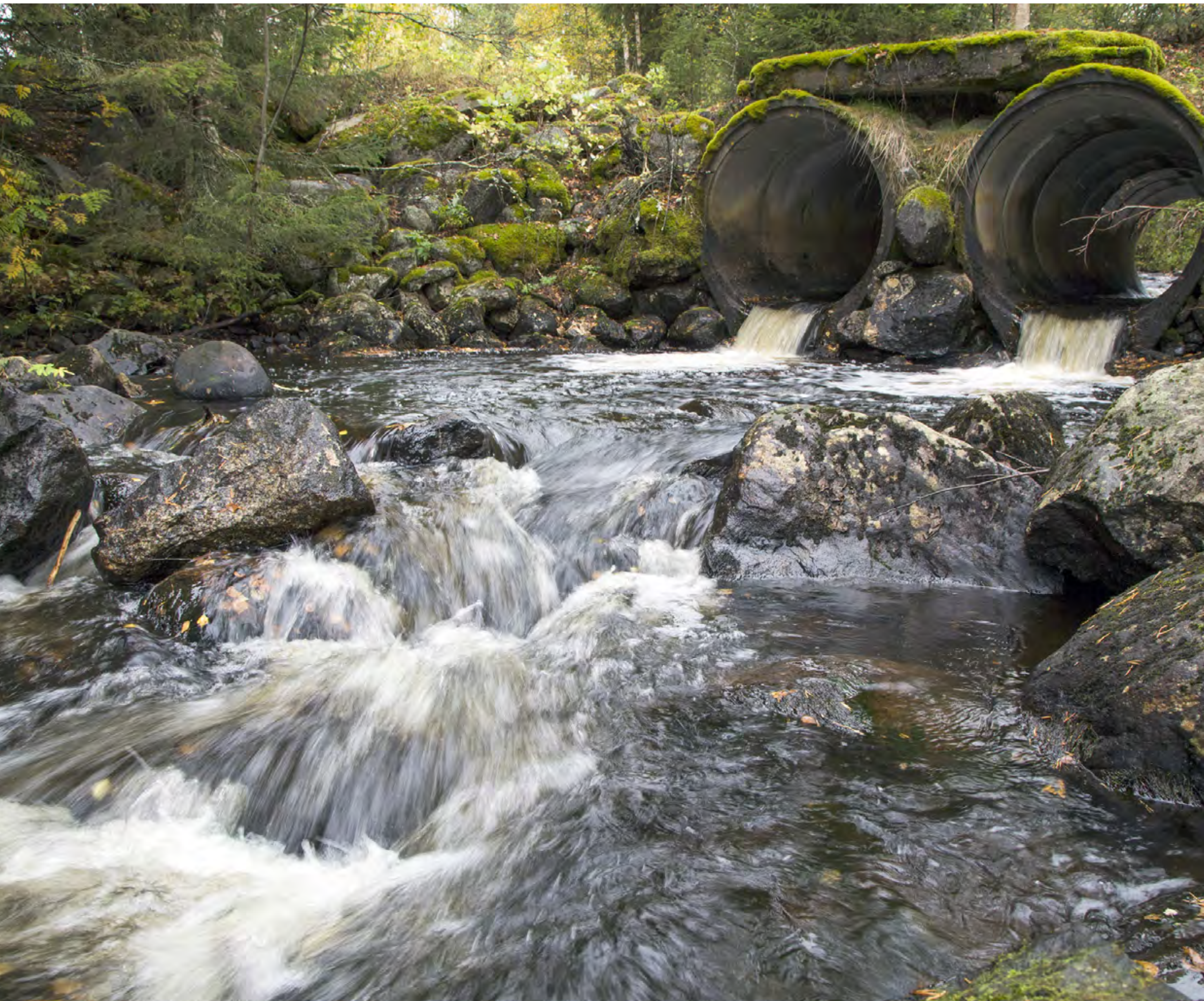
REMIBAR



Ecologically adapted stream crossings for forest roads

– a guide (for planning and construction)

Title: Ecologically adapted stream crossings for forest roads – a guide (for planning and construction).

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Introduction

This manual is aimed primarily at technicians, contractors and land owners and should be viewed as an aid to the planning and construction of crossings over smaller streams on forest roads, but it can also be used for advice in the construction of smaller public roads.

There are around 400,000 kilometres of water courses in Sweden and 280,000 kilometres of private roads, the majority of which are forest roads. Estimations show that a natural watercourse is crossed by a road approximately every third kilometre, and inventories taken show that many road-water crossings constitute migratory barriers for aquatic animals.

Appropriate technical solutions and sound technology are required in the construction process in order to reduce the environmental impact of roads that cross over water. This guide should be an aid in the work to design stream crossings in a manner that is environmentally and technically correct, to make them sustainable and their construction and maintenance as economically viable as possible. A long and problem-free operational life is another important environmental aspect where construction solutions and technology can make a valuable contribution. The construction phase can itself bring about major disruptions - there is a great risk that damage caused in the construction process will result in damage to the environment. At the same time, the serviceable life of the construction is an important aspect in respect of the structure's economy. Sound technology in the construction of stream crossings is therefore both an economic and an environmental issue.

In order to build economically and environmentally sustainable constructions for stream crossings, expertise is required in respect of planning, implementation and maintenance. This guide contains guidelines for how this can be achieved, and these principles can be used within a construction document. On the other hand, the construction of bridges always requires clarification and specifications in the form of a technical description and diagrams.

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Paying attention to streams when constructing roads over them

Introduction

The construction of a crossing over a watercourse is often technically demanding and requires thorough planning, preparation and reconnaissance. In addition to the technical aspects, consideration must also be paid to environmental aspects and the impact on plant and animal life. It is also important to pay attention to the physical processes that create and maintain the aquatic environments, such as erosion and the transportation and depositing of sediments and organic material. An incorrectly constructed crossing can lead to long-term physical changes that affect both the aquatic environment and the immediate surroundings.

Streams are ecological corridors in the landscape, and they contain species-rich habitats that differ from the surrounding landscape. In addition to the biological life directly linked to the aquatic habitat, the terrestrial surroundings of the streams are used as migratory routes for insects, birds and wildlife. Most aquatic species require continuity in the streams in order to spread and reproduce.

In Sweden, in average, there is a road crossing every two kilometres along a stream. Through inventories, we know that every third stream crossing can be a migratory barrier for fish and other aquatic animals. Today there is more awareness and knowledge than ever before with regard to how we can create crossings that provide fish and other animal life with the best conditions possible. The technology exists to build good crossings that preserve the natural function of the stream while still protecting the road from damage at times of high water flow. We use this knowledge in the Remibar project to reduce the number of migratory barriers in our streams.

A colony of freshwater pearl mussels. The freshwater pearl mussel is a red-listed (endangered) species that depends on free migratory routes for its survival. Photo: Kenny Ärlebrand.

The processes of the stream

The physical processes in a stream form and maintain all the structures that in turn create living environments for aquatic animals. It is therefore important that crossings over streams have as little impact as possible on these processes. An incorrectly placed crossing can create both instantaneous effects, such as backwater upstream of the crossing, as well as slow changes in the stream's form and substrate that lead to a gradual deterioration of its ecology.

Different streams have different morphological sensitivity to the disruption that a crossing over water can entail. This can in turn affect what type of crossing is chosen. One important factor in respect of sensitivity is the natural stability of the stream, i.e., how quickly the stream's shape, cross section or bottom substrate change. In general, steep streams with a slope of over 2 per cent consisting of boulders and stones are often stable. In many cases, a 50-year flood is needed in order to reshape these streams. These streams are often dominated by high flow speeds and powerful turbulence. This type of stream is less sensitive to road crossings, at the same time they are often smaller in size.

The streams that are most sensitive to crossings are those dominated by the pronounced transportation of gravel and sand, for example as a result of pronounced gravel banks in the stream's inner curves, or cushions and reefs at the bottom. In the majority of cases, these streams occur in the middle of the drainage basin and with a slope of between 0.1-0.3 per cent. These streams often wind back and forth somewhat, in a regular pattern with stretches of stream alternating with pools, i.e., deeper sections. A crossing, for example a culvert, may require a large part of a cross section and restrict the transportation of sediment downstream. This can have significant consequences for the natural variation of the stream's bottom substrate, the topography of the stream bed, etc. Upstream the consequence will of course be that the stream becomes shallower, which in turn can lead to a widening the stream. In these streams, solutions should therefore be employed that have a minimal impact on the steam's cross section.

Streams that run through pure sand often have a small slope, but these are also sensitive in respect of bedload transport. In these streams, protecting the vegetation along the edge of the stream is also important, since it governs the form of the water furrow. If the vegetation is destroyed, extensive erosion could easily occur along the edges of the furrow, both upstream and downstream of the crossing. It is important to understand how such a stream changes naturally. If it meanders strongly with clear signs of erosion in the outer curves and deposits in the inner curves, or if there are trees in the outer curves with exposed root systems, this may indicate that the stream is in an active state. The water furrow may then want to move laterally, which in the long term can affect a crossing over the water. If there are clear signs of active erosion and depositing of sediment, a closer examination of the physical processes must/should always be conducted.

Streams in types of soil that are finer than sand and with dense, continuous vegetation or trees along the edges of the stream's furrow will often be stable. The slope is always less than 0.1 per cent and the flow speeds are often low, apart from when the flow is high. This means that there is little sediment transportation along the bottom and that erosion and depositing only occur to a limited extent. If the stream does not flow straight but meanders naturally, then the meanders are moving slowly downstream, sometimes by only a few centimetres per year. A crossing over water often has a limited effect on theses streams since the (sediment) transportation is dominated by suspended material. Generally speaking, where meandering streams are concerned, a road bridge should be located in the middle of two curves, where the furrow is shallower and straighter.

