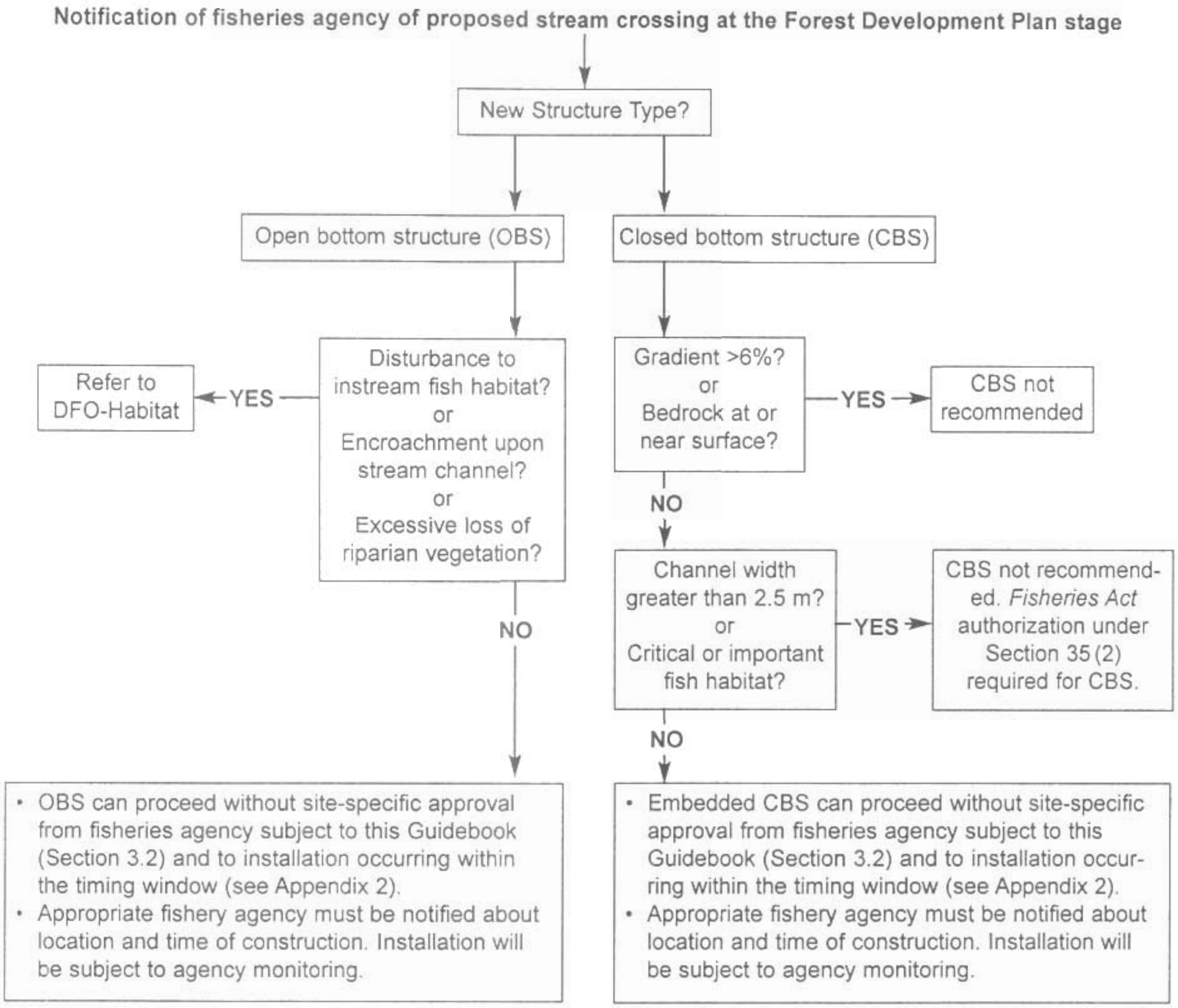


Figure 3. Review process for new installations.

2.2 Replacement Installations

Replacement structures are defined as those that occupy the same riparian management area and crossing location in plan view as the original structure.

- All replacement structures should be treated as new installations (see Section 2.1), except where a closed bottom structure is being replaced with an open bottom structure.
- Replacement structures can proceed without site-specific approval. The appropriate fisheries agency should be notified of the location and timing of the construction.

2.3 Provincial Review

The provincial review is focused on achieving the following objectives at the crossing site:

- protecting of fish and fish habitat by:
  - preventing impacts on fish eggs and alevin that are present in the gravel, or on adult and juvenile fish that are migrating or rearing, and
  - reducing the risk of releasing sediment or other deleterious substances during work at stream crossings; and
- providing for fish passage.

2.3.1 Timing windows

Timing windows (see Appendix 2) are periods of time when work in and about a stream can be conducted with reduced risk to fish and fish habitat. They are also referred to as "windows of least risk" and define the period of time when equipment may be permitted to work in a stream.

Timing windows are specific to fish species and the geographic area within which the work is conducted. This period of least risk is determined by such factors as the time when there are no known fish eggs or alevin (pre-emergent fry) present in the stream substrate, and when streamflow is low and soil conditions are dry.

- During the planning of instream work, consideration should be given to all of the fish species present in a stream. Depending on the mix of species present, there can be overlapping constraints on the timing of operations. The following conditions, if met, result in a year-long timing window (i.e., January 1–December 31):
  - The structure does not encroach into the stream channel width, no work is proposed within the stream channel of a fish stream or fisheries-sensitive zone, and the risk of sediment delivery is low.
  - The work is on a non-fish stream and the appropriate measures should be taken to prevent the delivery of sediments into fish habitat.
  - During construction, modification, or deactivation activities, the stream channel at the crossing is completely dry.
  - Construction, modification, or deactivation activities on a non-fish stream that is a direct tributary to a fish stream are carried out by isolating the work area and keeping dry conditions by temporarily pumping, or otherwise diverting, the flow around the work site while instream activities occur.

- During a timing window, juvenile or adult fish may still be present on site. This is generally the case for resident fish species and for those fish that reside in streams for a period of time before migrating to other areas. For this reason, construction should stop any time it is anticipated that unfavourable soil moisture or rainfall conditions exceed an operation capability for sediment control. Work should not resume until conditions permit. Indicators that sediment control capacity has been exceeded include dirty ditch water, mud holes, and unstable road cuts near the stream.

- If a timing extension is required, the appropriate fisheries agency should be notified and approval obtained if required.

2.4 Federal Review

The *Decision Framework for the Determination and Authorization of HADD of Fish Habitat* (1998) describes DFO-Habitat's approach to reviewing requests for subsection 35(2) *Fisheries Act* authorizations. Such authorizations are not required where there is no harm to habitat. A stream crossing avoids damage to fish habitat if it spans the stream without:

- disturbing the instream fish habitat,
- encroaching on the stream channel width, or
- causing excessive loss of riparian vegetation

- Figure 2 provides an initial screening step in determining the need for project referral to DFO-Habitat. In general, a DFO-Habitat review centres on the value and sensitivity of the fish habitat. All fish habitats contribute to the success and productivity of fish generally, albeit often indirectly through food production and other factors. Therefore, any reduction in the quantity and quality of fish habitat may reduce fish productivity to some degree. Some habitat types make a greater contribution to fish productivity than others. Critical habitats are those where incremental reductions in their supply may result in the largest incremental reductions in fish productivity. Cumulative changes in ecosystems may result in a non-critical habitat becoming critical, and in this way shifts the focus in the selective protection of critical habitats.

- As illustrated in Figure 4, when a referral to DFO-Habitat is required (boxes A to E and G to H, Figure 2), a qualified professional or technologist with adequate training or knowledge of fish habitat should prepare a proponent application plan. Then, DFO-Habitat should review the value and sensitivity of the habitat involved and the mitigation or compensation proposed to determine whether an authorization under Section 35(2) of the *Fisheries Act* may be issued. A decision by DFO-Habitat to authorize the harmful alteration, disruption, or destruction (HADD) of fish habitat triggers an environmental review under the *Canadian Environmental Assessment Act* (CEAA). In critical habitat (see Figure 2, boxes A to D and G), the HADD of fish habitat is generally unacceptable and it is unlikely that approval from DFO-Habitat will be given in these situations. Therefore, an open bottom structure that does not affect fish habitat is strongly recommended. However, should a proponent wish to proceed with the installation of a closed bottom structure in critical habitat, the application should be accompanied by a proponent application plan for stream crossings, for review by DFO-Habitat (see Section 2.5 below).

- Installation of stream crossings that result in a HADD can proceed only under a Section 35(2) authorization. Proceeding to a Section 35(2) authorization should be considered only after all relocation and redesign options have been investigated and rejected with appropriate justification. If relocation or redesign is not practical, the complete project should be assessed, including proposed compensation measures, to ensure all concerns relating to HADD of fish habitat have been addressed prior to authorization. Conditions regarding habitat compensation measures should be formalized in the terms and conditions of the authorization.

- Installation of an embedded closed bottom structure is normally acceptable where stream gradients are 6% or less, stream channel width is 2.5 m or less, and there is adequate streambed depth to permit excavation. Such installations may proceed with no site-specific approval or authorization in marginal habitat (see Figure 2, boxes F and I), provided requirements to mitigate any damage to fish habitat are met (as outlined in Section 4 of this guidebook). In important habitat, these installations will require a *Fisheries Act* authorization under Section 35(2). However, expedited reviews are anticipated for those closed bottom structures that meet the criteria above and are not excessively long.

