Reducing river bank erosion

A best practice guide for farmers and other land managers
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1 About this guidance

River bank erosion can be costly. It can result in losses of productive land and damage to fencing, tracks and other infrastructure.

This guidance describes practical ways you can protect eroding river banks without increasing erosion risks to other banks downstream.

To use the techniques, **YOU MUST** comply with the rules in the following General Binding Rules (GBRs):

(a) GBR25 for the placement of the trees or parts of trees;

(b) GBR9 if you are going to operate a vehicle or other machinery in the river to carry out the work

If you cannot comply with these rules, an application for a licence will be required. If you are in doubt at any point you can contact your [local SEPA office](mailto:local SEPA office).
2 Why should I use the techniques?

The most sustainable way to protect your river banks is by using living or dead tree stems, roots, or branches to cushion the bank from the force of the river. This guidance provides a step-by-step guide on how you can do this.

One of the main benefits of these techniques is that, unlike others, they don’t increase the risk of erosion to banks downstream. If you use live trees to cushion some of the force of river flows, you will gain the added benefit that, as the roots of these trees grow, they will increase the strength of the bank.

Even if you do not use live trees, we recommend that you re-establish trees along the top of the river bank behind the bank protection. This is because the trees’ root systems will make the banks more resistant to erosion and, as the dead wood decays, give long-term, sustainable protection against bank erosion.

Eroding outer banks lacking trees: River banks become vulnerable to erosion when they are not lined with trees or surrounded by wetlands, and when there is no wood in the river channel to cushion them from the force of the river.

3 Are there restrictions on where I can use the techniques?

You can use the techniques to protect:

- any eroding river bank;
- the current line of that bank.

GBR25 will not allow you to:

- reclaim land by placing protection on a previous line of the bank;
- use trees or parts of trees to create a smooth, wood wall against the river bank. Such a wall would not dissipate the force of the river. Instead, it would transfer the river’s energy downstream, potentially putting other banks under stress.
4 What do I need to know before I use this guidance?

We hope you find this guidance easy to follow. However, there are a few terms that we think it would be worth familiarising yourself with first. These are set out in Table 1 below.

To make sure the protection you put in place works properly, we also recommend that you seek professional advice on its design. Other farmers and land managers who have used the techniques, your local river or fishery trust or the River Restoration Centre may be able to point you to someone they have used, or whom they know, that has suitable experience.

Table 1: Terms used in this document

<table>
<thead>
<tr>
<th>Term</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank toe</td>
<td>The zone along the lowest part of a river bank at the intersection of the bank with the channel bed. The bank toe will either be submerged for much of the year or the first part of the bank to be inundated as the river rises to submerge exposed sediments on the channel bed adjacent to the bank.</td>
</tr>
<tr>
<td>Brash</td>
<td>Any of the following that are easily moveable by hand: parts of a branch, whole branches or parts of tree stems with branches attached.</td>
</tr>
<tr>
<td>Brash bundles</td>
<td>Individual pieces of brash tied sufficiently tightly together to form a coherent structure but not so tightly as to leave virtually no space between the pieces.</td>
</tr>
<tr>
<td>Eroding bank</td>
<td>A bank of a watercourse that is being eroded by the action of the river when river levels are sufficiently high.</td>
</tr>
<tr>
<td>Large trees</td>
<td>Whole trees that are of such a size that they cannot be lifted and installed by hand.</td>
</tr>
<tr>
<td>Large wood</td>
<td>Parts of the following that are of such a size that they cannot be lifted and installed by hand: tree trunks with their branches attached, tree limbs with their branches attached or large branches with smaller branches attached.</td>
</tr>
<tr>
<td>Root plate</td>
<td>The portion of the tree that would normally be below ground before the tree is uprooted.</td>
</tr>
<tr>
<td>Root wad</td>
<td>The lower part of the trunk of a tree with the roots still attached and as much of the soil as possible removed so that the roots are left exposed. The tree may be dead or alive.</td>
</tr>
<tr>
<td>Small trees</td>
<td>Whole trees small enough to be lifted and installed by hand without any mechanical assistance.</td>
</tr>
<tr>
<td>Willow spiling</td>
<td>Live willow rods woven between live willow stakes driven into the bank or bed of a watercourse.</td>
</tr>
</tbody>
</table>
5  How do I select the appropriate technique?