Streams in silt or clay often have a broad flat area around the stream, known as a flood plain. These areas are formed partly by the meanders slowly moving downstream, but above all by sediment being deposited during the flooding that occurs every one to ten years. There are several reasons to avoid constructing forest roads and road bridges on flood plains. One compelling reason is that the flood plain indicates that the stream can have a water level higher than the edges of the furrow, which could lead to backwater effects around the road bridge and the road embankment or, in the worst-case scenario, that the water level reaches above the road bridge. Another reason is that untouched flood plains are one of our most species-rich land ecosystems. A third reason is that the groundwater level is often close to the soil surface with an abundant discharge of groundwater with groundwaterdependent ecosystems.

Dead wood is another material that is transported in streams. The steeper the stream, the greater the risk that the wood will be mobilised.

The stream's inhabitants

In order to preserve the stream's natural conditions, we must pay attention to all species and living environments concerned. Animals should be able to migrate freely along the stream so that the species' genetic variation is preserved and its survival ensured. We have fragmented the streams through dams and badly constructed bridges and culverts, which has had a negative effect on animal life.

Fish migrate between spawning, nursery and feeding areas. They also move to overwinter or to temporarily get away from unfavourable conditions. Certain species, especially small individuals, have difficulties swimming against a strong current. Animals that live on the stream bed are, like the fish, dependent on being able to move along the stream. The species that lack a flying stage, i.e., crustaceans, molluscs and leeches, are particularly dependent of the waterways. Bottom-dwelling animals that crawl along the stream bed and lack

The brown trout is one of the species that migrates between spawning, nursery and feeding areas. Photo: Dan Blomqvist, County Administrative Board of Norrbotten the ability to swim are of course dependent on the discharge from the culverts not being affected by a descending slope. If the base of the culvert is corrugated, then they may be able to crawl along this, but a great deal of turbulence is created by just moderate water speed, which hampers migration for smaller animals. The land animals that move along the stream, such as otters and water shrews, need safe crossings over the roads. Where there are culverts with high water speeds, and where the stream has no shore, many of these animals choose instead to run over the road, risking being run over.

A natural shore means that land-dwelling animals can move freely along the stream. Photo: Mats Lindqvist, Swedish Transport Administration.

Paying attention to actions taken at the stream

Shoreline

Have as little impact as possible on the shoreline in order to reduce the risk of erosion. The natural shade over the crossing provided by the surrounding vegetation also guides swarming insects in the right direction along the stream. Shade over the stream also keeps the water temperature down and benefits the brown trout that live in the stream. Sharp contrasts between shadow and light resulting from culverts exposed to the sun can frighten young, migrating salmon in smaller streams and, in the worst-case scenario, they refuse to pass. Vegetation along the stream also gives the fish the chance to avoid birds of prey.

Minimise clouding

Crossings over streams should be constructed so that they do not lead to clouding, damage the stream bed or create migratory barriers. Clouding means that bottom substrate, in the form of organic material or fine mineral particles, is moved up through the water. By avoid-ing to work within the existing stream, it is possible to minimise clouding and counteract future erosion problems. The work should be conducted during periods of low flow, since this reduces the risk of serious clouding. In certain cases it may be necessary to take specific preventative measures in order to avoid clouding. Where there are freshwater pearl mussels downstream,

Sediment traps can be constructed to minimise clouding during the construction period. Photo: SCA.

Scheduling measures

The timeplan for the construction should be adapted to the species living in the stream. Bear in mind when the fish migrate to spawn, when the eggs and fry will be found in the gravel of the stream bed, and consider the other sensitive life forms in the stream. In order to reduce clouding (see above), it is good if there is a low stream discharge in the stream while the construction work is conducted. Late summer is often the best time for work on streams, since the activity associated with spawning and fry is lower and stream discharge is minimal during the low water levels of July and August.

Adapted crossings over streams

If crossings over streams are designed correctly, the risk of migratory barriers is small. If migratory barriers have occurred, the construction may need to be replaced, but temporary solutions can also be considered in the meantime. Sometimes the revision of an existing culvert is enough. One common measure, which often fails however, is "thresholding". This implies that a backwater is created downstream of the culvert so that the water level in the culvert rises and the water speed is thereby reduced. The problem with thresholding is that it is difficult to make the threshold stable, so that it is not washed away. And if a stable threshold is successfully created, there is a risk that the threshold itself constitutes a migratory barrier. However, in certain circumstances, thresholding can be an effective temporary solution. For thresholding to succeed, there must be an obvious, pronounced stream furrow with high banks on each side of the stream. In this way, the stream is prevented from spreading out when the thresholds are constructed.

Thresholds can be an effective solution if the conditions are right, but should be seen as a short-term solution. Photo: Swedish Transport Administration.

General considerations

The vegetation on the shoreline is important for how animals living in and near the water perceive the stream. It is therefore good if care is taken to minimise damage to the surrounding vegetation in connection with the construction work. By choosing suitable constructions and sufficient spans, design and foundation work can be conducted in the dry.

Side ditches contain eroded material in the form of fine particles of minerals that are harmful for filter-feeding animals, i.e., freshwater pearl mussels and gnat larvae. Side ditches should therefore never be allowed to flow directly into streams. The side ditch outlets should instead infiltrate water into forested land. If ditches are already to be found adjacent to streams, then they should be revised. The best thing to do is to construct the drainage system so that the surface water infiltrates forested land. One alternative is to construct sludge dams that allow fine particles to sink to the bottom before the water reaches the stream. On erosion-sensitive land, such as silt, the sections of the ditch where the water runs at a high speed should be protected against erosion. Vegetation in the ditch should never be removed from the last couple of metres of land closest to the stream.

The historic impact on our streams

Human activities have impacted on the appearance of our streams and aquatic environments over the years; this had led, amongst other things, to the silting up of stream beds and deteriorations in the living environments (habitats) of many sensitive aquatic animals. Various types of ditches and the damming of wetlands have led to silt and humus being transported out into our streams. The floating of timber, which occurred between 1850 and 1970, led to major changes for our streams. The streams were cleansed of obstacles such as stones and boulders and were straightened, and narrow sections were excavated. This led to the destruction of suitable fish spawning beds and a reduced variation in habitats.

Dams for hydroelectric power have presented major migratory barriers for fish that migrate upstream, but migration downstream is also affected. The fish are often sucked into the turbines, and many of them get stuck there and die. Poorly adapted road crossings, such as culverts and bridges, have become migratory barriers for aquatic animals. High water speeds, long culverts without resting places, an insufficient depth of water and free fall out of the culvert are examples of migratory barriers. Bridges or culverts without natural shores also mean that land animals that depend on the stream may be forced to cross the road, or they may choose to move away from the stream.

Terminology and definitions

Various different technical solutions can be used in the design of crossings over streams. With regard to terminology, the span of a construction dictates whether it is referred to as a bridge or a culvert. Culverts have a span of less than 2 metres, whilst bridges are constructions with a span greater than 2 metres.

Span for culverts. Photo: Swedish Transport Administration.

Span for arches. Photo: Fredrik Broman, www.humanspectra.com.

Span for supported bridges. Photo: Per Christoffersson, Swedish Forest Agency.

Culverts are often designed as circular drums or half-drums, but they also include other solutions, for example geonet-reinforced constructions.

Bridges can be designed as tubes, arches with foundations and as free-standing bridge superstructures. Bridge superstructures can be constructed in many different ways (see the Construction section).

This guide should only be used for private roads that are basically intended for forest use (forest roads where 50 per cent of the usage should be related to forestry), and for crossings where the theoretical span is less than 12 metres. The guide can also be used for simpler roads with uses other than forestry, if attention is paid to the type of transport, especially when considering traffic safety solutions. The guide also confines itself to simpler construction scenarios, especially as far as the geotechnical conditions are concerned. The construction of bridges on semi-cohesive and cohesive soil should be conducted in accordance with the Swedish Transport Administration's latest instructions in respect to bridges. The instructions currently relevant are TRVK Bro (TRV 2011:085), TRVR Bro (TRV 2011:086) and TK Geo (TRV 2011:047).

Before a decision regarding the construction of a crossing over a stream is made, an estimation should be conducted of the loads that the bridge construction will bear; an investigation should also be conducted of the environmental values to be found in and around the stream. Find out how great the flow of water is. For smaller streams, refer to the Swedish Meteorological and Hydrological Institute's (SMHI) web site http://vattenweb.smhi.se/modelarea/. For larger bridges, information regarding 100-year floods can be ordered from SMHI.

The Swedish Environmental Code

The construction of a crossing over a stream can be classified as a water operation according to the Environmental Code. A permit is normally required for water operations, but this obligation may be replaced by a duty to report as far as smaller streams are concerned (if the stream discharge is less than 1 m3/s). In certain cases, if it is obvious that no public or private interests will be harmed, neither reporting nor a permit are required (Environmental Code, Chapter 11). An application to conduct a water operation is made to the county administrative board, and a permit application is submitted to the environmental court responsible for the area where the operation is to be conducted. In cases where a permit is required, a description of the environmental consequences of such operations should normally be produced. More information regarding water operations according to the Environmental Code can be found in the Swedish Environmental Protection Agency's (Naturvårdsverket) manual 2009:5.

