Engineering in the Water Environment
Good Practice Guide

Intakes and outfalls

Second edition, August 2019

Your comments

SEPA is committed to ensuring its Good Practice Guides are useful and relevant to those carrying out engineering activities in Scotland's rivers and lochs.

We welcome your comments ont his Good Practice Guide so that we can improve future editions. A feedback from and details on how to send your comments to us can be found in Appendix 2.

Acknowledgements

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(Document reference: WAT-SG-28)

Contents

1 Introduction

This document is one of a series of Good Practice Guides produced by SEPA to help people involved in the selection of sustainable engineering solutions. The Guide is intended for use by those considering engineering activities in rivers or lochs to provide solutions that:

- reduce the impact on the physical habitat (morphology) of rivers and lochs;
- reduce the need for long-term maintenance, helping to reduce cost.

Any engineering works must be designed to suit site-specific conditions. The Guide is not intended as a technical design manual but focuses on the environmental aspects that should be considered when undertaking a project.

Using the Guide will help with the process of obtaining an authorisation for works under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (As Amended) (CAR) (see www.sepa.org.uk/wfd for more information).[1]

1.1 What's included in this guide?

SEPA expects all applications for new engineering activities under CAR to follow good practice. Good practice is defined as the course of action that serves a demonstrated need and is sustainable (i.e. the work is justified and the chosen design is effective), while minimising ecological harm, at a cost that is not disproportionately high.

Applicants proposing to undertake an engineering activity will be expected to demonstrate to SEPA that good practice has been adopted (Box 1).

Box 1: Summary of SEPA good practice tests

1. Have you demonstrated a need for the proposed activity?
2. Have you considered appropriate alternative approaches?
3. Does the proposal represent the best environmental option?
4. Is the activity designed appropriately?
5. Have all necessary steps been taken to minimise the risk of pollution and damage to habitat or flora/fauna during construction?

This Guide is designed to help applicants follow the steps outlined in Box 1 to:

- select sustainable river engineering solutions;
- provide the information required in the CAR application form

[1] Under CAR, new engineering activities in Scotland's rivers, lochs and wetlands require and authorisation. Authorisations take various forms and more information is available in the CAR Practical Guide available from www.sepa.org.uk

To help applicants through the process, the guidance is divided into four stages (Figure 1).

Figure 1 Key sections of this Guide

Section 3 Demonstrated need	The first step when identifying a sustainable engineering solution is to determine whether new engineering work is necessary. This section will help applicants assess the need for new engineering.
Section 4.1 Identification of options	There are often multiple solutions to a river engineering problem. This section provides information on relevant engineering options.
Section 4.2 Selecting best option	This section provides guidance to help you select the most suitable and sustainable engineering option.
Section 5 Design and implementation	Successful river engineering requires selection of a suitable option followed by appropriate design and implementation. This section provides guidance on design and implementation considerations.

Colour-coded boxes in the Guide highlight key information.

Blue boxes provide details of other useful sources of information

Green boxes provide summaries of important points

Orange boxes provide summaries of regulatory information

1.2 Basic terminology

Figure 2 gives details of some basic structural components of intakes and outfalls that will be referred to throughout this Guide. Descriptions of these components are given in the Glossary (Section 7).

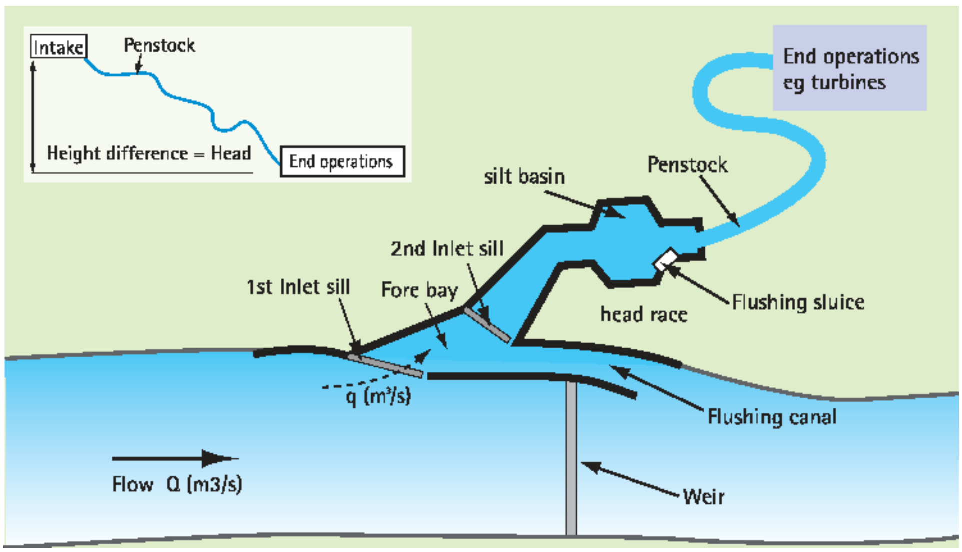
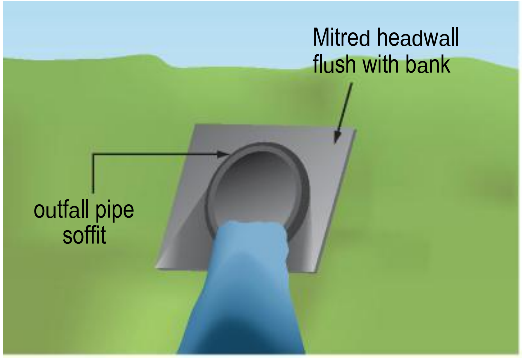


Figure 2a Schematic diagram of an intake associated with a weir showing the main structural components



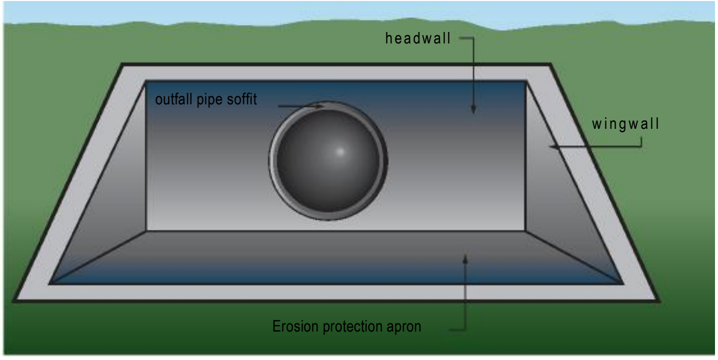


Figure 2b Typical outfall details showing the main structural components.

2 How intakes and outfalls impact on rivers and lochs

Intakes and outfalls can result in many impacts to the physical habitat (morphology) of rivers. These impacts are explained below.

Main impacts of intakes

- Deposition of sediment and a reduction in sediment supply to downstream reaches
- Deposition can lad to the need for dredging
- Entrapment of fish
- Direct loss of bank-side (riparian) habitat

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

Main impacts of outfalls

- Outfalls can increase erosion and lead to an increase in sediment supply to downstream reaches of rivers and lochs
- Trapping (accumulation) of sediment
- Entrapment of fish
- Direct loss of bank side / riparian habitat

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

2.1 Sediment at intakes

As water is abstracted through the intake, sediment is typically drawn towards the intake structure or point of diversion. Sediment may either be drawn into the intake structure or may be trapped behind it. This reduces the amount of sediment that is supplied to downstream reaches. If sediment is drawn into the intake, there is the risk of damage to the intake facility and end operation machinery (e.g. turbines, gates and valves).

As water is abstracted at the intake, the amount of water in the river is reduced. This reduces the amount of sediment that the river can carry downstream. It causes the sediment to be deposited at the intake structure and leads to a decrease in the amount of sediment that is supplied to downstream reaches.

Large amounts of sediment deposition at the intake structure can require regular dredging to stop sediment being drawn into the intake and to maintain the efficiency of the abstraction. This dredging disrupts and damages habitat, and can risk causing pollution by releasing finer sediment downstream.

The reduction in sediment transported downstream can lead to erosion of the bed and banks at downstream reaches. This may lead to the failure of bank-side and in-stream structures (e.g. bridges, culverts, outfalls and hard bank protection structures), and a change in flood risk.

The reduction in sediment downstream and increased erosion can damage important habitats (e.g. bank-side habitat) and habitats that depend on a supply of sediment from upstream reaches (e.g. spawning gravels, gravel bars and islands).

The quality of habitats in rivers and lochs is controlled by relationships between flow and sediment. Disturbing one can have a range of impacts on the other. It is therefore important to consider all potential impacts when choosing the best design solution for intakes.

2.2 Erosion around outfalls

Increased flows due to discharges can cause erosion (scour) of the bed and bank below an outfall which increases the supply of sediment to downstream reaches of rivers and lochs.

The outfall structure itself can extend into the channel and create localised turbulent flows, leading to localised erosion (Scour) of the bed and bank of the river (see figure 3 below). This increased erosion also increases the supply of sediment to downstream reaches of rivers and lochs.

Figure 3 shows where the outfall structure extending into the channel has caused erosion (scour) of the bank, increasing sediment supply downstream and leading to damage of the structure itself

Rivers may also attempt to adjust to an increase in flow and sediment supply. This may lead to increased bank erosion and channel widening downstream of the outfall. The increased bank erosion can lead to more sediment being supplied to the system, leading to still further channel adjustments, thereby exacerbating the problem.

Increased amounts of sediment in rivers and lochs can smother habitats important for fish spawning, aquatic invertebrates and macrophytes.

Localised erosion around the outfall structure itself, can lead to the structure being damaged.

2.3 Trapping of sediment

Sediment may be trapped behind or in front of outfall structures, such as erosion aprons (if extending into the channel) and outfall pipes (for example pipes leading to outfalls submerged under the water), leading to localised accumulations.

Larger accumulations of sediment can affect flood risk by reducing the flood conveyance capacity of the channel and resulting in partial or full blockages of culverts and bridges.

A significant build up of sediment around a submerged outfall may result in a partial blockage of the outlet pipe. This can result in the back up of effluent, e.g. sewage, and the inefficient operation of the outfall system.

2.4 Entrapment of fish

If appropriate screens are not in place fish can be drawn into intakes and submerged outfalls, especially small and juvenile fish. This can have a significant effect on fish migrations. In lochs, fish often follow currents to guide migration and can be attracted to intakes and outfalls instead of the loch outlet. This can also have a significant effect on migrations.

Intakes and their associated infrastructure (e.g. impoundments) may also cause a physical barrier to fish migrating upstream. Consideration of fish passage for impoundments is beyond the scope of this Guide but this is essential for any new intake structure where impoundments are required. Contact your local SEPA office (www.sepa.org.uk) or go to Fisheries Management Scotland (http://fms.scot/) for contact details of the Local District Salmon Fishery Board for more advice on this matter.

