SEPA
Scottish Environment Protection Agency

Engineering in the water environment:
good practice guide

Sediment management

First edition, June 2010

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Your comments

SEPA is committed to ensuring our good practice guides are useful and relevant to anyone carrying out engineering activities in Scotland's rivers and lochs.

We welcome your comments on this good practice guide so that we can improve future editions. A feedback form and details on how to send your comments to us can be found in Appendix 2.

Engineering in the water environment good practice guide Sediment management

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Contents

1 Introduction

This document is one of a series of good practice guides produced by SEPA to help people select sustainable engineering solutions that minimise harm to the water environment. The guide is intended for anyone considering engineering activities in rivers or lochs and also for SEPA staff who provide advice on, and regulate, engineering in the water environment.

It is important to recognise that any engineering works must be designed to suit site specific conditions. This document addresses the environmental aspects that should be considered when undertaking a project. It is not intended to be a technical design manual.

Regulations

New engineering activities (including sediment management) in Scotland's rivers, lochs and wetlands require an authorisation under the Water Environment (Controlled Activities) (Scotland) Regulations 2005 (also known as the Controlled Activities Regulations or CAR).

There are three different levels of authorisation under CAR, based on the risk an activity poses to the water environment.

General Binding Rules (GBRs) have been specified for certain low risk activities in the regulations. Provided an activity can comply with these rules, no application to SEPA is required.

Registrations are required for medium risk activities. Operators must apply to SEPA to register an activity.

Licences are required for high risk activities. Operators must apply to SEPA for a licence.

Details of what level of authorisation an activity requires can be found in the *CAR Practical Guide* on our website at: www.sepa.org.uk/water/water_publications.aspx

SEPA has a position statement which sets out our regulatory approach to applications for sediment management. This states that **we have a presumption against sediment removal unless it is sustainable**. This position statement is available from our website at: www.sepa.org.uk/water/water_regulation/guidance/idoc.ashx?docid=660d8a75-54d6-454f-9ced-046a66a4947b&version=-1

In addition to complying with environmental standards, we expect new engineering activities authorised under CAR to be carried out in accordance with good practice.

SEPA defines good practice as: "…the course of action which serves a demonstrated need, while minimising ecological harm, at a cost that is not disproportionately expensive."

Following the basic principles of good practice shown in the box below will to help to ensure that the impact on the water environment is minimised and will also help applicants fill in licence application forms. The sections in this guide are based around these basic principles.

Basic principles of good practice

Demonstrate need	Sometimes engineering activities may be carried out to address a perceived problem rather than a real problem. Eg removing sediment from an area where sediment deposition is not increasing. Quantifying the problem will help to determine if engineering is required and will ensure that any solution is proportionate to the scale of the problem.
Consider a range of options	Most engineering requirements can be addressed in a number of ways so a range of options to address any problem or need should be considered. The cause of any problem should be identified and options that address the cause, not the symptoms, should be considered. Without considering a range of options it is not possible to determine if the chosen approach represents the most suitable option - ie the option that minimises ecological harm at a cost that is not disproportionately expensive.
Include mitigation	All reasonable mitigation should be identified and implemented eg ensure measures are taken to reduce the risk of pollution when works are being carried out.

2 Sediment in rivers and lochs

Key points

- Water carries sediment downstream gradually over time, particularly during high flows and floods, like a 'jerky conveyor belt'.
- The natural size and shape of a river is balanced and has evolved over time to accommodate the amount of water and sediment moving through the system.
- River sediments and the movement of these sediments form habitats such as pools, riffles, bars and islands that are important for plants and animals.
- Sediment removal can lead to the loss of or damage to habitats, plants and animals.
- Sediment removal can disturb the natural 'balance' of a river and can cause serious problems with river stability (eg excessive erosion).
- Dredging rivers can increase flood risk downstream.

2.1 What is sediment?

Sediment covers all natural river bed substrate from fine silts and sands up to large boulders (see Figure 1 below).

Figure 1: Different sizes of river sediments; sand (top left), gravel (top right), pebble and cobble (bottom left), boulder (bottom right).

2.2 What is sediment management?

Sediment management covers a wide range of activities that includes anything from the small scale removal of dry gravels to the dredging of whole river channels and the reintroduction of removed sediment into the water environment. Historically, sediment management has been carried out for several reasons, including reducing flood risk, reducing bank erosion, for use as aggregate and to improve land drainage.

2.3 The natural role of sediment in rivers

Sediment in rivers forms the substrate over which water flows and on which plants and animals thrive.

Sediment movement

Water carries sediment downstream gradually over time, particularly during high flows and floods. Large volumes of sediment can be moved in floods and deposited at a location on a temporary basis then moved along to another location during the next flood event. This natural movement of sediment along a river channel has been likened to a 'jerky conveyor belt'.

Water naturally erodes sediment from the bed and banks of rivers (source) and transports it downstream through the catchment, depositing it in areas of 'lower energy' eg where the flow is slower and areas of land are flatter (channel gradient is lower), such as flood plains and the inside of meander bends, resulting in features including gravel bars and islands (see Figure 2 below).

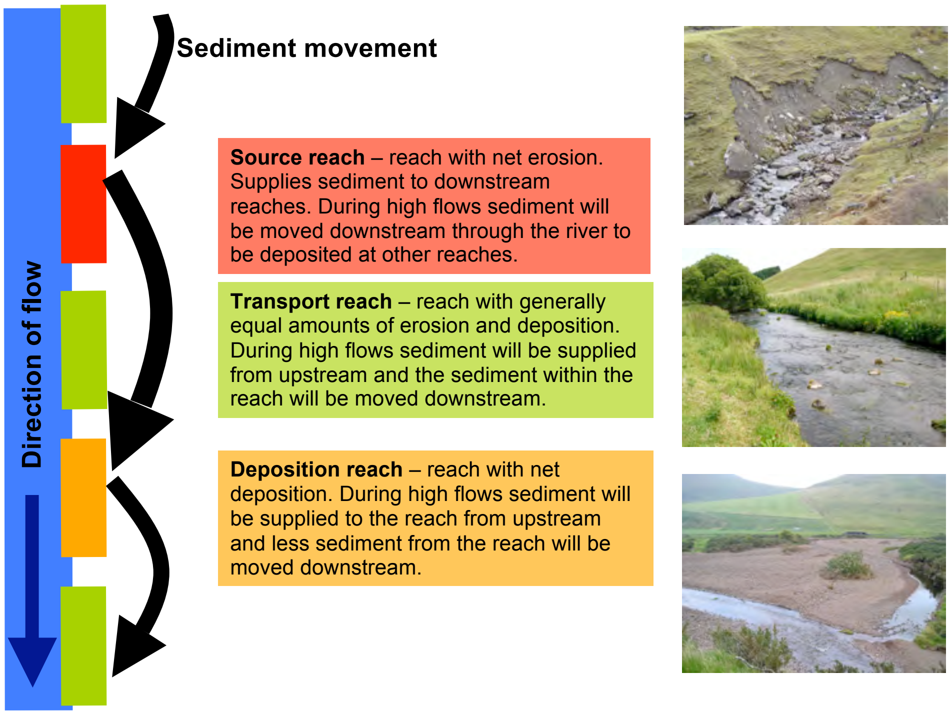

Figure 2: Sediment is moved through the river system during high flows like a 'jerky conveyor belt' with source → transport → deposition areas.

Channel equilibrium

A river's shape will naturally adjust to accommodate the amount of water and sediment moving through the system. The shape of a river is largely created during high flows as sediment is moved downstream through erosion, transport and deposition. In undisturbed rivers, these processes create a river shape that is accommodates the typical range of floods and the amount of sediment available. Sediment removal disturbs this natural balance and processes, and can cause serious problems with river stability (eg excessive erosion) as well as habitat loss.

2.4 The natural role of sediment in lochs

Sediment also plays an important role in lochs. As with rivers, sediment in lochs forms the substrate over which water flows and on which plants and animals thrive. Sediment is supplied to lochs from in-flowing watercourses and from erosion of the loch bed and banks. The movement of sediment along and around the loch shore is principally controlled by wind-generated waves, while the movement of sediment between shallower and deeper sections of the loch is controlled by both waves and variations in loch water level. This movement of sediment creates features such as beaches, spits and cliffs. As in rivers, the loch's natural shape and distribution of habitats is in balance with the rate at which sediment is transported into, around and out of the loch. Sediment removal can disturb the natural balance and processes, having a negative impact on the loch habitats and the plants and animals that depend on them.

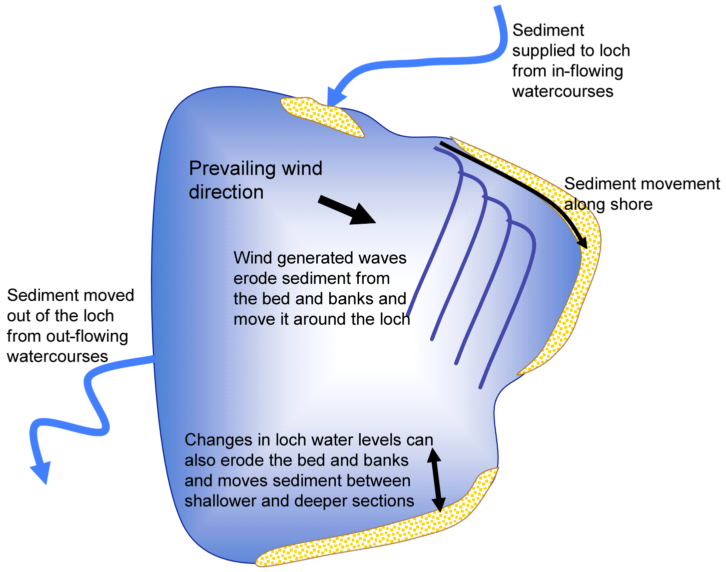

Figure 3: Sediment movement in lochs.

2.5 The ecological value of sediment

Habitat provision

River flows, especially high flows, continually move and sort river sediments into features such as pools, riffles, bars and islands creating a range of habitats important for plants and animals (see Figure 4).

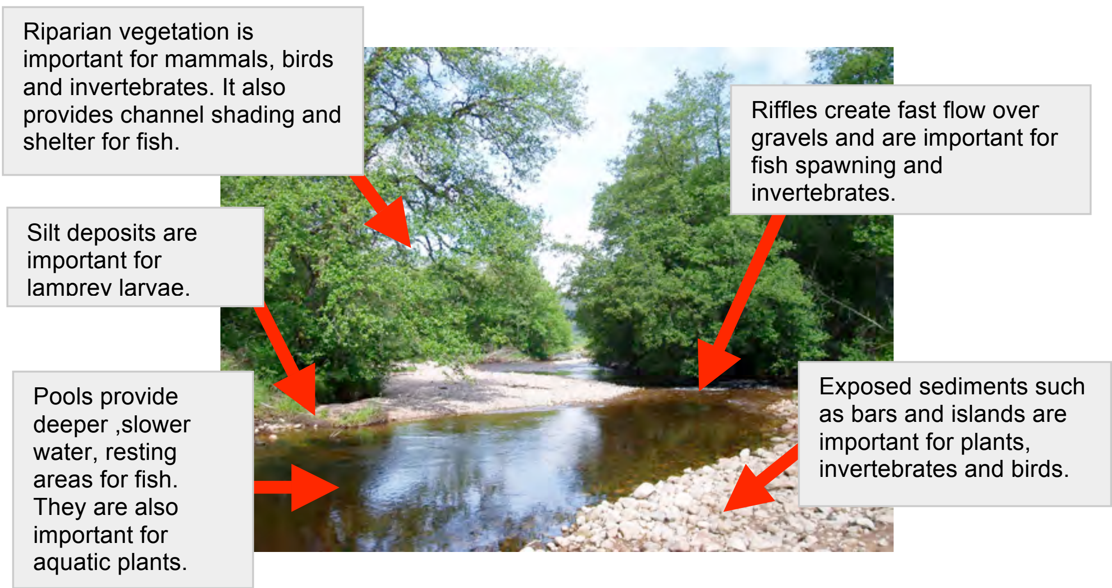

Figure 4: River flows sort sediments into a wide range of different habitats.