Water areas (see Chapter 11, Section 2 of the Environmental Code)

"Water operations" encompasses construction work in a water area, i.e., the construction of bridges, foundations or embankments. This means that the construction of bridges, culverts and embankments is, in many cases, a water operation.

A water area is an area that, when the water level is at its highest predictable level, is covered with water. Read more in the Swedish EPA's manual or in Chapter 11 of the Environmental Code itself.

The planning of stream crossings

The most important adaptation in respect of crossings over water is to ensure that the positioning of the construction site offers favourable building conditions and has as little an impact as possible on the natural environment. This means not only avoiding areas with high natural values, but also paying attention to soil conditions, topography and hydrology, in order to facilitate a straightforward construction process.

Choosing the correct position for a crossing over water can limit both the cost of the project and its environmental impact. Larger constructions with greater spans make strenuous demands of soil conditions and hydrology.

The positioning of stream crossings
In the first instance, a position should be chosen for a crossing over water where the foundation can be set in bedrock or moraine, or in another type of soil with frictional soil qualities. Foundation in bedrock should only occur if the rock surface is relatively horizontal at the foundation points. The topography around the stream should be such that the stream has a distinct position but without the slopes down to the stream being too steep (maximum 30 per cent for moraine that is coarser than sandy, silty moraine (for more details see Geotechnical examination and investigation).

The position of the bridge may need to be moved along the stream in order to improve the prevailing conditions. Better conditions can also be obtained by moving the points for the foundation of the bridge footing. For example, the foundation points may need to be moved further away from the central furrow, or the floor of the bridge might need to set higher (raised elevation) to improve the foundation conditions. Since both of these alternatives imply a greater span, they also mean that the construction will become considerably more expensive. On the other hand, there may be environmental advantages with a greater distance between and foundations and the stream.

The repair of stream crossings
When a crossing over water needs to be repaired, the consequences and costs for changing the inclination of the road and building a new water crossing should always be assessed in comparison with those for the repair of the existing construction. It may be better to move the road if the construction lies on a poor foundation or if the stream's topography is unsuitable for a crossing. If the stream crossing is moved so that it ends up on the best possible foundation, the total cost may be reduced and the environmental burden minimised.

Geotechnical examination and investigation

UInformation is required in order to assess the suitability of the substrata and the appropriate type of construction. This requires knowledge of the area's geology and topography, the material qualities and thickness of the soil layers, and the groundwater conditions.

Knowledge of the qualities of the substrata makes it possible to assess the stability of the soil layers and the probability of subsidence. It also provides a basis for deciding on a suitable design and type of construction for the stream crossing.

Geotechnical examination, pre-examination and investigation should be conducted in the project's early stages. Erroneous decisions in respect of the crossing's positioning can have major economic and environmental consequences. The larger the project, the greater the care and safety required in the geotechnical investigation.

Geotechnical investigation methods and measurements

This guide should only be used for projects where the foundations can be set in relatively solid substrata and for crossings with a limited span. In these cases, only a visual investigation and basic geotechnical testing are required. For constructions in more challenging soil conditions, TRVK Bro (TRV 2011:085) and TK Geo (TRV 2011:047) should be used.

The investigations should aim to assess:

- the total stability of the bridge location
- suitable foundation
- suitable footing
- the extent and design of erosion protection
- the design of approach embankments and slopes.

Plane and elevation

In order to be able to select the correct position for a crossing over water, the status of the soil surface must be determined. This can be achieved by a cross sectioning of the stream (a longitudinal profile of the road along its centre and possibly along the road sides or outside the road sides) or through the production of a terrain model. Terrain models can be produced with the assistance of Lantmäteriet's height model (based on airborne laser scanning of the soil surface) or by using separate measurements. If Lantmäteriet's height model is used, this should be complemented with a measurement of the water surface position and the estimated positions for high-water levels and the water area boundary.

The water channel´s geometry and topography

In addition to the measurement of shorelines and soil surface, the water channel should be sounded and a simple cross section of the stream furrow drawn. This is required in order to estimate the flow and changes in water levels.

Smaller streams or brooks are measures simply with a folding rule and spirit level. One alternative is to level out using levelling instruments, total stations or the equivalent. Broad and deep streams can be echo-sounded.

Water flows and water levels

In order to determine the dimensions of a span and erosion protection, an estimation of stream discharge and water speed is required. How this is calculated is described in detail in the VVMB 310 method description (Vägverket 2008:61).

Runoff from forested land is calculated in accordance with the description found in section 2.3 Naturmark i metodbeskrivningen [nature areas in the method description] (page 17). The size of the catchment area and the size of the lakes in the runoff area need to be determined. The lakes constitute buffers in the event of intensive rain, and ensure that the water rises at a slower rate in the streams. Through calculation, it is possible to estimate the highest rate of discharge at a given recurrence interval, i.e., 50 years. Longer recurrence intervals mean greater security against unusually high rates of discharge.

It is also possible to obtain computed water flows and catchment area characteristics via SMHI's "vattenwebb" [water website]. This is based on extensive measurements and model calculations conducted in hydrological climate models. From a web-based map, characteristics for designated main catchment areas and sub-catchment areas can be downloaded. Depending on the location of the bridge in relation to the catchment areas, you can decide whether to use your own determination of the catchment area and your own calculations, or if you should obtain information regarding the highest rates of discharge from the SMHI's water web page (http://vattenwebb.smhi.se/).

To reduce the risk of migratory barriers, you should ensure that the culvert or bridge is not constructed so that it dams up too much or creates speeds that are too high. A calculation of backwater should therefore be conducted with the help of trial and error calculations of the span. See VVMB 310, section 4.5 regarding backwater calculations, page 42, etc. No backwater calculation is required if the bridge has a span allowing for a shoreline alongside the bridge even with high stream discharge and no construction measures affect the cross section of the stream.

For this calculation, you need to determine how much backwater the area can withstand. A hilly area will withstand somewhat more backwater than a flat area, but you should also take into consideration the water speed and changes in the water speed.

An assessment of water speed should be the starting point for backwater calculations. This can be achieved by repeatedly measuring the speed at which a float is transported in or by the water over a pre-determined, measured stretch of the stream. This gives an idea of the main water speed, but in vortexes the water speed can deviate considerably. A suitable float should lie as low as possible in the water. Apples and oranges are often used as floats. There are also other instruments that can measure flows. To get the correct figures, repeated measurements in various different sections of the stream are required.

The characteristic water level in the sections up and downstream of the intention bridge location also needs to be determined, and a suitable Manning's roughness coefficient for the stream needs to be selected. The Manning's coefficient constitutes a measurement of friction for flowing liquids, and depends on the liquid's properties and the evenness of the flow channel. See VVMB 310 section 4.5.4, p. 44 and the section 4.5.5 pp. 45–46. A selection of Manning's coefficients can be found on page 52 in VVMB 310.

It is also important to take into consideration the width of the stream when selecting the span of the bridge. The width varies with the water level, and a mean high-water mark therefore needs to be identified. It can often be difficult to find the high-water mark. Signs of the mark can be material that has settled above the stratum in question (moss, grass) or remains of vegetation that appear to have been transported in the water, for example brown grass or tree branches that seem out of place in this particular habitat. A clear sign that the mark is often under water is that the tree trunks have rings around their base. Where the rings disappear is an approximate border for the mean high-water level.

Groundwater level

The groundwater level is often assessed based on topography and soil conditions. Vegetation conditions can also be used for assessing groundwater conditions. Note pools of water, springs and water-dependent vegetation at various heights and distances. This can give a relatively good idea of how the groundwater behaves in relation to the soil surface.

Soil types

Soil types are divided up based on their technical properties and the manner in which they are formed. Frictional soil is soil where the shear stress if primarily absorbed by frictional resistance between particles in the soil. Typical frictional soils include sandy and gravelly soils and coarser moraines, for example sandy moraine, gravelly moraine and rocky moraine.

In semi-cohesive soils, stresses are absorbed by both frictional forces and cohesive forces. Typical semi-cohesive soils are silty sediment and silty moraines. Resistance in semi-cohesive soils is greatly affected by the water content, and soil moves in line with the level of water saturation. Permeability is low, and the capillarity very high, which leads to extremely frost-sensitive soils. Semi-cohesive soil is also extremely sensitive to erosion. Sedimentation of silt is extremely negative for many aquatic animals, for example the freshwater pearl mussel. Extra care should therefore be exercised in assessments prior to excavations adjacent to natural watercourses. It is also important to undertake protective measures, such as erosion protection in the form of inverted rock filters or temporary protection in the form of fibre cloths or booms. The risk also reduce if the construction work is carried out at times of the year when the water level can be expected to be low.

The stress caused by semi-cohesive soils can lead to landslides, especially when water levels vary, and the consequences of landslides at valuable watercourses are extremely negative. Extra care should therefore be taken in the construction and dimensioning of crossings over water in areas where semi-cohesive soil is prevalent.

Silty moraines occur in many conditions, whilst silty sediments are very rare above the highest coastline. Silty sediments normally overlay sand and moraine. When setting foundations in semi-cohesive soil, geotechnicians should conduct a geotechnical examination and investigation, especially in the vicinity of streams. Weight or pressure sounding, sampling with helical augers and observation of the groundwater level should be included in the examination.

