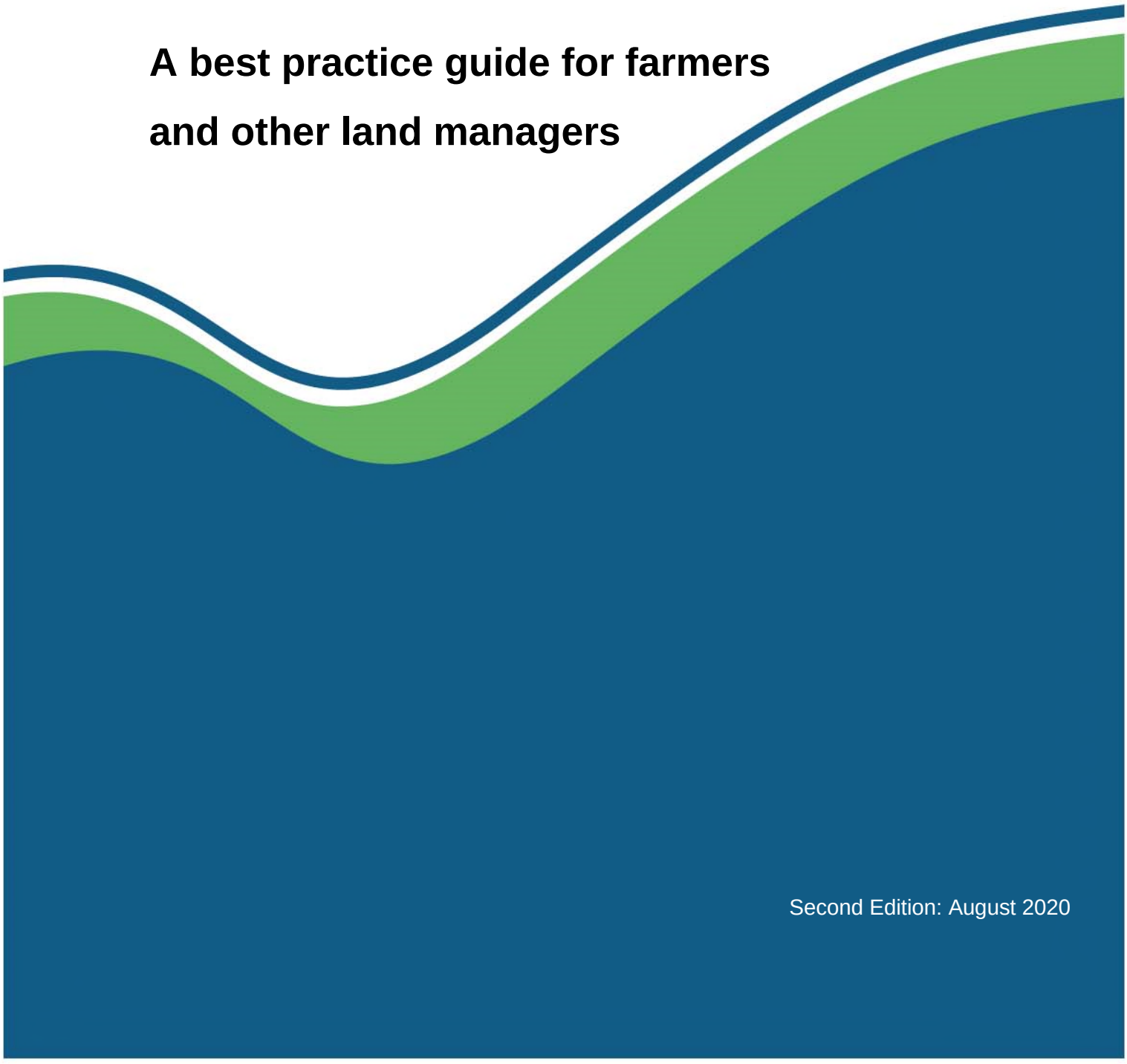
Sustainable Riverbank Protection

Reducing Riverbank Erosion

A best practice guide for farmers and other land managers



Second Edition: August 2020

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1 About this guidance

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

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

Many river bank protection techniques can be carried out without a permit or expressed permission from SEPA providing you are able to follow a set of specific rules relevant to the activity you are carried out, these are known as General Binding rules (GBRs).

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

The details of each GBR are set out in Controlled Activity Regulations: A Practical Guide available on SEPA's website. If you cannot comply with these rules, an application for a licence will be required for any riverbank protection works. If you are in doubt at any point you can contact your 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. However it's worth noting that simply fencing the riverbank to keep livestock away from the edge can by itself help prevent erosion problems and restore the bank by encouraging natural regeneration.

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 provide advice and /or point you to someone that has suitable experience.

Table 1: Terms used in this document

Term	Meaning
Bank toe	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.
Brash	Any of the following that are easily moveable by hand: parts of a branch, whole branches or parts of tree stems with branches attached.
Brash bundles	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
Eroding bank	A bank of a watercourse that is being eroded by the action of the river when river levels are sufficiently high.
Large trees	Whole trees that are of such a size that they cannot be lifted and installed by hand.
Large wood	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.
Root plate	The portion of the tree that would normally be below ground before the tree is uprooted.
Root wad	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.
Small trees	Whole trees small enough to be lifted and installed by hand without any mechanical assistance.
Willow spiling	Live willow rods woven between live willow stakes driven into the bank or bed of a watercourse.

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 9:

Technique	Step-by-step guide
Willow spiling and willow stakes	Page 9
Brash or small trees	Page 13
Large wood	Page 17
Large trees	Page 19
Root wads	Page 23

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

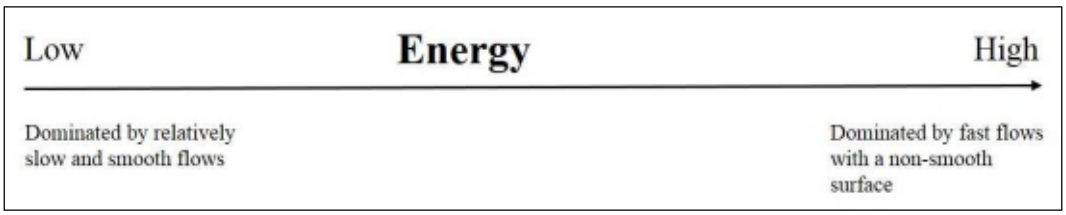
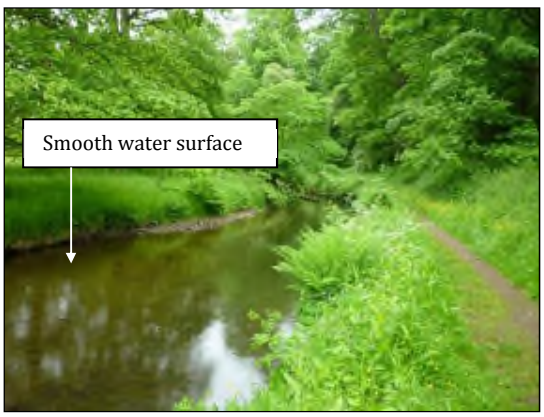


Figure 2a: Examples of rivers with relatively low energy levels.
Note the smooth water surface.