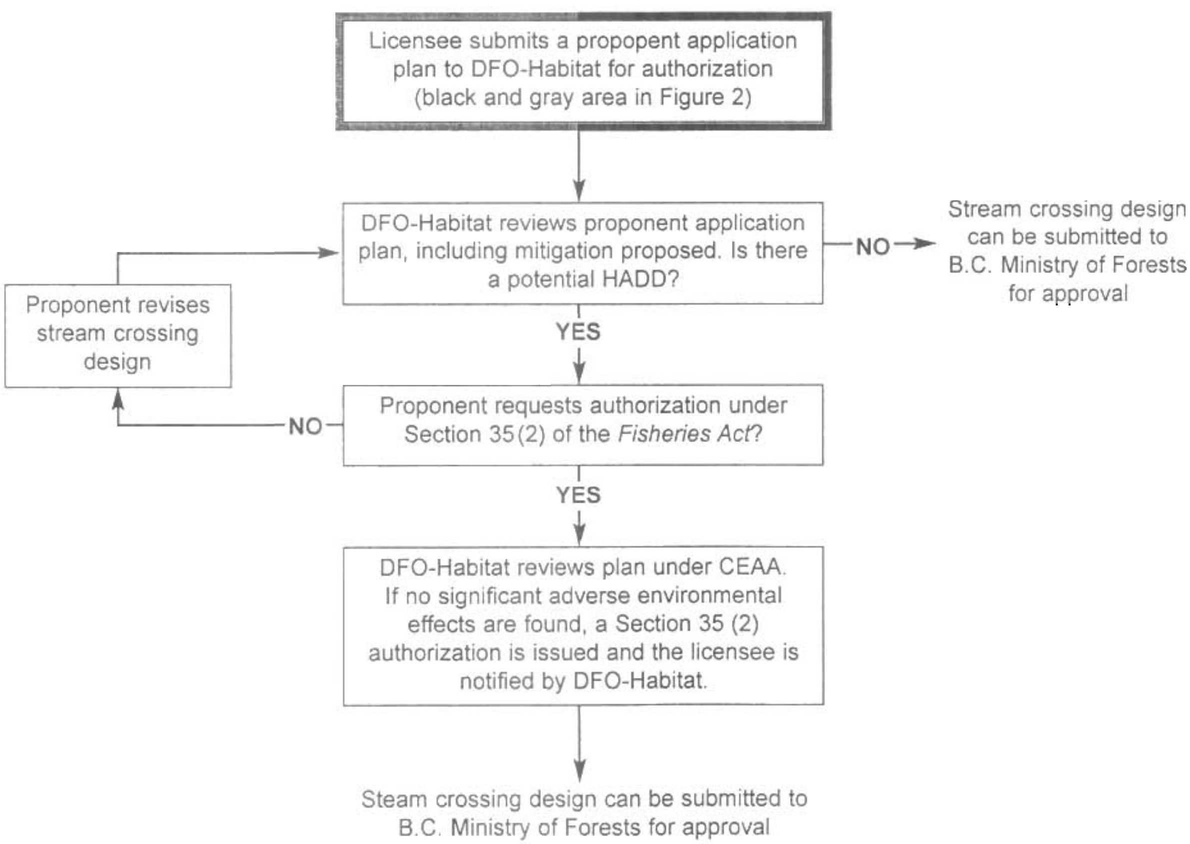


Figure 4. The federal review process for new and replacement fish-stream crossings.

- The proponent should conduct an evaluation of the fish habitat at the crossing site to determine whether the habitat is critical, important, or marginal (see Figure 1). This habitat evaluation should be conducted by a qualified professional or technologist with adequate training and knowledge of fish habitat. Consideration should be given to flow, current, cover, depth, substrate, and general habitat type (pool, riffle, and glide) to justify classification of marginal habitat. It is important to keep in mind that the indicators that differentiate the three habitat types provided in Figure 1 are generalized. Fisheries agency consultation is required where regionally specific guidance is needed for habitat evaluation and classification at the crossing site.

Before the installation of any fish-stream crossing structure goes ahead, DFO-Habitat should be notified. The installations should be identified on a map of an appropriate scale so that they can be monitored to ensure that the habitat at the site has been properly classified, and to ensure that they are consistent with the objectives outlined in this guidebook.

- Practitioners should be adequately trained in the design and installation of an embedded closed bottom structure (as outlined in Section 3.2) and in the recommended techniques for mitigating impacts to fish habitat during construction of an embedded culvert. The goal is to retain the natural stream substrate characteristics within the culvert. Migrating fish should suffer no changes or stress and no delay in upstream migration. Substrate should also move through the culvert naturally.

2.5 Proponent Application Plan for Stream Crossing Projects

- For proposals that require review by DFO-Habitat, a proponent application plan should be completed and submitted along with the stream crossing plan.

- This plan encompasses five major components that outline the proposed works, describe possible impacts on fisheries resources or water quality, and set out steps that should be undertaken to minimize or avoid any possible impacts. The plan should detail:

1. Fisheries Resource Values
Provide a detailed description of the existing fisheries resource values of the area that could be affected by the proposed works, including hydrologic features, water quality, species of fish that frequent the waterbody, fish habitat present (e.g., spawning, rearing, over-wintering, or migration), and riparian vegetation. The sensitivity of the habitat to disturbance should also be described (e.g., soil type, bank stability, substrate type, and gradient).

2. Description of Proposed Activities
Provide a detailed description of the proposed works, along with general arrangement drawings that indicate how the works are to be carried out, including all machinery and materials to be used, road maintenance requirements, and deactivation plans. A project time schedule is also required, which should include activities and applicable timing windows that may apply. In addition, methods to maintain fish passage for the lifespan of the structure should be clearly stated.

3. Impacts to the Fisheries Resources
Discuss anticipated impacts to fisheries and habitat values, including the identification of the nature, duration, magnitude, and location of potential impacts, and the effects on fish and fish habitat in downstream areas. All anticipated changes to fish habitat as a result of construction, maintenance, and deactivation should be stated. Justification for any changes in the natural stream boundary, such as relocation of the channel or constriction of the stream channel width due to fill or rip rap, should be provided, as well as for any predicted changes to downstream flows, bars, and streambanks.

4. Mitigation Proposed
Provide a description of all measures (actions and contingencies) that should be taken to avoid, reduce, or eliminate any impacts outlined in point 3 above. It should include a discussion of any proposed habitat compensation works undertaken to achieve "no net loss" of fish habitat as required. A subsequent *Fisheries Act* authorization may require approved habitat compensation works to be carried out.

5. Environmental Monitoring
Environmental monitoring may be required where construction occurs in critical or important habitats or where construction is authorized outside of the timing window. The purpose of this is to identify actions to be taken to ensure that all proposed activities as outlined are completed and meet the requirements of the fisheries agency granting approval for the works.

Environmental monitors may be qualified professionals or technologists who have adequate training or knowledge of fish habitat and a comprehensive working knowledge and understanding of the principles and requirements outlined in this guidebook. The impacts of construction activities can be continually monitored or periodically inspected, depending on the sensitivity of the site to disturbance and the nature of construction. The environmental monitor should be given authority by the proponent to stop operations in the case of non-compliance with approved conditions, or where it is anticipated that unforeseen circumstances are likely to cause environmental problems.

- See Appendix 3 for an example of a proponent application plan.

3 Design and Installation of Fish-stream Crossings

This section discusses the design considerations and installation practices recommended for various types of stream crossing structures. Refer to the Forest Practices Code *Forest Road Engineering Guidebook* and the *Forest Service Bridge Design and Construction Manual* for details on the location and design of forest roads and stream crossings.

- Fish-stream crossing structures should retain the pre-installation stream conditions to the extent possible. The objective is to ensure that the crossing does not restrict the cross-sectional area or change the stream gradient, and that the streambed characteristics are retained or replicated.

- The choice and design of fish-stream crossing structures are determined by a number of factors, including sensitivity of fish habitats, engineering requirements, cost and availability of materials, and cost of inspection, maintenance, and deactivation. Not all options are appropriate on all sites. The types of structures recommended in this guidebook for use on forest roads include:
  - open bottom structures (e.g., bridges, open bottom culverts [log culverts, arch culverts])
  - closed bottom structures (e.g., corrugated metal pipes)
  - other structures (e.g., ice bridges and snowfill)

- This list does not preclude the use of other structures, or a combination of structures, provided they meet the requirements of provincial and federal legislation. However, baffled culverts are not recommended for new installations. The hydraulic design requires specialized hydraulic modeling skills that go beyond the scope of this guidebook. In addition, locating roads and crossing structures in alluvial fans, where streams are in active floodplains, or where streams are meandering or braided may require special design considerations not included in this guidebook. Where such installations are considered, a professional engineer and fisheries biologist should should be consulted.

3.1 Open Bottom Structures

3.1.1 Design of open bottom structures

For forest roads in British Columbia, open bottom structures for fish-stream crossings include bridges and culverts.

3.1.1.1 Bridges

When designed and constructed with abutments that do not constrict the stream channel, bridges have the least impact on fish passage and fish habitat.

- Bridges can be designed for permanent, temporary, or seasonal installation. They range from log stringer bridges with gravel or timber decks, to steel girder bridges with timber or pre-cast concrete decks (see Figure 5). Bridges can be supported by various means, including log cribs, steel pipes, steel bin walls, cast-in-place concrete, and pre-cast lock block walls, timber, and piers. Where practicable, instream piers should be avoided. Piers can collect debris during flood events, resulting in scouring of bridge foundations. Instream piers can also result in hydrologic changes such as bedload scour or deposition, which may adversely affect fish habitat.

It can be expected that fisheries agencies may approve only bridges with support piers after all other options (clear span) are considered.

