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Contents

Closed-bottom corrugated-steel embedded culverts in British Columbia: overview of twelve sites

Abstract

The Forest Engineering Research Institute of Canada (FERIC) surveyed users of closed-bottom corrugated-steel embedded culverts within British Columbia and visited selected sites. This report presents information about the installations visited, including the installation procedures and costs. This report also provides suggestions for the implementation of future embedded culverts.

Keywords

Stream crossing, Water crossing, Embedded pipe culvert, Corrugated steel pipe culvert, Fish habitat.

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Introduction

In some situations, closed-bottom corrugated-steel embedded culverts[1] may be an appropriate and cost-effective alternative to conventional structures for stream crossings on forest roads in British Columbia. Stream crossings on forest roads should maintain water quality, protect fish and fish habitat, and provide safe fish passage. In British Columbia, fish habitat must be identified and treated appropriately (BCMOF 2002a). While the use of embedded culverts is increasing, little information is available to potential forest industry users about installation procedures and costs of these structures.

To address this gap, FERIC worked with the Engineering Section of the B.C. Ministry of Forests (BCMOF) Resource Tenures and Engineering Branch to inventory closed-bottom corrugated-steel embedded culverts on forest roads in British Columbia and to describe selected installations in more detail. This report describes twelve embedded culvert installations and presents implementation suggestions grouped by installation phase.

Objectives

The primary purpose of this study was to document the use of embedded culverts within British Columbia. The locations of embedded culverts were identified, and field visits were conducted to selected sites. Although there are many options available for crossing fish-bearing streams, only embedded culverts are presented in this report to help address the lack of literature describing the installation of these structures in British Columbia.

[1] An embedded culvert differs from a typical water-passing culvert in that it is purposefully installed below the natural streambed level and filled with aggregate through the length of the culvert, up to the natural streambed level. Typical target infill depths are: round culverts filled to 40% of diameter, and pipe arch culverts filled to 20% of their rise. When filled to these infill depths, round culverts have 63% and pipe arches have 83% of the original cross-sectional end area remaining for water flow.

Note:
The Ministry of Forests contracted with FERIC to inventory closed-bottom embedded culvert systems to demonstrate the viability of embedded culverts as an option for consideration for fish stream crossings. Two primary objectives of embedded culverts are safe fish passage now and in the future, and protection of fish habitat. It should be noted that all but one of the sample projects cited were carried out prior to the completion and dissemination of the Forest Practices Code publication Fish-stream Crossing Guidebook in March, 2002. Consequently, the reader should not interpret the data presented herein as recommended procedures, unless they happen to reflect the multi-agency consensus results that are found in the Guidebook. The key differences will be in the habitat criteria (if any), depth of embedment in the pipe (infill depth) and required survey accuracy (precise construction level recommended). The reader is encouraged to draw on the details provided in the Guidebook, which can be found on the Internet using the following address: http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/guidetoc.htm.
—Ron Davis, P.Eng. Chief Engineer, B.C. Ministry of Forests.

Methods

Major forest licensees and BCMOF district offices in every Forest Region were contacted to identify installations of closed-bottom corrugated-steel embedded culverts. Installations that were candidates for field visits potentially fulfilled the following criteria:[2]

- round culverts filled to 40% of their diameter, or pipe-arch culverts filled to 20% of their rise
- installed structures with gradients of less than 6%
- natural stream channels less than 2.5 m wide
- the culvert had been in place for at least one year and/or had experienced at least one freshet

The twelve installations cover a range of geographic areas, culvert types (round and arch), dimensions, infilling techniques, and site characteristics. The installations presented are considered appropriate examples for the purpose of informing potential users about installation techniques, costs and requirements for embedded pipe culverts.

Results

The survey identified 94 closed-bottom corrugated-steel embedded culvert installations on forest roads throughout British Columbia. FERIC visited twelve of these sites to document information such as their installation procedures and costs. This information is contained in the Appendix of this report, and is organized by site.

Engineering designs were prepared for all but Sites 7 and 10 (Appendix). These two culverts are not major culverts, which legally require a professional engineer to take design responsibility.[3] However, it is recommended that drawings and designs be produced for stream culverts not classified as major culverts that are installed on fish-bearing streams (BCMOF 2002b). Embedded culverts are

[2] The first three criteria are general guidelines for the use of embedded culverts found in the Forest Practices Code of B.C.: Fish-stream crossing guidebook (BCMOF 2002a).

[3] The Forest Road Regulation (B.C. Reg 106/98) of the Forest Practices Code of B.C. Regulations defines a "major culvert" as a stream culvert having a pipe diameter of 2000 mm or greater, or a maximum design discharge of 6 m^3/s or greater.

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significant structures and need to be installed properly to meet the desired goals. The culverts described in Sites 7 and 10 were carefully installed and met their desired goals.

All the culverts that were left to infill naturally had accumulated stream bedload material at the time of field inspections. Sites 5 and 6 are examples where natural infilling occurred (Appendix). The culverts at these two sites were functioning well and presented no barriers to fish passage at the time of inspection. Natural infilling is not specifically excluded in the Fish-stream Crossing Guidebook as an option for creating the simulated streambed, but use of this technique requires prior approval from the Department of Fisheries and Oceans Canada.

All but one of the embedded culverts (Site 7) was installed prior to publication of the current Fish-stream Crossing Guidebook that was published in March, 2002. The designs of these installations were guided by the working draft for 1997/98 of the Stream Crossing Guidebook for Fish Streams (Poulin and Argent 1997), as well as by B.C. Ministry of Water, Land and Air Protection guidelines in the form of local "Timing windows and measures for the conservation of fish and fish habitat."[4] The working draft for 1997/98 specified the same infill depths for both round culverts and pipe arches: "a minimum of 300 mm or 20% of the diameter/vertical rise, whichever is greatest." The current guideline for round pipes is "40% of culvert diameter or 0.6 m, whichever is greater" and for pipe arches "at least 20% of the vertical rise." Few round embedded pipes meeting the new 40% embedment depth criterion were identified during the survey.

The description for each site in the Appendix includes a table that provides information on the culvert, site, cost, and installation data. Stream classification is noted as either S3 or S4.[5] The average natural stream widths shown in the tables were measured by FERIC, and do not necessarily match the stream classification parameters. The stream classification was taken from the designs or given by the cooperators. FERIC and/or the cooperators assessed the fish habitat for most of the sites in the Appendix. The fish habitat at the sites were described as either "Marginal" or "Important".[6]

Implementation

Planning

- Site plans developed from site surveys are useful design tools and should be utilized when preparing engineering designs for the installation. Appropriate engineering design can greatly enhance the ease of installation and help to ensure that the desired objectives are achieved. Culvert positioning through the road, depth of excavation, and gradient of the installation are all easily referenced on the designs. Size distribution of the aggregate to be used within the culvert can also be referenced on the designs.
- Benchmarks, reference points, or working points should be semi-permanently established in the field. These points are used to establish horizontal and vertical culvert locations during installation.
- Plan the installation work to take place during the preferred in-stream work window ("fish window") for the local area. During this time, the risk to local fish species due to in-stream work activities

[4] The purpose of these documents is to provide timing windows (windows of least risk) and measures for work related to stream crossings, to facilitate compliance with the Forest Practices Code of British Columbia Act. The documents were prepared by the Designated Environmental Officials of the Ministry of Water, Land and Air Protection. Individual documents were prepared for either a BCMOF Forest Region, or a BCMOF Forest District.

[5] S3 and S4 stream classifications refer to fish and/or community watershed streams; S3 streams are 1.5 to 5 m wide, and S4 streams are less than 1.5 m wide (BCMOF 1998).

[6] The definitions and indicators for "Marginal", "Important" and "Critical" fish habitat are given in BCMOF 2002a. "Marginal" habitat has low productive capacity and contributes marginally to fish production. "Important" habitat is used by fish for feeding, growth, and migration, but is not deemed to be critical. This habitat category usually contains a large amount of similar habitat that is readily available to the fish stock.

is considered reduced. Risks to water quality are also considered reduced due to the typical low flow during the "fish window".
- Compared to conventional culvert installations, embedded culverts require additional excavation and infilling with aggregate. The cost of this additional work must be budgeted when planning the installation and allocating machine time to the project.

