Engineering in the water environment: good practice guide

River crossings

Second edition, November 2010

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 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 aspects of the water environment that should be considered when undertaking a project. It is not intended to be a technical design manual.

New engineering activities (such as bridges and culverts) in Scotland's rivers, lochs and wetlands require an authorisation under the Controlled Activities Regulations (CAR) (see box below).

SEPA expect new engineering activities authorised under CAR to be carried out in accordance with good practice, as well as complying with environmental standards.

Regulations

New engineering activities (such as bridges and culverts) 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 CAR. 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 culverting of watercourses. This position statement is available from the SEPA website at:
www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx

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 obtain an authorisation under, and comply with, the Controlled Activities Regulations. The sections in this guide are based around these basic principles.

Basic principles of good practice

Demonstrate need →	The first step in identifying a sustainable engineering solution is to determine whether new engineering work is necessary.
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 during the construction phase.

2 Impacts of crossings

Poorly designed river crossings can:

- lead to the loss or damage of plants, animals and their habitats;
- create a barrier to the movement of fish and other wildlife;
- prevent sediment and woody debris being moved downstream
- prevent natural river movement;
- increase flood risk.

Following the good practice in this guide will help reduce the risk of these impacts.

2.1 Construction phase impacts

Construction on and disturbance of the river bed and banks can lead to the loss of or damage to important plants, animals and habitats such as fresh water pearl mussel (see Figure 1), river jelly lichen, water voles, salmon and lamprey eggs and juveniles as well as spawning gravels and nursery habitats.

Fresh water pearl mussels and river jelly lichen are protected species under the Wildlife and Countryside Act 1981. It is an offence to kill, injure or disturb any fresh water pearl mussels or river jelly lichen or to damage their habitat. It is the responsibility of the operator to ensure that no protected species will be killed or disturbed. For further information contact Scottish Natural Heritage.

Figure 1: Protected species such as fresh water pearl mussels can be killed or disturbed during the construction phase. ©Sue Scott/Scottish Natural Heritage

If proper care is not taken during the construction phase, fine sediments and other pollutants can be released into the river smothering or poisoning plants and animals directly or smothering the habitats they depend on. For example fine sediment pollution can smother fresh water pearl mussels and river gravels which are important fish spawning habitats (see Figure 2).

Figure 2: Poor practice. Release of fine sediments during the construction phase can pollute watercourses leading to loss of, or damage to, protected species and habitats such as fish spawning areas.

2.2 Barrier to fish passage and other wildlife

Migration and movement throughout the river catchment is essential to the survival of many animal species including salmon, trout, lamprey, otter and watervoles. Poorly designed river crossings such as bridges and culverts can prevent fish and mammals moving up and down river catchments. This prevents animals reaching essential areas in the catchment, such as breeding and feeding habitats, leading to a reduction in or loss of populations.

Salmon travel as adults from the sea up river to spawn and then, as juveniles, migrate back downstream to the sea. Other fish such as brown trout use different parts of the river catchment throughout their life cycle, migrating upstream to smaller headwaters to spawn and moving downstream to feed and grow in lochs or larger rivers where more food may be available. Sea trout, eels, sea lamprey and river lamprey also make significant migrations.

Other fish species may be involved in shorter migrations within the catchment and can be affected if a crossing creates a barrier and prevents access to a key area of habitat. For example Artic charr can make limited migrations from lochs to rivers and brook lamprey can also make smaller migrations, associated with spawning, within a catchment.

Poorly designed river crossings can be a significant barrier to fish passage. Some of the main problems than can result in barriers include:

- perched inverts (bridge aprons, weirs or culvert outfalls that create a drop from the structure to the down stream river bed). This can be the result of poor initial design (Figure 3) or may arise if the invert is placed at bed level which leads to subsequent erosion downstream due to scour (Figure 4). In some cases erosion may be triggered elsewhere in the river and move up or downstream to the structure, creating a drop.

- undersized crossings that are too small for fish to pass through and may also increase the speed of water flowing through the structure leading to flows that are too fast for fish to swim against (see Figures 5 and 6);
- excessively wide crossings which create flows that are too shallow for fish to swim through (see Figure 7);
- a lack of resting places and pools. Some species of fish can jump up some obstructions if there are adequate pools downstream. If a crossing is difficult for fish to swim through or is very long and there are no resting places then fish can get exhausted and be washed downstream.

Figure 3: Poor practice. Culvert installed with a drop from the culvert outfall to the downstream riverbed (perched culvert) creating a barrier to fish passage.

Figure 4: Poor practice. A bridge invert may be level with the riverbed at the time of construction but subsequent erosion downstream due to scour can led to a drop forming (perched invert) that can create a barrier to fish passage, it can also lead to flows that are too shallow for fish to swim through.

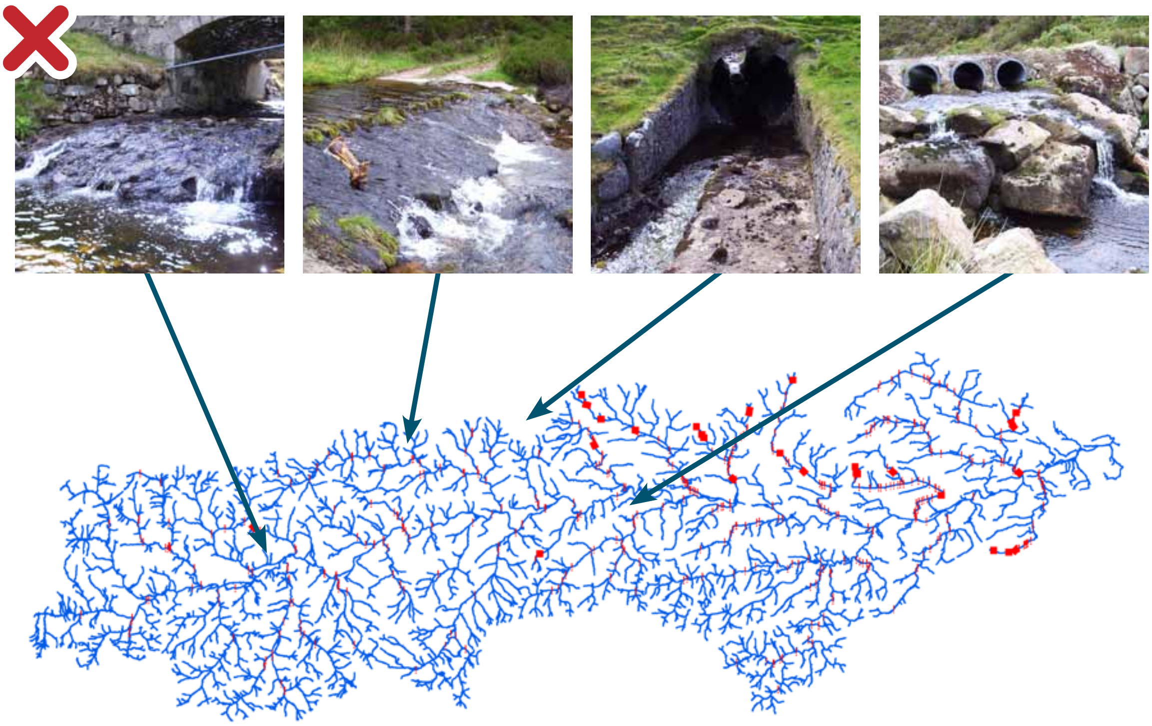
Figure 5: Poor practice. Pipe bridges create undersized crossings that are too small and dark for fish to enter. In high flows water may be too fast for fish to swim against.

Figure 6: Poor practice. Pipe bridge creating a barrier to fish passage, showing a drop from the invert to the riverbed (perched). Undersized pipes are too small and dark for fish to enter and in high flows water may be too fast for fish to swim against.

Figure 7: Poor practice. This ford has widened the river, leading to flows that are too shallow for fish to swim through. Photograph courtesy of the River Dee Trust.

A single crossing can be a complete barrier to fish passage (ie it prevents all fish passage all of the time), leading to the loss of certain fish populations such as salmon upstream of the structure. Some crossings however may form partial barriers to fish passage (ie some fish can get past under certain conditions). Even if crossings form partial barriers the cumulative impact of these over a whole catchment can have a significant impact on fish populations. The River Dee catchment in Aberdeenshire is largely rural yet still has more than 500 crossings (Figure 8). Some of these crossings pose a complete or partial barrier to fish passage, which can prevent or reduce fish species such as salmon reaching parts of the catchment.

Figure 8: Crossings in the River Dee catchment. Some of these pose a complete or partial barrier to fish passage and can negatively affect fish populations throughout the catchment. Photographs courtesy of the River Dee Trust.



Being able to move up and down a river is also essential for other wildlife such as otters and water voles. These species not only depend on a healthy river ecology (fish and invertebrates), but also on good bank-side (riparian) habitat where they live and feed. This habitat is important in small burns and ditches as well as larger rivers eg water voles in particular often use small watercourses including ditches and upland burns. Culverts and other crossings that do not maintain the riparian corridor can create barriers for these mammals as well, preventing them from reaching feeding grounds and establishing populations elsewhere. In more urban environments, the riparian habitat may be one of the few corridors they have left in which to move around. Ensuring mammal passage under river crossings may also help prevent animals such as otters crossing roads, reducing their risk of being hit by road vehicles.

Figure 9: Mammals such as otter also need to move up and down the river corridor and can be adversely affected by river crossings that do not allow mammal passage. Photograph © Scottish Natural Heritage.

2.3 Barriers to sediment and wood transport

Rivers also carry a significant amount of sediment as well as water. River sediment covers all natural river bed load including silts, sands, gravels, cobbles and boulders. This is stored and transported throughout the river creating habitats for many species such as spawning gravels for fish and gravel bars and islands essential for many invertebrates.

Where crossings are poorly designed, sediment can deposit at bridges and culverts which can reduce flow capacity and increase flood risk (Figure 10). This may lead to the need for regular dredging at the structure. Dredging increases long term maintenance costs and can lead to the loss of important species and habitats such as fresh water pearl mussels and fish spawning gravels and may also pollute the river with the release of finer sediments that can smother habitats and species downstream. See the SEPA good practice guide: *Sediment Management* for more information on sediment removal and its impacts available from the SEPA website www.sepa.org.uk/water/water_publications.aspx

Figure 10: Increased sediment deposition at a bridge can increase flood risk

Large woody debris is important to river ecosystems, and should be retained in the river channel where possible. It provides food for organisms and its presence increases the physical diversity of the channel. Woody debris can be trapped at bridges (Figure 11), which can increase flood risk and the risk of the bridge collapsing in high flows. This woody debris is often removed from bridges and culverts to stop such potential impacts.

Figure 11: Large woody debris trapped at a bridge. Photograph courtesy of the City of Edinburgh Council.

2.4 Preventing the lateral migration of rivers

Many rivers move naturally across their floodplain through the process of erosion and deposition. This process is called lateral migration (Figure 12). The area within which a river channel is likely to move over a period of time is referred to as the channel migration zone. This movement or migration creates new habitats and re-works older habitats providing different habitat types and ages, important for maintaining a diverse range of plants and animals. For example rare species of plants and insects such as river shingle beetles, a UK Biodiversity Action Plan group, live on bare river gravels created by this movement.

If a structure is located poorly, it may prevent lateral movement (Figure 13) of the river. This may interrupt the natural processes of erosion and deposition, therefore damaging habitats and it may also lead to damage to or loss of the crossing structure itself (Figure 14). This can result in the need for further engineering works to stabilise the structure or stabilise the river, increasing costs. Trying to stabilise a naturally dynamic river is likely to result in long term maintenance issues and may cause further impacts such as increased erosion upstream or downstream.

Figure 12: Movement of the River Clyde and River Medwin between 1848 and 1977. Illustration modified from Werritty and McEwen in Gregory (ed), Fluvial Geomorphology of Great Britain 1997, after Brazier et al.

