Review of the use of temporary log crossings in NSW coastal State Forests

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Executive summary

Background

Undisturbed riparian buffers along drainage lines, and drainage control structures along forest roads and tracks are key to reducing connectivity and limiting sediment delivery to streams. In some settings, the drainage network within a forest compartment is structured such that access to parts of the planned harvest area can only practicably be achieved by having snig tracks cross drainage features. Construction of crossings removes part of the riparian buffer and provides, at least temporarily, a direct pathway for sediment and nutrient delivery to the waterway. Crossings are therefore a key concern, in terms of the potential for harvesting activities to impact waterways and water quality.

Waterway crossings within Coastal Integrated Forestry Operations Approval (CIFOA) areas of NSW State Forests may be constructed in a variety of ways, including as temporary log crossings, causeways, culverts, bridges and existing stable gully stuffers. For snig tracks, causeways and temporary log crossings are the two main options that are used. Use of track crossings in general, including both causeway and temporary log crossings, are regulated by Condition 106 of the CIFOA. Specific operational plan requirements for causeways are defined in Protocol 9.7, and planning and operational requirements for temporary log crossings are defined in Protocol 32. Protocol 17 describes requirements for track crossings (including causeways and temporary log crossings) on waterways that are classified Class 1 aquatic habitat.

The outcome statement for Chapter 8 of the CIFOA requires that monitoring programs are applied at multiple landscape scales to ensure the ongoing effectiveness of the CIFOA in delivering its objectives and outcome statements. Drainage feature characteristics and track conditions are key aspects that are accounted for in Protocol 38 and are considered in the Waterway and Wetland Health Monitoring Strategy under the wider CIFOA monitoring program. Monitoring the impacts of track crossings ensures the outcome statement "*Water quality, aquatic habitat and native fish movement are maintained through the implementation of best management practices for tracks and track crossings*" can be achieved.

There is a detailed regulatory framework in place to ensure best management practices are applied in the construction, use and rehabilitation of temporary log crossings. However, the impacts of temporary log crossings on water quality and waterway conditions, and the effectiveness of the current regulations for their design and rehabilitation have not previously been comprehensively explored. This review was instigated by the Natural Resources Commission to understand the effectiveness of temporary log crossings in achieving the desired outcomes of the CIFOA. It is informed by peer-reviewed and other ("grey") literature, geomorphic principles, a comparative analysis with alternative crossing designs and (limited) field assessments of snig track temporary log crossings and causeways. The review's objectives also included advice on any potential improvements to the implementation of temporary log crossing in an adaptive management context and advice on any further research or monitoring. The review partly addresses the CIFOA monitoring program's requirement to monitor and evaluate the effectiveness of drainage feature crossings (Protocol 38.3(1)).

Rationale for using temporary log crossings on snig tracks

Causeways have traditionally been used for temporary track crossings of ephemeral waterways in the coastal native forests of New South Wales. Temporary log crossings were not included in the former IFOA rule set. However, they were introduced into the CIFOA on the basis they would, in at least some settings, provide improved environmental performance compared with causeways. The rationale for their introduction was that they would reduce deformation of the drainage features' bed and banks during construction, use and removal and hence preserve their stability. This would, in turn, reduce sedimentation and downstream water quality impairment. CIFOA Protocol 32 Temporary log crossings was agreed as the specific mechanism to regulate their use.

Regulatory framework for temporary track crossings of ephemeral waterways

CIFOA Conditions and Protocols provide the agreed regulatory framework for planning and operation of all forms of temporary track crossings of ephemeral waterways, including causeways and temporary log crossings. While Condition 106 *Temporary track crossings* apply to both types of crossing, temporary log crossings face several operating conditions (under Protocol 32) which have no parallels for causeway crossings. Some of these differences reflect unique features of temporary log crossings, and other differences reflect that causeways may also be used for other, more permanent and non-track crossings. Key differences in the regulatory framework for temporary log crossings and causeway temporary track crossings include:

- Restrictions on the number of temporary log crossings in use at one time within a compartment
- Limits on the number of days during which temporary log crossings may remain open
- Specifying how soon temporary log crossings must be rehabilitated
- Proscribing the use of temporary log crossings in compartments with seasonality restrictions.

Performance of temporary log crossings and causeways

Literature review

There is a limited body of peer-reviewed literature on the relative performance of temporary log and other broadly similar forms of snig track waterway crossing. That literature is supported by a somewhat more extensive grey literature and various regulatory prescriptions relating to the use of temporary track crossings. While the literature is informative in considering the use and merits of temporary log crossings in a NSW coastal native forest context, there are no exact parallels in landscape setting, regulation, design or operation. Consequently, there is potential for the impacts of temporary log crossings to be slightly different in NSW Coastal Native Forest settings than the studied environments. However, based on first principles considerations, the broad findings of this review should largely apply to the NSW Coastal Native Forest context.

Notwithstanding the qualifications given above, the literature supports the general conclusion that temporary log crossings and similar structures are likely to result in less downstream sediment movement than temporary causeway track crossings in some settings. It also indicates that:

- Log crossings should only be applied to temporary track crossings on low-order, ephemeral waterways. Use on higher order, flowing waterways can result in increased sediment load as well as other hydrological and ecological impacts compared to some other crossing types
- Temporary log crossings can be constructed so that they result in minimal bed and bank disturbance during installation, use and following removal of the structure from the channel
- Causeways tend to have more significant impacts on water quality than other crossing types, including temporary log crossings, because streamflow passes over the snig track, allowing it to introduce sediment directly into the stream during construction and use
- The physical setting, and operational use of the track crossing significantly influences the estimated erosion potential and volume of sediment generated
- During and following removal of a temporary track crossing, causeways produce significantly more suspended sediment than other elevated crossing types, including log crossings. Causeways continue to contribute suspended sediment to streams after their removal and rehabilitation.
- Placing slash material on the approach to temporary crossings can significantly reduce the erosion potential at the crossing.

Field experience

Despite being allowed under the CIFOA, there is limited experience in the use of temporary log crossings in NSW coastal native forests. This is likely to be at least partly due to risk aversion by harvesting contractors faced with a less familiar technique that is also subject to some more onerous regulatory restrictions than causeways.

The small number of examples where log crossings have been adopted in coastal native forests appear to provide at least preliminary support for several inferences about benefits and risks in using temporary log crossings for snig tracks that cross small ephemeral waterways, namely:

- Temporary log crossings reduce the physical impacts of skidders and snigged logs on the bed and banks of ephemeral waterways compared to conventional causeways
- Temporary log crossings may be rehabilitated, with minimal residual risk of sediment generation from the crossing point

- Where the approach to the crossing point is relatively steep, the main potential sources of sediment into the waterway during crossing operation and following rehabilitation are from the snig track.

Unlike a causeway, use of log fill reduces the grades, elevates traffic above the channel and reduces disturbance to the bed and banks of the waterway. Temporary log crossings appear to be more appropriate in settings where:

- The approaches to a crossing point on an ephemeral waterway are relatively steep
- The waterway channel is incised
- Soils remain damp and unable to resist deformation by machinery and log traffic.

Conversely, causeways may be a more appropriate form of crossing for:

- Ephemeral drainage features with lower approach slopes and minimal channel incision
- Settings where the natural bed substrate is highly resistant to erosion and deformation (i.e., rock or gravel).