Site preparation

- Isolate the construction site from fish passage. Install fish screens (typically wire-mesh) within the stream, above and below the construction site. Capture and remove any fish present between the fish screens.
- De-water the construction site to allow the culvert installation to take place in predominantly dry conditions. If using a pump-and-hose system, monitor the pumps during installation to ensure they are working properly. Have a spare pump-and-hose set on-site in case of pump failure.
- As an alternative to a pump-and-hose system and/or a precaution to a pump failure, consider installing a bypass culvert. For installations that require more than one day to complete, a bypass culvert eliminates the need to monitor pumps overnight.

Installation

- Use appropriate survey equipment during the installation to help achieve the design elevations, gradients, and depths.
- Sediment-laden water should be collected and delivered to the forest floor away from the stream. Seepage will often occur within the excavated trench prepared for the culvert, creating a sediment source. A sump at the downstream side of the construction site will collect this water, which can then be pumped onto the forest floor.
- Match the infilling technique to the size of the culvert. Small culverts may require manual infilling with wheelbarrows and buckets, while small loaders or self-dumping wheelbarrows may be effective for larger culverts. Other culvert features, such as baffles, may also influence the choice of infilling technique and equipment. Natural infilling by the stream may also be effective.
- Ensure the infill material is well graded and contains sufficient fines and sand to fill the voids in the simulated streambed. If the infill material is without sufficient fine particles, the result may be subsurface streamflow which could preclude fish passage. Fines and sand can be spread over the surface of the simulated streambed and hosed down to drive the finer particles into the voids.

General

- Site 7 is the smallest embedded culvert of the twelve culverts documented (Appendix). This culvert has a rise of 970 mm, which is close to the smallest size that a culvert can still be manually filled with material. Conversely, Site 8 is the largest culvert documented, and has a diameter of 3.4 m. Culverts larger than this may incur significant costs for the delivery of infill material.
- Round embedded culverts work well in roads where the road profile and prism contains or requires a "deep" fill (see Site 1, Appendix). The height of a round culvert helps negate the volume of fill required. Where the road does not contain or require a deep fill, shallower profiled stream-crossing structures (pipe arches) may be preferred.
- The descriptions in the Appendix are not exhaustive. Further information on specific installations can be obtained from the contacts identified, and from Gillies (2002a, b).

References

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Gillies, C. T. 2002b. Installation of an embedded pipe culvert: Hotfish Creek. FERIC, Vancouver, B.C. Advantage Report Vol. 3 No. 38. 11 pp.

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Appendix

Description of 12 culvert sites

Site 1

Embedded round culvert at Cecil Creek, Campbell River Forest District

Location
Vancouver Forest Region
Campbell River Forest District
Elk Bay Forest Service Road, km 3.1 (from Highway 19)
Crossing: Cecil Creek

Company/proponent
International Forest Products Limited, Campbell River Operations

Date of installation/field visit
September 8–11, 1998/November 27, 2002

Figure 1a. Embedded culvert more than three years after installation.

Table 1. Culvert, site, and installation data—Site 1

Culvert shape	round
Culvert dimensions	
Diameter (mm)	2 400
Length (m)	19
Installed culvert gradient (%)	2.4
Simulated streambed gradient (%)	1.6
Avg. depth of embedding material (mm, % diam.)	517, 21.5
Avg. natural stream width and gradient (m, %)	2.2, 3.8
Stream classification	S3
Design flood event (m^3/s)	10.2
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Planning & desing ($)	5 000
Materials ($)	1 720
Delivered culvert ($)	8 580
Installation ($)	21 500
Total ($)	36 800

Project description
- A 0.5-m by 2.0-m wooden box culvert, under 3 to 4 m of fill, needed replacement. The opening size was considered to be restrictive to high flows, and the structure was near the end of its effective age.
- Failure of the structure could lead to loss of fish habitat and a section of road.
- The replacement structure was a closed-bottom corrugated-steel embedded round culvert (Table 1, Figures 1a and 1b).
- Installation works were completed under contract.
- The replacement was funded by Forest Renewal BC.

Habitat description/indicators
- Fish are present at the site (confirmed visually) and are assumed to be cutthroat and rainbow trout.
- The stream flows directly into Cecil Lake (approximately 120 m away). Cecil Lake connects directly to Roberts Lake (approximately 200 m between the two lakes).
- The stream flows year round; stream features include undercut banks, woody debris, and natural step patterns. The streambed contains rounded cobble, gravel, and sand. Small sandbars have deposited in areas of low velocity.
- Based on limited observations by FERIC and/or the cooperators during the field review, the stream habitat was considered to be "Important" (the installation pre-dates the March 2002 Fish-stream Crossing Guidebook).
- The stream ranged in width from 180 to 280 cm, and was not constricted by the width of the embedded culvert (Figure 1c).
- Water depth during the field visit date ranged from 4 to 12 cm (measured near the centre of the stream at various locations); bank indicators of high water depths measured from 10 to 32 cm.

Planning and design
- A site plan and a detailed, signed and sealed set of design drawings were produced by StoneCroft Project Engineering of Black Creek.

- Two benchmarks were established in the field at the time of the site plan survey; inlet and outlet elevations were shown on the design drawings with respect to the benchmark elevations.
- The installation site is located at a sharp bend in the road requiring the road running surface to be increased to 6 m.
- Load rating of the embedded culvert is 68 tonnes.

Pre-installation works

- A temporary sandbag dam was constructed on the upstream side of the installation site. A pump-and-hose system delivered water around the site.

Construction works

- Mike Hamilton Logging Ltd. of Courtenay installed the embedded culvert. Primary equipment used was a Kobelco 300 excavator.
- On-site supervision and material delivery within the culvert were done by StoneCroft Project Engineering.
- A plate compactor was used to compact 200-mm lifts on either side of the culvert.

Embedment method

- A rubber-tired Bobcat loader was used to deliver material through the length of the culvert.
- Gravel-sized material was placed in the culvert to a target depth of 500 mm; measured widths of the simulated streambed were from 185 to 206 cm.

Additional information

- A round culvert was chosen over a pipe arch because of the deep fill over the existing wooden box culvert. The size of the round culvert helped to minimize the amount of backfill required to build the road back to original grade.
- The embedded culvert was shown on the detailed design drawings, and constructed with a 1.5 to 1 step-bevel at both ends.
- The culvert was delivered in two sections with a coupler (including nuts and bolts).
- The road is extensively used for local recreation as well as access to a commercial recreation facility.

Figure 1b. Inlet of embedded culvert.

Figure 1c. Culvert inlet showing match to natural stream width and gradient.

Observations and comments

- Riprap was well interlocked, with no exposed soils.
- Alder/willow whips were sprouting on the fill slopes.

Prepared designs

StoneCroft Project Engineering. 1998. Elk Bay FSR #1104 Cecil Creek. Design drawings prepared for International Forest Products Limited, Campbell River Operations.

For further information:

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Site 2

Embedded pipe arch at Benoit Creek, Kalum Forest District

Location
Prince Rupert Forest Region
Kalum Forest District
West Kalum Forest Service Road, km 18.6
Crossing: Benoit Creek

Company/proponent
BCMOF, Kalum Forest District

Date of installation/field visit
August 24–31, 2001/October 18, 2002

Figure 2a. Embedded pipe arch one year after installation.

Table 2. Culvert, site, and installation data—Site 2

Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	3100
Rise (mm)	1980
Length (m)	14
Installed culvert gradient (%)	1.4
Simulated streambed gradient (%)	1.3
Avg. depth of embedding material (mm, % rise)	570, 28.8
Avg. natural stream width and gradient (m, %)	2.2, 2.0
Stream classification	S3
Design flood event (m^3/s)	7.3
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Planning & design ($)	2 500
Materials ($)	1 440
Delivered culvert ($)	18 300
Installation ($)	20 000
Environmental monitor ($)	2 330
Supervision ($)	2 330
Total ($)	46 900

Project description
- A 9-m long, 1200-mm diameter, round culvert was replaced. The culvert was perched at the outlet and was determined to be a barrier to fish passage.
- The replacement structure was selected to be a closed-bottom corrugated-steel embedded pipe arch culvert (Table 2, Figure 2a).

