DEMONSTRATING
STRATEGIC
RESTORATION
AND
MANAGEMENT OF
THE RIVER AVON SAC

advice note

RIVER RESTORATION

Demonstrating STrategic REstoration And Management (STREAM) is a £1 million four-year conservation project centred on the River Avon and the Avon Valley in Wiltshire and Hampshire, Southern England. The STREAM project is supported financially by the European Commission's LIFE-Nature programme.

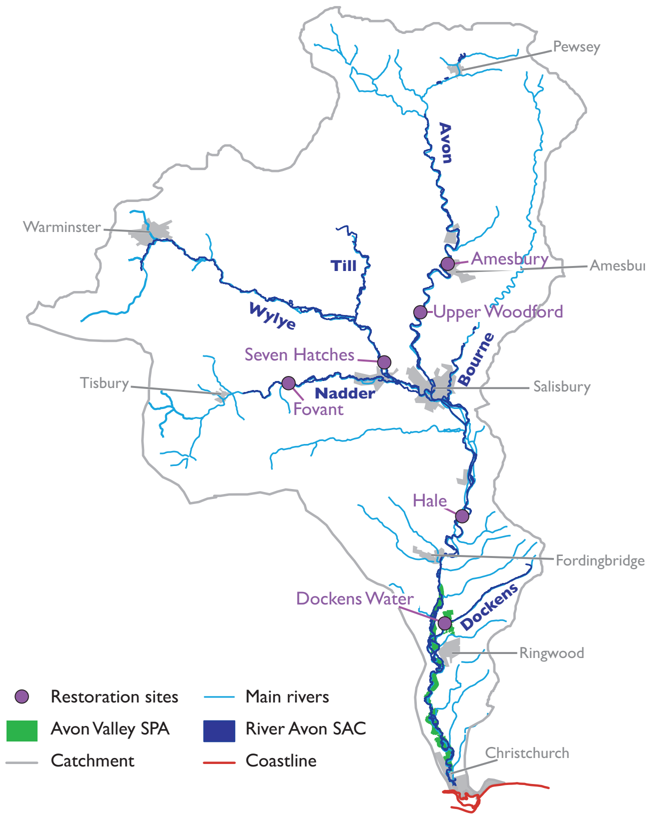
STREAM has worked to address two key issues: the need for a strategic approach to large-scale river restoration, and the need to integrate the management of the river and valley. It is part of a broader initiative that encompasses restoration of designated sites, wider biodiversity work and a programme of community engagement.

This advice note summarizes the Project's experience of river restoration techniques. It is one of three advice notes, covering planning and delivery of river restoration and operating protocols for water level management structures.
For more information visit www.streamlife.co.uk

Background

The River Avon and its main tributaries are designated as a Special Area of Conservation (SAC), and the Avon Valley is designated as a Special Protection Area (SPA) for birds. Past drainage activity has resulted in many parts of the river channels being widened, deepened and natural bed material removed, resulting in

~ Destruction of habitats, channels too wide and deep for natural river flows
~ Damaged vegetation communities
~ Silting up of naturally clean river gravels, reducing habitat for fish, plants and insects
~ Disconnection of the river from the floodplain, resulting in loss of wetland habitat



Within the River Avon SAC, STREAM has undertaken strategic river restoration activities and linked management of the river and valley to benefit the river habitat including water crowfoot and populations of Atlantic salmon, brook and sea lamprey, bullhead, and Desmoulin's whorl snail.

Between 2006 and 2009, the STREAM Project restored a total of seven kilometres of river at six sites on the Avon, Nadder, Wylye and the Dockens Water. The aim of the restoration work is to:

- Restore suitable conditions for the River Avon SAC habitats and species
- Address the effects of past engineering and land drainage
- Demonstrate innovative techniques and proven habitat enhancement methods
- Share best practice through advice notes, demonstration days, seminars and community conservation days

Chalkstreams such as the River Avon and its tributaries are characterised by their relatively stable flow regime and low energy. The STREAM project's experience of using a number of techniques to restore chalkstream habitat is summarised below. Further detailed information on some of the techniques can be found in the Wild Trout Trust Chalkstream Manual (2008).

Whole River Restoration Planning

Whole river restoration planning supports the future restoration of rivers to naturally functioning, self-sustaining systems with the full range of characteristic habitats that benefit their distinctive flora and fauna. The plans identify degraded reaches and suitable costed restoration actions in the context of the whole river system. Whole river restoration plans are therefore a vital first stage in sustainable restoration of rivers.

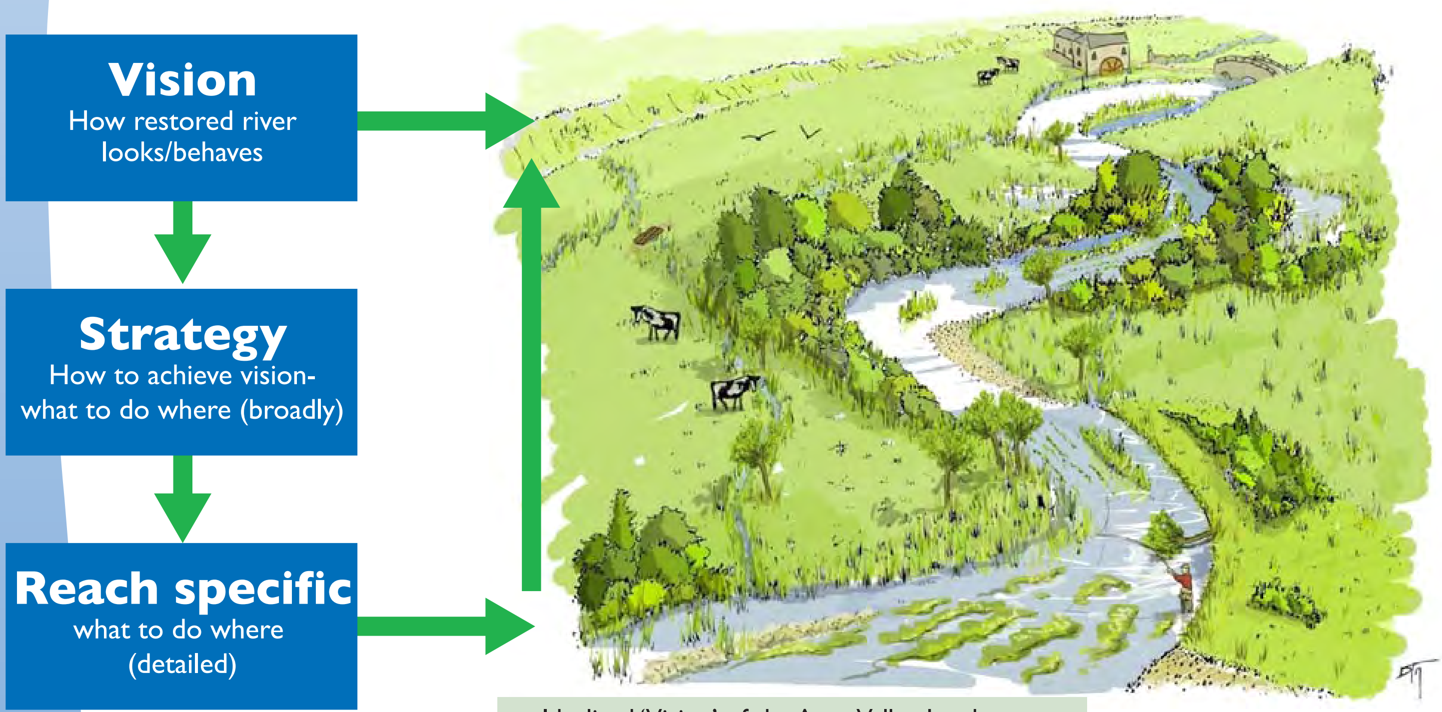
In order to meet the needs of wildlife and those who live on, use, farm or enjoy the rivers, the plans must be developed in consultation and respect the long heritage of the river system. Alongside our knowledge of pollution and water flows, whole river restoration planning ensures that public funding is targeted most effectively for the benefit of the river's wildlife.