There are a number of different ways of using trees or parts of trees to protect eroding river banks. You can find a step-by-step, technical guide on how to use each of the techniques starting on page 7:

<table>
<thead>
<tr>
<th>Technique</th>
<th>Step-by-step guide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willow spiling and willow stakes</td>
<td>Page 8</td>
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<tr>
<td>Brash or small trees</td>
<td>Page 11</td>
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<tr>
<td>Large wood</td>
<td>Page 15</td>
</tr>
<tr>
<td>Large trees</td>
<td>Page 16</td>
</tr>
<tr>
<td>Root wads</td>
<td>Page 19</td>
</tr>
</tbody>
</table>

The technique or combination of techniques that will work best depends largely on the energy of the river. Consequently, the first thing you need to do is to consider the river’s energy levels.

Figure 1: Description of low and high energy rivers

![Figure 1: Description of low and high energy rivers](image)

Figure 2a: Examples of rivers with relatively low energy levels.
Note the smooth water surface.

![Figure 2a: Examples of rivers with relatively low energy levels](image)
Figure 2b: Rivers with medium to high energy levels. Note the uneven water surface and presence of white water corresponding to breaking waves.

Your river will be somewhere on a spectrum from very low energy to high energy. You can use Figure 3 below to help you identify the type of techniques likely to perform best depending on where your river is on this spectrum. In general, the higher the river’s energy, the larger the diameter of stems, roots and branches that you will need to use to cushion the bank from the force of the river.
Figure 3: Matching the technique to the river’s energy

<table>
<thead>
<tr>
<th>Technique</th>
<th>River’s energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willow stakes or willow spiling</td>
<td>Increase diameter of stakes</td>
</tr>
<tr>
<td></td>
<td>Protect bank toe (wood or stones)</td>
</tr>
<tr>
<td></td>
<td>Combine with other techniques</td>
</tr>
<tr>
<td>Brash, brash bundles or small trees</td>
<td>Increase size of brash</td>
</tr>
<tr>
<td>Large wood</td>
<td>Large wood (with brash)</td>
</tr>
<tr>
<td>Large trees</td>
<td>Whole trees</td>
</tr>
<tr>
<td>Root wads</td>
<td>Root wads (with brash)</td>
</tr>
</tbody>
</table>

Whatever technique you use, you will need to secure the trees and parts of trees in place to prevent them being washed away by the river. This is particularly important if you are using large wood, large trees or root wads, which, if they were to break free, could cause damage to any bridges and other structures downstream.

The method you need to use for this will depend on the strength of the bank. Figure 4 provides a guide to help you select the most appropriate method.

Figure 4: Selecting the most appropriate structure (bank strength)
6 What else do I need to think about when deciding on the technique to use?

The costs of bank protection will vary. For example, installing large wood, large trees and root wads requires mechanical assistance and, in the case of root wads, significant earth works. This may be a significant factor in your choice of technique, depending on whether or not you have to hire in contractors or machinery.

Similarly, whether or not you need to buy-in trees or parts of trees is likely to affect your choice of technique. If you use willow spiling, you will normally need to buy the spiling. Typical costs for this, including installation, might be in the range of £75 to £150 per metre.
7  Technical guide to the different techniques

7.1  How to use live willow stakes and spiling

7.1.1  Live willow stakes and willow spiling can provide protection and support to steep, eroding banks within a range of soil types and flows. They can also be used in combination with some of the other techniques described below. Willow stakes and spiling are one of the easiest and cheapest structures to install since they can be secured in place by simply hammering them into the bed or bank. Examples of willow spiling are shown in Figures 5 and 6.