Steel girder bridge

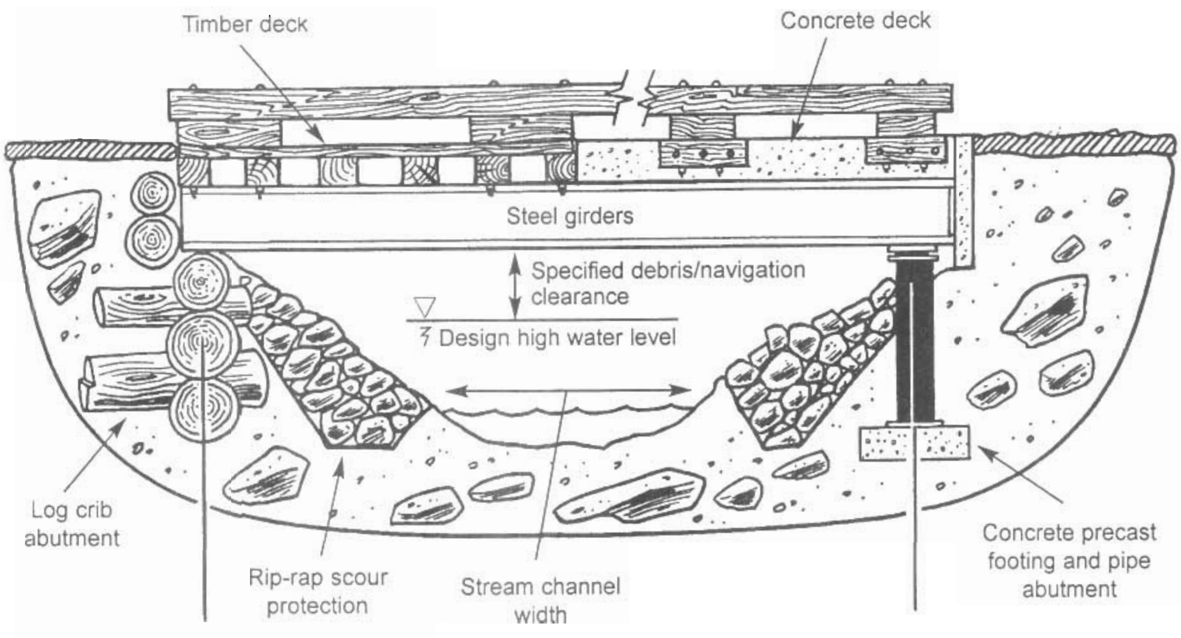
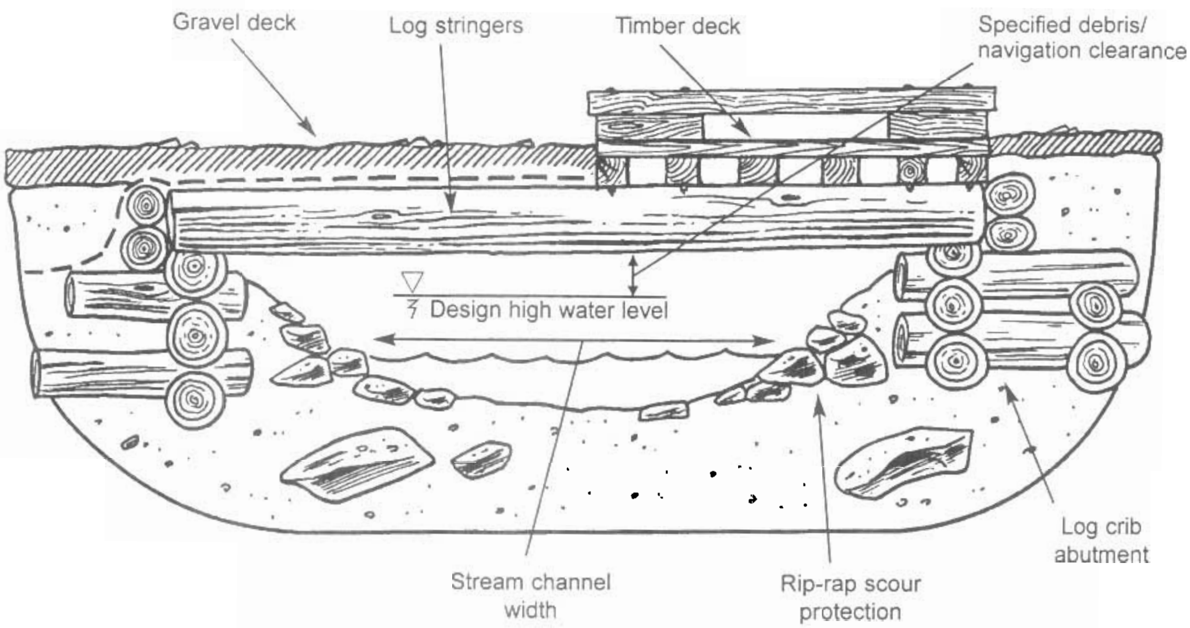


Figure 5. Common types of bridges.

Log stringer bridge



Concrete slab bridge

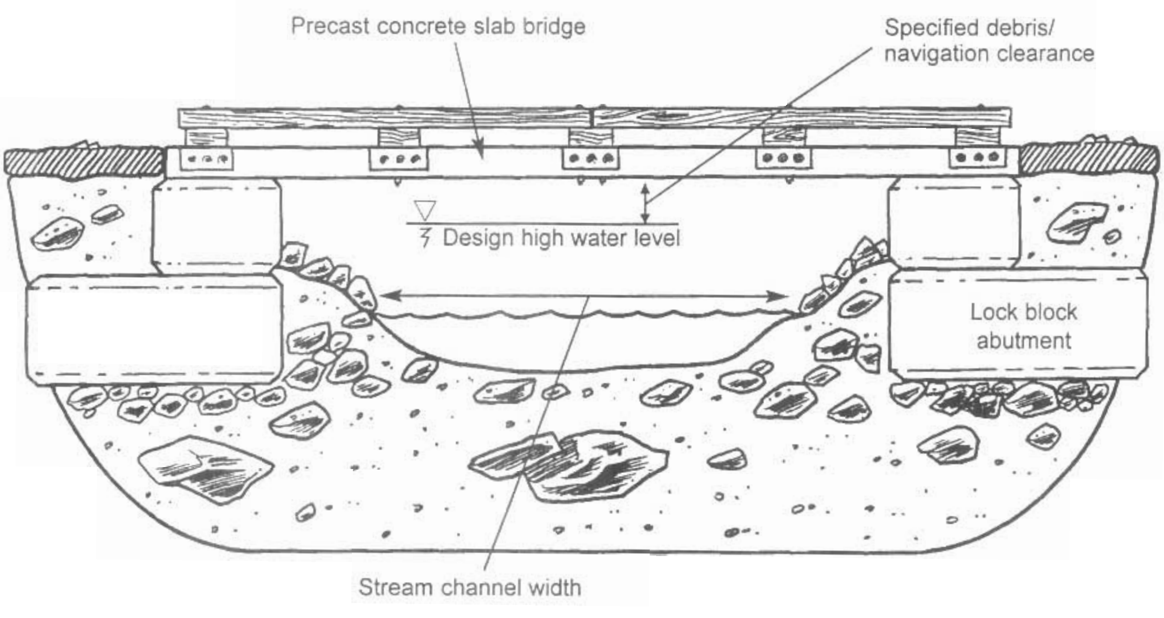


Figure 5. Common types of bridges (continued).

- Decisions to use a bridge rather than a culvert can be driven by economics, engineering requirements, site parameters, environmental or hydraulic concerns, or bedload and debris transport factors. References related to each of these activities are contained in "References and Recommended Additional Reading."

3.1.1.2 Open bottom culverts

Open bottom culverts are similar to bridge structures, generally spanning the entire streambed and minimizing impacts to the natural stream channel (see Figure 6). They are differentiated from bridges in that the fill placed over these structures is an integral structural element.

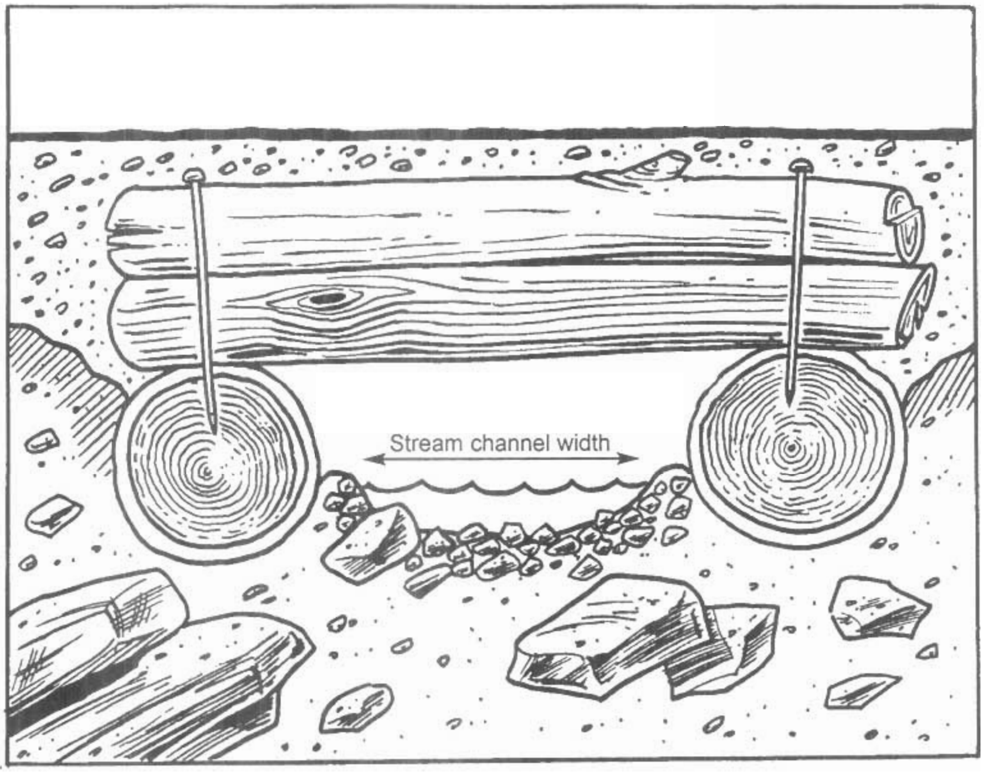
- The most common type of open bottom structure is the log culvert. It is widely used in areas where the availability of suitable logs makes it an economical alternative to steel or concrete. Log culverts are readily adapted to meet flood requirements and generally do not pose a risk to fish passage when sill logs are placed to maintain the stream channel width. The bottomless culvert should be designed to span the stream channel width and so avoid impacts on fish habitat and fish passage.