The approach to whole river restoration planning is summarised below and in the diagram:

1) review historic information and undertake a geomorphological audit of the river

2) determine the naturalness and degree of modification of the river at present

3) develop a 'vision' of what the ideal River SSSI/SAC should look like (through consultation) to meet its statutory targets for nature conservation and develop a costed and prioritised restoration plan to achieve that vision.



Idealised 'Vision' of the Avon Valley Landscape.
Note: not all features will be found on all river types.

The whole river restoration plan can be used to in the future to:

1) help prioritise grant aid for restoration projects by riparian owners and fishery managers

2) prioritise and guide river restoration work undertaken by Statutory bodies and others

3) develop our understanding of the implications of the current, historic and future river channel shape.

Restoration Techniques

Whole river restoration planning identifies degraded reaches and suitable restoration actions in the context of the river system. Turning the plan into reality on individual lengths of river requires careful selection of restoration techniques. Restoration projects are most successful when clear, quantifiable aims are identified at the start. The aims must link to the overall vision for the restored river, and work with natural river processes at all times.

The techniques summarised below were developed to suit site specific criteria and may not be appropriate for other locations. There are many other restoration techniques available, and choosing appropriate solutions, with due regard to the natural shape and form of chalkstream channels is crucial to the success of any restoration.

Expert advice and the relevant permissions should always be sought before carrying out any work within rivers. Key areas that must be considered at the planning stage include flood risk, protected species and health and safety. A number of permissions are likely to be required including flood defence consent, waste, felling and species licences, and planning permission. No project should be undertaken without due health and safety planning and the development of appropriate risk assessments. **Further information is contained in the** STREAM Planning River Restoration Advice Note.

Large Woody debris

Large fallen trees (or large woody debris) are a vital natural component of chalkstreams. However, traditional chalkstream management has included their removal, on the grounds that they may restrict angling access, collect debris and could pose a risk of flooding.

The retention or replacement of large woody debris in chalk streams can have a significant benefit in creating habitat.

Large woody debris causes local changes in water speed and direction, with consequent downstream scouring of gravel substrate in high flow areas. Deposition of fine sediment and subsequent growth of emergent vegetation can also be achieved in river margins.

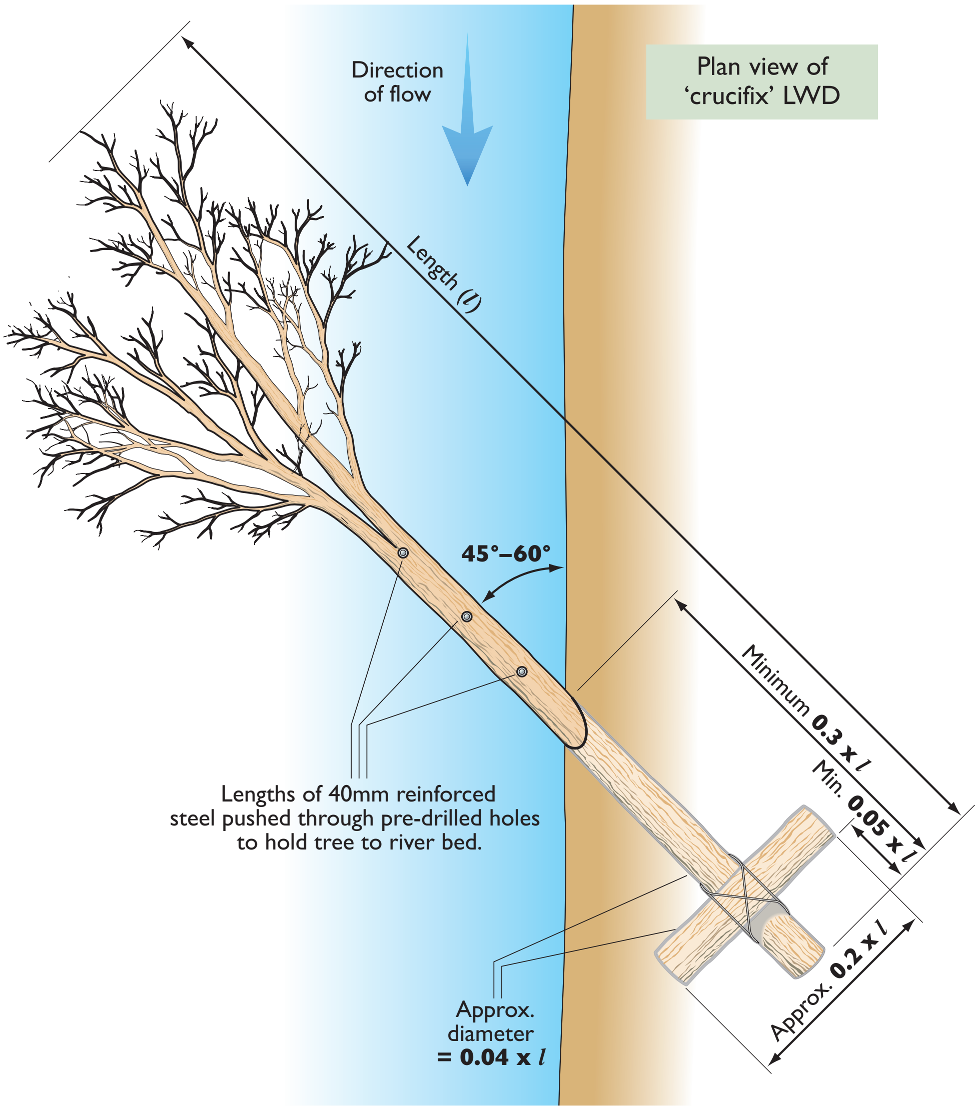
Large woody debris structures are designed to deflect the main flow into the centre of the channel, whilst still allowing some flow through. The amount of debris that will collect on them should be limited, however, some material will snag on the structures, helping the river channel re-gain a more natural shape and providing good habitat for invertebrates and fish. In areas where large amounts of cut vegetation float down the river channel, as a result of weedcutting for example careful consideration should be given to the size and location of the structures.