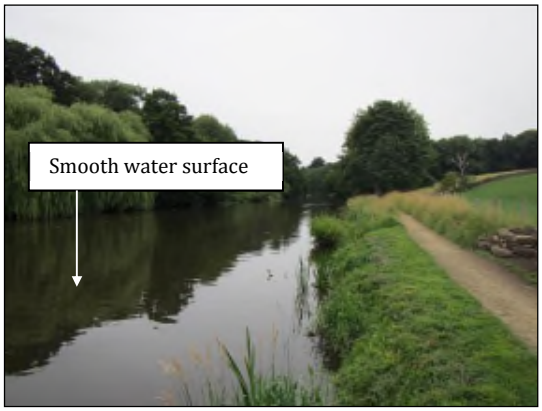
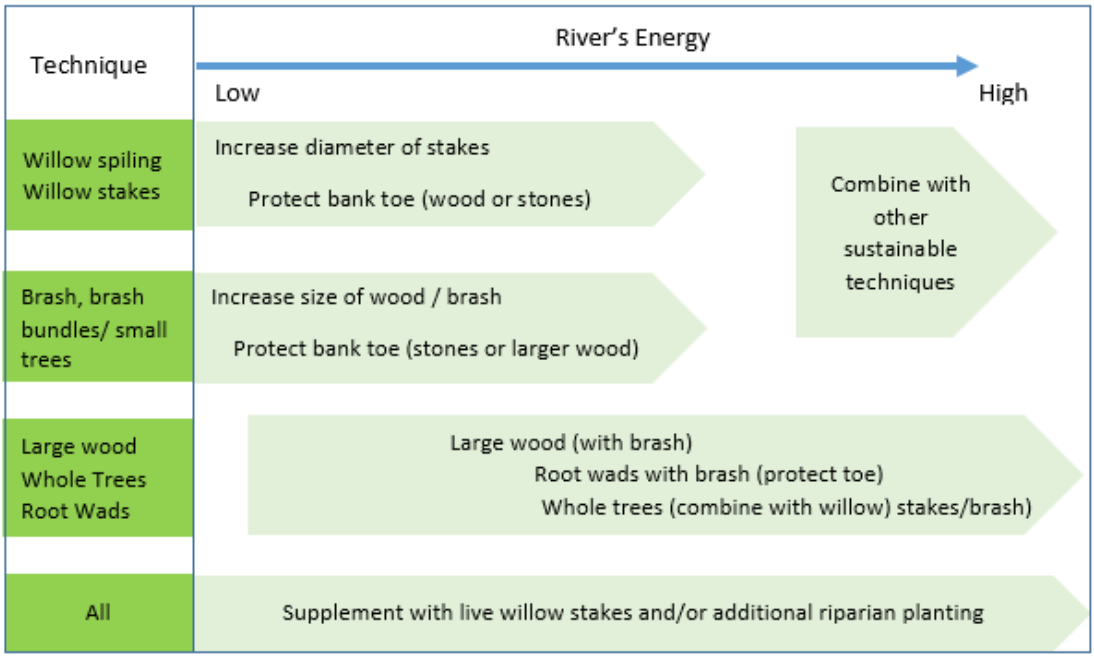


Figure 2b: Rivers with medium to high energy levels.
Note the uneven water surface and presence of white water corresponding to breaking waves.

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.

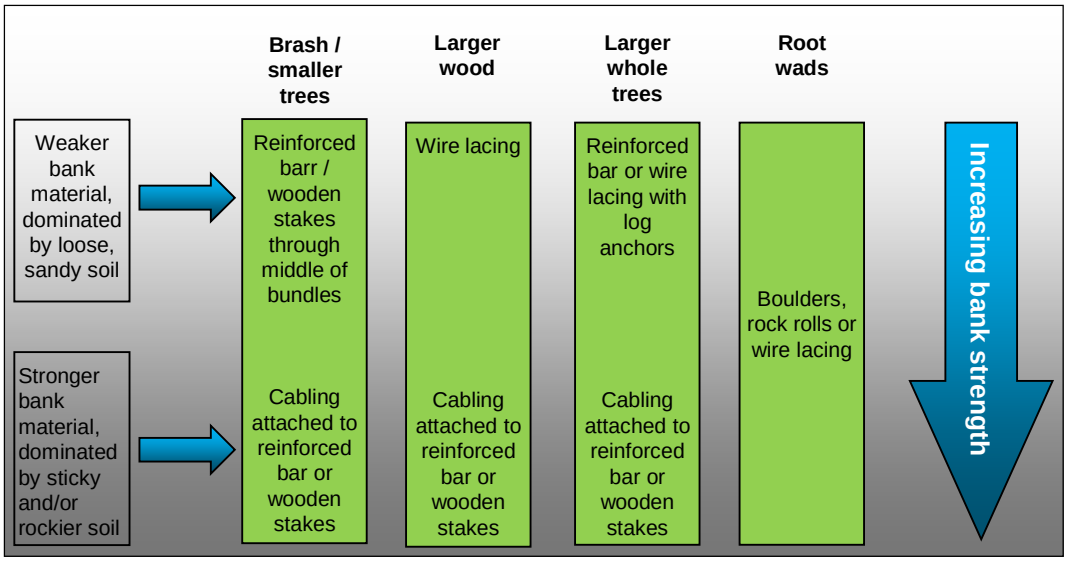
Figure 3: Matching the technique to the river's energy



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

Live willow stakes and willow spiling can provide protection and support to eroding banks within a range of soil types and flows. Steep banks should be terraced or reprofiled. 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.

Installation should generally include the following steps:

i. All willows should be planted or installed between November and March, this should be done in a manner which does not disturb fish redds (spawning sites) or introduce silt into the river. Planting in this period allows 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

ii. 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

iii. 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).

iv. 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 grows, it will develop the roughness and complexity required to dissipate flow energy.

v. 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.

vi. If you use stones, 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.

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

viii. 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.

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.

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.