Habitat description/indicators
- Undisturbed streambed material contains an estimated 30% cobble, 50% gravel, and 20% sand.
- A Watershed Restoration Program riparian assessment during December 1997 showed coho salmon, cutthroat trout, and rainbow trout present within Benoit Creek.
- Only cutthroat trout were noted to be present immediately prior to and during the culvert installation.
- Pools exist at the inlet and outlet of the culvert. The inlet pool is approximately 7 m from the culvert and is 55 cm deep (Figure 2b), and the outlet pool is adjacent to the culvert and is 40 cm deep.
- Based on limited observations by FERIC and/or the cooperators during the field review, the stream habitat was considered to be "Marginal" (the installation pre-dates the March 2002 Fish-stream Crossing Guidebook). Additional planned restoration works, including the removal of several beaver dams and the promotion of old growth characteristics within the riparian area may improve the habitat qualities in the future.
- Water depth during the field visit date ranged from 4 to 7 cm (measured near the centre of the stream at various locations).
- Bank indicators of high water depths measured from 29 to 39 cm.
- Benoit Creek flows into the Kitsumkalum River (an S1 stream classification) within 3 km of the installation site.

Planning and design
- A site plan was prepared by Skeena Project Services Ltd. of Terrace.
- The site plan was used by a BCMOF engineer (Prince Rupert Forest Region) to produce a detailed, signed, and sealed set of design drawings.

- A benchmark and two reference points were established during the site plan field survey; inlet and outlet elevations were specified on the design drawings relative to the benchmark elevation.
- The road section at this location was straight and aligned perpendicular to the stream.
- The load rating of the embedded culvert is 68 tonnes.

Pre-installation works

- Fish isolation fences were installed prior to the installation date. Minnow traps were set overnight, and electroshocking was conducted in the morning, to capture and remove any fish present.
- A coffer dam made of lockblocks and sandbags was constructed on the upstream side of the installation site. Pumps and hoses were used to deliver water around the site. A gravity-fed diversion was also added because of high water flows caused by heavy rain that was in excess of pump capacity.

Construction works

- A & D Trucking Ltd. of Terrace installed the embedded culvert. The primary equipment used included a Linkbelt 3400 excavator, two Moxy rock trucks, and a Caterpillar 966 loader that was used for loading backfill and embedding material (pit-run).
- The pit-run material was delivered from a pit approximately 3.5 km away (one way).
- A plate compactor was used to compact 200-mm backfill lifts on either side of the culvert.

Embedment method

- Spray paint was used inside the culvert to indicate the desired fill height for embedding material.
- The excavator delivered pit-run material to both the inlet and outlet areas. This material was shovelled into wheelbarrows and delivered within the culvert. Wheelbarrows worked from each end of the culvert, delivering the embedding material to the centre of the culvert and working towards their respective ends.

Additional information

- The pit-run material used for constructing the simulated streambed through the length of the culvert contained a mix of aggregate sizes, which essentially filled the voids and promoted the stream flow to the surface.

Figure 2b. Culvert inlet showing pool area and shallow fill height above culvert.

Observations and comments

- The beaver dam upstream has created a large pool.
- Exposed soils were hand-seeded following the culvert installation and were well established with grasses during the field visit.

Prepared designs

BCMOF, Prince Rupert Region, 2000. West Kalum FSR - km 18.6 Benoit Creek Culvert Design. Prepared for Kalum Forest District, Terrace, B.C.

For further information:

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Site 3

Embedded pipe arch at an unnamed creek, Prince George Forest District

Location
Prince George Forest Region
Prince George Forest District
West Lake Connector, km 0.5
Crossing: unnamed

Company/proponent
Canadian Forest Products Ltd.,
Prince George Division

Date of installation/field visit
September, 2001/October 23, 2002

Figure 3a. Embedded pipe arch one year after installation, showing armoured streambanks, height of fill, and varying sizes of riprap and embedding material.

Table 3. Culvert, site, and installation data—Site 3

Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	2060
Rise (mm)	1520
Length (m)	14.9
Installed culvert gradient (%)	1.9
Simulated streambed gradient (%)	2.2
Avg. depth of embedding material (mm % rise)	350, 23.0
Avg. natural stream width and gradient (m, %)	1.6, 1.0
Stream classification	S3
Design flood event (m^3/s)	7.7
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Planning & design ($)	5 125
Materials ($)	1 792
Delivered culvert ($)	12 652
Installation ($)	23 033
Compaction testing ($)	260
Monitor, certification, reports ($)	6 314
Total ($)	49 176

Project description
- Two corrugated round metal pipes were replaced with an embedded pipe arch. Both round pipes were approximately 10 m long, and 600 mm and 300 mm in diameter. The pipes were undersized for the channel and flow characteristics of the stream.
- The selected replacement structure was a closed-bottom corrugated-steel embedded pipe arch culvert (Table 3, Figures 3a and 3b).

Habitat description/indicators
- Electroshocking within the creek determined that rainbow trout were present.
- The natural streambed's upper layer contains predominantly very fine and/or organic material. The stream near the crossing site is abutted by a deciduous stand, resulting in an abundance of leaf litter present within the stream.
- Small deposits of sand and/or gravel were located in areas of deposition.
- The stream has well-defined banks.

Planning and design
- A site plan and detailed, signed and sealed set of design drawings were produced by AllNorth Consultants Limited of Prince George.
- Three benchmarks were established in the field during the site plan field survey and were referenced on the design drawings. Two working points were also referenced on the design drawings.
- The working points showed the precise desired position (including elevation) of the culvert invert (bottom) at the inlet and outlet.
- The native streambed composition was sampled and shown on the design drawings: 40% silt, 30% from 1 to 5 mm, 15% from 5 to 50 mm, and 15% from 50 to 250 mm.

Pre-installation works
- A gravity-fed diversion culvert was used to de-water the work site prior to any installation work. Pumps and hoses were also on-site to de-water the stream if required.

Construction works

- Blackwater Construction Ltd. of Prince George installed the embedded culvert. The primary equipment used during the installation consisted of two Caterpillar 225 excavators.
- An environmental consulting firm provided on-site supervision during the installation and approved the materials (local gravel material, washed gravel, and washed riprap) placed within the culvert.
- After placing the material within the culvert, the material was flushed with water, which was collected and pumped onto the forest floor (to filter). This process was done until the water was running clearly.
- A 450-kg diesel plate compactor was used for compacting beside and over the culvert. Compaction tests were done to verify proper compaction of the culvert backfill material.

Embedment method

- The culvert was filled using a small trailer pulled by a four-wheel-drive all-terrain vehicle. Wheelbarrows were also on-site. The larger material within the culvert measured 30 cm in diameter.
- The design drawings specified the use of clean gravel for the simulated streambed, with pieces of riprap equal to the largest 10% of existing material, placed at 50-cm spacing.

Additional information

- The design channel width through the culvert was to be 1.7 m (average) as per an environmental management plan; the constructed width of the simulated streambed is approximately 2.0 m.

Observations and comments

- A rock spur was built of riprap to help prevent road and/or ditch water from entering the stream directly from the ditchline. The spur will also act as a sediment trap, reducing suspended sediment delivery into the stream (Figure 3c).
- Fillslopes and exposed banks were seeded with a reclamation mixture (mainly grasses).

Figure 3b. Outlet of embedded culvert.

Figure 3c. Looking downstream from culvert outlet showing deciduous forest, and rock spur on left hand side of image (arrow indicates obvert/ top of outlet).

Prepared designs

AllNorth Consultants Limited. 2001. Unnamed Creek, West Lake Connector, km 0+540. Design drawings prepared for Canadian Forest Products Ltd., Prince George Division. 3 pp.