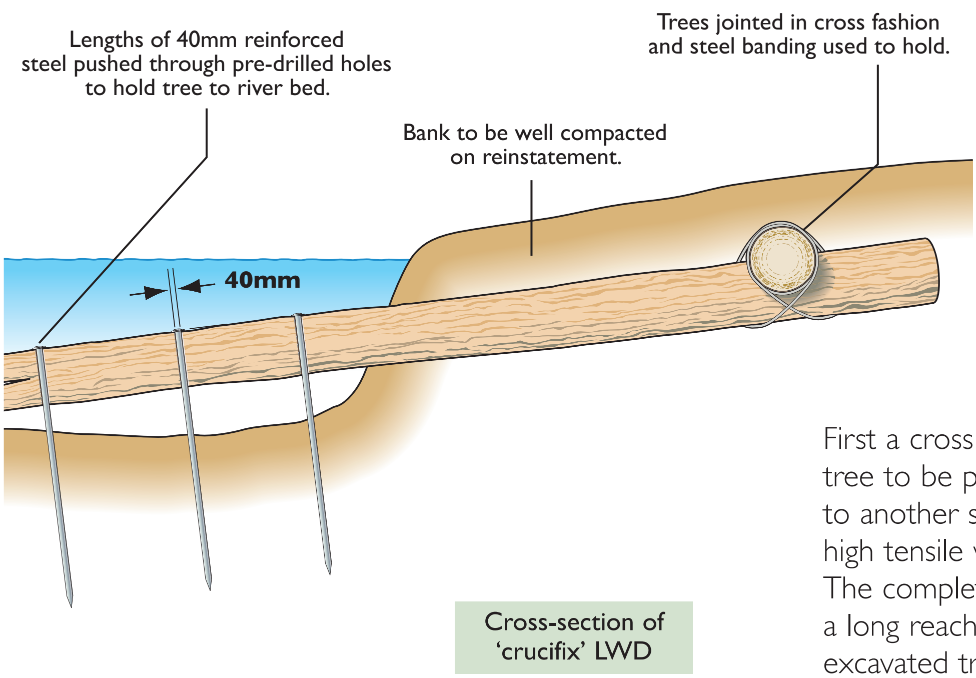
Where large woody debris occurs naturally, as long as it is stable, not causing excessive erosion or flood risk, or preventing fish passage it should be retained. In reaches where there is no remaining source of large woody debris, it may be appropriate to reintroduce it.

Installation of large woody debris in large channels may be limited by the size of trees and machinery available - it is difficult to create structures that are big enough to significantly influence flow speed and direction, and still practical to handle.

STREAM has used three methods for introducing and anchoring large woody debris, as summarised below.

1. Crucifix





First a cross shape trench is excavated. The tree to be placed in the stream is attached to another shorter section of timber using high tensile wire, forming a crucifix shape 1. The completed structure is then lifted (using a long reach excavator), placed into the excavated trench 2 and backfilled 3.

2. Ground anchoring -“tree on a rope”

First attach a high tensile steel cable to the main trunk. Then dig a narrow trench in the bank to accommodate the cable. Using a long reach excavator place the tree in the river, and lay the cable in the trench. Pin the end of the cable into the bank with a ground anchor, then backfill the trench, completely covering the cable

3. Staking

This technique is used where river banks are soft. First sharpen the end of the tree trunk, and then push the sharpened end directly into the bank (using a long reach excavator) to a depth of about 2 metres.

In all cases the trees were also pinned to the river bed with 40mm diameter reinforced steel bars. Holes were drilled in the trunk before placing it in the river. The structure was then pinned in place by pushing the reinforced steel bars through the pre-drilled holes into the river bed. Alternatively, if the river bed is soft enough and/or reinforced bars are not desirable, chestnut stakes and wire can be used to anchor the tree to the river bed.

Summary of methods for installing large woody debris

	Crucifix	Ground anchoring	Staking
Advantages	Simple and quick Provides good structural stability	Useful on gently sloping/soft banks Provides good structural stability	Very simple and quick Minimal bank disturbance Provides reasonable structural stability
Disadvantages	Bank disturbance	More complicated and slower	Less structural stability Only used on soft banks
General considerations	Structures must be big enough (projecting approximately 30% across channel width) to significantly affect direction and speed of flow. This method may be limited in large channels. Consider river bank material, acceptable bank disturbance and what flows the structures will need to withstand when choosing an anchoring method. A long reach machine and a highly skilled operator are required. Where cut vegetation and other debris regularly floats down the river, consider future management of structures carefully.		

Flow Deflectors

Deflectors function by concentrating flow vertically or horizontally, increasing the speed of flow locally and creating areas of differential scour and deposition. Knowing where you want areas of scour and deposition is the main consideration when planning where to install deflectors.

When water strikes a deflector, it is deflected at approximately right angles. A simple deflector installed pointing downstream will tend to deflect flow into the bank, causing erosion, whilst an upstream facing deflector will tend to deflect water into the centre of the channel, eroding a small pool here.

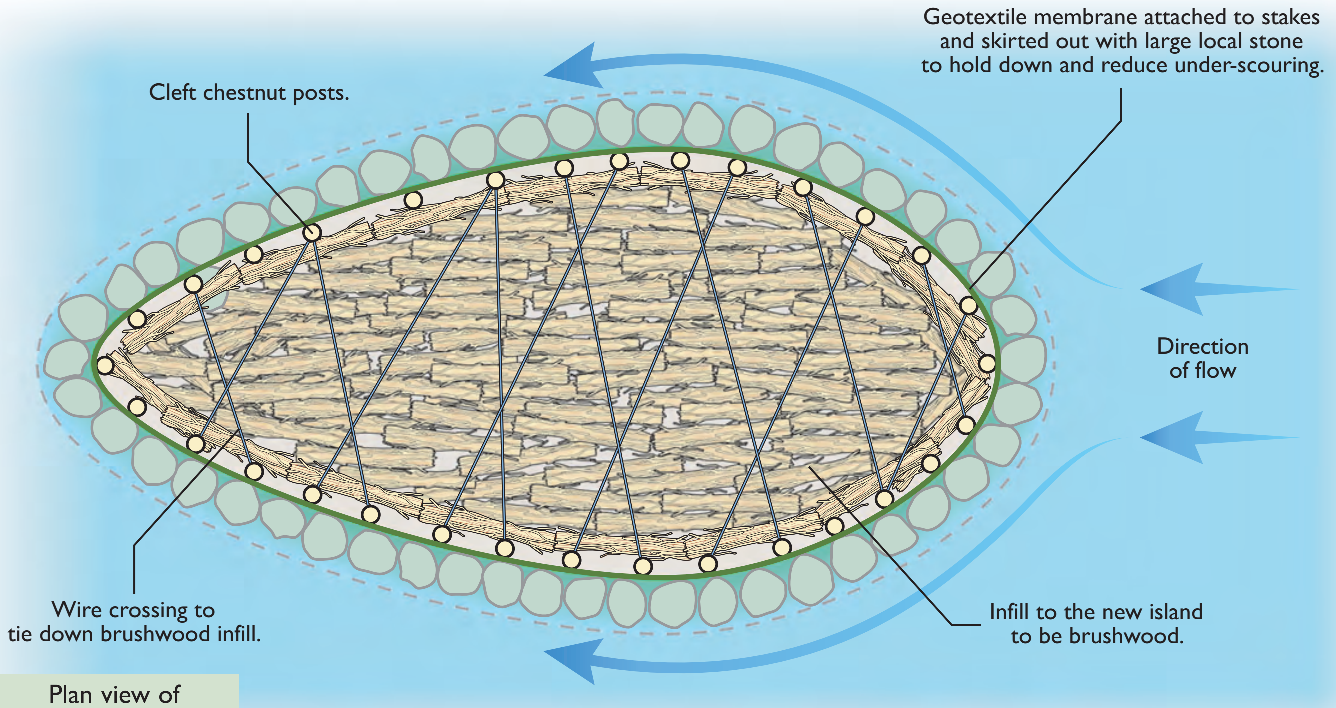
STREAM has used three methods for deflecting flow, as summarised below.

1. D deflectors

Untreated wooden stakes are driven into the river bed, creating a D shape outline 1, which is slightly wider at its upstream end. Brushwood bundles are then tied or wired to the inside of the posts, giving the structure a defined edge. The centre of the D is then filled with brushwood and tied/wired in place 2 and gradually becomes vegetated 3 4.