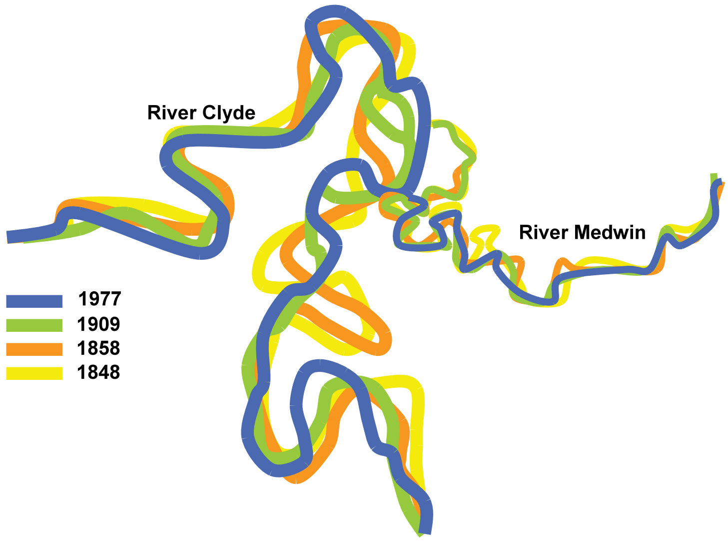


Figure 13: River migration affected by roads and river crossings. Photograph courtesy of Aberdeenshire Council.

Figure 14: Bridge structure at risk of failing due to erosion from inappropriate location on an active river.

2.5 Flooding and floodplain connectivity

Floodplains are an important part of the river system; they provide storage for water during high flows and, under natural conditions, can act as storage areas for sediment and nutrients. They also provide important food sources and nursery areas for fish and other aquatic plants and animals.

Poorly designed structures can increase flood risk upstream due to a lack of capacity beneath the structure. Other structures may have sufficient capacity to take even the highest flows but, if they block the floodplain (eg by road embankments, see Figure 15), an increase in upstream flooding can still occur. Disconnecting the floodplain from the river can also lead to the loss of floodplain habitats.

Crossings can constrict flood flows, forcing flood flows through a relatively narrow opening at a crossing point (see Figure 16). This can increase bed and bank erosion, and alter sediment deposition damaging river habitats and crossing structures.

Figure 15: Road embankment crossing a floodplain. Photograph courtesy of Aberdeenshire Council.

Figure 16: Crossings can constrict flood flows which can increase bank and bed erosion and alter sediment deposition, damaging river habitats and crossing structures.

3 The good practice process

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

Figure 17: River crossings good practice process

Demonstrate need (Section 4)

Can a route be chosen that minimises the number of crossings?

↓

Can existing structures be used?

↓

Can existing structures be upgraded or replaced (opportunity for environmental improvement)?

↓

Consider a range of options (Section 5)

Identify key site specific requirements

Identify ecological requirements (protected species and habitats, fish/mammal passage).

Identify water user requirements (eg navigation, recreation).

Identify Hydrological requirements.

↓

Options appraisal

Identify a range of options.

Carry out options appraisal (taking into account site requirements and long term maintenance requirements).

Choose the option that minimises ecological harm at a cost that is not disproportionately expensive.

↓

Implement good practice (Section 6)

Consider location and alignment

Avoid active river areas, particularly meander bends.

Avoid depositional areas.

Make the crossing perpendicular to the river.

Consider flood plain crossings

↓

Design structure in accordance with good practice.

↓

Ensure care is taken during the construction phase to avoid damage to protected species and habitats and to reduce the risk of pollution.

4 Demonstrating need

Key points

- Can a route be chosen that minimises the number of crossings?
- Can existing structures be used?
- Can existing structures be upgraded or replaced? (opportunity for environmental improvement).

The first step in identifying a sustainable engineering solution is to determine whether new engineering work is necessary.

4.1 Is there a demonstrated need?

The following considerations should be taken into account before deciding if a new crossing structure is required. It is essential that these considerations are taken into account in the early stages of the planning and design process.

- Can a route be chosen that minimises the number of crossings?
- Can existing structures be used?
- Can existing structures be upgraded or replaced (opportunity for environmental improvement).

Upgrading or replacing existing crossings

When upgrading or replacing an existing crossing the opportunity should be taken to improve any environmental impact the existing crossing may have. For example fish and mammal passage can be provided if the existing crossing creates a barrier. If improving fish passage the local district salmon fishery board (www.asfb.org.uk) and local fisheries trusts (www.rafts.org.uk) can be contacted for advice. They can advise on fish populations present (native as well as non-native) and any potential impacts of removing a barrier.

If an old structure is being replaced, the old structure should be removed rather than leaving it in place and building a new structure next to it. However, there may be exceptions to this, such as if structures need to be retained for access purposes, or if they have some historical or local significance. In such instances, Historic Scotland (www.historic-scotland.gov.uk) and the local authority planning department should be consulted.

See section 6.4 for further information on maintenance and improvement of existing structures.

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 ie 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.

This section describes possible crossing options and provides guidance to help applicants select the most suitable and sustainable type of crossing.

5.1 Identify key site specific requirements

In order to carry out a thorough options appraisal it is essential that the key requirements for a site are identified. It is essential to ensure that the key requirements are met when assessing the options.

Key requirements that should be identified for each site include:

Ecological

- Identify sites that have been designated for nature conservation (SSSI, SAC, SPA) and ensure the conservation requirements for any designated site are met. Contact Scottish Natural Heritage for further information (www.snh.org.uk).
- Identify protected species nearby that could be affected (eg freshwater pearl mussel, lamprey, river jelly lichen, otters) Contact Scottish Natural Heritage for further information (www.snh.org.uk).
- Identify important habitats (eg fish spawning and rearing areas) and ensure they are not damaged.
- Identify fish species present up stream and down stream if there is a risk that fish passage may be affected. 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. A suitably qualified ecologist should be consulted to ensure that fish surveys are carried out appropriately and to ensure that fish passage is not affected.
- Identify mammals present in the area.

Other users of the river

- Identify other users of the river and ensure the use is not affected (eg is the river used for navigation, recreation canoeing/rafting).

Size and capacity of crossing

- What hydraulic capacity is required (see box below)? Contact the relevant roads authority for further information (this will be the Local Authority or Transport Scotland if the crossing is likely to affect a trunk road.
- Consider allowance for sediment transport through the crossing (not just hydraulic capacity).
- Freeboard, consider the amount of freeboard that is required eg to aide passage of large woody debris and other water uses eg navigation and recreation.

Hydraulic capacity

The hydraulic capacity of crossing structures will vary depending on the location of the crossing and the purpose the crossing infrastructure serves. Requirements must be discussed with the relevant organisations.

If crossing structures require planning permission they should conform to the Scottish Planning Policy. This states that no new development should increase the probability of flooding elsewhere. The Scottish Planning Policy is available from the Scottish Government website at www.scotland.gov.uk/Publications/2010/02/03132605/0

Further information on flooding and the different responsibilities in relation to flooding can be found on the SEPA website at: www.sepa.org.uk/flooding

If a crossing is in an urban area, close to other development, close to or will effect a trunk road or will be adopted by the roads authority (this will be the Local Authority or Transport Scotland for trunk roads) then the relevant roads authority must be contacted to advise on hydraulic capacity and other requirements.

The hydraulic capacity of crossing structures will vary depending on the location of the crossing and the purpose the crossing infrastructure serves. Requirements must be discussed with the relevant organisations.

These considerations must be taken into account in the early stages of the planning and design process.

Remember sediment moves down rivers as well as water, especially during high flows. Allowance for sediment should be taken into account when assessing capacity and the required size of structure.

For further information on hydraulic capacity of structures see:

- *CIRIA Culvert design and operation guide* (C684) www.ciria.org
- Highways Agency *Design Manual for Roads and Bridges*, Volume 4 Section 2 Design of outfall and culvert details www.standardsforhighways.co.uk/dmrb/index.htm

5.2 Options appraisal

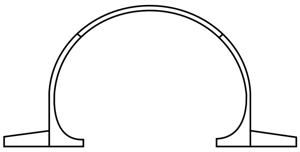
This good practice guide identifies five generic types of crossing including pipeline and cable crossings; these can be seen in Figure 18 below and are described in Table 1. The flow chart in Figure 19 will help to determine what range of crossing types may be suitable for your circumstances, and should be considered in an options appraisal. Guidance on selecting the most suitable option is provided in Section 5.3 of this document.

Figure 18: Types of river crossing

General increase in impact ↓

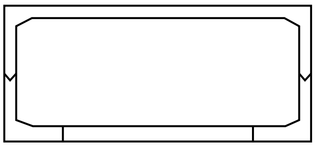
I. Single span structures (bridge or pre cast structures with natural bed – no artificial invert)	V. Pipe or cables under watercourse
II. Span structures with in-stream supports (bridge or pre cast structures with natural bed – no artificial invert)	
III. Closed culverts (structures with artificial invert)	
IV. Fords	

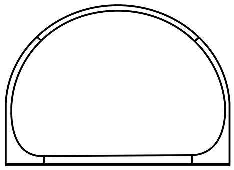
Table 1: Different types of river crossing

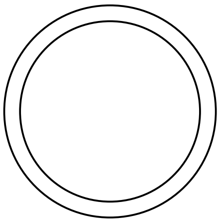
I. Single span structures Structures that span the width of the channel with no in-stream support and do not affect the bed of the river, ie they have no artificial invert and a natural bed is maintained. Bank habitat can be maintained under the crossing if abutments are set back. They can come in a variety of forms from pre-cast concrete structures (arch or portal [rectangular]), panel bridges that come in pre-fabricated sections to bridges designed for site specific requirements. Some prefabricated structures require foundations to be constructed at the site and others can have prefabricated foundations.	Photograph courtesy of the Highland Council    
II. Span structures with in-stream supports In-stream supports (piers) can be used to increase the crossing width where single span is not possible or prohibitively expensive. Bank habitat can be maintained under the crossing if abutments are set back. They can come in a variety of forms, from bridges designed for site specific requirements to panel bridges that come in pre-fabricated sections with supports.	 

III. Closed culverts

Closed culverts have an artificial invert (floor) and so have a greater impact on the bed and banks of the river. Closed culverts can be made from a variety of materials and come in a range of shapes (eg pipe, box, closed arch) and sizes. Installation of a closed culvert causes significant disruption to the river bed and, if not designed correctly, can cause a barrier to fish migration.







IV. Fords

Fords are river crossings built at the level of the river bed. They can be made of natural materials (natural bed and bank material maintained) or they can be reinforced with artificial material (bed and/ or banks).

V. Pipe or cable crossings under a watercourse

If pipelines or cables have to cross river they should be buried underneath the river bed. They can also be spanned above a river using a span structure or span structure with in-stream supports.

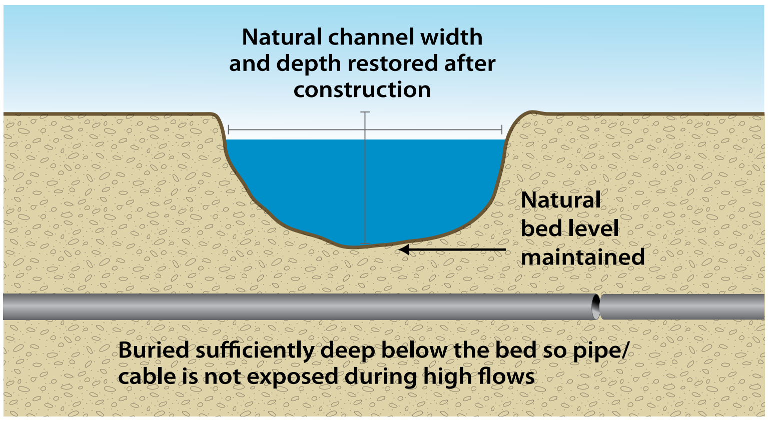
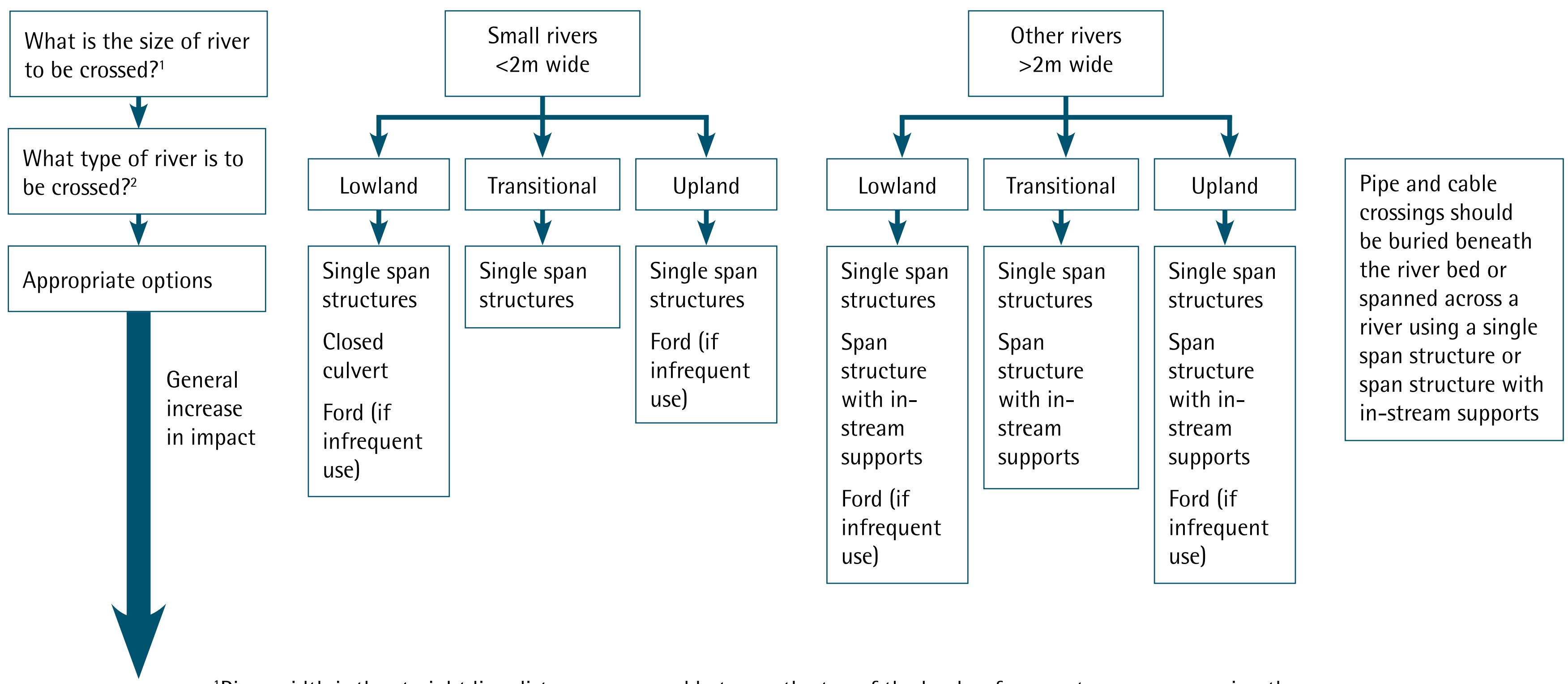


