses over the line of the original *(see Part 8)*. This ford acts like a small weir and therefore 'fixes' both bed and normal water levels upstream.

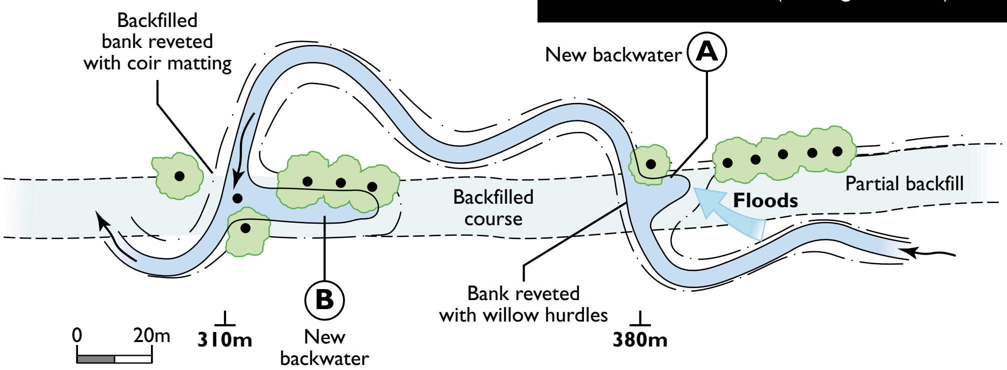
Figure 2.2.2
NEW BAY AT START OF LOWER MEANDERS
(For location see Figure 1.2.1)



View of shallow bay **X**

ENHANCING REDUNDANT RIVER CHANNELS

Figure 2.2.3
BACKWATERS ON LOWER MEANDERS AT CH 310m AND 380m
(see Figure 1.1.1)



Backwaters within lower meanders (fig. 2.2.3)
Two backwaters were created where the new course crosses over the old course. One is much larger than the other, and each is different in nature.

Backwater **A** is located where backfilling of the old channel was kept to a low level so that a valuable line of old river bank trees were not buried. The new river channel approaching the backwater marks the inside of a meander, necessitating further lowering of ground levels, with the result that floodwaters regularly sweep across it to enter the backwater as indicated. This flood flow sustains open water in the backwater as well as shoal deposition, creating varied off-river habitat.

Backwater **B** contrasts with **A** in that the retained trees along the old course all overhang open water and the new channel approaches from behind the trees rather than towards them. The hydraulics are entirely different as a result. The old river bank, behind the trees, remains at a high level preventing any floodwater from passing into the backwater save for small volumes that occasionally pass over the infilled length of channel. The backwater is thus a quiet refuge of still water, and hydraulic interaction with the river is limited to rise and fall of water levels.

The river banks opposite the mouth of each backwater were formed from backfill right up to the new channel profile after infilling of the old river bed. Each was reveted *(see 4.6)*.

Small backwater **A**

Large backwater **B**

SUBSEQUENT PERFORMANCE 1995/8

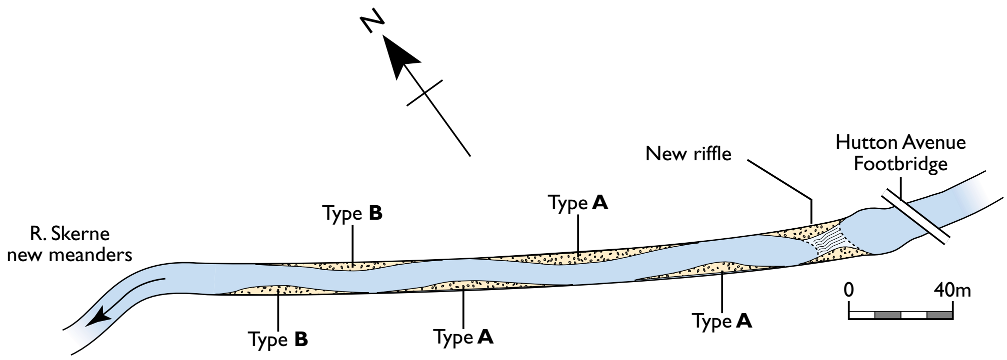
The new backwaters and bay all add considerably to the overall ecology and landscape amenity of the restored river. Each represents a unique habitat feature created at virtually no direct cost. Savings on the cost of revetment were, however, offset by the need to haul surplus soil to nearby landform areas rather than simply infilling *in situ*. The value of the features created more than justifies the cost of haulage involved.

3 ENHANCING STRAIGHTENED RIVER CHANNELS

3.1 Current deflectors

RIVER SKERNE
LOCATION – Darlington, Co Durham, NZ 301160
DATE OF CONSTRUCTION – August 1995
COST – Type A - £1100 Type B - £900

Figure 3.1.1
PLAN OF LOCATION OF DEFLECTORS



DESCRIPTION

The river had been straightened and enlarged to carry floodwaters safely through an urban area. A gas main runs parallel to one bank and contaminated landfill lies close to the other. The channel was uniformly trapezoidal although bank toes had been eroded. No diversity in the shape of the bed or banks, or of flow currents, existed and the ecological and visual amenity was poor.

View downstream before deflectors constructed

Diversity was introduced by building a series of low level structures in the bed that intermittently narrowed the channel causing variation in flow currents and localised pockets of erosion and deposition (deepening of the bed and accreting at the banks). The structures were necessarily small scale to avoid creating any scour of the river banks or significantly impeding flood flow.

DESIGN

A series of artificial shoals were built, projecting up to one third of the way across the river bed (3m shoals in 9m bed). The shoals were semi-eliptically shaped in plan and elevated above normal water level by only a small amount. Their spacing along the reach varied, but they were placed on alternating sides of the river to encourage a small degree of sinuosity to the normal flow regime.

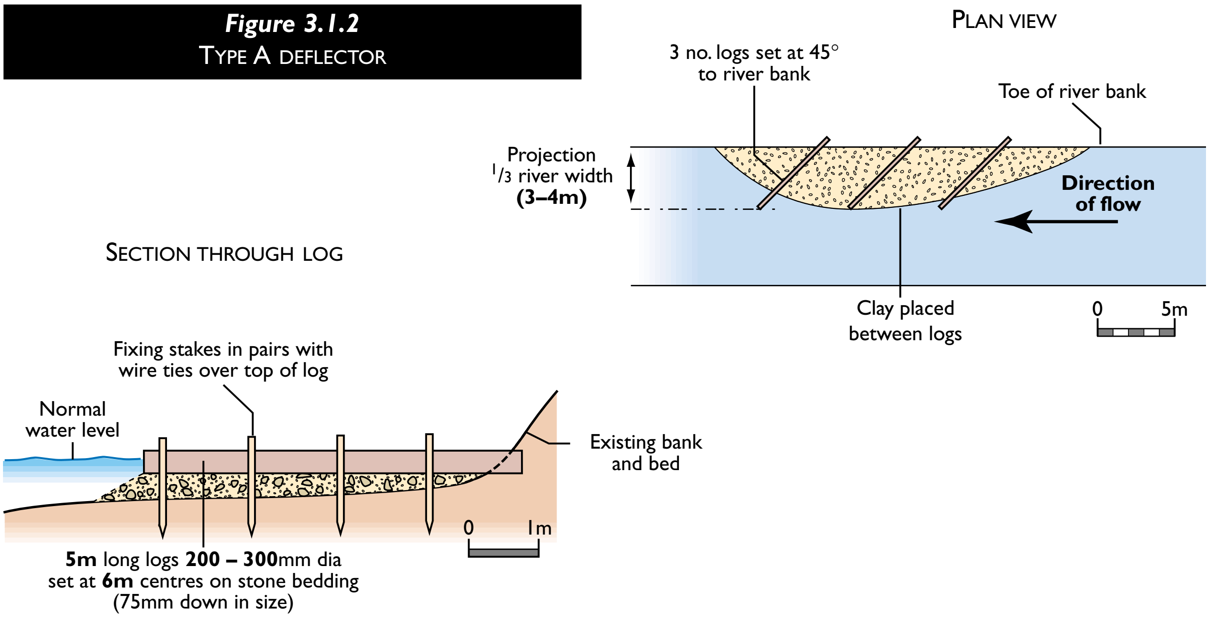
As this form of shoaling was not natural to the straightened reach, the design needed to impose conditions that would generate and sustain both scour and sediment deposition. This was achieved by incorporating a series of current deflectors, of varying length, out from the water's edge. These impede river flows, causing scour at their tips, whilst creating eddy currents within which silt is deposited closer to the bank. The anticipated form of silt deposition was simulated by adding stone and clay between the deflectors to initiate shoal formation.

Tree trunks (logs) of c. 300mm diameter were specified for deflectors as this is the most suitable material generally available near rivers, although all were imported at this urban location. Logs were secured with fence posts and wire after setting to line and level on a bed of stone.

Two variations of the designs were introduced. The deflectors of 'type A' point downstream *(fig. 3.1.2)*, whereas those of 'type B' *(fig. 3.1.3)*, point upstream. This was done to help determine the most effective alignment for future application of the technique.

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

Figure 3.1.2
TYPE A DEFLECTOR



The height of the deflectors above normal water levels was also important. If set too low they would not create enough flow variation or visual benefit but if set too high they would create excessive erosion and would resemble terrestial features.

The type **A** deflectors were specified at about 200mm above water level and type **B** sloped from 300mm above water level at the bank down to water level at the projecting end.

Some planting using marginal species was planned for the end of the first winter's season after the river had adjusted the shape of the 'as built' structures.

SUBSEQUENT PERFORMANCE 1995/98

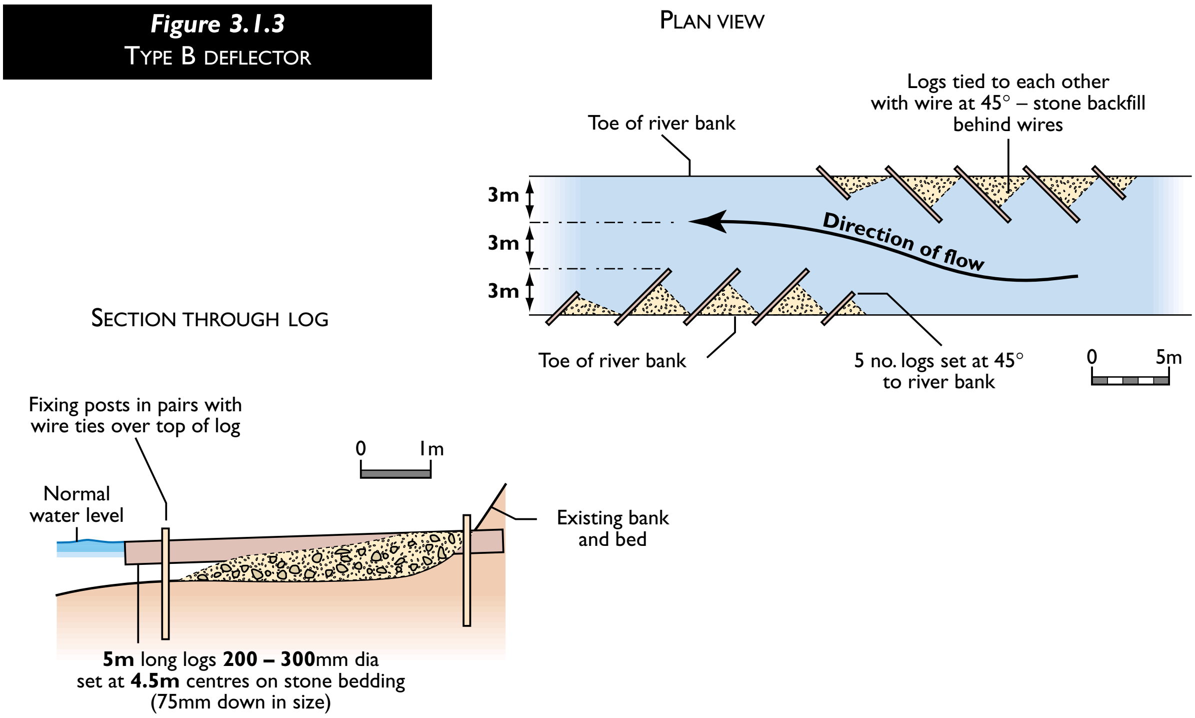
Whilst the deflectors have added a useful degree of diversity to the reach, this was not achieved without post-works modification following reaction by the river to their imposition; particularly those of 'type A'.

The primary difficulty was experienced when setting the level of the deflectors in relation to the normal range of low water levels; a critical factor. Deflectors were installed at the start of extensive river restoration works further downstream, when water levels were temporarily raised. Consequently, the 'type A' deflectors were set higher than designed and 'type B' were set lower. Live willow logs were used in 'type A' and inevitably began to grow, threatening to cause obstruction to flood flows.

Type A deflector
– vegetation established

Type B deflector before planting

Figure 3.1.3
TYPE B DEFLECTOR



As a result of these factors, over winter floods washed out much of the fill from 'type **A**' deflectors, leaving them perched above the water level, and causing erosion of the opposite river bank. Conversely, 'type **B**' deflectors had no discernible effect on the river regime.

Repairs to 'type **A**' deflectors comprised removal of the logs and replacement with pre-planted fibre rolls set at the surviving shoal level, as well as some planting using fibre mattresses. 'Type **B**' were not modified but some plant pallets were introduced near the bankside.

Subsequently 'type **A**' deflectors continued to adjust but show signs of becoming stable at about the levels designed and indicated in the figure. Small pools exist just downstream and currents are discernibly faster through the narrows created. 'Type **B**' deflectors remain less evident and would ideally be raised in level to bring them up to those designed.

The technique appears to be very worthwhile, but success is clearly sensitive to the size and level of the structures introduced. Both types were further enhanced by adjoining marginal planting at a later date *(see 3.2)*.

3.2 Narrowing with aquatic ledges

A) RIVER SKERNE

LOCATION – Darlington, Co Durham, NZ 301160
DATE OF CONSTRUCTION – Type A – Autumn 1997, Type B – Autumn 1998
LENGTH – 320m
COST – Type A – £45 metre, Type B – £40 metre

Attaching coir matting to create Type A ledges on River Skerne

DESCRIPTION

The river had been straightened and enlarged to carry floodwater safely through an urban area. A gas main runs parallel to one bank and contaminated landfill lies close to the other. The channel was uniformly trapezoidal although bank toes had been eroded. No diversity in the shape of the bed or banks, or of current flows, existed and the ecological and visual amenity was poor.

Ledges were installed both upstream and downstream of Hutton Avenue footbridge; in the former location along an unmodified channel and at the latter in association with current deflectors. These ledges help control undercutting of the river bank toe as well as introducing desirable habitat and improved visual amenity. They also narrow the normal flow channel encouraging velocity variations in an otherwise sluggish river.

DESIGN

As marginal plants were absent in the reach it was evident that the straight river would not naturally sustain the shallow, silty edges necessary for their growth. The design needed to create these conditions artificially in a manner that would eventually become self sustaining.

Two designs were developed utilising proprietary matting to hold backfilled river silts in place along the waterside *(fig. 3.2.1)*. The ledges created were either planted with pre-grown materials or left to colonise from planting introduced nearby.

Type **A** design is suited to wide ledges (up to 2m at this site) but the width can be varied to introduce curvature to the plan alignment.

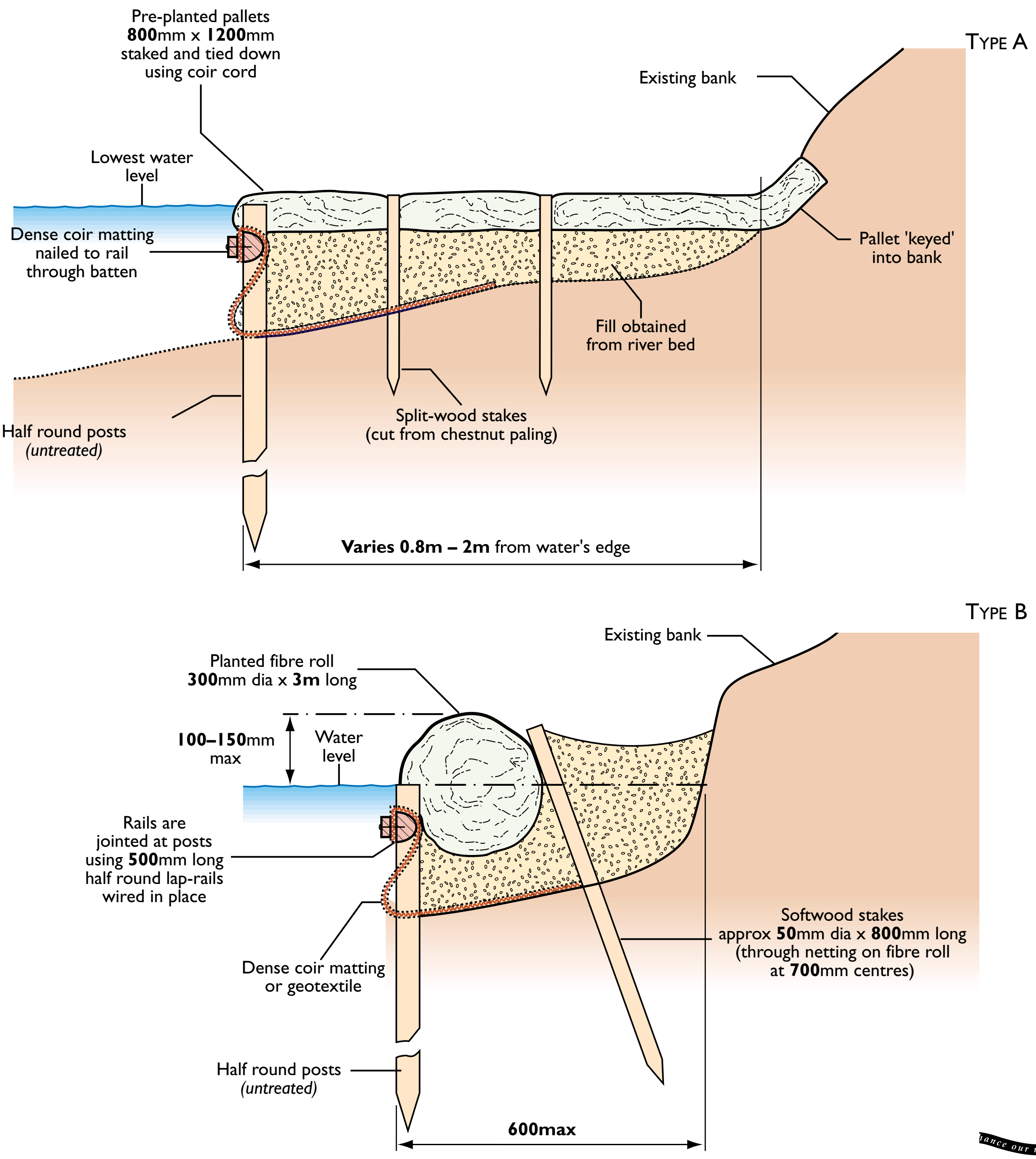
Type **B** design is suited to narrow ledges and is most appropriate where the river bed falls away steeply at waters edge and a small fringe of marginal vegetation is all that can reasonably be sustained.