Observations of additional temporary log crossings and more detailed monitoring would be required to provide definitive evidence confirming these inferences

Research gaps and monitoring

Research

There are few international peer-reviewed studies and none from Australia that compare water quality impacts from log and other types of ephemeral waterway crossings in forestry settings. Limited research evidence and scant NSW field experience with temporary log crossings in native forests contributes somewhat to uncertainty regarding this review's findings in relation to their appropriate use.

Water quality in natural streams is highly variable, being significantly influenced by the physical setting (including climate and weather) and treatment. Designing and executing a research program to definitively test and compare water quality implications of temporary log crossings and causeways within the CIFOA area would be quite problematic. Key issues for any research design to address would include:

- Sampling the diversity of landforms, soils, forest types and prevailing climatic conditions
- Achieving uniformity of crossing setting, construction and rehabilitation
- Accounting for weather conditions during use of the crossing and following its rehabilitation, as well as any post-harvest fuel reduction or regeneration burning
- Cost, expense and physical disruption associated with installing water quality and flow measurement equipment up and downstream of the crossing location
- Establishing baseline conditions prior to construction of the crossing
- There is limited use of both causeways and temporary crossings in native forest operations, given the general preference to avoid construction of any form of snig or other type of temporary track crossing.

It would be difficult to successfully control for key variables and hence allow proper attribution of any observed impacts on water quality to crossing type.

While there are significant research gaps relating to the use of temporary log crossings and causeways in coastal native forests, the preceding discussion suggests that research to address these would be expensive compared to the potential benefit, take several years to complete and likely not yield definitive results. It is therefore not recommended that such research be directly commissioned.

Monitoring

Protocol 38 of the CIFOA specifies that the approval's monitoring program must be designed to monitor and evaluate the effectiveness of the conditions of the approval, including those relating to drainage feature crossings. It is recommended that monitoring be undertaken to satisfy this requirement.

The monitoring program is suggested to include two main components:

- Establishment of a network of temporary track crossing monitoring sites that include 15-20 temporary track crossings and causeway crossings. The sites would be set up for:

  - Photo point monitoring: establishment of a series of photo points in the vicinity of the crossing site to establish its initial conditions, state during use and conditions following rehabilitation. Monitoring would continue approximately quarterly during the two years following rehabilitation, as well as episodically, following major rainfall events.
  - Waterway stability classification: a visual assessment of waterway / channel stability would be completed in conjunction with photo-point monitoring. This assessment would be undertaken with reference to a set photographic standards and descriptions that scale the stability of the crossing point and success in rehabilitation. Categorisation would account for vegetation regrowth, erosion within the channel, and the effectiveness of the cross bank in diverting overland flows from the snig track. Monitoring would be undertaken quarterly for two years post-rehabilitation.

  An annual independent site inspection and review / audit of the waterway rehabilitation categorisation data and photo point records would be undertaken. The review / audit would be undertaken annually for the first two-years following rehabilitation.

- Routine compartment monitoring: crossing establishment and management recording system would be developed for routine monitoring and assessment of temporary track crossings: records of the siting, construction, use and rehabilitation of the crossing would be collected.

Introduction of waterway stability classification monitoring would need to be preceded by work to develop the photographic standards and descriptions.

Data, observations from monitoring and the independent review / audit would be collated and reviewed at the end of the monitoring period to assess relative impacts, identify opportunities to improve crossing construction and rehabilitation, and reduce any soil or water quality impacts. In the context of snig track crossings, it is expected that it will be possible to compare relative impacts for the two most commonly used tracks, causeways and temporary log crossings, such that it can be determined under which conditions each track crossing would be considered the more appropriate option.

Potential modifications to Protocol 32 Temporary log crossings

Based on the limited available literature on temporary track crossings of ephemeral waterways, first principles consideration of the relative potential effects of temporary log crossings and causeways on such waterways and our review of relevant CIFOA protocols and conditions, we suggest several amendments to Protocol 32: Temporary log crossings. These include:

- Inclusion of a reference to bankfull level (as per CIFOA Protocol 16.5) as the point from which the allowable (1m) depth of an ephemeral waterway is measured, when determining eligibility for construction of a temporary log crossing
- Remove the limit of one *in situ* temporary log crossing at a time within a compartment and the time over which it may be used
- Making provision for the use of bark as matting on the trafficked surface of the crossing
- Requiring crossings to be rehabilitated as soon as practicable following completion of use and within five days
- Removal of the prohibition on temporary log crossing use in areas of a compartment subject to seasonality restrictions
- Include a requirement to remove temporary log crossings ahead of anticipated rainfall events that will exceed the 1:10 y peak flow design requirement mandated by Condition 106.8.

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1. Introduction

1.1 Background

Research shows that effective measures are available to help reduce the effects of timber harvesting operations on water quality and waterways (refer to Sections 2 and 5). One of the key principles of mitigating risks to water quality from timber harvesting operations is to limit connectivity between the drainage network and eroding areas on the hillslopes, from which water quality constituents (sediment and nutrients) are typically sourced.

Undisturbed buffers along drainage lines and drainage control structures along forest roads and tracks are key to reducing connectivity and limiting sediment delivery to streams. In most settings (e.g., tracks, landings and general harvest areas), the buffers and drainage structures are applied as a combined treatment to ensure that disturbed surfaces are adequately decoupled from the drainage network. Rehabilitation of disturbed surfaces is also an important mitigation once harvesting activities are completed.

Drainage networks within some timber harvesting compartments are structured such that is either necessary or expedient to construct snig tracks across drainage features to enable access to parts of the planned harvest area. Construction of such crossings removes part of the riparian buffer and provides a direct pathway for sediment and nutrient delivery to the waterway. Crossings are therefore a key concern in terms of the potential for harvesting activities to impact on waterways.

Track crossings that are permitted to be used in timber harvesting areas within NSW State Forests include temporary log crossings, causeways, culverts, bridges and existing stable gully stuffers. For new snig tracks constructed within individual compartments, causeways and temporary log crossings are the main forms of drainage feature crossing that are available for use.

Structures similar to the temporary log crossings described in the NSW Coastal Integrated Forestry Operations Approval (CIFOA; NSW EPA, 2018) are widely used by other native forest management agencies in Australia and overseas. They are also regularly used in NSW hardwood forestry plantations. Prescriptions for their use in NSW Coastal State Forests are given in Protocol 32 and Condition 106 of the CIFOA. The application and effectiveness of these conditions is being considered under the CIFOA's Waterway and Wetland Health Monitoring Strategy.

1.2 Review objectives

The CIFOA was established by the NSW Government in late 2018 to regulate native forestry operations in coastal State Forest. It sets out the rules for native timber harvesting in these forests and establishes environmental outcomes that must be achieved under the approval. Under terms of reference from the Premier, the Natural Resources Commission (the Commission) is independently overseeing a monitoring program, the Waterway and Wetland Health Monitoring Strategy, to ensure the ongoing effectiveness of the CIFOA in achieving its objectives and outcomes.

The Commission has led the development of the monitoring strategy, which was jointly approved by the NSW Environment Protection Authority and NSW Department of Primary Industries in March 2020. In developing the monitoring program, the Commission has worked with research groups and consultants to summarize the science related to timber harvesting and water quality, establish benchmarks, and develop tools to help focus monitoring efforts, particularly in relation to improving the design and management of the forest road network.

