FPInnovations prepared this guide to provide forest and resource workers with information on the planning and design considerations for streambed simulation in closed-bottom structures for fish streams. Other important considerations that are key to the successful implementation of a streambed simulation culvert include structure installation, streambed material, and monitoring. These subjects will be covered in future guides.

FPInnovations worked in close co-operation with British Columbia's Fish Passage Technical Working Group in the development of this guide.

References:

BC Ministry of Forests, Lands and Natural Resource Operations, BC Ministry of Environment, and Fisheries and Oceans Canada. (2012). *Fish-stream crossing guidebook* (rev. ed.). Victoria, BC: BC Ministry of Forests, Lands and Natural Resource Operations and Fisheries and Oceans Canada.

Forest Service Stream-Simulation Working Group. (2008). *Stream simulation: An ecological approach to providing passage for aquatic organisms at road-stream crossings.* San Dimas, CA: National Technology and Development Program.

* Barnard, R. J., J. Johnson, P. Brooks, K. M. Bates, B. Heiner, J. P. Klavas, D.C. Ponder, P.D. Smith, and P. D. Powers (2013), Water Crossings Design Guidelines, Washington Department of Fish and Wildlife, Olympia, Washington.

Cover photo courtesy of the B.C. Fish Passage Technical Working Group. 100 Mile House Forest District (B.C.); Streambed simulation with a round embedded culvert installed in 2001.

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Stream Simulation: Planning and Design for Closed-Bottom Structures for Fish Streams

A PRACTICAL GUIDE FOR FOREST AND RESOURCE WORKERS

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SITE SUITABILITY

To identify suitable sites and design of appropriate crossing structures, it is critical to understand the site specific processes and characteristics of the natural stream channel by conducting and utilizing a comprehensive site assessment, survey and site plan. Highly active streams, with significant debris or bedload movement (e.g., alluvial fans), should be avoided. Steep streams may also have excessive bedload and debris, and should be avoided. Sensitive reaches within streams (e.g., high value spawning and rearing habitat, spawning gravels, deep pools, undercut banks) should be avoided. Sites that have thin soils over bedrock are likely not suitable, as ensuring appropriate levels of embedment may be a challenge. Streambed simulation should be considered where the crossing structure design can maintain the natural stream slope, channel width, and the capacity to move bedload and woody debris downstream. The objective for fish streams is that fish (including juvenile and resident fish) can move through the structure in either direction and access habitat as they would in a natural channel. The crossing will result in a simulated streambed, with characteristics similar to that of a natural stream, including hydraulic diversity.

- The culvert must address the design flood and be of adequate size such that the natural stream channel width is not constricted. Some of the larger culverts produced in B.C. are 3600 mm diameter helical corrugated round culverts, and 2130 by 1400 mm (span by rise) helical corrugated pipe arch. If larger or wider structures are needed, multi-plate structures are available.
- The invert of the culvert should be placed at or below the depth of scour, as determined through an appropriate long profile. Stream simulation culverts placed above this elevation are at greater risk of losing bed material and failing to allow fish passage.
- The simulated stream's substrate should be similar to that of the natural stream, and the form and structure (depth, velocity, turbulence, etc.) should be replicated by use of substrate placement and sizing. This may include entraining large boulders (D90) to help "anchor" the streambed material and prevent scour in the culvert. The addition of boulders that project above the streambed will provide velocity shadows which help fish navigate through the culvert during high flows.
- The aquatic habitat at the site should be assessed. The relative importance of the fish habitat at the site, including features like undercut banks and fish cover, should be considered, as these are difficult, if not impossible, to reproduce in a streambed simulation culvert.

CHOICE OF STRUCTURE

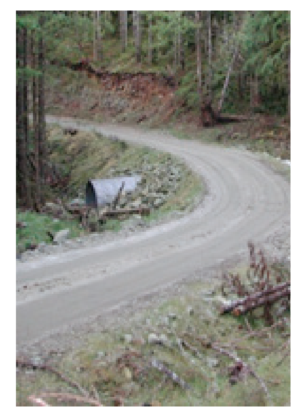
A closed-bottom structure for fish-stream crossings should provide aquatic habitat and passage through its length. Streambed simulation mimics natural stream channel characteristics, including slope, width, channel bed roughness, and hydraulic diversity. A simulated streambed crossing should be installed with careful consideration of site-specific characteristics. The end result will provide habitat connectivity for aquatic species present in the stream system and will allow safe, efficient vehicle passage over the stream and allow the stream to adjust itself within the culvert for the life of the crossing structure.

Appropriately aligning the culvert with the stream, including a provision for the passage of debris and bedload as well as consideration for road alignment, are critical aspects of planning and design.

Road alignment

Streambed simulation is often well suited for areas of geometric complexity, such as where horizontal and vertical curves in the road are unavoidable and where a linear bridge would not be appropriate. A buried culvert is often more suitable to efficient road alignment.