Migration throughout the river catchment is essential to the survival of many species of fish. For example, salmon travel as adults from the sea up the river to spawn and then, as juveniles, migrate back downstream to the sea. Other fish such as brown trout use the whole river catchment throughout their life cycle, migrating upstream to smaller headwaters to spawn and moving downstream to feed and grow in the larger rivers where more food may be available. Other fish species that make significant migrations are sea trout, eels, sea lamprey and river lamprey.

2.5 Impact to the riparian zone

Bank side or riparian habitat can also be lost, either through the direct removal of vegetation by the construction of an intake or outfall structure, or indirectly by exacerbating bank side erosion and resulting in bank collapse.

Riparian habitat is crucial for the proper functioning of aquatic ecosystems, and provides an important habitat for many aquatic and terrestrial species. It is also an important source of food for many aquatic invertebrates.

3 Demonstrated need

3.1 Introduction

The first step to identifying a sustainable engineering solution is to determine whether new engineering work is necessary. This Section will help applicants assess the need for new engineering.

A significant number of engineering activities are undertaken to address a perceived rather than real problem (e.g. bank protection on river bank that isn't eroding or gravel removal from a pool that hasn't filled in).

Activities that are carried out without a demonstrated need can negatively impact on ecological quality and tie up capacity in the water environment that is no longer available for activities associated with real problems.

Therefore in order to demonstrate best practice, the applicant must satisfy SEPA that their application is associated with a real need to carry out the works.

3.2 Is there a demonstrated need?

In general a new discharge or abstraction will require a new outfall or intake structure, so demonstrating a need for a new structure is relatively straightforward. However, options for using existing outfalls and intakes should always be explored and discussed with SEPA.

After 1st April 2007, surface water drainage systems for new developments must be treated by a sustainable urban drainage (SUD) system. A discharge from a SUD system to a river or loch may not always need a new outfall structure, particularly if the discharge is via a constructed channel / swale and replicates a natural drainage system. The objective of a fully sustainable urban drainage system for surface water should be to dispense with an outfall structure altogether.

The questions in Box 2 should be considered before deciding if a new intake is necessary.

Box 2 Is a new intake structure required?

Am I using my water efficiently?

Ensure that existing water is used efficiently before increasing volumes abstracted or creating new sources/intake structures. Contact SEPA for more information on the efficient use of water.

Can I use an existing abstraction point?

It may be possible to take water from an existing abstraction point. But before increasing abstraction volumes, contact SEPA to discuss potential impacts on the water environment and implications for existing abstraction authorisations.

4 Options appraisal

4.1 Introduction

It is a basic principle of good practice to consider a range of alternatives in addressing an identified problem or need. Without consideration of alternatives it is not possible to determine if the approach represents the best environmental option. There are often multiple solutions to a river engineering problem or need. This section will provide information on relevant engineering options and will provide guidance to help applicants select the most suitable and sustainable type of intake or outfall structure.

4.2 Alternative approaches

This Guide identifies five generic types of intake (Box 3) and four generic types of outfall (Box 4), which are examined in more detail in Section 4.3.

A range of suitable options should be considered when planning a new intake or outfall structure. The guidance given in Section 4.3 will help you determine the range of options that may be suitable for your circumstances.

Box 3 Types of intake

I **Bank-side with no in-stream structure**
Intake structure built into the bank with no flow deflection or fore bay structures.

II **Bank-side with in-stream structure**
Intake structure built into the bank with a flow deflection structure or fore bay.

III **Bank-side with weir**
Intake structure built into the bank drawing water from a storage area behind a weir.

IV **Bed intake**
Intake structure is buried in the river bed and spans the width of the channel. Inlet feature is flush with the substrate or raised to form a small weir.

V **Submerged**
Intake structure on the bottom of the bed submerged under the water. Structure does not span the river

Box 4 Types of outfall

I **Submerged**

II Partially s**ubmerged**

III Bank side

IV **Set back has one inlet port, or a series of inlet**

4.3 Selecting the best option

Once all the alternatives have been evaluated the best practical environmental option should be chosen. This does not always mean adopting a soft engineering approach, best practical environmental option means choosing the approach that that is effective at address the problem or need, while minimising environmental impact as far as practical. It also has to be cost effective (see box 5) and achievable.

Box 5 Proportionate cost

The most cost-effective solution is the one that minimises environmental harm or maximises environmental benefit at a proportionate cost. In itself, large absolute cost does not constitute disproportionate cost. For example, incurring significant costs to prevent significant environmental harm or achieve significant gain would be considered proportionate. But incurring significant cost for minor environmental gain would be considered disproportionate and not cost-effective.

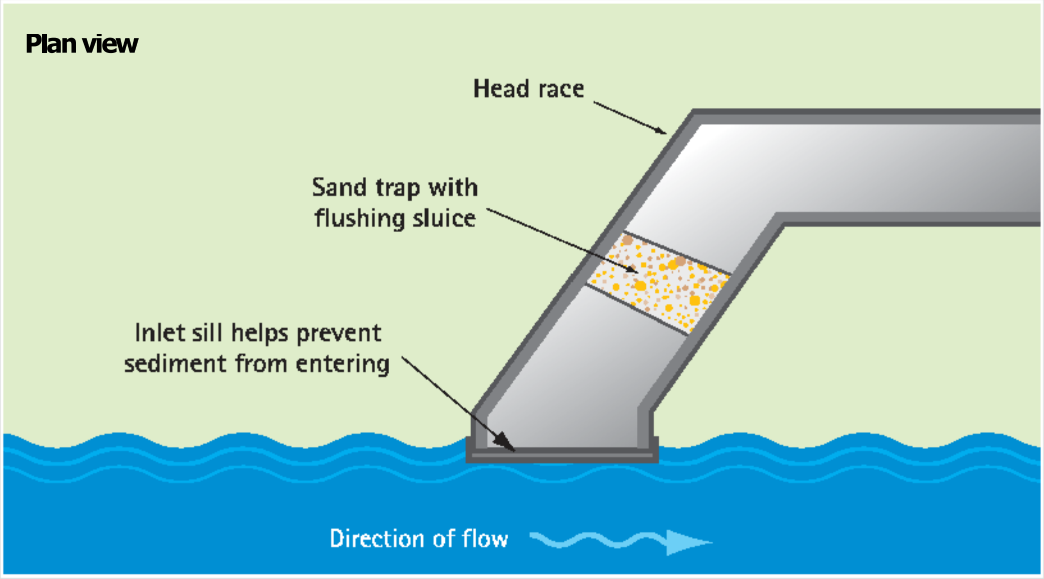
The type of intake or outfall will largely depend on the abstraction properties or type of discharge and site conditions. This document attempts to guide you through some of the key points that should be considered for each type of structure.

Many different designs will fall into the generic types of intake and outfall identified by this Guide, it is important to recognise that the diagrams below are intended as examples.

Type of intake I: Bank-side with no in-stream structure

Intake structure built into the bank with no in-stream flow deflection structures in the river (Figure 4). It may have a control structure such as a sluice.

Figure 4 Example of plan view of bank intake without in-stream structure



LOW IMPACT – please note this is the impact on the physical habitat (morphology) of the river and does not take into account the impact of any water abstracted.

Suitable for:

- Abstraction of relatively low volumes of water;
- Lowland environments (see Appendix 1 for a description).

Not suitable for:

- Environments where there are large fluctuations in water level as is often the case in upland environments (see Appendix 1 for a description).

Key points:

- No or limited in-stream works required for construction, thus reducing impacts.
- Choosing a location where the water is deepest will allow greater submergence of the intake.

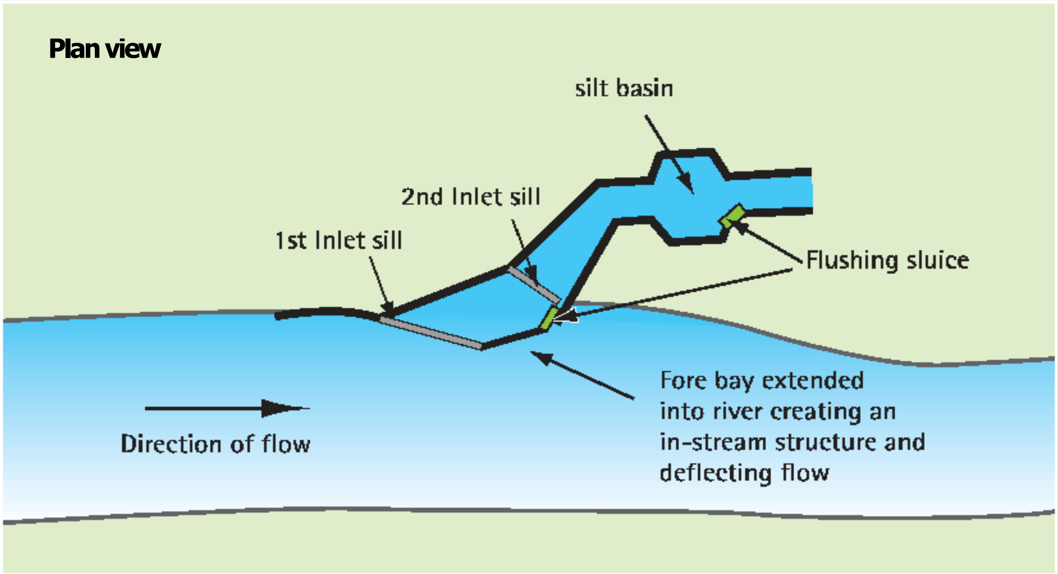
Considerations:

- Abstraction is dependant upon the water level; very low water levels can be a problem.

Type of intake II: Bank-side with in-stream structure

Intake structure built into the bank with a flow deflection structure in the river used to divert flow towards the intake and/or used to trap sediment.

Figure 5 Example of plan view of bank intake with in-stream structure creating a fore bay



MINIMAL/MODERATE IMPACT – please note this is the impact on the physical habitat (morphology) of the river and does not take into account the impact of any water abstracted.

Suitable for:

- Situations where sediment ingress may be a concern;
- Straight sections of a river to help sweep flow past the intake.

Not suitable for:

- Streams with a large fluctuation in flow, e.g. upland environments (see Appendix 1);
- High energy environments (i.e. most upland streams). Placing in-stream structures in such an environment can lead to significant erosion and scour of the bed and banks. The structure itself also risks failure in such a high energy environment.