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

Both designs rely upon a face of untreated timber posts and rails to hold the matting containing silt backfill. To ease construction, these are firstly assembled with matting in place just above water level and then the posts are pushed below water using an excavator bucket. The use of wire ties at rail joints affords the necessary flexibility.

Biodegradable coir matting was favoured, but some nylon matting (Enkamat) was utilised in the type B application where hydraulic conditions suggested a long life material was needed. Under most conditions the root growth of the plants introduced is expected to consolidate the underlying silts whilst matting and timber slowly decay, perhaps over a 5-10 year period. Emergent growth was expected to attract silt deposits as plants become established.

Figure 3.2.1
SECTIONS THROUGH TYPE A AND TYPE B LEDGE DESIGNS



Type A Ledge on the Skerne – May 1998

SUBSEQUENT PERFORMANCE 1996/8

Type B margins utilising plant rolls were installed upstream of the footbridge in August 1996. In 1998 they are attractive features much favoured by resident ducks that have created some bare patches between well established runs of lesser pond-sedge, yellow flag and reed canary-grass. The attraction of silt within the overwinter dormant vegetation along the ledges is significant; ledges have built up by as much as 300mm in places before being assimilated within new spring growth.

Type A margins using plant pallets were installed downstream of the footbridge in the autumn of 1997 and overwintered satisfactorily in dormant conditions after several floods. Early summer 1998 growth was patchy with some silt banks smothering pallets. Growth was sufficient to ensure the spread of species to generate the dense cover required. Noteable species that survived include occasional purple loosestrife and meadowsweet.

Type B Ledge on the Skerne after 2 years

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

B) River cole

Location – Coleshill, Oxon/Wilts border, SU 234935
Date of construction – Autumn 1997
Cost – £56/metre

Description

Ledges of both type **A** and type **B** designs used on the Skerne were created on a short reach of the river located immediately downstream of the main road bridge at Coleshill. The work followed the installation of a new gas pipe crossing under the river bed and were part of the contractors river bank reinstatement programme.

The river conditions are more fully described in 1.2. The reach is part of the original river within which water is impounded by newly created meanders downstream.

Post and rail was driven up to 2m out of from the waters edge, coir matting attached and then backfilled with soil excavated from the same river bank. Excavation from the river bank enabled the width of the ledge to be extended, to more than 2m in places but, more importantly, it afforded a flatter, more varied bank profile than the previous 1:1 batter. Transitions into the existing banks at each end used the type **B** design.

Subsequent performance 1997/8

The ledges overwintered well in dormant conditions with no structural damage by floods although little more than 50% of the plants appeared to have survived to grow on during summer. The ledges are developing very well (1998) and creating both emergent vegetation habitat and landscape enhancement in the short stretch of river that previously had the least habitat and visual amenity value.

Type A and B ledges on the Cole after one winter

Prior to re-profiling and ledge construction – May 1996

3

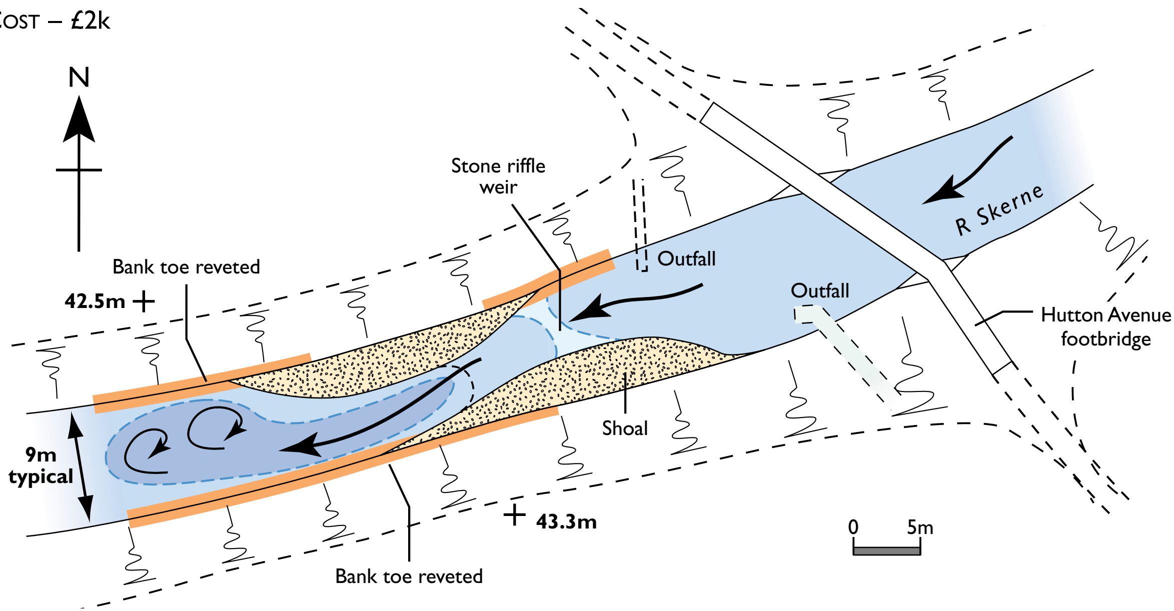
ENHANCING STRAIGHTENED RIVER CHANNELS

3.3 Stone riffle

RIVER SKERNE

LOCATION – Darlington, co Durham, NZ 301160
DATE OF CONSTRUCTION - August 1996
LENGTH – 60m
COST – £2k

Figure 3.3.1
PLAN OF STONE RIFFLE



DESCRIPTION

The Skerne has no natural gravel sediments in the restoration reach, so the introduction of a stone riffle feature needed to be entirely artificial and self sustaining. A riffle located just downstream of Hutton Avenue footbridge afforded several benefits within what was a featureless, straight reach of river (*see 3.1 and 3.2 for other enhancements in the same reach*).

Firstly, the sight and sound of water cascading over the riffle is enjoyed by people using the footbridge. Also, the regulation of normal water levels upstream has helped in introducing stable marginal planting ledges where water birds and mammals can always be seen. Two surface water outfall pipes just upstream (one 900mm diameter) are always submerged because of the riffle (*see 9.1*). Children regularly paddle in the shallow flow over the riffle. In anticipation of this the design needed to be as intrinsically safe as possible.

Stone Riffle downstream of Hutton Avenue footbridge

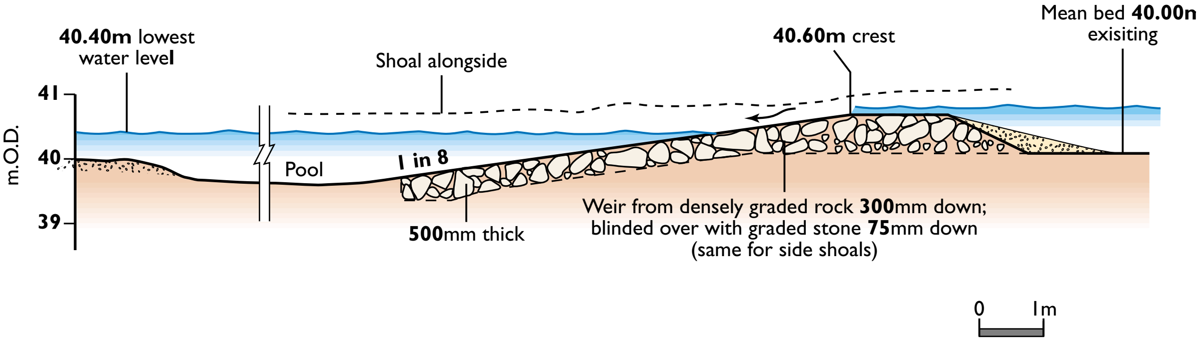
DESIGN

Although described as a riffle, the structure was designed as a low weir. Scour of the structure, as well as the river bed and banks downstream, were primary considerations.

The riffle is configured as two semi-eliptical shoals, diagonally opposite each other, that are linked by a shallow sloping weir, such that the whole is a single, homogeneous structure. During low flows, only the weir is submerged but the shoals quickly drown as flows increase. The configuration sustains a deep,

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

Figure 3.3.2
SECTION THROUGH WEIR



faster flow of water around the downstream shoal that noticeably eddies as the currents merge with the lower river. These variations in the speed, depth and direction of flow all sustain habitat diversity. The river banks alongside each shoal are graded as flat as practical to make access to the water's edge easy and safe. The toes of the river banks are reveted with stone where river flows are accelerated during passage over the structure and beyond.

The stone used for construction was a densely graded crushed rock mixture sized 300mm down to 5mm. The dominant size (at least 50%) was in the range 125-300mm to ensure that the structure would not wash away during floods, albeit some adjustment to form would inevitably occur. As a final measure, the entire structure was covered in a layer of smaller crushed stone to simulate gravel. This mixture was sized 75mm down. Its purpose was to smooth out the irregularities in the core rock surfaces improving appearance. Much of this material would be washed away by floods, but was expected to settle out in desirable niches close downstream.

At normal water levels the new structure is free-flowing, but spates of floodwater cause downstream levels to rise more quickly than those upstream such that the structure is 'drowned out' at an early stage; an important flood defence and fishery requirement. Weed growth downstream of the structure also causes seasonal rises in normal water level that partially submerge the structure.

SUBSEQUENT PERFORMANCE – 1996/8

The new riffle/weir has performed well and adds greatly to the amenity of this well visited location. The river has scoured away much of the smaller sized stone, as anticipated, but a stable structure has evolved in the form required. The slope of the weir has steepened significantly (from 1 in 8 built to perhaps 1 in 4).

It was anticipated that washed out stone would lead to the formation of a smaller, secondary riffle close downstream but this has not occurred. Consideration has been given to building this in order to stabilise normal water levels at the bottom of the main weir, whilst adding an additional element of diversity.

Of particular note is the popularity of this spot with children who can gain safe access to the river and paddle in the shallow water, where the bed is firm and stoney.

The riffle allows easy access down to the river
– *November 1996*

4 REVETTING AND SUPPORTING RIVER BANKS

4.1 Willow spiling

RIVER SKERNE
LOCATION – Darlington, Co Durham, NZ 301160
DATE INSTALLED – November 1995 and May 1996
LENGTH – 75 metres
COST – £115/metre

NOTE: A full description of this technique is provided in the Environment Agency R & D Technical Report W83:– *Revetment Techniques used on the River Skerne Restoration Project* (1998)

Willow spiling 2 years after construction

DESCRIPTION

This revetment technique utilises willow poles woven around vertically driven stakes and is particularly suited to steep river banks that need both support and erosion protection.

Spiling was installed at both the entry and exit of a reach of river that was re-meandered. These locations were selected for spiling because the existing banks of the straight channels within which the revetment starts were near vertical due to erosion of the bank toe.

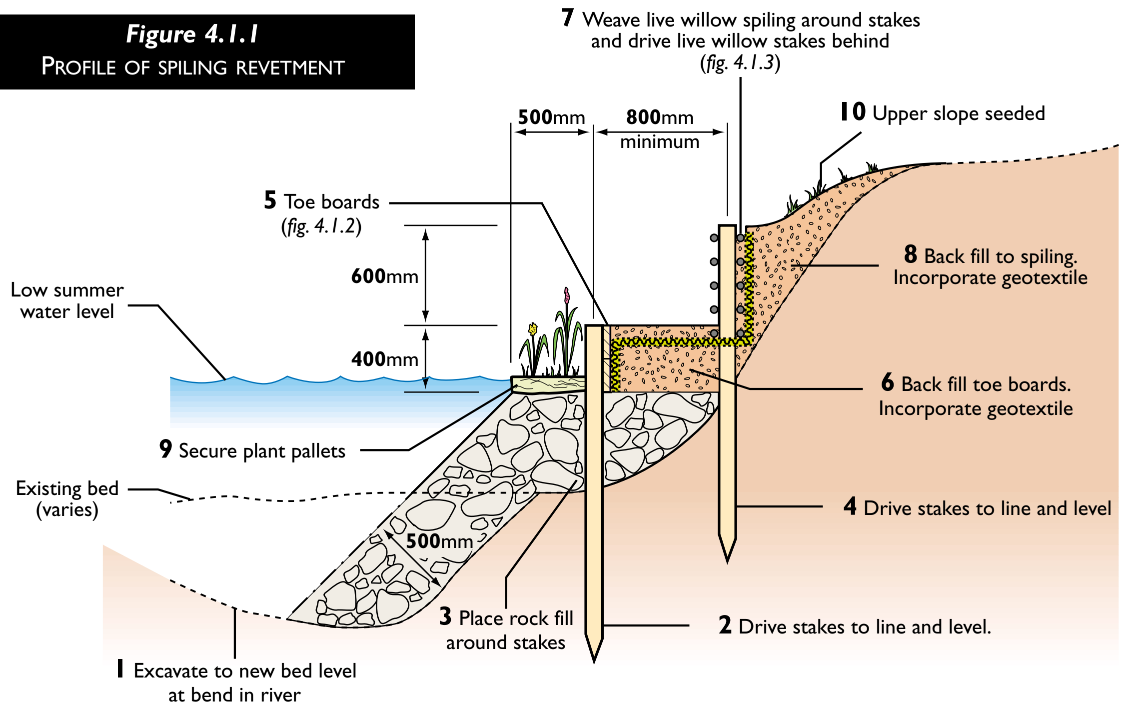
The technique often utilises osier willow because of its prolific production of long, slender, pliable poles suitable for weaving. Other species are less suited to weaving so the availability of indigenous river bank willow for spiling may be limited and other techniques might be more appropriate *(see 4.2 – 4.3)*. The introduction of non-indigenous species, through revetment works, is rarely justified; osiers thrive in withy beds or plantations but less so in many river bank situations.

The technique is demonstrated at the Skerne because it is popular with construction teams and relatively easy to install. It is not necessarily best suited to the overall environment at this site, although it is otherwise adequate to protect the banks.

DESIGN

- Below water a densely graded rock matrix is used to line the bank having first excavated down to a designed bed level and to provide room for the rock without it protruding beyond the adjoining natural bank profile. (*see 4.2 for the rock details);*
- At the water's edge the rock is incorporated into a shelf formed behind toe-boarding*;*
- Spiling behind and above this shelf is formed from wooden stakes driven to line and level around which the osiers are densely woven. Vertical live willow posts can then be independently placed behind the spiling and can be of a different species. A nylon geotextile was utilised behind the spiling

Figure 4.1.1
PROFILE OF SPILING REVETMENT



and the toe boarding to help stabilise the soil back filling which follows;

- The upper bank is then graded back to a safe slope that is un-revetted and either seeded with grass or turfed in extreme circumstances.

The basis of this design is to provide a stable underwater environment as a foundation for the spiling which is located just above water level where willows thrive best. The rooted osiers that develop from the woven poles will gradually occupy the underwater rock, and the marginal shelf, as the toe boarding rots away. Pre-planted pallets were placed in front of the toe boards to add to visual amenity and habitat diversity. Over time, the osiers will become dominant and will secure the river bank against further erosion whilst providing valuable habitat. Coppicing of the osiers is planned in line with normal procedure for maintaining the security and integrity of this species.

Commercially available woven willow hurdles can effectively replace the in-situ weaving, but more support posts will be needed. Live willow posts introduced behind the spiling can be allowed to mature into trees (if the osiers are coppiced sufficiently often) and these may be of an indigenous species intended to succeed the osier over time.

This technique does not have the intrinsic flexibility to accommodate bank settlement that is a feature of techniques 4.2 and 4.3 because it is, in essence, a vertical retaining wall. It is, however, less demanding of space which is sometimes advantageous.

SUBSEQUENT PERFORMANCE 1995/98

The river banks at both entry and exit sites are stable and silts are accumulating around a dense line of willow shoots up to 2.5m tall. The planted ledges are equally densely covered with marginal aquatic species that are similarly accumulating silts. Exceptionally, growth over one short length has been limited to the willow posts introduced behind the spiling. This is because the spiling poles, installed in the autumn, had been stored for too long in dry conditions.

Figure 4.1.2
PLAN OF TOE BOARDS

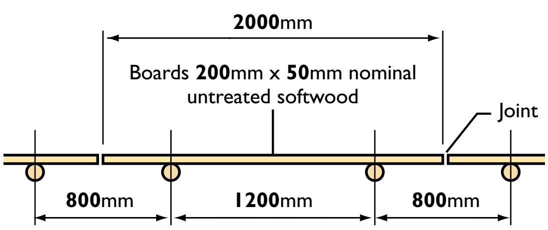
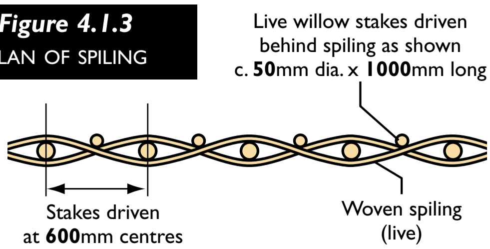


Figure 4.1.3
PLAN OF SPILING



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REVETTING AND SUPPORTING RIVER BANKS

4.2 Willow mattress revetment

RIVER SKERNE
LOCATION – Darlington, Co Durham, NZ 301160
DATE INSTALLED – October 95
LENGTH – 59 metres
COST – £164 /metre

NOTE: A full description of this technique is provided in the Environment Agency R & D Technical Report W83:– *Revetment Techniques used on the River Skerne Restoration Project* (1998)

Mattress revetment under construction – October 1995
NOTE: Additional poles inserted to close up spacing after photo taken

DESCRIPTION

This technique demonstrates revetment using willow branches that may be readily to hand in riverine situations through routine maintenance or pollarding of trees. They are laid along the reformed river bank and secured with sheep netting such that rapid growth of willow shoots will initiate a long term ecologically sustainable revetment.