  Depending on the stream profile, large sill logs or log cribbing may be required with log culverts to achieve adequate flow capacity. Alternatively, small sill logs can be used, but the span should be increased to get sill logs well above and outside the scour zone of the stream.

- Other types of open bottom culverts include arches constructed of steel, plastic, and other materials. Arches come in various shapes, ranging from low to high profiles and are typically installed on concrete or steel foundations.

- It is important to differentiate small, arch-type open bottom structures requiring excavation and reconstruction of the streambed from larger arches that are constructed without disturbance to the streambed. The small bottomless arches should be installed with the same considerations afforded closed bottom structures (see Section 3.2). Careful engineering is required to ensure that the footings of these small arches are secure and not subject to undercutting.

Log culvert



Low-profile arch

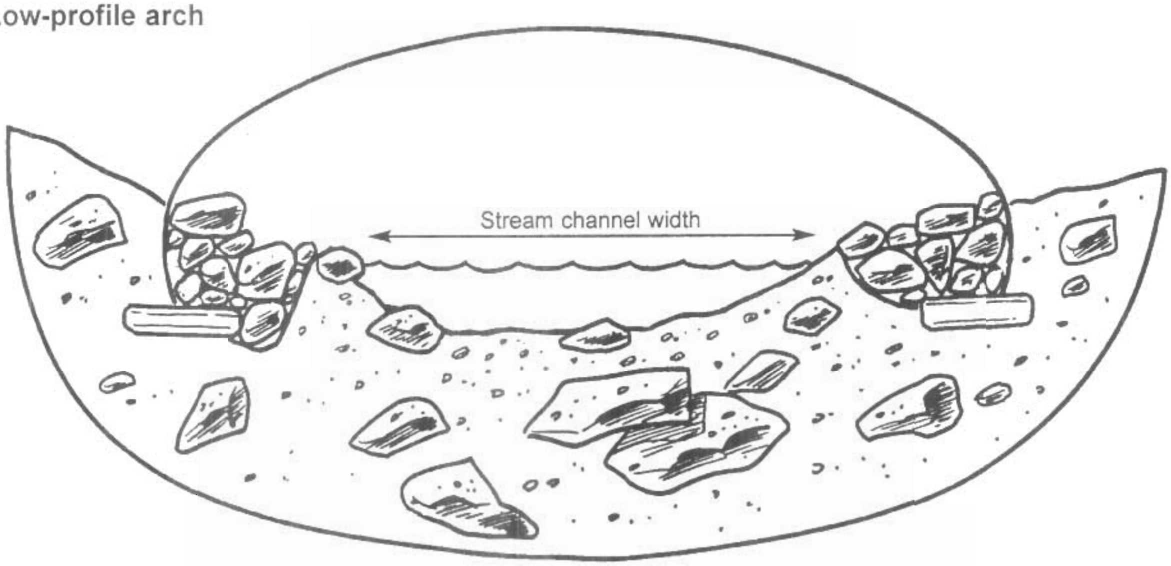


Figure 6. Types of open bottom culverts.

3.1.2 Installation of open bottom structures

- The steps below outline the general installation procedure for open bottom structures as they apply to fish streams. Refer to the *Forest Road Engineering Guidebook* and the *Forest Service Bridge Design and Construction Manual* for more details on construction practices.

Footings:
Ensure that excavation and backfilling for footings does not encroach on the stream channel width.

Vibrations during construction:
Practices such as pile driving and blasting that result in vibrations potentially harmful to fish or fish eggs should be carried out during the instream timing windows. Fish salvage may be required to remove the fish from harm. See Wright and Hopky (1998).

Sediment control at work site:
Where feasible, operate all equipment from above the top of the streambank, isolate the work area from water sources, contain sediments within the work site, and pump out sediment-laden water to a settling site during construction and installation.

Drainage:
Do not allow road ditches to drain directly into the stream (see Figure 13). Divert ditch water into a constructed sump or, where possible, onto stable forested vegetation that can filter sediments before reaching the stream. Ensure that adequate cross drainage is in place before the bridge approach, to minimize water volume directed into approach ditches at bridge sites. Consider crowning the surface, using rolling grades, or employing other practices to divert runoff from the road surface. Where cross-ditches are used, ensure that they are properly armoured at the outlet and along the base.

Constricting the stream:
Do not allow activities, including the placement of rip rap, to cause any constriction of the stream channel width (see Figure 6).

Deleterious materials:
Use precautionary measures to prevent deleterious substances such as new concrete, grout, paint, ditch sediment, fuel, and preservatives from entering streams. If wood preservatives that are toxic to fish are used, they should be used in accordance with the publication entitled *Guidelines to Protect Fish and Fish and Fish Habitat from Treated Wood used in Aquatic Environments in the Pacific Region.*

Seepage barriers:
Consider using geotextiles to prevent loss of fines and gravel through seep-

age along the arch wall. The fabric, or other cut-off measures such as sandbagging or use of prefabricated seepage barriers along the arch wall near the inlet, is intended to prevent most of the seepage and mitigate potential support fill erosion that can occur along the arch.

Geotextiles:
For gravel-decked bridges or log culverts, use a geotextile filter fabric to fully cover the stringers or some other measure to prevent road material from entering the stream.

Turnouts:
Construct turnouts a sufficient distance from the bridge to prevent road material from entering the stream and to minimize impacts on riparian vegetation.

3.2 Closed Bottom Structures

3.2.1 Design of closed bottom structures

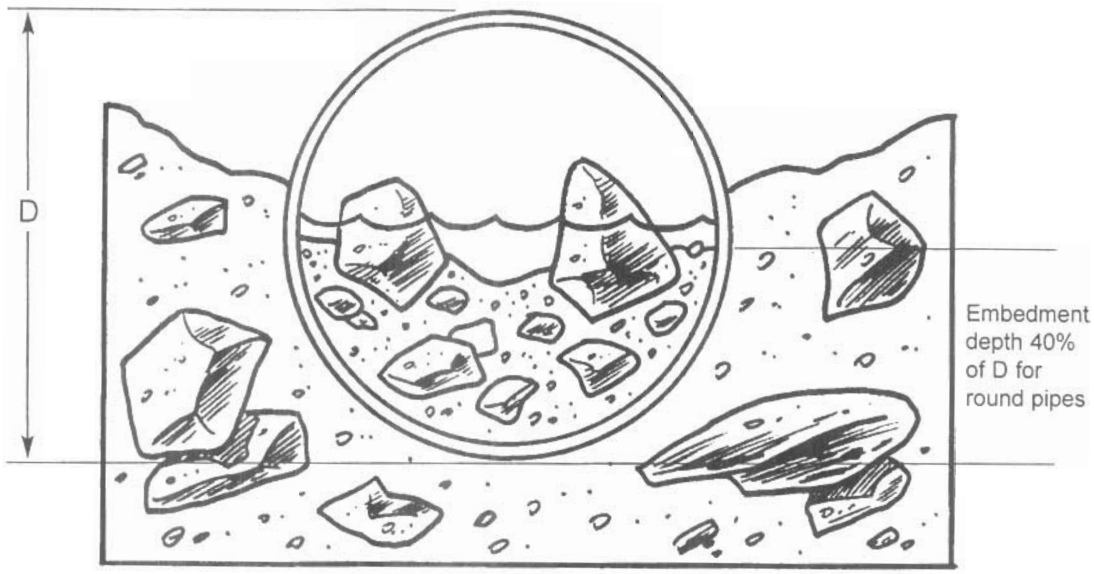
For forest roads in British Columbia, closed bottom structures for fish-stream crossings are corrugated pipes (metal or plastic), which, embedded to retain stream substrate, provide fish habitat and fish passage.

- Closed bottom structures are not allowed in critical fish habitat, but are an option in small streams with a stream channel width 2.5 m or less (small S3 and S4 streams) and 6% average stream gradients or less (see Figure 7). Should a proponent wish to proceed on a larger or steeper-gradient stream, an application should be submitted with the proponent application plan for fisheries agency review.[4]

- Experience in other jurisdictions, particularly Oregon (Robison 2001), has shown that closed bottom structures can be successfully installed when careful consideration is paid to site location conditions and structure design parameters. The embedment methodology (also known as stream simulation) consists of selecting a culvert (pipe) of adequate opening to encompass the stream channel width, and emulating the streambed within the culvert by lining the bottom with representative streambed substrate. The natural substrate materials are supplemented with additional larger material to help retain the substrate within the culvert and assist fish passage. By emulating the streambed and stream channel width, the culvert's streamflow characteristics should reflect the natural streamflow characteristics.

4 Alternatively, such application must be made to the Oil and Gas Commission concerning petroleum roads or the Ministry of Energy and Mines concerning mining access roads.