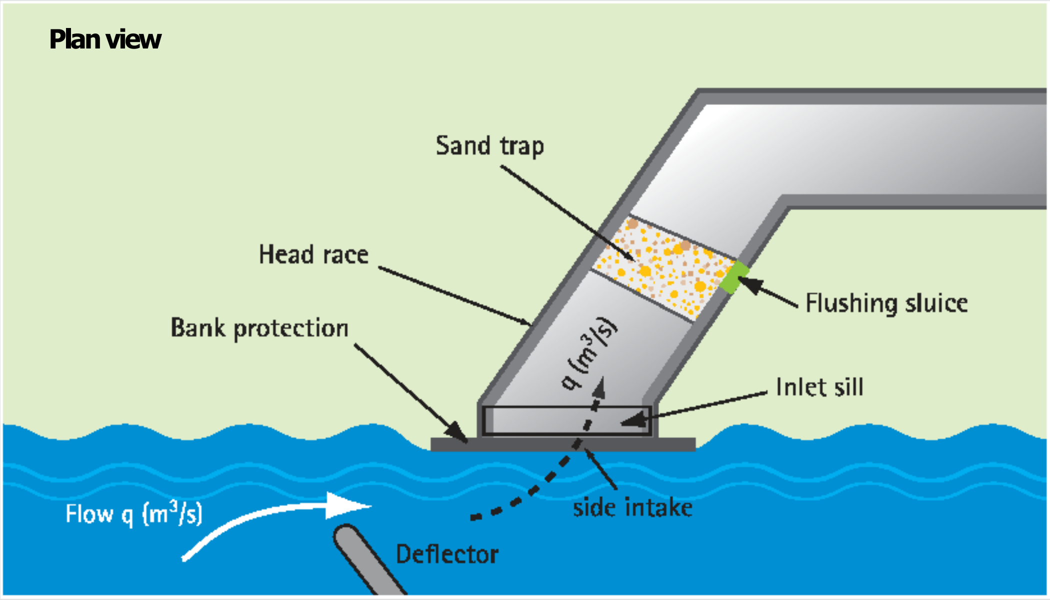
Key points:

- Fore bays can be used to help trap sediment in front of the main inlet structure. The first sill into the fore bay will stop large bed load from entering the intake. The second sill at the end of the fore bay will stop finer sediment from entering the head race and conveyance system.
- Flow deflectors placed in straight channels can be used to sweep the flow towards the intake and carry bed load away from the intake (Figure 6). The angle to the main channel flow and position of the deflector are crucial as they determine the direction and strength of flow past the intake.

Considerations:

- Any deflector structure must be positioned correctly as there is a risk it could lead to erosion of the bed and bank downstream of the intake. The position and angle of the deflector is likely to be site-specific and specialist advice from hydrologists and geomorphologists should be sought during the design stage.
- If flow is diverted towards the intake, the increased flow can reduce the efficiency of the fish screens.

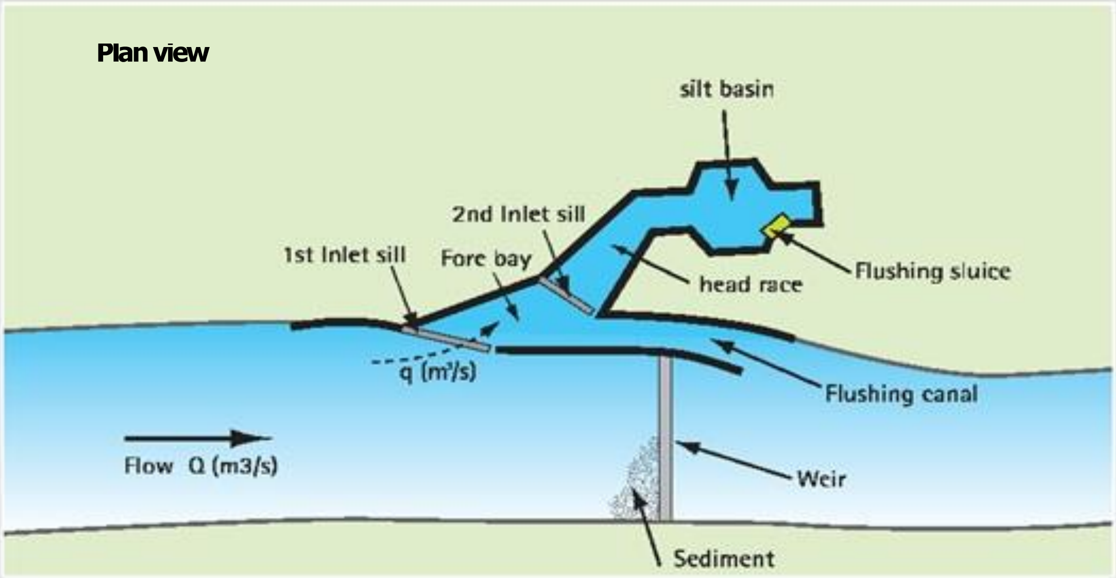
Figure 6 Schematic plan view of bank intake with in-stream structure used to divert flow



Type of intake III: Bank-side with weir

Intake structure built into the bank drawing water from a storage area behind a weir (Figure 7).

Figure 7 Schematic plan view of a bank intake with weir



HIGH IMPACT – please note this is the impact on the physical habitat (morphology) of the river and does not take into account the impact of any water abstracted.

Suitable for:

- Most stream types;
- Streams with variable flow regime or where a substantial portion of the flow is to be diverted.

Not suitable for:

rivers with high sediment loads – the storage area in front of the weir can fill up well before the design life is reached if used in rivers with a high sediment load, and result in high maintenance costs (need for regular dredging).

Key points:

- Suitable for wide variety of stream types.

Considerations:

- High risk of sediment accumulation behind weir and may require dredging.
- May be a barrier to fish passage. Will need to consider fish passes and screens.

Type of intake IV: Bed intake

Intake structure is buried within the river bed or sunk within a small weir and spans the width of the channel. There are two generic types:

Bed intake – sometimes called 'Tyrolean' type (Figure 8). Can be built directly into the bed. Bars across the top of the structure stop boulders, though not fine sediment, from entering the intake chamber.

Coanda screen intake built into a small weir that spans the channel (Figure 9). Employs the 'Coanda screen affect' allowing water to be abstracted efficiently without the ingress of sediment. Can exclude fine sediment.

Figure 8 Schematic diagram of bed intake 'Tyrolean' type

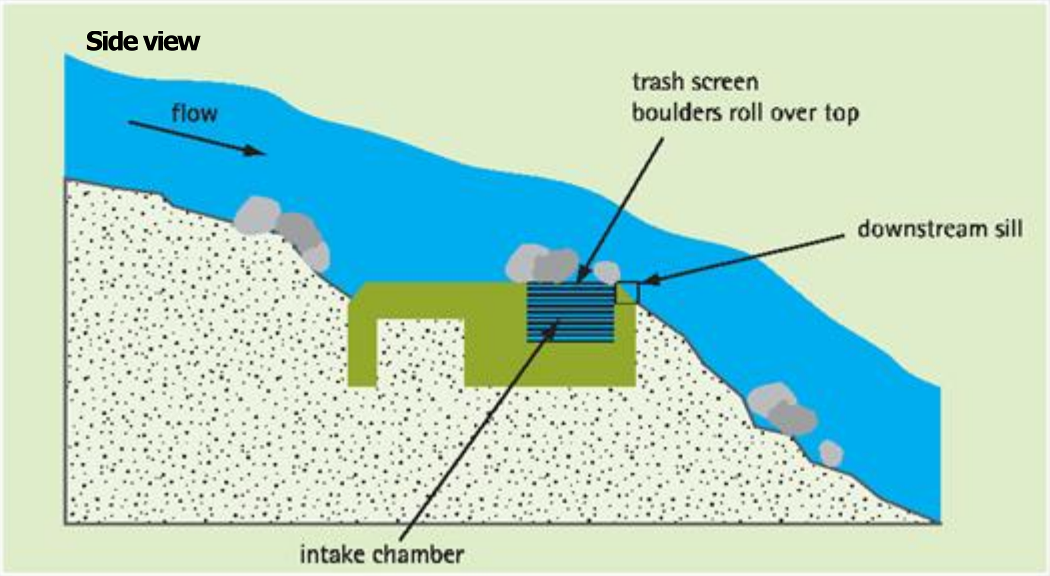
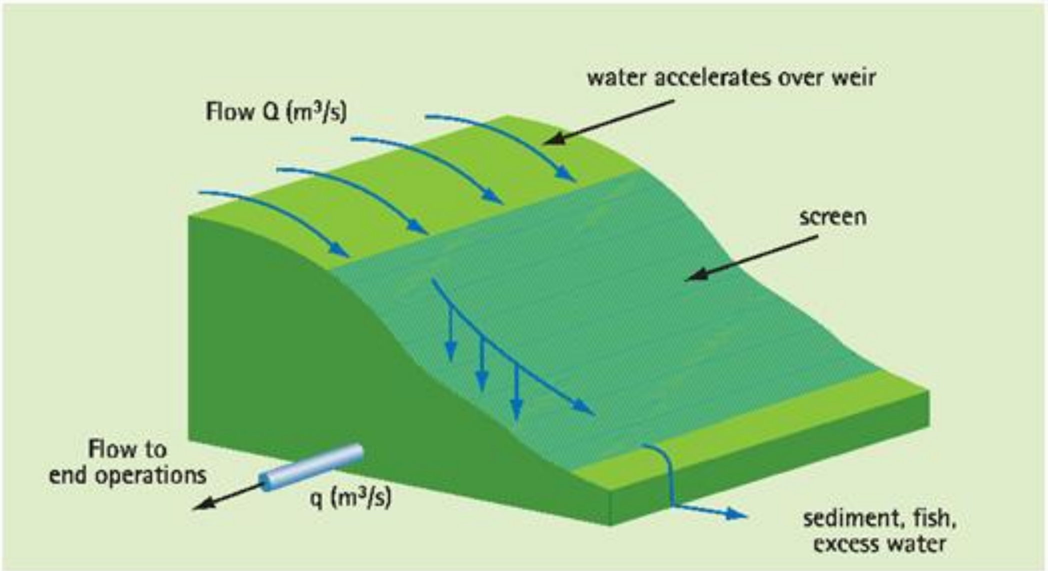


Figure 9 Schematic diagram of bed intake 'Coanda' type



The 'Coanda' type intake (Figure 9) has a screen with a wedge wire panel installed on the sloping downstream face of a weir. This screen allows water to pass through while allowing fine sediment, larger sediment, debris and fish and excess water to flow safely downstream. Water flows through the wire mesh screen to the collection system at the base.

MODERATE/HIGH IMPACT (where impoundment involved) – please note this is the impact on the physical habitat (morphology) of the river and does not take into account the impact of any water abstracted.

Suitable for:

- Upland streams;
- Straight stream sections;
- Streams with high coarse bed load (e.g. boulders and cobbles). ‘Coanda’ types can exclude finer sediments.

Not suitable for:

- Streams with high suspended load or fine bed load component (e.g. silt and sand);
- Lochs and lowland rivers.

Key points:

- The design of bed intakes allows larger sediments (boulders/cobbles/gravel) to be carried downstream of the obstruction when flows are sufficient.
- The ‘Coanda’ type also allows finer sediments to be carried downstream excluding them from the intake.
- Can operate in highly variable flow regimes.
- Limited maintenance required.
- Low maintenance, self-cleaning screen – no moving parts and no power required to remove debris and sediment.

Considerations:

- ‘Tyrolean’ type may require a removal system for fine sediments.
- ‘Coanda’ type intakes need a weir of sufficient height for the screen to operate properly.
- Need to consider fish passage with a ‘Coanda’ weir.