Figure 19: Identifying suitable options



[1]River width is the straight line distance measured between the toe of the banks of any watercourse, spanning the bed of the watercourse, including any exposed bars and vegetated islands.

[2]See Appendix 1 to help determine your river type.

5.3 Selecting the most suitable option

Table 2 provides some key points to help choose the most suitable option. Remember the option chosen should meet all the key site specific requirements identified (see Section 5.1).

Table 2: Considerations for different types of crossing

Type of crossing	Impact	Considerations
I. Single span structures	Least impact	• Preferred type of crossing. • Has minimal impact on the river system if designed appropriately. • May not be suitable for very wide rivers. • Bank habitat can be maintained under the crossing if abutments are set back. • Minimal disturbance to the river during the construction phase if abutments are set back. • Low risk of causing a barrier to fish and other wildlife if designed appropriately. • Lower risk of disrupting navigation or recreation if designed appropriately. • Pre-fabricated structures are generally cheaper than a site specific design. • Span structures can take longer to install and may be more expensive than other crossing types as specialist construction techniques may be required. • Can be used to carry pipe or cables across watercourses.
II. Span structures with in-stream supports	Moderate Impact	• Only appropriate where in-stream support is necessary to ensure structural integrity (ie very wide rivers). • Bank habitat can be maintained under the crossing if abutments are set back. • Low risk of causing a barrier to fish and other wildlife if designed appropriately. • Careful consideration required if river is used for navigation or recreation. • Higher risk of causing damage to the river during the construction phase (requires work in the river bed). • In-stream supports can significantly affect local channel hydraulics, increasing the risk of erosion and sediment deposition. • Higher risk of blockage by debris. • Span structures with in-stream supports can take longer to install and may be more expensive than other crossing types as specialist construction techniques may be required. • Can be used to carry pipe or cables across watercourses.

III. Closed culverts	High Impact	• Only suitable for small streams in lowland rivers. • Higher risk of causing a barrier to fish and other wildlife passage. • Higher risk of causing damage to the river during the construction phase (requires work in the river bed). • May not be suitable if river is used for navigation or recreation • Higher risk of blockage by debris. • Culverts are generally cheaper than span structures because the design and construction process is generally less complex than for spanning structures. • Not suitable for carrying pipelines or cables across rivers.
IV. Fords	High Impact	• Only suitable if infrequent crossing is expected. • Should not be used where there is a high risk of pollution eg at construction sites. • Higher risk of pollution from surface water runoff and increased bed and bank erosion. • Moderate risk of creating a barrier to fish passage. • Risk of damaging fish spawning habitat. • A low cost solution.
V. Pipeline or cables under watercourse	Minimal impact	• Pipelines or cables can be carried above rivers using a single span bridging structure or span structure with in-steam supports. • If they are not bridged over a river, they should be buried below the bed of the river and should not be laid in the channel. • Depending on the construction technique there may be a high risk of causing damage to the water environment during the construction phase. • Burying below the channel should be suitable for all types of river but may depend on ground conditions.

6 Design and implementation

Successful adoption of good practice requires selection of a suitable option followed by appropriate design and implementation. This section provides guidance on design and implementation. Many of the considerations highlighted in this good practice guide need to be taken into account in the early stages of the planning and design process. For larger scale projects, this includes consideration of the whole transport route as well as the crossing structures themselves.

6.1 Location and alignment

Key points

- Avoid crossings over active areas, particularly at meander bends.
- Avoid crossing rivers at depositional areas.
- Ensure the crossing is perpendicular to the river.

Selecting an appropriate location, or taking into account the characteristics of the location, is the first step in reducing:

- the impact of the river crossing on the water environment;
- the risk of damage to the crossing structure itself;
- future maintenance costs.

Channel migration/active zones

As stated in Section 2.5 the area within which a river channel is likely to move over a period of time is referred to as the channel migration zone. Failing to recognise this natural process may lead to the damage of habitats and damage to or loss of the crossing structure.

Locate crossings on straight/stable sections of the river (Figures 20 and 21). Avoid crossings over active areas, particularly on the outside of meander bends, because there is a high risk that the structure will be damaged or fail due to river migration or localised scour (Figure 22). Extensive maintenance works to stabilise the structure and river may then be required, which will increase costs. Trying to stabilise a naturally dynamic river will result in long term, potentially significant, maintenance issues and may cause further impacts such as increased erosion upstream or downstream.

Active channels can be found in a variety of settings and are often found in transitional type rivers (see Appendix 1 to help determine if your river is a transitional type). Indications of an active river include:

- signs of erosion especially on the outside of meander bends (Figure 22);
- depositions of unvegetated larger sediment sizes – gravel, pebble, cobble (Figure 23);
- steeper river gradients (0.1–3% and above).

It is difficult to predict how a river might migrate over time and there are many different ways in which a river may move. If there are concerns that the river to be crossed has the potential to migrate significantly over time then a suitably qualified geomorphologist should be consulted to assess the site to estimate rates of migration and suggest mitigation measures.

For information on suitable assessment techniques see:

Review of River Geomorphology Impact Assessment Tools and Post Project Monitoring Guidance for Engineering Activities (WAT-SG-30) available from the SEPA website at: www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx

Figure 20: Good practice, locate crossings on stable sections of a river to avoid erosion. This is an example of a straight, stable section of river – note no evidence of active erosion.

Figure 21: Good practice, locate crossings on stable sections of a river to avoid erosion. This is an example of a straight, stable section of river – note no evidence of active erosion.

Figure 22: Poor practice, do not locate crossings on actively eroding areas. Indicators of an active river include bank erosion on the outside of meander bends.

Figure 23: Poor practice, do not locate crossings on actively eroding areas. Indicators of an active river include the presence of unvegetated sediment deposition.

Depositional areas

As stated in Section 2.3, rivers carry a significant amount of sediment as well as water.

Avoid crossing rivers at locations where sediment is depositing, as there is a risk that sediment will accumulate at the structure, reducing flow capacity and increasing flood risk. Any modifications to the channel could also lead to increased sediment deposition reducing flow capacity and increasing flood risk. This could lead to a need for regular dredging, which increases maintenance costs and damages the ecology of the river.

Depositional areas are widely found in lowland and transitional types of rivers (see Appendix 1 to determine your river type). Depositional areas are the result of various factors including valley gradient, geology and sediment supply.

In many rivers, deposition occurs where there is a reduction in valley gradient. If the slope is lower, the river has less energy and sediment is deposited. This may occur where relatively steep tributaries with high sediment loads join the main river to form large areas of deposition at river confluences (alluvial fans). Deposition also occurs downstream of areas that supply large volumes of sediment. Avoid such locations if possible. Indicators of depositional areas include:

- sediment depositions in rivers such as gravel bars and islands present (Figures 24 and 25);
- smaller sediment sizes of gravel, sand or silt;
- low river gradients or where the gradient changes quickly from high to low.

If it is necessary to cross a river in a depositional zone, ask a suitably qualified geomorphologist to assess the site and suggest mitigation measures.

For information on suitable assessment techniques see:

SEPA 2005 Review of River Geomorphology Impact Assessment Tools and Post Project Monitoring Guidance for Engineering Activities (WAT-SG-30) available from the SEPA website www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx

Figure 24: Poor practice, do not locate crossings on depositional areas. Indicators of a depositional area include gravel islands.

Figure 25: Poor practice, do not locate crossings on depositional areas. Indicators of a depositional area include gravel bars.

Alignment

Crossings should be perpendicular to the river (Figures 26 and 27). This ensures that the crossing is as short as possible – reducing impact and, in some instances, cost. This also reduces the risk of localised scour at the structure.

Figure 26: Good practice, ensure the crossing is perpendicular to river.

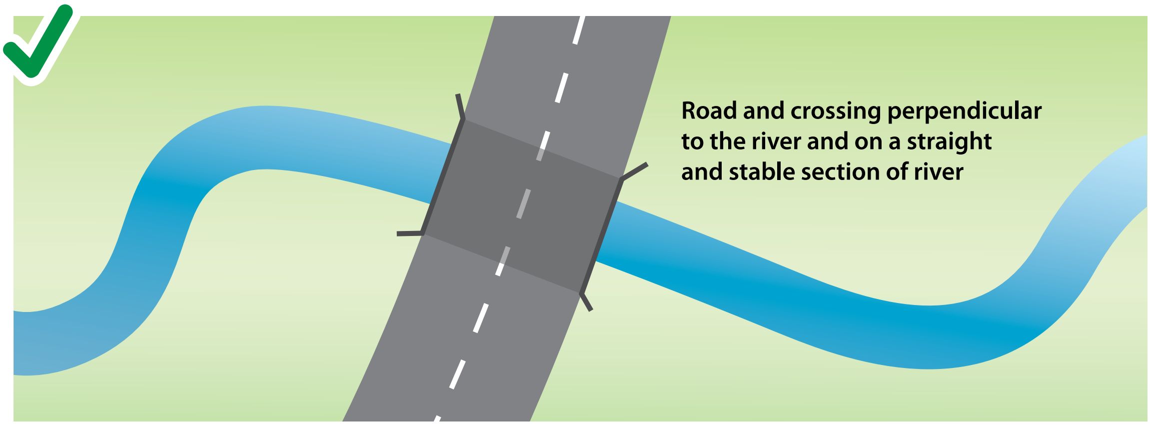
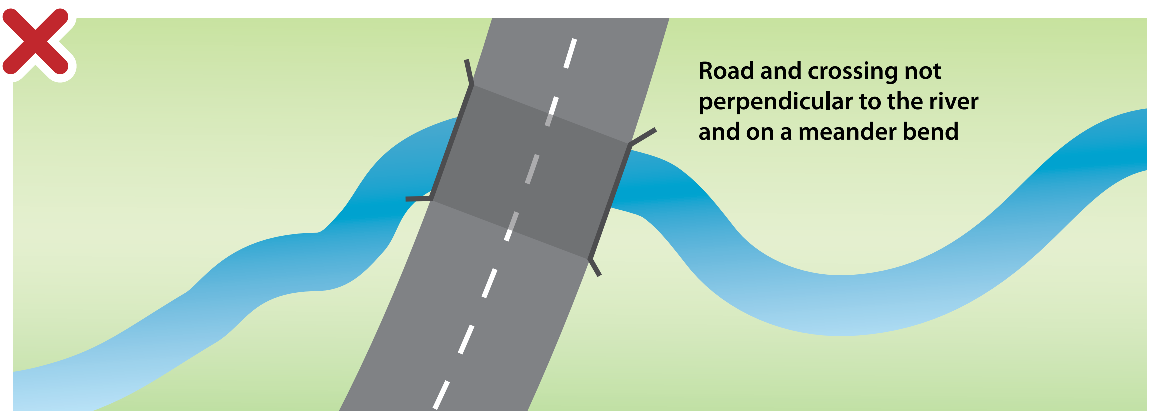


Figure 27: Poor practice, crossing not perpendicular to river and on a meander bend.