7.1.2  Installation should generally include the following steps:

7.1.2.1  All willows should be planted or installed between November and March; the earlier the better within this time frame, so long as this does not disturb fish reds (spawning sites) or introduce silt into the river. This will allow the willows to start growing as soon as the weather is warm enough and will ensure they have the entire growing season to become established. Live willow needs to be installed in moist and soft soil so that the roots can start to grow and penetrate to a greater depth, providing greater stabilisation. Planting in the summer months in dryer locations, such as the tops of banks, will decrease the likelihood of the willows becoming well established.

7.1.2.2  Ideally, only freshly cut willow stakes and rods should be used, though as long as they are kept damp and cool, they can be stored for two to three weeks before installation.

7.1.2.3  Stakes should be at least 50mm to 100mm thick, 2m long and should be hammered into the bank face, including a line along the bank toe if it is exposed, roughly every 0.5m. Stakes should be hammered through blocks of slumped material if present in order to stabilize them. At least two-thirds of the stake’s length should be driven into the ground to provide a strong anchor (Figure 7).

7.1.2.4  Weave live willow rods between the live willow stakes. The rods should be about 2.5m long for use on lower energy rivers and from 6m to 7m long to produce stronger structures for use on higher energy rivers. 20 to 30 rods should be used for 1m high spiling. The surface created will initially be relatively smooth but, as the willow

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1  http://www.jprenvironmental.co.uk/Top_tips_willow_spiling.pdf
3  http://www.jprenvironmental.co.uk/Top_tips_willow_spiling.pdf
grows, it will develop the roughness and complexity required to dissipate flow energy.

7.1.2.5 The bank toe may need to be protected while the willow becomes established. This is because erosion of the bank toe can lead to the bank being undercut and then collapsing. If there is evidence of scour at the bank toe or a likelihood of scour because of the energy of the river, you can use one of the other techniques or stones to help protect the toe whilst the willow becomes established.

7.1.3 If you use stones, ideally they should be sized to the river. You can do this by selecting sizes up to the size of the largest stones that have been deposited in the channel in the vicinity of the eroding bank. On some river beds, there may be much larger rocks than those deposited by the river. These are rocks left from glacial periods and not representative of the size of stones you should use. You only need to protect the bank sufficiently to prevent undercutting. Once the willow has grown and its roots have become established, you should not need to maintain the toe protection as the willow will stabilise the bank and help resist undercutting.

7.1.3.1 A willow spiling wall should be no more than 1m high. When banks are higher than this they should be reprofiled into a series of terraced steps. This technique can be used in conjunction with the other forms of bank stabilization described below to provide improved protection, especially in higher energy systems.

7.1.3.2 Sheep, cows and deer eat young willow shoots, so fencing is necessary to ensure the success of the structures in locations where this could occur.

7.1.4 Over time, the willow should establish a root network in the bank material, which reinforces it. Branches will grow and form flexible stems that will increase roughness, dissipate more energy and protect the bank from erosion.

7.1.5 Where individual trees grow out over the river at a steep angle, pruning (coppicing) may be required to stop the trees maturing into heavy trees that may fall into the river and pull a section of bank with them.

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4 [http://www.jprenvironmental.co.uk/Top_tips_willow_spiling.pdf](http://www.jprenvironmental.co.uk/Top_tips_willow_spiling.pdf)
Figure 5a: Example of newly installed terraced willow spiling for bank protection.

Figure 5b: Terraced willow spiling one year later, viewed from the opposite direction to Figure 5a.
Note the complexity and roughness of the bank compared to that in Figure 5a.

Figure 6a: Examples of recently installed willow spiling for bank protection on a low bank.

Figure 6b: Example of already vegetated willow spiling used in the Cairngorms in a relatively high energy river.
The photograph was taken after the protection had withstood the floods of the 2015 – 2106 winter.

