ACCESS OPTIONS FOR RIVER CROSSINGS

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INTRODUCTION

The development of a roading network for harvesting or forest establishment often involves the crossing of small streams and rivers. Each crossing will be site specific and many factors need to be considered when determining the most appropriate structure. This paper briefly describes crossing options commonly used in New Zealand and the advantages and disadvantages of each type of structure.

DETERMINING FACTORS

The type of crossing will depend on many factors. The more important ones are : -

- The stability of the banks and riverbed.
- The stream gradient.
- Height of the proposed road level relative to the stream.
- Flood flow levels.
- Whether all weather access is required.
- Availability of suitable fill.
- Access to the site for cranes, etc.
- Available funding.

A site with unstable banks and a frequently shifting stream should be avoided if possible. A culvert is usually unsuitable. Such situations often require the installation of expensive rip-rap protection, piled abutments and/or additional bridge spans.

Steep stream gradients often indicate rapid runoff. For bridges, a large waterway area may be necessary and scour of abutments and piers could be a problem. For culverts, a large pipe size may be required. Corrosion of the steel lining may also be a problem unless a roughened concrete base is laid. Additional scour protection will also be required at the outlet.

To obtain an acceptable grade it may be necessary to have a road level high above the stream. Where a wide and deep gully has to be crossed, crossing costs may be high if a long span bridge or high culvert fill is required. Usually the culvert will be the more cost effective solution.

Catchment and climate characteristics have an important influence on the flood flow and the required waterway area. The larger the waterway area, the higher the cost of the crossing. A bridge will usually be a lower risk structure over a high flood flow stream.

If all weather access is not required then a low cost battery culvert or ford may be acceptable.

If there is a lack of suitable fill for a culvert then a small log bridge may be an economic alternative to a culvert for a temporary logging access road.

A heavy lift crane is required when prestressed concrete bridge beams are to be lifted onto abutments. Usually a crane is required on each side of the stream. Heavy lift cranes are very expensive and their site time needs to be minimised by having good access to and firm ground on both sides of the proposed crossing. For example a 12m span prestressed bridge beam requires at least one 40 tonne crane for lifting into position. For limited life crossings a steel bridge with bolted precast deck slabs would be the appropriate type of crossing.

Available funding has an impact on the type of crossing chosen since this may limit the location and type of crossing.

FACTORS AFFECTING COSTS

The waterway area has the greatest effect on crossing size and cost. Therefore the smallest possible waterway that will be sufficient to pass most floods without problems should be provided. A bridge does not necessarily need to be clear of the 50 year or 100 year flood level if the cost is too great. A low level bridge which may be occasionally inundated could be an acceptable risk.

Savings in the crossing cost can also be made by keeping foundation investigations to a minimum. Careful inspection of the crossing site, reference to old photographs of floods, speaking to long term residents (where applicable), and use of a backhoe to dig an inspection trench or two will invariably provide sufficient information.

Where new river crossings are planned it is frequently worthwhile investigating several alignments to achieve the most cost effective and acceptable solution.

The cost of additional investigation will usually be recovered several times over.

Other factors that minimise bridge costs include :

- Keeping approach works to a minimum.
- Crossing the waterway at right angles.
- Keeping bridge structure and connections as simple as possible.
- Using gabions or crib walling instead of long and/or high concrete wingwalls.
- Detailed evaluation of the most economic structural members.

The end result should be a functional, permanent, low maintenance and minimum cost structure which is able to carry all road traffic and pass normal floods without problems.

DESIGN STANDARDS

In New Zealand bridges are designed to a national standard, the Transit NZ Highway Bridge Design Brief. Culverts are also designed to this standard in that the design standard determines the minimum cover over the pipe. The loading used by bridge design engineers is called HN-HO-72. HO denotes Highway Overload. It is a theoretical load on a bridge of two axles 5m apart and each of 24 tonne, and a uniformly applied live load on the deck of 350 Kg/m2. This is the appropriate loading in the design of permanent forest bridges. A lower design loading is used for bridges where approach speeds are low, and lower load criteria apply.

CROSSING OPTIONS

In the plantation forests of New Zealand there are many small streams and rivers, but few large ones. As a result, the majority of forestry bridges are less than 16m span.

The types of bridges constructed by the New Zealand forest industry are more limited than those used in the state highway system. For example you will rarely find steel truss, suspension or prestressed concrete I beam bridges in a forest environment. This is invariably due to the cost of these structural options.

For any specific site in difficult terrain there are three basic types of structures that may be appropriate. These are :

- Low level crossings
- Culverts
- Beam type bridges.

Although the type of terrain will determine the type of structure to a certain extent, it is the characteristics of the stream itself which really determine the most appropriate structure. For example in difficult terrain a stream may :

- have a wide but shallow waterway
- be deeply incised into a papa gorge
- have a confined channel and average gradient.

Assuming the terrain is the same, three different solutions are required.