Buried pipe or cable crossings should also be perpendicular to the river (Figure 28). Do not use rivers as conduits for pipes or cables (Figure 29). This can increase the risk of the pipe or cable being damaged which may lead to pollution of the watercourse and may also increase bed and bank erosion.

Figure 28: Good practice, the pipe or cable should cross perpendicular to the river and should be buried below the river bed.

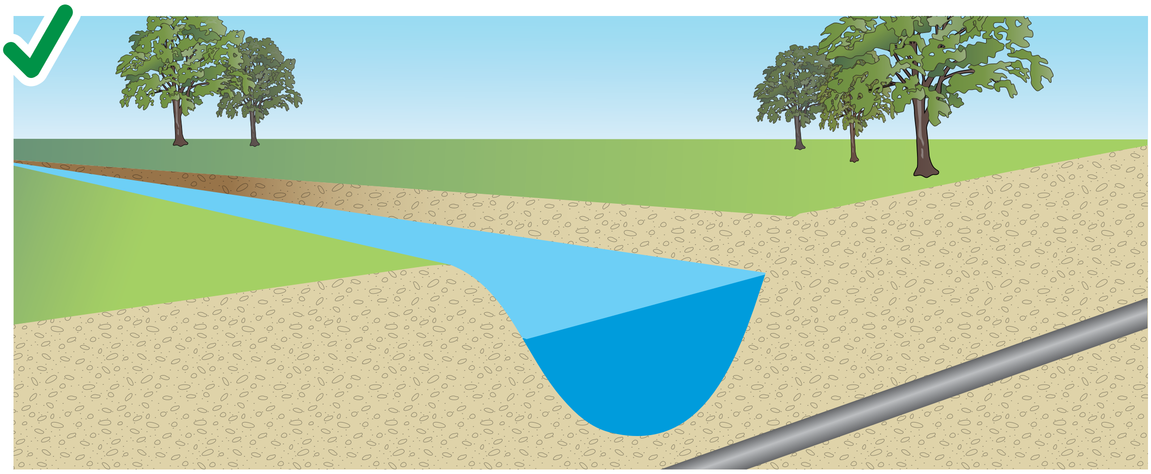
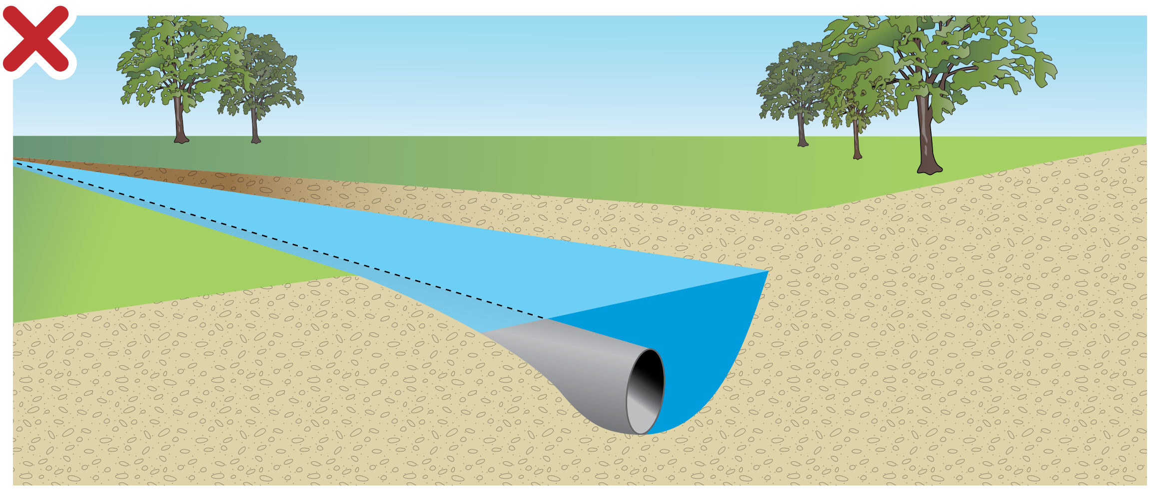


Figure 29: Poor practice, do not lay pipes or cables on the river bed or use rivers as conduits for pipes and cables.



If it is not possible to align the crossing perpendicular to the river then mitigation measures should be considered, including:

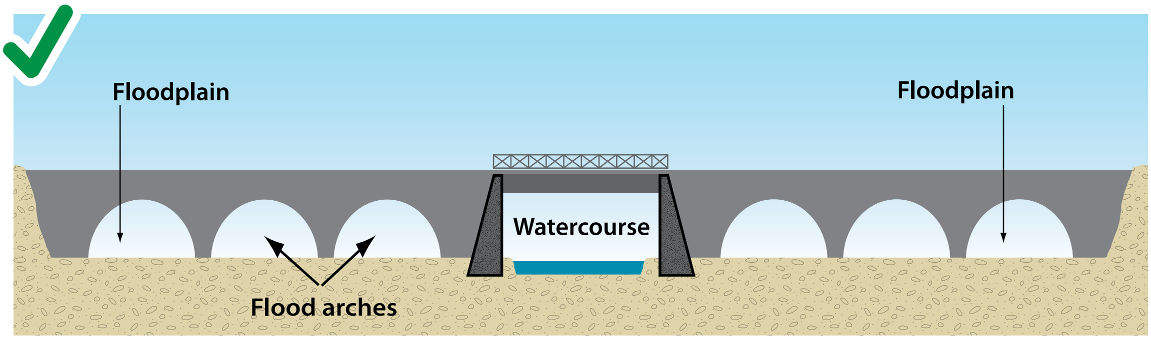
- design a structure that can cope with channel migration (eg larger single span, additional spans with piers or viaduct structure);
- realignment of the river should only be considered if other options are not possible. Careful consideration of the design of the new river channel is essential to ensure that it is geomorphically stable (ie the design does not result in increased erosion or deposition). If realignment of the watercourse is necessary then a suitably qualified geomorphologist should be consulted to ensure the new river channel is designed appropriately.

6.2 Crossing a floodplain

As stated in Section 2.5, floodplains are an important part of the river system. Viaducts (a road deck spanning between piers) should be used to cross floodplains rather than embankments (Figure 30). This option greatly reduces the impact on the floodplain, but can have cost implications.

Where embankments are unavoidable, 'normally dry culverts' in embankments can be used to connect the floodplain. There may be hydraulic design issues to overcome, which can result in reinforcement around the culverts to prevent scour and embankment failure during high flow events.

Figure 30: Good practice, viaducts should be used to cross floodplains.



6.3 Design of structure

Once the most suitable type of crossing has been selected implement the design details necessary to minimise the impact on the water environment. This section provides information on the design features that can help minimise the impact on the water environment.

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

Good practice design: I and II single span structures and span structures with in-stream supports

The principles below should be followed for all types of single span structures and span structures with in-stream supports.

- Minimise the potential for localised bed and bank erosion (scour) or excessive sediment deposition at the crossing structure through careful consideration of the location and alignment as discussed in Section 6.1.
- Set abutments back from the river channel and banks to allow the continuation of the riparian corridor underneath the structure. This helps to minimise or prevent the need for bed and bank reinforcement, reduces the risk of creating a barrier to fish passage and allows mammal passage under the structure (see Figures 31, 32 and 33).
- Make the distance between the bridge abutments as wide as possible and maintain the bank habitat, maximising the riparian corridor and allowing the river some space to move.
- Ensure the natural channel width is maintained and provide mammal passage if bank habitat cannot be retained and abutments cannot be set back.
- Bury foundations (of abutments and in-stream piers) deep enough to minimise or prevent the need for bed or bank reinforcement or bridge weirs or aprons. This maintains the natural bed material and bed levels, protecting habitat and allowing fish passage (Figures 31 and 33). The foundations should be buried deep enough to allow for scour during high flows. A suitably qualified engineer or geomorpholgist should be consulted to advise on an appropriate depth.
- Design the structure including in-stream piers to facilitate the passage of woody debris.
- Consider requirements for bed and bank reinforcement only if the risk of erosion cannot reasonably be eliminated through the above measures.

Figure 31: Good practice, pre-cast span structure showing set back abutments and deep foundations

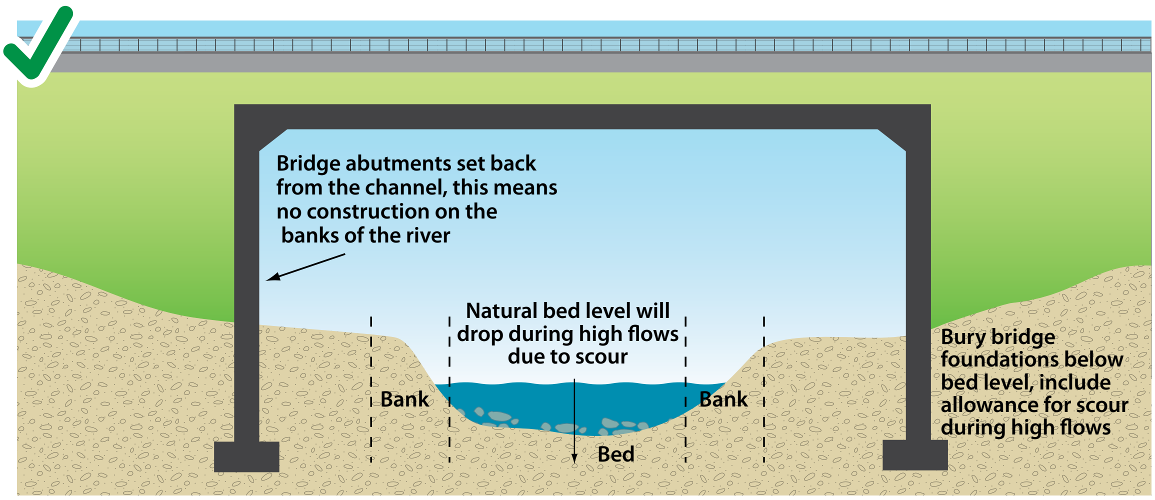
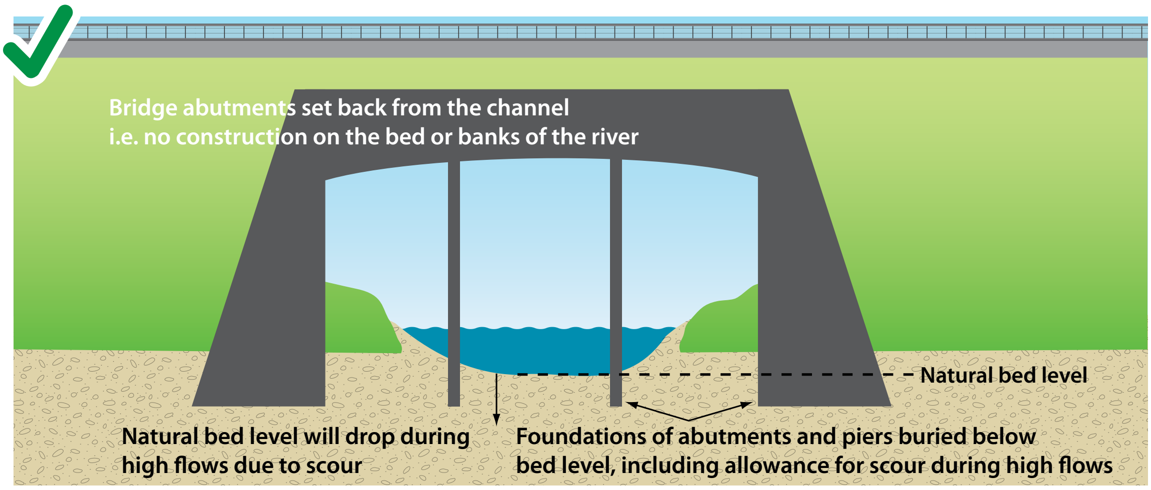


Figure 32: Good practice, span bridge showing set back abutments and bank habitat maintained through the structure allowing mammal passage and no risk to fish passage. Photograph courtesy of the Highland Council.

Figure 33: Good practice, bridge with piers showing set back abutments and deep foundations.