Photo courtesy of Arup

Photo courtesy of Spey Fishery Board
Figure 6c: Willow spiling for bank protection starting to vegetate

Figure 6d: Willow spiling for bank protection two years after construction

Figure 7: Details of willow stakes and rods installation

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7.2 How to use brash and small trees

7.2.1 Brash and small trees with branches are good for diffusing flow energy due to their flexibility and because the river loses some of its energy when flowing between and around the individual pieces of the brash or branches.

7.2.2 Brash and small trees can be used on a range of stream sizes and can be combined with willow spiling for additional stability. The size and weight of the brash and small trees can be adapted to reflect differences in energy conditions, with heavier more solid branches being used in higher energy rivers.

7.2.3 The techniques involve:

7.2.3.1 the use of bundles of brash tied together and pinned in place to protect the bank face;

7.2.3.2 brash or small trees simply put in place in front of the eroding bank and secured using the techniques shown in Figures 9 and 10.

7.2.4 Brash use is appropriate for banks with a slope of 1:1 (45° from the horizontal) or steeper. It can be used on its own or alongside small trees or large branches.

7.2.5 Brash should be tied sufficiently tightly to form a coherent structure (Figures 8 and 9d-f) but not so tightly that there is virtually no space between the individual pieces.

7.2.6 Installation should proceed as follows:

7.2.6.1 Hammer a matrix of wooden posts (50mm to 100mm in diameter) into the bank at regular intervals between a stable section of the bank top and the bed in front of the eroded bank. Two-thirds of each post's length should be hammered into the bank. The area over which the posts extend should cover the eroded bank face and overlap with the unaffected bank at either side (Figures 9b 10). Particular care should be taken to firmly secure the brash to the bank at the upstream and downstream ends to prevent flanking.

7.2.6.2 Weave layers of brash between the posts (Figure 9b) and place a mixture of brash bundles, small trees and large branches between the eroding bank face and the line of posts closest to the wetted channel (Figures 9c and10b).
7.2.6.3 Secure the brash, small trees and large branches using one of the following techniques:

7.2.6.3.1 Drive live willow stakes through the structure at intervals along the eroding bank. The stakes should be long enough to just stick out above the structure and for at least two-thirds of their length to be driven into the bank face (Figure 10a).

7.2.6.3.2 Drive live willow stakes into the bank top, set back about a metre from the bank edge, and into the bank toe. The bank toe stakes should be long enough to just stick out above the structure. The bank top and toe stakes should be long enough for at least two-thirds of their length to be driven into the ground and to at least a depth of 1m on the bank top. Stretch suitably strong stainless steel wire from the posts at the bank toe, tightly over the structure to the base of the bank top post. Attach the wire to the posts using stainless steel staples or similar (Figures 9d-f and 10b).

7.2.6.3.3 Augment the strength of the structure described in 7.2.6.3.2 above by weaving live willow rods or large branches between the stakes along the bank toe (Figure 10c). If this approach is used, the stakes will need to be installed as described in Figure 7.
Figure 9: Installation of willow and brash between wooden stakes

(a) Before work commences on the eroding bank face

(b) Installing willow in the wet areas between the posts. Branches are left attached along the water’s edge to increase diffusion of flow energy.

Wild Trout Trust

Argyll Fisheries Trust

(c) Filling the void area behind the posts with brash. Note the overlap of the protection with the un-eroded bank in the left middle of the photograph

Argyll Fisheries Trust

(d) Finished brash bank protection held in place with wire and posts. The tops of the posts just need to be sawn off to prevent them from trapping debris in higher flows

Argyll Fisheries Trust

(e) View downstream after the winter flood events in 2015 – 2016

Argyll Fisheries Trust

(f) Further example of brash bank protection fixed with posts and wire.
Figure 10a: Securing brash, brash bundles, small trees or large wood to the bank face with wooden stakes or reinforced bar

Figure 10b: Securing brash, brash bundles, small trees or large wood to the bank face with wooden stakes or reinforced bar and stainless steel cabling

Figure 10c: Securing brash, brash bundles, small trees or large wood to the bank face with wooden stakes or reinforced bar, stainless steel cabling and willow spiling
7.3 How to use large wood

7.3.1 Large wood can be used on its own or in combination with the other techniques in the guidance. If the energy of your river is high, it can be used like a weightier form of brash and small trees. It can also be used to protect the bank toe from undercutting whilst willow spiling establishes.