Many important species rely on river sediments for survival. For example Atlantic salmon and lamprey migrate upstream as adults into rivers to reach spawning areas, which are normally clean stony or gravelly stretches of faster flowing water (see Figure 5). They spawn in these areas, laying eggs in nests made by moving stones to form a shallow depression. After hatching, both species move to other parts of the river to feed and grow. Freshwater pearl mussels are globally very rare and Scotland supports some of the most important populations in the world for this species (see

Figure 6). Freshwater pearl mussels require clean river sediments and live buried in coarse sand or fine gravel and rely on a healthy salmon or trout population for the dispersal of juveniles.

Figure 5: Salmon rely on clean river sediments such as gravels for spawning and feeding. © Scottish Natural Heritage

Figure 6: Freshwater pearl mussels live in clean sands and gravels. © Sue Scott and Scottish Natural Heritage

The sediment transported into and around lochs is also important for creating habitats that support a large variety of plants and animals (see Figure 7). Wave washed shores support distinctive invertebrate assemblages, and the coarser sediments found near inlets and outlets may be important spawning areas for fish species such as Arctic charr.

Figure 7: Left: waves washed shore in lochs are important for a range of invertebrates and shallow water offshore provides habitat for aquatic plants. Right: inlets of lochs can be important fish spawning areas.

Continual change

As sediments continually move in rivers, new habitats are created and older habitats are reworked. This provides a range of different habitat types and ages, which is important for maintaining a diverse range of plants and animals including rare species of plants and insects such as river shingle beetles, which need bare river gravels to colonise.

The continually changing shingle islands of the River Tummel (see Figure 8) in Perth and Kinross have been designated as a Site of Special Scientific Interest (SSSI) and a Special Area of Conservation (SAC) to protect the biodiversity that the islands support. These shingle islands, formed from river gravels, support a wide range of plants and invertebrates which in turn provide shelter and food for breeding birds such as ringed plover and common terns.

Although lochs are generally less dynamic than rivers, and the volumes and rates of sediment movement are much lower, the dynamics of sediment movement around loch shores are nevertheless just as important for generating and maintaining habitats as in rivers.

Figure 8: Gravels on the River Tummel have conservation designations for their biodiversity.

Figure 9: River gravels are important habitats for many animals including the ringed plover that nests in river gravels. © Scottish Natural Heritage

2.6 Impacts of sediment removal

Sediment removal can have a significant adverse impact if it is undertaken without careful consideration.

Impact on ecology

Removing sediment from rivers and lochs can directly lead to the loss of the plants and animals that live in the sediments such as salmon and lamprey eggs and juveniles (see Figure 10), bird nests and eggs and protected species such as fresh water pearl mussels.

Figure 10: Juvenile lamprey stranded after dredging in a Special Area of Conservation.

Fresh water pearl mussels are a protected species under the Wildlife and Countryside Act 1981. It is an offence to kill, injure or disturb any fresh water pearl mussels or to damage their habitat. It is the operator's responsibility to ensure that no freshwater pearl mussels will be killed or disturbed during any sediment removal activities. Contact Scottish Natural Heritage www.snh.org.uk for further information.

Sediment removal can also reduce or lead to a loss of habitats such as pools, riffles, gravel bars and beaches, leading to a reduction or loss in the number of plants and animals that require these different habitats for survival.

Removing sediment can also indirectly damage plants, animals and habitats by altering river and loch processes. For example sediment removal may lead to a release of fine sediments that can smother species such as fresh water pearl mussels, and it can smother important habitats such as gravels, which are important for fish spawning.

Reduction in sediment supply downstream (sediment starvation)

Removing sediment at one location reduces the amount of sediment transported downstream in rivers or along the shore in lochs leading to sediment 'starvation' (see Figures 11 and 12). In rivers it may appear that sediment supply is abundant in one location as sediment is supplied from upstream, but if that sediment is continually removed then it will not be supplied downstream of the removal site. Reducing the amount of sediment available downstream or along a loch shore can lead to increased erosion of the bed, banks and shore. This may turn depositional areas into erosional ones or increase the rate of erosion where it already exists. This can lead to the loss or reduction of habitats such as riffles and pools and may cause scour and damage to structures such as bridges and flood walls.

Even taking out small amounts of sediment at one location can lead to a large reduction in sediment supply downstream. Scottish Natural Heritage funded a sediment audit of the River Tay which indicated that removal of even relatively small volumes of gravel could lead to a reduction in sediment available downstream (a copy of this can be obtained from Scottish Natural Heritage on request www.snh.org.uk).

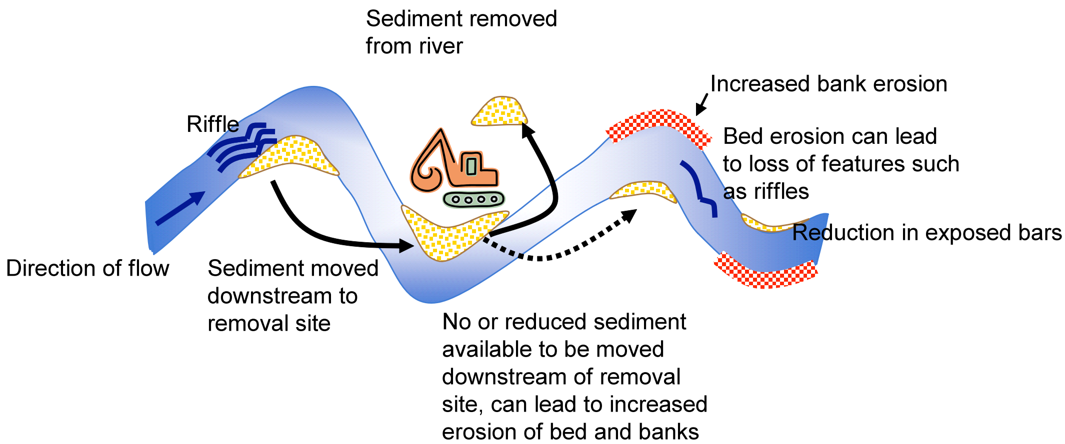

Figure 11: Repeated removal of sediment from one location can reduce the amount of sediment moved downstream of the removal site leading to 'sediment starvation' and erosion downstream.

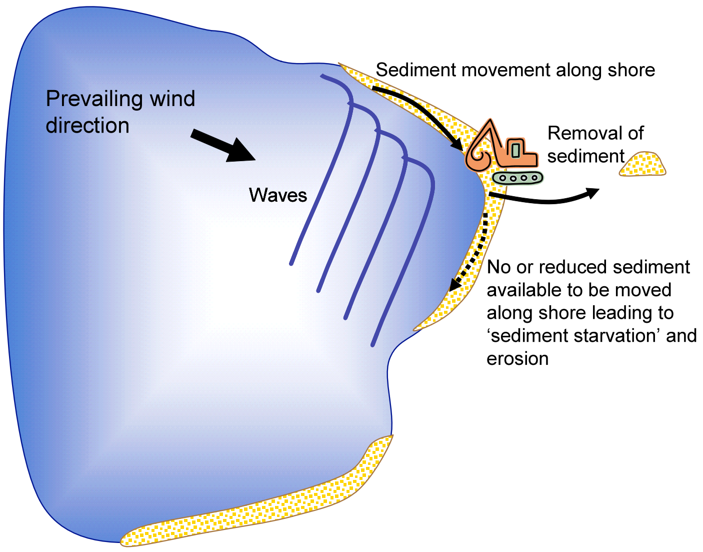

Figure 12: Removing sediment from lochs can lead to sediment starvation.

River instability

In many Scottish gravel bed rivers the surface layer of the river bed is armoured with a layer of generally larger gravels and cobbles that protect the smaller and more erodible materials below. This armour layer can be very strong, which prevents the river bed substrate being transported in all but the largest flood flows (see Figure 13).

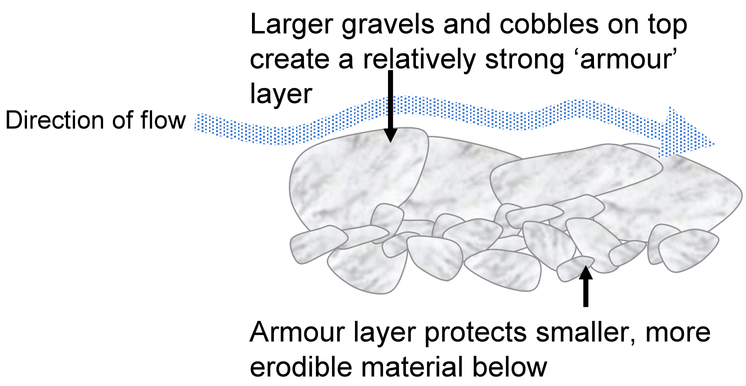

Figure 13: The 'armour' layer on river beds can protect the underlying finer material of the river bed against being transported in all but very high flows.

Removing this armour layer can expose the smaller sized sediments making the river bed substrate much easier to move in smaller flows. This may lead to a gradual increase in erosion and sediment movement or it may trigger sudden significant erosion and instability.

Removing sediment and the armour layer can create a step in the river bed called a 'knick point'. Water flows over the bed very quickly, eroding it and making the knick point move upstream (see Figure 14). This leads to a drop in the river bed level in the eroded channel, undermining banks, overloading the river downstream with sediment and leading to extensive bank erosion and collapse (see Figure 15).