Piers increase the risk of large woody debris becoming trapped which in turn can increase localised flooding and put the structure at risk of failing. Passage of large woody debris through the structure should be considered, eg design piers to facilitate the passage of large woody debris by streamlining the upstream facing side (Figure 34).

Figure 34: Good practice, streamlined pier to facilitate passage of large woody debris.

Maintain natural channel width

Maintain the natural channel width if bank habitat cannot be retained under the bridge (Figure 35 and 36) (width of river measured between the toe of the banks see glossary). This will help ensure adequate water depth and velocity for fish passage. If the channel under the bridge is too wide this will increase the risk of creating slow and shallow flows. This can prevent fish from swimming through the bridge and may lead to sediment deposition, reducing the flow capacity at the structure which could increase flood risk. If the channel under the bridge is too narrow it may lead to faster flows that fish are unable to swim against and may increase erosion which could damage the structure. If necessary a two-stage channel can be created under the bridge to maintain adequate water depth in low flows.

Mammal passage

Provide mammal passage if bank habitat cannot be retained under the bridge. In general mammal passes should be designed with otters in mind, although if larger mammals such as badgers are present then larger passes may be required.

Passage can be provided by constructing a ledge under the bridge (Figure 35) or providing a tunnel adjacent to the bridge (Figure 36).

Minimum headroom of 60 cm should be provided. The width of the ledge or tunnel will depend on the length of the crossing (see SNH guidance) but should be a minimum of 60 cm for tunnels and 45–60 cm for ledges, but may need to be wider for larger mammals.

For information on the height of ledges and tunnels see the Scottish Natural Heritage guidance and the Design Manual for Roads and Bridges.

Both tunnels and ledges which are above the natural bank height should have access ramps leading up to them from ground level. Fencing may be required in order to guide mammals to the crossing areas if they are to be effective (see Scottish Natural Heritage guidance for further information).

For further information see:

- Scottish Natural Heritage Guidance on mitigation for otters available from: www.snh.org.uk/publications/on-line/wildlife/otters/mitigation.asp
- Design Manual for Roads and Bridges, Volume 10 Section 4 Nature Conservation. Available from: www.standardsforhighways.co.uk/dmrb/index.htm

Figure 35: Good practice, natural channel width maintained and mammal passage provided by a ledge where bank habitat cannot be retained.

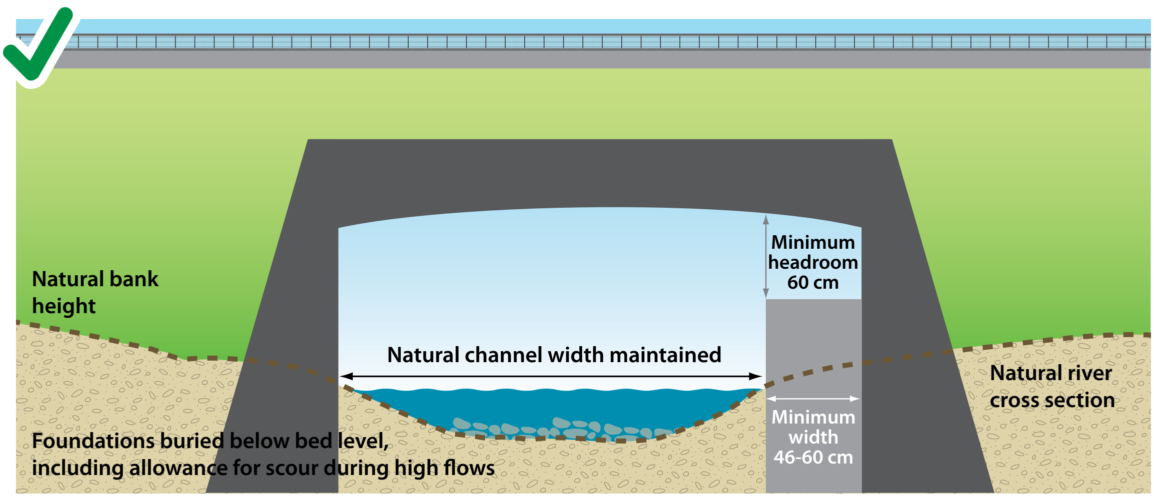
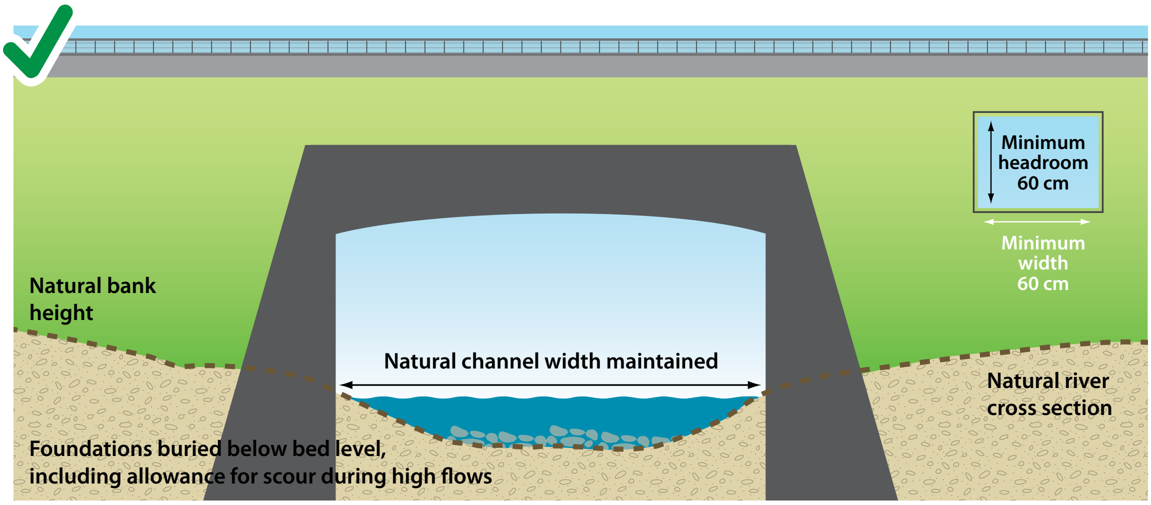


Figure 36: Good practice, natural channel width maintained and mammal passage provided by a tunnel where bank habitat cannot be retained.



Other mitigation

Where a crossing affects a longer length of river, consider light penetration and soil moisture deficit. Lack of light and moisture can prevent the establishment of vegetation under the crossing and weaken the banks (Figure 37). This can result in increased erosion under the crossing and potential exposure of the structure foundations. This may result in the requirement for bank reinforcement however the natural bed should still be maintained.

In general the need for bank reinforcement should be minimised through careful consideration of the location and alignment as discussed in Section 6.1 and following the guidance above. However where bank reinforcement is necessary, 'softer' measures should be considered in lower energy lowland environments (see Appendix 1). 'Harder' techniques may be needed if the crossing is located in a higher energy upland or transitional environment (see Appendix 1) where there is high risk of erosion. For more information on bank reinforcement please see the SEPA good practice guide: *Bank Erosion Management* www.sepa.org.uk/water/water_publications.aspx

Bed reinforcement should not be placed under a span structure. However if bed reinforcement is deemed necessary it should be buried below the natural bed level, deep enough to allow for scour during high flows. This will allow the natural bed level and bed material to be maintained.

Figure 37: Longer crossings may lack light and moisture which can prevent the establishment of vegetation under the crossing and weaken the banks. This may result in the requirement for bank reinforcement however the natural bed should still be maintained.

Good practice design: III closed culverts

Poorly designed closed culverts have a high risk of creating a barrier to fish passage and mammal movement throughout the river corridor.

Following the principles below for all types of closed culverts will reduce the risk of creating a barrier to fish and mammals.

- Minimise the potential for localised bed and bank erosion (scour) or excessive sediment deposition at the crossing structure through careful consideration of the location and alignment as discussed in Section 6.1.
- Design culverts so that they are passable to all fish species, even if some fish species are not present as the culvert could affect future measures to improve passage in the catchment.
- Maintain natural river bed level and slope, bury the culvert invert below the natural bed level.
- Maintain natural channel width.
- Ensure there are no physical obstructions to fish passage. Avoid 'perching' –when there is a drop at the culvert outlet to the river bed (ie at the downstream end). This can happen due to poor initial design or to subsequent erosion of the river bed downstream, if poorly designed.
- Ensure adequate water depth (maintaining natural bed level, slope and channel width contributes to this).
- Ensure appropriate water velocity (maintaining natural bed level, slope and channel width contributes to this).
- Ensure adequate fish resting places (pools or slower water) above and below the structure especially for longer culverts. Longer culverts may also require resting places within the structure.
- Provide mammal passage.
- Specific fish passage requirements will depend on the species of fish. For more detailed information on this see the Scottish Government's *River Crossings and Migratory Fish: Design Guidance* at: (www.scotland.gov.uk/consultations/transport/rcmf-00.asp).

Further information on culvert design can be found in CIRIA's Culvert design and operation guide at: www.ciria.org

Figure 38: Good practice, culvert maintaining natural channel width, bed level and slope ensuring adequate water depth and water velocity for fish passage.

Maintain natural bed level and slope

Bury the culvert invert below the natural bed level. This allows the natural bed level, slope and bed material to be maintained (Figures 39 and 40). The invert should be buried sufficiently deep to ensure it is not exposed during high flows. The culvert should be sized to carry both flood flows and river bed sediment.

Maintaining the natural bed level and slope will help ensure adequate water velocity (and water depth) for fish passage. It will ensure the slope of the culvert is not too steep, increasing risk of fast flows, erosion and 'perching', or too shallow, increasing the risk of deposition which may reduce flow capacity, and increasing flood risk.

The values below can be used as a general guideline as to how deep a culvert invert should be buried below the natural bed level (Figure 40). However it some circumstances it may need to be deeper to suit site specific conditions and a suitably qualified engineer or geomorphologist should be consulted. For further information see CIRIA C689 Culvert design and operation guide.

For culverts less than 1.2 m diameter or height (internal height) the invert should be buried at least 15 cm below the natural bed level.

For culverts 1.2 - 1.8 m diameter or height (internal height) the invert should be buried at least 20 cm below the natural bed level.

For culverts greater than 1.8 m diameter or height (internal height) the invert should be buried at least 30 cm below the natural bed level.

Figure 39: Good practice, longitudinal section of a culvert showing invert buried below bed level allowing the natural bed level, slope and material to be maintained.