Enhancements to the basic concept include the use of underwater rock, plant pallets at water's edge, and standard trees along the upper bank.

Revetment was needed to protect a gas main in the bank and loose backfill closing off a length of redundant channel.

DESIGN

Three vertical zones within the river bank were considered as follows:

Below water
Crushed rock was used to line the newly excavated channel around a sharp bend, as well as the initial infill of the redundant channel (fill 1). Few alternatives to rock were practical in this urban situation, but rock does form a flexible revetment which tree roots and aquatic flora/fauna will colonise. Most importantly, the rock used was mixed at the quarry to provide a densely graded '300mm down' matrix to the following specification:

aGeneral Rock Revetment Specification (used throughout)

Hard, dense, homogeneous, frost resistant, local rock free from foreign matter

% passing	Sieve size (mm)
100	300
40 – 50	125
30 – 45	75
20 – 40	37.5
10 – 30	10
5 – 20	5
0 – 10	0.6

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

As an alternative to rock, tree branches may be secured underwater by stapling to sheep netting to form a floating mattress which is then loaded with soil fill to sink it in to place. (Ward *et al.* 1994)

Water's edge and lower bank
The newly aligned and graded river bank was formed to about two thirds height by filling on top of the underwater zone described above. Rolls of sheep netting, cut to length, were incorporated under the fill as shown.

Selected live crack and white willow poles, 50-100 diameter, were then laid horizontally all along the face of the fill and pressed into it. Finally the free ends of the netting were drawn tightly over the poles and secured to stakes driven well back in the fill. Due to the shortage of willow locally, up to 30 % non-regenerative sycamore was incorporated intermittently. The netting was stapled to the poles to create a structurally integral unit.

Upper bank
This was made up with fill, leaving a ledge, and seeded with grass.

As a final measure, pre-planted coir pallets were fixed along the water's edge to provide visual amenity and variety of habitat. The following year, standard trees were planted along the upper ledge. These may outgrow the revetment willow as they mature, provided the latter is regularly coppiced.

Ward *et al*, 1994. *New rivers and Wildlife Handbook*. RSPB, Sandy – case study 3.7c – River Clwyd, North Wales.

SUBSEQUENT PERFORMANCE 1995/98

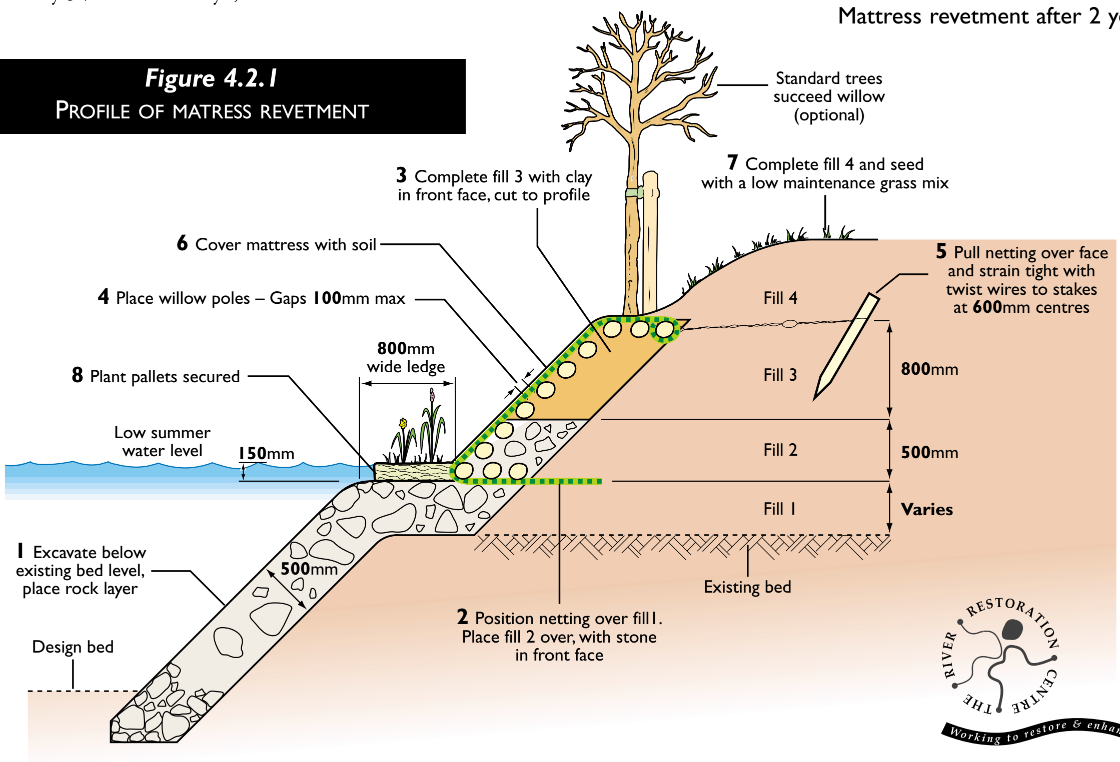
The revetment has remained stable, and dense willow growth up to 3m high covers the bank. Marginal sedge and iris complete what is a most desirable habitat niche favoured by water voles and birds.

Due to autumnal installation, no growth of willow occurred for the first 6 months, when winter floods washed out some soil. Since then the situation has reversed and silts are accumulating within the willow whilst roots extend into underlying soils and rock.

Rotational coppicing is planned, cutting around one third of the willow annually, as part of a river bank maintenance programme. On the Clwyd (Ward *et al.* 1994) no maintenance has been undertaken for 20 years and large trees have developed without hindrance by the netting which is now subsumed within the trunks.

Mattress revetment after 2 years

Figure 4.2.1
PROFILE OF MATRESS REVETMENT



Revetting and Supporting River Banks

4.3 Log toe and geotextile revetment with willow slips

River Skerne

Location – Darlington, Co Durham, NZ 301160
Date installed – October 1995 (standards planted March 1996)
Length – 91 metres
Cost – £146 /metre

Note: A full description of this technique is provided in the Environment Agency R & D Technical Report W83:– *Revetment Techniques used on the River Skerne Restoration Project* (1998)

Log toe revetment three years after construction

Description

This technique demonstrates revetment using tree trunks or large boughs along the water's edge to stabilise the toe of reformed banks. Proprietary nylon geotextile is used to revet the bank above the logs so that willow plants can safely be established within it. Revetment was needed to protect a gas main in the bank and loose backfill closing off a length of redundant channel.

Design

Three vertical zones within the river bank were considered as follows:

Below water
Crushed rock was used to line the newly excavated channel around a sharp bend, as well as the initial infill of the redundant channel. Details of the rock, and the rationale behind its use, are as explained in 4.2. The rock was incorporated around fencing posts driven to mark the line of the new bank toe.

Water's edge and lower bank
Logs were laid out along the top of the rock and lightly wired to the fencing posts to prevent flotation. Logs were then strained tight against the posts using twist wires anchored to stakes set well back into the fill. These ensure that the logs can never float away even if major settlement or scour of the river bank arises.

The logs selected were of oak, sized up to 500mm diameter, but virtually any timber is suitable because they need not be durable if willow is to be planted above. The use of live willow logs that will rapidly regenerate along the toe may be appropriate in some situations.

Backfill was then extended to about two thirds bank height and profiled as shown. Geotextile (Enkamat 7220) was fixed to the log under nailed wooden boards, pinned down over the bank and covered with soil.

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

Upper bank
Infilling was completed leaving a ledge as shown. All of the above represents no more than a secure but flexible matrix within which plants can be introduced to become established as the long term revetment medium. Coir pallets pre-planted with marginal aquatic species were fixed along the front of the logs and reed canary-grass planted in the damp zone above. Grey and goat willow plants, as well as some un-rooted slips, were set within the geotextile and standard trees planted along the upper ledge.

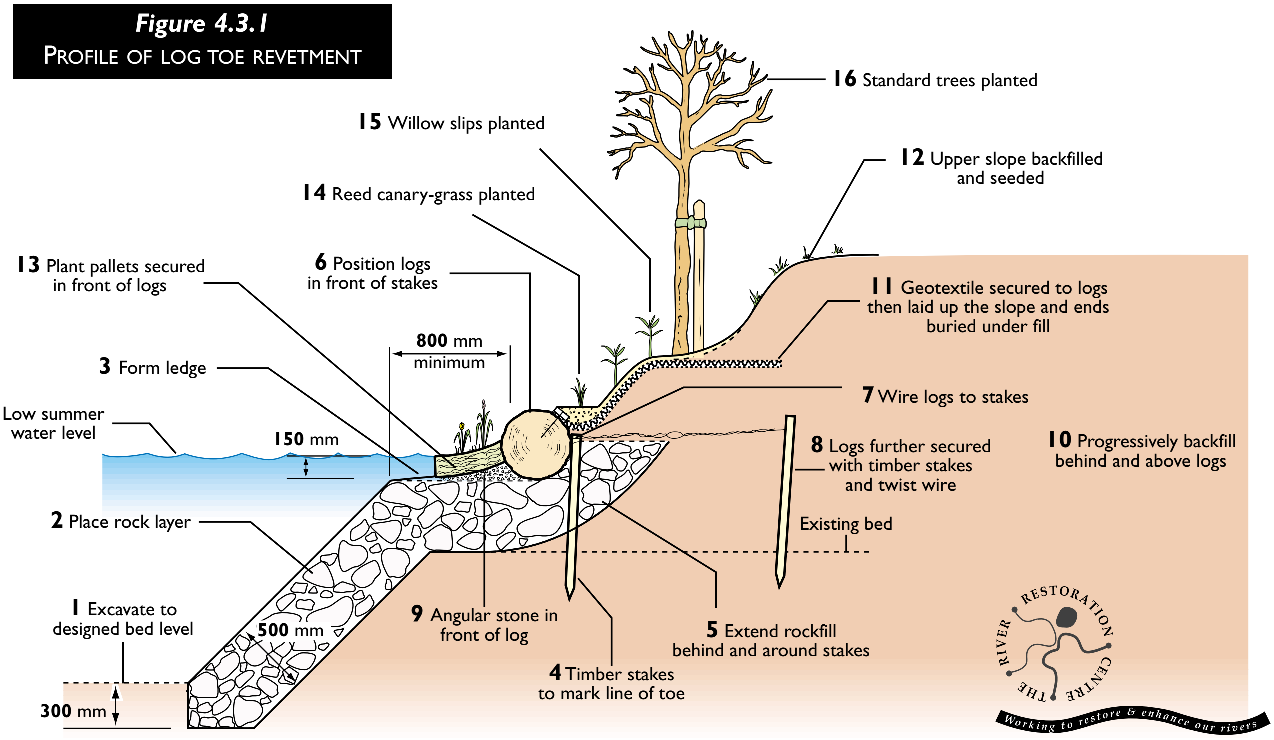
This mixture of plants is intended to be successional. Whilst the willow will quickly dominate the lower banks, as roots penetrate the underwater rock, the standard trees may eventually dominate the willow, particularly if this is regularly coppiced.

SUBSEQUENT PERFORMANCE 1995/98

This technique was used in two locations and both have performed well with dense willow growth up to 2m high along the bank and a thick margin of plants along the water's edge, all of which are acreting river silts in successive floods. Rooted willow plants established much more strongly than unrooted slips, but this is not uncommon with the grey/goat species selected. Other willow varieties are known to strike readily from slips. Species that are indigenous to the site are always preferable. Brushwood containing willow cut locally can be built into the lower banks as an alternative to the geotextile utilised at the Darlington site which was virtually barren of trees.

Log toe revetment during construction

Figure 4.3.1
PROFILE OF LOG TOE REVETMENT



4.4 Plant roll revetment

RIVER SKERNE
LOCATION – Darlington, Co Durham, NZ 301160
DATE INSTALLED – Oct 1995 to June 1996
LENGTH – 119 metres
COST – £130/metre

NOTE: A full description of this technique is provided in the Environment Agency R & D Technical Report W83:– *Revetment Techniques used on the River Skerne Restoration Project* (1998)

Transitonal revetment at installation (water level artificially low in photo)

DESCRIPTION

This technique demonstrates the use of proprietary revetment materials in a situation where the potential for erosion is not severe. A flexible revetment is provided within the water's edge zone at the toe of the bank utilising rock rolls and plant rolls to resist undercutting. At this site, it is used to form a smooth transition between the un-reveted river banks and the fully reveted banks described in 4.1 to 4.3.

DESIGN

Rock rolls are flexible 'sausages' of crushed rock contained within nylon netting, whereas plant rolls are of dense coir within which selected marginal aquatic species can be pre-grown. Plant rolls fixed over rock rolls will become homogeneous as roots penetrate downwards into the rock and the adjacent soil. The design provides inbuilt flexibility whilst allowing the plants to develop in stable conditions.

Rock rolls are set out below water on ledges cut to suit and secured by driving posts through the netting. Long term stability and flexibility is achieved by pulling the rolls tight against the posts using twist wires anchored to stakes set well back.

Plant rolls are set out at low water level and wedged tight up against the rock rolls by driving stakes at a suitable angle along the rear of these.

Pre-planted flat pallets of coir were added above the plant rolls to increase the extent of marginal vegetation although this is largely an aesthetic measure.

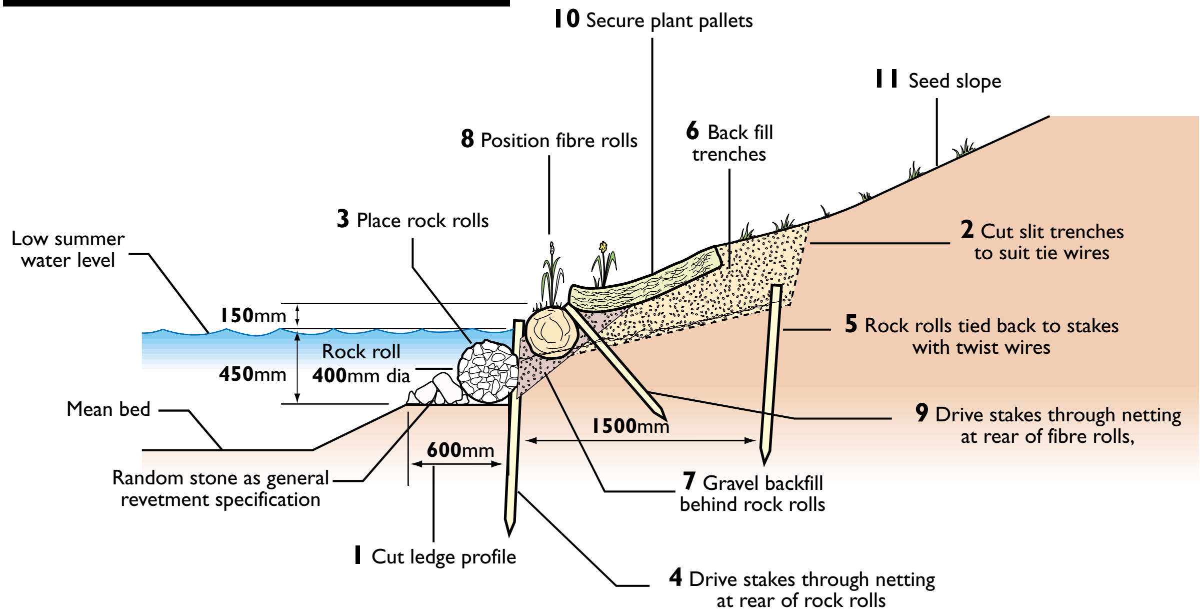
The toe of the bank needs to be permanently damp for this to be worthwhile, which is most likely in situations where undercutting has already occurred and the bank toe is being reinstated, e.g. through boat wash.

Subsequent performance 1995/98

Several lengths of this revetment were installed in various alignments, e.g. entry and exit of bends and in backwaters. All have established well with reed canary-grass proving to be the most dominant plant best suited to the habitat niche created. Growth is generally limited to within 500mm of river level where the bank is damp. Above this the pallets have been colonised by ruderial plants such as himalayan balsam, which is being controlled by mowing before seed heads form.

Children walking along the bank toe, behind the plant rolls, have created ledged paths, which are stable, and are accreting significant amounts of silt due to eddy currents set up as floods pass over the stands of reed grass. This desirable situation contrasts with the erosion of river bank toes that typified pre-works conditions in the straight trapezoidal river.

Figure 4.4.1
Profile of transitional revetment



4.5 Supporting bank slips and exposed tree roots

River Skerne

LOCATION – Darlington, Co Durham, NZ 301160
DATE OF CONSTRUCTION – October 1995 / November 1996
LENGTH – 40 metres, 9 metres
COST – Bank Slip £3k, Tree Roots £400

Slipped slope during work – September 1995

DESCRIPTION

Slipped slope
During works, water seepage from gravel at the bottom of a newly excavated river bank caused it to slip. As the bank was close to bunded industrial fill, repair was necessary. The route of a proposed footpath was also at risk if this bank remained unstable.

Exposed roots
The roots of a mature willow had been exposed during river bank re-profiling works and were being undermined by high flows and damaged by people. Although in no immediate danger, this tree had become an important resting place, providing the only shade along this bank. Positioned on the apex of a meander, it was decided to protect the roots using a simple revetment.

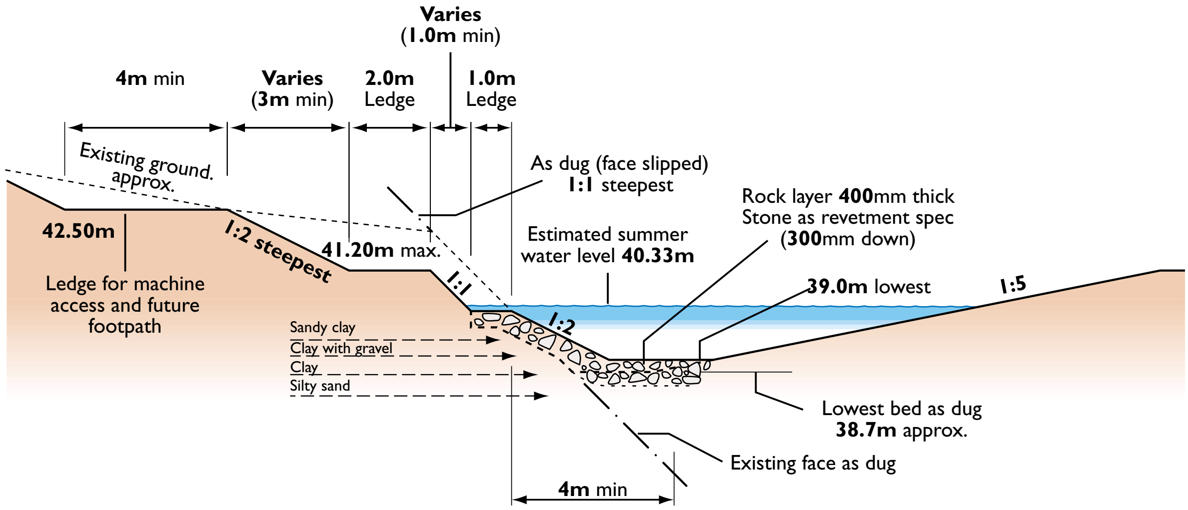
DESIGN

Slipped slope (fig. 4.5.1)
To stabilise this slope it was reformed incorporating a rock layer using stone sized 300mm 'down' as specified for use on nearby revetments *(see 4.2).* Ledges of varying widths were introduced at metre intervals up the slope, above water.