Drainage feature crossing and road conditions are being considered in the Waterway and Wetland Health Monitoring Strategy. Monitoring the impacts of track crossings over drainage features helps to ensure the outcome statement "*Water quality, aquatic habitat and native fish movement are maintained through the implementation of best management practices for tracks and track crossings*" can be achieved.

It is stated in the monitoring strategy that "*To inform the waterway and wetland health monitoring, the Commission will conduct a desktop study to review the current state of our knowledge in water quality and timber harvesting in NSW forests. In addition, should the desktop study into the current state of knowledge of temporary log crossings require their monitoring to evaluate their effectiveness in maintaining water quality, a* *methodology to monitor a set of temporary log crossings will be developed as part of the broader site-based monitoring*". Therefore, as part of the development and implementation of the monitoring strategy, the Commission has initiated this review to understand what is known about environmental impacts of the use of temporary log crossings and subsequently provide recommendations for monitoring temporary log crossings in NSW coastal State Forest. Additionally, since the adoption of the CIFOA in 2018, the effectiveness of the current regulations on temporary log crossings and their design and rehabilitation has not been explored in detail. As such, this review also considers the effectiveness of the conditions for temporary log crossings in achieving the desired outcomes of the CIFOA and suggests potential modifications to the regulations, based on the information gathered.

The review has been developed in context of timber harvesting in NSW coastal State Forests and is informed by peer-reviewed and other literature, geomorphic principles, a comparative analysis with alternative crossing designs and field assessments of snig track temporary log crossings and causeways. The outcome from the review will partly address the CIFOA monitoring program's requirement to monitor and evaluate effectiveness of drainage feature crossings (Protocol 38.3(1)).

1.3 Review methodology

The review seeks to evaluate the likely effectiveness of current settings for temporary log crossings in the CIFOA in achieving its intended outcome to minimise impacts of timber harvesting operations on waterways.

The scope of the review, as outlined by the Commission, is to:

- Conduct a desktop study to compile and review peer-reviewed and other relevant literature concerning the use of temporary log crossings in Australia and internationally
- Focus review and advice on NSW coastal native hardwood State Forest
- Advise on impacts from the use of temporary log crossings under the CIFOA when compared with traditional bed-level causeway crossings
- Advise on any improvements on the implementation of temporary log crossings that could be considered as part of the CIFOA adaptive management and improvement process
- Advise on any further research or monitoring, if and where required.

The review was also informed by site visits to native forest within the CIFOA area, primarily to observe causeways and active and rehabilitated temporary log crossings. It was also informed by photographic and video records of operational temporary log crossings and temporary log crossing removal.

2. Risks to waterways from timber harvesting operations

2.1 Sediment sources and connectivity with drainage networks

Timber harvesting operations have the potential to degrade water quality due to erosion and sedimentation. The main sources of sediment in harvested catchments are (Croke, *et al*., 1999; Croke and Hairsine, 2006):

- Unsealed roads
- Snig tracks
- Log landings
- General harvesting areas.

The potential impact of these sources is assessed in terms of their runoff-generating capacity and erosion rates, and the pathway or mechanism of sediment delivery to a downstream receiver (Croke, *et al*., 1999; Carrol, 2008). Runoff-generating capacity is determined by the catchment area of a landscape and is a critical factor in determining the amount of sediment that will be carried to a stream. Erosion rates are determined by several factors, including soil characteristics such as soil type, erodibility and compaction, as well as physical characteristics of a landscape and the frequency and intensity of flows.

Sediment-delivery pathways can be broadly categorised into:

- Incised channels or gullies – where flow is concentrated, resulting in high sediment-transport capacity and runoff delivery downslope
- Non-channelised pathways – where water disperses or spreads over the hillslope, reducing flow depth and velocity, and consequently, the ability of the flow to transport sediment (Croke, *et al*., 1999)

Figure 2-1 depicts differing sediment-delivery pathways resulting in varying levels of impact. The upper portion of the figure demonstrates that when non-channelised pathways dominate, surface runoff that is generated on areas of high disturbance is slowed and reduced in volume as water moves through an area of low disturbance and vegetation downslope. In the lower portion of the figure, overland flow is concentrated in a channel or gully that formed as a result of scour below a road drainage outlet feature. These pathways are characterised by high-energy flow with little, or no, potential for deposition of sediment. In this case, the buffering of the source areas from the stream by the presence of vegetated areas adjacent to the stream is minimal (Croke and Hairsine, 2006).

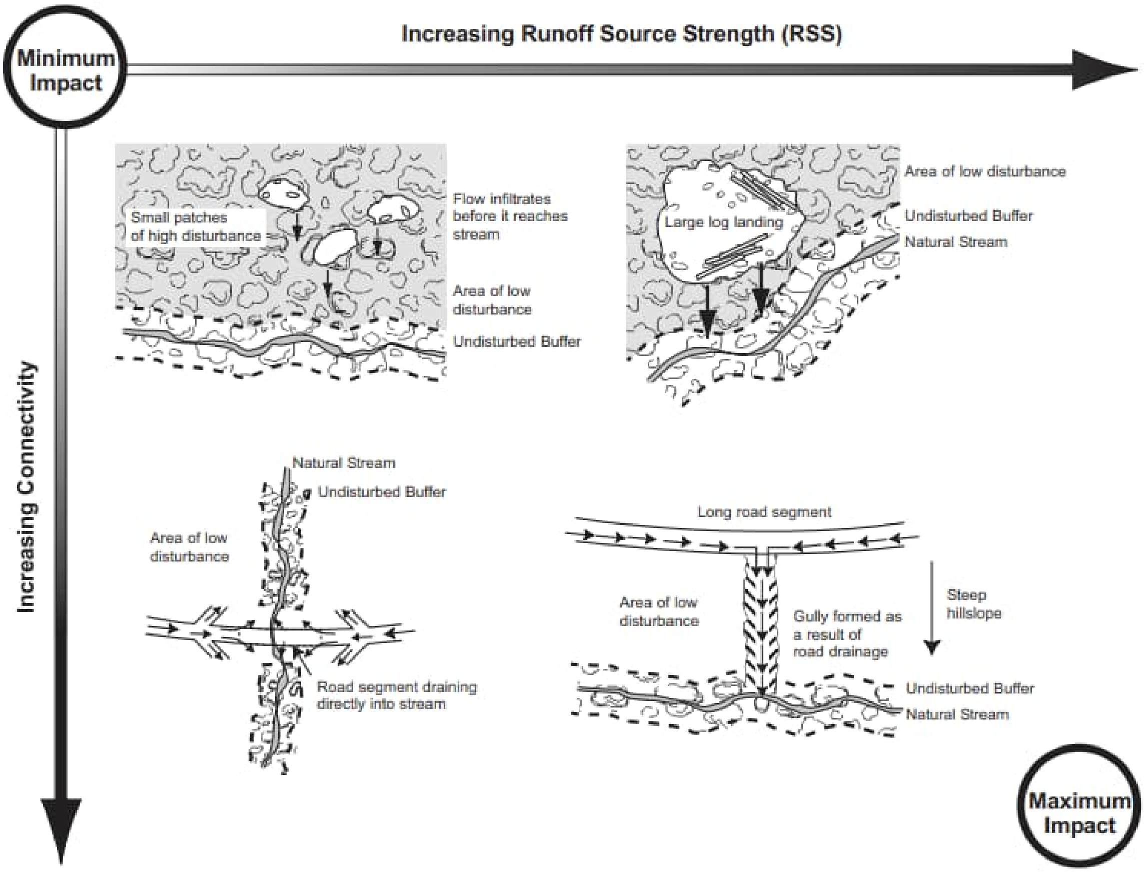

Figure 2-1 Conceptual framework of how runoff source strength and the connectivity of the delivery pathway combines to determine the delivery of sediment to the stream network. The overall delivery of sediment to the stream varies from very little in the top left of the diagram to very high in the bottom right. (Source: Croke and Hairsine, 2006).