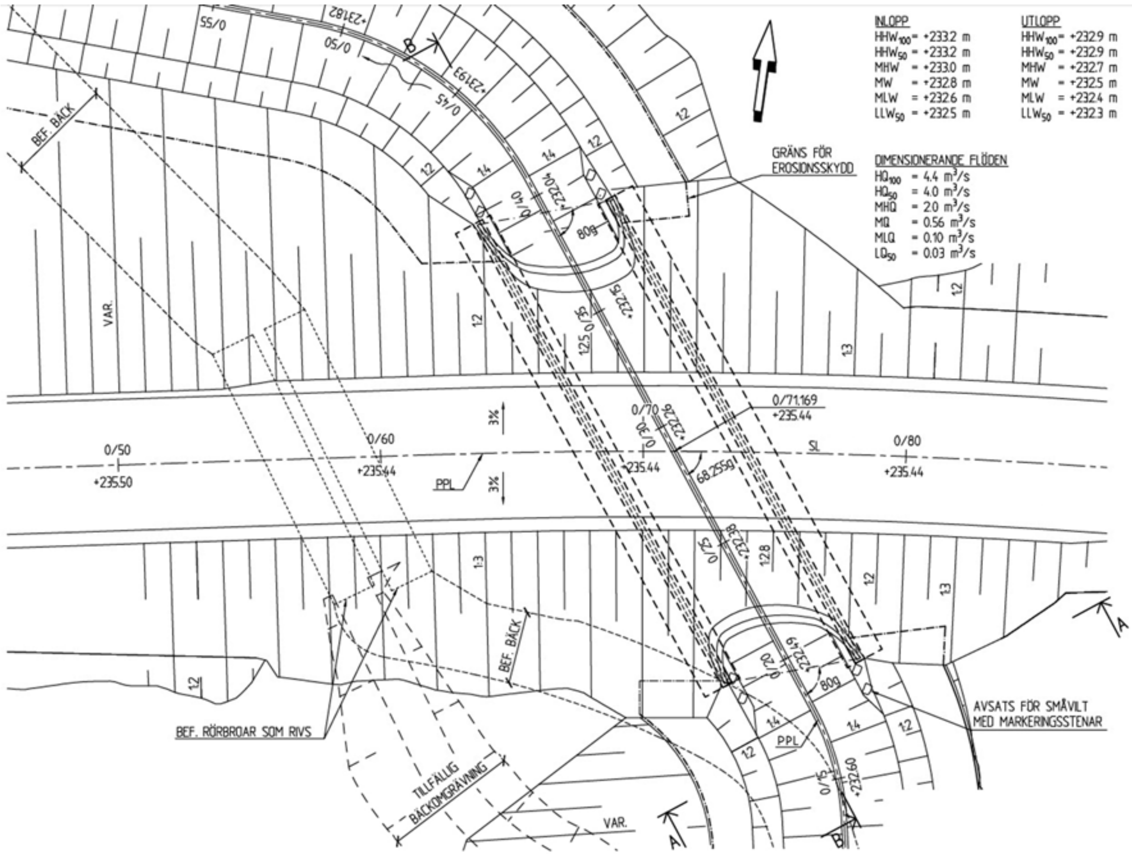
Cohesive soil is dominated by cohesive forces. The cohesive soils are normally clays, boulder clays or clayey moraines. It is difficult to assess the stability in clays and such assessment should therefore always be conducted by geotechnicians, who also decide on the methods of examination.

Construction and building documents

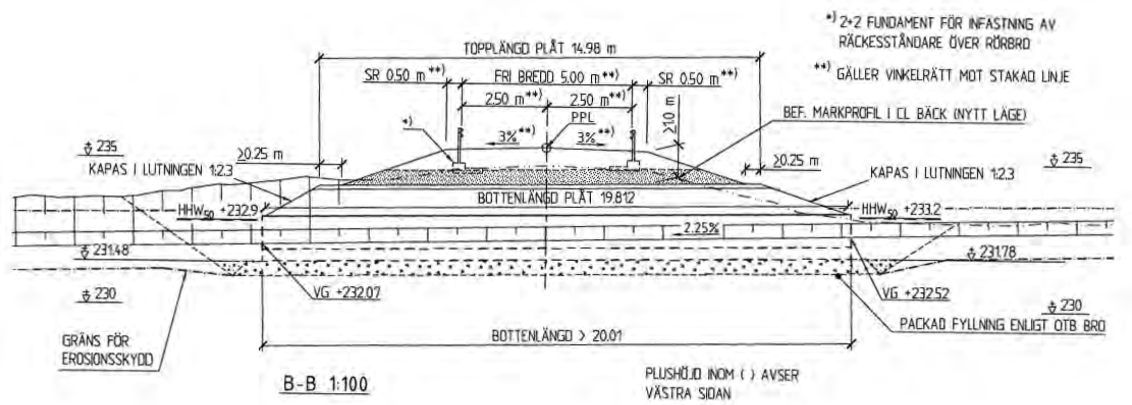
BThe location of the bridge and the construction solutions and dimensions chosen are described in the construction documents. The documents describe both the soil and environmental conditions and the finished construction, in as much detail as is necessary for the work to be safely executed. The documents should consist of the following:

- Map: The map should give an overview of the area and make it easy for contractors to position the stream crossing in relation to quarries and transport roads. The appropriate scale is 1:20 000–1:50 000.
- The plan drawing should be of scale 1:200–1:500: The plan drawing shows the road, the bridge and its fixtures in plane. The drawing should have contour lines with an equidistance of 1-2m and slope markings. This, or another drawing can also include the soil examinations conducted and the various water marks observed.
- Drawing of the longitudinal profile along the centre of the road and bridge in elevation (road and bridge seen from the side "through the road's centre line") with marking of geotechnical observations: If soil layers and groundwater levels are known, then these should be described in the longitudinal profile. The sounding of the stream can also be recorded here (the road's longitudinal profile becomes a cross section of the stream), as can estimated water marks (high-water, the mean level and low-water).
- Drawing of cross sections of approach embankments: For large arches and culverts, the drawing should show cross sections through the centre of the construction.
- Environmental information: This is a description of the protective measures that the construction work requires, such as the distance required between the stream and the site in respect of machinery, fuel tanks, etc.

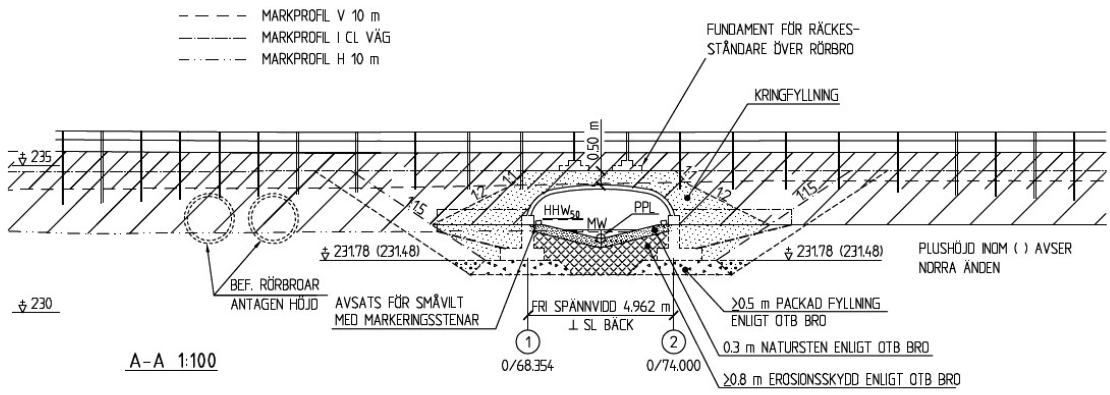
Specific protective measures are to be described in the construction document. If, for example, there are freshwater pearl mussels in the stream, the document shall state how these are to be protected. Photo: Andreas Broman, Ecocinclus.



Plan drawing for an arch, example of Swedish construction plan. Picture: Swedish Transport Administration.



Longitudinal profile for an arch, example of Swedish construction plan. Picture: Swedish Transport Administration.



Cross section for an arch, example of Swedish construction plan. Picture: Swedish Transport Administration.

If necessary, further cross sections of the stream can be described, approximately 20 metres up and downstream from the centre of the road. Measured water surface is used in flow and backwater calculations (see the “Water flows and water levels” section)

Choice of construction type

Different constructions suit different conditions to a varying degree. From an environmental point of view, a bridge superstructure on a footing is often preferable to an arch, and an arch is preferable to a culvert. A ridge superstructure constructed on a foundation and correctly dimensioned leaves the stream relatively unaffected and provides migrating animals with access to both shorelines and an undisturbed stream bed.

However, if bearing capacity in the soil is low, or if the stream runs off in a terrain that lacks a distinct slope down to the water, then culverts should be chosen ahead of other constructions. A culvert has a large contact surface with the substrata and can therefore be constructed with fewer reinforcement measures. On flat, irrigated land, the road must connect to an embankment. A low-built culvert or two parallel culverts in the embankment is a relatively sound solution.

Culverts

Culverts are available in several designs - completely circular or elliptical, for example, low-built culverts.