The underwater rock layer added weight to the toe of the slope to help support it and was free draining. The upper bank re-profiling removed weight from the slope further stabilising it. The ledge closest to water level was subsequently planted with trees to add visual amenity as well as a longer term revetment via their root system. The upper ledge later incorporated a new footpath.

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

Figure 4.5.1
PROFILE OF SLIPPED SLOPE



Slipped slope 2 years after repair – 1997

Revetting and Supporting River Banks

Figure 4.5.2
Profile of exposed roots

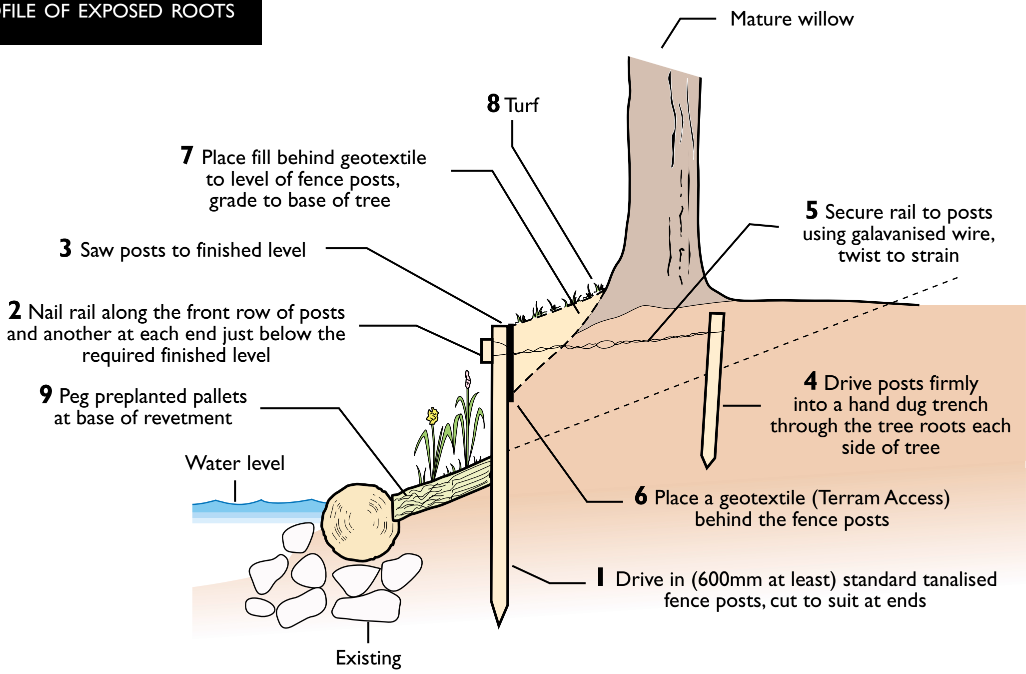
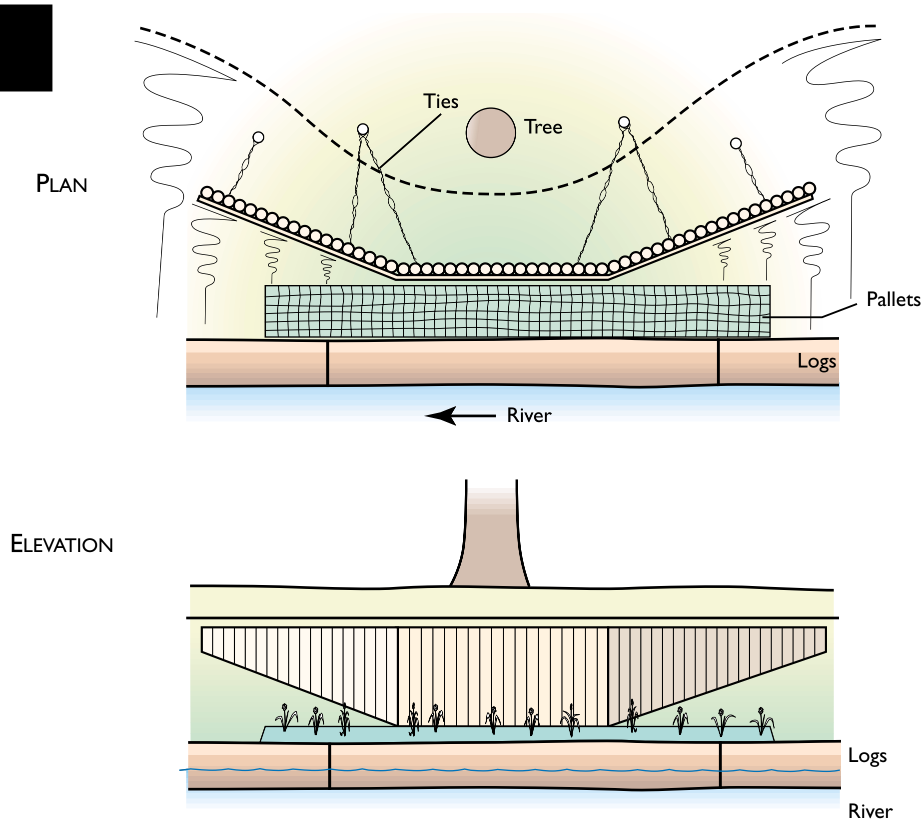


Figure 4.5.3
Plan and elevation



Exposed roots (figs. 4.5.2 – 4.5.3))
The design had to ensure that people could continue to use the spot without further damage. Vertical fence posts were used to revet the bank before back-filling with soil. A geotextile, 'Terram Access', was placed behind the posts to prevent soil migration. Turf was placed on the surface to achieve an instant result.

SUBSEQUENT PERFORMANCE 1995–98

The bank slip has remained stable and appears natural with no visible signs of support. Water continues to seep from the bank and maintains a small wetland habitat on the ledge above river level.

The revetment of the exposed roots has performed well, following many high flows since its construction. The roots are no longer exposed and the turf and other planting has grown to give added protection. Well used by a variety of people, the structure has become a seating area providing shade.

Protected roots after work completed – February 1997

4

Revetting and Supporting River Banks

4.6 Hurdle and coir matting revetments

River Cole

Location – Coleshill, Oxon/Wilts border, SU 234935
Date installed – Autumn 1995
Length – Hurdles – 15 metres. Matting 3 lengths of 20 metres
Cost – Approx £40/metre

Construction of coir matting revetment
– river being released

Description

The revetments were installed where an old, straight channel is crossed tangentially by a new, smaller, meandering channel at three separate locations.
At each crossing point, the old channel was partially infilled and compacted and the new channel then excavated within this fill. As the new river flowed straight across the old, the risk of scour was not great, which suggested that only light revetments were needed, sufficient to protect the bank and bed until soils consolidated and vegetated over.

Two bio-degradable materials were selected to line the newly formed banks, coir matting and dead willow hurdles. Stone lines the new bed in both examples.

Coir was installed on both banks at the crossing located mid way between the ford (ch. 280m) and the stock bay (ch. 100m), as well as opposite the large backwater. Hurdles were installed opposite the small backwater. A plan of the reach can be found in 1.2.

Design

A primary consideration was achieving a satisfactory method of infilling and compacting the old channel such that the new channel could then be excavated within reasonably stable soils. The complicating factor was the need to work around a flowing river. Failure to achieve sufficient compaction would have required more robust and costly revetments.

Two methods of managing the river flows were combined; pumping round the works and blocking off the flow creating a temporary lake upstream. This put great pressure on the contractors to quickly complete the work, but adequate compaction was achieved. Construction details are similar for both types of revetment *(figs. 4.6.1 – 4.6.2)*.

Once the new river channel had been roughly formed (steps 1 and 2) it was relatively straightforward to complete the revetments as indicated by steps 3 to 5.

Points of note are that all joints between individual hurdles or matting were overlapped downstream to avoid lifting in high flows and each run of revetment was securely fixed within undisturbed soils at each end. A single willow hurdle was pegged down over each end of the coir matting for additional security, but some have washed away (without damage to the coir) suggesting they were not necessary. The stone bed was sized 100mm -150mm and spread up to 300mm deep.

Subsequent performance 1995/98

The revetments are all secure with no instability and are vegetated, particularly where turfy backfill was incorporated under the coir. Crack willow has successfully established from the live poles incor-

Figure 4.6.1
PROFILE OF COIR REVETMENT

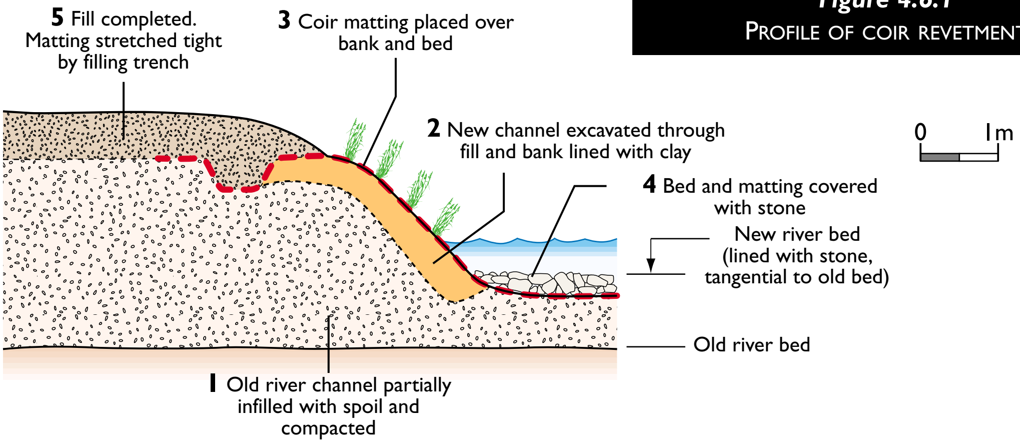
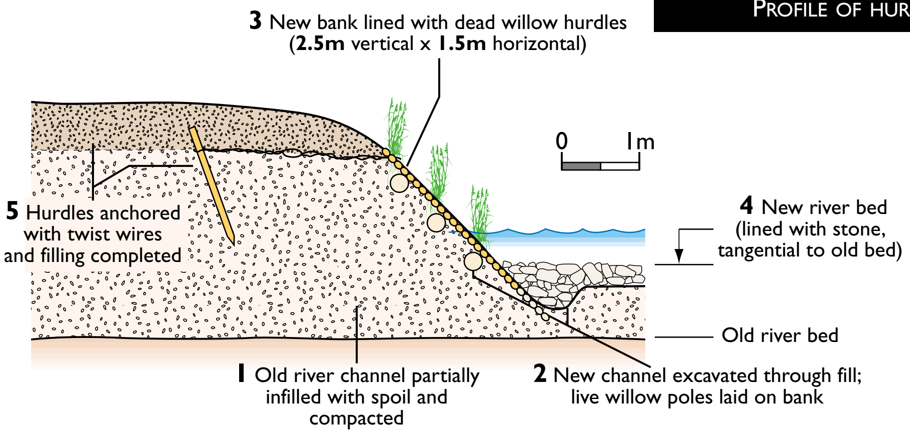


Figure 4.6.2
PROFILE OF HURDLE REVETMENT



porated underneath the hurdles. None of the materials have seriously deteriorated in the three years since installation but will do so eventually.

In some places, the revetments have proved to be more secure than the adjacent undisturbed soil resulting in a hard 'engineered' line that contrasts with the subtle sculpting of the unprotected banks by river flows.

Alternative techniques for securing infilled river banks elsewhere on the same reach include bays, and backwaters *(see 2.2)*, and fords and stock drinks *(see 8.1)*. These alternatives have created much greater amenity/habitat value than the revetments and might, therefore, be regarded as preferable if circumstances permit.

5

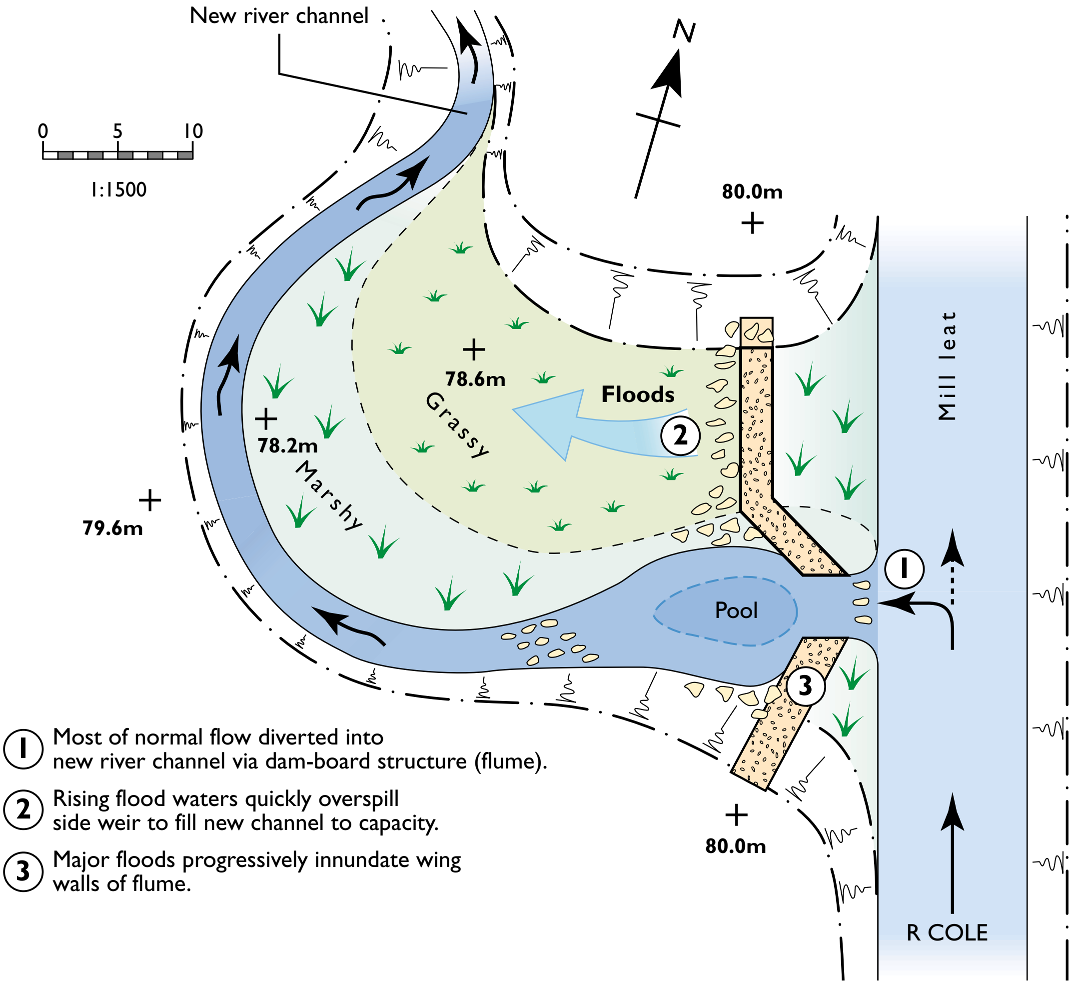
CONTROLLING RIVER BED LEVELS, WATER LEVELS AND FLOWS

5.1 Bifurcation weir and sidespill

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995
LENGTH – 30m
COST – £10.5k

Figure 5.1.1
PLAN OF BIFURCATION WEIR



DESCRIPTION

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

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

A further hydraulic requirement was that the new channel should have filled with floodwater via the new structure just before the mill leat itself over-spilled at a point some 250m further downstream. A designed 'high level' overspill exists here (at 79.2m) to initiate general inundation of the floodplain. If the new channel was only partially full at such time, then floodwaters would drop into it causing serious scour of the banks, risking breaching between the new channel and the leat.