2.2 Water quality risks at drainage feature track crossings

Figure 2-1 demonstrates that the level of water quality impact from a potential erosion source is strongly influenced by connectivity to a downstream receiver. As they facilitate such connectivity, stream crossings on haul roads and snig tracks are a likely significant source of sediment (Kochenderfer, 1970; Megahan & Kidd, 1972; Patric 1976; Corbett, *et al*., 1978; Rothwell,1983; Swift, 1984; Taylor, *et al*.,1999). Swift (1984) concluded that stream crossings are the most critical sections of road influencing water quality because during and for some time after construction, raw and exposed fill reaches into the channel.

Potential water quality impact also varies with the frequency of flows at a stream crossing and the length of time the crossing is used for. Permanent crossings, whether on ephemeral, intermittent or perennial streams, have greater potential to deliver sediments than temporary crossings that are properly rehabilitated following completion of use[1]. Similarly, crossings located on ephemeral streams receive flows less frequently than intermittent streams, and therefore there are likely fewer opportunities for sediment to be mobilised.

While temporary snig track crossings fall into the high connectivity category (when in use), they are usually constructed on ephemeral headwater tributaries in the upper reaches of the catchment, where flows are infrequent, and are rehabilitated following use to sever the connection they provide between the harvest area and stream. Thus, their risk of impact to downstream receivers would be expected to be lower than for

[1] Rehabilitation would typically involve removal of logs, soil or other fill material from the stream channel and formation of a structure/ cross bank to intercept water and sediment draining along the track and divert it into slash or undisturbed vegetation within the riparian buffer. While in use, the temporary crossing connects the snig track to the drainage network. The rehabilitation process seeks to sever, or at least reduce, that connection.

temporary or permanent crossings on larger streams lower in a catchment. Figure 2-2 illustrates the relative levels of risk of water quality impacts for various types of stream crossings.

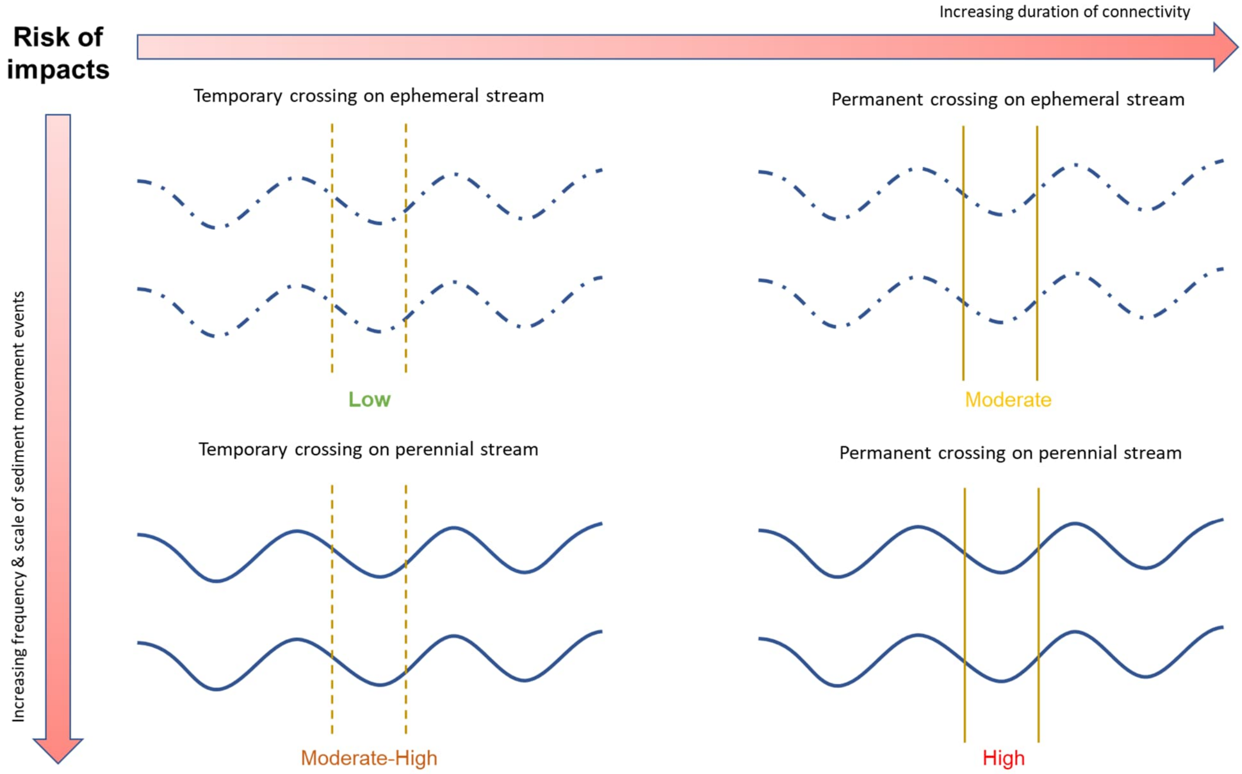

Figure 2-2 Conceptual risk matrix for temporary and permanent track crossings of ephemeral and perennial streams.

3. Track crossings - regulatory settings in the Coastal IFOA

3.1 Definitions and general requirements

The CIFOA (Protocol 39 Definitions) defines tracks as snig or other extraction tracks. Track crossings are structures designed to allow the crossing of a drainage feature and may comprise a "*bridge, culvert, causeway, temporary log crossing or an existing gully stuffer".*

Conceptually, track crossings may be temporary or permanent features. However, due to the short duration of individual harvesting operations, and the majority of track crossings being located on low order ephemeral streams, track crossings are almost always temporary. That is, they are removed following the completion of harvesting operations (see Table 3-1)".

For reasons of practicability and cost-effectiveness, bridges and culverts are not normally used for temporary snig track crossing. Since neither construction of new nor upgrading existing gully stuffers is permitted under the CIFOA, causeways and temporary log crossings are the main form of stream crossing for snig or other extraction tracks. Accordingly, this review only discusses track crossings using either causeways or temporary log crossings.

Table 3-1 draws on Protocol 39 of the CIFOA and establishes the terminology used in this review.

