Design and Installation of Embedded Culverts

Kamloops
March 12, 2002

Pilot 2

Part 2: Design
Part 2: Design

6 Main Topics

1. Evaluation of site suitability
2. Detailed streambed profile
3. Sizing the pipe
4. Design embedment
5. Embedment material
6. Design drawings
Culvert Terminology

- Slope/Gradient
- Barrel
- Perching
- Invert
- Jump/Rest Pool
- Weir

Design and Installation of Embedded Culverts

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1. Evaluation of Site Suitability

Should consider the following:

- Fish stream
- Stable stream channel
- Stream gradient \(\leq 6\%\)
- Stream channel width \(\leq 2.5\) m
- Depth of excavatable fill
- Suitable for both stream and road geometry
- Evaluate diversion options
2. Detailed Streambed Profile

- Use precise instruments
- Establish elevation benchmarks
Field Survey Reference Control

- Elevational benchmarks
- Horizontal reference stakes

Spike BM in blazed tree
Profile Length

- Extended distance upstream and downstream (~50m minimum)

- Note potential influences such as log/debris jams, bedrock, nick points
Detailed Streambed Profile

Elevation (m)

Length (m)

Existing Stream Bed Profile

Proposed Stream Bed Profile

Slope and Elevation (at low points)
3. Sizing the Pipe

Stream Channel Width

- Culvert diameter / span must span SCW at point of embedment

Edges of rooted vegetation

Definite change in vegetation and sediment texture
Diameter/Span

- Determination of Stream Channel Width with field measurements
- Use systematic approach to avoid skewing the results

(FSCG - 6 equally spaced intervals along 100 m length)
Depth of Embedment

- Round pipes - 40% of diameter or 0.6m, whichever is greater

- Pipe-arch - 20% of vertical rise of the arch
Sizing the Pipe

Round Pipes

- 40% of diameter or 0.6m, whichever is greater
- Span the stream channel width (SCW) at embedment depth

Pipe Dia > Stream channel width

Present water level

40% embeddment

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Arch Pipes

- Pipe-arch – 20% of vertical rise of the arch
- Span the stream channel width (SCW) at embedment depth

Arch Span ≥ Stream channel width

Present water level

20% embedment
Check Q100

- Check that Q100 will pass @ embedment depth

Non-embedded pipe

Culvert Cross Sectional Area ~ 3 x Visible Highwater Area

- Round pipe at 40% embedment => loss of 37% of area

- Arch pipe at 20% embedment => loss of 17% of area
Check Q100

- Round pipe at 40% embedment -> loss of 37% of area

- Arch pipe at 20% embedment -> loss of 17% of area

Round Culvert X-sectional Area Required $\sim 1.37 \times (3 \times \text{visible high water area})$

Arch Culvert X-sectional Area Required $\sim 1.2 \times (3 \times \text{visible high water area})$
FPC Forest Road Regulations

- Require P.Eng. For:

\[ \geq 2000 \text{mm} \]

or \[ \geq 6 \text{ m}^3/\text{s} \]
Factors Influencing Culvert Length

- Depth of fill and fill slopes
- Road surface width
- Culvert gradient
- Skew angle of culvert to road
Factors Influencing Culvert Length

- Include:
  - depth of fill
  - R/W width
  - gradient
Factors Influencing Culvert Length

- Include:
  
  amount of skew to road r/w
4. Design Embedment

Depth of Embedment

- Round pipes - 40% of diameter or 0.6m, whichever is greater
- Pipe-arch - 20% of vertical rise of the arch
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Design Embedment

Elevation (m)

Existing Stream Bed Profile

Estimated Culvert Invert Elevation & Slope

Proposed Stream Bed Slope and Elevation (at low points)

40% or 20% Embedment
5. Embedment Materials

• Objective is to emulate/simulate natural streambed
• Fish passage is related to “Hydraulic Roughness” (HR)
• HR related to size of bed materials
• Bed materials, in turn, are related to water velocities and water depth in culvert which influence fish passage
Material Size Influence on Velocity

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Embedment Materials

Velocity Refuge (Shadows)

Roughness reduces velocity and creates shadows
Embedded pipes - modeling/simulating the natural streambed
“Rule of Thumb”

• Size similar to that found in adjacent natural streambed
Range of Material Size

- Design should specify composition and distribution sizes of material to be used
Embedment Materials

Range of Material Size

- A range of substrate sizes (gradation) should be specified in the design
- Materials must be well graded to “seal” the streambed
- Ensure sufficient fines (sands & gravels) to “seal” the streambed
- Supplement with larger D90 material to help retain substrate
- D90 or greater particularly important on stream between 3 and 6%

Defn. D90 is the size of which 90% of the material will be smaller than
Range of Material Size

General Size Distribution of Embedded Material

Embedment Materials

Rule of thumb - aka George Robison

Cobble  Gravel  Fine  Boulder
Embedment Materials

Substrate Volume Determination

- Round pipe embedded 40% ~ 37% of area
  \[ \text{Area}_{(\text{Round})} = \pi \left( \frac{\text{Dia}}{2} \right)^2 \]

- Arch pipe embedded 20% ~ 17% of area
  \[ \text{Area}_{(\text{Arch})} \text{ from manufacturer info} \]
Design Drawings