The advantages and disadvantages of each type of crossing are listed in Appendix 1. and the site characteristics and relevant structures are listed in Appendix 2.

LOG BRIDGES

Log bridges using indigenous timber have been a traditional method of providing low cost river crossings. These days it is no longer environmentally or economically acceptable to use rimu logs.

Logs are structurally inefficient when used as bridge stringers. Allowable design stresses are low and deflections are high due to the wet condition of log bridges. A major disadvantage of untreated log bridges is their limited life. The life span of log bridges depends on the type of log species chosen, location, climate, and the construction method. For example the lack of an effective moisture barrier between the abutment logs and backfill inevitably reduces the life of the bridge. Moisture provides the ideal conditions for rapid timber decay. Placing gravel or soil on top of the logs is also guaranteed to greatly reduce the life of the bridge. Log bridges are suitable when short span temporary bridging is required, such as for forest establishment or short term logging.

CURRENT CONSTRUCTION COSTS

A large culvert and a bridge have recently been completed in Awahohonu Forest located 60 km north west of Napier.

The 2.4 m diameter x 32 m long corrugated steel culvert replaced an existing 14 m span log bridge. The rimu stringers and abutments were decayed and unsuitable for loaded logging trucks. Grades and approaches onto the bridge also were unsatisfactory. A culvert was the most appropriate structure for this site since a high road level was required to lower the approach grades and improve the alignment of the existing road. The first attempt at a new alignment resulted in excellent grades but excessive fill was needed. A second survey resulted in an alignment following the existing road closely with significantly less fill being required.

The 6 m fill over the culvert and skew to the road resulted in a 32 m long culvert. The cost of culvert installation, back filling, reconstruction of 300 m of road, and inlet and outlet protection works cost $55,000. The work, including removal of the existing log bridge was completed in six weeks.

A bridge consisting of two double tee prestressed beams on precast concrete abutments was used to replace an existing log bridge which was unsuitable for loaded logging trucks. The site characteristics were ideal for a single span bridge. Due to the distance of the site from major population centres a structure that minimised on-site labour costs was chosen. The double tee 12m span beams were more economical than double hollow core units. Additional advantages were that the double tee beams were available complete with precast abutments, bearing pads and hold down bolts, were simpler to install, were relocatable, maximised waterway area and would have minimal long term maintenance costs. Five tenders were received, ranging from $45,000 to $52,000. The bridge was completed in six weeks.

Double tee beams cost approximately $400/m. Two are required for a single lane bridge of 3.6 m width.

I have recently costed and designed a bridge to span 29 m across a deep gorge. Fortunately it was possible to support the bridge at 1/4 points using inclined steel legs. This greatly reduced the size and depth of beam required. A tapered high strength steel beam proved to be the most economical structure by a wide margin. The costs were :

29m long glulam beams	- $25,000
Renovated railway girders	- $15,000
Tapered steel beams	- $10,000

Costs for the railway girder option and tapered steel beams include fabrication, sandblasting and painting. Other costs such as abutments and decking are much the same for all options.

At present tapered high strength steel beams appear to be the cheapest structural members available for bridging up to 20 metre spans. The cost of these beams is approximately $1500/tonne of steel fabricated. Prestressed concrete deck slabs (4m x 1.2m) cost approximately $500/m. Steel beams are particularly attractive for use in remote sites where getting heavy cranes on site could be difficult.

There is a higher labour content in the construction of steel beam bridges compared to prestressed concrete bridges. Long term maintenance costs are also higher. For example repainting of steel beams is often necessary after ten years, and timber decking may last less than ten years.

CONCLUSIONS

There are many factors which determine the type of structure which is most appropriate for crossing a stream or river.

Minimising crossing costs involves detailed site investigation, knowledge of current costs and the advantages and disadvantages of particular structural materials and forms.

The stream characteristics determine the type of structure that should be used and not the terrain.

LOW LEVEL CROSSINGS

ADVANTAGES	DISADVANTAGES
No loading restrictions. No heavy lift machinery required. Can be used by logging trucks with 400 mm of floodwater across the concrete pad. Much cheaper than a bridge: \$1000 - \$2000/m. Simple materials used.	Will be impassable part of the time. Regular inspection required. Grading of channel above may be required after a flood. Downstream scour of structure may lead to continual maintenance. Ramp gradients often too steep. High strength concrete required.

CULVERTS

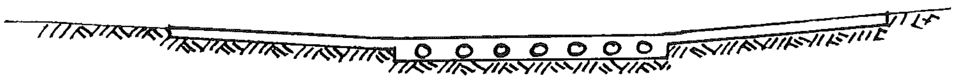
ADVANTAGES	DISADVANTAGES
No loading restrictions if above minimum fill. Invariably cheaper than a bridge (but not always) Wide range of sizes up to 3.6m diameter available. Special shapes available (concrete box, superspan, multi-plate).	Choking of the entrance by silt, brush, boulders or other debris is the most common cause of culvert failure. Scouring of outlet may require continual remedial work. Corrosion of steel culverts may occur in certain situations.