Table 3-1 Relevant temporary track crossing types as defined in CIFOA Protocol 39

Term	Definition
Track	A snig track or extraction track.
Track crossing	A structure designed to allow the crossing of a drainage feature with a track comprising: a bridge; a culvert; a causeway; a temporary log crossing; or an existing gully stuffer.
Gully stuffer	A type of crossing for a road, or track across a drainage feature. It is formed by filling the drainage feature with trees, debris, spoil, soil, rock or other material to the level of the road or track. A crossing constructed in accordance with Protocol 32: Temporary log crossings is not considered a gully stuffer.
Temporary track crossing	A type of track crossing or crossing structure that is removed at the completion of harvesting operation in the areas specified in the approval
Causeway	A natural or constructed crossing which enables vehicles to ford a drainage feature. The pavement of a causeway may consist of gravel, rock, bitumen or concrete or of a stable natural surface. The upper surface of a causeway must not vary by more than: 1. 10 centimetres from the bed of the drainage feature upstream of the causeway; and 2. 50 centimetres from the bed of the drainage feature downstream of the causeway. Note: This definition sets out the physical attributes of what defines a causeway. Compliance with this definition does not imply compliance with the fish passage provisions of the approval and associated protocols or the FM Act and associated Policy and Guidelines for fish habitat conservation and management (updated 2013). Refer to Protocol 17: Fish passage for compliance requirements.
Temporary log crossings	A type of temporary track crossing where logs are temporarily placed in a drainage feature to enable the short-term passage of a machine or vehicle.

Note:

1. This definition sets out the physical attributes of what defines a causeway. Protocol 29 notes that compliance with this definition does not imply compliance with the fish passage provisions of the approval and associated protocols or the FM Act and associated Policy and Guidelines for fish habitat conservation and management (updated 2013). Refer to Protocol 17: Fish passage for compliance requirements.

Details of planning and operational requirements for track crossings are specified in Condition 106 and Protocols 9.4 and 9.8 of the CIFOA (Table 3-2 and Table 3-3, respectively).

Table 3-2 Conditions for all track crossings as outlined in Condition 106.

#	Condition 106: Track Crossings
106.1	A track must not cross a wetland
106.2	A track crossing must not be used when: a) Water is flowing from the drainage feature across the pavement or running surface of the crossing; or b) The track crossing is saturated.
106.3	A track crossing must be stable and capable of withstanding snigging
106.4	A track crossing must only be a bridge, a culvert, a causeway, a temporary log crossing, or an existing stable gully stuffer
106.5	A new gully stuffer must not be constructed
106.6	An existing gully stuffer must not be upgraded. Where an existing gully stuffer becomes unstable or not capable of withstanding snigging, it must be removed and replaced with a bridge, a culvert, a causeway or a temporary log crossing
106.7	The construction, use and removal of each temporary log crossing must be carried out in accordance with Protocol 32: temporary log crossings
106.8	Each track crossing must be capable of withstanding the peak flow from a 1:10-year storm event, as determined in accordance with Protocol 14: Design methods for crossings and drainage structures
106.11[1]	A track must be drained between five and 20 metres on each side of a drainage line crossing, measured from bankfull level
106.12	Each outlet of a track crossing must discharge onto a stable surface capable of handling concentrated water flow
106.13	Where a track is in dispersible soils, the track surface must be stabilised for a length of 20 metres each side of a track crossing, measured from bankfull level
106.14	Each temporary track crossing must be removed at the completion of its use
106.15	Spoil derived from track crossing construction, upgrading, maintenance, removal or use must: a) Be removed from drainage features, and b) Not be placed in an ESA or ground protection zone
106.16	If the removal of spoil from a drainage feature disturbs an area, that area must be re-shaped and stabilised.
106.17	Any area of land 20 metres either side of a track crossing of a drainage line that is disturbed by concentration, upgrading, maintenance or removal of a track crossing must be re-shaped and stabilised.
106.18	The construction, upgrade or maintenance of a track crossing must restrict the disturbance of vegetation and groundcover in the riparian exclusion zone to the area that is three metres upstream and downstream of the track crossing unless otherwise approved in accordance with Protocol 5: Approval for restricted activities
106.19	Any in-stream works in class 1 aquatic habitat, including the construction or upgrading of track crossings must comply with Protocol 17: fish passage, unless otherwise approved in accordance with Protocol 5: Approval for restricted activities

Note:

1. Conditions 106.9 and 106.10 are only applicable to permanent track crossings and have not been included here as they are not relevant to any discussion regarding temporary log crossings.

Table 3-3 General CIFOA requirements for track crossings (as specified in Protocol 9 Pre-operational road and crossing assessments)

#[1]	Protocol 9.4 General requirements (for operational planning) for a new or replaced crossing	#	Protocol 9.8 General requirements for an existing crossing assessment
a	Location of the crossing to be constructed (corresponding with the operational map)	a	Location of the crossing to be constructed (as shown on the operational map);
c	If a track crossing is to be constructed, whether9.4a the crossing is a causeway, culvert, bridge or temporary log crossing	b	Type of existing drainage feature crossing;
d	Site-specific sediment control measure to be used	c	Stability assessment of the existing cross structure;
e	Measures required to stabilise any disturbed areas within 20 metres either side of a drainage line	d	A description of any stabilisation works to be undertaken to ensure the crossing can withstand the peak flow from a 1:10 year storm event (if required)

#[1]	Protocol 9.4 General requirements (for operational planning) for a new or replaced crossing	#	Protocol 9.8 General requirements for an existing crossing assessment
			(determined in accordance with Protocol 14: design methods for crossings and drainage structures);
f	Specific requirements to stabilised dispersible soils within 20 metres either side of a drainage line	e	Stability assessment of the existing crossing surface;
g	If a crossing requires in-stream works where there is an expected threatened species distribution as presented in documentation provided to FCNSW by DPI, an aquatic habitat assessment undertaken in accordance with Protocol 18: Aquatic habitat assessment	f	The type of surface material to be used on the drainage features crossing (if required)
		g	Site specific measures to retain the surface material at the crossing
		h	Reshaping of the bed and banks that will be required
		i	Site-specific sediment control measures to be used
		j	Crossing works to be in accordance with Protocol 17: Fish passage
		k	Aquatic habitat assessment must be undertaken in accordance with Protocol 18: Aquatic habitat assessment for crossings requiring in-stream works where there is expected threatened species distributions as presented in documentation provided to FCNSW by DPI.

Note:
1. Section (b) of Protocol 9.4 related to road rather than track crossings and has been excluded.

3.2 Specific requirements for causeway crossings

Protocols 9.7 of the CIFOA outlines specific planning requirements for causeway crossings (see Table 3-4). Protocol 17.5 additionally provides requirements for causeway crossings in Class 1 aquatic habitat. The latter is unlikely to be encountered when constructing a snig track crossing over a low order ephemeral waterway for which a temporary log crossing might also be appropriate.