Culvert/streambed cross-section



Culvert/streambed cross-section

Culvert/streambed profile

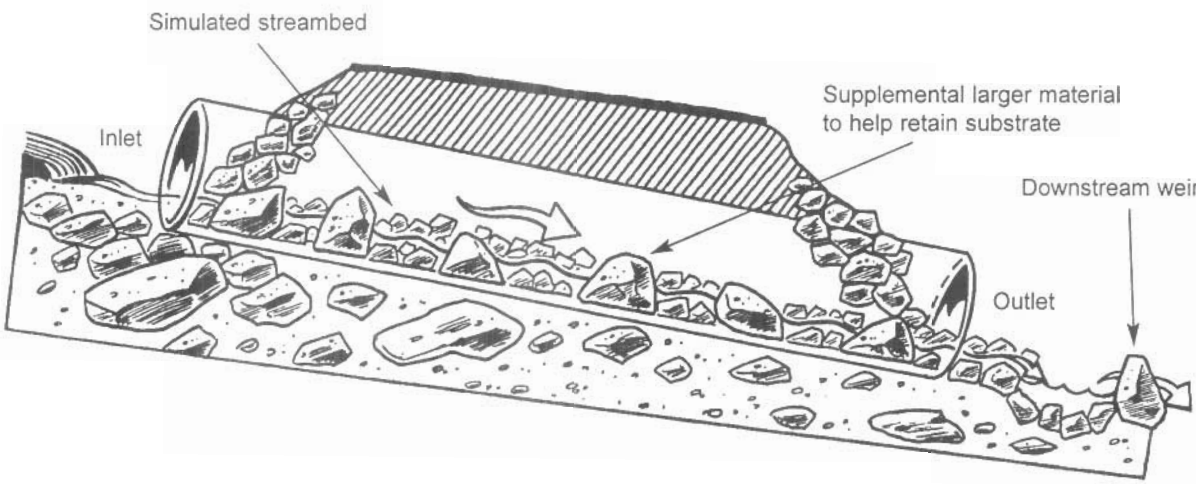


Figure 7. Typical closed bottom structures.

- The use of closed bottom structures in fish streams requires careful design and layout, paying particular attention to fish passage and fish habitat over the lifespan of the structure. The following requirements should be addressed.

Streambed profile determination:

- A detailed profile of the existing streambed using precise instruments is required for an extended distance upstream and downstream of the proposed crossing (approximately 50 m each way). Benchmarks for elevation and construction control should be established. The objective is to accurately model the streambed profile. This should assist in determining the culvert slope, invert elevation, and streambed. An example is provided in Figure 8. Streams that have bedrock outcrops or little variation in bed elevation should generally require shorter profiles. Existing pipes with local sediment retention or scour as a result of the culvert may require longer profiles to get beyond the zones of induced disturbance.
- A closed bottom structure should be designed and installed at the same slope as the stream (see Figure 8), and should retain the same stream substrate characteristics within the culvert. For migrating fish, this would impose no changes or stress, nor induce any delays at the crossing struc-

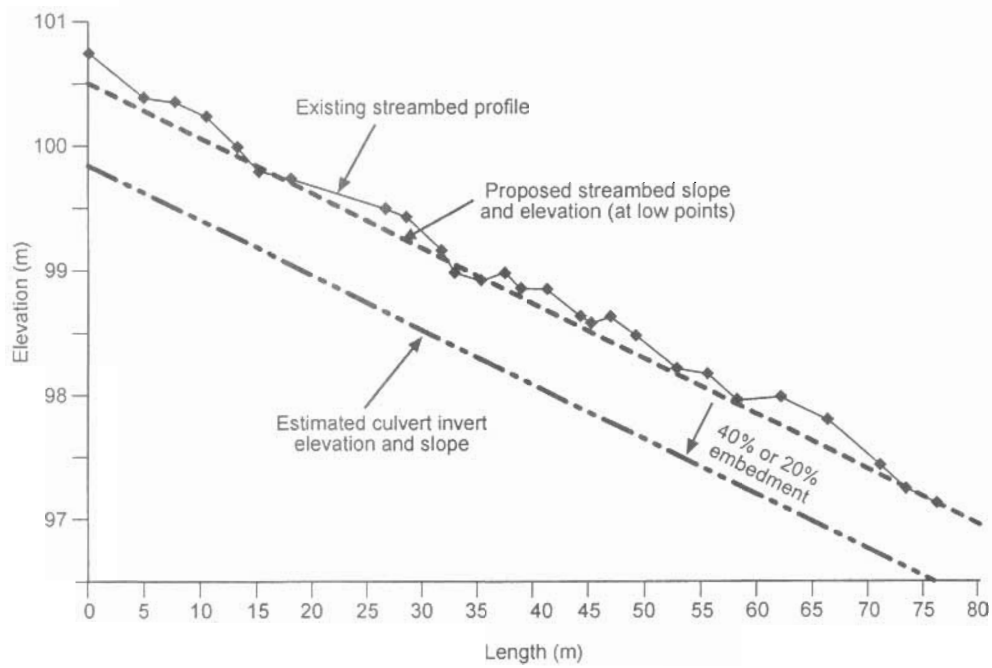


Figure 8. Stream elevation profile example for use in determining culvert slope and minimum invert level for an embedded culvert.

Note: *The vertical placement of the culvert in relation to the overall stream longitudinal profile is extremely important. The culvert invert should be determined from the longitudinal profile of the streambed, ensuring that the culvert is located at a low point along the streambed profile. Special note should be made of any artificial or other non-permanent anomalies (such as large debris-holding or storing-bed material) that may not provide a suitable invert elevation.*

ture in upstream migration. Substrate transport should move through the culvert naturally, and there should be no sediment build-up upstream or deprivation downstream.

- Where practicable, the natural meander pattern of a stream should be retained. A closed bottom structure should not be placed in the bend of a stream, as this leads to bank erosion and debris problems. Where the above cannot be achieved, the crossing structure should be relocated or another chosen, such as an open bottom structure.

Pipe size:

- A systematic, objective methodology to measure stream channel width is presented in Appendix 1. The stream channel width should determine the required culvert diameter/width. The width of the replicated or simulated streambed within the culvert should be equal to or greater than the stream channel width, to emulate the natural stream and to prevent deposition, scouring, or other damage at the outlet. Figure 9 illustrates stream channel width.
- A closed bottom structure must be sized to accommodate the 100-year return period peak flow after embedment. This flow determination must be carried out, and the pipe enlarged if it cannot otherwise pass the 100-year design flow.
- Factors in determining the appropriate culvert length include: depth of fill, skew angle of the culvert to the road, gradient of the culvert, and required road width.
- The closed bottom structure should be properly designed to avoid letting side slope and backfill material enter the culvert or flow channel. Rip rap should be used to provide scour protection for materials potentially exposed to erosion.

Design embedment:

- For circular culverts, the embedment should make up at least 40% of the culvert diameter or 0.6 m, whichever is greater. For pipe-arch or box culverts, embedment depth should be at least 20% of the vertical rise of the arch.
- The vertical placement of the culvert in relation to the overall stream longitudinal profile is extremely important. The culvert invert should be determined from the longitudinal profile of the streambed, ensuring that the culvert is located at a low point along the streambed profile (as shown in Figure 8).
- The streambed should consist of sufficient layers of unconsolidated gravel, sand, cobble, and other sediment lying over the top of the bedrock to allow for proper embedment. If little streambed is available to be excavated, then culvert sinking and embedding strategies become impractical.

Substrate placement within the pipe:

- Knowledge of the type of material found in the natural streambed and a specification for replicating this material are critical to successful substrate placement. As a general rule of thumb, the sizing of material placed within the culvert should be similar to the size of material in the adjacent natural stream channel. The "hydraulic roughness" of the culvert bottom is related to the size of bed material. Hydraulic roughness in turn is related to water velocities and water depth inside the culvert.

- Based on a design specification for gradation, the closed bottom structure should be filled with substrate material to the natural streambed level, using clean, well-graded material and supplemental material that is equal to or greater than the stream channel D90[5] particle size. A heterogeneous mixture of various substrate sizes that contains enough fine material to seal the streambed is recommended. Where the streambed is not sealed, subsurface flow may result, creating a barrier to fish passage. It may be necessary to supplement the substrate by washing in sand and gravel to seal the bed. Wash the simulated streambed and intercept the sediment at the outlet of the pipe before it enters the stream.
- Where closed bottom structures are installed in streams with gradients between 3 and 6%, the physical placement of supplemental larger material (D90+) is even more important. Note that oversized material may be problematic, creating increased hydraulic roughness and flushing out fines through the poor gradation of the embedment materials. At these gradients, the pipe should be large enough to allow for the physical placement and orientation of these larger elements. This should assist in retaining substrate and preventing scour in the culvert. The design should note the dimensions and quantity of the additional larger material.
- A thalweg (low-flow channel) should be established through the culvert to enable fish passage at low flow.
- Where a structure is to be replaced and a gravel wedge has been stored above the structure, take steps to maintain the stability of the wedge.

3.2.2 *Installation of closed bottom structures*

- The steps below outline the general installation procedures for closed bottom structures as they apply to fish streams. See Appendix 4 for sample construction drawings of a typical closed bottom structure.

Assemble in advance:

Deliver all required materials and mobilize equipment in advance so the installation can proceed without delay on a dry bed within the timing window. Appropriate work site isolation techniques (see Section 4.6.1) should be employed during the closed bottom structure's installation.