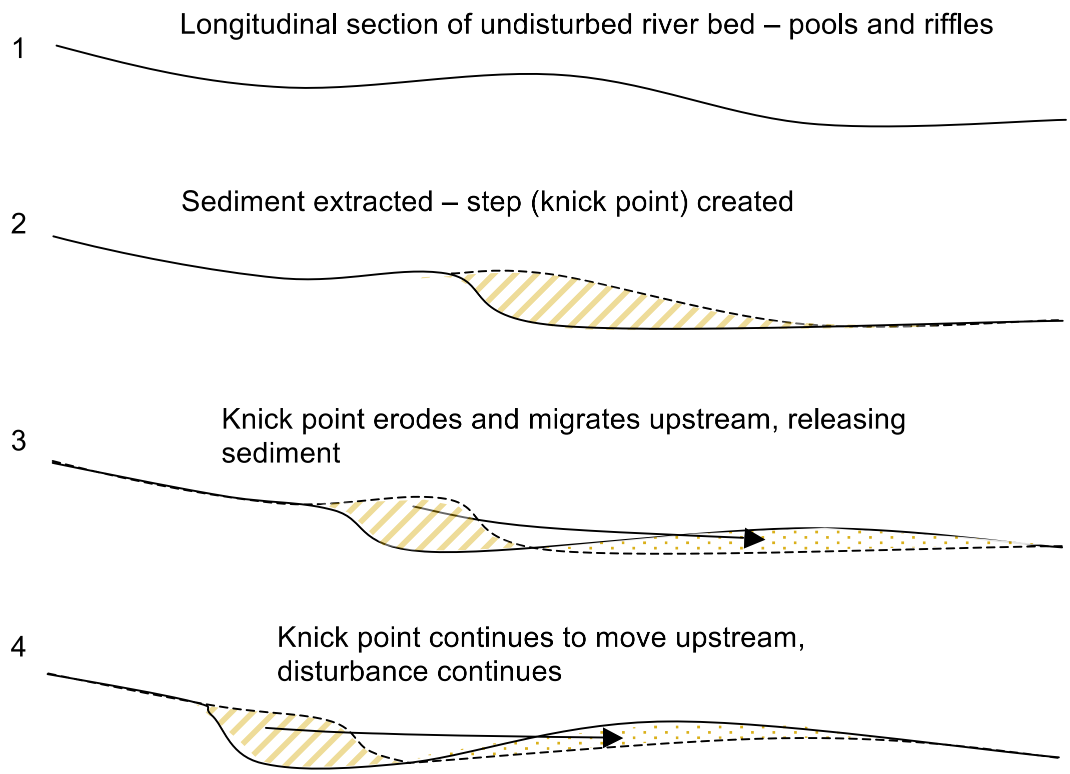

Figure 14: Creation of a knick point and erosion upstream can lead to a drop in the river bed level and bank erosion, overloading the river downstream with sediment.

A knick point can lead to significant impacts such as long-term or permanent habitat damage, land loss and undermining structures such as bridges. These effects can be unpredictable and can last for many years. An example of this can be seen on the Water of Ruchill (see Figures 15 and 16).

Figure 15: Water of Ruchill knick point has eroded upstream. Left: downstream of knick point showing extensive erosion of bed and banks and lowering of bed level. Right: upstream of knick point, note natural bed level and stable banks.

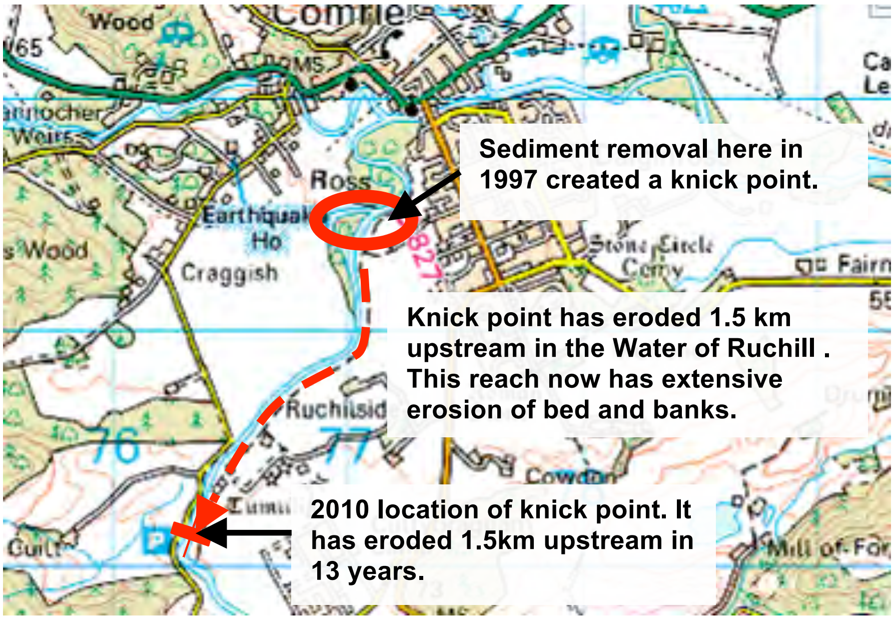

Figure 16: Map showing extent of erosion on Water of Ruchill © Crown copyright. All rights reserved. SEPA licence no. 100016991 (2010).

Increased flood risk downstream

Dredging rivers (making rivers deeper, wider and smoother) may mean that more water can be carried downstream faster during flood flows, which can increase water levels downstream and increase the risk of flooding.

Sediment removal can also trigger river instability, leading to significant erosion of the bed and banks in one location. In such cases large volumes of sediment will be transported further downstream, increasing deposition at locations further downstream and potentially reducing channel capacity or capacity at structures such as culverts and bridges, potentially increasing flood risk.

3 The good practice process

These steps should be followed to ensure good practice is carried out.

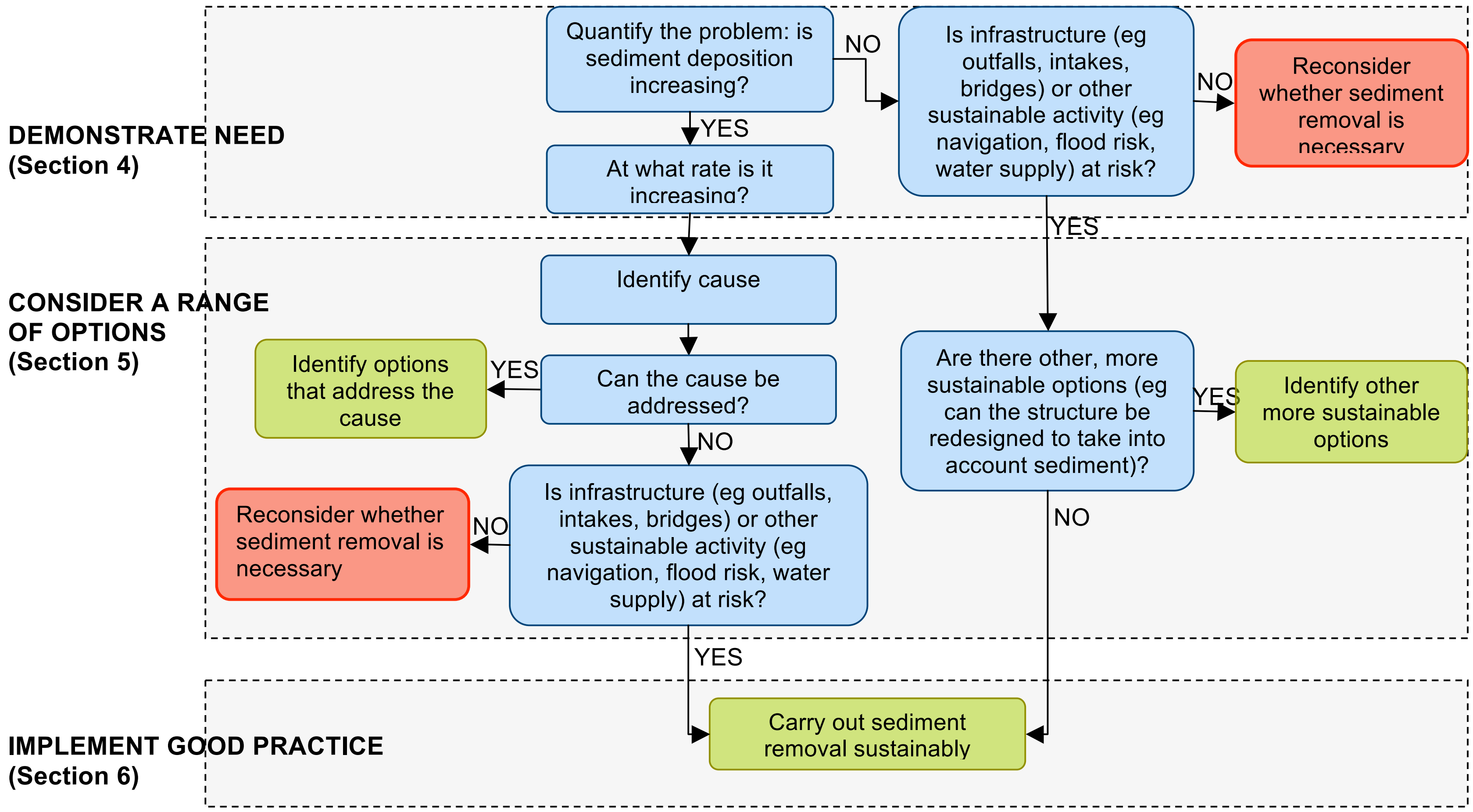

Figure 17: Sediment removal good practice process.

4 Demonstrating need

The first step in identifying a sustainable engineering solution is to determine whether new engineering work, such as sediment removal, is necessary.

In some cases engineering may be carried out to address a perceived, rather than real, problem. For example sediment deposition could be perceived to be increasing but closer investigation may show that it is not. Quantifying the scale and the significance of the problem will help to determine whether or not sediment removal is required, and will also ensure that any solution is proportionate to the scale of the problem.

SEPA's position statement provides further information on how we regulate applications for sediment management:
www.sepa.org.uk/water/water_regulation/guidance/idoc.ashx?docid=660d8a75-54d6-454f-9ced-046a66a4947b&version=-1

4.1 Is infrastructure or other sustainable activity at risk?

Sediment removal should only be considered if there is a risk to infrastructure (eg outfalls, intakes, bridges) or other sustainable activity (eg navigation, flood risk management, water supply). If there is no significant risk to these activities then the requirement for sediment removal should be reconsidered.

4.2 Quantify the problem

Key points

It is necessary to quantify the problem in order to determine if engineering works are necessary and to ensure that any solution is proportionate to the scale and risk of the problem. The following points should be considered.

- Is sediment deposition increasing?
- Will sediment deposition continue to increase or will it reach a stable state?
- At what rate is sediment deposition increasing?

River states: basic concepts

Due to the ecological damage caused by its removal, sediment should only be removed where the rate of deposition is clearly increasing – known as 'aggrading'. Removing sediment from a reach that is stable or incising/eroding creates a high risk of destabilising the river. Even in aggrading rivers, care must still be taken because removal could still lead to destabilisation which can alter or even stop downstream sediment supply.

Quantifying the rate of sediment deposition can be difficult, as described in Section 2, sediment is continually moved down rivers like a 'jerky conveyor belt' and is a natural process. Sediment deposition may appear to have increased after a flood event but this in turn may be moved downstream at the next high flow event.

Some basic concepts may be useful, such as trying to identify if the reach of river you are interested in is incising, stable or aggrading. These concepts are explained in Table 1 below and in more in detail Appendix 1. It should be noted that these states can occur naturally or as a result of human intervention. Some examples of assessment techniques are given in the section below that may help determine the state of a river reach.