Table 3-4 CIFOA causeway construction or replacement design, planning and operational plan requirements (as specified in Protocols 9.7 and 17)

#	Protocol 9.7 Operational planning requirements for causeway construction and replacement
a	Design and installation requirements for the causeway to withstand the peak flow from a 1:10 year storm event (determined in accordance with Protocol 14: Design methods for crossings and drainage structures);
b	Site-specific techniques to minimise the disturbance of the bed and banks of the drainage feature;
c	Type of surface material to be used;
d	Site-specific measures to retain the surface material at the crossing;
e	Site-specific measures to stabilise the outlet (if required); and
f	Aquatic habitat assessment must be undertaken in accordance with Protocol 18: Aquatic habitat assessment for crossings requiring in-stream works where there is expected threatened species distributions as presented in documentation provided to FCNSW by DPI.
	Protocol 17 Fish passage
17.5 Causeways	
1	Causeways must be designed, constructed and maintained so that the upper surface of the causeway varies by no more than 100 millimetres from the natural centre line surface level of the drainage feature, both upstream and downstream of the causeway.
2	When any maintenance is being carried out on the causeway, FCNSW must ensure that the causeway continues to comply with the condition 17.5(1) of this protocol.
3	During any works to construct, upgrade or maintain a causeway crossing, FCNSW must ensure that the causeway discharges so that scouring of the drainage feature below the outlet does not occur.

17.6 Vegetation clearing at crossings	
1	Clearing of vegetation for the purpose of works associated with a drainage feature crossing may only occur at, or as close as possible to, right angles to the water flow unless an angled approach reduces soil disturbance.
2	When carrying out works relating to a crossing of a drainage feature, or its associated road, track or fire trail, vegetation must not be disturbed or cleared in: (a) the riparian exclusion zone for the drainage feature; or (b) the riparian exclusion zone that is more than three metres upstream or downstream from the crossing or road, track or trail.
17.7 Drainage feature crossing to be constructed at right angles to the feature	
1	A crossing of a drainage feature must be constructed only at (or as close as practicable to) right angles to the drainage feature unless an angled approach reduces soil disturbance.

3.3 Specific requirements for temporary log crossings

Specific requirements for the design and use of temporary log crossings are regulated by Protocol 32 of the CIFOA. The applicable prescriptions in Table 3-5 differ somewhat from those applying to causeways.

Table 3-5 CIFOA requirements for temporary log crossings (as specified in Protocol 32)

#	Protocol 32.2 Management requirements for temporary log crossings
a	A temporary log crossing must only be constructed on a drainage depression, first order ordered drainage feature, second order ordered drainage feature, class 1 classified drainage line or class 2 classified drainage line that is no more than one metre deep.
b	Water must not be flowing at the time of temporary log crossing construction
c	Only one track with a temporary log crossing can be used in a compartment at any time.
d	Earth fill is not permitted to be used in a temporary log crossing.
e	A temporary log crossing must be capable of withstanding snigging
f	No branches or tree heads are to be used in the construction of a temporary log crossing
g	The location of a temporary log crossing must be approved and shown on the operational map.
h	A temporary log crossing must not be used after the date that is two weeks from the date of construction.
i	A temporary log crossing must be removed within five days of the completion of snigging at that crossing, and following removal, the area in which the crossing was located must be stabilised and rehabilitated prior to opening another crossing in that area.
j	When removing a temporary log crossing, logs must be lifted out of the drainage feature.
k	Where a temporary log crossing causes a diversion of the drainage feature or erosion, such as undercutting: ▪ the crossing must be removed within five business days of the occurrence of the diversion or erosion; and ▪ if the soil is: - not saturated, soil stabilisation measures must be put in place within five days of the occurrence of the diversion or erosion to achieve a stable cross-section; or - saturated, then the saturated soil condition in condition 98 of the approval applies.
l	A temporary log crossing must not be used in an area of a compartment that is subject to seasonality restrictions.
m	Where a temporary log crossing is removed, the crossing must be reshaped and: if the soil is not saturated, soil stabilisation measures put in place within five days to achieve a stable cross-section; or if the soil is saturated, saturated soil conditions apply.
n	Following the removal of a temporary log crossing, material used to construct the temporary log crossing must not be left in the riparian exclusion zone or ground protection zone.

4. Regulatory settings for temporary log crossings in other jurisdictions

The use of temporary log crossings, as well as other broadly similar structures (i.e., log culverts), in native forest harvesting operations is widespread in Australia (Section 4.1) and internationally (Section 4.2). It is recognised that they are a good practice measure in preventing damage to the bed and banks of drainage features (Reeves, 2012; Monk, 2009; NCFS, 2021; SCFC, 1998; Catanzaro, *et al*., 2013; NHDNCR, 2019; DFPR, 2018). NSW state-owned plantation operations that are conducted under the Plantations and Reafforestation (Code) Regulation (2001) recognise the protection to drainage features provided by temporary log crossings (referred to as 'slash crossings' in that Code). It states:

Slash crossing means a temporary crossing formed by the placement of logging slash in the drainage line or drainage depression (generally to prevent damage to the banks of the drainage line or rutting within the depression).

The following sections review and discuss the conditions and restrictions applying to track crossing structures that are broadly similar to temporary log crossings. It is important to note that there is no universally applicable definition of "temporary log crossing" and variable operational, environmental, and regulatory settings governing the use of broadly similar structures.

As such, this section is not intended to directly compare these regulatory requirements to those of the CIFOA, but to describe how analogous track crossing structures are regulated in other jurisdictions.

4.1 Regulation of temporary log crossings in Australia

Temporary log crossings (or similar) are permitted in most other forestry jurisdictions in Australia. The extent to which these crossings are regulated, and the nature of prescriptions varies between jurisdictions (Table 4-1).

4.2 International regulations for temporary log crossings

Temporary log crossings or similar features used to traverse waterways are an accepted feature of timber harvesting operations internationally, including in the United States and New Zealand. Examples of regulatory requirements for temporary log crossings (typically referred to as 'pole log crossings' or 'poled ford' in USA) are provided in Table 4-2.

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Table 4-1 Examples of regulations for snig track and other temporary waterway crossings in other forestry jurisdictions in Australia

Jurisdiction	Crossing Type	Regulatory documentation	Relevant section	Prescriptions
NSW State-owned plantations	Slash crossing	*Plantations and Reafforestation (Code) Regulation (2001)*	37(3)	Harvesting machinery may cross drainage lines or drainage depressions by using slash crossings, but only if there is no water flowing in the channel or depression.
			37(4)	Any temporary crossing over a drainage feature must be removed within 5 days of the completion of the plantation operation in respect of which it was erected.
			37(5)	The removal of any temporary crossing must be done in a manner that prevents, as much as is reasonably practicable, disturbance to the bed and banks of the drainage feature.
			37(6)	If the bed and banks of a drainage feature are in an unstable condition after the removal of a temporary crossing, the bed and banks must be reshaped to provide for a stable cross section where water flow is not impeded.
Tasmania	Extraction and other temporary track crossings	Forest Practice Code (Forest Practices Authority, 2020)	B3.3 Construction of crossings	Watercourse crossings will be constructed with minimum disturbance to banks and existing channels. Temporary crossings over Class 3 and 4 and dry Class 2 watercourses will provide a designed opening for water passage (e.g., log culvert, see diagram), unless they are being constructed solely to provide access by machines during road construction. Temporary watercourse crossings will be either: removed with minimal disturbance to the watercourse prior to the expiry of the relevant FPP (forest practices plan) and resulting road or track ends water barred to divert the road or track drainage into surrounding vegetation; or upgraded to the standard for Class 3 or 4 road permanent watercourse crossings. Any potential erosion points will be stabilised.
			C6.1.1 Construction and use	Forwarders may operate across a flowing Class 1 or 2 watercourse using a culverted or bridge crossing, or a ford when there is no water flow, provided measures to avoid sediment entering the watercourse (e.g., matting or gravelling of approaches) are implemented. Such crossings may also be used by other types of machines, provided they are unladen, to move around a coupe. Skidders may cross a flowing Class 1 or 2 watercourse using a culverted or bridge crossing, or a ford when there is no water flow, provided: it is not feasible to use alternative extraction routes; measures to avoid sediment entering the watercourse (e.g., matting or gravelling of approaches) are implemented; CFPO approval is obtained. The number of crossings of Class 3 and 4 watercourses will be minimised and restricted to clearly marked crossing points. Crossing points on any watercourse should be at least 100 m apart.