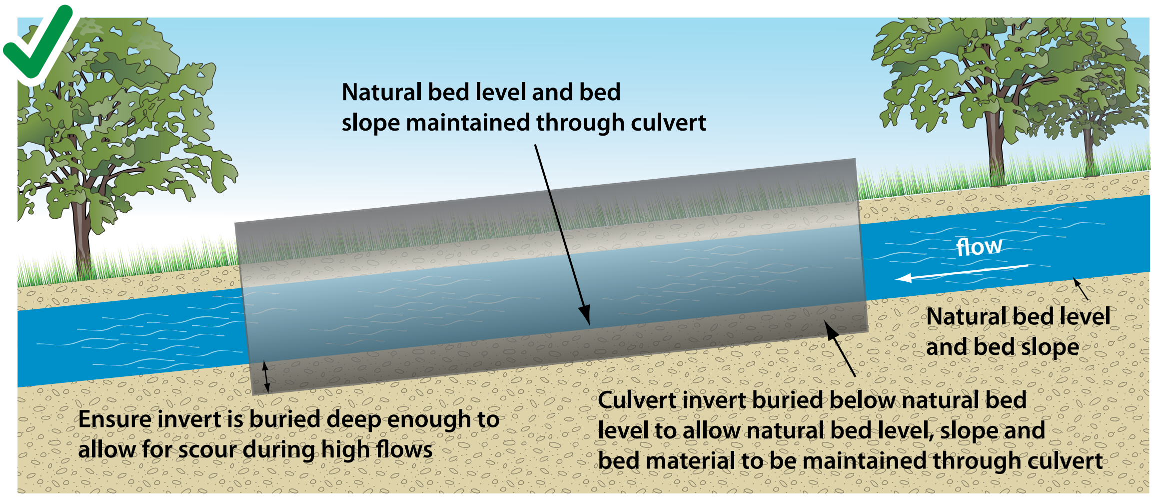
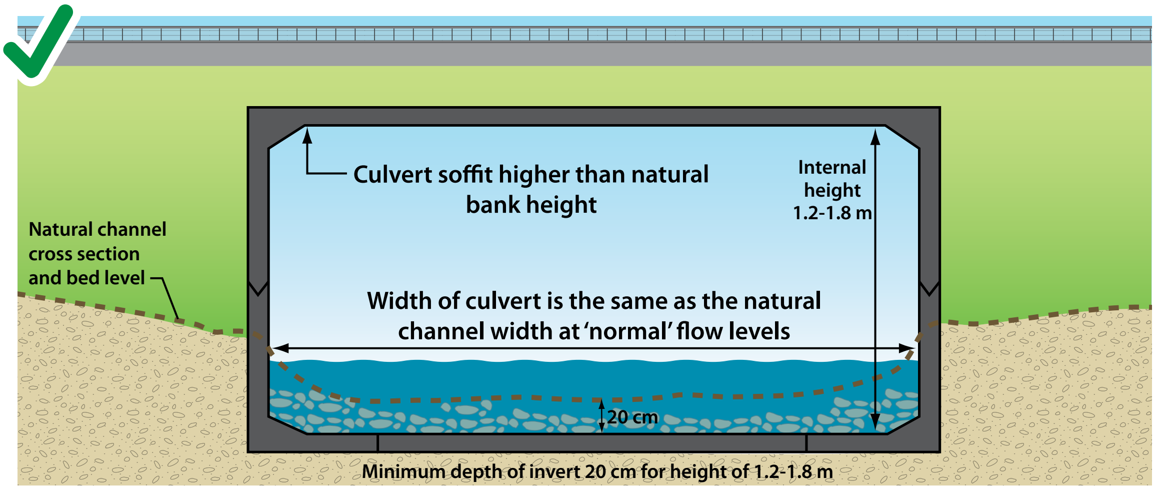
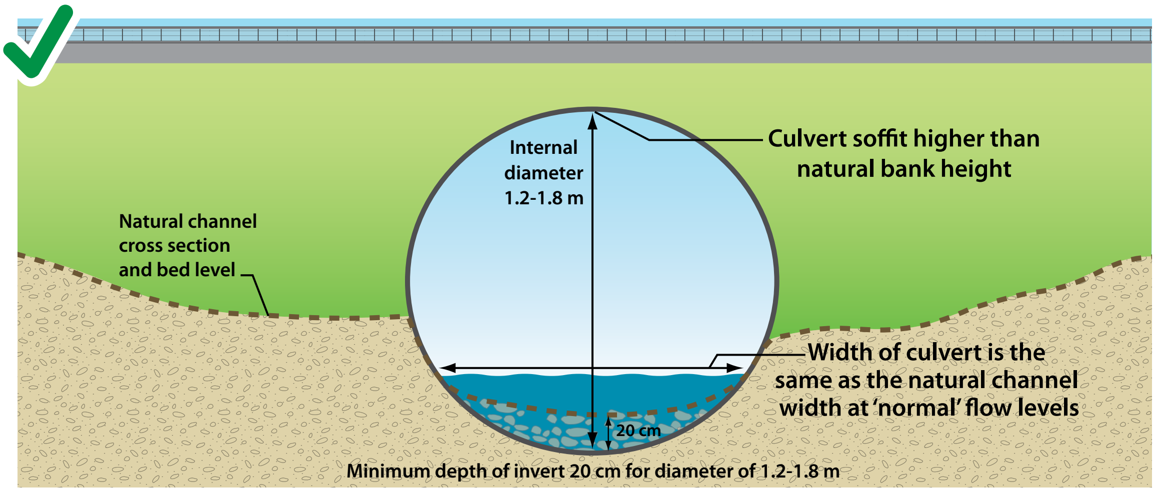


Figure 40: Good practice, culverts showing invert buried below bed level allowing the natural bed level, slope and material to be maintained. Culvert also maintains natural channel width.





Maintain natural channel width

The culvert should maintain the natural channel width (Figures 38 and 40) (width of river measured between the toe of the banks see glossary).

Maintaining the natural channel width will help ensure adequate water depth and velocity for fish passage. Culverts that are too wide will increase the risk of creating slow and shallow flows. This can prevent fish from swimming up or down the culvert and may lead to sediment deposition, reducing the flow capacity at the structure which could increase flood risk. If the culvert is too narrow it may lead to faster flows that fish are unable to swim against and may increase erosion and could lead to a drop forming downstream, creating a barrier to fish passage. Water velocities and depths in the culvert under different flow conditions can be checked to ensure they are adequate for fish passage. For more information on this see the Scottish Government's *River Crossings and Migratory Fish: Design Guidance* at: (www.scotland.gov.uk/consultations/transport/rcmf-00.asp).

Use larger single culverts (Figure 41) rather than multiple smaller culverts or pipes as fish prefer larger barrel sizes and can be discouraged from entering smaller pipes. Smaller diameters also increase the speed of water during high flows that fish are unable to swim against (Figure 42). Multiple smaller pipes may trap sediment that could increase flood risk and may stop river sediments moving downstream.

Twin barrels should only be used where a single span structure or single barrel culvert is not possible (Figure 43). If a twin barrel is used the natural channel width should still be maintained.

Figure 41: Good practice, use a single large culvert for crossings that maintains the natural channel width.

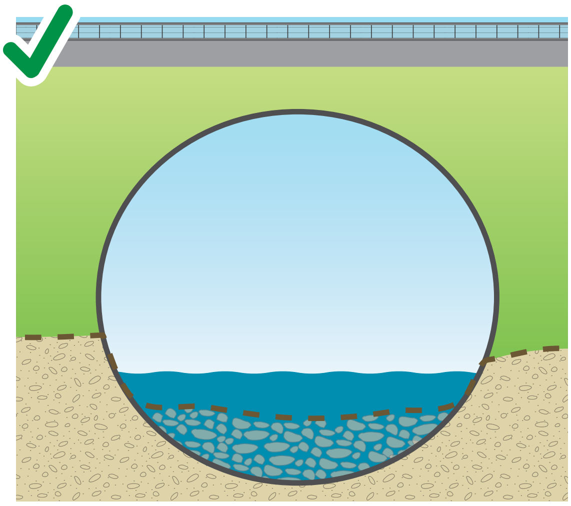


Figure 42: Poor practice, do not use smaller multiple pipes; they can create a barrier to fish passage.

Figure 43: Twin barrel culvert that maintains natural channel width and invert buried below the natural bed level. Should only be used where single span structure or single barrel culvert is not possible.

Mammal passage

Mammal passage should be provided. In general mammal passes should be designed with otters in mind, although if larger mammals such as badgers are present then larger passes may be required.

Passage can be provided by constructing a ledge under the culvert (Figure 44) or providing a tunnel adjacent to the culvert (Figure 45).

Minimum headroom of 60 cm should be provided. The width of the ledge or tunnel will depend on the length of the crossing (see SNH guidance) but should be a minimum of 60 cm for tunnels and 45–60 cm for ledges, but may need to be wider for larger mammals.

For information on the height of ledges and tunnels see the Scottish Natural Heritage guidance and the Design Manual for Roads and Bridges.

Both tunnels and ledges which are above the natural bank height should have access ramps leading up to them from ground level. Fencing may be required in order to guide mammals to the crossing areas if they are to be effective (see Scottish Natural Heritage Guidance for further information).

For further information see:

- Scottish Natural Heritage Guidance on mitigation for otters available from: www.snh.org.uk/publications/on-line/wildlife/otters/mitigation.asp
- *Design Manual for Roads and Bridges*, Volume 10 Section 4 Nature Conservation. Available from: www.standardsforhighways.co.uk/dmrb/index.htm

Figure 44: Good practice, mammal passage provided by constructing a ledge in the culvert.

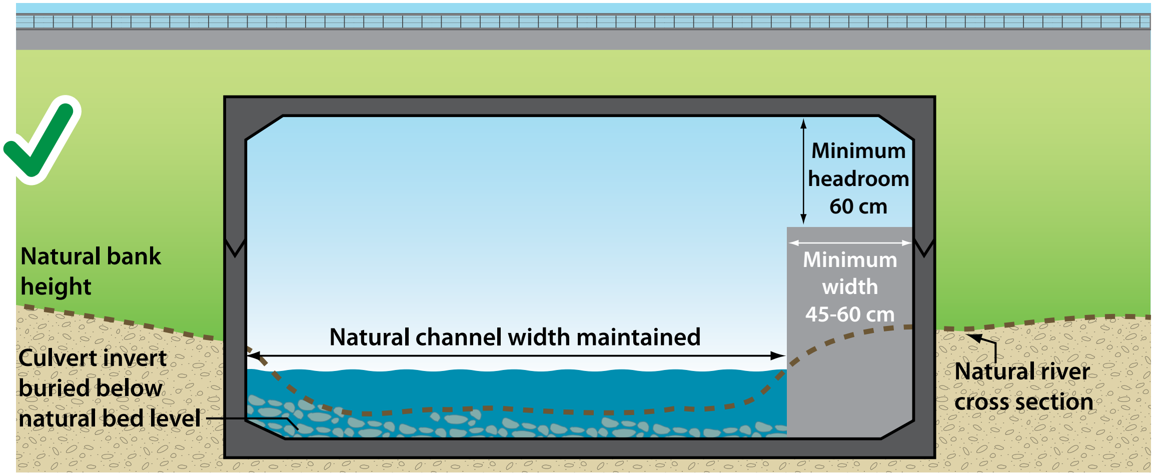
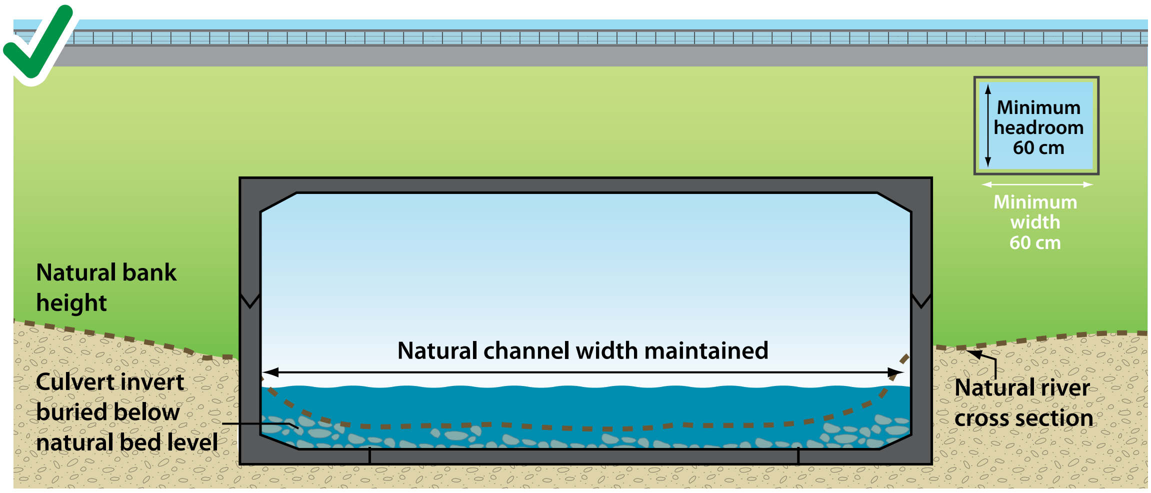


Figure 45: Good practice, mammal passage provided by constructing an additional tunnel.



Other mitigation measures

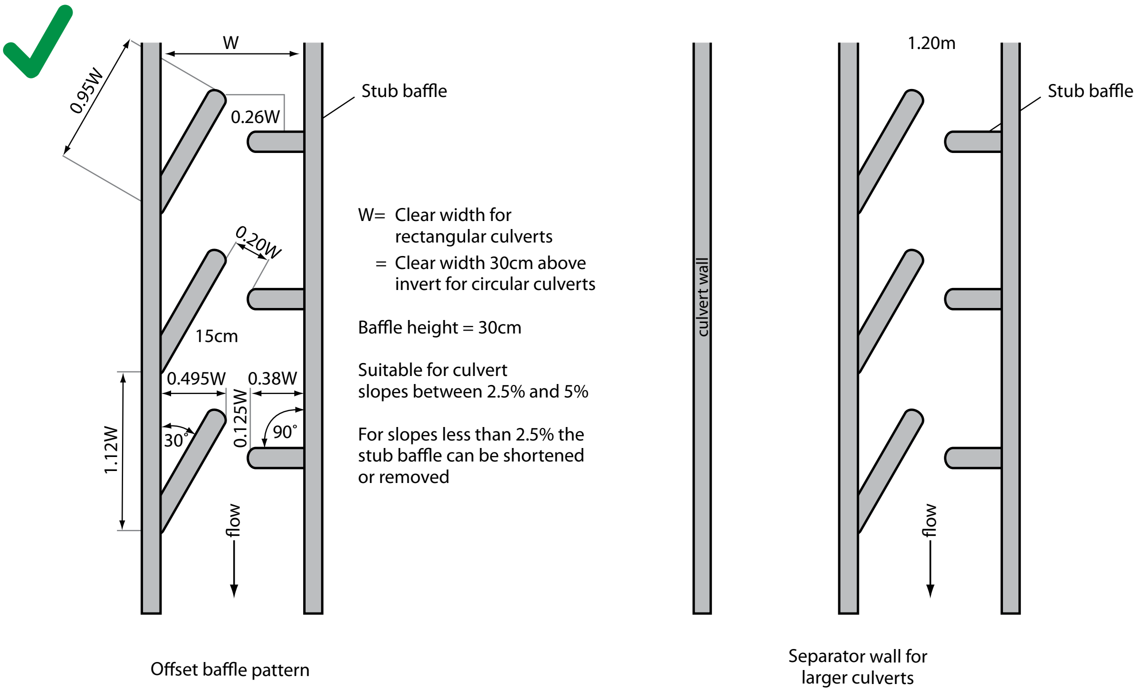
The culvert soffit (top) should be higher than the natural bank height (Figure 38 and 40).