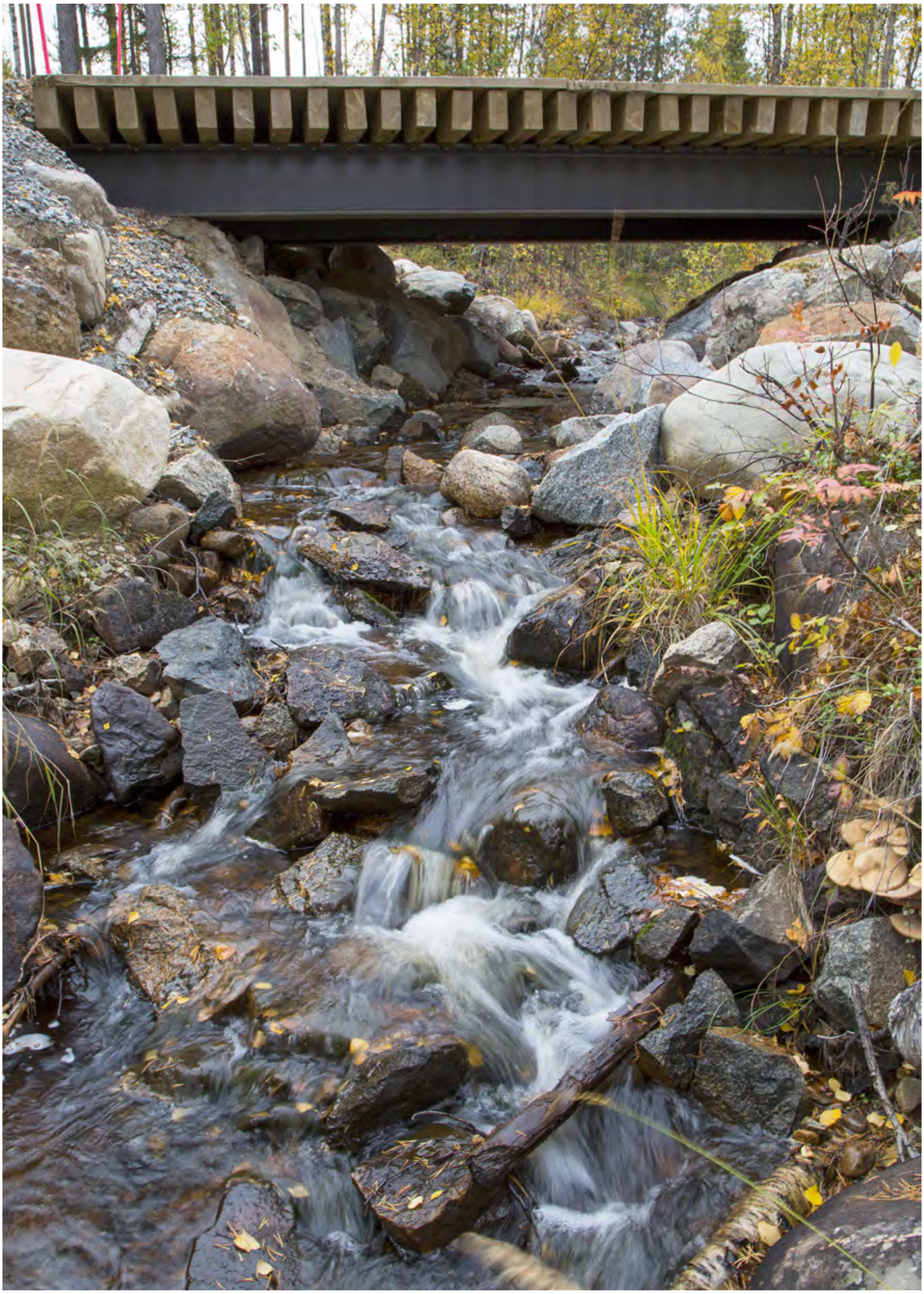
Low-built culverts can be used if, for example, the road embankment is low. Photo: Swedish Transport Administration.

Arches

Arches with sheet metal feet make it possible to create a natural base. Photo: Fredrik Broman, www.humanspectra.com.

Arches with a cement footing make it possible to create a natural base. Photo: Swedish Transport Administration.

Girder bridges



Simple girder bridge with natural shore and recreated stream bed. Photo: Fredrik Broman, www.humanspectra.com.

Transversely prestressed bridge

Wooden bridge with natural shore and recreated stream bed. Photo: Martinsson Träbroar.

Construction

Choice of span

The span is selected based on the flow, the profile and width of the stream and the foundation conditions. The span should be large enough to leave room for a shoreline alongside the bridge footing at normal water levels. This stops the stream crossing from becoming a migratory barrier for aquatic animals. A normal recommendation is that the span should be at least 1.2 times the width of the stream at normal water levels and flows. This span should always be compared with hydrological calculations and adapted to the local hydrological conditions.

Constructing a culvert

Foundation

In order to avoid subsidence and deformation, it is important to consider the nature of the substrata when constructing the foundation.

If the substrata consists of fine-grained soil, for example a silty type of soil, there are normally two methods for foundation:

1. If the depth down to the solid stream bed is small, excavation and filling is conducted down to the stream bed.
2. If the depth is greater, the substrata should be reinforced, i.e., by putting down geotextiles and plank fencing.

Material

A culvert can be made of sheet metal or cement. The type to be chosen depends above all on the nature of the substrata and the properties of the water.

Elliptical sheet metal culverts can be chosen if the substrata is silty, since the elliptical form provides a greater bearing surface compared with a circular construction.

Cement constructions should be chosen primarily of the water has a low pH, under 6.5 (acidic water). For cement to be a suitable material, the hardness of the water also needs to be low, less than 29 mg Ca/litre, the alkalinity should be less than 1 meq/litre, and the conductivity should be less than 100 mS/metre.

Warning

It is common for residual products to be used in constructions. This is normally bad and we strongly advise against this. Furthermore, the use of waste in construction is, in many cases, subject to a permit, according to Chapter 9 of the Environmental Code. Common occurrences are the use of wire cloth from paper machines instead of geotextiles, or that scrapped fuel tanks are used for culverts. This is to be condemned, both from a technical and an environmental point of view, since it leads to uncertainties in the construction’s serviceable life and its bearing capacities, and there is a risk of environmentally hazardous deposits.

Execution

Before building operations commence, a construction document should be drawn up so that damage to the environment is avoided. One of the major problems with construction is the risk of clouding downstream, something that can have serious consequences for aquatic animals. If there is a risk of clouding, the necessary protective measures must be taken; these vary from case to case. It may, for example, be necessary to conduct construction operations when the water flow is low. The gradient of the excavation slope for culverts should lie around 1:2. Filling material should not be susceptible to frost, i.e., the fine-grain content should be less than 15 per cent, and it is always to be continuously packed down. Within 50 cm of the tube, the grain size should be no larger than 65 mm. Outside this distance the grain size may be a maximum of 300 mm. Large boulders near the tube mean that it will get damaged quicker, since the boulders will become pressed against the tube. If the filling material is not packed down correctly, the culvert may be deformed, and this causes both major costs and damage to the environment.

It is important that the amount of material above the culvert is sufficient. The majority of manufacturers recommend 600 mm of material above the top of the tube, but this can vary depending on the dimensions and the construction. Follow the tube manufacturer's recommendations in respect of the thickness of the superstructure from the top of the tube to the road surface. The culvert should be dug down at least 300 mm under the bottom of the stream. In order to make the tube seem more natural, material from the stream bed is put inside the tube. The slope of the tube or the culvert is not to be more than 0.5 per cent. Erosion protection should always be used, in order to protect the road embankment, the bridge and the stream.

Constructing an arch

Foundation

An arch has less bearing surface that a culvert. It is therefore important to have the necessary geotechnical expertise to decide how the foundation is to be executed. If there are doubts over the bearing capacity of the soil type, then a culvert should be selected instead. If it is assessed that the soil type has a good bearing capacity, then a bearing surface is created by shaping the substrata. The bearing surface for the arch should lie above the normal water level and be reinforced with a material that is not sensitive to erosion, such as a 0-80 mm subbase of crushed rock. If more reinforcement is necessary, a coarser subbase can be laid at the bottom, for example 0-200 mm of crushed rock. The hard strip should be well-packed and smoothed out. The bearing capacity of an arch is seriously affected by the quality of the support that the arch has in relation to the substrata. In order to avoid damage to the environment downstream, protective measures should be taken that are adapted to the specific object.

Material

The arch can be made of galvanised steel or cement. The arch footing can be constructed using L beams of galvanised corrugated steel plate or concrete T supports.

Execution

When choosing an arch, minimising the impact on and of the aquatic environment should be the starting point. There should be as little impact as possible to the stream bed. If the construction will impact on the stream bed, it should be restored so that it resembles the stream bed up and downstream. This applies when old culverts are replaced with arches so that the stream can be restored and migratory barriers removed. The stream bed is restored by boulder of various sizes, preferably naturally rounded ones, being placed on the old cylinder bed.

In cases where erosion protection is placed on the stream bed, or where it is used to protect the inside of the bearing surface, the natural stone is to be used for the uppermost layer. Try to create a varied stream bed structure.

Follow the tube manufacturer's recommendations in respect of the thickness of the superstructure from the top of the arch to the road surface. The gradient of the excavation slope for arches should lie around 1:2 in order to avoid uneven frost heaving. Filling material should not be susceptible to frost (less than 15 per cent fine-grain), and within 50 cm of the arch the grain size should be no larger than 65 mm. Outside this distance the grain size may be a maximum of 2/3 of the layer thickness, up to a maximum of 300 mm. It is important that the material is continuously packed down, in order to give the arch sufficient support. Incorrect packing down may result in the arch becoming deformed. This leads to damage to the arch, a shorter serviceable life and, consequently, the risk of increased costs and damage to the environment. Erosion protection should always be used to protect the road embankment, the arch's bearing surfaces and the stream.