2. Islands

Untreated wooden stakes are driven into the river bed, creating an egg shape outline for the island **1**.
A vertical coir/geotextile "skirt" is pinned to the outside of the posts, and local stone or flints used to weigh it down. This stops water scouring underneath the structure. The centre of the island is then densely packed with brushwood which is firmly tied or wired into place **2** and becomes vegetated **3**.

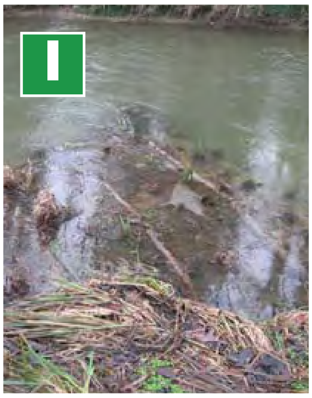


Plan view of 'Island' flow deflector

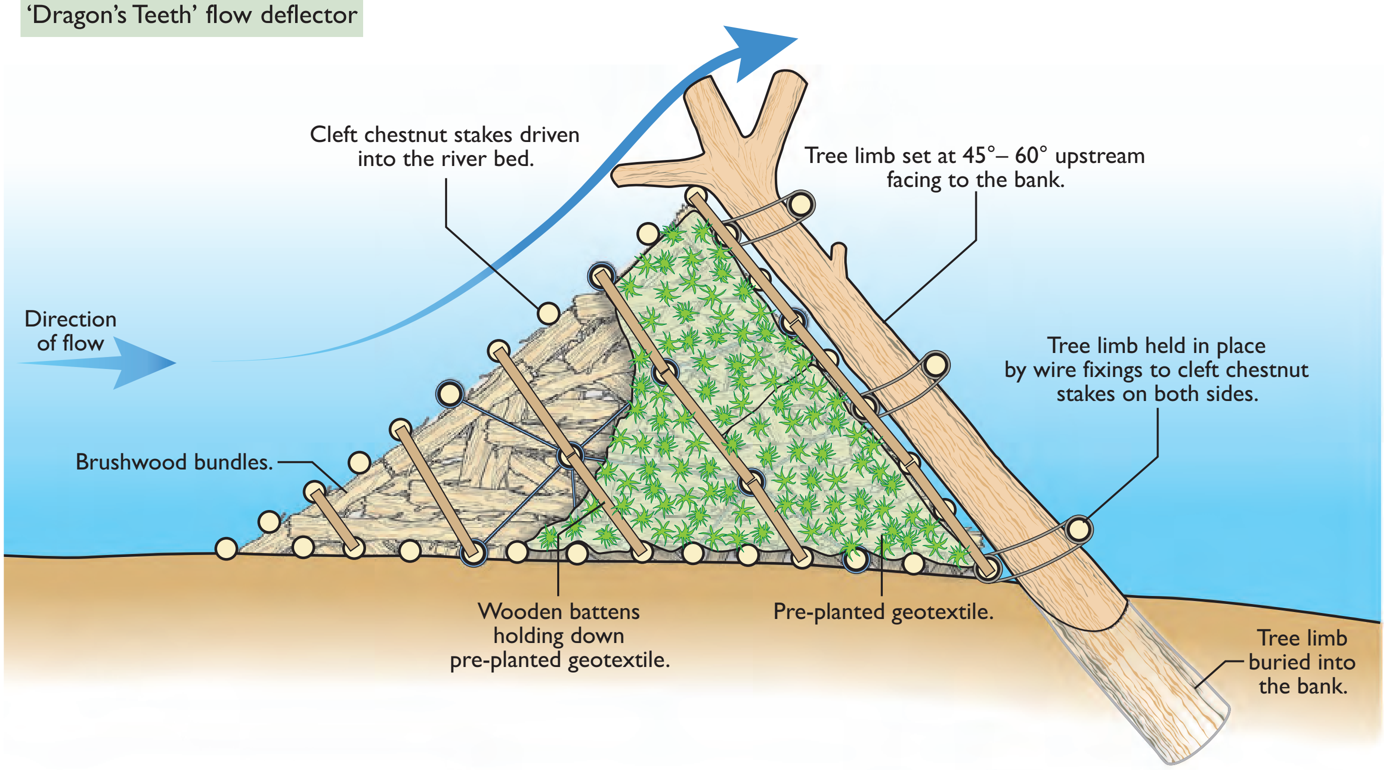
3. Dragons teeth

Place a large tree trunk in the river at 45-60 degrees to the bank. With the machine bucket, hold the trunk down and push it backwards into the bank. Using a post rammer adapted for use on a long reach machine, drive untreated wooden posts into the river bed on either side of the tree trunk, then wire the trunk to the posts **1**. Push any gravel into the centre of the channel so the structure does not cover it.

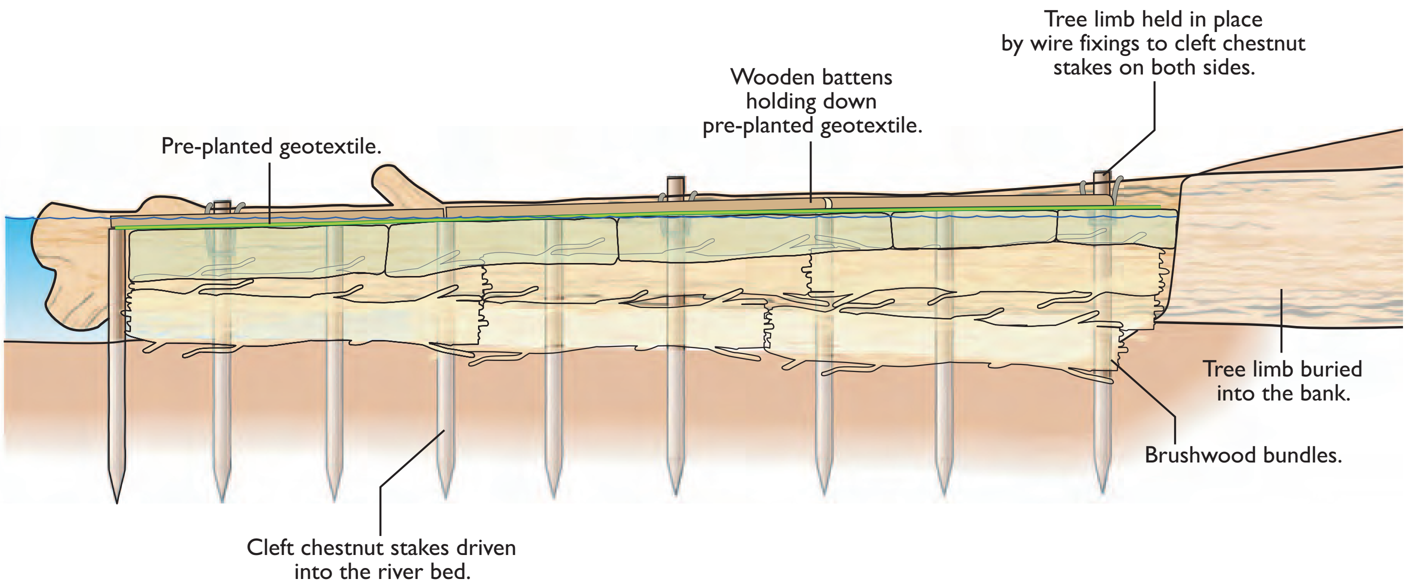
Next drive posts upstream of the tree trunk, forming a triangle between the tip of the trunk and the bank. Drive more posts inside this triangle, and pack it tightly with brushwood, which is then wired to the posts **2**. Structures that will experience strong flows should be topped with pre-planted geotextile **3** anchored with wooden battens. Structures that are less vulnerable can be topped with silt and left to colonise naturally **4**.