For further information:

Wayne Patterson, Canadian Forest Products Ltd., 5162 Northwood Pulpmill Rd., P.O. Box 9000, Prince George, B.C., V2L 4W2. Tel.:(250) 962-3339, Fax.:(250) 962-3217, Email: wpatterson@mail.canfor.ca

Site 4

Embedded pipe arch at St. George Creek, Prince George Forest District

Location
Prince George Forest Region
Prince George Forest District
West Lake Connector, km 0.2
Crossing: St. George Creek

Company/proponent
Canadian Forest Products Ltd.,
Prince George Division

Date of installation/field visit
September, 2001/October 23, 2002

Figure 4a. Outlet of embedded pipe arch one year after installation showing submerged embedding material, height of fill, and riprap armouring.

Table 4. Culvert, site, and installation data—Site 4

Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	2590
Rise (mm)	1880
Length (m)	14.9
Installed culvert gradient (%)	1.1
Simulated streambed gradient (%)	1.2
Avg. depth of embedding material (mm % rise)	450, 23.9
Avg. natural stream width and gradient (m, %)	1.1, 1.9
Stream classification	S3
Design flood event (m^3/s)	5.0
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Planning & design ($)	5 125
Materials ($)	1 792
Delivered culvert ($)	15 669
Installation ($)	25 365
Compaction testing ($)	260
Monitor, certification, reports ($)	5 976
Total ($)	54 187

Project description
- Two corrugated round metal pipes were replaced with an embedded pipe arch. Both round pipes were approximately 12 m long and 600 mm in diameter. The pipes were undersized for the channel and flow characteristics of the stream.
- The selected replacement structure was a closed-bottom corrugated-steel embedded pipe arch culvert (Table 4, Figures 4a and 4b).

Habitat description/indicators
- Electroshocking within the creek determined that rainbow trout were present.
- The natural streambed's upper layer contains predominantly very fine and/or organic material. The stream near the crossing site is abutted by grasslands and a deciduous stand, resulting in an abundance of leaf litter within the stream.
- Large woody debris was present within the stream near the crossing location, including one piece submerged into the streambed near the outlet of the culvert.
- The stream has well-defined banks and ranged in width from 90 to 163 cm. Water depth during the field visit ranged from 9 to 15 cm (measured near the centre of the stream); bank indicators of high water depths measured from 16 to 40 cm.
- Based on limited observations by FERIC and/or the cooperators during the field review, the stream habitat was considered to be "Marginal" (the installation pre-dates the March 2002 Fish-stream Crossing Guidebook).

Planning and design
- A site plan and detailed, signed and sealed set of design drawings were produced by AllNorth Consultants Limited of Prince George.
- Three benchmarks were established in the field during the site plan field survey and were referenced on the design drawings. Two working points were also referenced on the design drawings. The working points showed the precise desired position (including elevation) of the culvert invert (bottom) at the inlet and outlet.

- The native streambed composition was sampled and shown on the design drawings: 60% silt, 30% from 5 to 50 mm, 10% from 50 to 250 mm.

Pre-installation works

- A gravity-fed diversion culvert was used to de-water the stream prior to any installation work. Pumps and hoses were also on-site to de-water the stream if required.

Construction works

- Blackwater Construction Ltd. of Prince George installed the embedded culvert. The primary equipment used during the installation consisted of two Caterpillar 225 excavators.
- An environmental consulting firm provided on-site supervision during the installation and approved the materials (local gravel material, washed gravel [Figure 4c], and riprap) placed within the culvert.
- The design drawings specified the use of clean gravel for the simulated streambed, with pieces of riprap equal to the largest 10% of existing material interspersed at 50-cm spacing.
- After placing the material within the culvert, the material was flushed with water which was then collected and pumped onto the forest floor (to filter). This process was done until the water was running clear.
- A 450-kg diesel plate compactor was used for compacting beside and over the culvert. Compaction tests were done to verify proper compaction of the backfill material.

Embedment method

- The culvert was filled using a small trailer pulled by a four-wheel-drive all-terrain vehicle. Wheelbarrows were also on-site. The larger material within the culvert measured 37 cm in diameter.

Additional information

- The design channel width through the culvert was to be 2.1 m (average) as per an environmental management plan; the constructed width of the simulated streambed is approximately 2.4 m.

Observations and comments

- Fillslopes and exposed banks were seeded with a reclamation mixture (mainly grasses).

Figure 4b. Inlet of embedded culvert showing leaf litter and gravel material placed within the culvert.

Figure 4c. Gravel material placed within the culvert.

Prepared designs

AllNorth Consultants Limited. 2001. St. George Creek, West Lake Connector, km 0+183. Design drawings prepared for Canadian Forest Products Ltd., Prince George Division. 3 pp.

For further information:

Wayne Patterson, Canadian Forest Products Ltd., 5162 Northwood Pulpmill Rd., PO Box 9000, Prince George, B.C., V2L 4W2. Tel.:(250) 962-3339, Fax.:(250) 962-3217, Email: wpatterson@mail.canfor.ca

Site 5

Embedded multiplate pipe arch at an unnamed creek, Mackenzie Forest District

Location
Prince George Forest Region
Mackenzie Forest District
Finlay-Philip Forest Service Road, km 4.8
Crossing: unnamed

Company/proponent
Slocan Group, Mackenzie Operations

Date of installation/field visit
July 15–18, 1999/October 24, 2002

Figure 5a. Culvert three years after installation, showing naturally deposited bedload material.

Table 5. Culvert, site, and installation data—Site 5

Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	3100
Rise (mm)	1980
Length (m)	19.5
Installed culvert gradient (%)	1.7
Simulated streambed gradient (%)	2.1
Avg. depth of embedding material (mm, % rise)	490, 24.7
Avg. natural stream width and gradient (m, %)	2.4, 2.3
Stream classification	S3
Design flood event (m^3/s)	8.7
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Planning & design ($)	2 800
Materials ($)	3 216
Delivered culvert ($)	18 881
Installation ($)	33 668
Other ($)	2 128
Total ($)	60 693

Project description
- Five round corrugated metal culverts were replaced with an embedded pipe arch. The round pipes were 600 and 800 mm in diameter, and ranged in length from 13.5 to 18 m. Four of the round culverts were positioned above the streambed and water passed through during high flows. One culvert was positioned at the streambed level and year round flows passed through.
- The selected replacement structure was a closed-bottom corrugated-steel embedded multiplate pipe arch culvert (Table 5, Figures 5a–c).
- The replacement was funded by Forest Renewal BC.

Habitat description/indicators
- The stream was assumed to contain resident bull trout, rainbow trout, dolly varden, and grayling.
- The stream ranged in width from 203 to 265 cm. Water depths during the field visit ranged from 8 to 15 cm (measured near the centre of the stream at various locations); bank indicators of high water depths measured from 21 to 54 cm.
- Based on limited observations by FERIC and/or the cooperators during the field review, the stream habitat was considered to be "Marginal" (the installation pre-dates the March 2002 Fish-stream Crossing Guidebook).

Planning and design
- A site plan and detailed, signed, and sealed set of design drawings were produced by D.R. Estay Engineering Ltd. of Prince George.
- Three benchmarks were established in the field during the site plan field survey. Three working points were referenced on the design drawings. The working points showed the precise desired location (including elevation) of the installed culvert invert at the inlet and outlet, as well as the post-installation road centreline.

- The native streambed composition was sampled and shown on the design drawings: 20% from 0 to 2 mm (sand/silt), 40% from 2 to 64 mm (gravel), 35% from 64 to 256 mm (cobbles), and 5% greater than 256 mm (boulders).

Pre-installation works

- A temporary log-sill bridge was installed downstream from the work site, allowing the road to remain open for forestry operations.
- Three silt fences were installed downstream of the installation site.
- At the upstream side of the work site, an earthfill dam wrapped with filter fabric diverted stream flow into a diversion pipe. This allowed the installation of the new culvert to take place in a de-watered work site.
- A sump hole was excavated at each end of the proposed embedded culvert placement. Pumps and hoses were used to pump sediment-laden water from the sump holes onto the forest floor.

Construction works

- Ruskin Construction Ltd. of Prince George installed the embedded culvert. AllNorth Consultants Ltd. of Prince George supervised the installation.
- AGRA Earth and Environmental Limited of Prince George conducted field (nuclear) and laboratory (standard Proctor) density/ compaction tests of the culvert backfill material. A driveable roller compactor achieved the designed level of compaction by compacting 200-mm lifts of select granular backfill.
- The embedded culvert was delivered pre-assembled and installed as one piece. Two excavators were required to lift and place the culvert.