BRIDGE TYPES

ADVANTAGES	DISADVANTAGES
1) Glulam Beams with Concrete/Timber deck	
Beams are light, dimensionally stable, durable. Timber absorbs energy well and can withstand severe short term overloads. High strength to weight ratio. Up to 30 m single spans can be manufactured. Relocatable if timber deck used.	Limited number of manufacturers High cost of manufacture. Easily damaged if mishandled. Transport costs to site may be high. Difficult to design an effective and economical connection between beams and timber deck. High cost of cast in-situ concrete deck. Bridge requires specific design.
2) Prestressed Deck Units (Double Tee or Hollow Core)	
Widely available throughout NZ to 16 m span. Precast abutments available. No separate decking required. Double tee beams can be re-located. Low on-site labour costs. The most cost effective beams available. Minimal long term maintenance requirements. No specific design required. Completed bridge costs of \$3500 to \$4000/m.	Heavy lift crane(s) required. Require good foundation material or piling.
3) Steel beams with Concrete/Timber Deck	
Beams can be re-used. Second hand beams sometimes available. Wide range of sizes available. Long spans can be used. High strength to weight ratio.	Require specific design. Long term maintenance costs can be high. Medium lift crane required. Difficult to obtain effective connection for timber bearers.

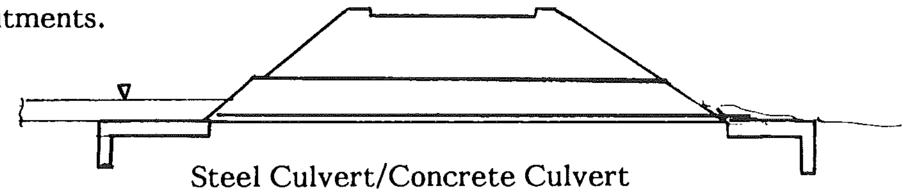
SITE CHARACTERISTICS | **TYPE OF STRUCTURE**

Wide straight gravel riverbed.
Constant shallow gradient.
Gravel banks.
Low traffic volumes.
Flash flooding occurs.
Excessive span for bridge.
A bridge would require piling.



Battery Culvert/Concrete Pipe Ford

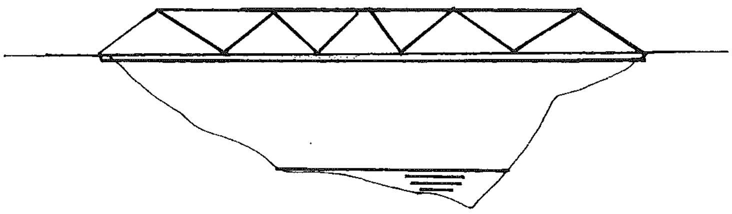
Small stream.
Moderate flood flow volume.
High road level required.
Erodible banks requiring piled abutments.
Suitable fill readily available.
Good access for machinery.



Steel Culvert/Concrete Culvert

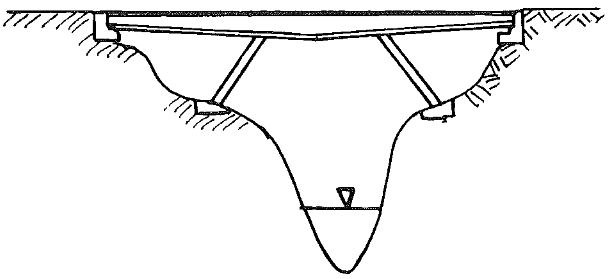
Deep gorge, pier impracticable.
Long span required (20m or more).
Good rock available.

Steel Truss for spans greater than 30m



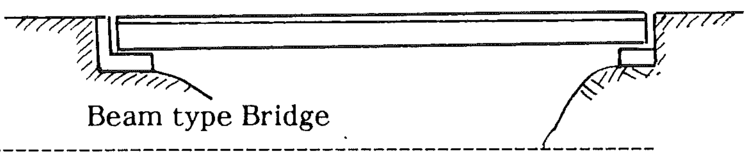
If lower level rock shelf available propped beam may provide more economic solution.

Tapered steel beams Concrete or Timber deck.



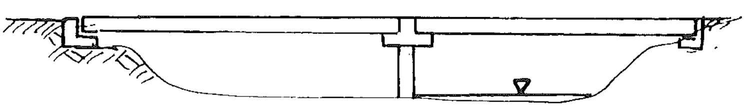
Confined river channel between stable banks.
Underside of bridge at least 1.2m above design flood flow.
All weather access required.
Moderate traffic volumes on minor road.
High flood flow volume beyond capacity of largest culvert.
High risk of large debris in channel.

Prestressed double Tee or Tapered steel beams



Beam type Bridge

Wide river bed.
Frequently changing channel(s).
Aggregation or degradation occuring.
All weather access required.
Moderate to high traffic volumes on major road.
High flood flow volume.



Multiple span Bridge

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