Plan view of
'Dragon's Teeth' flow deflector



Cross-section of
'Dragon's Teeth' flow deflector



Summary of methods for installing flow deflectors

	Islands	D deflector	Dragons teeth
Advantages	Simple and quick, little machinery required. No impact on bankside habitat. Provides an additional habitat type.	Simple. Use of local materials. Can minimise impact on bankside habitat by leaving a gap between brushwood and bank e.g. for water voles.	Structures are reasonably robust in more flashy lowland rivers. Appearance quickly naturalises as vegetation grows.
Disadvantages	Need to protect nose and tail to avoid undercutting. May not be a "natural" feature for chalk streams.	Labour intensive. Height of leading edge crucial to avoiding high flows cutting into the bank.	Time consuming. Relatively expensive and requires machinery. Need to protect structures in vulnerable positions with geotextiles and planting.
General considerations	Structures must be big enough to significantly affect direction and speed of flow. Require a lot of woody material from sustainable local sources. The finished height and position in the channel is crucial to trapping silt, vegetation colonisation and appearance. All rely on the establishment of strongly rooted marginal vegetation to optimise their stability and resistance to erosion. Timing of their installation should allow vegetation to establish before winter. Structures may need regular, minor maintenance.		

Channel re-shaping

Extensive past drainage activity has resulted in many river channels being widened, deepened and embanked, and the natural bed material removed.

Channel re-shaping aims to reinstate an approximation of the channel's "natural" cross-sectional area. The template for the new section cross section is usually decided by looking at a more unaffected reaches of the river, or by hydraulic modelling. Following restoration, natural processes encourage the deposition of fine sediment in marginal, low velocity areas, where it will consolidate, further reshaping the channel.

The profile of the new bank is important - steeper banks may be desirable for access, but softer, gently sloping banks with undefined edges are often much better for vegetation growth and variety. Where possible, importing materials to site should be avoided, but may be acceptable in certain circumstances.

STREAM has used three methods for channel re-shaping, as summarised below.

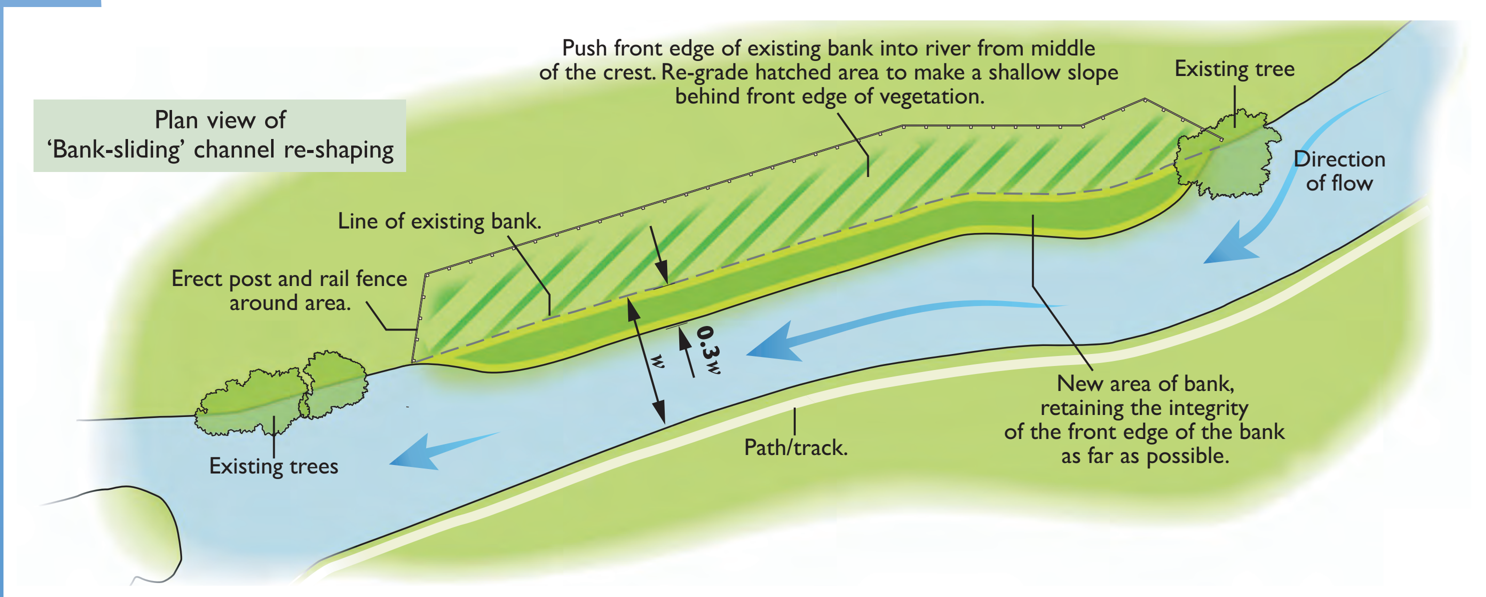
1. Bank-sliding

An embanked section of river with well established, deep rooted marginal vegetation is selected **1**.

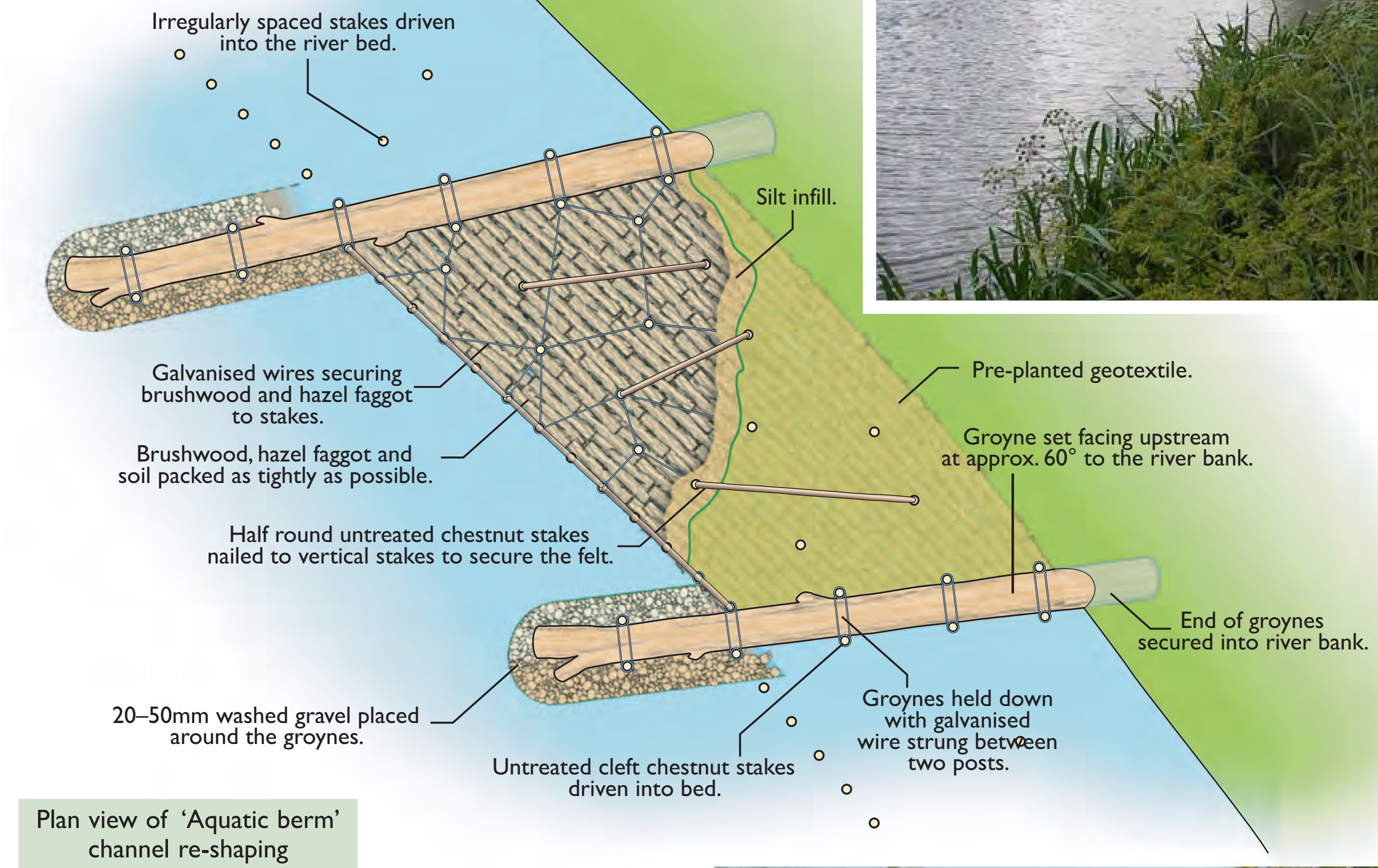
Using an excavator bucket, the vegetation fringe is gradually pushed out 2- 3 metres into the channel **2**. The machine operator has to "feel" how far out to push the vegetation without it breaking up and being washed away.