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

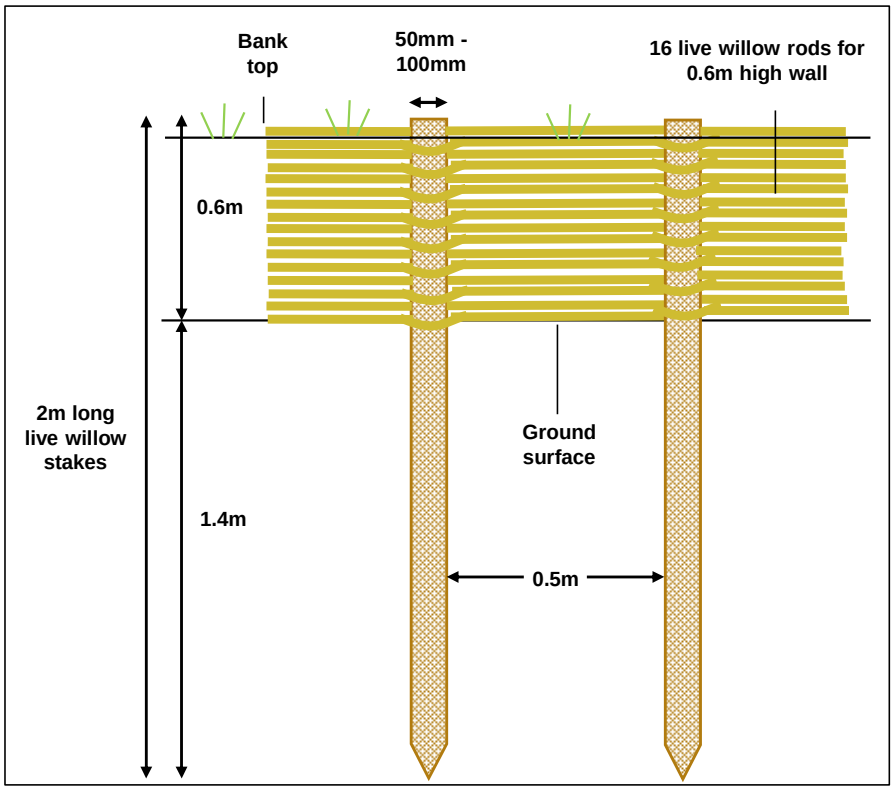
Figure 6b: Example of already vegetated willow spiling used in the Cairngorms in a relatively high energy river.
The photograph was taken after the protection had withstood the floods of the 2015 – 2106 winter

Photo courtesy of Spey Fishery Board

Figure 6c: Willow spiling for bank protection being installed

Figure 6d: Willow spiling for bank protection two years after construction[1]

Figure 7: Details of willow stakes and rods installation



Key points, recommendations and case studies are shown in Section 8

1. Revetting and Supporting River Banks. River Restoration Centre

7.2 How to use brash and small trees

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.

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.

The techniques involve:

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

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.

Brash use is appropriate for many situations. It can be used on its own but is particularly useful when used in combination with other techniques e.g. filling gaps between rootwads.

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.

Installation should proceed as follows:

i. 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.

ii. 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).

iii. Secure the brash, small trees and large branches using one of the following techniques:

(a) 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).

(b) 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).

(c) Augment the strength of the structure described 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 8a: Good example of brash bundle packing

Photo courtesy of Gloucester Angling Club.
www.gloucesteranglingclub.co.uk

Figure 8b: Good example of brash installation

Photo courtesy of Professor Malcolm Newson

Figure 9: Installation of willow and brash between wooden stakes

(a) Before work commences on the eroding bank face

Wild Trout Trust

(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.

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

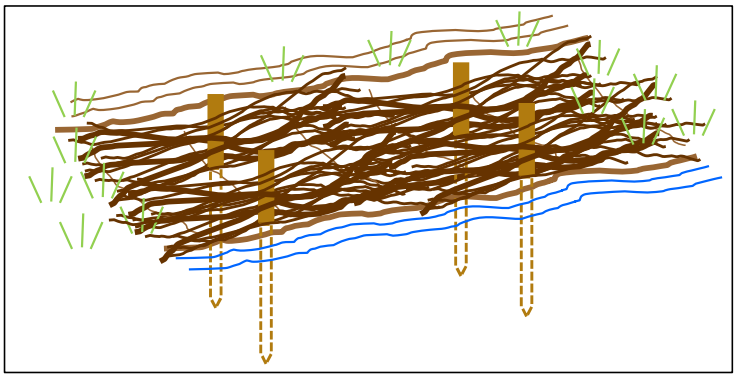


Figure 10b: Securing brash, brash bundles, small trees or large wood to the bank face with wooden stakes or reinforced bar and stainless steel cabling

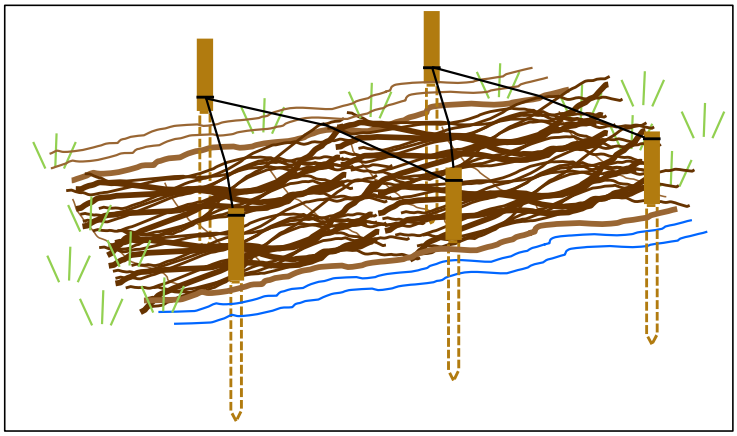
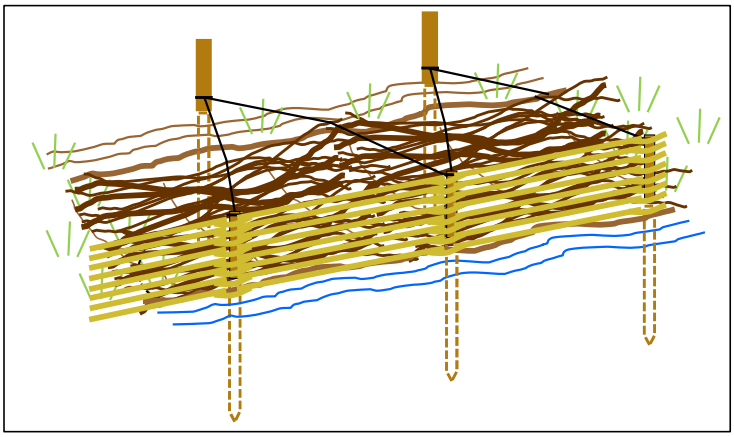


Figure 10c: Securing brash, brash bundles, small trees or large wood to the bank face with wooden stakes or reinforced bar, stainless steel cabling and willow spiling



Key points, recommendations and case studies are shown in Section 8

7.3 How to use large wood

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.