Design

Control weir (location 1 on plan)

Figure 5.1.2
Elevation of downstream side of weir

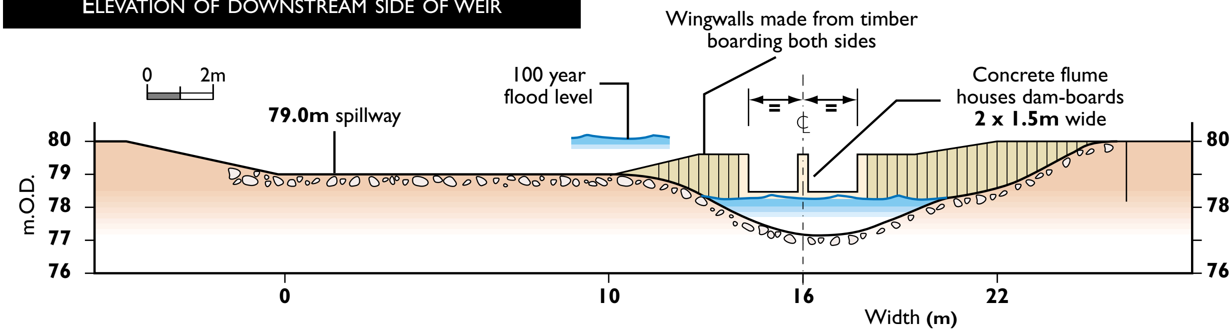
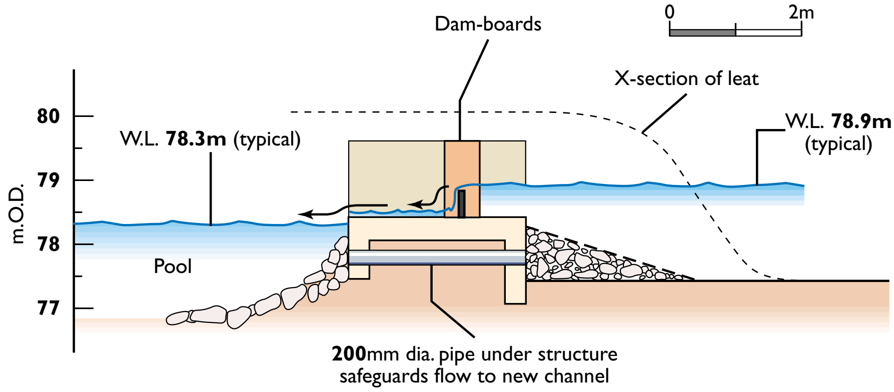


Figure 5.1.3
Section through dam-board structure



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

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

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

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

Subsequent performance 1995/8

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

Spilllway alongside bifurcation weir
– April 1997

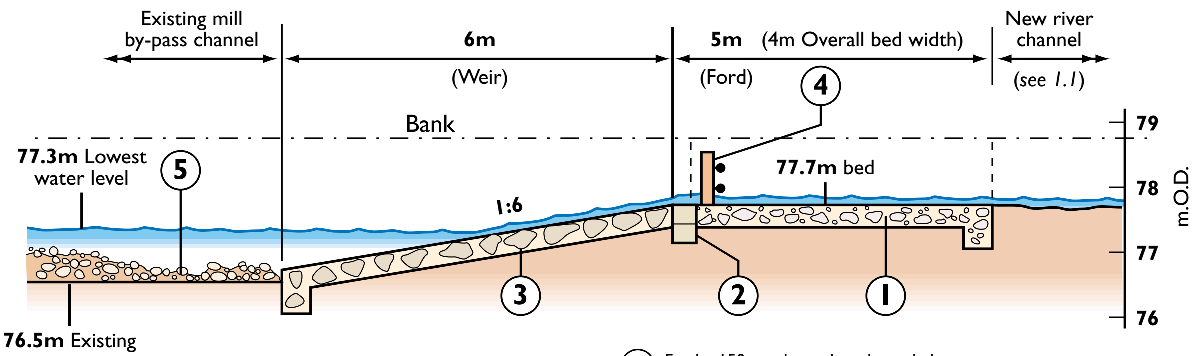
Flood filled channel downstream of bifurcation weir

5.2 Drop-weir structures

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995
COST – Upstream drop-weir £2.8k. Downstream drop-weir £2.5k

Figure 5.2.1
DROP-WEIR ON NEW RIVER UPSTREAM OF MILL



1. Ford – 150mm down densely graded stone over polythene membrane
2. Cut-off wall – concrete kerb blocks (incorporates membrane)
3. Weir – 300mm down densely graded stone over filter membrane
4. Stock fence comprising two strained cables
5. Gravels deposited over existing bed of old mill by-pass

DESCRIPTION

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

Weir and rock apron

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

DESIGN

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

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

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

Gabion weir and pool

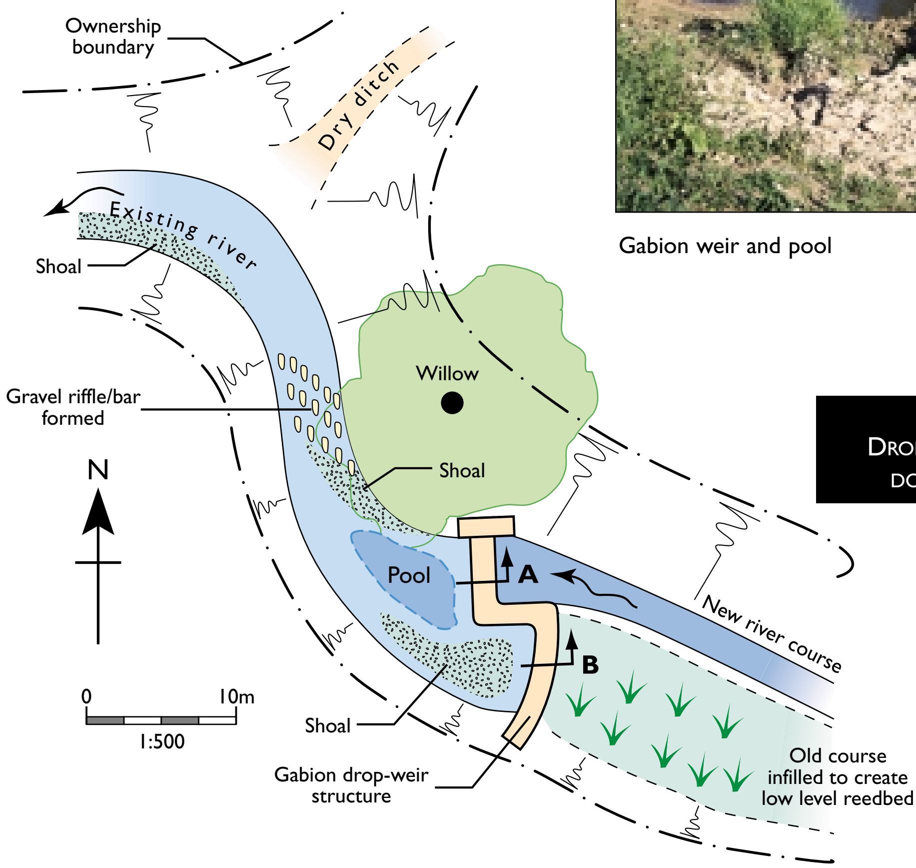


Figure 5.2.2
DROP-WEIR ON NEW RIVER DOWNSTREAM OF MILL

Figure 5.2.3
SECTION A THROUGH GABION DROP-WEIR

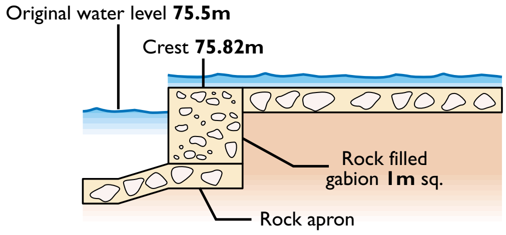
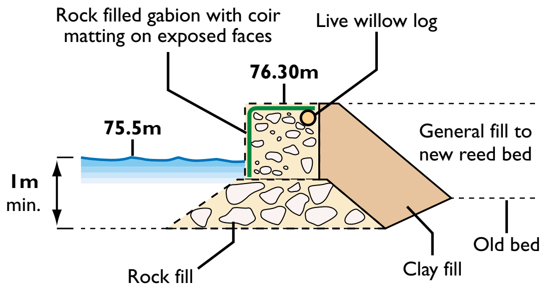


Figure 5.2.4
SECTION B THROUGH GABION DROP-WEIR



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

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

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

SUBSEQUENT PERFORMANCE 1995/8

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

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

The upper confluence structure has lost stone from the weir because the size used was below the 300mm graded mix specified. The structure remains functional because the block wall is stable - numerous larger stones have settled out below it. The stone work was re-built in summer 1998.

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

5

CONTROLLING RIVER BED LEVELS, WATER LEVELS AND FLOWS

5.5 Raising river bed levels

UPPER KENNET

LOCATION - Ramsbury, Wiltshire
DATE OF CONSTRUCTION - 2nd October – 20th October 2000
LENGTH – 210m
COST - £12, 000 – £14, 000 for construction and reinstatement works only†

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

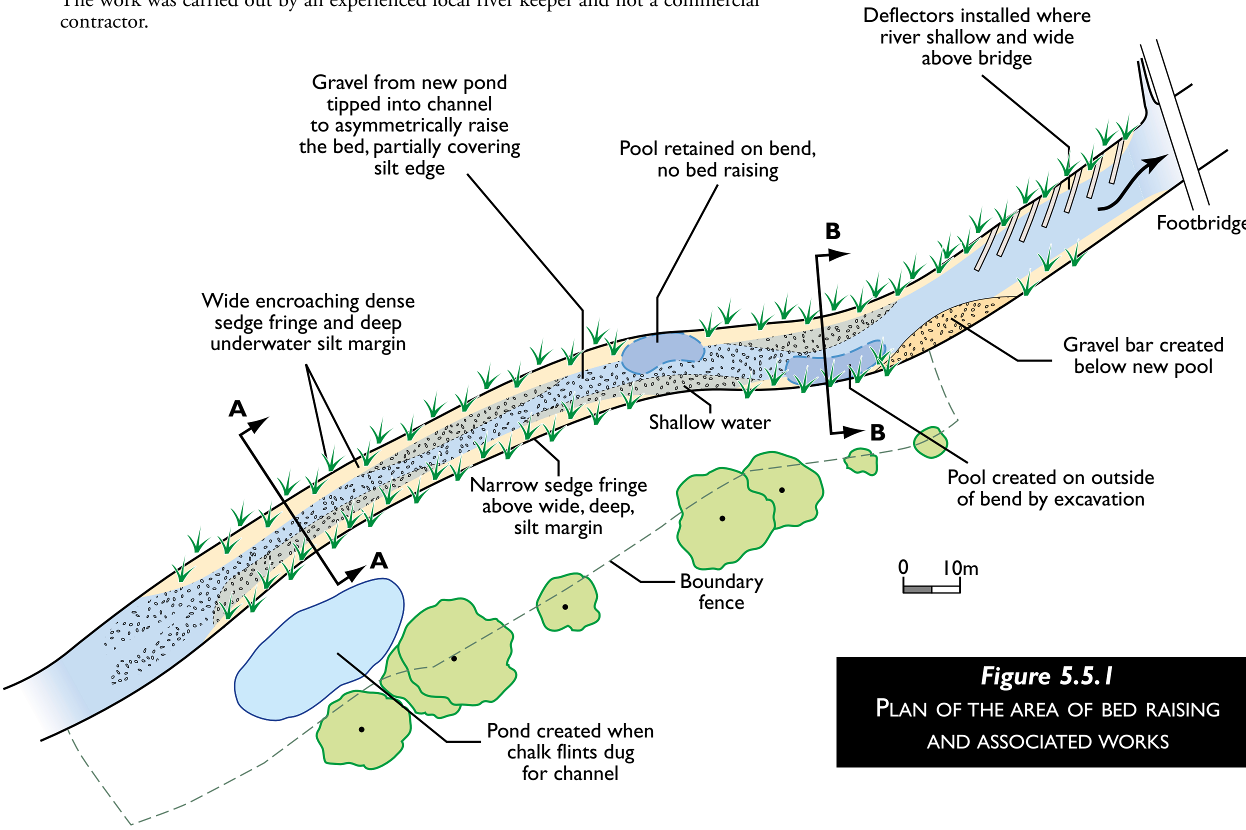


Figure 5.5.1
PLAN OF THE AREA OF BED RAISING AND ASSOCIATED WORKS

DESCRIPTION

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

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

Before: sluggish deep water with encroaching sedge

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

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

A common approach to achieving self-sustaining habitats in enlarged degraded rivers is to narrow the river bed width and thereby concentrate flows within a defined low-flow channel. However, where the river also has a history of deepening, this may simply lead to the formation of a very constricted, deep course. To restore a more appropriate width to depth ratio, bed raising may also need to be considered (*see 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 500mm at low water level (based on the Q90 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 <100mm. The Q90 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 500mm at Q90 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 Q90. 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

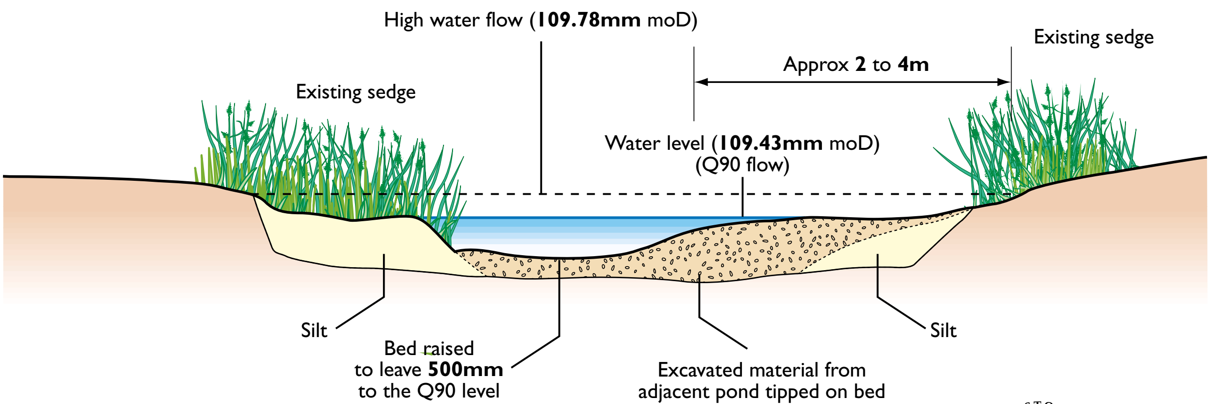
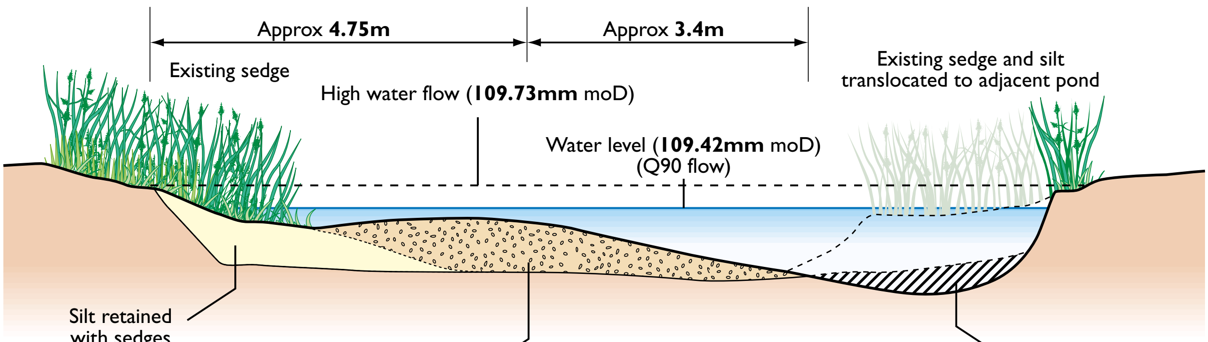


Figure 5.5.2
SECTION A THROUGH RAISED BED AND MARGINAL SHOAL

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 20 to 10mm, 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 (*fig. 5.5.2*) is a typical section across this reach. Silt colonised by sedge represents up to half of the total channel width.

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

Gravel has been used to shallow and narrow the remaining open water channel by up to a half, with the shallower margins finishing just below the Q90 level. The remaining low-flow channel is raised to within 500mm of the Q90 surface.

B. *'S' bend with some marginal sedge*
The outsides of each bend are enhanced with a pool, the first by retaining existing very deep

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

A few months after completion, the raised bed evident

water, the second by dredging the silty sedge margin (material then used to provide marginal substrate in the new pond). Cross section B (*fig. 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 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, and 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 1 year indicates that the reduction in channel size has not resulted in any bank erosion, and that the gravel has stayed predominantly in place. Minor local changes in gravel composition have occurred, with less fines in the low-flow channel.

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

During subsequent high flows the full (c10m) channel width will be occupied by water, yet under Q90 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.

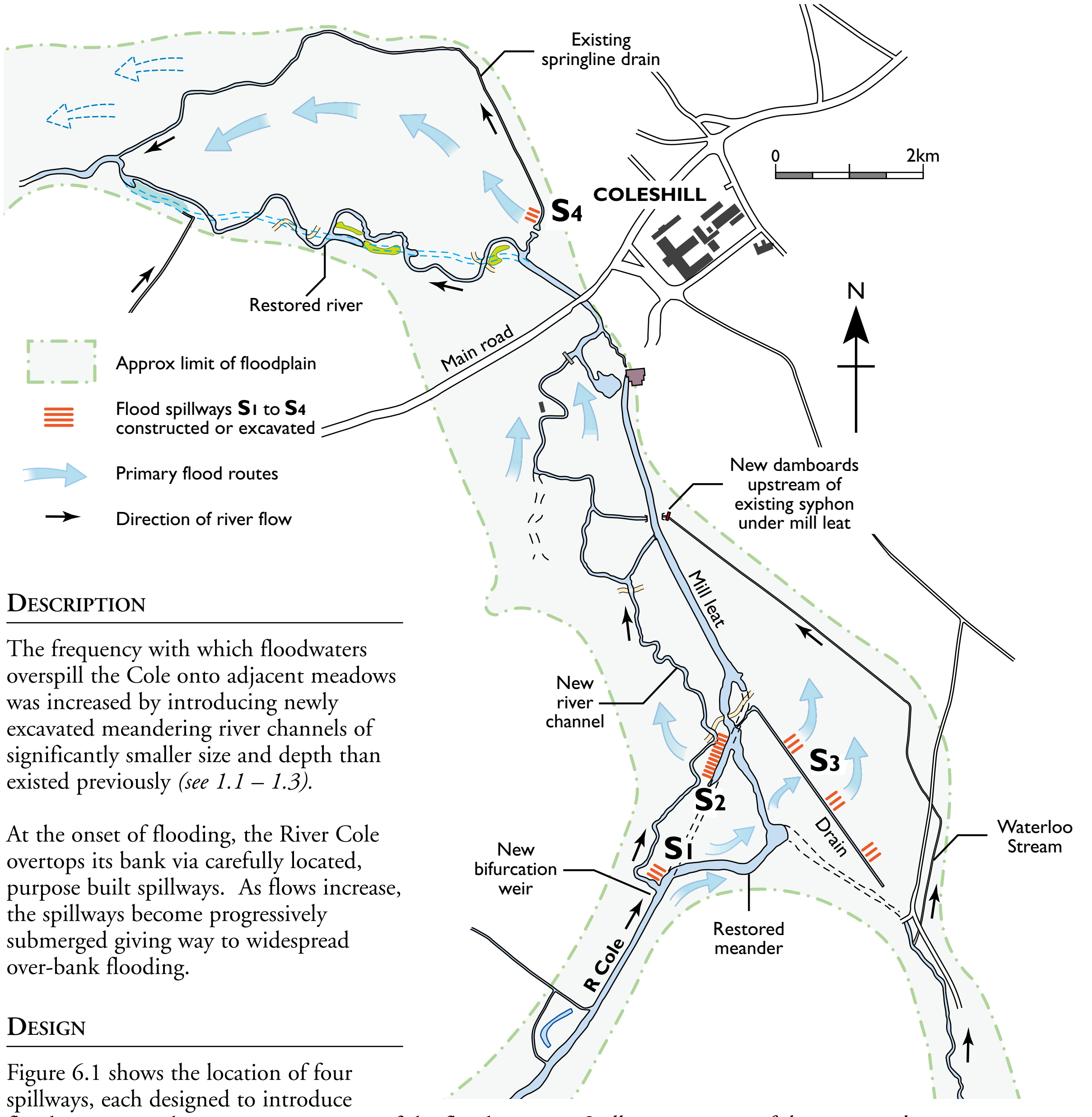
Contact:
Nick Lutt and Mike Crafer, Thames Water, Environment & Quality (RBH2), Clearwater Court, Vastern Road, Reading. RG1 8DB, Tel: 0118 957 7666.
Kevin Patrick, Hankinson Duckett Associates, Landscape Studio, Reading Road, Reading. RG8 9NE, Tel: 01491 872185.