Constructing a girder bridge or slab bridge

Base plate and foundation

Bridges absorb all the loads to which they are subjected in their bearing surfaces. The majority of the loads are absorbed by some type of layer, a foundation and a base plate that transfer the load to the substrata.

Within the forestry industry, beam and slab bridges are often constructed with shallow base plates. Both the design and the material in the plates can vary. The support is provided by the substrata and the bridge superstructure is mounted directly onto this, or with a thin transitional construction. A proper geotechnical examination is rarely conducted; instead, a visual assessment of soil type based on experiences from previous work is carried out.

This method works when the substrata conditions are good and when a sufficient span is selected. But it implies major risks if there are uncertainties in the assessment of bearing capacity. If a shallow base plate is to be used, it is extremely important that resources be devoted to a thorough geotechnical examination. Based on this, the area and design that the plate needs to have can be decided, along with its placement in relation to the crest of the embankment.

In many cases, the geotechnical examination can indicate that a shallow plate is unsuitable. In these cases, the plate should be laid at the depth required, which means that supports must be constructed so that the bridge superstructure reaches the correct height.

The bottom plate often consists of an L beam or a concrete plate without end shield. The area of the plate that transfer the bridge loads to the substrata varies. The distance to the crest of the embankment also varies. Plates without end shields mean that the beams lack protection from the soil. This means that the beams are exposed to damp soil, which in turn leads to corrosion damage and a reduced serviceable life. Instead, you should ensure that the L beam has an end shield that protects the beam from the soil. Most often, wing walls are also required to stabilise the embankment.

Material

Especially within forestry and on private roads, the main load carrying structure often consists of steel beams or a transverse tension wooden plate. The base plate normally consists of concrete and the supports are constructed in concrete or wood. Always appoint bridge manufacturers in order to avoid uncertainty in the choice of type and proportionate load.

Using steel beams of an unknown origin and quality that have been used before may entail major risks, both financially, environmentally and in respect of the working environment. With this type of material, the person legally responsible for the bridge, in many cases, cannot guarantee the permitted traffic load.

Execution

Always draw up construction documents before the work commences, in order to reduce the risk of increased costs and environmental damage connected with or following the completion of the construction. The construction documents shall state how the work is to be conducted and the environmental measures to be taken. This applies both to measures to counteract damage to the environment and measures to improve the living conditions for aquatic animals.

Erosion protection and slope inclinations

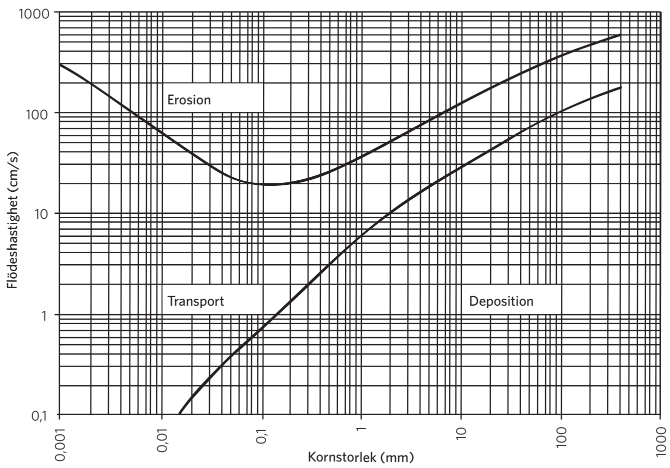
The soil material in a bridge construction can be damaged both by landslides, where the slopes are too steep, and by water eroding material away. Erosion can also lead to the remaining material collapsing or the occurrence of subsidence.

Every type of soil has a specific angle of repose, and the slopes should not be steeper than this (with a certain safety margin). Finer-grained soils requires flatter slopes that coarse-grained soils. The slopes or cones in a bridge construction should not lean more than 1:1.5 if they are coarse-grained and 1:2 if they are more fine-grained. Really fine-grained soils should not be used at all in slopes and cones.

Erosion of soil material occurs when the water speed changes and becomes too great for the shear resistance in the soil. When material erodes, a new state of equilibrium comes about where the material's weight and fraction are balanced with the water speed.

Erosion can be avoided by dimensioning and designing the crossing so that it affects the water speed as little as possible, and by installing erosion protection. Small spans means that the water is forced into a smaller space, which increases its speed. This leads to erosion until the stream widens again to a point where the speed decreases to a level at equilibrium with the soil material. To avoid this, erosion protection is required. Part of what is saved through constructing a crossing with a smaller span is lost due to the requirement for more extensive erosion protection.

Erosion protection of natural stone in the slopes where a bridge has been built. Photo: Swedish Transport Administration.



A "Hjulström diagram" showing the water speeds at which various soil materials erode and settle respectively. Sand erodes the most easily, silt and clay have difficulties settling and are easily transported. With a moderate flow rate of 1 m/s, everything with a particle size finer that 10 mm erodes, i.e., even some types of gravel. In a normal silty sandy moraine, this means that approximately 70 per cent of the soil mass is sensitive to erosion. Picture: Filip Hjulström.

Erosion protection often consists of heavy rock material with a composition that makes it difficult to erode. The size of the largest stone depends on the water speed. The cross section's mean speed is the starting point (flow in volume per time/cross section area). In order to get the variation in flow in the different parts of the cross section, a dimensioning of 1.5 times the mean speed should be employed. The inverted filter, the actual erosion protection, should have at least 50 per cent of its material larger than 0.02 times the dimensioned water speed.

Example: If we estimate the water speed at 2 m/s, then the filter should be d50=2*1.5*0.02 m = 60 mm. d50 is the fraction that constitutes half of the material, i.e., the sieve size suited to half of the material. d100 is the largest stone in the material, and for erosion protection, d100 is reckoned as 1.5*d50; i.e., in the example, the largest stone is 90 mm. The erosion protection should therefore be set at 0/120 mm. The material should be fully stratified but with a certain stone suspension. The thickness of the strata depends on the size of the largest stone, but the strata should be at least 500 mm thick, and always at least twice the size of the largest stone. If there is reason to lay out heavy erosion protection, this should be divided up into several layers, where the outermost is of the coarsest dimensions.

All sections of a construction that comes in contact with water, and which consists of erosion-sensitive soil, may need to be protected from erosion.

Preventative maintenance for different types of constructions

Preventative maintenance refers to measures taken to preserve the function and capital value of the construction.

Culverts

The function of the culvert is as an interface between the thin sheet metal and the filling around the bridge.

The maintenance that a culvert requires is strongly linked to the quality of the construction work. If there are shortcomings, primarily in the foundation and packing down, there may be substantial maintenance costs and damage to the environment, and in the worst case, the whole construction may need to be rebuilt.

Stalps (waterfalls downstream of the tube) and a water depth that is too shallow are caused by the culvert not being dug sufficiently deep. When the water speed is much too high, the material on the stream bed is flushed out. This can in certain cases be remedied without the culvert needing to be replaced, but if it becomes evident that the damage to the environment cannot be remedied through simple measures, than consideration should be given to digging deeper or replacing the bridge.

Shortcomings with the packing down can lead to subsidence and erosion damage. This can also lead to the water seeking a new route on the outside, directly adjacent to the steel or concrete construction. A steel construction may be damaged in such a way that it becomes deformed or, in the worst-case scenario, so that it must be replaced. This type of damage is remedied by exposing the side of the bridge and refilling and packing down according to the manufacturer's recommendations.

Shortcomings in the foundation may cause the same type of damage as shortcomings in packing down. The difference, however, is that the construction must be completely rebuilt. Cement constructions are susceptible to faults in the foundation. Stiffness means that cracks in the construction can easily occur and the tubular element can break up.

A correctly constructed culvert with the right dimensions normally requires only minor maintenance; this involves cleaning away brushwood and removing bits of wood and other items that can lead to damming. But a culvert is more susceptible to the formation of dams and the damage risks associated with this, especially the breaking up of ice. Bridges should be monitored at these times.

Girder bridges and slab bridges

Preventative maintenance is similar for beam bridges and slab bridges, and supervision of them is very important. It is a great advantage if the various types of damage are discovered and remedied at an early stage, since major costs and damage to the environment can then be avoided. The risk of damage is greatest at the spring flood, when the water flow is high and strong. Supervision should therefore be carried out after the spring flood, when the water level is low.

Slopes and cones

Possible damages primarily include the flushing out and subsidence that can arise when erosion protection is insufficient. Unwanted vegetation should also be removed. Flushings and subsidence are remedied by the installation of erosion protection.

Supports and retaining walls

The total load of the bridge is absorbed by the bearing plate and the underlying foundation. The bearing plate can be subjected to subsidence due to faulty foundation work, and to erosion damage. The risk of damage is greatest at the spring flood, when the water flow is high and strong. Remedy erosion damage and subsidence at the first sign of it, before more damage occurs.

Supervision is important since the retaining wall bears the whole of the bridge's load and is also subjected to transverse loads. Through supervision it is possible to discover the formation of cracks and shifts in position at this stage of the bridge construction.

Main load-carrying structures

Beams normally consist of steel or cement and should be kept clean from soil and anything else that can cause damage and make inspection more difficult. In the case of insufficient maintenance, it is often the steel beams that are exposed to damp soil at the bearing surfaces and ends. This makes inspection more difficult.

Steel beam bridges normally have a wooden superstructure with hard-wearing planks. When the wooden superstructure is being replaced, it is important to install a moisture barrier between the steel beam and the superstructure. It is also important for the wooden superstructure to be anchored into the steel beams. Planks with nails sticking out of them or loose planks should be replaced.