Stability definition	**Key features to look for**	**Sensitivity to sediment removal**
Aggrading/depositing There is a net **increase** in sediment within the reach over several years. This leads to extensive deposition and may lead to the level of the river bed rising. 	Large areas of fresh exposed sediments: the level of exposed sediment is likely to rise and the area of the exposed sediment is likely to increase over time. Recent major or extensive changes to the course of the river (planform): these are likely to be obvious when compared to the historic course of the river from Ordnance Survey maps[1]. Extensive means that the reach has changed by more than a third within the past few years. The bed level may be rising because, as sediment fills the channel, water often flows to the sides of the bars – leading to localised bank erosion. Some reaches naturally aggrade and these should not be disturbed. Some reaches are aggrading due to past river engineering work.	Sensitive if the aggradation is natural. Relatively insensitive if the aggradation is due to past management or works and if not all sediment is removed.
Stable There is no significant increase or decrease of sediment within the reach. In most natural rivers the volumes of sediment moving into and out of a reach are roughly in balance and there is little or no net increase or decrease in sediment. 	Stable does not always mean static: stable rivers can still display patterns of change such as erosion and deposition, but the amount of sediment passing through the reach remains largely the same. Sediments may be stable with perennial vegetation and/or bryophyte growth, or areas of erosion and deposition may be present. Rivers that display this natural balance vary in appearance; some may appear to have little or no sediment storage, while others may have extensive bar deposits. There should be no net major change to the width or depth of the river (ie the bed level is not rising or degrading). If there are large deposits of sediment these should remain approximately the same size/level over time.	Medium: removing sediment can cause this type of river to become unstable, even where there appears to be extensive deposits of sediment.

[1] The National Library of Scotland has historic maps at: www.nls.uk/maps/

Incising/eroding There is a net **decrease** in sediment within the reach over several years. The bed and/or banks of the river may be eroding severely. The channel is either widening or deepening (incising) or both. 	High, unstable, and extensive eroding banks where even well-established vegetation is being undermined and washed away. Extensive means that most banks are eroding slightly, and some are eroding very rapidly (greater than1m per year along tens of metres of bank). The channel is likely to be increasing in width or depth or both over time. Bed incision can sometimes be difficult to identify.	Very high. This type of river usually has an excess of energy and/or too little supply of sediment from upstream, often due to past river engineering works. Removing more sediment would exacerbate the problem.

Table 1: Description of river states.

Assessment techniques

There are many ways to monitor sediment deposition and transport, from very simple visual assessments to complex modelling techniques. The method chosen should be proportionate to the scale of the problem and determined by what information is required. Some of the techniques may only quantify sediment deposition, which may help identify if a river reach is aggrading, stable or incising, while some also help identify the cause of the deposition. Table 2 below gives guidance on some potentially appropriate assessment techniques.

SEPA's *Review of geomorphological assessment techniques* provides more detail on these techniques: and is available on the SEPA website www.sepa.org.uk/water/water_regulation/guidance/idoc.ashx?docid=4d7c1fef-4fad-4ced-a80a-72cc241b008f&version=-1

Technique	Description
Fixed point photography	Fixed point photography provides a visual image at particular viewpoints within a river reach and therefore illustrates changes which occur over time. It does not identify any causes of increased sediment deposition.
Channel cross section surveys	Cross-section surveys are undertaken in a single line perpendicular to the flow, at a particular point and will show changes over time. It does not identify causes.
Topographic survey	Points are measured on the river and flood plain to build a 3D model, repeated to quantify change over time.
River reconnaissance	This is a walk-over visual survey by an experienced geomorphologist, who takes rapid notes and provides a written interpretation .It can highlight where there are major issues that could help inform if sediment management is appropriate.

Fluvial audit	This provides an estimate of what area of sediment lies within the river. As with river reconnaissance, it also provides an interpretation of what processes dominate the proposed extraction site and what sensitive features need protection.
Fluvial dynamics assessment	This is a basic modelling exercise to determine how sediment is moving into and through a reach.
Catchment sediment budget	Sediment budgets provide a quantification of how much sediment is moving down a river and, theoretically, how much could be extracted.
Modelling	This is an advanced modelling exercise to determine how much sediment is moving into and through a reach, and how this affects channel hydraulics. It requires specialist contractors.

Table 2: Assessment techniques.

5 Considering the options

As stated in section 1 most engineering requirements can be addressed in a number of ways. It is a basic principle of good practice to consider a range of options to address any river engineering problem or need and to carry out an options appraisal. Without considering a range of options it is not possible to determine if the chosen approach represents the most suitable option i.e. the option that minimises ecological harm at a cost that is not disproportionately expensive.

Proportionate cost

The most cost-effective solution is the one that minimises environmental harm or maximises environmental benefit at a proportionate cost. Large absolute cost, in itself, does not constitute disproportionate cost. For example, incurring significant costs to prevent significant environmental harm or achieve significant environmental benefits eg safeguarding protected species and designated sites, would be considered proportionate. But incurring significant costs for minor environmental benefits would be considered disproportionate.

5.1 Identify the cause

Options that address the cause of the problem, not the symptoms, should always be considered first. Addressing the cause of increased sediment deposition may mean that sediment removal is not required, or the requirement is reduced, therefore having less of an impact on the water environment. It will also ensure that the solution is sustainable in the long term and reduce the need for on-going maintenance, helping to reduce costs.

If it has been established that sediment deposition is increasing (see Section 4.2) then the cause should be identified to determine if it can be addressed.

As noted in Section 2, transport and deposition of sediment in rivers is a natural process, however human intervention can also increase sediment deposition.

Some of the assessment techniques listed in Table 2 can help identify the cause of any increased sediment supply. The basic principles below will also help when seeking to identify the cause. Common causes of increased sediment deposition are listed below and contain information on sustainable solutions that address the cause and do not involve sediment removal.

Basic principles

In order to understand any sediment deposition problem fully, it is necessary to consider the principles of source, transport, deposition that were described in Section 2:

- Source: where is the sediment coming from? Inputs of sediment are often natural (for instance, gradual bank erosion or a input from a tributary) or may be result of human activity. Natural sources should not normally be managed unless there is no alternative. If there is an artificial input of sediment then it would be best to manage the source, rather than to remove sediment downstream, where it is causing the problem eg if the supply from upstream is high because vegetation on the bank has been lost, replanting the bank can help to manage the input.

- Transport: many reaches store sediment temporarily, with material deposited from one flood being moved by the next. These natural processes should be preserved. If sediment accumulates within a reach that normally transports sediment without problem, it is worth investigating why. If sediment accumulates at a structure then is it due to inappropriate design and can that be remedied through redesign?

- Deposition: many reaches naturally store sediment, while in others sediment may be accumulating due to artificial over-supply from upstream. If sediment is accumulating naturally it is likely to have considerable ecological value that should be preserved. Remember that if sediment accumulates because of an artificially-increased supply from upstream, it would be most effective to manage the source.

5.1.1 Increased erosion from weakened banks

Cause

A common cause of increased bank erosion (and therefore increased sediment supply to the river or loch) is banks being weakened by lack of bank side vegetation and poaching by livestock.

Weakened banks → increased erosion → increased sediment supply


Figure 18 Left: This picture shows no erosion and stable banks where trees are present (see where arrow points) but significant erosion where bank-side vegetation has been removed, resulting in the banks being weakened. Right: Weakened bank due to lack of vegetation and 'poaching' from livestock.

General Binding Rule 19 – Keeping of livestock

General Binding Rule 19 (of the Controlled Activity Regulations) requires that when keeping livestock, significant poaching or erosion of land that is within five metres of a watercourse is prevented. See the *CAR practical guide* for more information on the General Binding Rules available from the SEPA website: www.sepa.org.uk/water/water_publications.aspx. Questions and answers on the diffuse pollution General Binding Rules can be found at: www.sepa.org.uk/water/water_regulation/regimes/pollution_control/diffuse_pollution/questions_and_answers.aspx.

See the further information below for other sources of guidance that will help comply with this General Binding Rule.

	
Figure 19: ✘ Poor practice. Lack of vegetation and poaching of the ground by livestock has led to increased bank erosion and input of fine sediment to the watercourse.	Figure 20: ✓ Good practice. Creation of a buffer strip by fencing off the river bank from livestock and allowing bank side vegetation to establish has strengthened the bank, reduced erosion and reduced input of fine sediments.

Sustainable solutions

Trees increase the strength of a bank, so it is good practice to plant bare banks with a mix of native vegetation such as alder, willow and birch. Rivers and lochs can be fenced off from livestock (see Figures 19 and 20) and alternative watering points eg troughs or limited river or loch access can be given if required. Green bank reinforcement may be appropriate in some cases. See our good practice guide on bank protection for further information

Further information

Good Practice Guide: Bank Protection in Rivers and Lochs
SEPA
www.sepa.org.uk/water/water_regulation/guidance/idoc.ashx?docid=ab578cba-418d-4916-b1c2-7066033ab214&version=-1

Good Practice Guide: Riparian Vegetation Management
SEPA
www.sepa.org.uk/water/water_regulation/guidance/idoc.ashx?docid=7c4571aa-4f09-45a1-ae5d-7cca72af65bc&version=-1

WWF Farming and Watercourse Management Handbook
www.sepa.org.uk/water/regulations/guidance/engineering.aspx

SEPA's Agricultural Best Management Practices give guidance on reducing pollution from agricultural activities for all pollutants including suspended solids:
http://apps.sepa.org.uk/bmp/Default.aspx

PEPFAA code
Scottish Government
http://www.scotland.gov.uk/Resource/Doc/37428/0014235.pdf

Information on funding available for fencing of watercourses is available from the Scotland Rural Development Programme:
www.scotland.gov.uk/Topics/farmingrural/SRDP

Restoring and Managing Riparian Woodlands
Scottish Native Woodlands, John Parrott and Neil MacKenzie.
http://scottishnativewoods.org.uk/index.asp?tm=23

5.1.2 Poor river engineering triggering increased erosion

Cause

If not carried out appropriately, river engineering works can alter the rate of erosion or deposition in rivers. As described in Section 2, removal of sediment in one part of the river can trigger significant river instability, leading to large rates of erosion by creating a 'knick point' in the river bed or disturbing the 'armour' layer. These high rates of erosion in turn increase the sediment supply to the river and will lead to increased sediment deposition downstream.

If channels are modified significantly, for instance by straightening them, they can become unstable. This causes increased erosion (see Figure 21) in one location which increases sediment supply to the river and leads to increased deposition downstream. If the channel is made very unstable then there may be a large amount of erosion in a short space of time. Increased rates of erosion may also occur over a longer period of time, for example if a river has been straightened it may try to recover its meandering form through more gradual rates of erosion and deposition – for instance through processes of erosion and formation of gravel bars at meander bends. This process of erosion and deposition should be allowed to continue where possible because it allows the river to evolve to a naturally balanced state with less erosion and deposition. However SEPA recognises that there are instances where rivers have been managed in the past and the space to allow natural processes isn't available, in which case a different approach may be necessary. Contact your local SEPA office for advice in such circumstances.

Straightening → steeper river gradient → increased erosion → increased sediment supply downstream

Figure 21: ✘ Left: inappropriate channel design and removal of armour layer leading to the river having more energy, and increased rates of erosion.
Right: increased erosion of bed (bed has incised) and banks after a 'knick point' created significant instability.

Sustainable solutions

River instability can be difficult to address and a suitably qualified geomorphologist should be consulted. If historical channel modifications have led to problems then the following should be considered:

- What is causing the instability? If it was past river engineering work, can the river be restored to a more natural and balanced state? Doing so treats the cause of the problem and can provide a permanent solution.