6.1 Floodplain spillways

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995
FLOODPLAIN AREA – 50ha.
COST – Approx. £28/metre for 100m of spillway

Figure 6.1
PLAN OF FLOOD ROUTING



DESCRIPTION

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

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

DESIGN

Figure 6.1 shows the location of four spillways, each designed to introduce floodwaters into discrete compartments of the flood-plain. Upstream of the main road three spillways (S1 to S3) operate with incremental rises in river level and flow. Downstream of the main road a single spillway (S4) introduces water to the right bank meadows. Flood waters pass under the road via the river bridge and two existing flood culverts set at field level.

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

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

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

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

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

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

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

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

Spillway **S2** in flood

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

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

form spillway **S4**. The spillway is located close to a natural gully that meanders down through the floodplain fields and probably marks an ancient river course. The spillway was completed by shallow excavation of the field to extend the gully right up to the bank of the drain.

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

SUBSEQUENT PERFORMANCE 1995/98

The hydraulic performance has closely matched the predictions of the hydraulic model, which were conservatively judged to avoid excessive summer flooding when hay or livestock are in the fields. Experience of flood levels during the two summers post construction led to the slight lowering of levels at S**3**, described above, as well as a similar degree of lowering at **S4**.

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

6

THE RIVER RESTORATION CENTRE
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MANAGING OVERLAND FLOODWATERS

6.2 Profiling of land between meanders

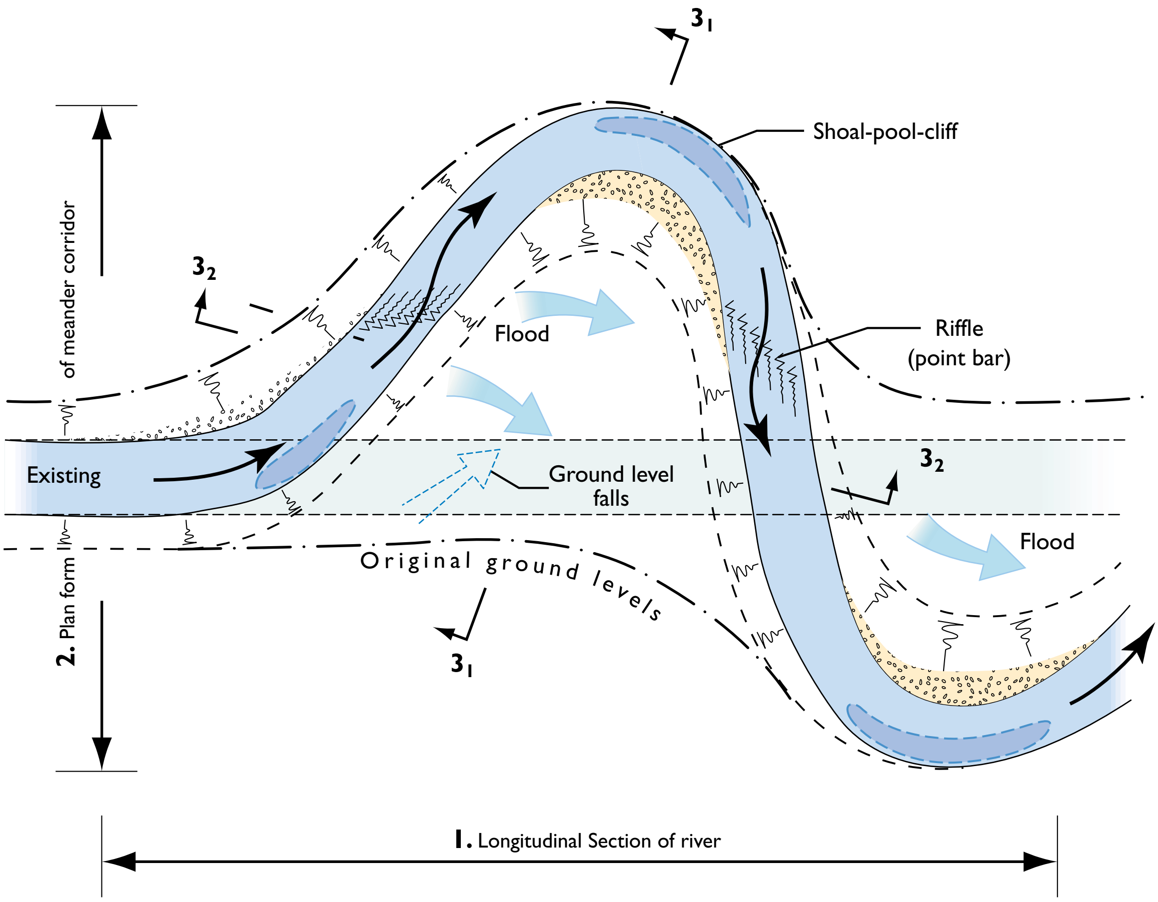
RIVERS COLE AND SKERNE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
– Darlington, Co Durham, NZ 301160

DATE OF CONSTRUCTION – Autumn 1995

LENGTH }
COST } – Integral part of new meandering works

Figure 6.2.1
PLAN OF SCHEMATIC MEANDER



DESCRIPTION

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

DESIGN

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

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

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

1. The mean longitudinal bed profile of the whole reach;

Figure 6.2.2
SECTION $3_1 - 3_1$

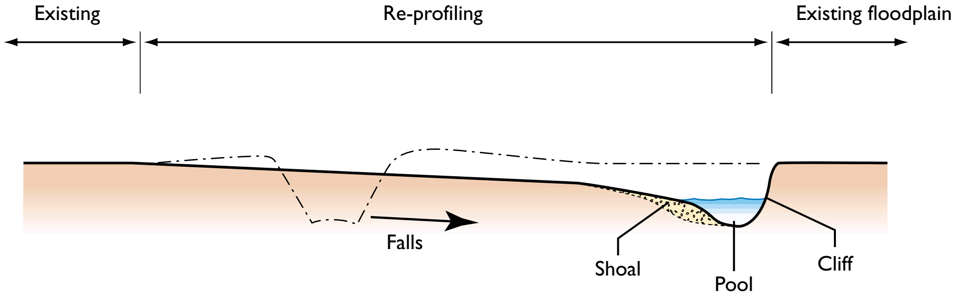
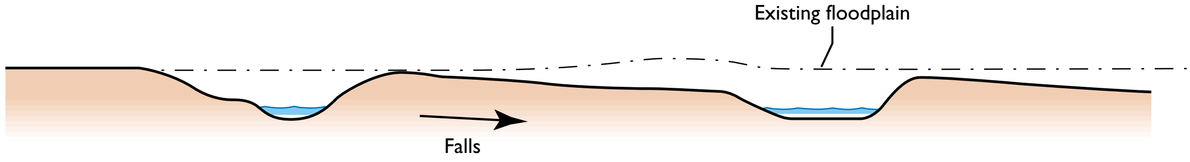


Figure 6.2.3
SECTION $3_2 - 3_2$



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

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

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

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

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

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

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

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

SUBSEQUENT PERFORMANCE – 1995/98

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

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

7

CREATING FLOODPLAIN WETLAND FEATURES

7.1 Floodplain scrapes

RIVER SKERNE
LOCATION – Darlington, Co Durham NZ 301160
DATE OF CONSTRUCTION – Autumn 1995 (in meanders), May 1996 (at Rockwell)
NUMBER– 2 excavated; 1 in backfilled chanel
COST– £1k each for excavation

Completed spring-fed scrape

DESCRIPTION

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

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

DESIGN

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

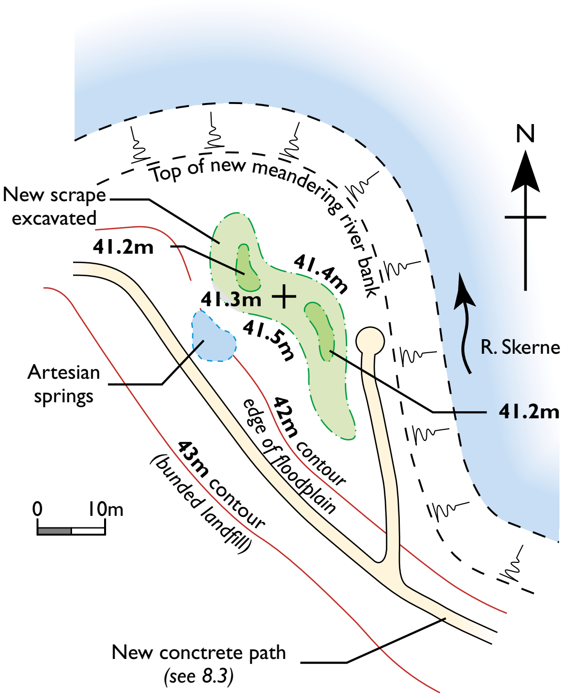
The irregular shape fits comfortably within the limited area available and the depth has been limited to 300mm in the interest of public safety, as well as to suit the emergent and marginal aquatic vegetation sought. The side slopes are very shallow for similar reasons. No overspill was built. In very wet periods excess water seeps towards the river over the grassed area alongside.

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

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

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

Figure 7.1.1
PLAN OF SCRAPE WITHIN MEANDER FED BY GROUNDWATER



View of Rockwell scrape site after removal of rubble piles

Comparitive view of Rockwell scrape after work completed

by piles of dumped soil and rubble that have overgrown with less desirable ruderial plants.

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

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

SUBSEQUENT PERFORMANCE 1995/6 – 98

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

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

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

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

8

PROVIDING PUBLIC, PRIVATE AND LIVESTOCK ACCESS

8.1 Fords and stock watering point

RIVER COLE
LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995
LENGTH – 4 fords and 1 watering point
COSTS – Fords £1k each. Watering point £1k

Stock watering point at ch. 100m

DESCRIPTION

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

DESIGN

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

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

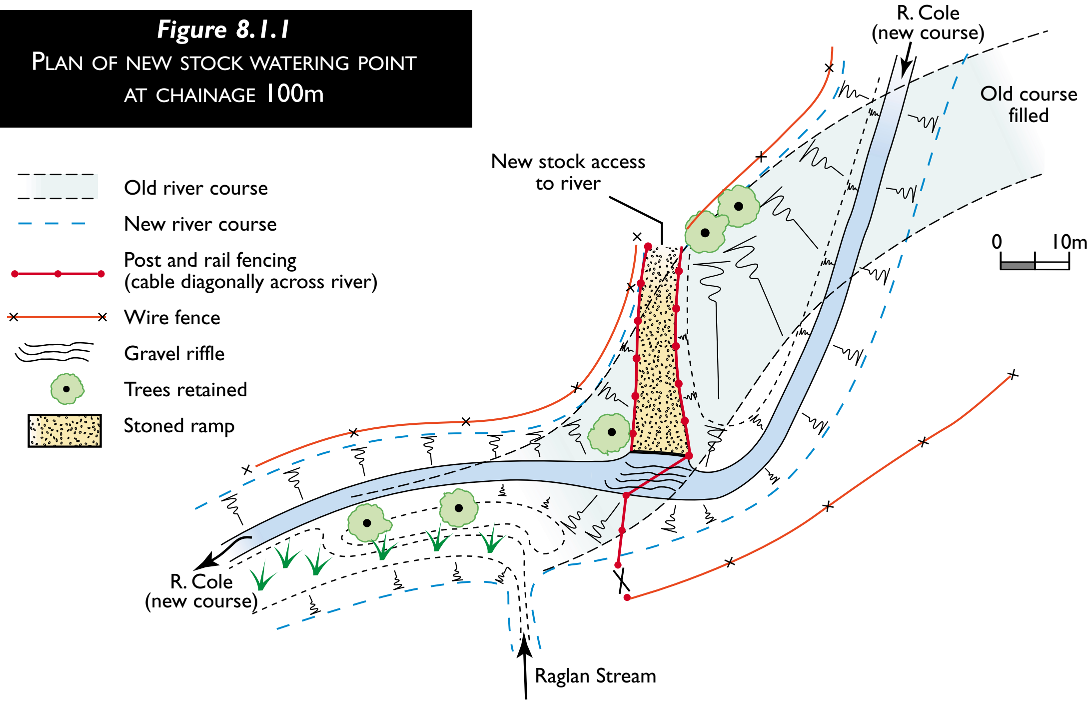
The river fencing comprises a single heavy wire cable strained tightly across on a diagonal line (see photograph). The extra length of the diagonal renders the cable less likely to form a complete blockage of the river if floating debris becomes snagged on it. The angle of the diagonal is aligned to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

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

The ford at ch. 280m (fig.8.1.2)
Aligned between three mature trees on the old river bank to create an 'S' shaped feature, it crosses the new river bed on a long diagonal (c. 15m compared

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

Figure 8.1.1
PLAN OF NEW STOCK WATERING POINT AT CHAINAGE 100m

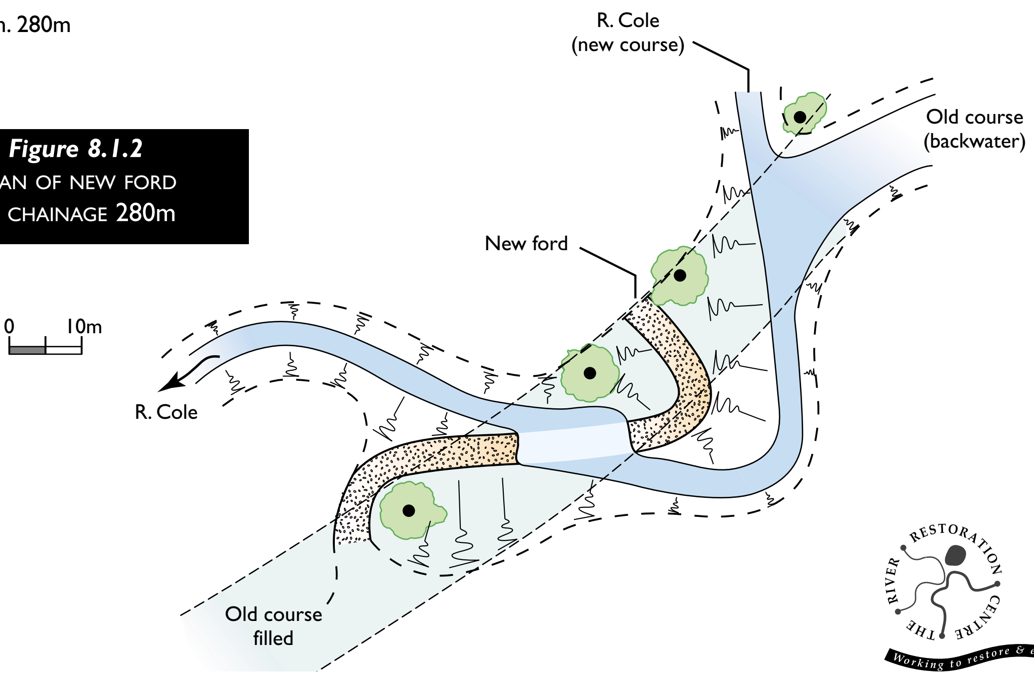


Ford at ch. 280m

with the typical bed width of c. 3m). The position of this diagonal approximates to the likely position at which a self-sustainable point bar of gravel would form, because of the sharp bend just upstream.

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

Figure 8.1.2
PLAN OF NEW FORD AT CHAINAGE 280m



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

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

The old river bed was infilled to a depth of 1m and reinforced with a 400mm thick layer of 150mm sized stone that was run-out downstream to provide a gently sloping 'riffle' effect. The ramps each side were sloped at 1 in 6 and smoothly contoured into the bank lines of both old and new channels, as indicated in the figure. This contouring resulted in flat bank slopes that did not need revetting, although largely formed within fill.

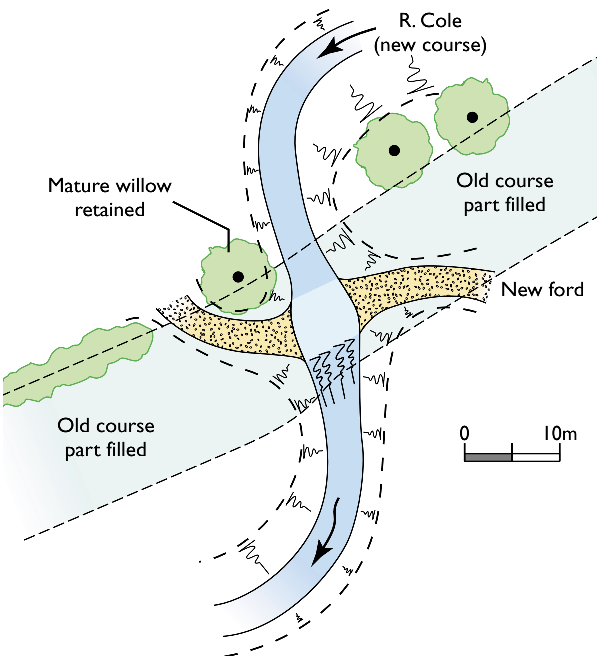
Upstream of the mill
Two fords are incorporated into the new meandering river channel excavated in undisturbed ground throughout its length.