Embedment method

- The culvert was installed 400 mm below the streambed and left to naturally fill with stream bedload material.

Additional information

- Some of the removed culverts were used for diverting the stream flow.

Figure 5b. Looking downstream through the embedded culvert, showing the stream flowing along one side of the culvert at this location.

Figure 5c. Outlet of embedded culvert showing height of fill, riprap armouring, and a small root wad deposited during high flows.

Observations and comments

- The position of the low-flow channel shifts within the culvert due to changes in the streambed caused by high-flow events. At the time of the field visit, the majority of the low-flow channel was located adjacent to one side of the culvert (Figure 5b). Hand-made rock spurs could be used to force the flow away from the edge of the culvert.
- The embedded culvert was delivered pre-assembled. The delivered culvert cost in Table 5 includes the supplier's assembly charge.

Prepared designs

D.R. Estey Engineering Ltd. 1998. Unnamed Creek Crossing, km 4.8 Finlay-Philips F.S.R. Design drawings prepared for Slocan Group, Mackenzie Operations. 6 pp.

For further information:

Brent Sinclair, RPF, Slocan Group, Mackenzie Operations, P.O. Box 310, Mackenzie, B.C., V0J 2C0. Tel.: (250) 997-2582, Fax.: (250) 997-2639, Email: sinclairb@mackenzie.slocan.com

Site 6

Embedded multiplate pipe arch at Reed Creek, Mackenzie Forest District

Location
Prince George Forest Region
Mackenzie Forest District
Finlay-Philip Forest Service Road, km 21.7
Crossing: Reed Creek

Company/proponent
Slocan Group, Mackenzie Operations

Date of installation/field visit
August 6–9, 1998/October 24, 2002

Figure 6a. Outlet of embedded culvert.

Table 6. Culvert, site, and installation data—Site 6

Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	3730
Rise (mm)	2290
Length (m)	22.6
Installed culvert gradient (%)	1.8
Simulated streambed gradient (%)	1.5
Avg. depth of embedding material (mm, % rise)	345, 15.1
Avg. natural stream width and gradient (m, %)	4.0, 1.3
Stream classification	S3
Design flood event (m^3/s)	9.7
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Planning & design ($)	3 124
Materials ($)	5 052
Delivered culvert ($)	16 105
Installation ($)	43 827
Other ($)	2 154
Total ($)	70 262

Project description
- Two round corrugated metal culverts were replaced with an embedded pipe arch. Both round culverts were 900 mm in diameter and approximately 19 m long. One culvert was positioned above the streambed and passed water during high flows. The other culvert was positioned at the streambed level and passed year-round flows.
- The replacement structure was a closed-bottom corrugated-steel embedded multiplate pipe arch culvert (Table 6, Figures 6a–c).
- The replacement was funded by Forest Renewal BC.

Habitat description/indicators
- The stream was assumed to contain resident bull trout, rainbow trout, dolly varden, and grayling.
- The stream ranged in width from 359 to 460 cm. Water depth during the field visit date ranged from 9 to 19 cm (measured near the centre of the stream at various locations); bank indicators of high water depths measured from 19 to 39 cm.
- Based on limited observations by FERIC and/or the cooperators during the field review, the stream habitat was considered to be "Important" (the installation pre-dates the March 2002 Fish-stream Crossing Guidebook).

Planning and design
- A site plan and detailed, signed and sealed set of design drawings were produced by D.R. Estay Engineering Ltd. of Prince George.
- Materials Testing Services in Prince George conducted sieve analysis of the proposed backfill material adjacent to the culvert.
- Three benchmarks were established in the field during the site plan field survey and referenced on the design drawings. Three working points were also referenced on the design drawings.
- The working points showed the precise desired location (including elevation) of the installed culvert invert at the inlet and outlet, as well as the post-installation road centreline.

- The native streambed composition was sampled and shown on the design drawings: 20% from 0 to 2 mm (sand/silt), 50% from 2 to 64 mm (gravel), 25% from 64 to 256 mm (cobbles), and 5% greater than 256 mm (boulders).

Pre-installation works

- A temporary log-sill bridge was installed downstream from the proposed embedded culvert installation site, allowing the road to remain open for forestry operations.
- Silt fences were installed downstream of the installation site.
- A soil dam wrapped with filter fabric was used to de-water the installation site by redirecting stream flow into a diversion pipe.
- A sump hole was excavated at each end of the proposed embedded culvert placement. Pumps and hoses were used to pump sediment-laden water from the sump holes onto the forest floor.

Construction works

- Ruskin Construction Ltd. of Prince George installed the embedded culvert. AllNorth Consultants Ltd. of Prince George supervised the installation. AGRA Earth and Environmental Limited of Prince George conducted field (nuclear) and laboratory (standard Proctor) density/compaction tests of the culvert backfill material used around the installed culvert.
- A drivable and handheld roller compactor achieved the designed level of compaction by compacting 200-mm lifts of select granular backfill.

Embedment method

- The culvert was installed 460 mm below the streambed and left to naturally fill with stream bedload material. Boulder lines were placed at 1-m spacing through the length of the culvert to reduce stream flow energy and promote bedload deposition/streambed development.

Additional information

- The embedded culvert was delivered unassembled (eliminating the pre-assembly charge). Additional labour was required to assemble the culvert.

Figure 6b. Hand-placed boulders during installation (photo courtesy of Slocan Group, Mackenzie).

Figure 6c. Embedded culvert showing boulders intermingled with natural deposits of sand and gravel.

Observations and comments

- Deposition of streambed material has occurred within the culvert. Small portions of the culvert were devoid of substrate (Figure 6c).
- Some of the smaller hand-placed boulders have moved and shifted within the culvert, while others have migrated downstream. The larger boulders have assisted in retaining natural bedload material.

Prepared designs

D.R. Estey Engineering Ltd. 1998. Reed Creek Crossing, km 21.7 Finlay-Philips F.S.R. Design drawings prepared for Slocan Group – Mackenzie Operations. 6 pp.

For further information:

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Site 7

Embedded pipe arch at an unnamed creek, Fort St. James Forest District

Location
Prince George Forest Region
Fort St. James Forest District
Meridian North, 500 Road, km 6.0
Crossing: unnamed

Company/proponent
Canadian Forest Products Ltd.,
Fort St. James Operations

Figure 7a. Looking towards inlet of embedded culvert showing cobbles along surface of simulated streambed and additional embedding material placed near the inlet.

Table 7. Culvert, site, and installation data—Site 7

Culvert shape	pipe arch
Culvert dimensions	
Span (mm)	1390
Rise (mm)	970
Length (m)	10
Installed culvert gradient (%)	2.9
Simulated streambed gradient (%)	2.9
Avg. depth of embedding material (mm, % rise)	260, 26.8
Avg. natural stream width and gradient (m, %)	0.9, 3.7
Stream classification	S4
Design flood event (m^3/s)	0.7
Site plan prepared	no
Detailed design drawings prepared	no
Cost estimates	
Supervision and survey ($)	2 159
Materials ($)	955
Delivered culvert ($)	2 166
Installation ($)	7 215
Fish isolation and salvage ($)	636
Total ($)	13 131

Date of installation/field visit
August 14–15, 2002/October 25, 2002

Project description
- The road was newly built and, during road construction, the unnamed stream had been crossed using a temporary modular steel bridge.
- The temporary bridge was removed and replaced with a permanent closed-bottom corrugated-steel embedded pipe arch culvert (Table 7, Figures 7a–c).

Habitat description/indicators
- The stream was assumed to contain rainbow trout; kokanee and burbot are also assumed by default due to the lack of barriers and the stream's connectivity to the Tsilcoh River. The stream joins the Tsilcoh River (an S2 stream) approximately 300 m downstream of the culvert installation.
- The stream has a well-defined channel and contains very low flows during the summer. Much of the stream has a sandy bottom and small deposits of gravel are present. Deep pools are not present in the vicinity of the road crossing.
- Based on limited observations by FERIC and/or the cooperators during the field review, the stream habitat was considered to be "Marginal".