- What is the river's capacity for natural recovery (ie will it recover to its natural form without any intervention)? Rivers have varying degrees of natural recovery potential depending on the nature of the disturbance and the characteristics of the river. In general the smaller the disturbance and the more energetic the river, the greater the potential for natural recovery.

- Is intervention required? If so, what type would be most effective?

Further information

Contact your local SEPA office for further information. The River Restoration Centre also has information on restoration projects and a manual of river restoration techniques at www.therrc.co.uk.

5.1.3 Poor river engineering leading to increased deposition

Cause

If not carried out appropriately, river engineering works can alter the rate of erosion or deposition in rivers.

If channels are modified (eg straightening, widening or deepening) then inappropriate design can lead to a highly unstable channel. The changes may lead to the channel having less energy and no longer being able to transport the same amount of sediment through the reach leading to increased deposition (see Figure 22).

Figure 22: ✘ Inappropriate design in modified channels: both rivers have less energy and are unable to transport sediment, leading to increased deposition. In the left photo, the river bed level is now above the flood plain.

Sustainable solutions

If historical channel modifications have led to problems then the following should be considered:

- Can the river be restored to a more natural and balanced state? This treats the cause of the problem and can provide a permanent solution.
- What is the river's capacity for natural recovery (ie will the river recover to its natural form without any intervention)? Rivers have varying degrees of natural recovery potential depending on the nature of the disturbance and the characteristics of the river. In general the smaller the disturbance and the more energetic the river, the greater the potential for natural recovery.
- Is intervention required? If so, what type would be most effective?

Further information

Contact your local SEPA office for further information. The river restoration centre has information on restoration projects and a manual of river restoration techniques. www.therrc.co.uk

5.1.4 Sediment deposition at structures

Cause

Sediment can build up under, in or around structures such as bridges, culverts, impoundments and intakes. This can occur even where the sediments moving down the river are otherwise balanced. In some locations there may not be an increase in sediment supply from upstream leading to increased deposition – poor design of a structure can cause sediment to deposit.

Figure 23: Sediment deposition at a bridge can increase flood risk.

Sustainable solutions

Consideration should be given to removal, modification or replacement of the structure. This will be more sustainable in the long term than repeated sediment removal. See Section 6 for further information on removal.

Further information

Good Practice Guide: Construction of River Crossings.
SEPA
www.sepa.org.uk/water/water_regulation/guidance/idoc.ashx?docid=813bf507-416f-4186-96d1-7ea4f963884f&version=-1

5.1.5 Increased deposition after rare events

Cause

Rare flood events with very high flows can transport more sediment than more frequent lower flow flood events, leading to a sudden accumulation of sediment. Other events such as landslides can also lead to an over supply of sediment to the river system, leading to a sudden accumulation of sediment. These events are natural occurrences and, where possible, the river should be allowed to adjust to the change. However SEPA recognises that there are instances where the space to allow natural processes isn't available, in which case sediment removal or similar works may be necessary. Your local SEPA office can be contacted for advice. See Section 6.4 on small scale sediment removal for localised problems.

Figure 24: Increased sediment deposition in the river channel and flood plain after a rare large flood event.

Further information

Dredging and flooding leaflet
SEPA – currently in press
www.sepa.org.uk/water/water_publications.aspx

6 Sediment management good practice

If you have determined that sediment removal and/or reintroduction is required, and that the cause of increased deposition cannot be addressed (as described in Section 5) then sediment management activities should be carried out in accordance with good practice. The topics below describe good practice for the different types of sediment management activities.

6.1 Removing sediment or dredging watercourses (open channels not associated with a structure) for reducing flood risk

Although the dredging of watercourses has been carried out in the past to reduce flood risk, in many situations the removal of sediment from watercourses has limited or no benefit in managing flood risk. Without careful identification of the flooding source and appropriate risk assessment depending on the scale of the proposal, dredging is unlikely to be supported without consideration of alternative options.

In many situations dredging is not effective because:

- there may be other, more dominant controls on water levels eg structures (such as bridges and weirs), channel slope, tidal effects or downstream river confluences;
- flood flows often transport a large amount of sediment which can quickly fill any dredged channel during a flood, quickly losing any extra capacity gained (see Figures 27-29);
- the high flood flows that can damage built property and infrastructure usually have far more water than even a dredged channel can contain, so removing sediment from rivers is unlikely to reduce water levels and flooding during these high flow events (see Figures 29-30);
- sediment removal is likely to be only a temporary measure to address flood risk and repeat dredging is often required (increasing long term costs) – long term sustainable solutions should be sought instead;
- in some situations dredging may increase flood risk downstream because dredged channels can pass water downstream faster, increasing water levels.

Sediment removal may be effective in some situations, including:

- when the benefits of sediment removal can be quantified;
- when there are no alternative, more sustainable, options;
- around structures such as bridges and weirs where natural sediment transport has been disrupted leading to sediment deposition and when the structure cannot be modified or redesigned;
- in stretches of small low gradient watercourses that have been modified in the past (eg straightened, over-widened etc) and the modification has disrupted the natural sediment transport leading to sediment deposition, and when restoration of the watercourse is not possible.

Careful consideration needs to be given to historically modified or managed channels. As stated in Section 5, if channels have been historically modified and managed in the past they might not be able to transport the same amount of sediment through the reach, leading to increased deposition and aggradation (see Figure 25). Historically modified channels may be aggrading because they are recovering to a more natural state. Careful consideration should be given to determine if a river will reach a stable state that will not increase the risk of flooding, or if other options such as channel restoration or ongoing management are required.

If it is not possible to restore historically modified channels then ongoing management such as sediment removal or larger scale dredging may be required. See Section 6.6 for good practice in dredging small historically modified channels and ditches.

Figure 25: Historically modified channels can lead to sediment deposition and aggradation and may require on-going dredging if there are no other, more sustainable options for reducing flood risk.

Case studies

Below are some case studies of sediment removal which highlight the issues surrounding the technique and which emphasise the importance of careful planning.

The Bowmont Water was dredged approximately 1m below natural bed levels. After one bank full flood event (that occurred one month after the dredging operations) enough sediment was transported to raise the bed level by approximately one metre back to natural bed levels. The bank full flood event is expected to occur approximately once a year (see Figures 26-28).

Figure 26: Bowmont Water channel dredged 05 August 2009 approx 1m below natural bed level.	
Figure 27: Bowmont Water 04 September 2009 bank full flow.	
Figure 28: Bowmont Water 14 September 2009 after one bank full flow event bed level has risen (approx 1m) and returned to natural bed levels.	

Modelling on the Liddle Water at Newcastleton (Halcrow 2005 technical note Newcastleton flood study commissioned by Scottish Borders Council) showed that removing gravel did not have a significant effect in high flow events that were likely to result in flooding of built property (water lever would reduce by less than 1cm in a one in 200 year event).

Modelling on the River Slitrig and the River Teviot (Halcrow 2005 technical note Hawick flood study commissioned by Scottish Borders Council) showed that removing gravel had a greater effect in lower return periods on the River Teviot and that removing half of the existing sediment deposit may reduce water levels by 18cm during a one in five year flood event. However on the River Slitrig is was shown that during the one in 200 year flood event removing gravel did not have a significant effect on water levels (see Figures 29-30).

Figure 29: Gravels in the River Slitrig at Hawick. Modelling showed that removing gravel did not have a significant effect on water levels during the one in 200 year event.

Figure 30: River Slitrig, Hawick during the 2005 flood.

Before carrying out sediment removal

- Obtain the correct CAR authorisation (for further information see the *CAR Practical Guide* on our website at www.sepa.org.uk/water/water_publications.aspx).

- Identify any sites that have been designated for nature conservation (eg SSSI, SAC, SPA) and ensure the conservation requirements are met (contact SNH for further information www.snh.org.uk).

- Identify any protected species (eg fresh water pearl mussels) and ensure they are not harmed or disturbed (contact SNH for further information www.snh.org.uk).

- Carry out good practice - determine whether sediment removal is necessary, quantify the problem and address the cause to ensure the best practicable environmental option is carried out.

Quantify the problem

- Is sediment deposition increasing?

- Will sediment deposition continue to increase or will it reach a stable state that will not increase flood risk?

- Will sediment removal reduce the risk of flooding? By how much?

Identify the cause: can it be addressed?

- Can the cause of deposition be identified and addressed (see Section 5)?
- Can the cause of flooding be identified and addressed?
- All options should be looked at for reducing the risk of flooding including looking at the whole river catchment.

Further information

Flood and Coastal Erosion Risk Management R&D programme FD1920 river sediments and habitats and the impact of maintenance operations and capital works (Stage 1 March 2004)
DEFRA / EA
http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/FD1920_2571_TRP_pdf.sflb.ashx

Technical guidance on flood risk
SEPA
http://www.sepa.org.uk/flooding/flood_risk/planning__flooding.aspx

Dredging and flooding leaflet
SEPA – currently in press
www.sepa.org.uk/water/water_publications.aspx

6.2 Removal of sediment at river crossings

General Binding Rule 13 – Removal of sediment from within 10m of a closed culvert

Sediment can be removed from within 10m of a closed culvert under General Binding Rule (GBR) 13 of the Controlled Activity Regulations (CAR). This means you do not have to apply to SEPA for authorisation and must follow the conditions in the GBR. See the *CAR Practical Guide* for more information on the GBR: www.sepa.org.uk/water/water_publications.aspx

Following the guidance in this section will help you comply with this General Binding Rule.


Figure 31: Sediment can accumulate at crossings which may lead to a risk of flooding.

Before carrying out sediment removal

- Obtain the correct CAR authorisation (for further information see the *CAR Practical Guide* on our website at www.sepa.org.uk/water/water_publications.aspx).

- Identify any sites that have been designated for nature conservation (eg SSSI, SAC, SPA) and ensure the conservation requirements are met (contact SNH for further information www.snh.org.uk).

- Identify any protected species (eg fresh water pearl mussels) and ensure they are not harmed or disturbed (contact SNH for further information www.snh.org.uk).

- Carry out good practice - determine whether sediment removal is necessary, quantify the problem and address the cause to ensure the best option is carried out.

Quantify the problem:

- Is sediment deposition increasing?

- If not does the sediment increase flood risk? By how much?

Identify the cause / can the cause be addressed?

- Can the cause of deposition be identified and addressed? (See Section 5).

- Does the structure cause deposition? If so can it be removed or redesigned? The long term costs of sediment removal should be compared to the cost of removing or redesigning the structure.

If sediment removal is required

- Minimise the area affected: only remove the sediment required to ensure operation of the structure. If possible, remove sediment only from the dry deposits (ie avoid working in the low-flow channel). Do not remove excess sediment in anticipation of future floods.

- The removal should not result in a vertical step being formed between the downstream river bed and the culvert or bridge invert (See Figure 32).

- Timing - Works should not be carried out during fish spawning times and fish emergence times. Key fish species to consider include salmon and trout (normally October – May), lamprey species (normally March – July). However these times can vary and you should contact the local district salmon fishery board (www.asfb.org.uk) or local fisheries trust (www.rafts.org.uk) if you are unsure what fish species are present or what times should be avoided.

- Consider placing removed sediment downstream (reintroduction) see Section 6.8 for further information.