For longer culverts or culverts where depth or velocity is an issue, resting places within the culvert may be required. Baffles in a culvert can provide resting areas for fish (Figure 46). Further information on the design of baffles can be found in the Scottish Government's *River Crossings and Migratory Fish: Design Guidance* (www.scotland.gov.uk/consultations/transport/rcmf-00.asp).

Where culverts are required, identify practical enhancement measures along the affected reach or elsewhere on-site in order to offset some of the impacts caused by the culvert. For example:

- re-establish riparian vegetation where it has been lost;
- remove existing unnecessary man-made structures.

Figure 46: Good practice, longer culverts may require baffles to aide fish passage. Illustration modified from Scottish Government, River Crossings and Migratory Fish: Design Guidance.



An assessment should be carried out to determine if trash screens are necessary. If trash screens are required bar spacing should be as large as possible to only trap larger debris that risks blocking the culvert. Smaller bar spacing could act as a barrier to fish passage, at least 230 mm spacing between each bar should be ensured. Smaller bar spacing can also trap a lot of smaller debris that can create a barrier to fish passage and may in itself cause some 'blocking' of the culvert and increase the risk of flooding if not cleared regularly (Figure 47).

For further information, see:

- CIRIA 2010 *Culvert design and operation guide* www.ciria.org;
- Environment Agency 2009 *Trash and security screen guide* http://publications.environment-agency.gov.uk/pdf/SCHO1109BRHF-e-e.pdf

Figure 47: Trash screen bar spacing should be as large as possible (see photo on left). Smaller bar spacing can create a barrier to fish passage (see photo on right).

Minimise the potential for localised erosion (scour) around the culvert through careful consideration of the location and alignment as discussed in Section 6.1 and following the guidance above.

If bed reinforcement downstream of the culvert is deemed necessary, lay it below the natural river bed level so that the natural bed level can be maintained.

Where bank reinforcement is necessary, consider 'softer' measures in lower energy, lowland environments (see Appendix 1). 'Harder' techniques may be required if the culvert is located in a higher energy upland or transitional environment where there is high risk of erosion. For further information see the SEPA good practice guide: *Bank Erosion Management* at: www.sepa.org.uk/water/water_publications.aspx

Good practice design: IV fords

Fords have the potential to cause pollution through erosion and the release of fine sediments. They can also create a barrier to fish passage where erosion leads to widening of the river and lowering of water depth (Figure 48), or where bed reinforcement leads to erosion downstream and a drop forms and the ford becomes 'perched' (Figure 49 and 51). It is important to ensure that an adequate water depth is maintained to allow fish passage.

The principles below should be followed to reduce the impact of fords:

- Only use a ford when infrequent vehicle use is planned. Fords should not be used between fish spawning and fish emergence times. Key fish species to consider include salmon and trout (normally October – May) and Lamprey species (normally March – July). However these times can vary and you should contact your local district salmon fishery board if you are unsure what fish species are present and what times should be avoided.
- Do not use fords where there is a high risk of pollution eg at construction sites.
- Ensure designated sites (SSSIs, SACs, SPAs) or protected species (eg fresh water pearl mussels) are not harmed. Contact SNH for further information www.snh.org.uk
- Avoid constructing fords where they may damage other important habitats such as fish spawning areas (eg riffles) and areas of aquatic plants.
- Minimise erosion and maintain natural channel width. Bank reinforcement may be required to minimise erosion (Figure 50). This will reduce the risk of sediment pollution and prevent the river from widening, helping to maintain adequate water depth for fish passage. For further information see SEPA's good practice guide on *Bank Erosion Management* at: www.sepa.org.uk/water/water_publications.aspx
- Bed reinforcement should be avoided; if erosion is excessive then provision of a span structure or culvert should be considered. If bed reinforcement is constructed it is likely that a drop will form between the reinforcement and the downstream river bed which can cause a barrier to fish passage (Figure 49 and 51).

Figure 48: Poor practice, ford crossing has lead to bank erosion and over-widened river. This leads to fine sediment pollution and lower water depths which are too shallow for fish to swim through, creating a barrier to fish passage.

Figure 49: Poor practice, bed reinforcement can lead to erosion downstream during high flows, this leads to a drop forming that can create a barrier to fish passage.

Figure 50: Good practice, natural bed maintained and bank reinforcement constructed to minimise erosion, sediment pollution and to maintain the natural channel width and depth to ensure adequate water depth for fish passage.

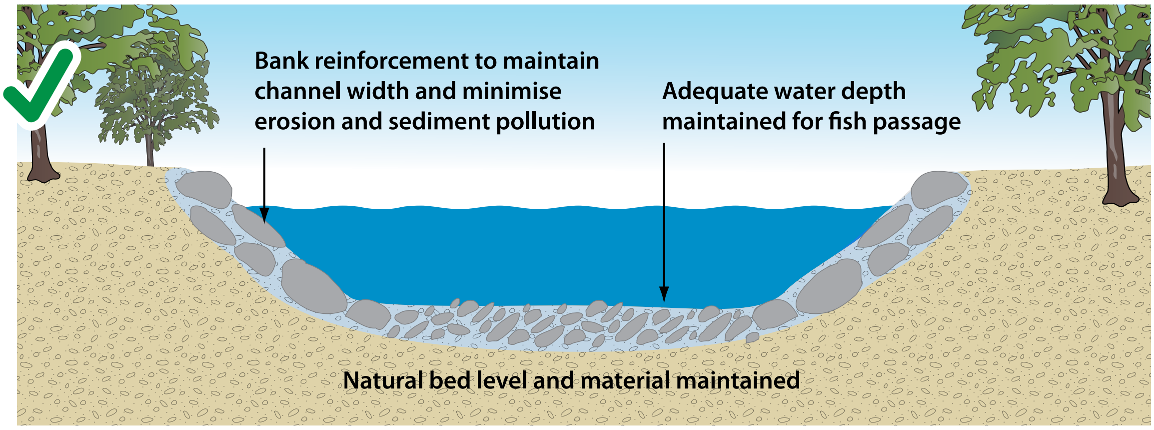


Figure 51: Poor practice, this is not a ford! Fords should not be above the river bed level and multiple pipes should not be used. This creates a barrier to fish passage and can prevent sediment being transported downstream. Raising the ford above bed level increases the risk of bed erosion downstream during high flows this can lead to a drop forming which creates further problems for fish passage and may lead to the need for further engineering.

Good practice design: V pipelines and cables buried below the river bed

If pipelines or cables are to be carried over a watercourse then the guidance for span structures should be followed. Where pipelines or cables are not carried over a watercourse by a single span structure or span structure with in-stream supports, they should be buried below the natural bed level of the watercourse.

The principles below should be followed to reduce the impact of pipeline and cable crossings:

- Remember location and alignment in section 6.1, ensure the pipe crossing is perpendicular to the river and do not use rivers as conduits for pipes or cables.
- Maintain natural bed level and bed material. Bury the pipeline or cable below the natural bed level to allow the natural bed level to be maintained (Figure 52). It should be buried deep enough so that it is not exposed during high flows.
- Do not lay the pipeline or cable on the river bed or in the channel or where it could obstruct high flows (Figures 53, 54 and 55). This increases the risk of the pipeline or cable being damaged and erosion of the bed and banks of the river. It may also increase flood risk.
- Minimise risk of pollution when laying pipe or cable below the river bed. Careful consideration should be given to the technique used to bury the pipe below the bed of the river. Boring underneath the river has the least impact as it does not affect the bed and banks if proper care is taken. If laying the pipe of cable in a trench then the area to be crossed should be isolated and kept dry. For further information see SEPA, 2007 good practice guide: *Construction Methods* www.sepa.org.uk/water/water_publications.aspx
- After construction restore the natural width, depth and bed material of the river and re-establish the banks with native riparian vegetation (Figure 53). If necessary bed material should be stored during construction and replaced. For further information see SEPA 2009 good practice guide: Riparian vegetation management available from www.sepa.org.uk/water/water_publications.aspx

Figure 52: Good practice, pipeline or cable buried below the river bed deep enough to ensure it is not exposed due to scour during high flows.

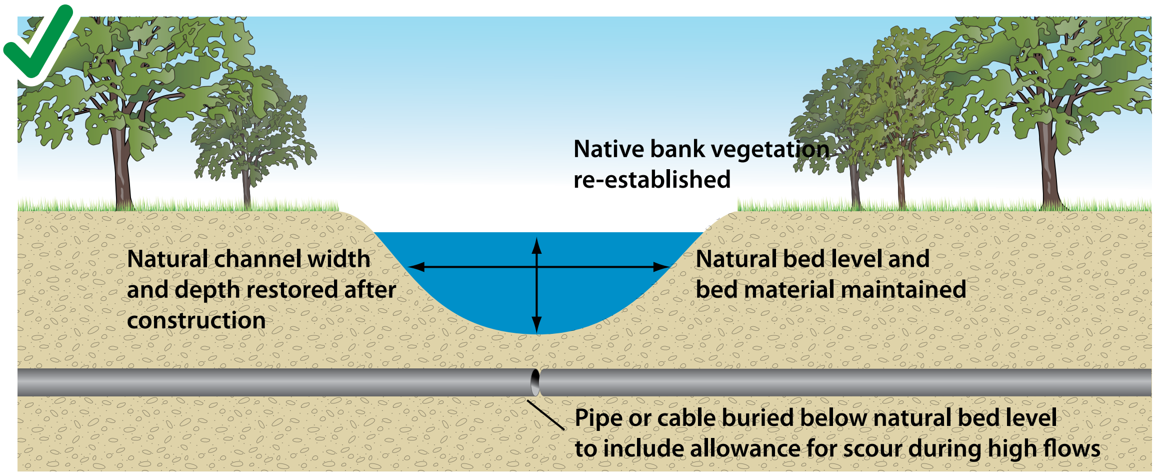


Figure 53: Poor practice, pipeline or cable laid on the river bed. Can cause scour around the structure and pipe is at risk of damage during high flows.

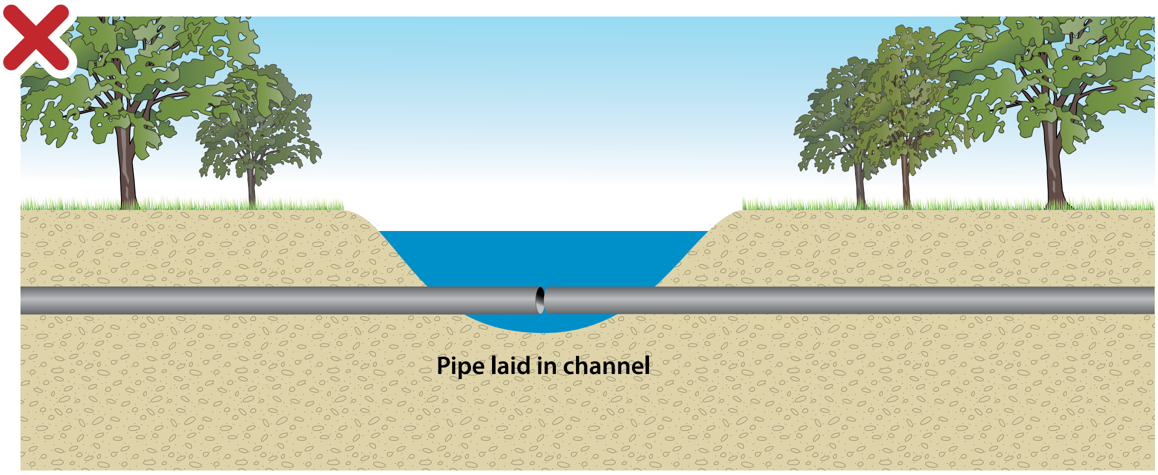


Figure 54: Poor practice, pipeline laid on the river bed. Can cause erosion of the bed and banks and scour around the structure which may damage the pipe during high flows.