Planning and design
- No site plan or design drawings were prepared.
- During the installation, precision survey equipment was used to guide the depth (elevation) of excavation. Benchmarks were established in the field and pre-installation measurements were taken along the stream. Target elevations for the culvert invert at the inlet and outlet were determined in the field, and were approximately 25 cm below the original stream channel.

Pre-installation works
- Stop nets were installed upstream and downstream of the site to keep fish from entering the area.

- A fish salvage was conducted to identify and remove any fish present; no fish were captured.
- A temporary sandbag dam was constructed on the upstream side of the installation site. A pump-and-hose system delivered water around the site.

Construction works

- K & D Logging Ltd. of Fort St. James installed the embedded culvert using a Hitachi 200 excavator. A plate compactor was used to compact the backfill material around the outside of the culvert.
- Environmental Dynamics Inc. of Prince George provided on-site supervision.

Embedment method

- The culvert was filled by hand, using buckets to deliver material through the culvert (Figure 7b).
- The majority of the material used within the culvert was road fill gravel. Approximately six rock lines, made of larger-sized cobbles, were installed prior to completing the infill. The rock lines are expected to help keep the finer material in place. This was capped with a layer of delivered drain rock. Large cobbles were placed randomly over the surface to promote the development of a low-flow channel.
- The corrugated culvert was delivered in two sections with a coupler (including nuts and bolts). Once the first section was in place, the forest workers started to fill it with aggregate.
- By filling the first section from both ends, a shorter distance was travelled within the culvert during the delivery of the aggregate.
- Additional embedding material was placed within the culvert near the inlet to promote further embedment (Figures 7a and 7c).

Additional information

- The gravel material used within the culvert was chosen for its mix of sizes. This mix helped to fill voids within the simulated streambed, and maintain surface streamflow in the culvert.
- The stream was sampled for fish during 2000 and 2001; no fish were captured/observed either time.

Figure 7b. Worker delivering material within the culvert during installation (photo courtesy of Canadian Forest Products Ltd., Fort St. James).

Figure 7c. Inlet of embedded culvert showing riprap armouring, use of drain rock along the ditch and fill slope, and minimal disturbance to natural streambank.

Observations and comments

- Construction caused minimal disturbance to the natural streambank immediately upstream and downstream of the installed culvert.
- The additional embedding material near the inlet will migrate during high flow events and blend with the embedding material downstream.

Prepared report

Environmental Dynamics Inc. 2002. Summary of environmental services provided for the installation of an embedded pipe arch on an unnamed tributary to the Tsilcoh River. Summary report prepared for Canadian Forest Products Ltd., Fort St. James Operations. 6 pp.

For further information:

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Site 8

Embedded round culvert at an unnamed creek, Clearwater Forest District

Location
Kamloops Forest Region
Clearwater Forest District
Vavenby-Adams Forest Service Road, km 13.2
Crossing: unnamed (BCMOF structure no. K845)

Company/proponent
BCMOF, Kamloops Forest Region

Date of installation/field visit
August, 1996/November 13, 2002

Figure 8a. Embedded culvert six years after installation showing various sizes of material retained within the culvert.

Table 8. Culvert, site, and installation data—Site 8

Culvert shape	round
Culvert dimensions	
Diameter (mm)	3400
Length (m)	34
Installed culvert gradient (%)	5.5
Simulated streambed gradient (%)	5.8
Avg. depth of embedding material (mm, % diam.)	820, 24.1
Avg. natural stream width and gradient (m, %)	2.2, 3.8
Stream classification	S3
Design flood event (m^3/s)	5.0
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Planning & design ($)	n/a [a]
Site survey ($)	1 200
Delivered culvert ($)	18 398
Supervision, installation, & materials ($)	31 427
Total ($)	51 025

[a] Design drawings produced in-house, no costs available.

Project description
- A 6-m-span by 6-m-wide log stringer bridge, supported on a 6.5-m-high log crib, was replaced. The log bridge structure was nearing the end of its effective life.
- The replacement structure is a closed-bottom corrugated-steel embedded round culvert (Table 8, Figures 8a–c).
- The replacement was funded by the BCMOF Bridge Replacement Program.

Habitat description/indicators
- The stream was assumed to contain rainbow trout.
- The stream reaches adjacent to the installation site were observed to contain an abundance of large woody debris.
- The water depth during the field visit ranged from 6 to 19 cm (measured near the centre of the stream at various locations). Bank indicators of high water depths measured from 24 to 37 cm.

Planning and design
- A site plan and detailed, signed, and sealed set of design drawings were prepared by the BCMOF, Kamloops Forest Region.
- The embedded culvert was installed approximately 10 m (towards higher chainage along the road) from the existing bridge location. The new location was selected and designed considering road alignment, road parameters (width, fill height, and fill slope angles), and the meandering stream channel.
- The native streambed composition was noted on the design drawings to contain cobbles, and boulders up to 600 mm in diameter.

Pre-installation works
- The stream primarily flowed in the natural stream channel and under the existing bridge during the embedded culvert installation.
- A short diversion channel near the inlet location of the embedded culvert was constructed to keep the stream flow from entering the work site. The diversion channel was lined with geotextile material to minimize sediment delivery into the stream.

Construction works

- On-site supervision, equipment/contractor coordination, and surveying were done by Troll Bridge Services of Penticton.
- A surveyor using precision survey equipment guided the excavation.
- A downstream sump was excavated to collect sediment-laden water. Pumps were used to remove the water from the sump and deliver it onto the forest floor away from the stream.

Embedment method

- A rubber-tired Bobcat loader delivered material within the culvert. The loader entered the culvert at the inlet. The loader deposited material within the culvert starting at the outlet and worked through the culvert towards the inlet.
- Larger cobbles and boulders were hauled to the site. Gravel and fine material were developed from the excavated material. The loader alternated loads of boulders and cobbles, with loads of gravels and fines.
- After the material was placed within the culvert, it was washed using pumped stream water. This helped to fill the voids within the delivered material and any initial suspended sediment was washed into the sump at the outlet.

Additional information

- The culvert was designed and constructed with a 1.5 to 1 step-bevel at the inlet. A step-bevel creates a distinct top and bottom to a round culvert section.
- The culvert was comprised of four sections. Prior to coupling two sections, the abutted sections were wrapped with a fibreglass insulation. This wrapping technique filled any prominent gaps between joined sections.

Observations and comments

- The height of fill over the culvert was approximately 5.5 m.

Figure 8b. Outlet of embedded culvert.

Figure 8c. Inlet of culvert showing step-bevel and high water markings along culvert wall.

Prepared designs

BCMOF, Kamloops Forest Region, 1996. Proposed replacement of Bridge #K058 - km 13.2 Vavenby Adams FSR. Design drawings. 4 pp.

For further information:

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Site 9

Embedded round culvert at Chuck Creek, Clearwater Forest District

Location
Kamloops Forest Region
Clearwater Forest District
Chuck Creek Forest Service Road, km 7.3
Crossing: Chuck Creek
(BCMOF structure no. K1104)

Company/proponent
BCMOF, Kamloops Forest Region

Date of installation/field visit
August, 2000/November 13, 2002

Figure 9a. Embedded culvert two years after installation showing various sizes of material retained within the culvert.

Table 9. Culvert, site, and installation data—Site 9

Culvert shape	round
Culvert dimensions	
Diameter (mm)	3300
Length (m)	20
Installed culvert gradient (%)	0.9
Simulated streambed gradient (%)	1.4
Avg. depth of embedding material (mm, % diam.)	600, 18.2
Avg. natural stream width and gradient (m, %)	2.7, 4.0
Stream classification	S3
Design flood event (m^3/s)	5.0
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Planning & design ($)	n/a [a]
Site survey ($)	1 000
Delivered culvert ($)	12 138
Supervision, installation, & materials ($)	23 961
Total ($)	37 099

[a] Design drawings produced in-house, no costs available.

Project description
- A 4-m-span by 6-m-wide log bridge, supported on a 4-m-high log crib, was replaced. The log bridge structure was nearing the end of its effective life.
- The replacement structure is a closed-bottom corrugated-steel embedded round culvert (Table 9, Figures 9a–c).
- The replacement was funded by the BCMOF Bridge Replacement Program.