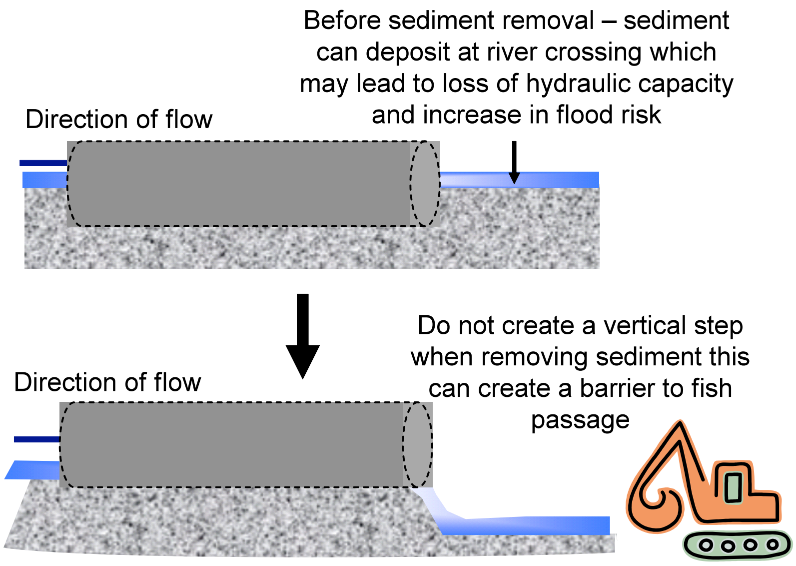

Figure 32 : ✘ Poor practice. Do not form a vertical step when removing sediment at a river crossing.

6.3 Removal of sediment at impoundments

Any sediment management at impoundments should be carried out in accordance with the conditions of the impoundment CAR licence. Impoundments can trap sediment and stop it moving downstream. This can lead to the downstream reach being starved of sediment which can cause increased erosion (see Section 2 for more detail on the impact of sediment starvation).

If impoundments are required for the purposes of water abstraction sediment build up can affect the efficiency of the abstraction, requiring sediment to be removed. More information for hydroschemes can be found in our *Guidance for applicants on supporting information requirements for hydropower applications* available from www.sepa.org.uk/water/water_publications.aspx

Figure 33: Sediment removal from behind an impoundment. Photograph courtesy of Scottish and Southern Energy.

General Binding Rule 12 – Removal of sediment at an authorised weir

Sediment can be removed from within 10m upstream of a weir that is authorised under the Controlled Activity Regulations (CAR) under General Binding Rule (GBR) 12. This means you do not have to apply to SEPA for authorisation and must follow the conditions in the GBR. See the *CAR Practical Guide* for more information on the GBR: www.sepa.org.uk/water/water_publications.aspx

Following the guidance in this section will help you comply with this GBR.

Before carrying out sediment removal

- Obtain the correct CAR authorisation (for further information see the *CAR Practical Guide* on our website at www.sepa.org.uk/water/water_publications.aspx).

- Identify any sites that have been designated for nature conservation (eg SSSI, SAC, SPA) and ensure the conservation requirements are met (contact SNH for further information www.snh.org.uk).

- Identify any protected species (eg fresh water pearl mussels) and ensure they are not harmed or disturbed (contact SNH for further information www.snh.org.uk).

- Carry out good practice - determine whether sediment removal is necessary, quantify the problem and address the cause to ensure the best option is carried out.

Quantify the problem

- Is build up of sediment affecting the efficiency of the water abstraction?
- When does sediment start to cause a problem?
- How does this affect the volume of water abstracted?

Identify the cause / can the cause be addressed?

- Can the cause of deposition be identified and addressed? (See Section 5).

- Can the structure be removed or redesigned? The long term costs of sediment removal should be compared to the cost of removing or redesigning the structure.

If sediment removal is required

- Minimise the area affected: only remove the sediment required to ensure operation of the structure. If possible, remove sediment only from the dry deposits (ie avoid working in the low-flow channel). Do not remove excess sediment in anticipation of future floods.

- Timing: works should not be carried out during fish spawning times and fish emergence times. Key fish species to consider include salmon and trout (normally October – May), lamprey species (normally March – July). However these times can vary and you should contact the local district salmon fishery board (www.asfb.org.uk) or local fisheries trust (www.rafts.org.uk) should be contacted if you are unsure what fish species are present or what times should be avoided.

- Place removed sediment downstream (see Section 6.8 for further information).

- Move sediment downstream of the intake at intervals suited to the rate of accumulation.

- Place sediment into the channel downstream as close to the intake as possible where it will be entrained by the flow. However this may not be possible if the river's capacity to transport the sediment has changed because large volumes of water are abstracted (ie it may not be suitable to place all sediment removed from behind the impoundment downstream). If abstracted water is returned the location of return should also be considered for sediment reintroduction.

Removing sediment from behind an impoundment and replacing it downstream can help stop the reach downstream being starved of sediment and can maintain sediment transport past the impoundment. However this still needs to be carefully considered to avoid any negative effects. Developing a sediment management plan for impoundments may help ensure good practice is carried out.

6.4 Small scale dry gravel removal


Figure 34: ✓ Good practice: small areas of sediment removed from dry deposits with no holes or pits formed (sediment is 'skimmed' from the top of the dry deposits).

Before carrying out sediment removal

- Obtain the correct CAR authorisation (for further information see the *CAR Practical Guide* on our website at www.sepa.org.uk/water/water_publications.aspx).

- Identify any sites that have been designated for nature conservation (eg SSSI, SAC, SPA) and ensure the conservation requirements are met (contact SNH for further information www.snh.org.uk).

- Identify any protected species (eg fresh water pearl mussels) and ensure they are not harmed or disturbed (contact SNH for further information www.snh.org.uk).

- Carry out good practice - determine whether sediment removal is necessary, quantify the problem and address the cause to ensure the best option is carried out.

Quantify the problem

- Is sediment deposition increasing?
- At what rate is it increasing?
- What problems is this increase causing? Can the river be allowed to maintain its process of erosion and deposition?

Identify the cause. Can it be addressed?

- Has there been a sudden increase in sediment due to a rare event (eg flood, landslide?
- Is there an increase in sediment supply from upstream? Can an increase in sediment supply from upstream be addressed (see Section 5)?
- Has the channel been modified in the past (eg straightened)? Can it be restored? If you are removing gravel from bars to reduce bank erosion then you should remember that if a river has been modified it may be recovering its meandering form through deposition of bars and erosion at meander bends. This is a natural process and should be allowed to continue where possible. Trying to keep a river straight will require ongoing management and may cause increased rates of erosion and deposition. Allowing a river to find its 'natural' state may lead to less erosion and deposition in the long term.

If sediment removal is required

- Only remove sediment from dry unvegetated deposits such as gravel bars and islands (see figure 34), do not remove sediment from the normal, wet, low-flow channel (see figure 36).
- Only 'skim' the top of the dry deposits (see figure 34). Do not dig deep enough to reach water and form holes or pits (see figure 37). This can cause sediment pollution, trap fish and increase the risk of erosion and river instability.
- Minimise the area affected: only remove sediment from less than 50% of the surface area of individual dry deposits. The total length of sediment removal should not exceed 30m when measured along the bank.
- Timing: avoid bird breeding season, normally March – July but it can vary. SNH (www.snh.org.uk) or the RSPB (www.rspb.org.uk) should be contacted if you are unsure what bird species might be present or what times should be avoided.
- Frequency: do not remove sediment more than once every three years within a distance equal to the average river width multiplied by 25 (eg if average river width is 5m the operation cannot be repeated within a distance of (5 * 25) = 125m).
- Maintain a distance of at least 2m between the wet edge of the low-flow channel and the area of removal.

- Removed sediment should not be used to form bank-top embankments.
- Consider reintroducing removed sediment downstream (see Section 6.8)

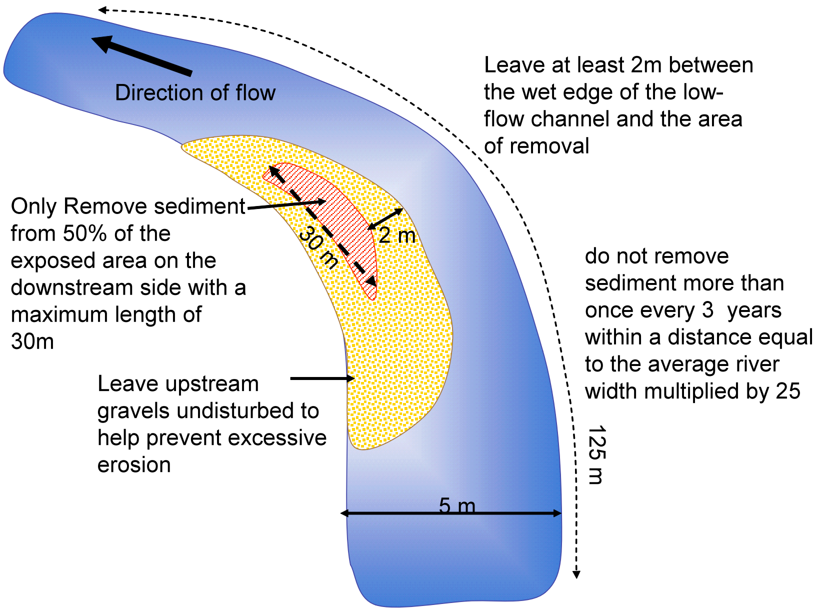

Figure 35: Good practice, small scale sediment removal from dry unvegetated deposits.

Figure 36: Poor practice, do not remove sediment from the normal, wet, low-flow channel. This can cause sediment pollution and increase the risk of erosion and river instability.

Figure 37: Poor practice. When removing sediment from dry deposits do not dig deep enough to reach water and form holes or pits. This can cause sediment pollution, trap fish and increase the risk of erosion and river instability

6.5 Removing gravel for fisheries pool maintenance

Figure 38: Fishing on the River Clyde.

Pools in rivers are not static features; over time they fill in, move position and naturally scour. Typically, however, the number of pools and riffles within a given length of river will remain approximately the same, even if their locations change.

Most change in rivers is likely to be seen after high flows: it may appear that a flood a pool has filled in, but there may be a new pool being created in a different place. Sediment removal should be carefully considered before it is carried out as it may lead to channel destabilisation and increased erosion (see Section 2). This in turn may increase sediment supply downstream and lead to other pools being filled in.

Before carrying out sediment removal

- Obtain the correct CAR authorisation (for further information see the *CAR Practical Guide* on our website at www.sepa.org.uk/water/water_publications.aspx).
- Identify any sites that have been designated for nature conservation (eg SSSI, SAC, SPA) and ensure the conservation requirements are met (contact SNH for further information www.snh.org.uk).
- Identify any protected species (eg fresh water pearl mussels) and ensure they are not harmed or disturbed (contact SNH for further information www.snh.org.uk).
- Carry out good practice - determine whether sediment removal is necessary, quantify the problem and address the cause to ensure the best option is carried out.

Quantify the problem

- Is the pool filling up? If so, at what rate?
- Is the overall number of pools reducing? If it is remaining constant over a sufficient length of reach then removal of sediment to maintain a pool in a static position should be reconsidered.

Identify the cause: can it be addressed?

- Is the pool naturally infilling and changing position?