Figure 55: Poor practice, pipeline laid in the river channel. Can cause scour around the structure and pipe is at risk of damage during high flows.

6.4 Maintenance of existing structures

The general design principles in Section 6 should be followed when maintaining existing structures.

If erosion of the bed and banks at a structure is exposing bridge foundations or leading to a drop forming at a bridge or culvert, the cause of the erosion should be identified and if possible addressed to ensure no further erosion takes place.

Erosion may be caused during high flows due to scour around the structure but it may also be due to erosion that has been triggered elsewhere in the river that has propagated upstream or downstream. For example 'knick points' can be created in river beds and during high flows the knick point can move upstream. This can result in significant bank erosion and bed incision (erosion and lowering of bed level), which can damage crossing structures. If bed incision is occurring then a suitably qualified geomorphologist should be consulted to help identify the cause and determine sustainable solutions.

If the foundations of bridge abutments or piers are being exposed due to scour around the structure then you should consider making the foundations deeper, new bed reinforcement should be avoided.

If bed reinforcement needs maintained or replaced then consideration should be given to removing the bed reinforcement and modifying the foundations so that bed reinforcement is not required eg consider making the foundations deeper. If this is not possible then replace bed reinforcement with new bed reinforcement buried below the natural bed level, deep enough to allow for scour during high flows. This allows the natural bed level and material to be maintained.

If bridge or culvert inverts are at bed level and a drop has formed due to scour around the structure then you should consider replacing the crossing with a span structure allowing a natural bed or a structure with a buried invert below bed level. If this is not feasible then where possible the invert should be replaced below bed level so that the natural bed level and material can be maintained.

If crossings are posing a barrier to fish passage then you should consider replacing the crossing with a structure that allows fish passage. If this is not feasible then you should consider modifying the structure to allow fish passage (eg baffles can be constructed in a culvert) or construct a fish pass. A suitably qualified ecologist should be consulted to ensure that any modification or fish pass is effective in providing fish passage.

6.5 Construction phase

An important part of good practice is to ensure that all practical steps are taken during the construction phase to minimise damage to important habitats and species and reduce the risk of pollution.

Separate guidance is available from SEPA on construction methods, including guidance on temporary crossings for construction (see below for details). However the following key points should be considered.

- Identify any sites that have been designated for nature conservation (eg SSSI, SAC, SPA) and ensure the conservation requirements are met (contact Scottish Natural Heritage 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 Scottish Natural Heritage for further information).
- Timing – If there is disturbance to the river bed then work 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) and 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 and what times should be avoided.
- If construction requires working in the bed of the river then the works area should be isolated and kept dry (see Figure 56).
- If required, store the natural river bed material during the construction phase and keep it clean. When construction is complete use the stored bed material to restore the river bed.
- Restore any affected banks by re-establishing native riparian vegetation.

Figure 56: Good practice, works area has been isolated and kept dry by a temporary diversion (left) to allow installation of a culvert (right) that requires working in the river bed.

For further information, see:

- CIRIA *Control of Water Pollution from Linear Construction Projects* www.ciria.org
- SEPA good practice guide: *Construction Methods* www.sepa.org.uk/water/water_publications.aspx
- Pollution Prevention Guidelines (PPG) www.sepa.org.uk/about_us/publications/guidance/ppgs.aspx
  Specifically:
  PPG 1 General guide to the prevention of pollution
  PPG 5 Works and maintenance in or near water
  PPG 6 Working at construction and demolition sites

7 Sources of further information

7.1 Publications

Culvert design and operation guide
CIRIA (C689)
www.ciria.org

Manual on Scour at Bridges and Other Hydraulic Structures
CIRIA
www.ciria.org

Control of Water Pollution from Linear Construction Projects. Technical guidance
CIRIA (C648)
www.ciria.org

Trash and security screen guide 2009
Environment Agency
http://publications.environment-agency.gov.uk/pdf/SCHO1109BRHF-e-e.pdf

Design Manual for Roads and Bridges
Volume 4 Section 2 Design of outfall and culvert details
Volume 10 Section 4 Nature conservation advice in relation to otters
Highways Agency
www.standardsforhighways.co.uk/dmrb/index.htm

Manual of River Restoration Techniques
River Restoration Centre
www.therrc.co.uk/manual.php

River Crossings and Migratory Fish: Design Guidance
Scottish Government
www.scotland.gov.uk/consultations/transport/rcmf-00.asp

Good practice guide: Bank Erosion Management
SEPA
www.sepa.org.uk/water/water_publications.aspx

Good practice guide: Construction Methods
SEPA
www.sepa.org.uk/water/water_publications.aspx

Good practice guide: Sediment Management
SEPA
www.sepa.org.uk/water/water_publications.aspx

Special Requirements for Civil Engineering Contracts for the Prevention of Pollution
SEPA
www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx

Guidance on Special Requirements for Civil Engineering Contracts
SEPA
www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx

Werritty A., and McEwen L.J. in Gregory, K. J. (ed) 1997 *Fluvial Geomorphology of Great Britain*, JNCC Peterborough

Brazier, V.B., Kirkbride, M. and Werritty, A. (1993) Scottish Landform examples: The river Clyde-Medwin meanders. *Scottish Geographical Magazine*, 109, 45–9.

7.2 Websites

Construction Industry Research and Information Association (CIRIA): www.ciria.org

Environment Agency (EA): www.environment-agency.gov.uk

Highways Agency: www.highways.gov.uk

River Restoration Centre (RRC): www.therrc.co.uk

Scottish Environment Protection Agency (SEPA): www.sepa.org.uk

Scottish Government: www.scotland.gov.uk/Home

Scottish Natural Heritage (SNH): www.snh.org.uk

8 Glossary

Abutment	Support of a bridge at the banks of a river.
Aggradation	Rising of the river bed level due to depositional processes.
Alluvial fans	Large areas of sediment deposition at river confluences, often cone shaped.
Baffles	Structure placed inside a culvert to deflect the flow of water, can provide resting areas for fish, helping fish passage.
Bed armour	Top layer of river bed sediment that has been compacted and held together by finer sediments.
Bridge apron/ weir	Structure than impounds water and raises bed level upstream, to prevent bed erosion at bridges.
Catchment	Total area of land that drains into any given river.
Channel migration zone (CMZ)	Area where a river naturally moves across a floodplain.
Closed culvert	Bridging culverts with artificial floor (invert) where a transport route (eg foot path, cycle path, road) crosses a watercourse, not for land gain. Affects the bed and banks of watercourses.
Deck	Component of bridge forming the surface of road.
Embankment	Earth, gravel or similar material raised above the channel or floodplain to form a bank, stop flood waters from leaving the channel, or retain flood waters within a specified area.
Incision	Deepening of a river channel due to erosion of the bed.
Invert	Lowest internal point of a culvert (floor of 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 it erodes upstream.
Large woody debris (LWD)	Accumulations of trees and branches that have fallen naturally into the river system.
Meander Bend	Bend in the river formed by natural river processes (erosion and deposition).
Perched culvert	Culvert that has a drop from the culvert base to the downstream river bed forming a 'step'.
Pier	In-channel supports of a multi-span bridge.
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 impacts on the aquatic ecosystem (eg shading, leaf litter input). In this standard, the term 'riparian zone' does not include the wider floodplain.
Rip rap	Large angular stone placed to protect eroding banks.

Scour	Erosion of river banks or bed, often due to the presence of a structure.
Soffit	Underside of bridge deck or highest internal point of a culvert.
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.
Viaducts	Road spanning a floodplain between raised supports.
Width of river	The width of a river is defined as the straight line distance measured between the toe of the banks of any watercourse, spanning the bed of the watercourse, including any exposed bars and vegetated islands.

Appendix 1 - River types

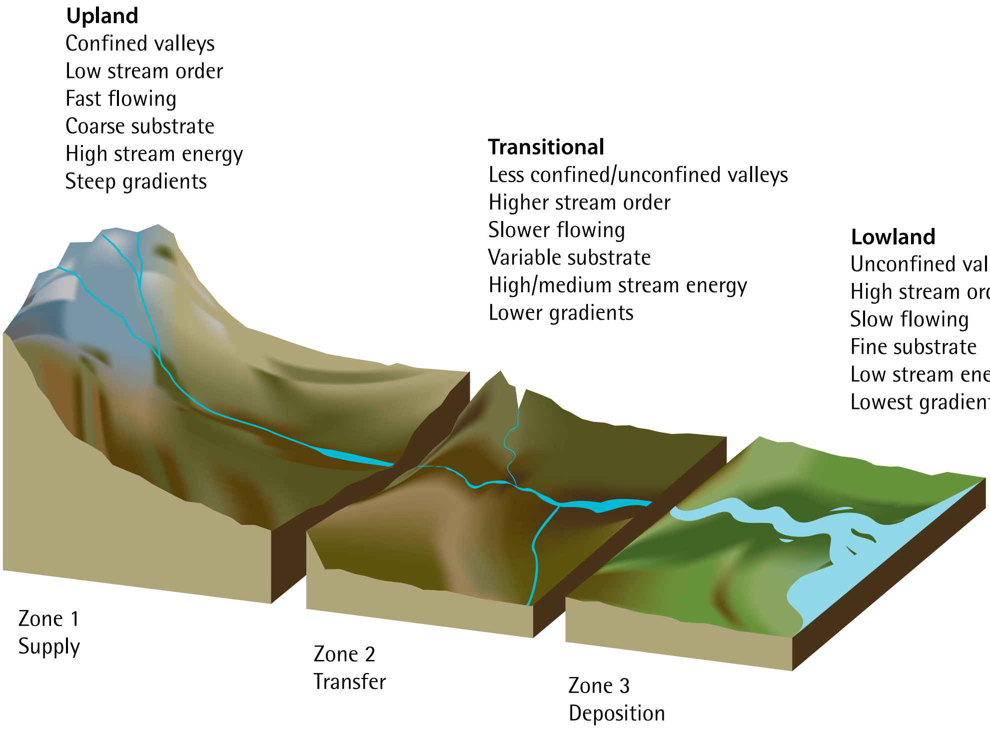
River typologies can be a valuable tool for identifying and interpreting river characteristics.

Different rivers (or sections of channel within a river) display distinct characteristics that can influence the considerations that need to be taken into account when constructing a river crossing.

For the purposes of this guidance rivers have been divided into three categories as shown in Figure A1 and outlined below:

- upland;
- transitional;
- lowland.

Figure A1: Generalised diagram of different types of environment within the river catchment.



River slope

One of the most important factors influencing river type is slope. If you do not know the slope, it can be determined by looking at the contour lines on an Ordnance Survey map.

Look at how many metres a river falls over a kilometre (eg a river falls 5 metres over 1 kilometre); to convert this to a percentage, divide the number of metres fallen over the distance and multiply by 100 eg in the example above, the slope percentage is calculated as follows Slope = 5 /1000 x 100 = 0.5%

Upland

Upland rivers (Figure A2) are generally fast and shallow. They typically have a slope greater than 1%. They are formed in steep high energy environments capable of mobilising and carrying cobbles or boulders during flood events.

The sides of the channel tend to be steep with little, if any, floodplain and relatively stable ie they do not tend to migrate across the floodplain. For the purposes of this guidance, relatively straight channels with coarse (pebble/cobble) sediment and erratically placed larger boulders should also be considered as upland type channels.

Figure A2: Examples of upland rivers.

Transitional

Transitional rivers (Figure A3) are typically characterised by wide floodplains and meandering channel patterns. They typically have a slope from 0.1 to 3%.

Pool–riffle sequences, braided sections and meandering are common features of transitional rivers.

Figure A3: Examples of transitional rivers.

Lowland

Lowland rivers (Figure A4) are lower energy environments where sediment sizes are generally a lot smaller than those in upland and transitional rivers (eg pebble, gravel and sand). Lowland rivers typically have a slope less than 0.1%. Meandering is a common feature. Man-made or modified (eg straightened) rivers are also included in this category.

Figure A4: Examples of lowland rivers.

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