Material from the embankment is then pushed into the space behind the vegetation, creating a gently sloping profile. The overall effect is to slide the whole river bank and part of the old embankment out, reducing the channel width in lower flows **3**, whilst keeping the overall wetted area the same in higher flows.

The upstream end of the new bank takes the brunt of flow and may need to be protected from erosion. In the STREAM project, the bank sliding was therefore done immediately downstream of an overhanging willow tree **4**. A flow deflecector can be instaled as an alternative. .



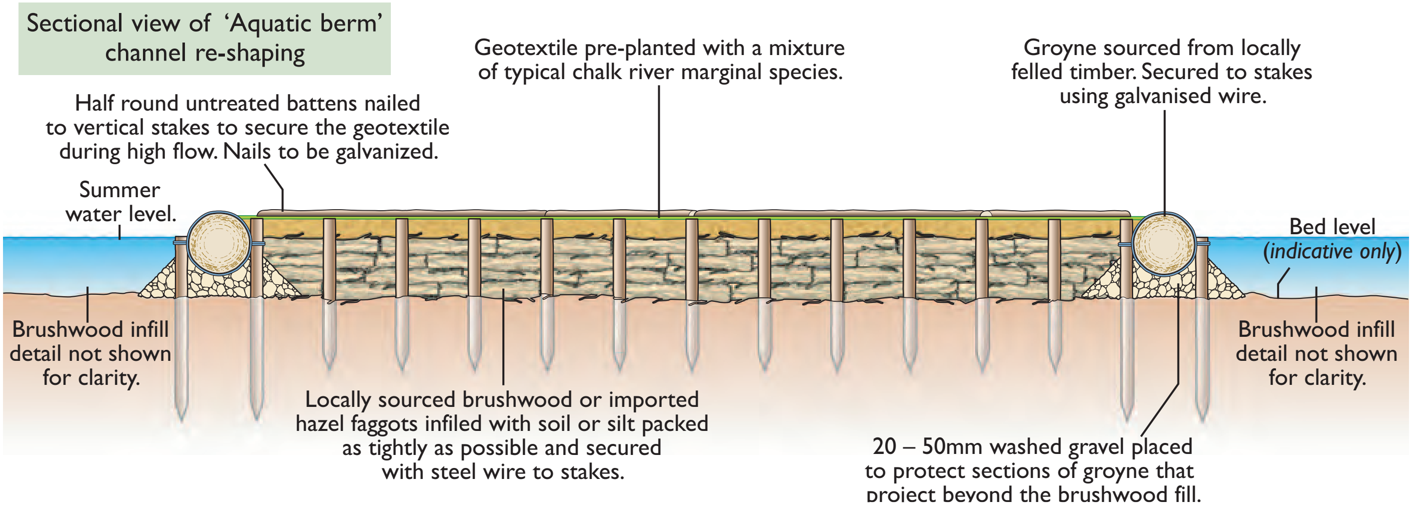
2. Aquatic berm



Plan view of 'Aquatic berm' channel re-shaping

First excavate a 1-2 metre long trench at 45 degrees to the bank face. Place a large tree trunk in the river with the base pointing towards the bank. With the machine bucket, hold the trunk down and push it backwards into the trench. Using a post rammer adapted for use on a long reach machine, drive posts into the river bed on either side of the tree trunk, then wire the trunk to the posts. Install trunks at intervals along the length of bank to be reshaped **1**.

Next drive a line of posts into the river bed parallel to the bank, and wire brushwood bundles to the inside of them to form the outline of the new bank. Having created the outline, the berm resembles a giant basket **2**. As well as having a structural function, the outside edge helps retain any fine sediment disturbed in the next stage.



Tightly pack the inside of the structure with brushwood, and suitable locally excavated sub-soil generated by creating cattle drinks, scrapes or removing berms **3**. Top this material with a layer of coir/jute geotextile mats, which may be pre-planted with suitable locally sourced plants to accelerate vegetation colonisation. Stake or tie the geotextile mats in place.

This will aid colonisation of the berm with vegetation **4** **5** .The structure may settle faster than it accretes sediment, which could expose the wires/ ties. If angler access is required on the berm, provision needs to be made for ensuring the wires are not a trip hazard **6** . Staking rather than wiring the geotextile mats in place is the best option, as the stakes can easily be driven in further.