Type of intake V: Submerged

Submerged intakes differ from a bed intake (type IV) in that they abstract water from a single point within a river or loch, as opposed to water abstraction across the entire width of the channel. The intake structure may:

- rest on top of the river or loch bed, submerged under the water, with the inlet feature raised into the water column (Figure 10); be buried under the bed of the river or loch, with the inlet feature raised into the water column;
- be associated with a tower structure raised into the water column with multiple inlets (Figure 11).

Figure 10 Submerged intake – piping above bed

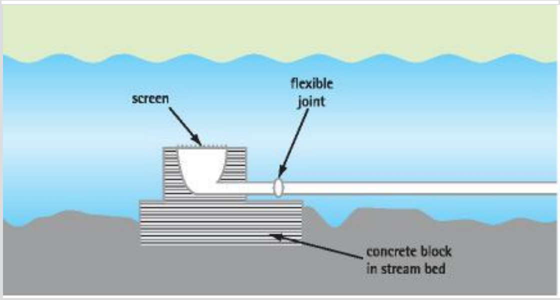
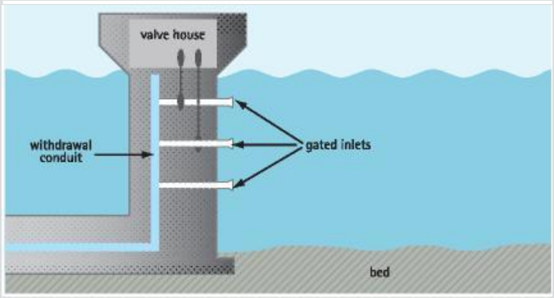


Figure 11 Tower intake



MODERATE IMPACT – please note this is the impact on the physical habitat (morphology) of the river and does not take into account the impact of any water abstracted.

Suitable for:

- Submerged intakes may be suitable for both lochs and rivers;
- Deep environments (e.g. lochs and deep rivers) with high amounts of mobile sediment.

Key points:

- Tower intakes allow water to be withdrawn from various depths, improving the quality of water abstracted and minimising the prospect of sediment intake if sediment builds up around the base.
- Operate within a large variation of water level.
- Can locate the structure off-shore to minimise the exposure of juvenile fish to the intake.
- Low impact on the bank and riparian zone.

Considerations:

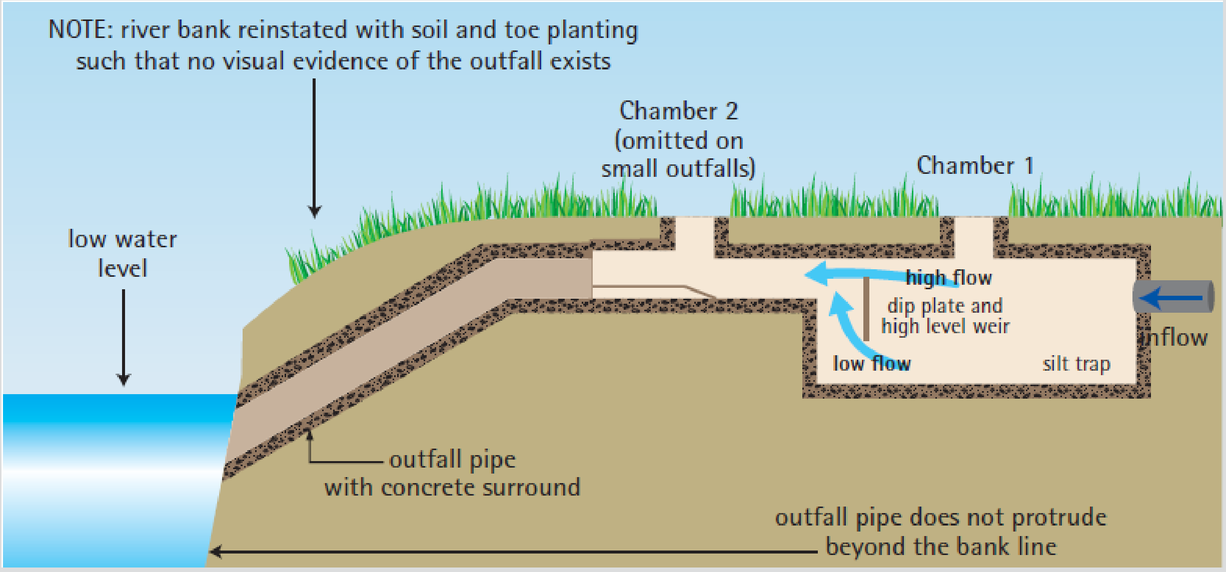
- Adequate depth required.
- May lead to localised erosion.
- The structure should not be located in areas that are likely to leave the inlet exposed during dry periods.

Types of outfall I - Submerged

Submerged outfalls are suitable for discharges that require initial dilution and also for high volume / velocity discharges, this includes:

- Sewage effluent
- Industrial effluent
- Cooling water
- Hydro-scheme discharge

Figure 12 submerged outfall



LOW IMPACT - please note this is the impact on the physical habitat (morphology) of the river and does not take into account the impact of any discharge on water quality.

Key points:

- Outfall soffit should be below low water level.
- Outfall pipe should not protrude beyond the bank line
- Pipe should be buried beneath the bank and native bank vegetation should be re-established
- Safe access should be provided
- Sample chamber should be provided (if necessary)

Considerations:

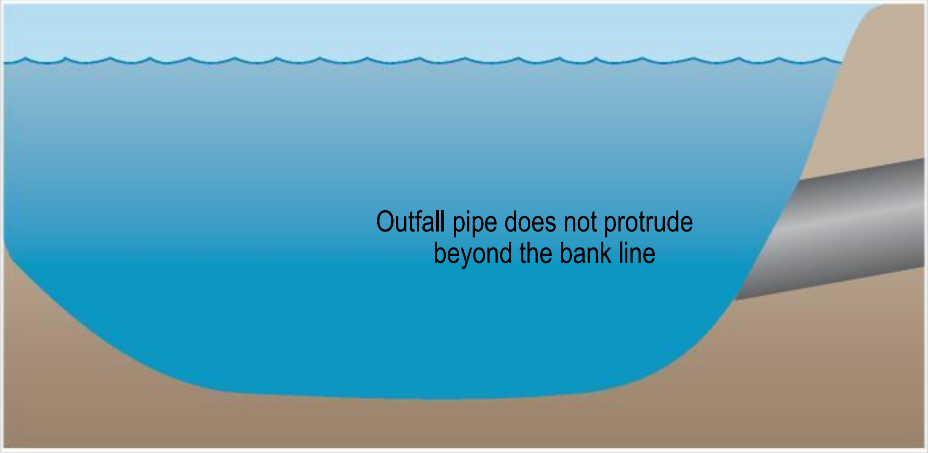
- Adequate river depth is required
- Location and alignment should be carefully considered (see sections 5.2 and 5.3)
- Type and extent of erosion protection required should be carefully considered (section 5.4). Underwater erosion protection may be required and should be laid below natural bed level.
- Maintenance inspections should be planned

Types of outfall II - Partially submerged

Partially submerged outfalls are suitable for clean water discharges often of high velocity such as;

- Hydro-scheme discharge
- Water treatment works discharge

Figure 13 partially submerged outfall



LOW IMPACT - please note this is the impact on the physical habitat (morphology) of the river and does not take into account the impact of any discharge on water quality.

Key points:

- Outfall pipe should not protrude beyond the bank line
- Pipe should be buried beneath the bank and native bank vegetation should be re-established
- Safe access should be provided
- Sample chamber should be provided (if necessary)

Considerations:

- Location and alignment should be carefully considered (see sections 5.2 and 5.3)
- Type and extent of erosion protection required should be carefully considered (section 5.4).
- Maintenance inspections should be planned

Types of outfall III - Bank side

Bank side outfalls should only be used where there is inadequate water depth for a submerged outfall or set back outfall.

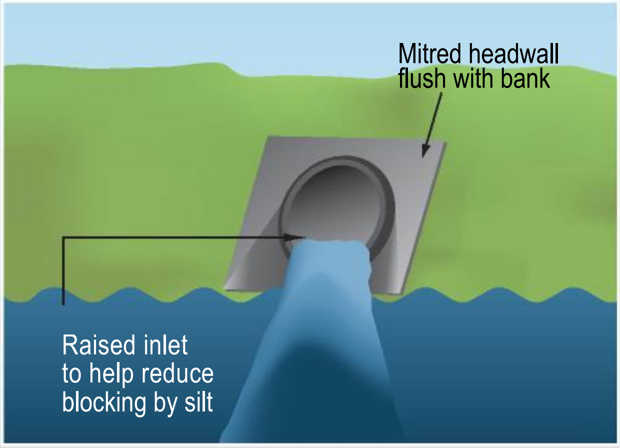


Figure 14 Bank side outfall

Figure 15 photograph Bank side outfall with mitred headwall

HIGH IMPACT - please note this is the impact on the physical habitat (morphology) of the river and does not take into account the impact of any discharge on qater quality.

Key Points:

- Should only be used where there is inadequate water depth for a submerged outfall or set back outfall
- Mitred headwall is flush with bank allowing for easy maintenance (e.g. mowing) and reducing trip hazard
- No part of the outfall structure should protrude beyond the line of the bank, this includes headwalls, wingwalls and protection aprons.
- Should have silt apron to aid silt removal / raised inlet to avoid silt build up in pipe
- Safe access should be provided
- Sample chamber should be provided (if necessary)
- Native bank vegetation should be re-established after construction

Considerations:

- Location and alignment should be carefully considered (see sections 5.2 and 5.3)
- Type and extent of erosion protection required should be carefully considered (section 5.4).
- Maintenance inspections should be planned

Types of outfall IV - Set back

Setback outfalls are suitable for low velocity clean water discharges such as discharges from a sustainable urban drainage (SUD) system. A SUD system mimics natural drainage systems that aim to reduce the impacts of flooding and pollution that were associated with some more traditional types of drainage systems. A SUD system aims to reduce impacts on water quantity, water quality, amenity and biodiversity.

The **Quantity** of water released is restricted to the rate at which water would leave the site before development took place. This is the 'greenfield rate' of run-off.

The **Quality** of run-off from SUDS systems is managed by removing silt and pollution 'at source' and designing a 'management train' too improve the quality of water in stages depending on the risk of pollution. The 'management train' is usually expressed as a design sequence: prevention – source control – site control – regional control with a series of 'treatment stages' or SUDS features used to ensure pollution is adequately controlled.

The **Amenity and Biodiversity** aspect of drainage is provided by maximising visual, social, environmental and wildlife opportunities.

- Wherever possible the outfall from a SUDS system should be an open low flow route e.g. swale, open channel, or linear wetland. Where water flows directly from this type of route then it is unlikely to block – but consideration should be made to making the outfall location visible for any future maintenance requirements.
- Where the outlet from a SUDS system is through a pipe it should finish some distance from the entry to the watercourse to provide a surface discharge route and semi-natural entry e.g. it should discharge to a set back channel or wetland (see fig 16 and 17 below). Where water is discharged through a grille or pipe then consideration should be given to blockage by debris. Where the end of the pipe is open then consider risk of blockage e.g. by children, debris or vegetation (see section 5.4 other mitigation: screens).