5 D90 is the largest size class of streambed substrate that may be moved by flowing water. Approximately 90% of the streambed substrate will be smaller than this size class

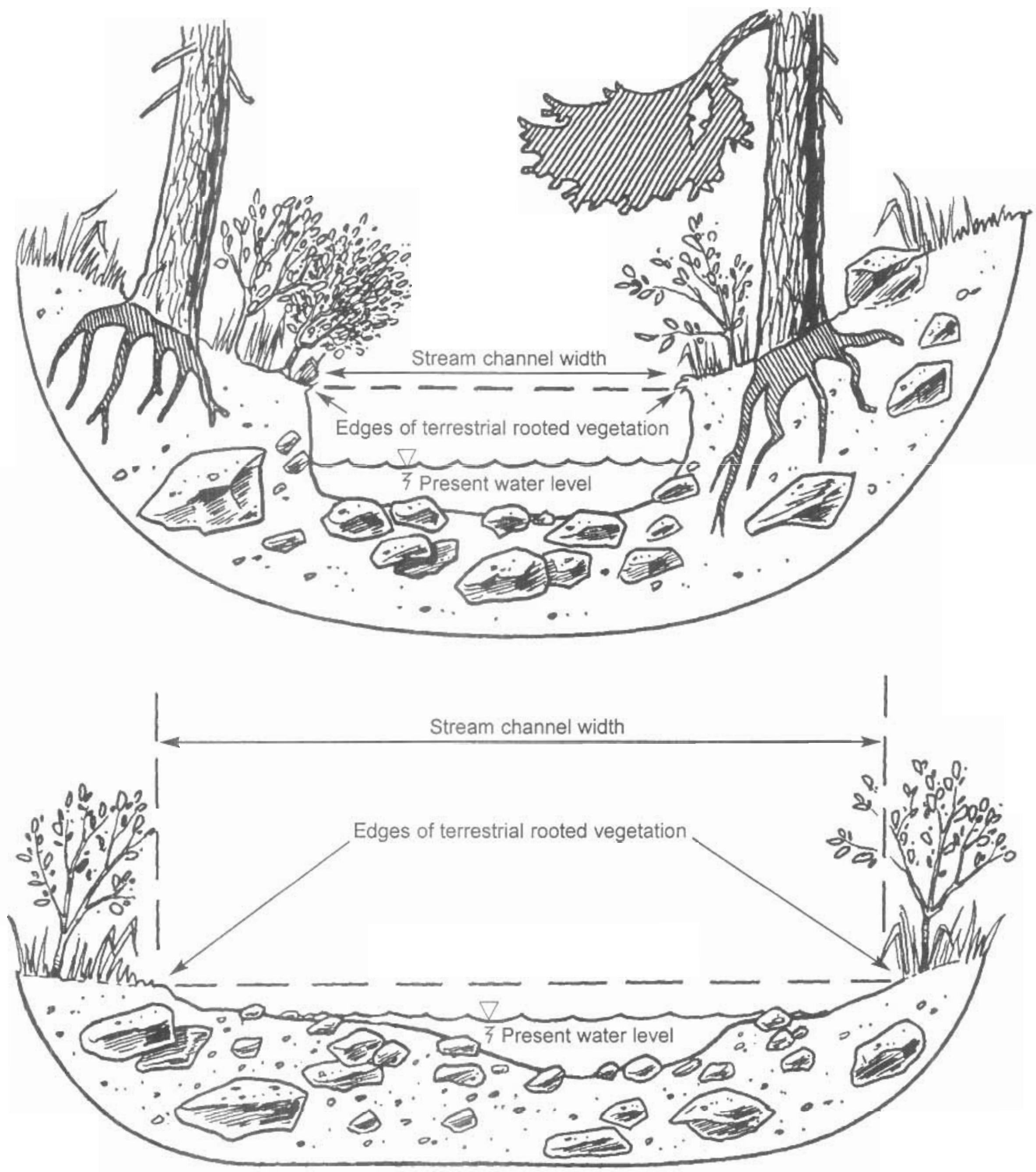


Figure 9. Determining stream channel width.

Survey:

- Lay out the work site with precise instruments, including establishing the horizontal and vertical field references to accurately locate the culvert invert elevation and slope during construction.

Bed preparation:

- Prepare and grade the culvert bed to conform to the design elevation and slope, using benchmarks and precise instruments. The barrel of the closed bottom structure should be set to the appropriate depth below the streambed and at the same natural stream gradient as shown by the longitudinal profile survey. The culvert foundation, trench walls, and backfill should be free of logs, stumps, limbs, or rocks that could damage or weaken the pipe.

Seepage barriers:

- Consider using geotextiles to prevent loss of fines and gravel through seepage along the culvert wall. The fabric, or other cut-off measures such as sandbagging or use of prefabricated seepage barriers along the culvert near the inlet, is intended to cut off most of the seepage and mitigate potential support fill erosion that can occur along the pipe.

Drainage:

- Do not allow side ditches to drain directly into the stream (see Figure 13). Divert ditchwater into a constructed sump or, where possible, onto stable forested vegetation that can filter sediments before the water reaches the stream. Ensure that adequate cross drainage is in place before the culvert approach to minimize the water volume directed into approach ditches at culvert sites. Consider the use of rolling grades to divert road surface runoff. Where cross-ditches are used, ensure that they are properly armoured at the outlet and along the base.

Constricting the stream:

- Do not allow any activities, including the placement of rip rap, to cause any constriction of the stream channel width.

Erosion protection:

- Begin erosion-proofing all exposed mineral soil as soon as possible after disturbance.

Downstream weir:

- An instream weir (see Figure 10) should be established within one and a half to two channel widths downstream of the culvert outlet, particularly for streams greater than 3% gradient, to retain substrate within the culvert and to prevent the formation of a plunge pool. The residual pool depth formed by this downstream weir should be less than 0.3 m.

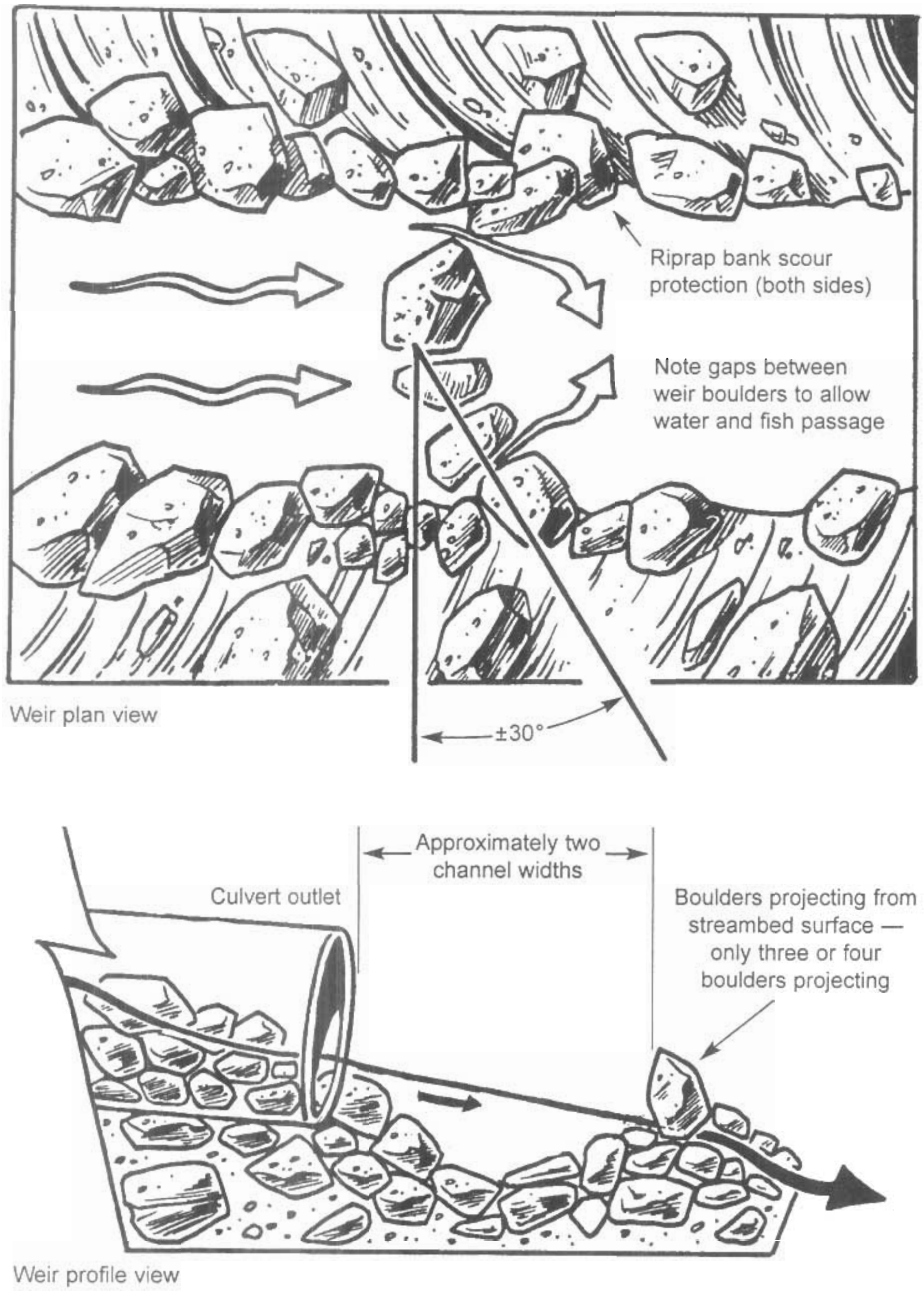


Figure 10. Typical downstream weir.

Backfill:

- Backfill practices should conform to those specified by the culvert manufacturer, or otherwise specified by an engineer, and incorporate mechanical vibratory compaction immediately adjacent to the culvert (see Figure 11).

3–6% grade:

- For culverts installed at slopes greater than 3%, larger material (D90 or greater) should be mixed into the substrate to help retain the substrate in the pipe. The larger material should be placed so that it projects from the streambed. This should create velocity shadows to enhance fish passage, retain substrate, and simulate conditions in the natural stream.