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

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

ii. 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.

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

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

v. 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).

vi. 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.

As well as the points above many of the principles for its use are very similar to those outlined in section 7.2 regarding brash and small trees above.

To date most examples using large wood in Scotland have been in combination with some of the other techniques in this guide. If you have experience of using large wood by itself, SEPA would be interested in hearing from you.

Key points, recommendations are shown in Section 8

Figure 11: Examples of large wood used for river bank protection

7.4 How to use large trees

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

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

i. 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[2] 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.

ii. 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).

iii. The tree should be anchored both at its trunk and towards its tip using one of options (a) and (b) below to secure it to the channel bed and one of options (c) and (d) below to secure it to the bank:

(a) 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).

(b) 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).

(c) 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.

(d) 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.

iv. 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

[2] http://mdc.mo.gov/property/pond-stream-care/streams-tree-revetments-stabilize-stream-banks.

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.

v. Repeat steps (i) to (iv) above 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.

Figure 12: Plan view of large tree placement and fixing techniques for different bank material strengths

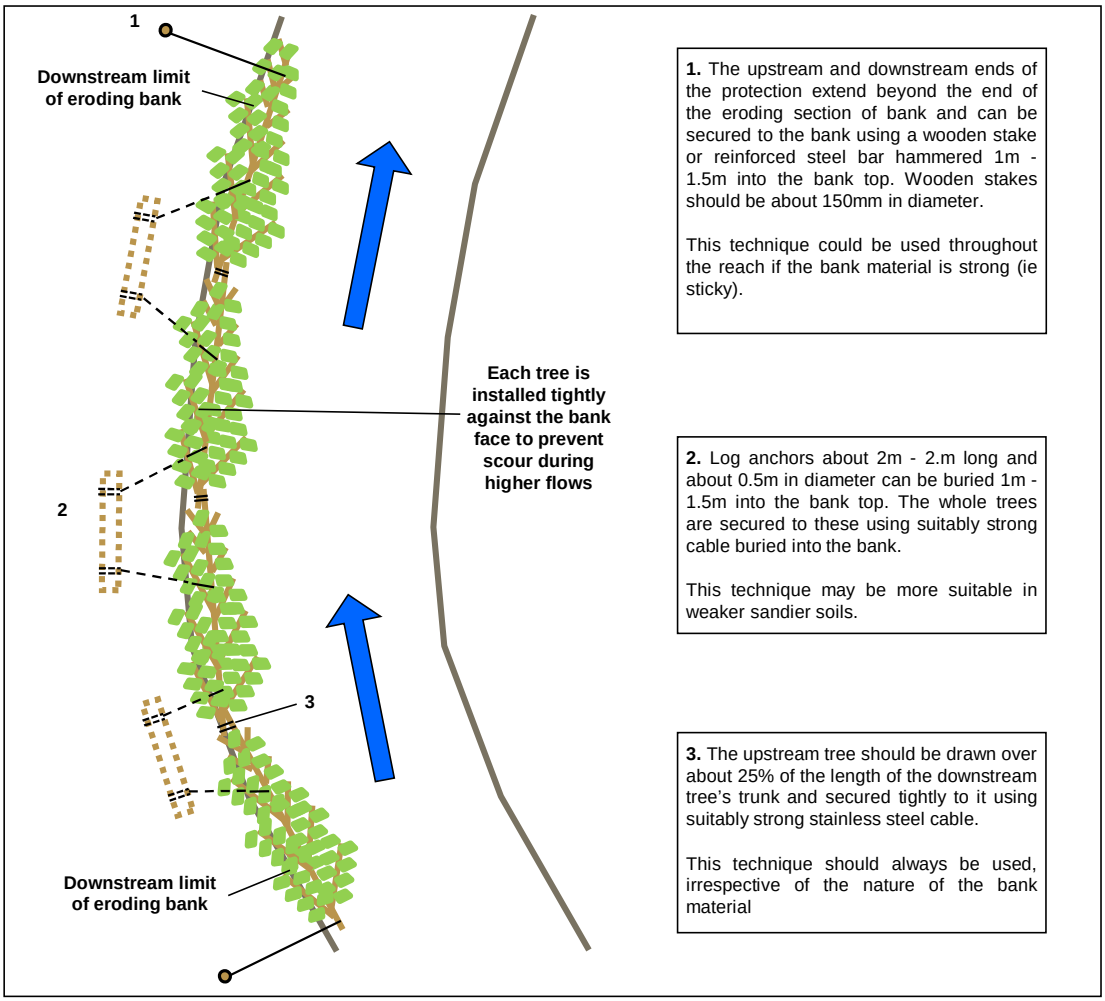


Figure 13a: Cross-sectional view of large tree placement secured using reinforced steel bar driven into the channel bed

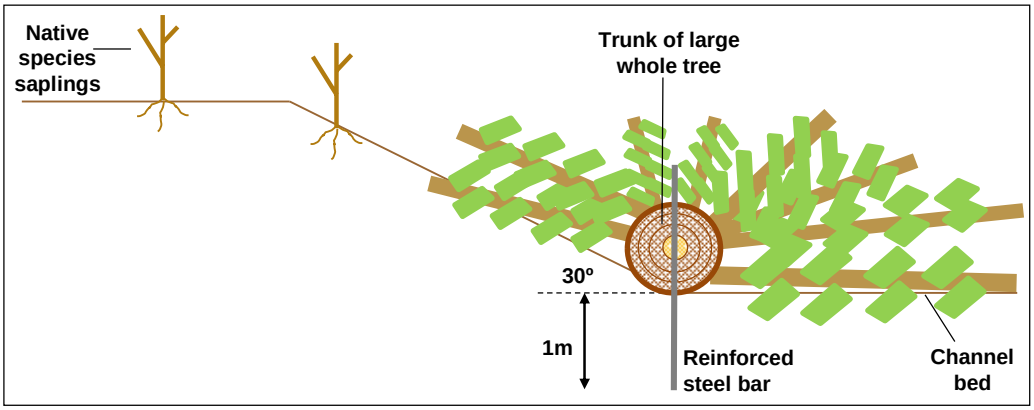


Figure 13b: Cross-sectional view of large tree placement secured using wire lacing attached to wooden stakes or reinforced steel bar driven into the channel bed