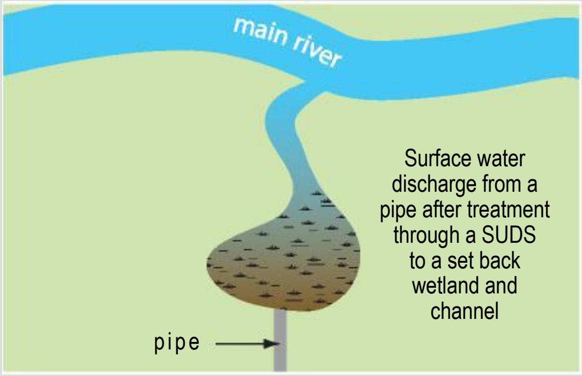


Figure 16 and 17 set back outfalls. Photograph courtesy of Robert Bray Associates

LOW IMPACT - please note this is the impact on the physical habitat (morphology) of the river and does not take into account the impact of any discharge on water quality.

Key Points:

- Outfall is setback from bank side and water edge
- Erosion protection should be minimal as low velocities involved.
- Bank side (riparian) and wetland can be planted with local native species so reducing the impact and maximising biodiversity.
- Swale / constructed channel bank profile should have a maximum slope of 1 in 3 for management and health and safety considerations
- Safe access should be provided

- Sample chamber should be provided (if necessary)

Considerations:

- Location and alignment of swale / constructed cannel should be carefully considered (see sections 5.2 and 5.3)
- Need to ensure outfall location is kept clear of vegetation to ensure easy inspection
- Outfall and wetland / channel maintenance should be planned

For futher information see:

- Sustainable drainage systems: promoting good practice – A CIRIA initiative (http://www.ciria.org/suds/)

5 Good practice design and implementation

5.1 Introduction

Successful adoption of good practice requires selection of a suitable option followed by appropriate design and implementation. This section will provide guidance on design and implementation considerations and at gives general principles that can be applied to all types of intake and outfall.

5.2 Location

Choosing an appropriate location for the intake or outfall is the first step in reducing the risk of sediment deposition or erosion and scour. This will help reduce the risk of damage to the structure, helps reduce the amount of erosion protection that may be required, and reduce the need for dredging.

Box 6 Location of intake and outfall structures

- Should be located on a stable bank with no evident signs of erosion or undercutting.
- Do not locate in areas of sediment deposition.

Location in rivers

Structures should be located on straight sections of rivers where there is less risk of erosion. The outside of meander bends where erosion naturally occurs should be avoided (figure 18). The inside of bends, where sediment tends to accumulate, should also be avoided.

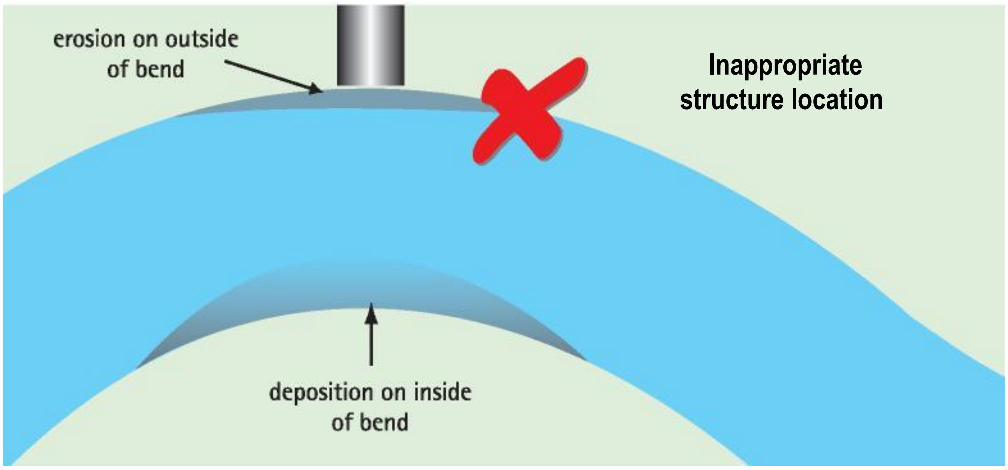


Figure 18 Incorrect structure location.

Evidence of bank erosion – structures should not be placed along sections of river where there is evidence of bank erosion. Figure 19 and 20 below provide some examples of bank erosion.

Figure 19 Erosion on the outside of a meander bend.

Figure 20 Erosion can also occur on straight stretches where banks can be weakened by factors such as livestock grazing.

There are several different types of bank erosion, for further information on the different types of bank erosion and different management solutions see the reference below.

For Further Information See

- SEPA 2008 Good Practice Guide: Bank Protection (www.sepa.org.uk/wfd)

Location in Lochs

Appropriate location - lochs

- Do not locate intakes and outfalls in areas where sediment is depositing
- Locate intakes and outfalls on a stable bank where there are no evident signs of erosion
- Pipe soffit sould be below loch low water level
- Avoid important habitats

Erosion occurs on the banks of lochs as well rivers. Areas where erosion is evident in lochs, such as wave washed shores should be avoided. Pipe soffit (top of pipe) should be located below low summer water levels so it is not exposed during dry periods (figure 21).

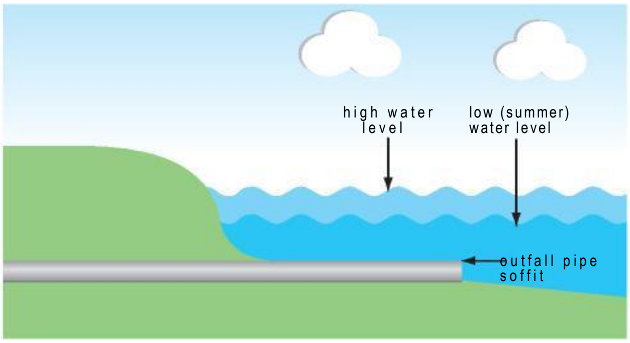


Figure 21 pipe soffit below low water levels of the loch

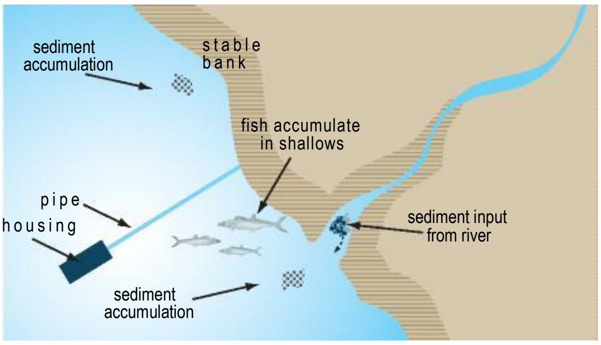


Figure 22 shows an appropriate location in lochs

Key habitats in lochs should also be avoided such as:

- Macrophyte beds
- Shallow littoral areas and embayments (habitat for some juvenile fish species)
- Wave washed shores
- Inlets and out lets (fish spawning areas)

5.3 Alignment and design of Intakes

Once you have mitigated impacts by locating the intake appropriately, the next step is to minimise impacts through careful alignment and design of the intake.

Alignment

The alignment of the intake can affect the localised scour and deposition of sediment around the intake structure. It may also affect the performance of fish screens and trash racks, and affect the potential for ice blockages and subsequent damage in cold climates. Alignment issues are important for rivers, but less relevant to lochs. The alignment of an intake will also depend on the type of intake proposed, however some general principles are discussed here.

A good alignment can:

- Minimise the change in flow direction between the source body and diverted flow, thus helping to reduce sediment ingress, deposition and erosion around the intake;
- Allow for a sweeping and self-cleaning passage of sediment, trash and ice past the intake in the downstream direction.

In rivers, the intake should be aligned so that the diversion angle between the main flow in the river and the intake entrance is 10–45° (Figure 23); the intake should not be aligned at an angle of 90° (Figure 24). An angle of 10–45° will help to minimise the change in flow direction between the source body and the diverted flow, thus helping in turn to:

- Reduce localised erosion and scouring of the bed and bank;
- Reduce sediment deposition near the front of the intake;
- Allow for a sweeping and self-cleaning passage of sediment, trash and ice past the intake.

Figure 23 Intake at 45° to flow – correct alignment

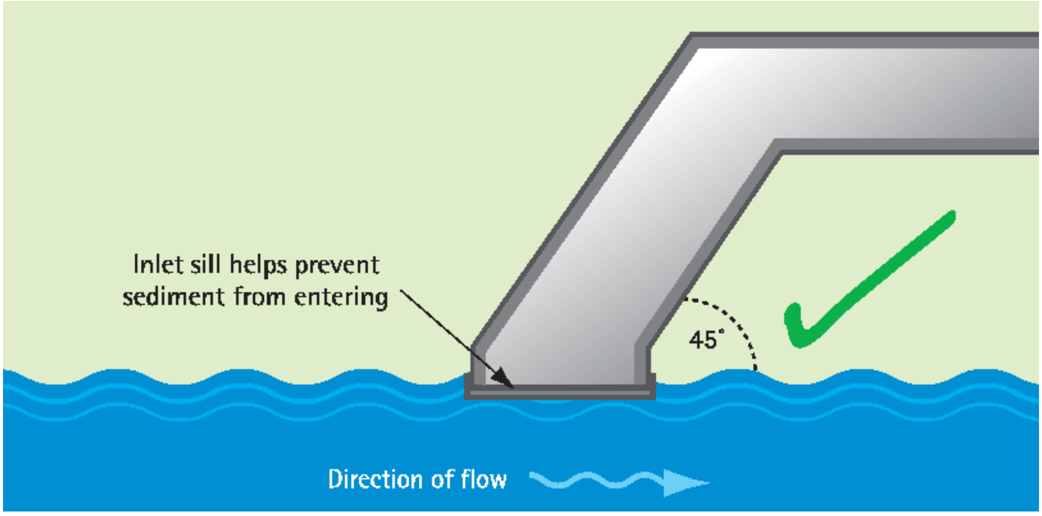
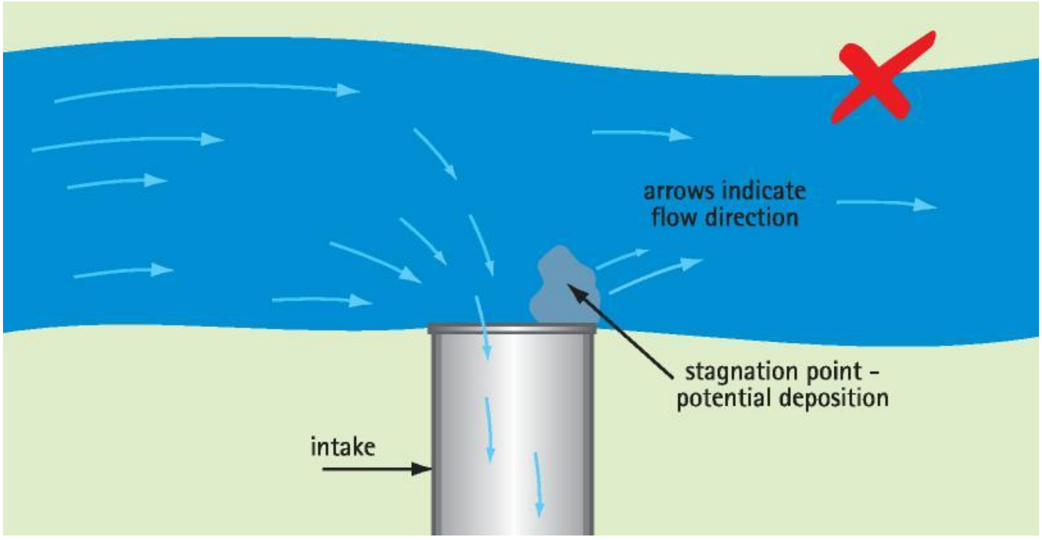