When designing the position of a new culvert, seek the best fit; evaluate the natural stream alignment and the road alignment to allow the stream to maintain its natural course and to provide for safe, efficient traffic flow.



Stream characteristics and hydrology

The natural stream channel width will not be constricted if the culvert is sized appropriately and the stream width is measured accurately. * Washington State have used a culvert sizing guideline of 1.2 X stream channel width, plus 0.6 m to provide additional width for overbank flow and natural function.

Where a natural channel shows signs of bedrock, the feasibility to embed the culvert to the required depth may be impractical.

The culvert should be sized to pass the 100-year event (Q100) without surcharge. Using empirical models to estimate Q100 events provides a greater certainty of the peak flows. The design flood event should also consider climate change.

STREAM SURVEY

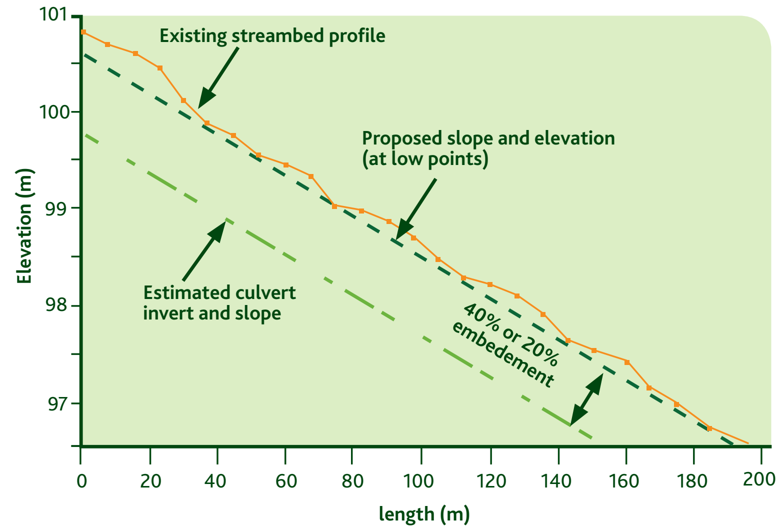
An elevation profile of the existing streambed thalweg (the deepest part of the cross section) is used to establish the design location, depth, and gradient for a culvert. It is critical to establish the vertical placement of the culvert so that it matches that of the existing natural stream slope. To measure the channel gradient and capture the channel characteristics (versus stream processes), a long streambed profile on the order of 100 m is required that includes channel segments both upstream and downstream of the crossing. Existing crossings, particularly undersized culverts, as well as other potential site impacts, will influence the profile both upstream and downstream. Practitioners will need to recognize these influences and consider them when selecting appropriate design crossing depth and grade.

Channel width should be measured at various locations upstream of the crossing to determine required culvert width. Where there is an existing road crossing or other upstream disturbance, stream width measurements should be taken far enough away so that the disturbed portion of the stream does not influence the width measurement.

Where an existing structure is present, identify any influences produced by the structure, such as sediment accumulation, scour pool formation or channel widening.

Show any existing structures in General Arrangement (GA) design drawings in plan, profile and cross section.

Take long profile thalweg survey points at the main stream channel features, such as pools and riffles, and measure the deepest point of that feature.



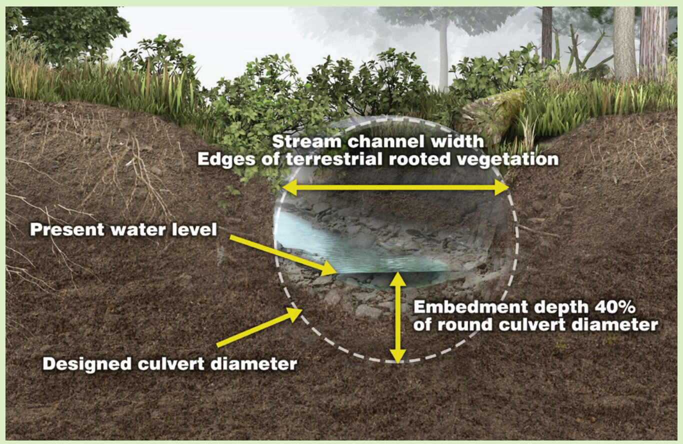
MEASURING A LONG PROFILE IS CRITICAL

The streambed profile should be long enough to collect a representative sample of the natural channel characteristics (depth of pools, riffle crests); 100 m upstream and downstream is a typical survey length.

The stable gradient of a stream is determined by a straight line drawn just below the low points plotted from the survey data of the long profile.