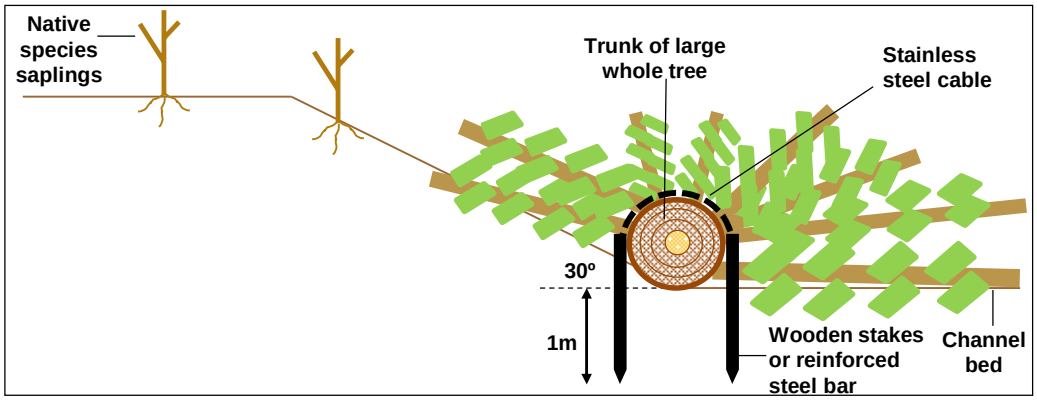


Figure 13c: Cross-sectional view of large tree placement secured using steel cabling attached to bank top wooden stakes or steel reinforced bar

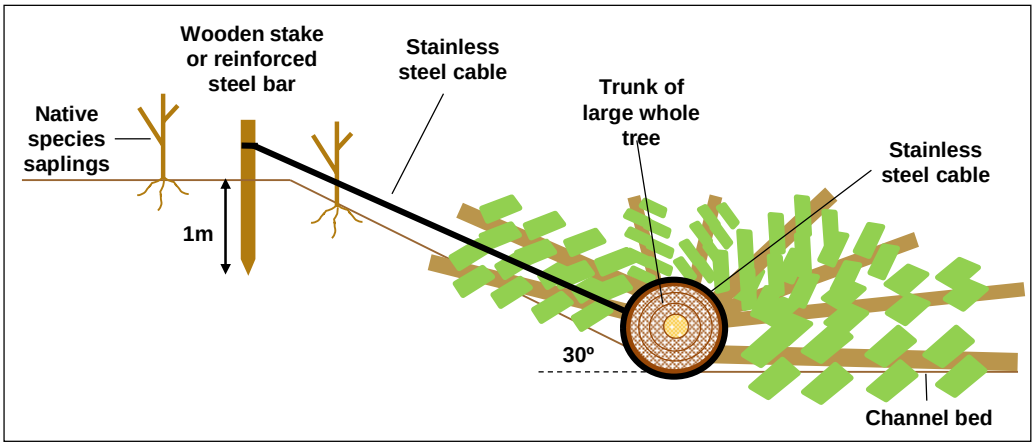


Figure 13d: Cross-sectional view of large whole tree placement secured using steel cabling attached to loch anchors buried in the bank

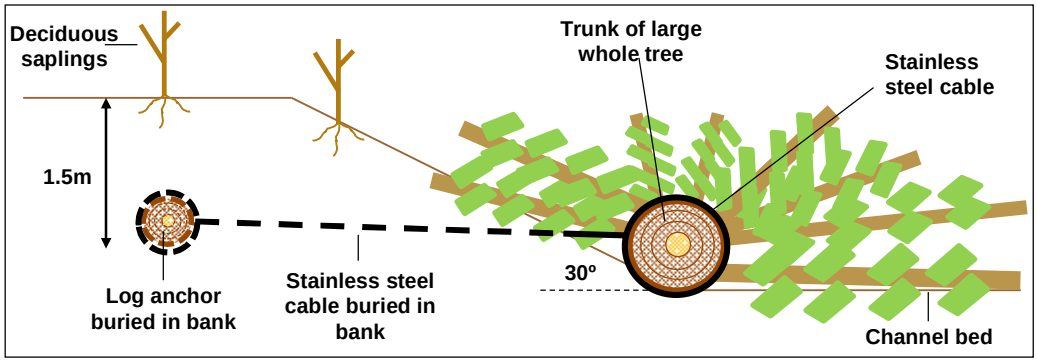


Figure 14: Example of bank protection using large trees

[Key points, recommendations and case studies are shown in Section 8]

7.5 How to use root wads

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.

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

i. 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.

ii. Excavate a trench either parallel or at 20º to the direction of flow (Figure 15) and sufficiently long to take the trunk length determined in step i. above.

iii. Root wads can be susceptible to scour at the toe. It's very important that the root plate is set into the bed and the stream side surface should be a rough as possible.

iv. If toe protection is considered then footer logs approx. diameter 30cm can be partly set into the bed as shown in figures 7d & e. The root wad is installed on top of this with the root plate on the stream side of the footer log. Additional live wood stakes and brash can be placed in front of the log to provide additional roughness.

v. The lowest layer of the root plate 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.

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

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

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

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

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

viii. 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[3]

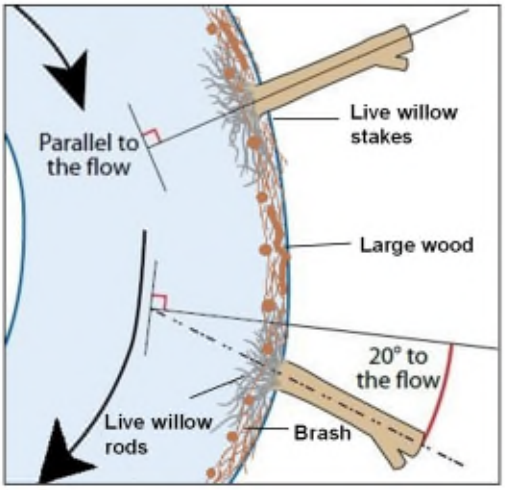
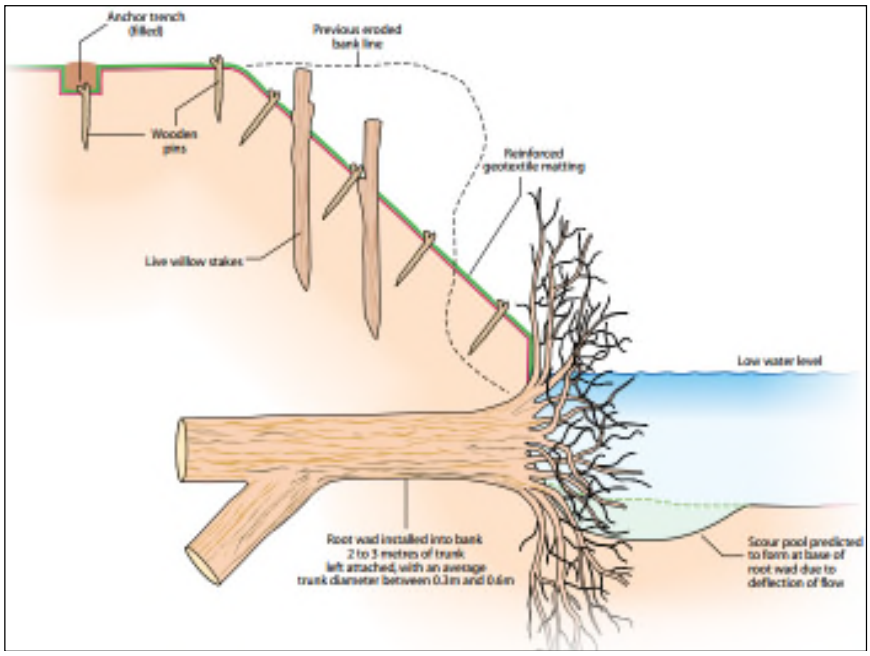