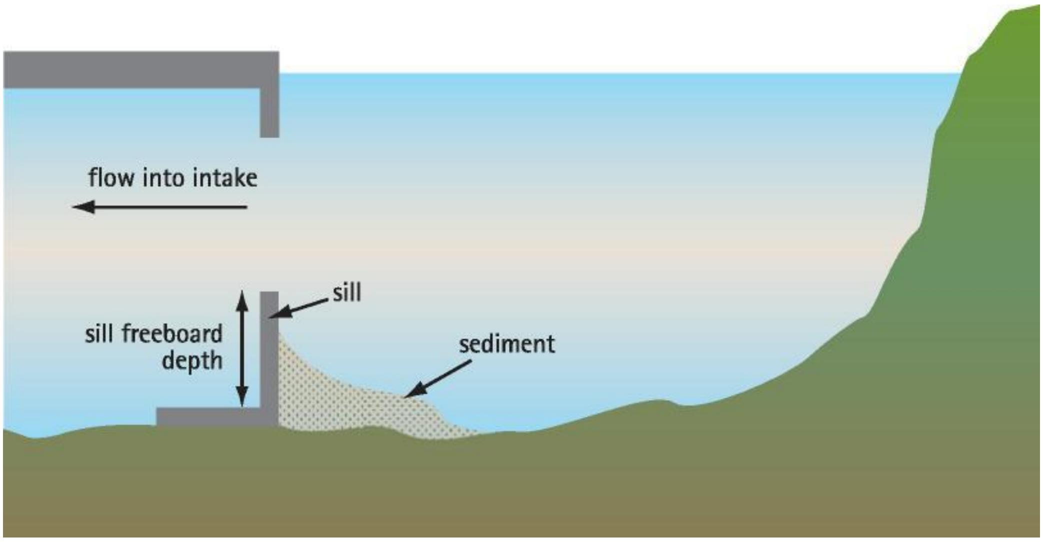
Figure 24 Intake at 90° to flow – incorrect alignment



Intake sill height

Locating the intake in deep water to allow for a high sill freeboard depth (height between the river bed and the inlet pipe/feature as shown in Figure 25) can reduce the risk of sediment entering the intake structure.

Figure 25 Diagram showing sill freeboard depth



Flushing structures

Where sediment does accumulate in the intake structure or behind a weir, flushing structures can be built into the intake to periodically flush out sediment during high flows.

Sluices and flushing canals can be incorporated into the intake structure itself (see Figure 7) or be incorporated into a weir (Figure 26).

Careful consideration should be given to the time of year that flushing is carried out to avoid pollution of downstream reaches with fine sediments.

Flushing should not be carried out during fish spawning times or in the period between spawning and the emergence of juvenile fish. Contact your Local District Salmon Fishery Board (http://asfb.hub.uk.com) for more information on appropriate timing.

Flushing should be carried out under high flows to ensure that the sediments are carried down stream.

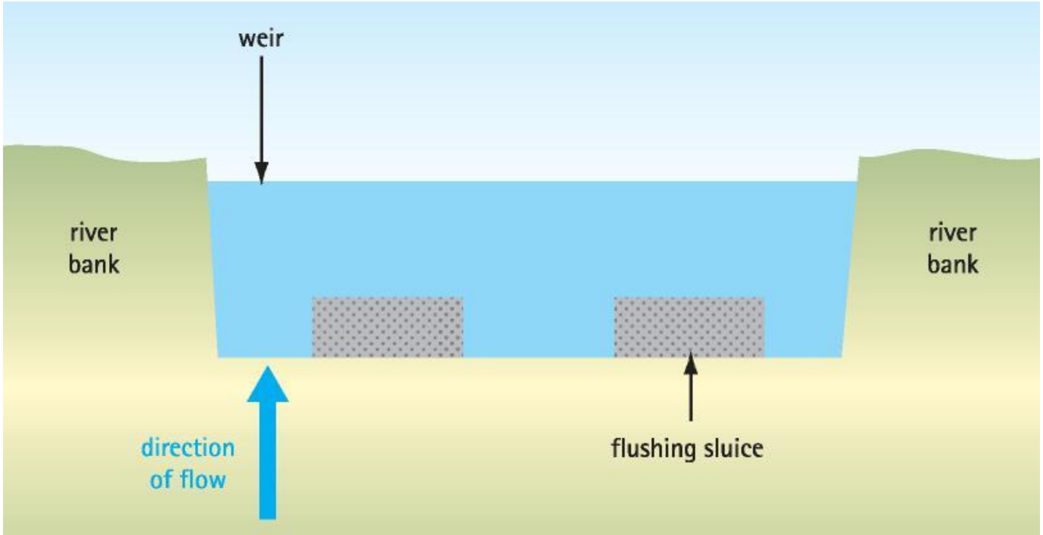


Figure 26 Schematic diagram of a weir with sluices for flushing sediment

5.4 Alignment of Outfalls

Correct alignment and design of the outfall can also help reduce scour around the structure and erosion of the bed and banks of rivers and lochs. This will also help reduce the amount of erosion protection required. If incorrectly aligned, the outfall can cause turbulence in the water and exacerbate scouring of the bed and banks, and could lead to the structure itself being damaged.

The discharge should be in line with the flow of the river as this helps to reduce turbulence and erosion.

No part of the outfall structure should protrude beyond the line of the bank, this includes headwalls, wingwalls and protection aprons. This helps to reduce turbulence and localised scour.

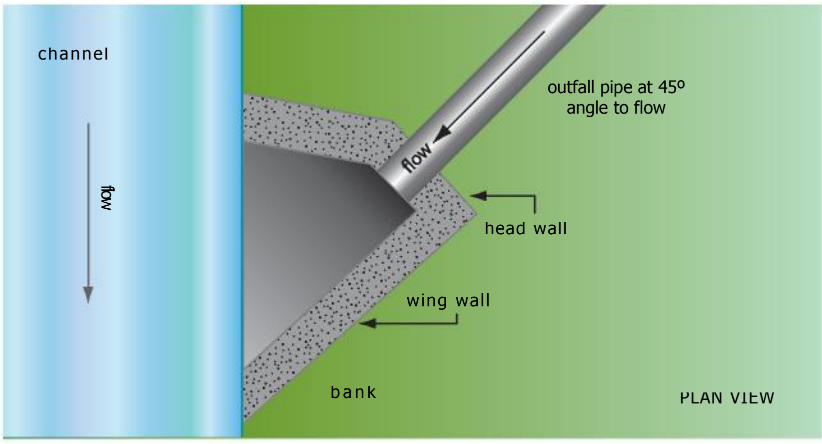


Figure 27
Discharge should be in direction of flow – ideally the outfall pipe should be angled at 45° to the direction of flow.
The Outfall structure should not protrude beyond the line of the bank. This includes headwall, wingwalls and protection apron.

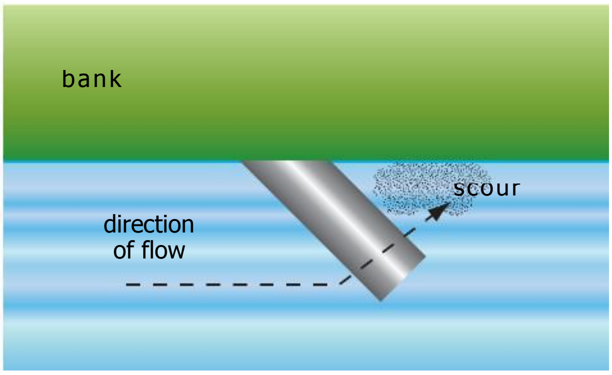
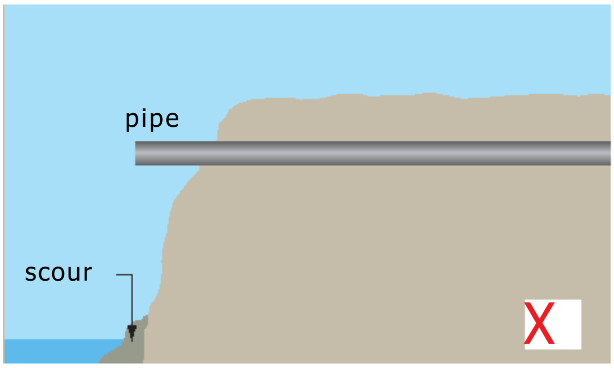


Figure 28 and 29 Outfall pipe protruding beyond bank

Figures 28 and 29 above show an outfall protruding beyond the bank that can lead to increased erosion. The outfall structure can act as a flow deflector and deflect flow toward the bank downstream leading to increased erosion and the requirement for further erosion protection.

The height between the outfall pipe and the river or loch bed should be minimised to help reduce erosion. This can be achieved by:

- laying the pipe as low as is practically possible
- If the banks are particularly high, a properly designed drop pipe structure can be used to move the water to a lower height (figures 30 and 31). They also have the advantage of acting as an energy dissipater (reducing the discharge velocity) if the lower outlet pipe is placed a few inches off the bottom of the drop structure.



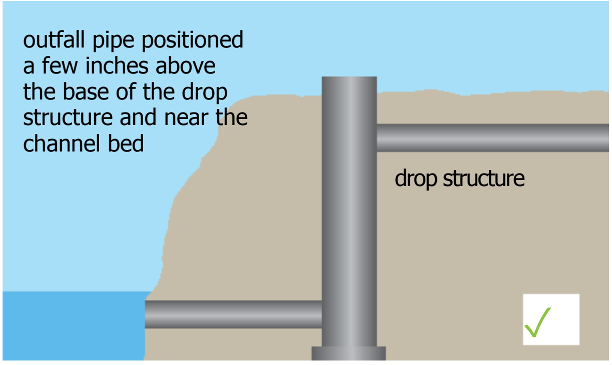


Figure 30 large height between outfall and water lead to scour

Figure 31 Example of a drop structure will

5.5 Other Mitigation

After impacts have been minimised by selection of an appropriate location and careful consideration of the alignment and design of the intake or outfall, other mitigation measures can be considered.