7.3.2 Installation of protection using large wood (Figure 11) should proceed as follows:

7.3.2.1 Use a mixture of different sizes and shapes of large wood to create a complex and rough matrix.

7.3.2.2 Starting at the bank toe, interweave the different large wood pieces so that a complex and strong matrix is created. Using at least some live wood will help create a stronger matrix, since live branches can take root in the bank or bed.

7.3.2.3 Willow spiling or planting native species on the bank top can be used with this technique to help stabilise the bank.

7.3.2.4 The same fixing techniques used for brash and small trees and illustrated in Figures 9 and 10 can be used for large wood protection.

7.3.2.5 Steel reinforcement bars (rebar) can also be used to fix large trunks into the bed or bank for additional strength or if fixing to the bank top is not possible (Figure 13a).

7.3.2.6 Particular care should be taken to firmly secure the large wood to the non-eroding bank at the upstream and downstream ends to prevent the river going around the protection.
Figure 11: Examples of large wood used for river bank protection
7.4 How to use large trees

7.4.1 Large trees can provide good protection in high energy situations. However, they do need to be properly secured in place to avoid risks to structures downstream should they break free.

7.4.2 The installation of protection using large trees (Figure 12) should proceed as follows:

7.4.2.1 Select the right type and size of tree. Coniferous trees such as spruce, fir or pine are most appropriate, although any locally available trees can also be used. The diameter of the tree’s crown should be roughly two-thirds the height of the eroding bank face and the tree should not occupy more than one-third of the wetted channel width. Any long lengths of trunk which do not have any branches should be cut off.

7.4.2.2 Starting from the downstream end of the eroding section, place a tree tightly against the bank face with the trunk end facing upstream. The tree’s downstream end should extend over, and be securely attached to, a short section of non-eroding bank to prevent flanking (Figure 12).

7.4.2.3 The tree should be anchored both at its trunk and towards its tip using one of options 7.4.2.3.1 and 7.4.2.3.2 to secure it to the channel bed and one of options 7.4.2.3.3 and 7.4.2.3.4 to secure it to the bank:

7.4.2.3.1 Drill a hole through the trunk and drive reinforced steel bar at least 1m into the channel bed. The reinforced bar should just stick out of the top of the trunk (Figure 13a).

7.4.2.3.2 Attach wooden stakes or reinforced steel bar to each end of a length of suitably strong stainless steel wire and hoop the wire over the trunk so that one stake is on either side. Drive these at least 1m into the bed so that the wire is tight across the trunk (Figure 13b).

7.4.2.3.3 Drive 150mm diameter wooden stakes into the bank top to a depth of at least two-thirds their length and no less than 1m. Hoop suitably strong diameter stainless steel wire around the trunk and attach this to the base of the bank top post using cable ties or stainless steel staples (Figure 13c). Trim off any excess post length. This technique may be more suitable if the bank material is stronger.

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7.4.2.3.4 Dig a 2m deep trench 5m back from the bank top that is big enough for a log anchor of length 2m - 2.5m and of 0.5m in diameter. Dig a narrower trench to the same depth running perpendicular to the first one and towards the bank top. Hoop suitably strong stainless steel wire around the whole tree trunk and attach this to the log anchor using cable ties or stainless steel staples. Place the anchor and cable into their trenches, backfill with soil and compact this down (Figure 13d). This technique may be more suitable if the bank material is weaker.

7.4.2.4 The second tree should then be drawn into position to overlap with the first tree over about 25% of its length, ensuring no gap exists between the two. The cable used for securing the trunk of the first tree to the bank can also be used to anchor the tip of the second tree to the trunk of the first. A new cable and anchor or stake should then be used for the trunk of the second tree.