Figure 16: Profile view of bank protection using root wads



[3] Modified from: River Restoration Centre (2016), Manual of river restoration techniques.

Figure 17a: Cross-section showing root wad stabilisation using individual large boulders

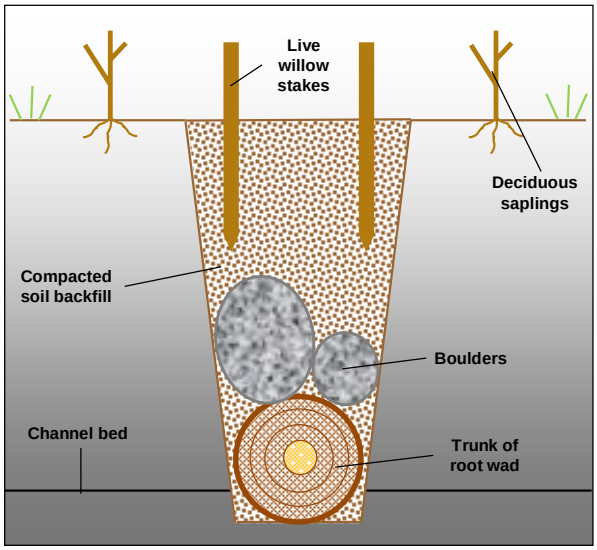


Figure 17b: Cross-section showing root wad stabilisation using wire rope lacing

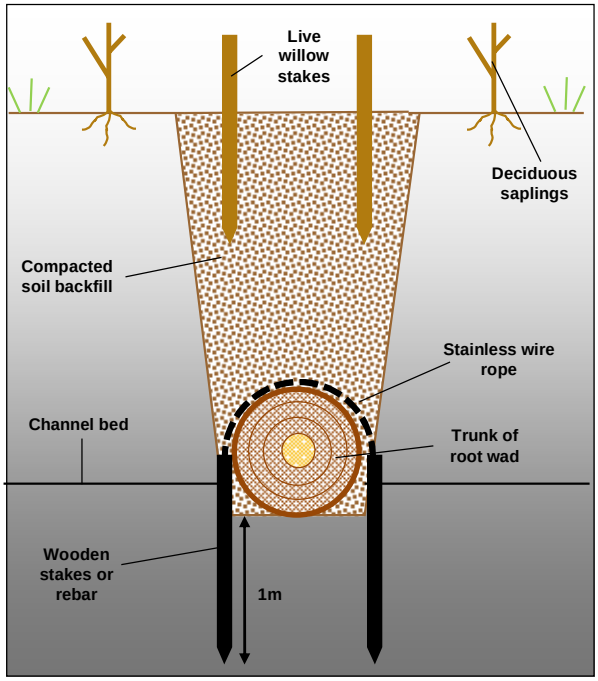
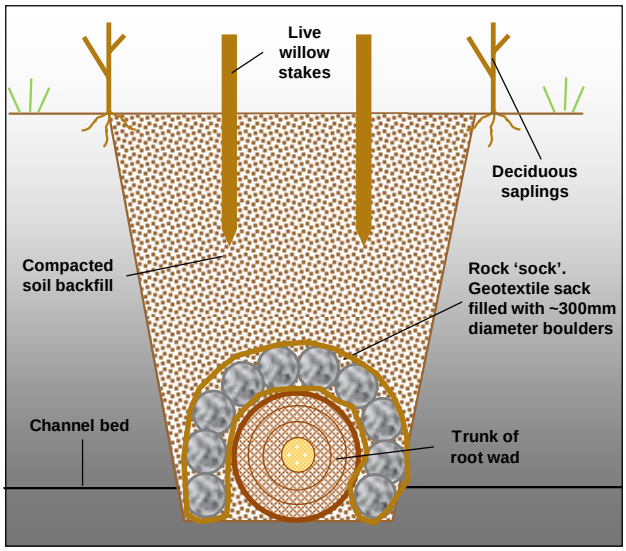
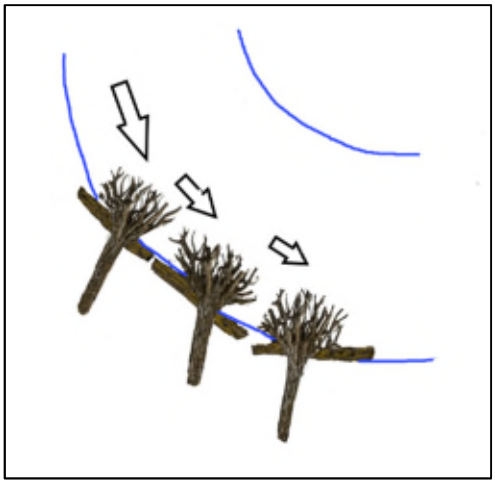
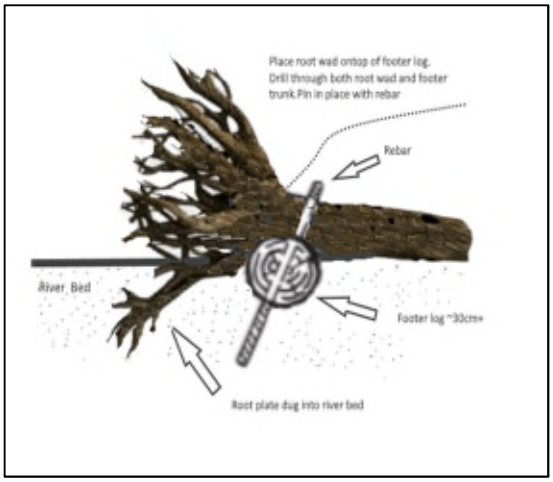


Figure 17c: Cross-section showing root wad stabilisation using a rock roll



Figures 17d & e: Toe protection can be achieved by setting a log partly into the bed then placing the root wad on top. The root wad can then be secured to the footer log by drilling through both trunks and using a rebar. It's important to maintain roughness in front of the footer log.