Contact a bridge specialist for suggestions of suitable actions if there is damage to supports, retaining walls or beams.

Edge beams, rail holders and crash barriers

Edge beams, rail holders and crash barriers are subjected to mechanical damage and accumulations of soil that are the breeding grounds for rust. This applies above all to the point where the rail holder is attached to the edge beam.

Normal maintenance measures include cleaning the edge beam, rail holder and crash barrier and replacing damaged rail holders and crash barriers.

Slab bridges

The construction of a slab bridge is similar to that of a beam bridge, apart from the fact that the main load carrying structure here consists of a plate made of cement or wood.

Wooden slabs

A wooden slab should not be exposed to damp and should have a moisture barrier, normally in the form of rubber sheeting. An advantage to wooden slabs is that they can withstand minor subsidence without damage to the slab. When inspecting the slab, checks should be made to ensure that there is no damage to the rubber sheeting and that moisture is not permeating through to the underside of the slab. Transverse tension wooden slabs with through bolts should be retightened in accordance with the manufacturer's recommendations.

Concrete slabs

A concrete slab normally has waterproofing and a tread, but it is not uncommon that they lack tread. During inspection, the waterproofing and tread should be checked and any damage repaired. A concrete slab is susceptible to subsidence which can easily cause cracks, meaning that the slab has to be replaced. During inspection, check carefully to see if there are any cracks. Contact a bridge specialist for remedial suggestions if there are cracks.

Maintenance measures contain environmental demands, which stipulate that protective measures must be taken, primarily with regard to blasting, painting and pressure grouting. The aim of this is to protect the aquatic environment. Environmentally hazardous waste is to be handled according to the relevant legislation.

Arches

As with culvert, the quality of the construction work for arches is decisive as far as the maintenance measures required are concerned. It is important for the wildlife that the arches are the correct height but also so that the flow through area is as expected. How comprehensive the maintenance will need to be for the serviceable life and environmental impact of the arch depends entirely on the packing out and foundation work being conducted according to the relevant standards. Since the arch has a smaller bearing surface to absorb the load, it is important that the foundation is constructed in the correct manner.

As with the other bridge constructions, it is important to inspect and maintain the arch regularly. During the inspections, the erosion protection and the material in the arch should be checked in addition to ensuring that subsidence has not occurred. Larger or more sensitive arches should be inspected annually, others every two or three years.

Subsidence

In the event of subsidence, material damage can occur that is difficult to repair. Furthermore, the area can decrease, which could lead to erosion and environmental damage. Subsidence must be registered at an early stage during inspection and remedial measures must be taken before the damage becomes more extensive.

Subsidence that caused material damage. Photo:Per Christoffersson, Swedish Forest Agency.

Packing down

Deficient packing down can lead to the arch becoming deformed and losing its load bearing capacity. During inspections, attention must be paid to changes in the width of the arch and other signs of changes in its shape. If there are signs of damage, these must be remedied without delay, to stop the damage getting worse.

Deficient packing down and foundation work that caused deformities. Photo: Per Christoffersson, Swedish Forest Agency.

Contact a bridge specialist if there are doubts regarding suitable maintenance measures or if damage has affected a crossing's load bearing capacity.

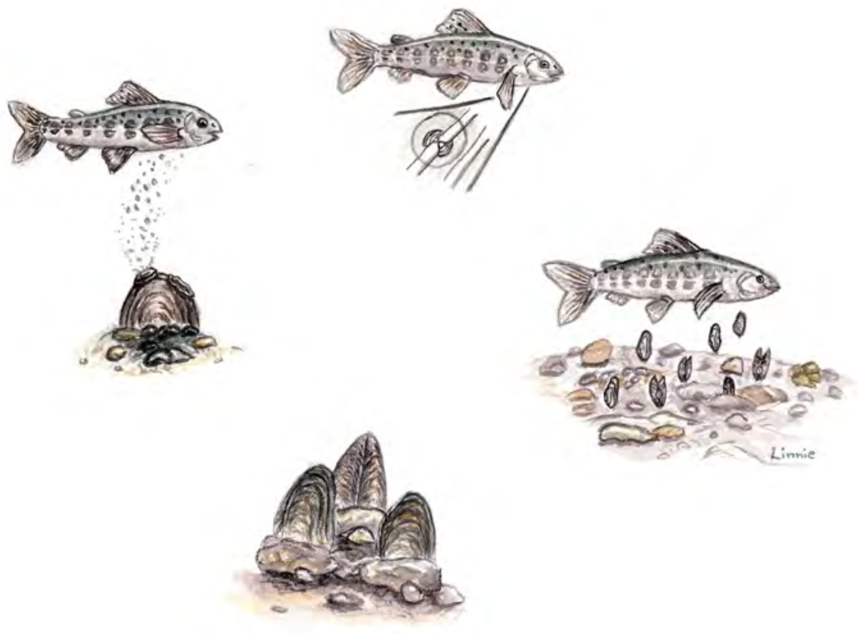
Species affected by stream crossings

Freshwater pearl mussel *(Margaritifera margaritifera)*

The freshwater pearl mussel is a protected species that lives in freshwater in both forested and agriculture landscapes. There are populations in many parts of the northern hemisphere, and the major ones are in Scandinavia. In rare cases, the mussel can cultivate valuable pearls that have fascinated mankind for hundreds of years, which has led to the widespread fishing of mussels in Europe.

The freshwater pearl mussel is dependent on fish in its life cycle. As larvae they look for a brown trout that will function as their host for approximately 7-11 months. The larva attaches itself to the trout's gills and stays there until it is a mussel of approximately 0.5 mm in size. It then leaves the trout and falls to the stream bed. The freshwater pearl mussel is probably an important source of food for other animals in the stream. Only one in 100 million mussel larvae survives, the rest are consumed by other animals. The adult individual grows to 10-16 cm and can live in excess of 200 years.

The freshwater pearl mussel has declined during the 20th century and it has disappeared completely from a third of Sweden's streams. Today, the mussel can be found in 400 streams in Sweden, even if they only reproduce in a third of these. The situation for the freshwater pearl mussel is serious. It is classed as endangered in the Swedish "red list", which means that the majority or all populations are declining. The species has been protected since 1994 in accordance with fishery legislation. It is even highlighted in the EU's species and habitats directive. Despite the decline, Sweden constitutes a key area for the freshwater pearl mussel, which means that we have an international responsibility for the species' long-term survival.

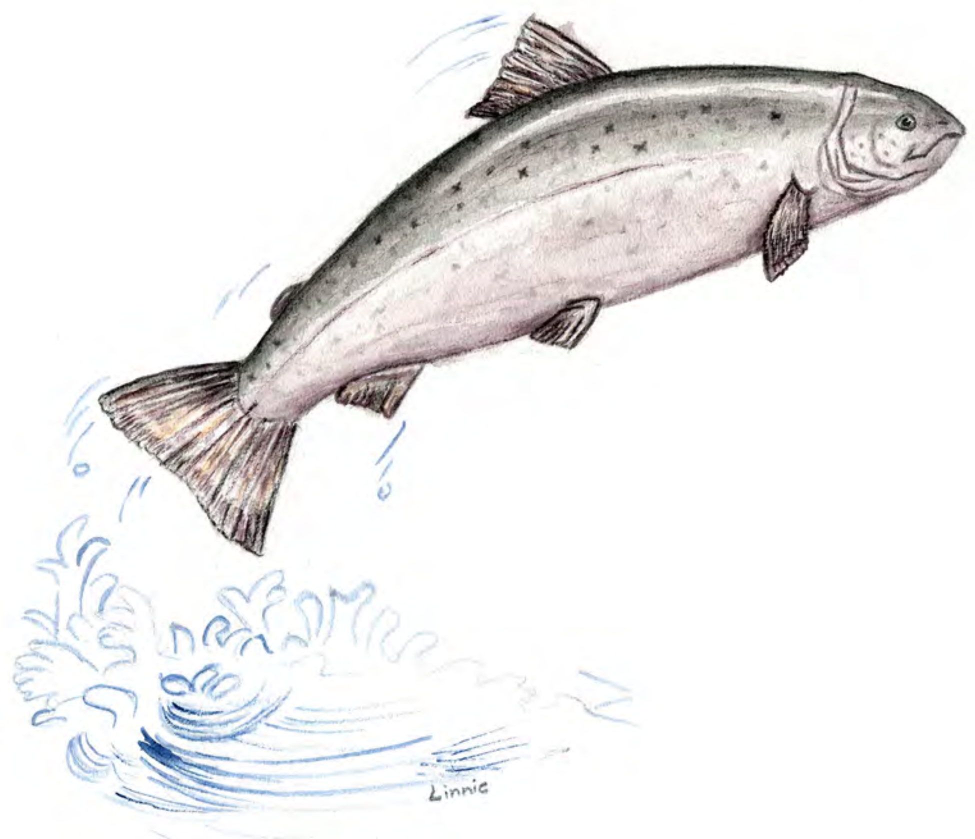


The freshwater pearl mussel lives as a parasite on brown trout for part of its life. The picture illustrates the life cycle of the freshwater pearl mussel. Illustration: Linnie Lodeståll.