Jurisdiction	Crossing Type	Regulatory documentation	Relevant section	Prescriptions
				Temporary crossings will not be used while water is flowing over them. Dry Class 4 watercourses may be crossed without a log crossing or culvert provided: ▪ Soils are dry and in low to moderate soil erodibility classes ▪ Banks into the watercourse are gently sloping (0-11°) ▪ The number of crossings is minimised Temporary culverts or log crossings will be provided in all other crossings. Machine damage to streambanks should be avoided. Crossings that are used for more than 12 months must be constructed with an opening designed cope with typical winter peak flows. Extraction tracks should be corded or matted during construction in wet areas and temporary culverts used to reduce soil degradation and maintain trafficability and water quality.
			6.1.2 Management and restoration	Installation of grips and restoration of stream crossings, rutted extraction tracks and tracks on which cording, and matting have been used should be undertaken on completion of a section of a coupe, provided conditions are dry enough for restoration works to be effective. If not dry enough, restoration should be done within a time specified in the FPP. On completion of harvesting or site preparation, temporary log crossings will be removed from watercourses to points outside the streamside reserve or machinery exclusion zone to allow unrestricted flow of the water along its original course. The streambanks will be left in a stable condition by constructing grips or other suitable drainage measures. If a stream is diverted onto an extraction track at a crossing point, water flow must be returned to its original watercourse. This must be done immediately unless an FPO specifies a delay until drier conditions prevail.
Victoria	Snig tracks and snig track waterway crossings	Code of Practice for Timber Production 2014 (amended November 2021) (DELWP, 2021)	Code 2.5.2 Coupe infrastructure	2.5.2.3 Coupe infrastructure (which includes snig tracks) must be rehabilitated on completion of timber harvesting operations, where not required for future timber harvesting operations or a sanctioned purpose for which native vegetation is not compatible. Rehabilitation techniques must ensure that suitable soil conditions are provided for the regeneration and growth of vegetation existing on the site prior to harvesting (refer to section 2.6.1). Progressive rehabilitation of coupe infrastructure during timber harvesting operations must be undertaken where operationally possible. 2.5.2.5 Tracks must have effective drainage to prevent soil erosion. Cross-drains, where used, must be spaced and angled as appropriate to the soil erosion hazard, to disperse surface run-off and prevent discharge of turbid water into streams or drainage lines.

Jurisdiction	Crossing Type	Regulatory documentation	Relevant section	Prescriptions
			Code: 4.2.1 Water quality, river health and soil protection	4.2.1.5 Where temporary crossings or log culverts are used, they must be removed immediately after harvesting or any subsequent replanting work for which they are required, using a technique that minimises soil disturbance. Note: this prescription applies to plantations rather than native forests.
		Management Standards and Procedures (MSP) for timber harvesting operations in Victoria's State forests 2014 (amended November 2021) (DELWP, 2021)	MSP 7.2.1 Snig track and landing construction	7.2.1.1 Crossing standards and procedures for roads (MSP 6.2, below) also apply to snig track crossings.
			MSP 7.2.2 Snig track and landing rehabilitation	7.2.2.1 Following completion of the timber harvesting operation rehabilitate all snig tracks to prevent: unacceptable movement of soil down or from the track surface; and soil movement into streams.
			MSP 6.2 Road construction	6.2.4.5 Place drainage structures at least 20 m from permanent or temporary streams, to allow discharge onto undisturbed vegetation and to maximise the flow distance between the drainage outlet and the waterway. 6.2.4.6 Where it is not practical to comply with clause 6.2.4.5, and a drainage structure must be located within 20 m of a permanent or temporary stream: use crown or cross fall techniques to drain roads into undisturbed vegetation; or pass drainage through an appropriate sediment control structure such as a sediment pond or silt trap before entering a permanent or temporary stream. 6.2.5.2 Culverts used in temporary roads are a minimum of 300mm in diameter. 6.2.5.3 All culverts are designed to withstand a 1 in 10-year rainfall event. 6.2.5.4 Construct culverts in catchment areas exceeding 100ha in accordance with engineering advice. 6.2.5.5 On drainage lines, stream and river crossings or soils of High Erosion Hazard place sandbags, timber, concrete, or rock at the head of the culvert and at the point of discharge to hold the culvert in place and protect it from erosion. 6.2.5.11 Ensure culverts do not project above the bed of a waterway in a way which may prevent the passage of aquatic fauna. 6.2.5.12 Where culvert construction diverts water from its natural course, return water to its natural course over a flume, rock spill, or other hard surface.
			MSP 6.4 Road rehabilitation	6.4.1.1 Close temporary roads (including removal of all bridges, crossings and culverts on streams or drainage lines) as soon as possible after harvesting and/or regeneration is complete in all coupes that use the road.

Jurisdiction	Crossing Type	Regulatory documentation	Relevant section	Prescriptions
				6.4.1.2 Drain the approach to any bridge, culvert or log fill crossing that has been removed to restrict soil movement into a stream or waterway.
Queensland	Snig track crossings	Code of practice for native forest timber production on Queensland's State forest estate 2020 (DES, 2020)	Schedule 3.5 Buffer zone standard conditions	New … major snig track crossings and minor snig track crossings on U- shaped gullies must be marked in the field. Crossings must: ▪ be located in straight, stable sections with low banks; ▪ be aligned at right angles to water flow; ▪ be more than 200m from another crossing where terrain permits (and in accordance with the Operating Guidelines); ▪ not involve pushing of soil or debris into watercourses or bank disturbance beyond the alignment; ▪ be constructed using gravel or corduroy with minimal earth fill. Use a culvert, temporary as necessary, if water is flowing or will flow during use; and ▪ have diversion drains on approaches and immediately stabilise and rehabilitate the crossing at completion of use. Minor snig tracks by rubber-tyred machines may only cross V-shaped gullies and waterways where the total height of any erosion face associated with the active zone is less than 30cm, and when: ▪ slump is not present outside the active zone, i.e. on the bank; ▪ operationally essential; ▪ the bed is dry; ▪ earthworks are not required; ▪ use does not create an erosion channel; ▪ the crossing must be moved to another site as soon as a wear track becomes evident.
			Schedule 3.6 Filter zone standard conditions	Major snig tracks must not enter the filter zone unless at a crossing.
			Schedule 8.5 Design of waterway crossings	Causeways and fords are suitable for crossings that are used infrequently, where usage occurs during periods of low flow or where regular flooding prevents economic or effective bridge construction. Sites must be naturally stable or engineered to provide function and environmental protection.