Habitat description/indicators
- The stream was assumed to contain rainbow trout.
- The water depth during the field visit ranged from 8 to 11 cm (measured near the centre of the stream at various locations). Bank indicators of high water depths measured from 18 to 39 cm.

Planning and design
- Integrated Woods Services Ltd. of Kamloops carried out a site survey and produced a detailed site plan.
- A detailed, signed, and sealed set of design drawings was produced by the BCMOF, Kamloops Forest Region.

Pre-installation works
- Stop nets were installed upstream and downstream of the installation site to prevent fish from entering the area. The stream length between the nets was electrically shocked to locate and remove any fish present.
- A soil dam covered with plastic was used to de-water the site. The dam diverted the stream flow into a diversion pipe.

Construction works
- On-site supervision, equipment/contractor coordination, and surveying were done by Troll Bridge Services of Penticton.
- Filter fabric and hay bales were installed downstream as sediment traps prior to commencement of excavation works. The log bridge was dismantled and piled on site. A downstream sump was excavated to collect sediment-laden water. Pumps were used to remove the water from the sump and deliver it onto the forest floor away from the stream.

- A surveyor using precision survey equipment guided the excavation.

Embedment method

- A rubber-tired Bobcat loader delivered material within the culvert. The loader deposited material within the culvert starting at the outlet and worked through the culvert towards the inlet.
- Larger cobbles and boulders were hauled to the site. Gravel and fine material were developed from the excavated material. The loader alternated loads of boulders and cobbles, with loads of gravels and fines.
- After the material was placed within the culvert it was hosed down with clean pumped stream water to "seal" the surface and minimize the initial sediment flush when the streamflow was reintroduced.

Additional information

- The culvert was designed and constructed with a 1.5 to 1 step-bevel at the inlet. A step-bevel creates a distinct top and bottom to a round culvert section.
- The culvert was comprised of two sections. Prior to coupling two sections, the abutted sections were wrapped with a fibreglass insulation. This wrapping technique filled any prominent gaps between the joined sections.

Observations and comments

- The height of fill over the culvert was approximately 1.5 m.
- Exposed soils along the fillslopes were seeded with a grass mixture at the time of the installation. There is a continuous cover of vegetation along the fillslope areas without riprap armouring (Figure 9c).

Prepared designs

BCMOF, Kamloops Forest Region. 2000. Proposed replacement of Chuck Creek Bridge - km 7.3 Chuck Creek FSR. Design drawings. 4 pp.

Figure 9b. Various sizes of aggregate within the culvert (hat can be used for scale).

Figure 9c. Inlet of culvert showing riprap armouring and height of fill over the culvert.

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Site 10

Embedded round culvert on tributary to Deer Lake, Kamloops Forest District

Location
Kamloops Forest Region
Kamloops Forest District
Taweel Forest Service Road, km 5.0
Crossing: tributary to Deer Lake

Company/proponent
Tolko Industries Ltd., Louis Creek Division

Date of installation/field visit
October, 2001/November 14, 2002

Figure 10a. Looking towards the culvert inlet, showing simulated streambed one year after installation.

Table 10. Culvert, site, and installation data—Site 10

Culvert shape	round
Culvert dimensions	
Diameter (mm)	1600
Length (m)	14
Installed culvert gradient (%)	3.5
Simulated streambed gradient (%)	2.8
Avg. depth of embedding material (mm, % diam.)	620, 38.8
Avg. natural stream width and gradient (m, %)	1.3, 3.5
Stream classification	S3
Design flood event (m^3/s)	unknown
Site plan prepared	no
Detailed design drawings prepared	no
Cost estimates	
Supervision and survey ($)	1 140
Delivered culvert ($)	2 330
Installation and materials ($)	8 600
Total ($)	12 070

Project description
- A 600-mm-diameter, 10-m-long round steel corrugated culvert was replaced. The culvert was undersized for peak streamflows and had a perched outlet posing a barrier to fish passage.
- The stream flow was passed through an existing adjacent culvert during construction; this adjacent culvert was removed after installation of the embedded culvert.
- The replacement structure is a closed-bottom corrugated-steel embedded round culvert (Table 10, Figures 10a–c).
- The replacement was funded by Forest Renewal BC.

Habitat description/indicators
- The stream contains rainbow trout.
- The stream formed a pond immediately upstream of the installation site. The stream ranged in width from 129 to 135 cm. Water depth during the field visit ranged from 8 to 11 cm, and bank indicators of high water depth ranged from 22 to 28 cm.
- The crossing location is approximately 30 m upstream from Deer Lake.
- Habitat was improved by the installation of the embedded culvert. The installation allowed fish access to additional rearing areas and approximately 2 km of stream length.

Planning and design
- No site plan or design drawings were produced.
- The embedded culvert replaced the undersized and perched culvert. During the installation, precision survey equipment was used to guide the depth of excavation. Benchmarks were established in the field and pre-installation measurements were taken upstream and downstream of the existing culverts. Target elevations for the embedded culvert's invert at the inlet and outlet were determined in the field during installation.
- Culvert centreline stakes were established upstream and downstream of the installation site to guide the excavation.

Pre-installation works

- A dam consisting of sand and gravel filled livestock feed bags was built to isolate the work site and divert the stream flow through an adjacent (second) culvert. This allowed the installation work to take place in dry conditions.

Construction works

- Hy-Pro Contracting of Kamloops installed the embedded culvert. The primary equipment used was a Hitachi 270 excavator and a rock truck.
- D.S. Cunliffe Consulting Services of Kamloops conducted on-site surveying during the installation.
- Two loads (approximately 22 m^3) of pit run material were hauled to the site for use within the culvert. This unwashed material was chosen for its mix of aggregate sizes, which helped to fill the voids within the simulated streambed.
- Riprap was hauled to the site for use as armouring and for placement within the culvert.

Embedment method

- Wheelbarrows were used to deliver the material within the culvert. Rakes and shovels were used to move and spread the material within the culvert.
- Riprap and/or boulders were placed within and along the surface of the simulated streambed.

Additional information

- The simulated streambed's width through the culvert averaged 149 cm.
- The culvert was delivered in two sections with a coupler. The inlet and outlet were constructed with a 1.5 to 1 step-bevel.
- The large-sized livestock feed bags, when filled with material, made the dam building fast and efficient. Fewer bags were needed compared to smaller traditional sandbags.
- The installation site is immediately adjacent to a B.C. Forest Service recreation site located at Deer Lake. The lake provides recreational fishing opportunities.

Figure 10b. Looking upstream showing the size of larger material within the culvert and riprap armouring of the fill slope.

Figure 10c. Looking upstream towards embedded culvert showing stream channel, height of fill above culvert, and road grade.

Observations and comments

- The maximum height of fill over the culvert was 1.1 m.
- The road grade was constructed so that the lowest section was away from the stream crossing, preventing potential road runoff from directly entering the stream.

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Site 11

Embedded round culvert with baffles on tributary (Stream no. 11) to Lewis Lake, Sunshine Coast Forest District

Location
Vancouver Forest Region
Sunshine Coast Forest District
Spring Lake Mainline, km 9.1
Crossing: tributary to Lewis Lake (Stream no. 11)

Company/proponent
Weyerhaeuser Company Limited, Stillwater Timberlands Operations

Date of installation/field visit
July, 2001/November 26, 2002

Figure 11a. Looking towards outlet of embedded culvert two years after installation. Note the large woody debris which has migrated into the culvert.

Table 11. Culvert, site, and installation data—Site 11

Culvert shape	round
Culvert dimensions	
Diameter (mm)	3000
Length (m)	17
Installed culvert gradient (%)	3.5
Simulated streambed gradient (%)	2.4
Avg. depth of embedding material (mm, % diam.)	867, 28.9
Avg. natural stream width and gradient (m, %)	1.7, 5.0
Stream classification	S3
Design flood event (m^3/s)	9.9
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Planning, design & env. monitor ($)	8 000
Delivered culvert ($)	10 652
Fish baffles for culvert ($)	7 160
Installation and materials ($)	26 174
Other ($)	200
Total ($)	52 186

Project description
- A closed-bottom corrugated-steel round culvert with baffles (Table 11, Figures 11a–c) was installed as an embedded structure for a stream crossing on a newly built section of mainline road.
- The mainline road on which the embedded culvert was installed has eight different types of stream crossings. These eight crossings demonstrate the biological, operational, and economical attributes of various crossing structures.