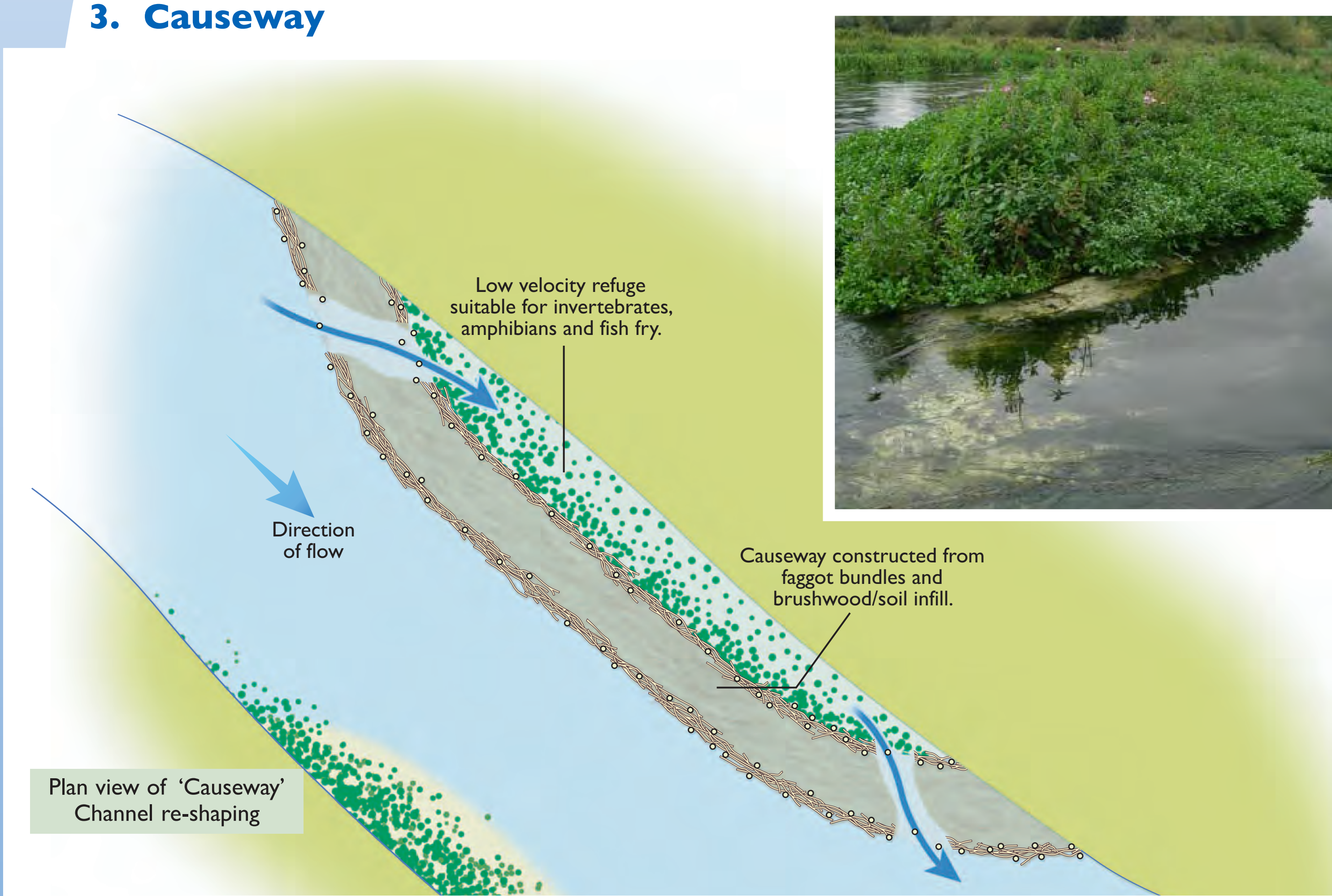
3

4

6

5

3. Causeway



Two parallel lines of untreated wooden stakes are driven into the river bed, creating the causeway outline 1 2. A coir/jute geotextile is then pinned to the inside of the posts, lining the inside of the structure 3. The vertical walls of the liner are further strengthened with brushwood bundles. The upstream and downstream limits of the causeway are firmly keyed into the existing bankline.

Careful setting of the upstream and downstream level of the structure allows water to flow over the causeway and into/out of the area behind in a range of discharges 4 . The centre of the causeway is filled with locally excavated sub-soil. Once full, the liner is closed over the top of the infill, sealing the whole structure, which will become covered with vegetation over time 5 .

The finished height of the causeway, berm and bank sliding relative to summer (low) water level is critical; too high and colonisation with emergent vegetation will be restricted, too low and they will be permanently submerged. As a guide aim to set the new bank/structures between 100mm – 300mm above summer water level - this can be a real challenge with increasingly variable summer flows being experienced in the UK.

Summary of methods for channel re-shaping

	Bank-sliding	Aquatic berm	Causeway
Advantages	Low cost, quick and easy. Creates excellent marginal wet habitat. Very quickly naturalises as vegetation grows up	Possible to avoid disturbing discrete areas of bankside habitat. Useful where bank sliding cannot be used because of unsuitable bank shape/ presence of water voles etc	Minimal impact on bankside habitat Creates shallow backwater behind causeway Relatively cheap and avoids import of large amounts of material if very significant narrowing
Disadvantages	Initially disturbs bankside habitat Upstream face requires protecting from high flows Experience required to know how far out to push vegetation.	Requires a lot of woody and organic material Cross wiring may become exposed May need regular minor maintenance	Requires a lot of woody and organic material and import of subsoil may not be acceptable. Initially looks very unnatural May need regular minor maintenance
General considerations	Can provide marginal habitat even in most canalised of channels. Large machines are required and construction can be challenging in deeper water Finished height relative to summer (low) water level is critical for successful vegetation colonisation and silt accretion Potential Health and Safety implications if access is required onto the re-shaped bank/structure		

Gravel reintroduction and enhancement

Past land drainage work often involved lowering the river bed. This resulted in a loss of characteristic areas of gravel dominated, fast flowing areas which are vital spawning and juvenile habitat for salmonids, lamprey, bullhead and invertebrates. Deepened channels also tend to collect fine sediment, reducing the quality of any remaining spawning gravel.

Raising the river bed speeds up flow, reduces the depth of water and can increase habitat diversity. It can be done by introducing suitable local stone topped by mixed size gravel, creating shallow, fast flowing gravel dominated areas. In order to be physically sustainable, any measures to improve or reinstate spawning gravels should be carried out alongside catchment-wide efforts to reduce sediment supply.

The STREAM project originally planned to reclaim gravel and stone from spoil deposited along the banks during previous dredging operations. However, this was not possible as it was not present in sufficient quantity to make this cost beneficial. Material had to be imported from local quarries, increasing the carbon footprint of the projects.

Bed raising is a complex technique and usually requires a flood risk assessment in order to get consent for the works. It is also relatively expensive and so should be targeted at areas where it will be most beneficial. Hydraulic modelling or conveyance estimation can be used to check the impact of the work on flood risk and water levels. It is recommended that assistance be sought from the Environment Agency and reputable consultants early in the planning stage.

STREAM has used three methods for gravel reintroduction, as summarised below.