7.4.2.5 Repeat steps 7.4.2.1 to 7.4.2.4 until the whole length of eroding bank is protected. The upstream end of the cover should extend over, and be securely attached to, a short stretch of non-eroding bank to prevent the river going around the protection.
1. The upstream and downstream ends of the protection extend beyond the end of the eroding section of bank and can be secured to the bank using a wooden stake or reinforced steel bar hammered 1m - 1.5m into the bank top. Wooden stakes should be about 150mm in diameter.

This technique could be used throughout the reach if the bank material is strong (ie sticky).

2. Log anchors about 2m - 2.5m long and about 0.5m in diameter can be buried 1m - 1.5m into the bank top. The whole trees are secured to these using suitably strong cable buried into the bank.

This technique may be more suitable in weaker sandier soils.

3. The upstream tree should be drawn over about 25% of the length of the downstream tree's trunk and secured tightly to it using suitably strong stainless steel cable.

This technique should always be used, irrespective of the nature of the bank material.

Each tree is installed tightly against the bank face to prevent scour during higher flows.
Figure 13a: Cross-sectional view of large tree placement secured using reinforced steel bar driven into the channel bed

Figure 13b: Cross-sectional view of large tree placement secured using wire lacing attached to wooden stakes or reinforced steel bar driven into the channel bed
Figure 13c: Cross-sectional view of large tree placement secured using steel cabling attached to bank top wooden stakes or steel reinforced bar

Figure 13d: Cross-sectional view of large whole tree placement secured using steel cabling attached to loch anchors buried in the bank

Figure 14: Example of bank protection using large trees

Photo courtesy of the Wye and Usk Foundation
7.5 How to use root wads

7.5.1 Root wads can be used in combination with the large wood technique described earlier, with one or two root wads installed to provide additional strength. Root wads work well on the outside of bends and near to fast flows. They can be used to provide anchoring points for brash and large trees arranged in series along the bank to be protected.

7.5.2 The installation of root wads may require significant excavation and should proceed as follows:

7.5.2.1 The length of trunk attached to the roots should be a minimum of three times the root plate diameter to help the structure remain stable during flood flows.

7.5.2.2 Excavate a trench either parallel or at 20° to the direction of flow (Figure 15) and sufficiently long to take the trunk length determined in step 7.5.2.1. The lowest layer of wood should be sunk below the existing bed surface to a depth equivalent to at least half the diameter of the root plate. Lay the trunk on the bed of the trench with the root plate extending into the channel itself.

7.5.2.3 To help ensure structural stability during floods use one of the following techniques before backfilling the trench with soil:

7.5.2.3.1 individual large boulders placed on top of the trunk (Figure 17a);

7.5.2.3.2 wire rope lacing attached to stakes driven into the bed of the trench (Figure 17b);

7.5.2.3.3 rock roll (ie a cylinder shaped bundle of rocks held together by wire or other binding material) lain over the trunk (Figure 17c).

7.5.2.4 Backfill the trench with soil and coarse sediment, compact this down and replant with live willow stakes and other native tree species (Figure 16).

7.5.3 The use of live willow root wads can provide greater stability, since the new shoots will eventually develop a root network that binds the soil more effectively than a dead root wad with no root network.
Figure 15: Root wads combined with large wood and brash

![Diagram of root wads combined with large wood and brash](image)

Figure 16: Profile view of bank protection using root wads

![Diagram of profile view of bank protection using root wads](image)

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7 Modified from: River Restoration Centre (2016), Manual of river restoration techniques.
Figure 17a: Cross-section showing root wad stabilisation using individual large boulders

Figure 17b: Cross-section showing root wad stabilisation using wire rope lacing
Figure 17c: Cross-section showing root wad stabilisation using a rock roll

- Live willow stakes
- Deciduous saplings
- Compacted soil backfill
- Rock 'sock', Geotextile sack filled with ~300mm diameter boulders
- Trunk of root wad