Purpose

• Tools to “design” culvert to fit site
• Document proposed works and final product
• Provides material and construction specifications
• Provide construction referencing
Design Drawings

Site Plan / Profiles

- Plan/profiles developed for the crossing
- Design drawings developed from site plan / profiles
- Used for design and documentation purposes
Site Plan

- contour map of the site
Fit Crossing to Site

- The selected crossing structure should be suited to both the stream and road

- consider road drainage to minimize potential sediment delivery to the stream

- avoid vertical dips, provide for roadway drainage
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Design Drawings
PROPOSED ROAD CENTRELINE PROFILE

NOTES

1. An objective is for the backfill in the culvert to simulate the natural streambed.
2. If suitable materials for backfilling the culvert are not available on site, suitable materials shall be imported.
3. The backfill in the culvert to be installed to the design streambed level using clean gravel, cobbles of similar size and distribution as in the natural streambed.
4. Substrate material to be supplemented with 80-100, 350-450mm diameter boulders distributed and mixed into the backfill matrix.
5. Substrate material to be imported into culvert to a nominal depth of 800mm (40% of culvert diameter) using suitable methods.
6. All voids in the substrate shall be filled in with clean sandy gravels.
7. Substrate material to be free of organicics (roots, logs, twigs, etc.).
8. If practicable, excavated streambed material shall be set aside to be utilized for placement in the culvert. Particular attention should be paid to salvaging the natural streambed surface material to be used for the upper layer in the culvert.
Plan Drawing

NOTES

1. Stream Class 53
2. Clogging Flow: 1.3 m³/s
3. Average Stream Gradient: 6%
4. Average Stream Width: 1.0m
5. Streambed/substrate: Gravel, sand and cobbles
6. Geosynthetics Design Life 40 years
7. Design Vehicle: MOD-L75
8. Scour Protection Details see eng. Embedded Plan – B4
9. Downstream Reroute Details see eng. Embedded Plan – B3

LEGEND

- PROPOSED CULVERT
- CULVERT CENTRELINE ALIGNMENT
- PROPOSED CENTRELINE ALIGNMENT
- SCALE BAR
- PLAN DRAWING
- DWG. (JUN 11/2001)
- T.O.L. CONTROL
- TOP OF BANK

CO-ORDINATE TABLE

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SCALE: AS NOTED (Metric)  PROJECT NO. ID-1172  SCALE 1:5000

SPANISH – ART F.S.R. CROSSING HOT FISH CR. – 2.0 km

Ministry of Forests
100 MILE HOUSE DISTRICT – CARIBOO FOREST REGION

Survey: CARIBOO RECON ENGINEERING
Design: CHOW / ROBISON
Drawing: M. DAVIES

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Riprap Specifications

1. Riprap shall be placed to the extent, depths and thickness noted on the drawings.
2. Riprap to be underlaid with non-woven geotextile underlay.
3. Riprap to be clean (free of fines), sound, angular, bucky stones well graded to fill gaps between larger stones, and placed carefully to attain well graded blankets of interlocking stones.
4. Minimum riprap layer thickness is 300mm.
**Design Drawings**

**Installation Measures**

1. All required materials and equipment shall be assembled in advance such that the installation can proceed without delay.

2. The installation site shall be isolated from running water such that the culvert bedding and installation can occur in the dry. The site shall also be isolated from water bodies such as lakes, streams, and rivers to prevent water from entering the culvert.

3. The culvert shall be removed using appropriate mechanical equipment such as backhoes. The spaceshall be cleared of debris and vegetation to ensure a level and smooth surface for installation.

4. Backfill shall be placed to a depth of 0.6 meters in the culvert shall be compacted in layers of not more than 0.3 meters. The backfill shall be placed to ensure a smooth and even surface.

5. Seed grass shall be sown with suitable erosion control mix following construction.

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Design and Installation of Embedded Culverts
Installation Referencing

Design and Installation of Embedded Culverts

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Other Details ie. Weir Design

- A downstream weir may required as part of the design to be installed within 1.5 – 2 channel widths downstream of culvert outlet
- Assists in maintaining adequate low flow depth
- Helps retain substrate
- Prevents formation of plunge pool
- Particularly important where stream gradient is > 3%

Design Drawings
Weir Design

Plan View

Longitudinal View

Design Drawings
Design Drawings

Weir Design

WEIR PLAN

WEIR PROFILE

WEIR SECTION B-B

SCALE BAR

SCALE: AS NOTED  (Metric)  PROJECT No. 8611.02  STRUC. No.

SPANISH ART  F.S.R. CROSSING HOT FISH CR.  - 2.0km

WEIR DETAILS

Ministry of Forests

100 MILE HOUSE DISTRICT  -  CARIBOU FOREST REGION

Survey: CARIBOU REGION ENGINEERING
Design: CHOW / ROBSON
Drawing: M. DAVIES

0 FOR CONSTRUCTION  BC  2009
Dwg No: EMBEDDED PILOT-B5

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Design should include:

- Stream data
- Plan
- Profile
- Construction referencing (vertical / horizontal)
- Materials specifications
- Installation specifications
- Other details (riprap, weir, etc.)