Current threat scenario for freshwater pearl

The threat to the freshwater pearl mussel is due to several factors. Activities such as road construction, forestry and ditching affect the mussel, for example, through stream beds becoming silted up and the deterioration of their habitat. Acidification and environmental pollution are major threats that reduce reproduction and lead to a lower number of young fish surviving. Hydroelectric and water regulation companies, along with various types of dams and incorrectly placed culverts hinder the migration of the host fish. This can result in the fragmentation and elimination of the freshwater pearl mussel population. The mussel's reproduction and distribution are dependent on the brown trout, and by removing migration barriers for the trout, we can help the freshwater pearl mussel.

Salmon *(Salmo salar)*



Salmon migrate between spawning–, nursery and feeding areas and require free migration routes. Illustration: Linnie Lodestål.

The salmon is an anadromous fish, just like the brown trout, and they have similar life cycles. They breed in freshwater but live the majority of their adult life at sea. At sea they feed so that later, usually after 1-3 years, they can return to their home waters to reproduce.

The migration upstream usually starts in the summer and varies in length between a couple of days and months on end. This migration is a challenge, with waterfalls, salmon ladders and obstacles of all kinds along the way. Even if the migration demands a great deal of energy and adult salmon stop eating during this period, the salmon can still survive the spawning. After spawning, the survivors migrate back to sea again and may return to spawn again. The young salmon stay in the stream for one to four years, until they are between 12 and 25 cm long. At that point they are large enough, and their behaviour and appearance changes. This prepares the fish for the ocean and they start their migration downstream as silver-coloured smolt. After reaching the sea, the salmon enters its growth period which will continue for 1 to 5 years.

Current threat scenario for salmon
Migratory barriers in streams are a threat to both salmon and brown trout. They hinder migration upstream and lead to the fish being deprived of important spawning grounds and nursery environments. These barriers might be poorly designed road crossings or maybe dams at hydroelectric power stations. Furthermore, the turbines at these stations can harm or kill adult fish or smolt that migrate downstream.

Other threats to salmon are acidification, silting up and emissions of environmental poisons into our streams, which can lead to shrinking habitats, reduced hatching of eggs and lower survival. What is more, the fishing in the Baltic Sea has also had a negative effect on the wild salmon population. There are currently wild salmon in only 12 of 44 streams that run out into the Bay of Bothnia.

Salmon are still thought to be thriving in Sweden though, which is why it is not on the “red list”. But in Europe it is classed as vulnerable.

Otter *(Lutra lutra)*

The otter is a mustelid that can be 50-100 cm in length and weigh 3-11 kg. It is adapted to life in the water, with webbed toes and nostrils that can be closed, and it eats mostly fish. The female normally gives birth to 2-4 young per litter and per year and the young remain with her for around a year. Otters mark their territory with their droppings and like to do this at strategic locations that are visible and protected from the elements, for example under a tree or on a stone under a bridge. The size of the female’s home territory varies between 7 and 10 km in diameter, whilst the male’s can extend over 20 km in diameter. By creating good marking locations and shore crossings at bridges, the otters can be persuaded to pass under the bridge rather than crossing the road.

The otter used to be common in Sweden, both inland and on the coast. But since 1950 the population declined drastically, primarily due to environmental pollutants (PCB). But other factors have also contributed to the otter’s decline, for example the destruction of habitats as a result of the exploitation of streams, as well as ditch drainage, intensive hunting and acidification. The population was as low as just 500 individuals, and in many parts of Sweden it had disappeared completely. In 1968, the otter became a protected species. The situation improved during the 1990s and today there are between 2,000-3,000 individuals, the majority of which can be found in northern Sweden.

Around 50 otters per year are run over by cars as they attempt to cross over roads. Badly placed crossings over streams and poorly constructed bridges contribute to this, since the otters prefer to cross the road rather than going through the culvert or under the bridge. As much as 89 per cent of all otters reported dead during 2000-2005 had been run over. If free

The otter is one of several land-dwelling animals that move along streams. Illustration: Linnie Lodestål.

migration routes are not created, then the local otter population is at great risk, as is their ability to spread out within and between areas.

Despite the fact that the population is increasing, there are still many threats, and the otter is therefore classed as vulnerable on the Swedish “red list”. It is also protected in accordance with the Protection Ordinance.

Current threat scenario for otters

Environmental poisons and traffic probably continue to represent the greatest threat to the species. Environmental poisons such as PBDE and PFOS have been shown to be stored in our ecosystems and in many animal species, including the otter’s prey. The percentage of otters killed in traffic has increased noticeably since the start of the 1980s and traffic can constitute a major regional threat to the otter. In several areas, work on otter-adapted fauna crossings has already started. By installing crossing in areas where otters are found, and where the intensity and speed of traffic is high, the number of otters killed in traffic can be reduced. Even if the hunting of otters is no longer permitted, it sometimes happens that otters are shot by mistake, or caught in traps intended to other wildlife, for example beaver and mink. A significant proportion of otters have also been killed by various types of fishing equipment.

European bullhead *(Cottus gobio)*

The bullhead is a fish with a powerful head and a large mouth, a tapering body that is green-brown or grey-brown with darker patches and a white belly. The bullhead can be up to 18 cm long.

It is a bottom-dweller that likes shallow water and firm stream beds. In winter it likes to move into deeper water. The bullhead can be found in many different types of freshwater habitats with rinsed beds, from shallow habitats with brackish water to small brooks. The species is most common in stretches of flowing water that have stony or gravelly bottoms, but they can also be found in stretches with bottoms that are boulder-rich or pure sand. It lives primarily on bottom-dwelling creatures such as insects and crustaceans. The bullhead spawns in the spring and the female lays up to 150 eggs in a pile on the stream bed. After that, the male guards the eggs, which hatch after 3-4 weeks.

The bullhead needs different habitats at different stages of its life. Coarse substrate with large stones seems to be essential for rejuvenation, even if other locations also seem to work. Shallow, stony streams are used by young fish, whilst larger fish prefer dead wood, tree roots, fallen leaves, larger vegetation or stones. It is important for the bullhead to be able to move between these areas, and it is sensitive to migratory barriers. It is impossible for the bullhead to manage vertical inclines of 18-20 cm. Populations upstream are sensitive to such structures and they therefore risk becoming fragmented, isolated and, ultimately, dying out. If another type of vertical obstacle is created without constructing free passages, then these can be a threat to the bullhead. The bullhead is also sensitive to chemical changes to the water. But it is not an endangered species in Sweden; it is quite common in streams in Norrland.

Current threat scenario for European bullheads

In addition to migratory barriers, the bullhead can also be threatened by water regulation and the cleaning of streams that leads to unstable bottom condition, increased sediment transport and reduced variation in its habitat. Tree-felling, the removal of trees providing shade and intensive agriculture can also reduce the bullhead's living space, since these factors can lead to the stream becoming overgrown. Emissions of environmental pollutants and acidification that can change the water quality are also a threat to the bullhead and may reduce its living space.

Bullheads are extremely sensitive to barriers and vertical obstacles of around 20 cm stop the fish in their tracks. Illustration: Linnie Lodestål.

The Azure Hawker (Aeshna caerulea). Many insects are negatively affected by migratory barriers. Photo: Sofia Perä.

Insects

There are several species of aquatic insects that live in flowing water, primarily from the three insect groups: mayflies (Ephemeroptera) and two families of flies (Diptera), non-biting midges (Chironomidae) and black flies (Simulidae). Amongst the mayflies we find stone flies that primarily live in oxygen-rich, flowing water and find it hard to propagate since they are poor fliers. Species from all of these groups of insects are important food for others animals. Among these species, some feed on algae, some on vegetation, and others are predatory animals and decomposers. Many species stay attached to the stream bed or in a tubular house that they build from sand and secretion, and they search for food by filtering water.

Black fly larvae filter water through a set of reticulated antennae. Like the majority of filtrating animals, these species are considered to be susceptible to clouding, i.e., suspended fine-grained mineral such as sand and silt. It is unclear whether the clouding itself is the major problem, or the fact that minerals settle in the insects' habitat. Experiments show that the proportion of insects that become detached from the location where they search for food increases with a greater amount of suspended material.

Remibar – Free migration routes for aquatic animals

Remibar is a project that aims to reduce the number of migration-hindering culverts and dams in five major water systems in the counties of Norrbotten and Västerbotten. The goal is the creation of free migration routes in the water systems for the benefit of aquatic animals.

The project began in September 2011 and will be running for five years. It represents the largest freshwater project initiative in Sweden and also one of the largest LIFE projects within the EU. The work is being conducted within the network of Natura 2000, and the goal is to improve the conditions for the target species - salmon, freshwater pearl mussel, bullhead and otter, along with their habitats. A total of 300 migratory barriers will be addressed. The project has a budget of approximately 8 million Euros. The EU Commission is supporting the project with more than 4 million Euros.

The water systems that are targeted by the project are:

- Ängesån (part of the Torne and Kalix river system)
- Råneälven
- Varjisån (part of the Pite river)
- Lögdeälven
- Sävarån

Within the project, various information and education initiatives are being implemented in order to avoid the creation of migration barriers in the future. This involves training and seminars aimed at contractors, road managers, landowners and public authorities.

The project will also create demonstration sites in both Norrbotten and Västerbotten in order to demonstrate how to build functional stream crossings.

Facts
The project is financed by the EU Commission through the Life+ programme, which is an EU environmental fund. The EU Commission has approved grants for 183 projects within the framework for the Life+ programme.

The projects within Life+ Nature and Biodiversity help to improve the conservation status of endangered species and habitats.

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REMIBAR

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SVEASKOG

SKOGSSTYRELSEN

Havs
och Vatten
myndigheten

Länsstyrelsen
Norrbotten

Länsstyrelsen
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