This section contains guidance sheets on measures that can be used to reduce the impact of intakes and outfalls on the morphology, hydrology and aquatic life of rivers and lochs. The sheets contain a summary of each of the measures including; key points, diagrams, potential advantages/disadvantages and where appropriate, details on installation and management requirements. The sheets do not provide definitive detail, but allow the user to understand how each measure can be applied and where to find more information.

Mitigation sheet I: Erosion Control

The potential for localised erosion (Scour) around the intake or outfall structure should be minimised through careful consideration of the location and design of the structure as described above. Once this has been done then further requirements for erosion protection should be considered.

Low velocity discharges (such as discharges from SUDS) or abstractions in low energy environments (see appendix 1) are unlikely to require any erosion protection. Where erosion protection is necessary, 'green' measures may be appropriate.

Whereas high velocity discharges, such as discharges from hydropower schemes or structures in high energy environments (see appendix 1), have a high risk of erosion and are likely to require 'harder' or 'grey' techniques to control erosion.

Green Erosion Protection

Green erosion protection has less impact on the bank side (riparian) habitat and biodiversity. In some urban areas it can also improve the riparian habitat and biodiversity. Green erosion protection is most suited to low energy environments. In the case of small structures in low energy environments, no erosion protection may be necessary. In these cases it should be ensured that the bank is restored after the structure has been constructed and the vegetation is re-established with appropriate native species. A large range of options are possible including:

Low maintenance tough grasses and herbs (use locally sourced native vegetation)

Bio-degradable Geo-textile matting and prefabricated planting pockets and vegetated plots. Geo-textile matting needs to be firmly secured to the bank to stop slippage and washout during high flows.

Grey Erosion Protection

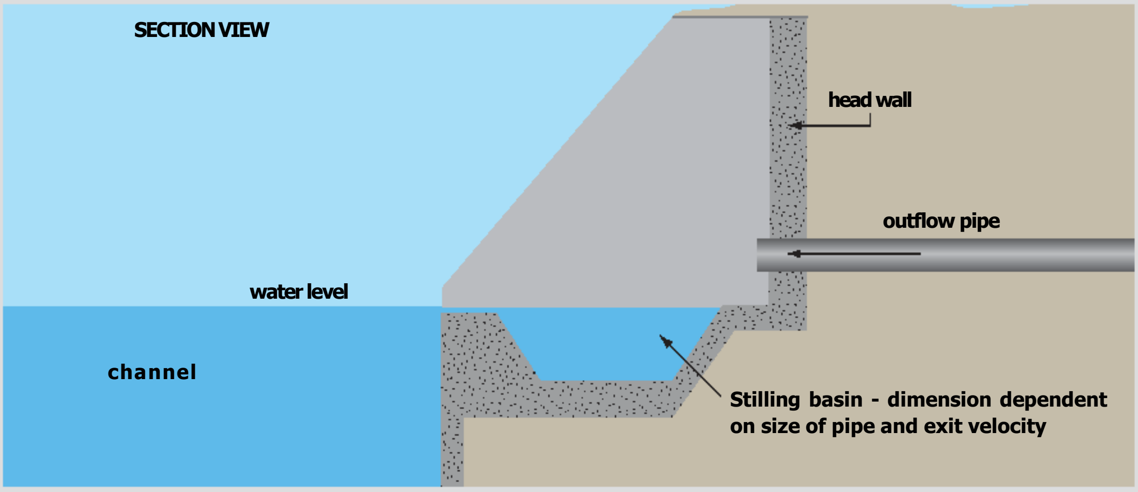
Harder material may be required in high energy / active environments such as stone rip-rap. The extent of erosion protection should be minimised and based on site specific requirements.

Figure 32 A Bedrock river

Natural features such as bedrock lined channels / pools are common in high energy upland areas (see figure 32 above). As these environments are very stable and not prone to erosion then little or no erosion protection may be necessary. These features can be chosen as an appropriate location for an outfall to reduce the need for erosion protection.

Discharges with high velocities may require energy dissipaters such as stilling basins (fig 33). Stilling basins must be appropriately designed to suit the discharge and site conditions.

Figure 33 High velocity discharge with stilling basin



For futher information see:

- SEPA 2008 Good Practice Guide: Bank Protection (www.sepa.org.uk/wfd)

Mitigation Sheet II: Screens

Screens maybe required to:

- stop fish and mammals (e.g. otters) from entering the discharge or abstraction system
- stop debris from entering and blocking the discharge or abstraction system
- Health and safety reasons e.g. stop vandalism and to stop children from entering pipes

The design of the screen depends primarily on the purpose. For example, if it is to stop the migrating fish from entering the outfall system, then the mesh size or spacing between the bars has to be appropriate for the size and age of the target species. Screens to stop vandalism or the entry of children into outfall systems on the other hand need to be strong enough so as to ensure the bars can not be bent or prised from the frame or mounting structure.

Fish Screens

Migrating fish are often attracted to the fast flowing and turbulent water from higher volume discharges or abstractions, significantly affecting upstream migrations. Screens are therefore required to stop fish entering the discharge system. The Local District Salmon Fishery Board should be contacted if this is a concern. Below are given some general principles on screens and where to find further information.

It is crucial to ensure that the appropriate type of fish screen is fitted to the structure. There are many different types, dependant primarily on the fish species targeted, its life stage (i.e. juvenile, adult etc) and the water velocity near the screen (commonly referred to as approach velocity).

Most fish screens require regular cleaning and maintenance to ensure that they operate at full efficiency.

Trash / Debris Screens

Screens to prevent debris from blocking the intake or outfall should be angled at 45°. This reduces the risk of debris building up at the screens and causing a blockage itself (figure 34).

Security/safety and mammal screens

Screens may be required on structure to prevent ingress by individuals. The design of these screens may mean that aperture or spacing between bars is restricted. This can have implication for fish and sediment movement through the structure and as such some further consideration may be required.

Dual apertures / Bypass facility

Screens could be fitted with dual apertures such that larger spacing is afforded below water level for fish and sediment movement passed screen and smaller spacing above water level for health and safety reasons. Bypass facilities could also be provided in locations sensitive to flooding where if screens become rapidly blocked there is an alternative route for flows to pass forward.

Maintenance

Screens should be maintained in order to ensure that they are operating effectively, this includes removal of debris caught up in screen apertures. Good housekeeping will ensure that screen and other surrounding infrastructure or river banks are not damaged through build-up of debris and sediment which may result in scour or flooding due to restricted flows as well as ensuring fish passage through the structure.

Figure 34 screen angled at 45° to prevent debris, such as falling branches from blocking the outfall and to prevent vandalism.

For further information see:

- CIRIA Culvert design and operation guide C689 2010
- Institute of Fisheries Management - Fish Pass Manual (page 161) https://ifm.org.uk/wp-content/uploads/2016/01/Fish-Pass-Manual.-minimum-size.pdf
- Design Manual for Roads and Bridges 2004

Mitigation Sheet III: Flap Valves

Flap valves are primarily used on outfalls to prevent backflow, i.e. prevent water from backing up into the pipe network during periods of high flow.

There are many different types, sizes and strengths of flap valves, and it is important to choose the one that is most appropriate for the outfall system. They can, if not appropriate for the system, result in inefficient discharge of effluent from the outfall.

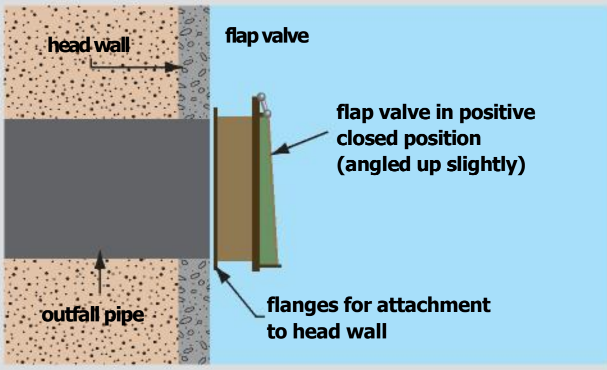


Figure 35 and 36 Outfalls with flap valve.

Key Points:

- Flap valves need to be robust to withstand damage during high flows
- Require regular maintenance and checking, the valve should be kept clear of debris
- Blockages increase the risk of damage and leave the outfall open to access from otters and fish, which can then become trapped within the outfall system
- The flap valve should be positioned to allow for easy access for routine maintenance and checking

Mitigation Sheet IV: Anti Seepage Collar

An anti-seepage collar is required to stop water from tracking along the pipe and causing bank erosion at the point where the pipe emerges from the bank. It may be required where the soils are unstable and there is significant overland and sub-surface flow.

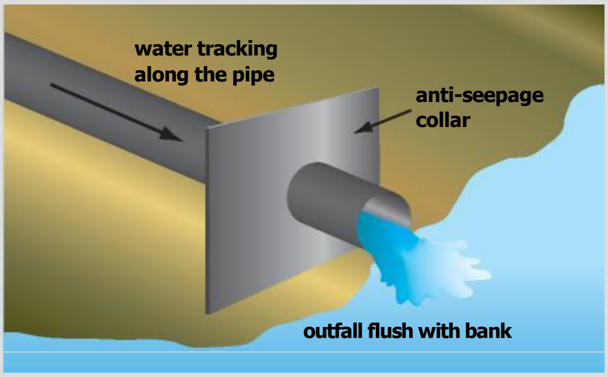


Figure 37 Anti seepage collar

Key Points:

- A clay barrier can form a natural anti-seepage barrier
- The anti-seepage collar should extend into solid ground

6 Sources of further information

6.1 Publications

Screening for Intake and Outfalls: a Best Practice Guide, Science Report SC030231, Environment Agency, 2005. Available from: http://publications.environment-agency.gov.uk/epages/eapublications.storefront [Accessed 5 April 2007].

A UK Guide to Intake Fish-Screening Regulations, Policy and Best Practice, Report prepared by Fawley Aquatic for the Department of Trade and Industry, 1998. Available from: www.dti.gov.uk/files/file15347.pdf [Accessed 5 April 2007].

A Guide to Mini Hydro Developments, British Hydropower Association, 2004. Available from: www.british-Hydro.org/mini-hydro [Accessed 5 April 2007].

Guide on How to Develop a Small Hydropower Plant, European Small Hydropower Association (ESHA), 2004. [Updated version of the Layman's Guide (see below)] Available from: www.esha.be/index.php?id=39 [Accessed 5 April 2007].

Layman's Guidebook on How to Develop a Small Hydro Site, European Small Hydropower Association (ESHA), 1998. Available from: http://ec.europa.eu/energy/library/hydro/layman2.pdf [Accessed 5 April 2007].