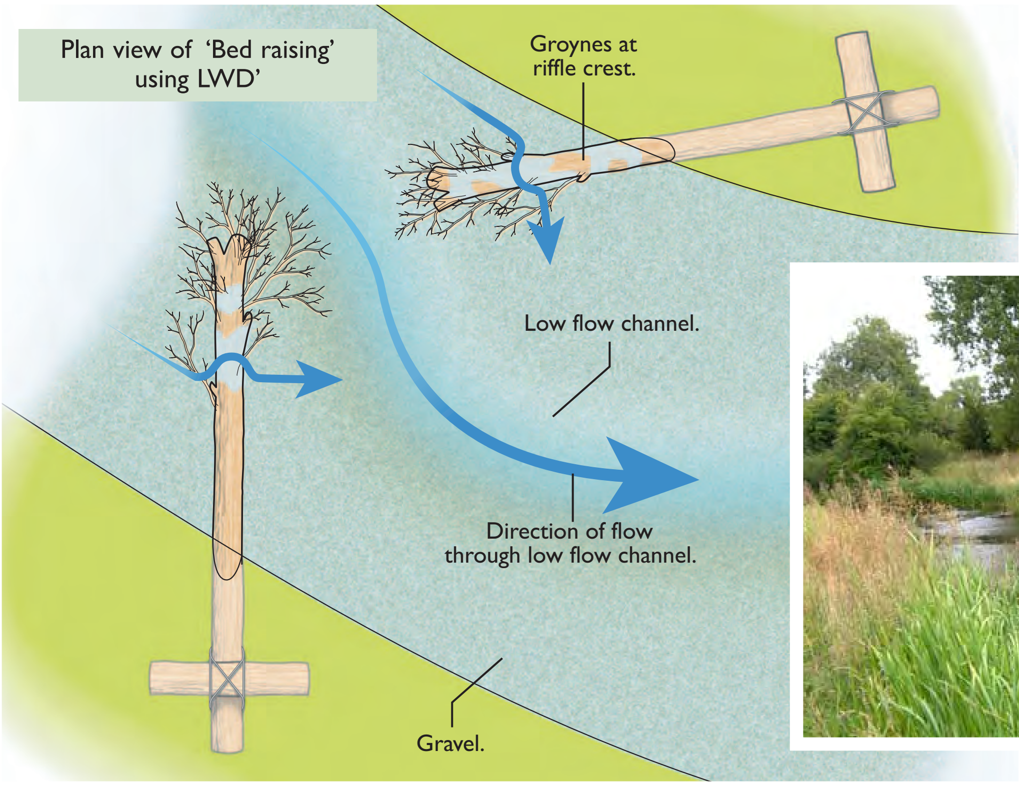
1. Bed raising

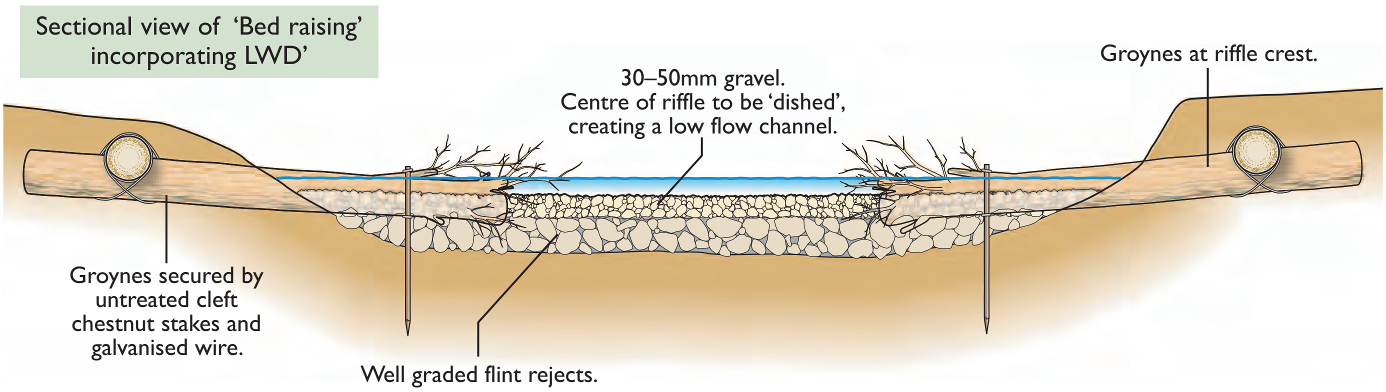
Detailed hydraulic modelling can be used to decide where and by how much to raise the river bed and to check that the flow velocity will be high enough to keep the gravel clean, particularly in very low gradient channels 1 .

Starting at the most downstream bed raising area, place a layer of 0.3m diameter stone, raising the river bed approximately 50 centimetres. Top with a 30cm layer of 20-50mm diameter washed gravel, placed unevenly 2 . The upstream "nose" of the raised area is to have a 1:3 slope, the downstream "tail" a slope of 1:10. Use a machine bucket to scrape a central, meandering channel to focus flow across the gravel.

The final stage is to position large tree trunks on top of the gravel at 45-60 degrees to the river bank. Push the trunks into the bank and then wire them to untreated wooden stakes. Large woody debris is a very effective way to scour the gravel and vary flow depth and speed 3.

A 50 metre length of bed raising in an 10 metre wide channel as described above requires 500 tonnes of material. The cost can vary greatly depending on the location of the stone supplier. Moving this amount of material around on soft/wet river banks means low ground pressure machinery must be used. In a larger river, cost and the availability of a long reach machine to place the stone may be limiting.





2. Enhancing existing gravel

Identify existing areas of gravel in river margins by quickly surveying the river bed. Using a long reach machine, push the marginal gravel into the centre of the channel, forming a gravel "sausage".

A series of large woody debris structures are then installed on alternate banks adjacent to the gravel sausage, using the crucifix method described earlier. The large woody debris speeds up and focuses flow, improving the gravel as spawning habitat.

3. Shoals

In certain locations, water levels may be very sensitive to changes in river bed level, so raising only part of the river bed may be the best approach 1 2 .

Identify areas where creating alternate gravel shoals will accentuate any existing variation flow speed and depth. Place 20-60 mm diameter gravel in the river margins adjacent to the banks. Spread more gravel unevenly between the shoals to a depth of at least 30 centimetres-this will be sorted naturally during high flows. The marginal shoals should be out of the water during lower flow periods, focussing flow over the mid channel gravels, and submerged during high flows, providing spawning areas.

Summary of methods for gravel re-introduction

	Bed raising	Enhancing existing gravel	Shoals
Advantages	Significantly improves habitat. Does not require maintenance.	Improves habitat with no need for import of stone and gravel	Improves habitat Does not require maintenance
Disadvantages	Import large amounts of material. Potential impact on soft banks during construction.	Hard to judge quantity/ quality of existing gravel Structures must be big enough to significantly affect direction and speed of flow.	Importing material Potential impact on soft banks during construction
General considerations	Effective method of rehabilitation of severely damaged habitat and offers significant habitat opportunities for a range of species. Requires specialist planning and installation and may not be possible iin areas with high flood risk sensitivity. Generally expensive, particularly in deep/large channels and requires large machinery. High carbon footprint if material is imported.		

More information

Brook, A (2006). *Large wood re-introduction in South East Australia: synthesis of a decade of rehabilitation projects.*
http://products.lwa.gov.au/products/PX061171

Halcrow Group Ltd. and GeoData Institute (2009). *Strategic Framework for Restoration of the River Avon System Non Technical Summary.*

Haskoning UK Ltd. (2006-2009). *Physical and biological monitoring of STREAM restoration Projects Years 1-4*
http://www.streamlife.org.uk/resources/publications/

Kail J, Hering D, Muhar S, Gerhard M, Preis S (2007). *The use of large wood in stream restoration: experiences from 50 projects in Germany and Austria. Journal of Applied Ecology 44(6): 1145.*

Mainstone, CP (1999). *Chalk rivers - nature conservation and management.*
http://naturalengland.etraderstores.com/NaturalEnglandShop/Product.aspx?ProductID=12e39f4d-e451-4cbb-85e3-4b74bea7535836.481_mm

STREAM (2009). *River Restoration Planning Advice Note.*
http://www.streamlife.org.uk/resources/publications/

The River Restoration Centre (1999 and 2002). *River Restoration Centre Manual of River Restoration Techniques.*
http://www.therrc.co.uk/rrc_manual_pdf.php

The River Restoration Centre (2009). *Assessment of STREAM River Restoration Sites.*
http://www.streamlife.org.uk/resources/publications/

The Wild Trout Trust (2008) *The Chalkstream Habitat Manual.*
http://www.wildtrout.org/index.php?option=com_content&task=view&id=324&Itemid=315

Acknowledgements

Our thanks to Allan Frake, Vaughan Lewis, and the landowners and fishing clubs who took part in the project.

Illustrations and design of this publication by:
Robert and Rhoda Burns
(Drawing Attention) 2009