- Is there an increase in sediment supply from upstream? Can an increase in sediment supply from upstream be addressed (see Section 5)?

- Has the channel been modified in the past (eg widened or straightened)? This can cause a loss of naturally-occurring and self-sustaining pools and riffles. Consider restoration of the natural channel shape and replanting of bankside vegetation.

If sediment removal is required

- Remove sediment from existing pools: do not create pools where none have existed previously.

- Pools should not be increased significantly in size or over-deepened, this could increase the risk of destabilising the channel leading to increased erosion. Do not change pools in size (width, length, depth) or frequency.

- Timing: works should not be carried out during fish spawning times and fish emergence times. Key fish species to consider include salmon and trout (normally October – May), lamprey species (normally March – July). However these times can vary and you should contact the local district salmon fishery board (www.asfb.org.uk) or local fisheries trust (www.rafts.org.uk) should be contacted if you are unsure what fish species are present or what times should be avoided.

- Removed sediment should not be used to form bank-top embankments.

- Consider placing removed sediment downstream: see Section 6.8 for further information.

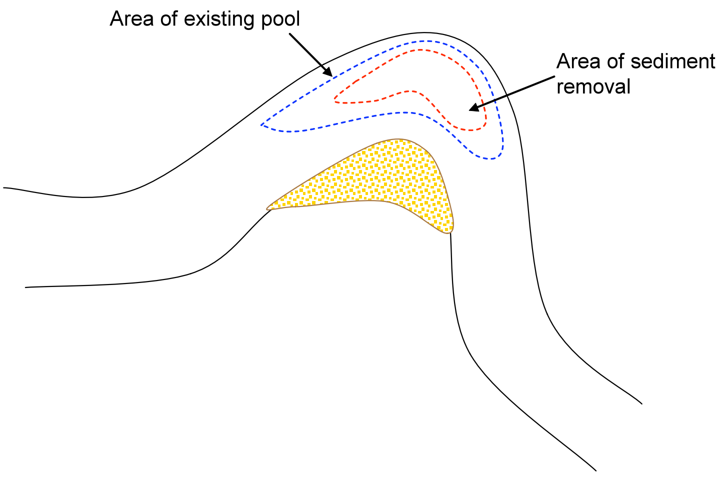

Figure 39: ✓ Good practice. Do not increase the area of the original pool.

6.6 Dredging modified channels and ditches

Many small burns have been historically modified and managed to provide land for development and agriculture and to improve land drainage. In many cases this historical modification, usually straightening, deepening and widening burns, makes regular management necessary because the burn can no longer function naturally. For example deepening and widening channels creates a lower energy environment (slower flows) which means that the burn can no longer move sediment downstream so sediment starts to deposit and the bed level rises. To maintain the burn in its modified form, regular maintenance – such as dredging – is often required.


Figure 40: Burns that have been artificially straightened and dredged in the past.

General Binding Rule 5 – Dredging of small modified burns and ditches
Artificially straightened ditches that are less than or equal to 1m wide at the stretch to be worked can be dredged under General Binding Rule (GBR) 5 of the Controlled Activity Regulations (CAR). This means you do not have to apply to SEPA for authorisation and must follow the conditions in the GBR. See the *CAR Practical Guide* for more information on the GBR: www.sepa.org.uk/water/water_publications.aspx

Following the guidance in this section will help you comply with this GBR.

Before carrying out sediment removal

- Obtain the correct CAR authorisation (for further information see the *CAR Practical Guide* on our website at www.sepa.org.uk/water/water_publications.aspx).
- Identify any sites that have been designated for nature conservation (eg SSSI, SAC, SPA) and ensure the conservation requirements are met (contact SNH for further information www.snh.org.uk).
- Identify any protected species (eg fresh water pearl mussels) and ensure they are not harmed or disturbed (contact SNH for further information www.snh.org.uk).
- Carry out good practice - determine whether sediment removal is necessary, quantify the problem and address the cause to ensure the best option is carried out.

Quantify the problem

- Is deposition increasing? If so, at what rate?

Identify the cause: can it be addressed?

- Is sediment accumulating because the channel is too wide? Can the low-flow channel be made narrower to encourage faster flows that will help move sediment downstream?

- Can the channel be restored to enable the natural processes of erosion and deposition?

- Will land drainage be improved by lowering the level of the watercourse?

- If the level of the watercourse is thought to be affecting field drains, is the outflow of field drains definitely the problem or are the drains themselves in need of repair?

- Is there an increase in the supply of fine sediment from upstream or from land management practices (see Section 5)? Good practice for land management should be followed eg create buffer strips to prevent run-off of fine sediments. More information on land management can be found at:

  Forests and Water Guidelines
  Forestry Commission
  www.forestry.gov.uk/pdf/FCGL002.pdf/$FILE/FCGL002.pdf

  SEPA's Agricultural Best Management Practices give guidance on reducing pollution from agricultural activities for all pollutants including suspended solids: http://apps.sepa.org.uk/bmp/Default.aspx

  Scottish Government PEPFAA code
  www.scotland.gov.uk/Resource/Doc/37428/0014235.pdf

If dredging is required

- Do not straighten, deepen or widen unmodified natural watercourses.

- Consider creating a two-stage channel (also called partial dredging). Creating a two-stage channel will narrow the low flow channel and may increase the speed of the flow. Increasing the speed of the flow may allow the river to transport more sediment downstream, reducing the amount of sediment deposition and therefore may stop or reduce the need for dredging (see figure 42).

- Removed sediment should not be used to form bank-top embankments. It should be spread evenly over fields away from areas of wildlife interest.

- Keep vegetation removal to a minimum: planting trees can help shade a channel which can help minimise weed growth that can 'choke' channels.

- Timing: works should not be carried out during fish spawning and fish emergence times. Key fish species to consider include salmon and trout (normally October – May), lamprey species (normally March – July). However these times can vary and you should contact the local district salmon fishery board (www.asfb.org.uk) or local fisheries trust (www.rafts.org.uk) if you are unsure what fish species are present or what times should be avoided. Trout in particular spawn in small burns and ditches.

- When dredging is being carried out measures should be taken to minimise the risk of fine sediments polluting watercourses downstream. Straw bales can be placed downstream of the dredging operations to prevent fine silts being washed downstream and should be removed when the works are finished. Any trapped fine sediment should be spread evenly on adjacent fields.

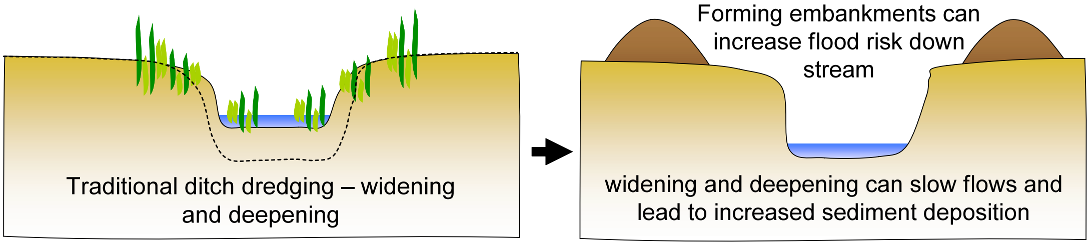

Figure 41: Poor practice. Traditional ditch dredging – widening and deepening – can slow flows leading to increased sediment deposition. Dredged material is often used to form embankments which can increase flood risk downstream.

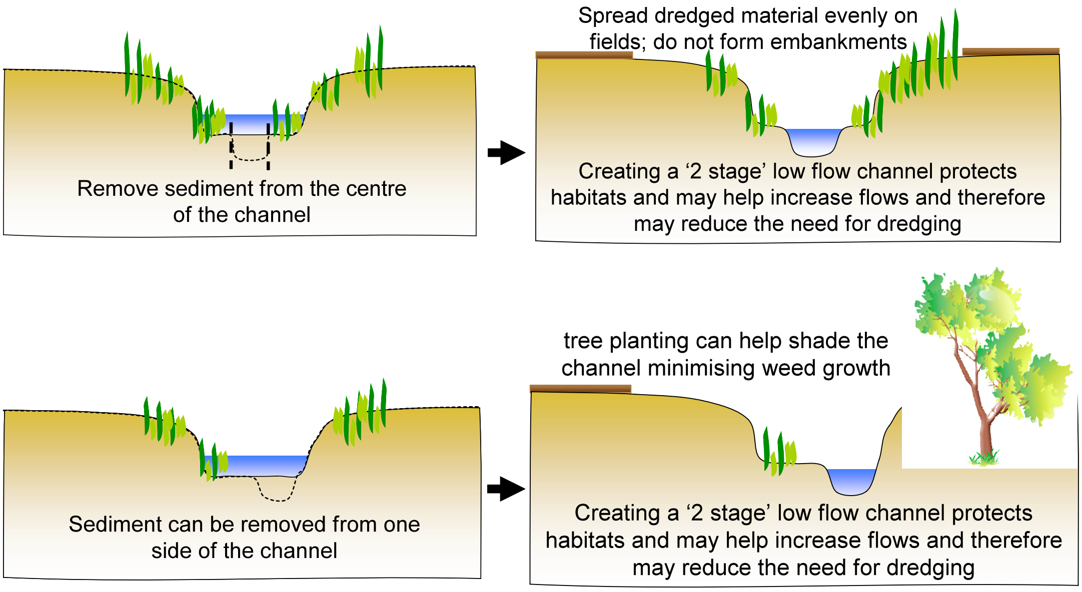

Figure 42: Good practice. Creating a two stage channel (or partial dredging) can speed up flows, leading to less sediment deposition and stop or reduce the need for dredging. Dredged material should be spread on fields. Planting trees can help shade the channel, minimising weed growth.

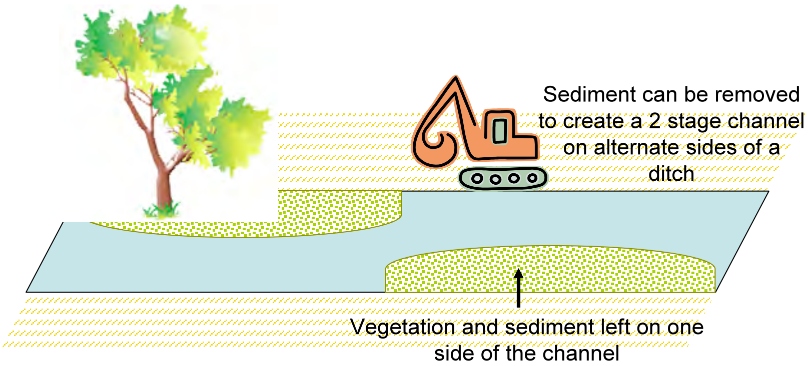

Figure 43: ✓ Good practice. Sediment can be removed from alternate sides of a ditch. Trees should be appropriately spaced to allow access for ditch maintenance.

6.7 Removing sediment from lochs

The process of sediment supply, transport and deposition in lochs generally takes longer than in rivers. This means that any sediment removed from lochs will usually not be replaced as quickly. In general, sediment should only be removed from lochs if there is a risk to infrastructure (eg outfalls, intakes, bridges) or to other sustainable development activities (eg navigation, flood risk, water supply, conservation objectives). If there is no significant risk to these activities then the requirement for sediment management should be reconsidered.