Good Practice Guide: Bank Erosion Management for Rivers, WAT-SG-23, SEPA, 2007: www.sepa.org.uk/wfd/guidance/engineering

Good Practice Guide: Construction Methods, WAT-SG-29, SEPA, 2007: www.sepa.org.uk/wfd/guidance/engineering

British Water, BW: 2/05, (2005), Guidance to proprietary sustainable drainage systems and components – SUDS: Technical guidance: www.britishwater.co.uk/Tech_Guidance_SUDS-final-1Jun05.pdf

CIRIA C697, The SUDS manual: www.ciria.org.uk

CIRIA C698, Site handbook for the construction of SUDS: www.ciria.org.uk

Environment Agency, (1999), River and wetlands best practice guidelines: www.environment-agency.gov.uk

6.2 Websites

Association of Salmon Fishery Boards (ASFB): http://asfb.hub.uk.com

British Hydropower Association (BHA): www.british-Hydro.org/mini-hydro

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

Environment Agency: www.environment-agency.gov.uk

CIRIA: www.ciria.org.uk

Sustainable drainage systems: promoting good practice – a CIRIA initiative: http://www.ciria.org/suds/

Highways Agency: www.highways.gov.uk

The River Restoration Centre: www.the RRC.co.uk

7 Glossary

Aggradation	Rising of the river bed due to depositional processes.
Apron	Erosion protection below the outfall discharge.
Buffer strip/zone	Area adjacent to the watercourse, left uncultivated – often fenced off.
Catchment	Total area of land that drains into any given river.
Channel incision	Deepening of the channel due to erosion of the bed.
Effluent	Any liquid, including particles of matter and other substances in suspension in liquid.
End operations	Where the abstracted water ends up (i.e. turbines, irrigation pump, water supply, etc.).
Flushing canal	Artificial canal used to flush sediment from fore bays, basins and traps back into the river or loch.
Flushing sluice	Valve or gate incorporated into intake structures and used for the purpose of flushing sediment out the system.
Fluvial geomorphology	Study of landforms associated with river channels and the processes that form them. It considers the process of sediment transfer – erosion, transport and deposition – in river channels and the relationship between channel forms and processes.
Fore bay	Area in front of the inlet feature used to help direct flow and trap sediment.
Gravity intake	Intake whereby the water is feed into a conveyance system to end operations by means of gravity.
Habitat	Specific area or environment in which a particular type of plant or animal, or group of plants or animals, live.
Head (hydraulic head)	Height of water above any point of reference; the energy, kinetic or potential, possessed by each unit weight of water (e.g. the height difference from the intake to end operations).
Head loss	Energy loss due to friction, eddies, changes in velocity or direction of flow.
Headwall	Structural protection for the outfall pipe.
Incision	Deepening of the channel due to erosion of the bed.
Inlet	Structure through which water passes from the channel or fore bay into the conveyance system.
Intake	Structure associated with the abstraction of water from a river or loch, including flow deflector, fore bay, inlet and sediment traps, sluices and sills (not including weirs).
Littoral zone	Area of shallow water at the loch shore between low and high water levels.
Macrophytes	Aquatic plants – can be emergent (above the water line) or submerged (below the water line).
Meander	A bend in the river formed by natural river processes e.g. erosion and deposition.
Mitred headwall	Headwall that is flush with the bank slope.

Penstock	Pipe that conveys water under pressure from the fore bay tank to the end operations.
Riparian	Area of land adjoining a river channel (including the river bank) capable of exerting physical, hydrological and ecological impacts on the aquatic ecosystem (e.g. shading, leaf litter input). In this Guide, the term 'riparian zone' does not include the wider floodplain.
Rip rap	Angular stone placed to protect eroding banks, also referred to as rock armour.
Scour	Erosion of the channel banks and bed due to excessive velocity of the flow.
Soffit	Highest internal point of a pipe
Swale	A natural depression or shallow drainage conveyance with relatively gentle side slopes, used to store, route or filter runoff.
Wingwall	Erosion protection at the sides of an outfall.

Appendix 1 Types of environment

River typologies have become a valuable tool for geomorphologists for identifying and interpreting river characteristics.

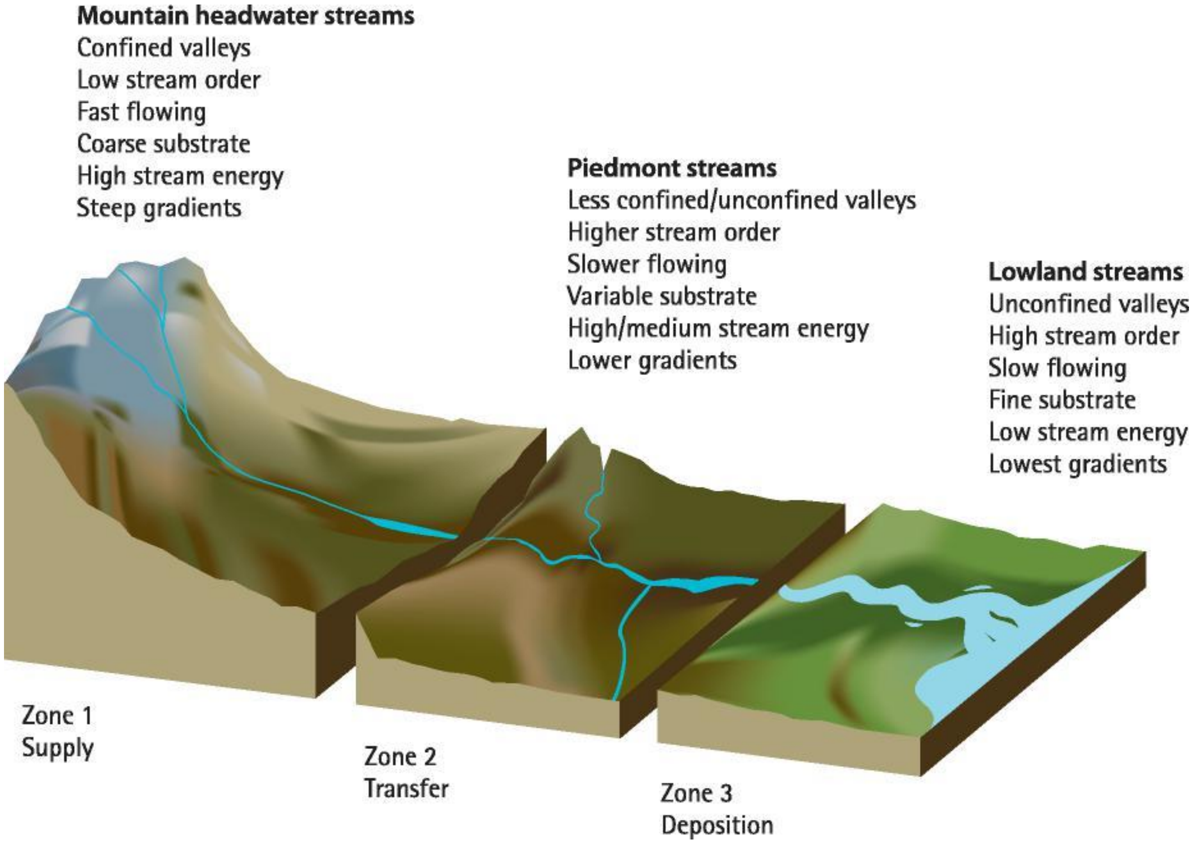
Different rivers (or sections of channel within a river) display distinct characteristics that can influence the considerations that need to be taken into account when installing an intake or outfall.

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

- upland;
- transitional (piedmont);
- lowland.

The different types of environment can be found throughout the catchment and Figure A1 gives a generalised overview of the different areas with a catchment.

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



Low Energy Environments

Transitional and lowland rivers are typically low energy environments where sediment sizes are generally a lot smaller than that in upland streams (i.e. small cobbles, gravel and sand). Common features include; meandering, riffle / pool sequences, braided. Also included in this category are man made, or modified (e.g. straightened) rivers.

One of the most important factors in influencing river type is slope. Low energy environments typically have a slope of less than 1%. If you do not know the slope, it can be determined by looking at the contour lines on an Ordinance Survey map. Look at how many metres a river falls over a kilometre e.g. a river falls 5 metres over 1 kilometre. To convert this to a percent, divide the number of metres fallen over the distance and multiply by 100.

Number of metres fallen/distance X 100 = % slope

For the example above the slope in % is worked out as follows:

5/1000 X 100 = 0.5%

Figure A2 and A3 Photos of low energy environments

High Energy Environments

Upland rivers are typically high energy environments where sediment sizes are generally larger than that in lowland streams (i.e. cobbles, boulders and bedrock). Common features include; exposed boulders, step-pool sequences, exposed bedrock.

One of the most important factors in influencing river type is slope. High energy environments typically have a slope of greater than 1%. If you do not know the slope, it can be determined by looking at the contour lines on an Ordinance Survey map. Look at how many metres a river falls over a kilometre e.g. a river falls 25 metres over 1 kilometre. To convert this to a percent, divide the number of metres fallen over the distance and multiply by 100.

Number of metres fallen /distance X 100 = %slope

For the example above the slope in % is worked out as follows:

25 /1000 X 100 = 2.5%

Figure A4 and A5 Photos of high energy environments

Appendix 2 Feedback form: Good Practice Guide WAT-SG-28

SEPA is committed to ensuring our Good Practice Guides are useful and relevant to those carrying out engineering activities in Scotland's rivers and lochs. We welcome any comments you have on this Good Practice Guide so that we can improve future editions. Please complete and detach the following questionnaire, and post to:

Water Policy
Scottish Environmnet Protection Agency (SEPA)
Strathallan House
Castle Business Park
Stirling
FK9 4TZ

The aim of this Good Practice Guide is to set out the environmental aspects that should be considered when undertaking engineering works and to help applicants choose sustainable engineering solutions that reduce environmental impacts. This will also help them obtain an authorisation for works under the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (As Amended) (CAR).

<table>
<tr><td colspan="8">Which of the following do you think describes how well the Guide meets these aims?</td></tr>
<tr><td>Excellent</td><td></td><td>Good</td><td></td><td>Average</td><td></td><td>Poor</td><td></td></tr>
<tr><td colspan="8">How relevant was the content of the Guide to your activity?</td></tr>
<tr><td>Very relevant</td><td></td><td>Sometimes relevant</td><td></td><td>Not relevant</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="8">What elements of the guidance did you find most useful?</td></tr>
<tr><td colspan="8"></td></tr>
<tr><td colspan="8">What elements of the guidance did you find least useful?</td></tr>
<tr><td colspan="8"></td></tr>
<tr><td colspan="8">Did you find the Guide clear and easy to follow?</td></tr>
<tr><td>Very relevant</td><td></td><td>Sometimes relevant</td><td></td><td>Not relevant</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="8">If there were areas that could be clearer, please let us know in the box below</td></tr>
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<tr><td colspan="8">Were there issues you felt should have been covered, omitted or dealt with differently in the Guide?</td></tr>
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Please use the box below for other comments or suggestions on the Guide (continue on a new sheet if required).