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

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

Equestrian ford at ch 620m

Figure 8.1.3
Plan of new ford at chainage 620m



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

SUBSEQUENT PERFORMANCE 1995/98

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

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

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

Vehicular ford upstream of mill at ch. 250m

8

PROVIDING PUBLIC, PRIVATE AND LIVESTOCK ACCESS

8.2 Watercourse crossings

RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995
COST – concrete culvert £8.7k
– steel culvert £3k

New concrete culvert crossing under construction

DESCRIPTION

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

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

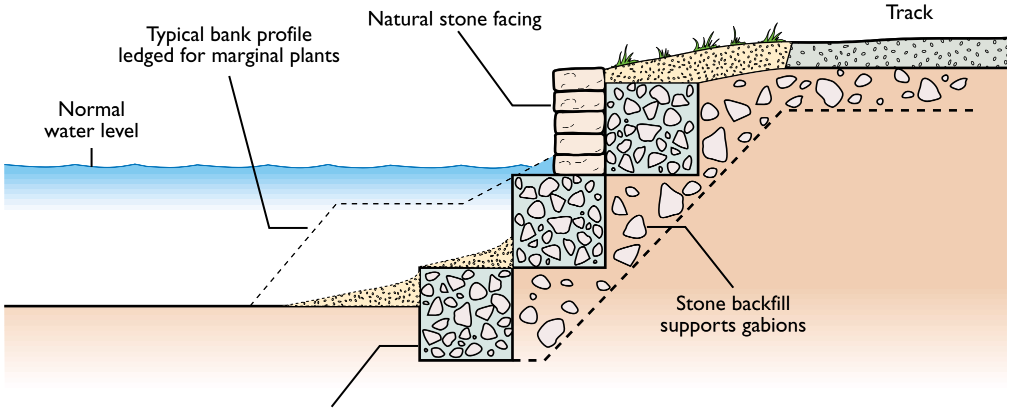
DESIGN

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

Three tiers of gabions were needed to achieve the full wingwall height from invert to track level. The lower two were set just below the retained water level in the mill leat where they are permanently out of sight. These two layers were set out in plan to follow a

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

Figure 8.2.1
SECTION THROUGH WINGWALL OF BOX CULVERT CROSSING



90 degree curve creating a wider river cross-section than the culvert. They were progressively stepped back from the vertical to create a ledge at the top of the first tier.

The upper tier followed a similar curve but was continuously stepped back sufficient to allow a stone wall to be built around the front face - this wall is the only visible element and it is decorative rather than structural. By stepping back the gabions the sloping river banks adjacent could be brought smoothly into line with the gabions and also accommodate an underwater ledge for aquatic marginal plants. The combination of marginal plants

Completed 'bridge'

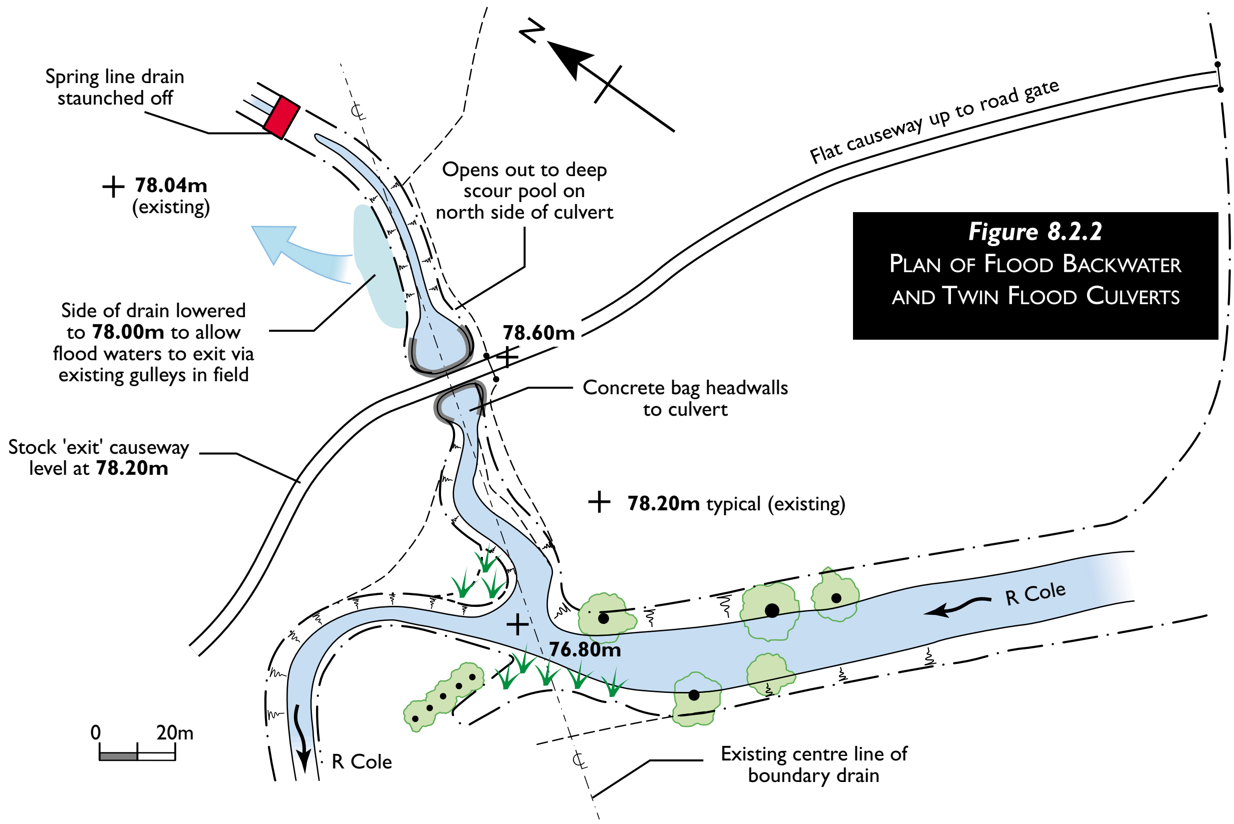


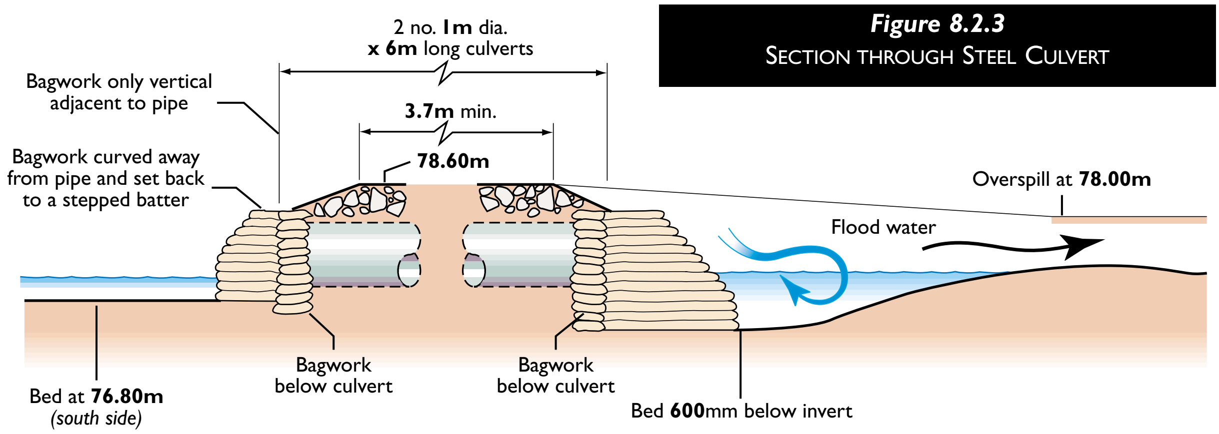
Figure 8.2.2
PLAN OF FLOOD BACKWATER AND TWIN FLOOD CULVERTS

and stone walling are intended to draw the eye away from the concrete box which is a relatively minor feature of the overall visual aspect evident in the photo.

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

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

Figure 8.2.3
SECTION THROUGH STEEL CULVERT



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

Concrete filled hessian sandbags were used to achieve this complex geometry. Another consideration was that the pressure of floodwaters passing through the pipes might produce high velocities and turbulence on exit. A distinct scour pool was excavated that was 'onion' shaped in plan and section to dissipate this energy. This is preferable to heavy revetment to contain the scour. Such pools can be attractive and also provide habitat potential.

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

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

Subsequent performance 1995/98

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

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

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

8

PROVIDING PUBLIC, PRIVATE AND LIVESTOCK ACCESS

8.3 Access paths suitable for disabled users

RIVER SKERNE

LOCATION – Darlington, Co Durham, NZ 301160

DATE INSTALLED – June 1997

LENGTH – Concrete path 1000 m x 1.8 m, Bitmac path 225 m x 2.5 m

COST – Concrete path £55k, Bitmac path £43k

Concrete footpath and meanders

DESCRIPTION

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

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

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

DESIGN

Concrete Path

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

To intercept rain water running down from the adjacent slopes gravel drains were placed under the path and in others they were positioned alongside the path. A 100mm layer of crushed stone was laid as standard but where vehicle crossing points were designated, extra stone was used to accommodate the extra loading. Coloured concrete (75mm min.) was poured and the surface finished in the prescribed pattern.

Bitmac Path (figs. 8.3.1 – 8.3.2)

A great deal of preliminary work was needed before the path could be laid, including:

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

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

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

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

SUBSEQUENT PERFORMANCE 1997/8

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

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

Bitmac footpath towards Skerne Railway Bridge

Figure 8.3.1
PLAN OF RIVERSIDE PATH TO SKERNE RAILWAY BRIDGE

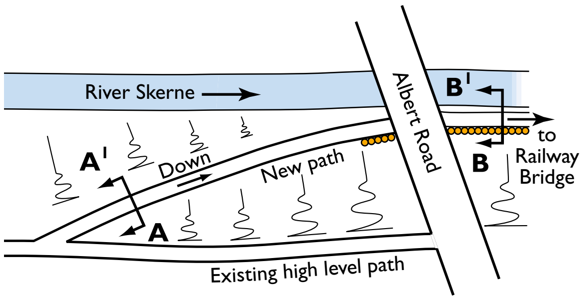
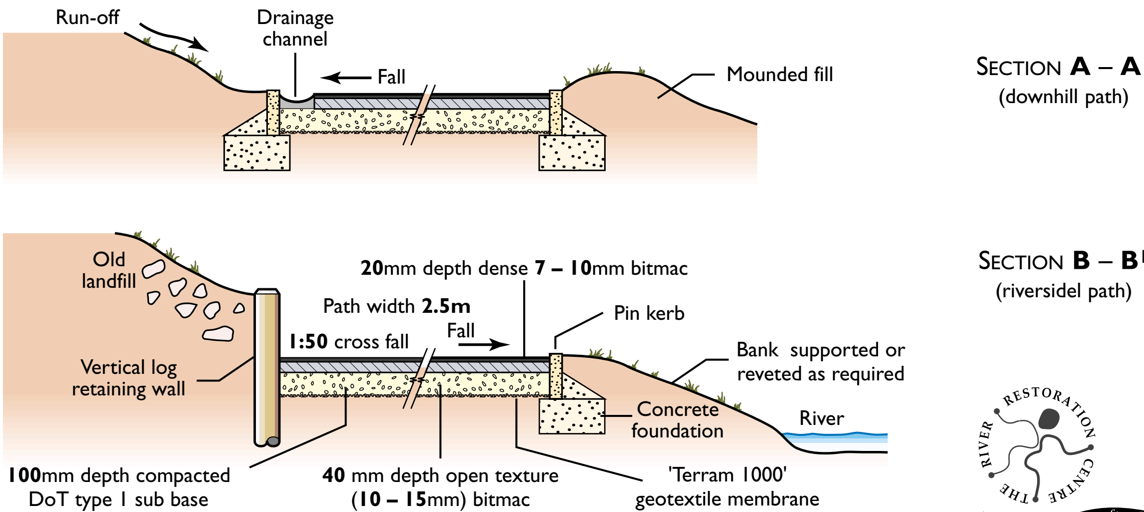


Figure 8.3.2
SECTION THROUGH RIVERSIDE RATH TO SKERNE RAILWAY BRIDGE



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

9

ENHANCING OUTFALLS TO RIVERS

9.1 Surface water outfalls

RIVER SKERNE
LOCATION – Darlington, Co Durham, NZ 301160
DATE OF CONSTRUCTION – August to October 1995
COST – £15k - cross connection survey, £23k - renewal of 13 headwalls, construction of pipe works and new chambers

Typical outfall before replacement

DESCRIPTION

Although the water quality of the Skerne has been steadily improving, public perception of the river was one of a polluted watercourse. Along the core reach of the river restoration project there were 13 public surface water outfalls with ugly concrete headwalls marking their points of discharge. Those with grills were cluttered with plastic and other litter. The project provided a unique opportunity to instigate further improvements to water quality and visual amenity.

Initial inspection by Northumbrian Water of surface water drainage areas and some 1125 premises revealed a number of pollution sources from illegal connections of washing machines, dishwashers, showers, baths and toilets. The water company helped property owners to rectify irregularities before issuing certificates of compliance.

DESIGN

The aims of the design for the surface water outfalls were:

- to improve the quality of discharge by reducing silt, oil, petrol and floating solids reaching the river;
- to improve visual amenity by removing concrete headwalls and positioning discharge pipes below river water level;
- to reduce the number of outfalls and make future management and monitoring more efficient and easier.

New underground outfall chambers were designed such that the amount of both silt and floating solids discharged into the river would be reduced. Under low surface water flows, silt settles and is trapped in a sump. A dip plate ensures that any oil, petrol and floating sewage items are also retained in the chamber. These can all be removed using a suction unit at regular intervals and disposed of appropriately. Initially this was planned at a frequency of four times per year. Under high flows some effluent will be carried into the river but will be much diluted.

Inspection of the chambers is via recessed covers, incorporating turf, which lie just above ground level and so are visually unobtrusive. These allow sampling and pollution monitoring when needed.

Angled to discharge below low water level, the outfall pipe lies on a concrete apron which reduces scour during high flows. The outlet is turned to face downstream so that the river draws the discharge. Additionally, an underwater gabion was installed upstream of the outlet to reduce the risk of pipe damage by floating tree branches, etc. Direct jetting via the chamber is possible if outlets become silted but they are expected to be self cleansing. The velocity of discharge achievable has been seen to make the river 'boil' after heavy rain.

At the large backwater *(see 2.2)* three outfalls have been combined to run into one inspection chamber linked to a single outfall pipe.

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

The advantages of discharging to a backwater include:

- introduction of periodic flow into the backwater;
- potential for natural filtration of the discharge;
- ease of staunching 'off-river' should any pollution incident occur.

SUBSEQUENT PERFORMANCE 1995/8

The outfalls appear to be working effectively. The level of maintenance required has not been as frequent as previously envisaged and is now undertaken once a year. No blockages by siltation of the river bed have occured. The outfalls are now virtually invisible.

New outfall chamber under construction

NOTE: River bank reinstated with soil and toe planting such that no visual evidence of the outfall exists

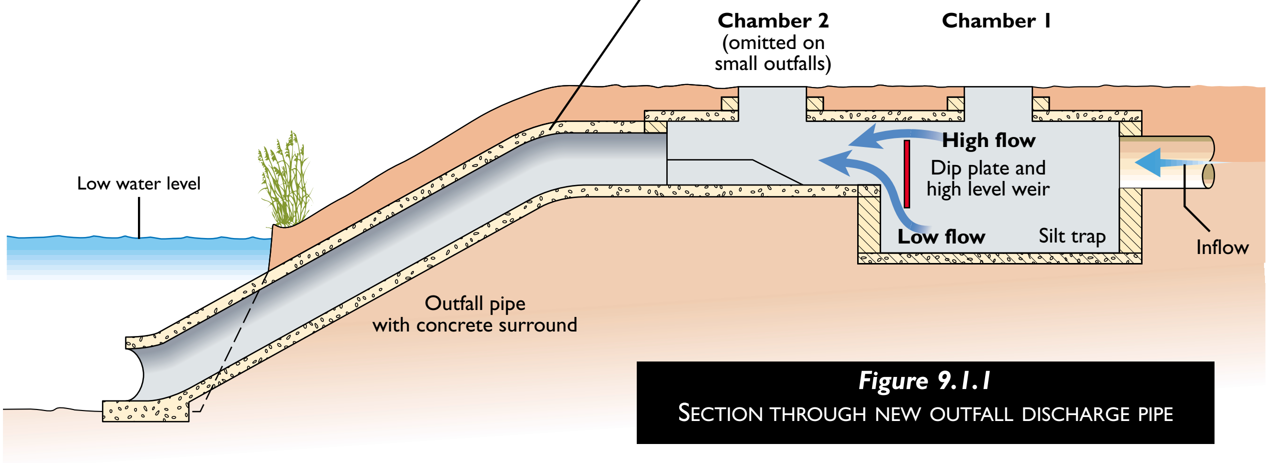


Figure 9.1.1
SECTION THROUGH NEW OUTFALL DISCHARGE PIPE

NOT TO SCALE

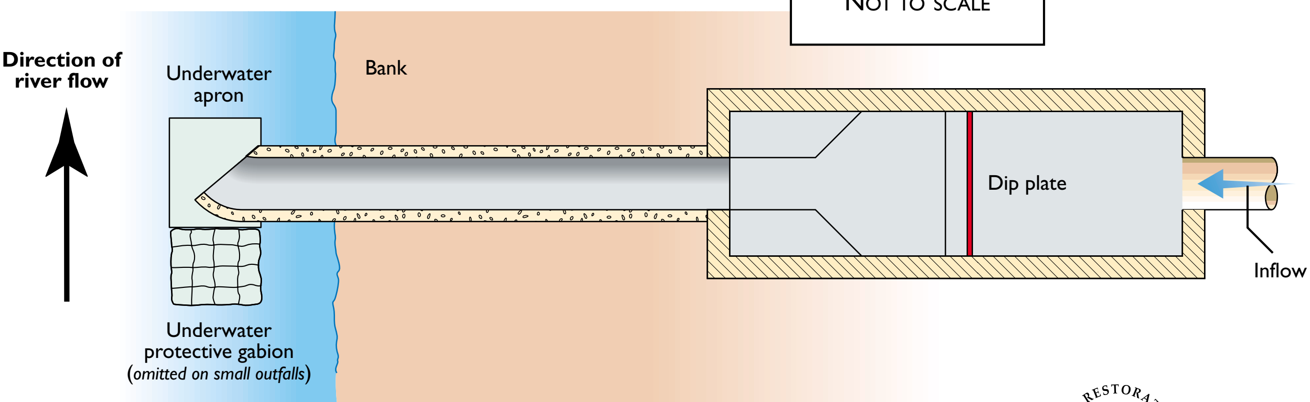


Figure 9.1.2
PLAN OF NEW OUTFALL DISCHARGE PIPE

9.2 Reedbed at Raglan Stream

RIVER COLE
LOCATION – Coleshill, Oxon/Wilts border, SU 234935
DATE OF CONSTRUCTION – Autumn 1995 – Spring 1996
AREA – 640m²
COST – £500

Planting reedbed – Spring 1996

DESCRIPTION

A new reedbed was formed in a redundant length of the Cole following the river's diversion to restore a smaller meandering course *(see 1.2)*. An adjacent small tributary stream, the Raglan Stream, was diverted to flow through the reedbed before entering the river.