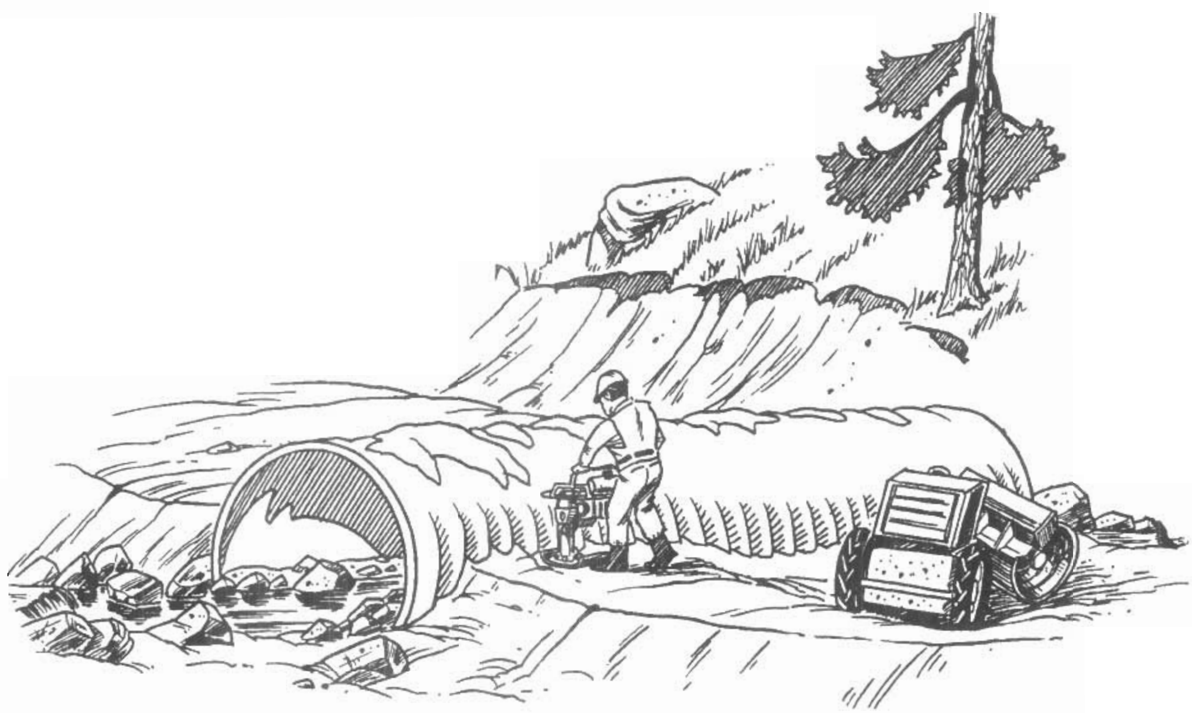


Figure 11. Culvert backfill compaction.

3.3 Snowfills

3.3.1 Design of snowfills

Snowfills (see Figure 12) are options that may be considered for seasonal use depending on the site, time of year, and other environmental constraints that may apply.

- Snowfills should be constructed and deactivated such that they should not affect fish or fish habitat at breakup. Deactivation is difficult and often results in channel disturbance as frozen material clings to logs.

- Snowfills are constructed by filling the channel with compacted clean snow (i.e., free of dirt and debris). Their use should be considered if the stream is dry or the water is frozen to the stream bottom. Unanticipated streamflow due to unseasonal thaws can be accommodated by log bundles or culverts. To avoid adverse impact on the stream, remove the log bundles, culverts, and snow prior to spring thaw.

3.3.2 Installation of snowfills

- The steps below outline the general installation procedures for snowfill as they apply to fish streams.

Construction period:

- Construct snowfill of dirt-free snow, only when there are sufficient quantities available for construction. Construction should begin after the stream has frozen solid to the bottom or the stream has ceased to flow, or when there is sufficient ice over the stream to prevent snow loading from damming any free water beneath the ice. Where possible, place snow into the stream channel with an excavator. Crawler tractors may be used to

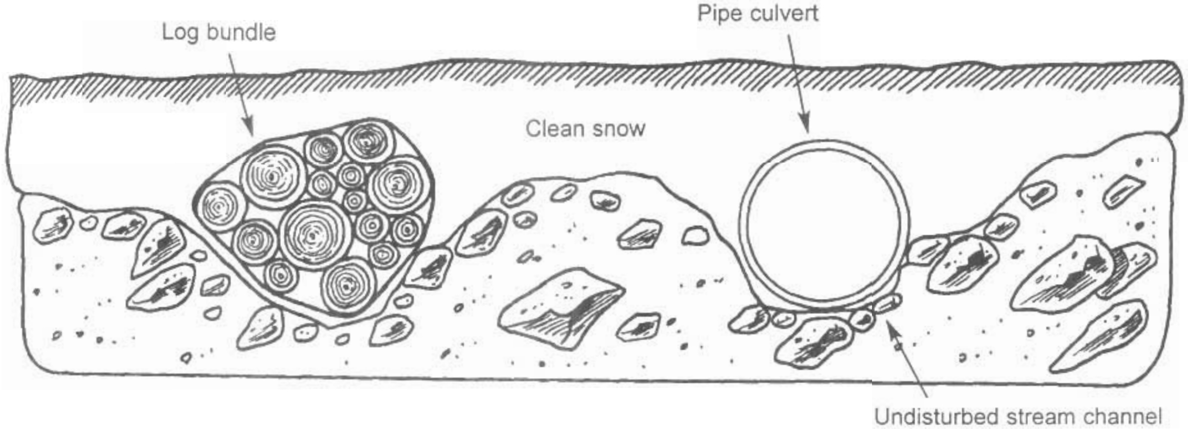


Figure 12. Temporary winter stream crossings using compacted snowfills. Culvert, heavy steel pipe, or log bundles allow meltwater to pass during warm weather trends.

push snow into the stream channel, but only if they can push snow unaccompanied by dirt and debris.

Streamflow:

- Where streamflow is anticipated during periodic winter thaws, place a pipe culvert, heavy steel pipe, or bundles of clean, limbed, and topped logs within the stream channel to allow for water movement beneath. The latter practice is not acceptable on streams where winter fish migration may be required. Heavy steel pipe is easier to salvage and has less chance of crushing under load and during removal.

Soil:

- Do not cap snowfill with soil. There is risk that soil placed within the stream channels could make its way into the stream during winter thaws.

Temporary removal:

- Remove any snowfill that may cause damage to the stream because of warmer weather, and reconstruct a new snowfill when colder weather returns.

Removal:

- Remove all snowfills and materials before the spring melt and place materials above the normal high water mark of the stream to prevent them from causing sediment and erosion. Deactivation should include the use of all appropriate measures to stabilize the site and facilitate its return to a vegetated state.

3.4 Ice Bridges

Ice bridges are effective stream crossing structures for larger northern streams and rivers, where the water depth and streamflow under the ice are sufficient to prevent the structure from coming in contact with the stream bottom ("grounding"), and where there are no concerns regarding spring ice jams. Grounding can block streamflow and fish passage and cause scouring of the stream channel.

3.4.1 Design of ice bridges

- Planning considerations in the design of ice bridges include depth of water, minimum winter daily streamflow, substrate, crossing location, maximum load strength, time of use, depth of ice required, approach construction, maintenance and monitoring, and decommissioning.

3.4.2 Installation of ice bridges

The steps below outline the general installation procedures for ice bridges as they apply to fish streams.

Reinforcing material:

- Determine whether using logs as reinforcing material could cause problems. There is a possibility that logs, if left in place through spring break-up, could contribute to debris jams and increase the risk of flooding, river channel alteration, erosion, and habitat loss. If this is an unacceptable risk, do not use logs. In most cases, log removal from a deteriorating ice bridge is an unsafe practice. The warmer weather and reduced ice thickness required to remove the logs can make working on the bridge unsafe for personnel and equipment. In these situations, removing all but the lowest logs from the ice bridge may be acceptable.

Thickness:

- Measure and record ice thickness and stream depth routinely. Evidence of grounding, or an increased risk of the ice base grounding with the streambed, may require that the bridge be temporarily or permanently decommissioned.

Approaches:

- Locate ice bridges where cutting into the streambank would be minimized during construction of the approaches. Remove all debris and dirt and place it at a stable location above the high water mark of the stream. Take steps to prevent it from eroding..
- Construct approaches of clean compacted snow and ice to a thickness that should adequately protect streambanks and riparian vegetation. Construction should begin from the ice surface. Where limited snow is available, locally available gravel from approved pits can be used to build up approaches, but should be removed when the ice bridge is deactivated.
- When it is time for deactivation, remove all ice bridge approaches. Where streambanks have been exposed to mineral soil, recontour and revegetate them using all appropriate measures to stabilize the site and facilitate its return to a vegetated state.

3.5 Fords

Fords, constructed as crossing structures, can result in habitat degradation through sedimentation, channel compaction, and the creation of barriers to fish passage. The construction of fords on fish streams is not encouraged by the authorizing agencies. When a ford is being considered, referral is required to the appropriate fisheries agency or the Oil and Gas Commission for petroleum-related operations, or the Ministry of Energy and Mines for mining projects.

4 Fish-stream Protection Measures

The practices described below apply to all fish-stream installations. Variations to those presented may be agreed to by the appropriate fisheries agency.

- The installation of a stream crossing should simulate conditions like those that existed before the structure in question was installed. Environmental objectives associated with the construction, installation, and use of stream crossings are:
  - protecting fish and fish habitat;
  - providing for fish passage;
  - preventing impacts on fish eggs and alevin that are present in the gravel, or on adult and juvenile fish that are migrating or rearing; and
  - reducing the risk of sediment release and other deleterious substances during work at stream crossings.