Key points, recommendations and case studies are shown in Section 8

8 Key Points, Recommendations and Case Studies

In 2017/18 SEPA funded a number of demonstration sites. SEPA have been assessing these and other sites across Scotland to further develop our knowledge of using these techniques. The points below have been produced to share the knowledge gained to date and will be updated as new findings come to light.

8.1 Key Points and Recommendations for all Techniques:

Experience has shown that:

- **Whole tree bank protection works have proven to be an especially effective technique in many high energy rivers in Scotland.**
- It is best to install protection in the later part of winter (Feb – Mar) to reduce exposure of recently disturbed ground to high flows and to provide a full first year growing season to help the establishment of vegetation.
- The first two years of establishment and settling in are often the key to success.
- It is very important to inspect the works following high flows and make quick repairs. Some replanting may be necessary.
- Brash and large pieces of wood are very good for making small repairs.
- Livestock must be kept away from the finished works. Not only can they eat planted tress they can also do damage by trampling. Be aware that livestock may be able to access the works from the opposite bank.
- Species of willow especially suited for these techniques are: osier; white and crack willow as they are fast growing and quick to establish.
- Goat willow is also suitable and will produce lower busy growth, however it can be slower to establish.
- Use live wood ‘willow’ stakes as much as possible as opposed to ‘normal’ timber posts as these establish quickly and result in a rougher and more resilient bank.
- Bank toe protection may be required in some situations to allow time for bank roughness to develop i.e. from planted trees. This protection should be rough wood/brash or small/medium sized stones similar to what is already on the channel bed and be submerged during normal flows.
- All methods benefit from riparian planting of trees on the banks and bank top. Species such as alder, aspen, hazel and willow are all suitable.
- Trees such as alder and willow should be coppiced after about 2 years to establish bushy growth and occasionally thereafter unless you want larger trees.

Pictures below of the main techniques: willow spiling; brash; whole trees & root wads.




8.2 Key Points, Recommendations and Case Studies: Willow Spiling

In 2017/18 SEPA funded a number of demonstration sites. SEPA have been assessing these and other sites across Scotland to further develop our knowledge of using these techniques. The points below have been produced to share the knowledge gained to date and will be updated as new findings come to light.

Experience over time has shown that:

- White, Crack willow and Osier are well suited willow species.
- Whilst suitable note that goat willow is slower to establish than other species.
- Steep upper banks should be re-profiled & terraced (no steeper than ~1 in 2).
- Vertical posts: ideally live wood, need to be driven in 2/3rd of length & installed at least every 0.5m.
- Willow rods 2- 6m in length to make spiling walls (~20-30 rods high.)
- Each spiling wall should ideally be in the range of 0.6m -1m high.
- Terrace width should be greater than the height of the each spiling wall.
- Bank toe protection may be required in some cases to allow time for bank roughness to develop i.e. from planted trees. This protection should be rough wood/brash or small/medium sized stones similar to what is already on the channel bed and be submerged during normal flows.
- Install between November and the end March, later part is recommended.
- Exclude livestock. Be aware that livestock may be able to access the works from the opposite bank.
- Coppicing is recommended after ~2yrs to promote bushy growth.
- Inspect after high flows and repair any damage quickly esp. in the first few years.
- During establishment watering may be needed if there are long dry periods.

Pictures above showing willow spiling with very strong growth after 8 months (left). Live white willow vertical posts and low gradient bank (right).

Pictures above showing steep bank with little or no re-profiling, narrow terraces, vertical posts too short and few live stakes all contributing to partial failure.

Case Study: Willow Spiling - River Don, near Dyce, Aberdeen.

Project description: 230m white willow spiling, arranged in two 0.6m high terraces, on the outside of a bend on large but relatively low energy river. Adjacent land is used for livestock farming. The bank was regraded to a slope of 1 in 2. Biodegradable geotextile was used to cover bare soil on the terraces and bank top. Extracted turf was replaced on top. The whole area of work was fenced off. Project was installed in April 2018. Costs for a project such as this excluding fencing are ~£45 -£90/m.

Progress to February 2020: The white willow spiling has established very well and grown quickly. The willows were coppiced after 2 years and have provided willow for use in other projects. There have been no problems and it has been successfully preventing further land loss.

Pictures below showing before, just after and 1 year after installation:

8.3 Key Points, Recommendations and Case Studies: Brash & Small Trees

In 2017/18 SEPA funded a number of demonstration sites. SEPA have been assessing these and other sites across Scotland to further develop our knowledge of using these techniques. The points below have been produced to share the knowledge gained to date and will be updated as new findings come to light.

Experience over time has shown that:

- Use of brash is a very versatile and flexible technique and doesn't need a high level of skill or experience to install.
- It can actively trap sediment helping to rebuild banks.
- Brash should ideally be secured using live willow stakes driven through matrix or live stakes and wire stretched over the matrix.
- Stakes and posts should be driven in around two thirds of their length, at least 1m deep.
- The effectiveness can be enhanced by weaving live willow rods or large branches between stakes.
- As with other techniques they should ideally be supplemented with live willow stakes and riparian planting.
- Exclude from livestock. Be aware that livestock may be able to access the works from the opposite bank.
- If continued access to the bank, say for angling, is required non live brash and stakes can be used, with fencing this can still achieve a stable bank.
- Repair any weak spots that may show after high flows with further brash and live wood stakes/cuttings.
- This technique is also suited for making small repairs to other techniques. E.g. filling any small scour holes around spiling; root wads or whole trees.

Photos below show good use of brash on the River Ehen in West Cumbria showing how it trapped sediment to repair and protect bank. Willow brash was secured with longer branches as batons. Photos courtesy of Gareth Pedley (Wild Trout Trust)

Case Study: Use of Brash – River Don

Project description: 40m of brash and small trees was used to protect an eroding bank on a side channel of the River Don towards the upper catchment. At this point the river is moderate to high energy. Live willow stakes were used to secure the brash and small trees. It was installed in Feb 2017. The cost was ~£40/m.

Progress to February 2020. The protection has performed well with no further erosion in this area. One issue that came to light was that the goat willow grew slowly or failed in places but given time this has now established well. The brash has held well and the willow is now starting to grow through it. A large amount of sediment has accumulated in front of the works. These sediment changes are seen as beneficial to the bank protection.

Below left shows bank before (2016) and right just after installation (June 2017)

Below shows bank in May 2019 with new willow growth from the laid branches

8.4 Key Points, Recommendations and Case Studies: Using Whole Trees

In 2017/18 SEPA funded a number of demonstration sites. SEPA have been assessing these and other sites across Scotland to further develop our knowledge of using these techniques. The points below have been produced to share the knowledge gained to date and will be updated as new findings come to light.