Habitat description/indicators
- Electroshocking within the stream prior to the installation works confirmed the presence of cutthroat trout.
- The streambed's upper layer contains fines and gravel materials; some cobbles are also present. There is an abundance of large woody debris both spanning and within the stream channel.
- Based on limited observations by FERIC and/or the cooperators during the field review, the stream habitat was considered to be "Important" (the installation pre-dates the March 2002 Fish-stream Crossing Guidebook).

Planning and design
- A site plan and detailed, signed, and sealed set of design drawings were produced by StoneCroft Project Engineering of Black Creek. The embedded culvert was designed with eight baffles, each 600 mm high and placed 2 m apart.
- Two benchmarks were established in the field; culvert inlet and outlet elevations, relative to field benchmarks, were shown on the design drawings.
- The design load of the embedded culvert is approximately 150 tonnes.

Pre-installation works
- Nets were placed through the stream to prevent fish from entering the installation site. The stream flow during the installation was minimal.

Construction works

- Pilldolla Creek Contracting Ltd. of Powell River installed the embedded culvert. A 35-tonne and a 40-tonne excavator, and a rock truck were used for the installation. The larger diameter culvert required two excavators during installation, which is reflected in the cost estimates.
- Drain rock was hauled to the site for use within the culvert. Finer material generated from a nearby natural source was also used.

Embedment method

- A rubber-tired Bobcat loader initially delivered material within the culvert. However, the loader was not suited to travelling over the baffles. A powered and tracked self-dumping wheelbarrow was used to complete the delivery of the remaining material within the culvert. Conventional wheelbarrows were also on site and used when needed.
- After the material was placed within the culvert, it was "washed" using pumped stream water to help fill the voids. Suspended sediment was collected in a sump at the outlet and pumped onto the forest floor.

Additional information

- The culvert was delivered in two sections with a coupler; the inlet was constructed with a 1 to 1 step-bevel.
- The stream is part of a Weyerhaeuser study examining fish presence and abundance before and after installation of stream crossing structures. Cutthroat trout were located below, within and above the culvert during a six-month post-installation review.

Observations and comments

- Cobble-sized material from within the culvert has migrated approximately 9 m downstream in the two years since completion. A "stop-log" and/or weir-log at the outlet (Figure 11b) was completely covered with bedload material during the field visit. The height of material within the culvert completely covered all the baffles.
- Boulders placed along the surface of the simulated streambed, such as the boulder at the inlet of the culvert shown in Figure 11c, should be considered when designing the hydraulic capacity of the culvert.

Figure 11b. Outlet of embedded culvert, showing woody debris placed within the culvert and worker conducting final wash of simulated streambed (photo courtesy Weyerhaeuser, Stillwater Timberlands).

Figure 11c. Inlet of embedded culvert showing width of natural stream and undisturbed stream banks.

Prepared designs and assessments

StoneCroft Project Engineering. 2001. Spring Lake Mainline, Spring no. 11 @ 9+087. Design drawings prepared for Weyerhaeuser Company Limited, Stillwater Timberlands Operations, Powell River, B.C. 2 pp.

FishFor Contracting Ltd. 2001. Utilizing baffled metal culverts in fish streams. Preliminary assessment prepared for Weyerhaeuser Company Limited, Stillwater Timberlands Operations, Powell River, B.C. 41 pp.

For further information:

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Site 12

Embedded round culvert with baffles on tributary (Stream no. 14) to Lewis Lake, Sunshine Coast Forest District

Location
Vancouver Forest Region
Sunshine Coast Forest District
Spring Lake Mainline, km 10.5
Crossing: tributary to Lewis Lake (Stream no. 14)

Company/proponent
Weyerhaeuser Company Limited,
Stillwater Timberlands Operations

Date of installation/field visit
September, 2001/November 26, 2002

Figure 12a. Embedded culvert showing woody debris and an abundance of boulders within the culvert.

Table 12. Culvert, site, and installation data—Site 12

Culvert shape	round
Culvert dimensions	
Diameter (mm)	2400
Length (m)	15
Installed culvert gradient (%)	4.7
Simulated streambed gradient (%)	5.2
Avg. depth of embedding material (mm, % diam.)	932, 38.8
Avg. natural stream width and gradient (m, %)	1.8, 8.0
Stream classification	S3
Design flood event (m^3/s)	2.9
Site plan prepared	yes
Detailed design drawings prepared	yes
Cost estimates	
Planning, design & env. monitor ($)	5 000
Delivered culvert ($)	6 470
Fish baffles for culvert ($)	6 500
Installation and materials ($)	13 580
Other ($)	200
Total ($)	31 750

Project description
- A closed-bottom corrugated-steel round culvert with baffles (Table 12, Figures 12a–c) was installed as an embedded structure for a stream crossing on a newly built section of mainline road.
- The mainline road on which the embedded culvert was installed, has eight different types of stream crossings. These eight crossings demonstrate the biological, operational and economical attributes of various crossing structures.

Habitat description/indicators
- Electroshocking within the stream prior to the installation determined that no fish were present. The stream was treated as fish bearing due to its connectivity to Lewis Lake, approximately 900 m downstream. Lewis Lake contains coastal cutthroat trout, dolly varden, and rainbow trout.
- The water depth during the field visit ranged from 3 to 6 cm (measured near the centre of the stream at various locations). Bank indicators of high water depths measured from 14 to 33 cm.
- Based on limited observations by FERIC and/or the cooperators during the field review, the stream habitat was considered to be "Marginal" (the installation pre-dates the March 2002 Fish-stream Crossing Guidebook).

Planning and design
- A site plan and detailed, signed and sealed set of design drawings were produced by StoneCroft Project Engineering of Black Creek.
- Two benchmarks were established in the field; culvert inlet and outlet elevations, relative to field benchmarks, were shown on the design drawings.
- The culvert was designed with seven 600-mm-high notched baffles spaced at 2-m intervals. The baffles can be seen in Figure 12b.

Pre-installation works
- Nets were placed through the stream to keep fish from entering the installation site. The stream flow during the installation was minimal.

Construction works

- Pilldolla Creek Contracting Ltd. of Powell River installed the embedded culvert. A 35-tonne excavator and a rock truck were used for the installation.
- Boulders were hauled to the site for use within the culvert. Finer material generated from a nearby natural source was also used.

Embedment method

- A powered and tracked self-dumping wheelbarrow was used to deliver the material within the culvert. Conventional wheelbarrows were also on site and used when needed.
- After the material was placed within the culvert it was "washed" using pumped stream water to help fill the voids. Suspended sediment was collected in a sump at the outlet and pumped onto the forest floor.

Additional information

- The stream is part of a study examining fish presence and abundance before and after installation of stream crossing structures. No fish were located during a six-month post-installation review.
- The culvert was delivered in two sections with a coupler; the inlet was constructed with a 1 to 1 step-bevel.

Observations and comments

- The baffles within the culvert were completely covered with embedment material. The baffles may help to maintain material in the culvert (up to the height of the baffles).
- Woody debris had migrated into the culvert during high flows.
- Careful consideration should be given to the placement of large woody debris and its effect on the hydraulic capacity of a culvert.

Prepared designs and assessments

StoneCroft Project Engineering. 2001. Spring Lake Mainline, Spring no. 14 @ 10+452. Design drawings prepared for Weyerhaeuser Company Limited, Stillwater Timberlands Operations, Powell River, B.C. 2 pp.

FishFor Contracting Ltd. 2001. Utilizing baffled metal culverts in fish streams. Preliminary assessment prepared for Weyerhaeuser Company Limited, Stillwater Timberlands Operations, Powell River, B.C. 41 pp.

Figure 12b. Embedded culvert before placing material within it, showing height of baffles (photo courtesy Weyerhaeuser, Stillwater Timberlands).

Figure 12c. Inlet of embedded culvert showing height of fill, riprap armouring, and use of woody debris.

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