- To achieve those objectives, the following fish-stream protection measures are recommended:
  - Complete the work during the appropriate instream work window.
  - Eliminate or reduce sediment-related problems during installation.
  - Prevent deleterious substances from entering streams.
  - Minimize or avoid disturbing fish habitat above and below the area required for actual construction of the stream crossing.
  - Ensure that the design specifications for safe fish passage are achieved.
  - Revegetate and stabilize the site to prevent post-construction erosion.
  - Minimize clearing width at the crossing site and retain streamside vegetation within the stream crossing right-of-way wherever possible, recognizing operational requirements.

4.1 Vegetation Retention at Stream Crossings

- It is important to retain as much understory vegetation as possible within the riparian management area of the stream crossing to prevent erosion and minimize disturbance to fish habitat. Only the vegetation required to meet operational and safety concerns for the crossing structure and the approaches should be removed. Consideration should be given to salvaging rooted shrubs during crossing construction to assist in post-construction site stabilization.

- All efforts should be made to minimize impacts to the riparian fish habitat beyond the toes of the approach and abutment fills at the crossing site.

4.2 Falling and Yarding

- Falling and yarding of trees at stream crossings can result in unnecessary stream damage. Falling should be away from the stream whenever possible, and consideration should be given to the method of falling, tree removal, and stream cleaning (Figure 13) to minimize potential damage.

- Where construction work poses a risk of erosion and bank damage, directional falling and machine-free zones should be considered. Where leaning trees are encountered, consideration should be given to directional falling techniques. Where trees have to be felled across the stream for safety and operational reasons, trees should be lifted rather than dragged out.

4.3 Grubbing and Stripping

- Grubbing and stripping includes the removal of stumps, roots, and downed (non-merchantable) or buried logs. It should not be done in any area of the riparian management area not required for road construction, ditchlines, and installation of the crossing structure.

4.4 Slash and Debris

- All slash and debris that enters the stream channel from felling and yarding should be removed concurrently with site development. This material should be placed where it cannot be re-introduced into the stream by subsequent flood events. On most streams, this location is above the elevation of the active floodplain. Stream cleaning should not result in the removal of any hydraulically stable, natural debris. For additional information, see the Forest Practices Code *Riparian Management Area Guidebook*.

- All burying, trenching, scattering, or burning of debris should be done outside the riparian management area of the stream. Where this is not possible, debris piles should be located where they cannot enter the stream (i.e., not in active floodplain nor on steep slopes adjacent to the stream).

4.5 Fording

- The fording of fish streams is generally limited to one location and one crossing (over and back) for each piece of equipment required for construction on the opposite side. Where additional movements of equipment may be required, approval should be obtained from the appropriate fisheries agency regardless of habitat type.

- If the streambed and streambanks are highly erodible (e.g., dominated by organic materials, silts, and silt loams) and significant erosion and stream sedimentation or bank or stream channel degradation may result from heavy equipment crossings, then a temporary crossing, or other practices, should be used to protect the streambed and banks.

4.6 Erosion and Sediment Control Measures

Sediment delivered to stream channels can harm fish and fish habitat. Most sedimentation occurs in the first year when soils are exposed, during and immediately following construction. The amount of sediment generated at a stream crossing is directly related to the sensitivity of the soil to erosion, the amount of area exposed to runoff or streamflow, and the disturbance caused by road construction.

- Prevention of sedimentation by minimizing disturbance to streambanks and retaining riparian vegetation is essential. Many small streams and adjacent worksites are dry during the instream work window and construction can be undertaken without special measures for erosion and sediment control. When water is present, most erosion and sediment problems can be avoided through the use of a variety of methods that control sediment at the source and prevent it from becoming entrained in the flowing water. The key is to isolate the flowing water from the work site.

- During periods of heavy or persistent rainfall, work activities should be suspended if they could result in sediment delivery to the stream that would adversely affect aquatic resources. During such a shutdown period, measures to minimize the risk of sediment delivery to the stream should be implemented.

Common methods for reducing erosion during and after construction are described below.

4.6.1 Work site isolation

Working "in the dry" can greatly facilitate installation construction and reduce the amount of sediment produced during the work. To isolate a site, the following techniques should be considered:

- On small streams or where flows are very low, pipes, flumes, or erosion-proofed ditches may be adequate to divert flow around the site. To minimize sediment loss at these sites from and along the diversion, installation of sediment traps, combined with the use of geotextiles, is recommended.

- Temporary stream diversions should always be excavated in isolation from streamflow, starting from the bottom end of the diversion channel and working upstream to minimize sediment production. To prevent loss of sediment, the bottom end of the diversion channel should be left intact until the trench is almost complete and it should not be opened until all measures have been taken to reduce surface erosion resulting from the channel. After the stream crossing has been completed, the diversion should be closed from the upstream end first and, on completion, actions should be taken to re-establish the pre-diversion conditions and to stabilize and revegetate the site.

- Where practical, water can also be pumped across the work site and discharged into the stream channel below the site. This technique requires the stream to be dammed above the construction site. This eliminates the need for a diversion channel, and thus greatly reduces the problems of sediment production associated with digging and operating a newly created stream channel. Pump intakes should be screened to prevent entrainment of juvenile fish.Backup pumps on site are highly recommended in all pumping situations.

4.6.1.1 Coffer dams

- Coffer dams may be required to isolate work from the streamflow. These structures should not reduce the stream channel width by an amount that could lead to erosion of the opposite banks or of upstream and downstream areas. Coffer dams can be constructed in various ways. For example, sandbags lined with geotextiles or rubber aqua dams can be used.

- All materials should be removed after construction is completed, and all water pumped from contained work areas within coffer dams should be discharged to a forested site to allow sediment to settle before the water re-enters the stream.

4.6.2 Fish salvage

- If channel de-watering is conducted, fish should be salvaged from the de-watered area and returned to the stream. The person undertaking the fish salvage operation should obtain and hold all necessary permits required by fisheries agencies to collect and transport fish. Fish salvage is the relocation of live fish from a work site to a safe location above or below the site. Salvage operations require the isolation of the work site and the collection and removal of all fish from areas where fish may be entrapped or destroyed by construction activities. Fish can be collected through the use of electrofishing equipment, small nets, and seines.

4.6.3 Vegetation soil stabilization

- Vegetation soil stabilization is the most cost-effective, long-term surface erosion control method because it controls sediment at the source. The Forest Practices Code requires that all mineral soil exposed during construction and installation of a stream crossing be revegetated following construction. Revegetation of approach ditches, cutslopes, and other disturbed areas reduces the possibility of stream sedimentation and should be undertaken immediately following completion of work. Standard revegetation techniques include hand-broadcast or hydraulic seeding, and mulching using regionally adapted seed and mulch mixes.

4.6.3.1 Seeding and time of application

- For information on regionally adapted seed mixes and procedures for seeding or planting vegetation, contact the B.C. Ministry of Forests, Forest Practices Branch, in Victoria. Seed mixes that are less palatable to livestock should be selected to minimize livestock activity at the crossing site.

- Time of seed application is determined largely by completion time of the stream crossing installation. It is recommended that all exposed soils in the vicinity of the stream crossing installation be seeded immediately following completion of construction, and that the site be re-seeded if necessary during the regularly scheduled road construction seeding program. Hydro-seeding is the most efficient means for seeding steeper slopes.

- Mulching accelerates seedling development and reduces the chance of seed being washed away by rainfall and runoff. When combined with hand-broadcast seeding, straw is a fast and cost-effective mulch substitute for dealing with smaller exposed areas near stream crossings. Seed and mulch can be applied by hand, independent of the seeding schedule, or by the method established for the rest of the road system. This practice can accelerate revegetation at higher-risk locations.

- Fibre-bonding agents are slurries of wood fibres and tackifiers that conform to the ground and dry to form a durable, continuous erosion control blanket that stays in place until vegetation is established. The fibre mats created are biodegradable and decompose slowly as vegetation is re-established. Like other forms of mulching, bonded fibre matrices hold seed and fertilizer in place, yet allow sunlight and plants to penetrate. Compared to conventional erosion control blankets, they require no manual labour to install and are not subject to under-rilling or tenting, as can occur with erosion control matting and netting.

4.6.4 Erosion control matting and netting

- Erosion control revegetation matting and seed overlain with a biodegradable netting material such as jute (woven fibres) are other effective methods for speeding germination and plant growth and holding materials in place. Stakes fix the matting or netting in place and can be made to overlie most slope angles adjacent to stream crossings. Jute netting may also be used to hold mulch and other materials in place, although it provides little if any soil protection.

4.6.5 Bioengineering solutions to erosion control

During and soon after construction, physical engineering solutions should be considered for erosion control (e.g., silt fences, straw bales), followed by bioengineering techniques. Examples of bioengineering solutions can be found in Polster 1997.

4.6.6 Rip rap

- Rip rap or a shot rock pad should be placed at the outlet of all cross drains where ditch water is being diverted from an approach ditchline and discharged onto erodible soils or fills. Ditches lined with rip rap, shot rock, or large gravel are an effective method for reducing erosion at approaches to stream crossings. Rip rap slows the velocity of ditch water and armours erodible ditch bed materials.

- All rip rap or rock used should be free of silt, overburden, debris, or other substances deleterious to fish. The material should be durable and sized to resist movement by streamflow. Where rip rap is not available, fabric linings can be used temporarily at approaches and culvert spillways.

4.6.7 Drainage control

- Drainage control is critical to the successful retention of sediments both during and after construction (Figure 13) and needs to be considered in relation to the existing drainage pattern on the site. A site sketch plan is the best tool to work with when developing a drainage control plan. The two most effective steps in reducing water-related problems are (1) reducing the volume of approach ditch water and (2) preventing ditch water from draining directly into the stream.

- To minimize these problems, cross-drain culverts should be placed in the road at a location that allows as much of the water to be diverted away from the stream crossing as possible. This minimizes the length of the approach ditch that contains water, and the amount of ditch open to erosion. Any berms that may be present should be breached and tail-out