Experience over time has shown that:

- The technique is especially well suited to all Scottish rivers.
- There have been a number of sites in Scotland where whole trees have been used in recent years. So far they are working very well and some have been subject to very high flows.
- Securing the trees with stainless steel cable to buried log anchor or large anchor posts has proved an effective method.
- Trees should be laid trunk pointing upstream, each tree overlapping by 25%.
- Banks can be re-profiled to no steeper than 30 degrees (approx. 1 in 2)
- It is important to supplement the works with tree planting especially live willow stakes (such as white or crack willow) to help provide long term bank strength
- Pay particular attention to protecting the up and downstream ends of the works.
- Fence off the works and make sure livestock cannot gain access to the bank protection by crossing the river- further trees brash etc. can help fend them off.
- Below are some comments from farmers and landowners after having this technique in place for about 2 year:
    - In early 2020 one of the sites experienced the highest ever flow recorded[4]. The farmer said "*With the extreme river levels I expected my bank protection of whole trees to be gone but I was very relieved to find it intact and it had protected the bank completely with no loss of land. An unprotected stretch downstream has lost 4 feet of bank in the same flood*"
    - "*It's been working very well an I'm very happy with it*"
    - "*It's good, no problems with erosion of the bank. I've now fixed the area where the cows managed to get in by placing further trees and brash. I'm now using the technique in another area on the farm*"

Photographs below show two sites where whole trees have been used successfully.

[4] Flow data taken from nearby SEPA flow gauging station

Case Study 1 Whole Trees: Teviot Water near Teviothead, Borders

Project description: 62m of eroding bank protected using whole trees (conifers) on an upland sheep farm. The trees were secured by steel cable to buried log anchors. Willow, alder and aspen trees were planted behind the protection and it was all fenced off. It was installed spring 2018. The cost was ~£116/m excluding fencing.

Progress to February 2020: The works have been subjected to several high flows in winter 2019/2020 and have performed well. Establishment of the planted trees was slow to start with because of very dry weather in 2018 but has since come on well. There have been no problems and no further loss of land. The farmer is very pleased with the technique and will use it again.

Below left show eroding bank before works in 2017. Middle picture shows the same bank after works in 2019 and the right hand picture show the area protected 2019.



Case Study 2 Whole Trees: Liddle Water near Newcastleton.

Project description: 180m of eroding bank protected using whole trees (conifers) on an upland sheep farm. Trees were secured by steel cable to large anchor posts. Willow was planted on the bank behind the works and it was all fenced off. It was installed in spring 2018. The cost was ~£31/m excluding fencing and some prior bank re-profiling work.

Progress to February 2020: The works have been subjected to several very high flows during winter 2019/2020 and have protected the bank with no further erosion or loss of land. There was some loss of small planted willow whips due to high flows and dry weather. The farmer is very pleased with performance.

Below left is eroding bank before works (2016). Below right is protected bank showing growth of willow (2019)


8.5 Key Points, Recommendations and Case Studies: Using Root Wads

In 2017/18 SEPA funded a number of demonstration sites. SEPA have been assessing these and other sites across Scotland to further develop our knowledge of using these techniques. The points below have been produced to share the knowledge gained to date and will be updated as new findings come to light.

Experience over time has shown that:

- The root wads **must** be partly set into the river bed. The trunk should be level with or very close to the river bed to help deal with toe scour.
- The root plate should contain as many roots and as rough as possible and be as large as is practical to transport and use.
- Use fairly fresh root wads as the roots will be more flexible. Old root wads may be brittle and not as effective.
- If live willow root wads can be obtained these are often the best as they will grow and further strengthen the bank.
- The root wads must also be properly backfilled with soil, rocks and brash and the ground well compacted. Otherwise a weak spot can be created which is susceptible to rapid erosion.
- To limit scour at the bank toe in higher energy situations make the bank toe as rough as possible (i.e. using brash or other large wood)
- Exclude livestock, be aware they may try to access from the opposite bank.
- Root wads work well in conjunction with brash.
- Supplement with tree planting around the root plate and on the bank to provide long term bank strength.
- Inspect regularly after high flows in the first few years and quickly repair any developing issues. Brash and large wood is especially useful for repairs.

Pictures below show two exmaples of well installed root wads:


Pictures below show root wads which were not set into the river bed resulting in toe scour and undermining (left). This progressed to washout of the bank behind (right).


Case Study Root Wads: Milton Burn, Maidens, Ayrshire

Project description: 75m of eroding bank protected with brash bundles and roots wads on a sharp bend on a small burn with highly erodible sandy banks. Willow was planted on the bank behind and it was all fenced off. It was installed September 2017. The cost was ~£88/m excluding fencing.

Progress to February 2020: The works have performed well protecting the bank from further erosion. In contrast, unprotected banks downstream have continued to erode at a rate of about 1m per year. Good bankside vegetation has now established. Some minor repairs, including filling small holes around root wads with brash, were undertaken during 2019. Additional planting of willow was also carried out as some of the original planting was lost during the drought of 2018.

Pictures below show eroding bank before works and during installation (2017)

Pictures above are courtesy of Chris Savage, Cassillis Estate.

Pictures above showing the works 2 years after completion.

9 Sources of Further Information

- Anstead, L. and Boar, R.R. (2010). Willow spiling: review of streambank stabilisation projects in the UK. *Freshwater Reviews*, 3, 33-47. DOI: 10.1608/FRJ-3.1.2.

- Fishery Management Scotland – contains a list of all fishery and river trusts and district salmon fishery boards in Scotland
- http://fms.scot/

- Scottish Natural Heritage (soon to be renamed Nature Scot) –Scotland's nature agency. Works to improve our natural environment in Scotland and inspire everyone to care more about it.
  https://www.nature.scot/

- River restoration centre -manual of river restoration techniques
  https://www.therrc.co.uk/manual-river-restoration-techniques

- Scottish Government Rural Payments and Services – Information, guidance and online services for people in rural areas across Scotland including agriculture and forestry.
  https://www.ruralpayments.org/

- SEPA Natural Flood Management Handbook
  https://www.sepa.org.uk/media/163560/sepa-natural-flood-management-handbook1.pdf

- Natural Flood Management Network Scotland – case study finder
  https://www.nfm.scot/case-studies

- SEPA River Engineering Good Practice Guide Bank Protection
  https://www.sepa.org.uk/media/150971/wat_sg_23.pdf

- SEPA – Engineering Guidance – page lists various documents
  https://www.sepa.org.uk/regulations/water/engineering/engineering-guidance/

- Woodland Trust – source of information about native tree species
  https://www.woodlandtrust.org.uk/