Before carrying out sediment removal

- Obtain the correct CAR authorisation (for further information see the *CAR Practical Guide* on our website at www.sepa.org.uk/water/water_publications.aspx).

- Identify any sites that have been designated for nature conservation (eg SSSI, SAC, SPA) and ensure the conservation requirements are met (contact SNH for further information www.snh.org.uk).

- Identify any protected species (eg fresh water pearl mussels) and ensure they are not harmed or disturbed (contact SNH for further information www.snh.org.uk).

- Carry out good practice - determine whether sediment removal is necessary, quantify the problem and address the cause to ensure the best option is carried out.

Quantify the problem

- Is the loch filling up? If so at what rate?
- Are there risks to infrastructure or other sustainable activity?

Identify the cause: can it be addressed?

- Is the loch infilling naturally and at natural rates?
- Is there an increase in sediment supply from upstream? If so, can it be addressed (see Section 5)?

If sediment removal is required

- Key habitats should be identified and avoided, including:
    - fish spawning areas
        - wave washed shores and beaches;
        - areas around loch inlet and outlets;
        - shallow areas near the shore (littoral areas) and bays;
        - sandy and silty deposits.
    - aquatic plants (macrophyte beds).
- Removed sediment should not be used to form bank-top embankments. It should be spread evenly over fields away from areas of wildlife interest or transported elsewhere for appropriate disposal.
- When sediment removal is being carried out, measures should be taken to minimise the risk of fine sediments causing pollution of other sections of the loch shore.

- Timing: fish spawning times and the period between spawning and the emergence of juvenile fish should be avoided. Lochs are particularly important for the following species of fish:
    - Powan;
    - Arctic charr;
    - Juvenile lamprey;
    - Brown trout;
    - Perch;

Contact the local district salmon fishery board (www.asfb.org.uk) or local fisheries trust (www.rafts.org.uk) if you are unsure what fish species are present or what times should be avoided.

6.8 Reintroduction of removed sediment

Placing removed sediment downstream (called reintroduction) can help minimise some of the impacts of sediment removal, such as sediment starvation.

However any reintroduction must be carefully planned, following the guidance below. If too much sediment is reintroduced, or reintroduced in the wrong place, it can have a negative affect on the water environment.

Before placing sediment downstream

- Identify any sites that have been designated for nature conservation (eg SSSI, SAC, SPA) and ensure the conservation requirements are met (contact SNH for further information: www.snh.org.uk).

- Identify any protected species (eg fresh water pearl mussels) and ensure they are not harmed or disturbed (contact SNH for further information: www.snh.org.uk).

- Identify any other important habitats and species that should be avoided, including water vole nests and sand martin nests in river banks, and ground nesting birds such as ringed plover and common tern that may be found on gravel bars and islands.

- Do not reintroduce fine silts and sands as they risk causing silt pollution.

- Invasive species: do not reintroduce sediments from a location which has invasive species to a location that has no invasive species. Invasive plant species include Japanese Knotweed and Canadian Pondweed (including plant fragments or seeds) and invasive fish and invertebrate species include Ruffe and North American signal crayfish (including their eggs).

Timing

- Avoid bird breeding season, normally March – July but it can vary. SNH (www.snh.org.uk) or RSPB (www.rspb.org.uk) should be contacted if you are unsure what bird species might be present or what times should be avoided.

- If placing sediment in the wetted channel cannot be avoided then sediment reintroduction should not be carried out during fish spawning times and fish emergence times. Key fish species to consider include salmon and trout (normally October – May), lamprey species (normally March – July). However these times can vary and you should contact the local district salmon fishery board (www.asfb.org.uk) or local fisheries trust (www.rafts.org.uk) if you are unsure what fish species are present or what times should be avoided. Trout in particular spawn in small burns and ditches.

How much to put downstream

- Carefully consider the volume to be reintroduced. It may not be appropriate to place all removed sediment downstream as this would be more than the river would naturally be able to transport and may lead to over-supply of sediment to the downstream reach, thereby causing problems such as smothered habitats and increased flood risk.

- The volume placed downstream should be comparable to what would naturally be transported by the river in a high flow event. If a large amount of sediment is being removed to reduce flood risk it may not be appropriate to put it all downstream, as only some of this sediment would have been transported naturally in a high flow event.

- The river's ability to transport sediment should also be considered. If there is a large water abstraction at the point of sediment removal (eg at a hydropower impoundment) the river may not have enough energy to transport all of the sediment, so only some may be able to be placed downstream. If abstracted water is returned to the river at a point downstream of the sediment removal activity (eg hydropower schemes) then the location of the returned water should be considered as an appropriate place to reintroduce sediment (see below) as the river may regain its energy to transport sediment downstream.

How often

- In general, the more frequently sediment is reintroduced downstream the more likely it is to correspond to natural rates of sediment transport, and hence levels that natural processes have adapted to.

- Ideally sediment should be removed from a depositional area as it accumulates, comparable to the natural rate of movement.

Where to put it

- Sediment should be reintroduced as close as possible to the removal site and downstream of the removal site. This minimises the length of river that may be affected by sediment starvation.

- It should be placed where it does not increase flood risk.

- Spread the sediment along the channel margins, so that the sediment can be moved by the river in higher flows. Only place sediment on dry unvegetated deposits or banks, do not place it in the wetted channel.

- Sediment should be evenly spread on the lower half of banks, embankments should not be formed.

- Spread evenly on existing dry unvegetated sediment deposits such as bars and islands.

- If large volumes of water are abstracted and then returned to the water environment (eg for hydropower) then the location of the returned water should be considered as a location for sediment reintroduction as the river may have more energy to transport larger volumes of reintroduced sediment.

- Consider placing sediment downstream of where tributaries join a river, as this may also help in situations where water abstraction might affect the amount of sediment a river can transport.

Appendix 1: River stability

Aggrading rivers: reaches with a net increase in sediment

Key features to look for:

- large areas of fresh exposed sediments;
- recent extensive changes to the course of the river (planform), likely to be obvious when compared to the historic course of the river from Ordnance Survey maps[2];
- bed level may be rising because as sediment fills the channel, water often flows to the sides of the bars, leading to localised bank erosion.

Figure A1: Aggrading river reach. Note areas of exposed sediments. The level of exposed sediment is likely to rise and the size of the exposed sediment area is likely to increase over time.

Figure A2: Aggrading river reach. Note the level of the bed of this channel has risen (aggraded) above the flood plain.

Stable rivers: no net increase or decrease of sediment within the reach

Key features to look for:

[2] The National Library of Scotland has historic maps at: www.nls.uk/maps/

- no recent major change to the width or depth of the river (bed level is not rising or degrading);

- some erosion or deposition may be present.

Rivers that display this natural balance vary in appearance: some may appear to have little or no sediment storage, whereas others may have extensive bar deposits.

Figure A3: Stable river reaches. Left: note stable sediments with bryophyte growth and mature vegetation. Right: net volume of sediment in this reach remains relatively constant over time.

Figure A4: Stable river reach where there are deposits of sediment these remain the same size and level over time (do not increase or decrease in size). Note the areas of sediment may move within the reach but there is no net increase or decrease in their size or volume.

Degrading/incising river: reaches with a net decrease in sediment

Key features to look for:

- high, unstable, and extensive eroding banks where even well-established vegetation is being undermined and washed away. 'Extensive' means that most banks are eroding slightly, and some are eroding very rapidly (greater than 1m per year along tens of metres of bank);
- the channel is likely to be increasing in width or depth or both over time;
- bed incision can sometimes be difficult to identify.

Figure A5: Incising river reaches. Note very extensive erosion of banks and obviously lowered bed.

Figure A6: Incising river reaches. Left, note the bed has incised vertically about 2m through the cobble bar (note the vertical bar face and exposed roots). Right, note vertical drop of approximately 4m downstream of a bridge, weir and bank reinforcement required to prevent bridge from being undermined and collapsing.

Appendix 2: Feedback form

SEPA good practice guide on sediment management

SEPA is committed to ensuring our good practice guides are useful and relevant to those carrying out engineering activities in Scotland's water environment.

We welcome any comments you have on this good practice guide so that we can improve future editions.

After completing the short questionnaire please detach it and post it to the address below or fax it to 01355 574 688.

Please return all comments to:

SEPA
Engineering Team
5 Redwood Crescent
Peel Park
East Kilbride
G74 5PP

The aims of this good practice guide are to set out the environmental aspects that should be considered when undertaking engineering works, and to help applicants choose sustainable engineering solutions that reduce impacts on the water environment. This will also help applicants obtain an authorisation for works under the Water Environment (Controlled Activities) (Scotland) Regulations 2005.

1. **How well does the guide meets these aims?**

Very Well		Good		Could be improved	

2. **Do you think the level of detail in the guide is appropriate (ie would you like the document to contain more or less technical information)?**

I would like the guide to contain more technical information	

I think the level of information in the guide is about right	

I would like the guide to contain less technical information	

3. **Were there issues you felt should have been covered, omitted or dealt with differently in the guide?**

4. **Could any aspect of the guide be clearer (eg diagrams, photos, content)?**

5. **Do you have any other comments?**

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http://serc.carleton.edu/NAGTWorkshops/geomoph/emriver/index.html

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http://randd.defra.gov.uk/Document.aspx?Document=FD1914_1147_TRP.pdf

Protecting river gravels: why removing gravels can be bad for rivers
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Environment Agency
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SEPA – currently in press
www.sepa.org.uk/water/water_publications.aspx

Good Practice Guide: Bank Protection in Rivers and Lochs
SEPA
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SEPA

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Scottish Natural Heritage
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Glossary

Active channel width	The width of a river is defined as the portion of the river channel characterised by open water and, if present, bare (unvegetated) river sediments.
Aggradation	Rising of the river bed level due to deposition of sediment.
Alluvial fans	Large areas of sediment deposition at river confluences, often cone shaped.
Bed armour	Top layer of river bed sediment that has been compacted and held together by finer sediments.
Catchment	Total area of land that drains into any given river.
Embankment	Earth, gravel or similar material raised above the channel or floodplain to stop flood waters from leaving the channel, or retain flood waters within a specified area.
Incision	Deepening of the channel due to erosion of the river bed.
Invert	The lowest internal point of any cross section in a culvert.
Knick point	Where a step has formed in the river channel and there is a sudden change in bed level. It can often lead to high rates of erosion as water flows over the knick point and erodes upstream.
Large woody debris (LWD)	Accumulations of trees and branches that have fallen naturally into the river system.
Meander Bend	A bend in the river formed by natural river processes (erosion and deposition).
Reach	A short section of river.
Riffle	Fast-flowing shallow water with distinctly broken or disturbed surface over gravel/pebble or cobble substrate.
Riparian	The area of land adjoining a river channel (including the river bank) capable of exerting physical, hydrological and ecological effects on the aquatic ecosystem (eg shading, leaf litter input). In this standard, the term ‘riparian zone’ does not include the wider floodplain.
Scour	Erosion of river banks or bed – often due to the presence of a structure.
Substrate	The river substrate is the material that the river bed is made up of. This can range from fine silts and sands, up to gravels, cobbles and boulders.
Sustainable engineering solution	A river engineering solution that minimises harm to the water environment and is effective both in the short term and the long term.