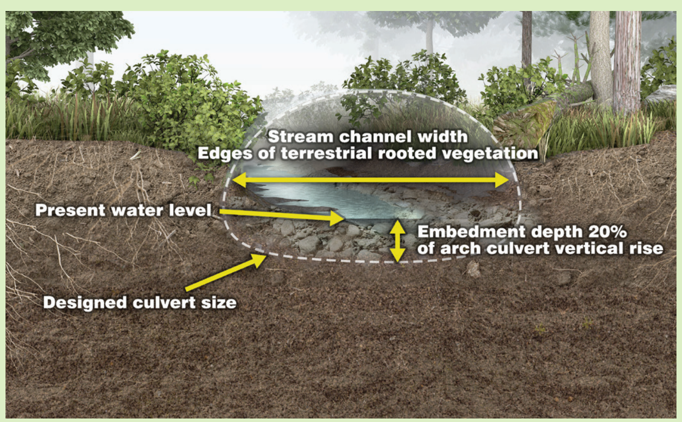
INCLUDE THE FULL EXTENT OF THE LONG PROFILE WITH GA DESIGN DRAWINGS.

STREAM CHANNEL WIDTH



The two diagrams depict a culvert cross section projected on a natural stream channel. It is critical that the design culvert width is as wide or wider than the natural stream channel to be a successful streambed simulation.

To determine stream channel width ensure channel measurements are taken along a reference reach that is outside of the influence of the road right of way and any other land disturbance that may have impacted stream channel width.



The stream channel width (normal annual flood level) is determined by averaging between three to six bank to bank measurements. The measurement point on each bank is often defined by a change in or absence of rooted vegetation, and the change in sediment texture. To avoid measurement bias, each channel measurement should be spaced a set distance away from the last measurement (usually a channel width from the previous measurement).

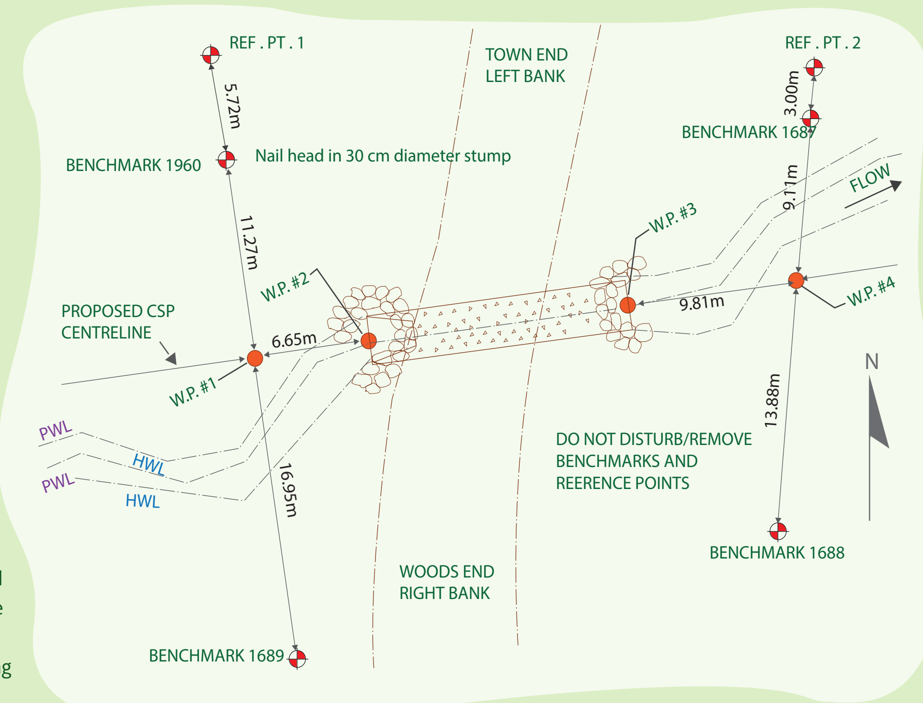
SITE PLAN

During the site survey determine locations to provide for simplified field referencing for the construction phase and subsequent long-term monitoring. Provide for the use of a standard construction levelling rod to facilitate establishment of elevations from benchmarks, and place horizontal reference points to allow lineal (straight) measurements that limit errors and which can quickly and easily be obtained with a measuring tape. Accurate working point (W.P.) locations can be determined in the field without the use of a total station survey instrument by using straight-line distance measurements as provided on the site specific engineered GA design. Field referencing should also consider providing for longer term monitoring of streambed elevations, and culvert settlement or shiffting. Include the full extent of the site plan with GA design drawings.

Conduct the initial site survey using total station survey equipment. During construction, less complex equipment can be used to locate final placement of the culvert (e.g., measuring tapes, construction levelling rod).

Establish reference points and benchmarks outside the construction disturbance zone and at a similar elevation to the crossing. Place elevation benchmarks clear of overhead and other obstacles, to facilitate measurements taken with levelling rod and measuring tape during the installation process.

Establish working points using straight-line distances between benchmarks/reference points and the end structure. This allows simple and accurate establishment of locations in the field using common equipment (e.g., measuring tapes, construction level and rod).



Clearly mark reference points and benchmarks in the field and describe them on design drawings. For example, "nail head in 30 cm diameter stump."

The spatial extent of the site survey should be of sufficient scope to provide the designer with adequate information to select appropriate culvert and road alignment geometry to suite site specific conditions.