The aim was to create a small buffer zone to help intercept silts contaminated with agricultural pollutants and to add habitat diversity to the river. The likely effectiveness of the reedbed as a buffer zone was considered to be low due to its small size and to its location, where river floods would frequently wash over it. The habitat potential was however high, and the marginal costs of construction small, so the reedbed was considered worthwhile and would demonstrate a useful river restoration technique.

DESIGN

The new river course *(fig. 9.2.1)* was excavated near parallel to the old, and the latter partially infilled to create a flat area elevated about 500mm above the new river bed. The two were separated by a ridge of hard gravelly clay soil about 800mm above river bed.

The flat area was then contoured in a series of longitudinal furrows to hold ponded water between ridges of wet, but not saturated ground *(fig. 9.2.2).*

The Raglan Stream was diverted to feed water into the furrows, but because the stream dries up in the summer a supplementary feed of water was diverted from the River Cole. The river flows into the reedbed through a 150mm diameter plastic pipe that discharges through a 90 degree bend which can be swivelled vertically to cut off the flow or reduce it, as required, to keep the reedbed wet but not flooded. This level of control was only critical during the establishment period of the reed.

Common reeds were introduced in spring 1996 using pot grown seedlings along one side of each furrow and seed along the opposite side *(fig. 9.2.3)*. The use of two methods increased the likelihood of successful establishment and enabled the performance of each to be monitored.

Figure 9.2.3
DETAIL OF REED FURROW

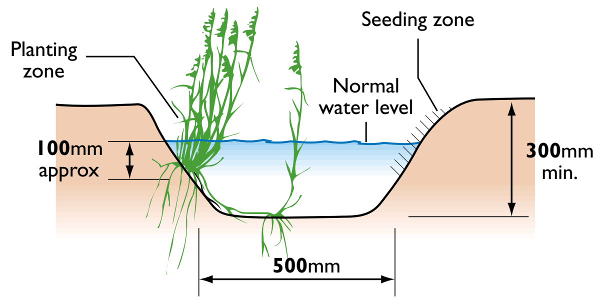


Figure 9.2.1
PLAN OF REEDBED

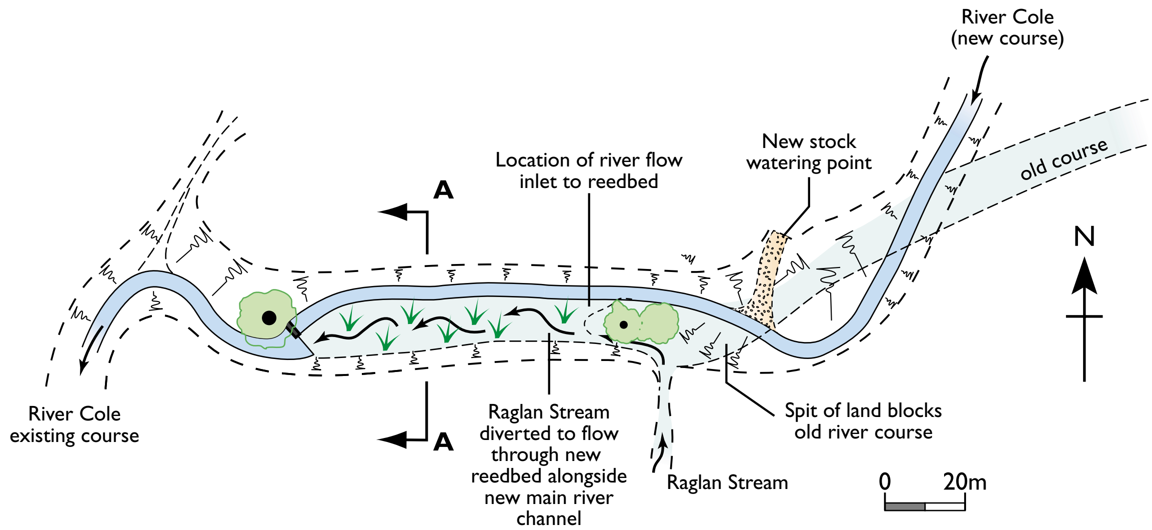
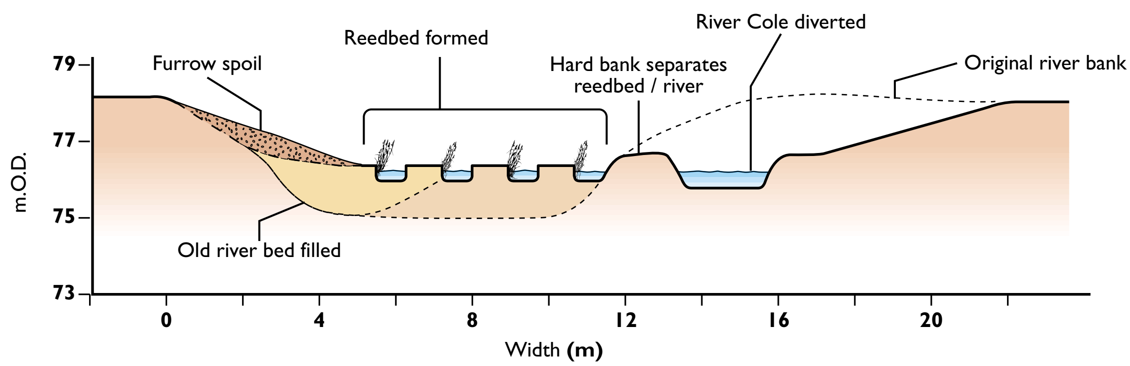


Figure 9.2.2
SECTION A – A



Reedbed established – Summer 1998

SUBSEQUENT PERFORMANCE 1995/98

The reedbed established exceptionally well with 93% of seedlings surviving to maturity, although seed germination was perhaps only 50%, but still sufficient to achieve full colonisation within two growing seasons. Other aquatic species colonised the area naturally, including greater water plantain and soft rush. Concerns that the River Cole might damage the reedbed when in flood proved unfounded because the overall size of the new river and adjacent reedbed is much greater than the exisitng cross-section downstream so flood flow velocities are low.

These hydraulic conditions may lead to progressive siltation of the reedbed in the longer term, but for the foreseeable future a valuable habitat has been created that additionally provides a buffer against contaminated silts from the Raglan Stream reaching the Cole.

10 UTILISING SPOIL EXCAVATED FROM RIVERS

10.1 Landforms at Keepsafe and Rockwell

RIVER SKERNE
LOCATION – Darlington, Co Durham, NZ 301160
DATE INSTALLED – August 1995, Summer 1996
AREA – 1.5 ha Rockwell and 1.1 ha Keepsafe (c. 19,000m³ of spoil carted to landforms)
COST – £60k Carting and creation of landforms

Rockwell after landform completion – 1998

DESCRIPTION

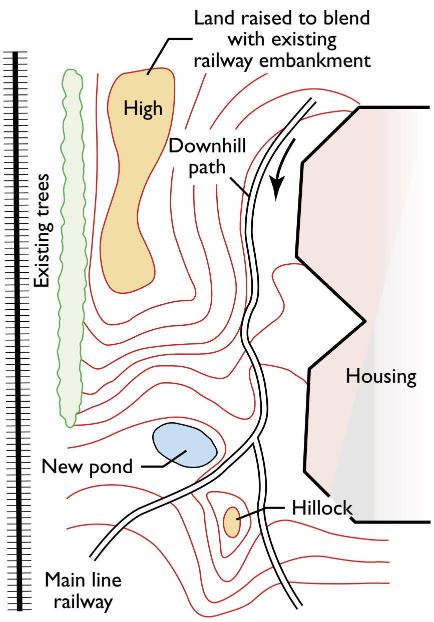
The restoration of the River Skerne necessitated the disposal of c.19,000 m³ of surplus spoil (*see 1.4*). Two locations on the adjacent valley slopes (known as Rockwell and Keepsafe) were considered suitable for re-profiling and accommodating the spoil. These were the only areas that had not been either modified through industrial landfill or developed for housing. Although they retained some desirable features, they were out of keeping with the severely modified landscape around them. New landforms were designed to ameliorate the impact of the old landfill and to enable planting to screen unsightly buildings.

DESIGN

The landform of the two areas was generally designed to simulate naturally occurring 'gullies and hummocks' found in some parts of the north of England. Involvement of the community including schools, local wildlife trust and residents was deemed essential. Ideas for formal and informal paths were included for use in the detailed design.

Rockwell (fig. 10.1.1)
This area positioned between housing, the main railway and a nature conservation area, was rough land with some dumped builders rubble. As part of a community environmental project a pond was excavated in a former 'seep' on the valley side. Key features are gentle slopes facing the housing and small hummocks to provide topographical interest.

Figure 10.1.1
PLAN OF ROCKWELL LANDFORM WORKS



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

French drains were installed in key places to prevent waterlogging of access routes and to alleviate surface water erosion problems.

Keepsafe (fig. 10.1.2)
This was a field gently sloping towards the river. The new landform has introduced a small valley feature and has raised the land adjacent to the industrial estate, built on landfill. Carefully positioned tree and shrub planting screens the industrial area on one side and ties in with an original hedgerow on the other. Most importantly, a smooth topographical transition has been created at the old tip face. A land drain was incorporated in the newly formed valley which also acts as a dry route for walkers.

Once the landforms were complete a landscape architect was appointed to design and install a suitable planting scheme. Each was seeded with a low maintenance grass mix incorporating wildflowers, followed a year later with 10,000 trees and shrubs planted in discreet planting areas. Bulbs were also planted on the lower slopes.

Subsequent performance – 1995/98

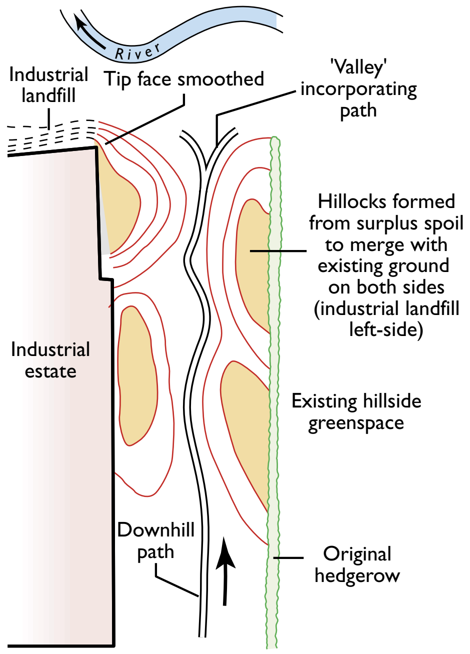
Participation in landscape design and planting has given the community ownership of these open spaces and may be a factor in the minimal level of vandalism experienced. Both areas blend with the surrounding landscape and they are not obviously artificial. Each is now more widely used by walkers taking natural desire lines. The tree and shrub planting is already helping to screen the industrial area and the railway.

The creative use of spoil in this beneficial way has overcome what would otherwise have been a prohibitively expensive operation of carting off site.

Keepsafe landform during construction

Similar view of Keepsafe after tree planting – 1998

Figure 10.1.2
Plan of Keepsafe landform works



10

THE RIVER RESTORATION CENTRE
Working to restore & enhance our rivers

UTILISING SPOIL EXCAVATED FROM RIVERS

10.2 Landform areas

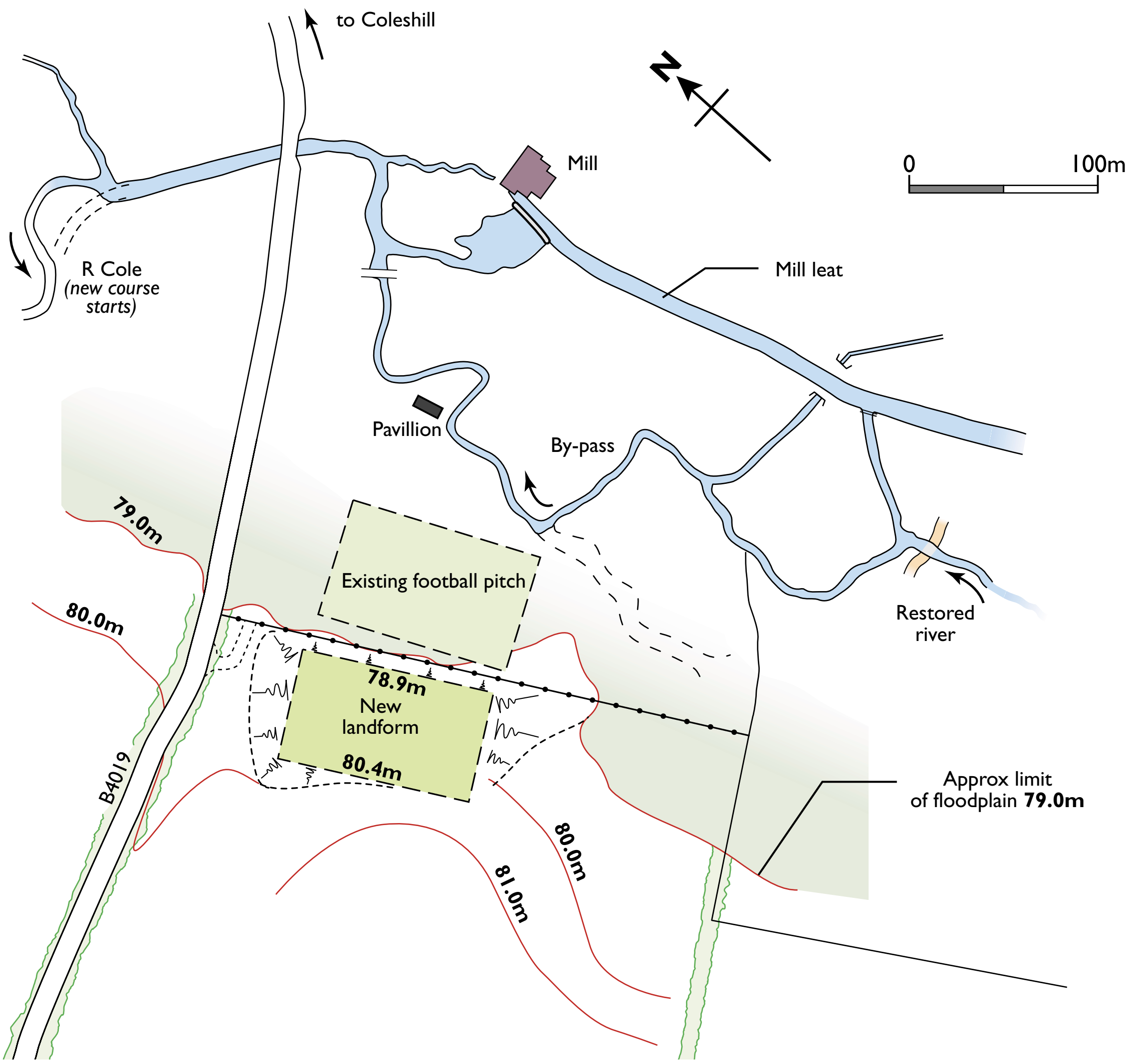
RIVER COLE

LOCATION – Coleshill, Oxon/Wilts border, SU 234935

DATE OF CONSTRUCTION – Autumn 1995 – June 1996

AREA – 0.6ha (c. 4,000m³ – main site)

COST – £13.6k Carting and creation of landform



DESCRIPTION

Excavation to create over 1 km of new meandering river channel resulted in c. 4,000m³ of spoil that needed to be transported away from the riverside. This was used to re-contour a nearby area of sloping arable field just off the floodplain. The landform created resembles a natural river terrace. It is large enough to serve as a second football pitch to compliment an existing pitch located on the adjacent floodplain, if needed. In addition, shallow mounds of spoil were created at two locations on the floodplain to serve as stock refuges in times of flood.

DESIGN

Most of the material excavated was used to infill redundant lengths of the old straight river channel, but not all. As an intrinsic part of the overall scheme, several lengths were left unfilled and developed to create sheltered off-river habitats (*see 2.2 and 9.2*).

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

Spreading of surplus material on the floodplain was not considered complimentary to the river restoration project objectives and carting all spoil off site would have been too costly. The concept of terracing the adjacent valley side was therefore adopted.

The site for the terrace was chosen to assist the local football club whose pitch is located on the floodplain of the river and suffers periodic inundation. It was possible to ensure that the area of the terrace was large enough for a pitch and that it was elevated above flood levels. In practice, the new terrace was restored to arable production but the opportunity for future flood free recreational use remains.

Construction of the terrace was a straightforward operation involving bull dozing of top soil to one side (post harvest) for re-use, prior to carting and spreading of fill. Detailing involved smoothly graded contouring around the edges to blend at 1 in 40 with existing land levels and ensuring a 1 in 130 cross-fall over the terrace to maintain surface run-off.

Elsewhere two smaller landform features were created on the floodplain in the form of gently sloping shallow mounds that will serve as stock refuges in times of flood, in areas where this is critical *(see 1.3)*. These do not adversely affect flood storage capacity because the amount of spoil utilised is small in comparison to the substantial surplus of spoil carted to the main landform.

Subsequent performance 1995/98

The new terrace is in full arable use with only a small part lost to production for one season. Although not unduly intrusive within the landscape, part of the designed 1 in 40 transitional slopes were steepened at the end of the contract to accommodate additional spoil resulting from extra works.

Concerns that increased flood frequencies generated by the river restoration works would advance the need to establish a second flood free football pitch have not materialised to date. The restored river has not developed the amount of in-stream growth conservatively estimated in the design, and seasonal rainfall has been below average since construction. Both these factors may account for this although hydraulic modelling did predict a manageable situation for the football club.

The concept of re-profiling valley sides near to the floodplain has proved to be a very effective way of avoiding excessive spoil disposal costs without any obvious detriment to the landscape.

Construction of landform in arable field to right of football pitch – 1995
Photo: Environment Agency