Jurisdiction	Crossing Type	Regulatory documentation	Relevant section	Prescriptions
				The crossing must be installed at the existing bed level height so as not to impede water flow and movement of aquatic species and at the same upstream-down-stream gradient as the watercourse. Approaches must be gravelled or otherwise stabilised to minimise turbidity in wet crossings. Temporary crossings must be minimised. Crossings must not involve earth fill but may be gravelled or corduroyed to bed level height. Use a temporary culvert if the crossing will be used when water is flowing, and use would otherwise create a threat to water quality. A temporary culvert is a drainage structure that allows water to be channelled under or across the road and is temporary in nature and is removed and stabilised.

Table 4-2 Examples of temporary log crossing requirements in various international forestry jurisdictions

Jurisdiction	Crossing Type	Code of Practice	Relevant section	Conditions, regulations, best practice guidance
United States of America				
North Carolina	Pole/log crossing	North Carolina Forest Practices Guidelines Related to Water Quality (FPGs) (NCFS, 2018) and North Carolina Forestry Best Management Practices Manual to Protect Water Quality (NCFS, 2021)	Chapter 5 Pole crossings	Avoid crossing streams where possible Establish the pole crossing in a way that: ▪ Allows water to pass through the crossing location ▪ Does not contribute to accelerated erosion, runoff or sediment transport ▪ Protect the integrity of the channel's structure. Use only topped and de-limbed logs that are free of soil and excess debris. Use logs of a large enough diameter so they do not pack too tightly together. Do not deposit soil within or on top of the pole crossing. Build up the pole crossing to an elevation higher than the adjacent channel or bank to allow for logs to settle. Pack down limbs, slash, or other woody debris on skid trail approach-ways, not in the channel. Immediately remove the pole material after the crossing is no longer needed, or when rain is forecast. Stabilize the crossing location during and after use to prevent accelerated erosion or sediment transport.
South Carolina	Woody fill	South Carolina's Best Management Practices for Forestry (SCFC, 1998)	Stream crossings	Woody material may be used as fill to protect stream banks and bottoms in crossing small intermittent and ephemeral stream with well-defined channels if: ▪ Soil is not introduced into the stream with the woody fill. Soil blocks the pore space among the woody debris, impeding drainage and increasing the amount of sediment in the watercourse ▪ Stream flow is not blocked or diverted. ▪ Woody material that restricts flow of water is removed.
Massachusetts	Corduroy or poled ford	Massachusetts Forestry Best Management Practices Manual (Catanzaro, *et al.*, 2013)	Stream crossings and approaches	Stream crossing options: ▪ Shallow (<30cm) - Rocky: ford with stabilised approach, corduroy, culvert, bridge - Soft: Corduroy, bridge, corduroy with culvert ▪ Steep (>30cm) - Rocky: Corduroy, culvert, bridge - Soft: Corduroy, culvert, bridge Required best management practices: ▪ Make every reasonable effort to avoid or minimize stream and wetland crossings. ▪ Where possible, cross at right angles and use approaches with gentle slopes

Jurisdiction	Crossing Type	Code of Practice	Relevant section	Conditions, regulations, best practice guidance
				▪ Use existing crossings, rehabilitated or restored to their original condition, when it can be shown to be less of a disturbance than establishing a new crossing. ▪ Design bridges and temporary culverts to accommodate at least the 25-year re-occurrence storm event. ▪ Protect and stabilize all banks and approaches to stream crossings during and at the end of the operation through measures such as timing, use of corduroy or poles, water diversions, straw bales, seeding, and/or specific measures as required by the service forester. ▪ Use a temporary bridge for crossing any stream within 1,000 feet of a public water supply reservoir. ▪ Remove all crossing structures within one year of the completion of the operation. Poled ford standards: ▪ Place logs in a stream parallel to the direction of flow. Logs should be large enough to keep the skidder out of the water and should be level with the stream banks. ▪ Place one or several culverts in and amongst the logs to permit streamflow through the ford and prevent damming. Ductile iron culverts or pieces of gas pipeline can withstand great impact and support heavy logging equipment, including fully-loaded forwarders, without collapsing. ▪ All poles and temporary culverts need to be removed from the stream channel at the completion of the harvest to allow water to flow freely. Leave material that is stabilizing the approaches and banks. Crossing approaches: It is very important to stabilize the approaches to a stream crossing both during the logging operation and after completion. Unstable approaches are one of the primary ways that sediment can enter a stream. Although water bars[2] are generally installed at the end of a timber harvest, it is advisable to install at least one directly uphill from a crossing to prevent water moving down a skid trail from reaching a stream. This water bar will need to be occasionally reinforced during the course of the job. The approaches can be corduroyed with poles to prevent rutting and the churning of soil. Consider staking a few straw bales in the skid trail at the approach to a stream crossing at the end of the day or week, especially if there are showers or heavy rains in the forecast. At the end of the job, leave the poles on the approach to help stabilize it.

[2] Water bars are similar features to the cross banks used to intercept flows on snig tracks in NSW coastal forests.

Jurisdiction	Crossing Type	Code of Practice	Relevant section	Conditions, regulations, best practice guidance
New Hampshire	Poled ford	Best Management Practices Manual: Utility Maintenance in and Adjacent to Wetlands and Waterbodies in New Hampshire (NHDNCR, 2019)	Best Management Practice 11: Poled fords	A poled ford is a temporary stream crossing made by stacking logs that are free of limbs and soil within the stream channel high enough so equipment can travel across. Fords are used for crossing streams. Poled fords can be constructed and used during periods of no or low flow, on a stable stream bottom. Locate poled fords where an access road has previously established a perpetual disturbance and where there is limited potential for sedimentation in the stream. Find stream banks that are firm and level with approaches that are reasonably level for a distance of 50 feet on each side of the stream crossing. Install the poled ford parallel to the flow of the stream in a manner that: ▪ Allows water to flow through the crossing location. ▪ Does not contribute to accelerated erosion, runoff, or sediment transport. ▪ Protects the integrity of the channel's structure. Consider placing one or more pipes within the poled ford to allow water to pass through. Use geotextile or other appropriate bedding, if needed, to stabilize the approaches to the crossing. Do not use poled fords when overtopped with water. Monitor the upstream end to ensure that it does not become plugged with debris that impedes stream flow. Remove poled fords immediately after use.
Vermont	Pole fords	Acceptable Management Practices for Maintaining Water Quality on Logging Jobs in Vermont (DFPR, 2018)	6.5.4 Stream crossings	Pole fords are allowed on skid trails where the streambed is cobble or ledge. Temporary stream crossings that are brushed-in or that use pole fords shall be removed after logging is completed as soon as ground conditions are stable or within 12 months of installation, whichever is sooner.
New Zealand				
New Zealand	Log bridges	Resource Management (National Environmental Standards for Plantation Forestry) Regulations 2017	46 Permitted activity conditions specific to various classes of river crossings	Temporary river crossings: ▪ Excavation of the banks or bed of a river must not exceed 200m^3. ▪ If logs are placed in the bed of a river, a culvert at least 300 mm in diameter must be placed in the bed first. ▪ All river crossing materials must be removed from the bed of the river within 1 week of completion of the construction or removal of the river crossing.

Jurisdiction	Crossing Type	Code of Practice	Relevant section	Conditions, regulations, best practice guidance
New Zealand	Temporary log crossings	Forest Owners Association, Forest Practice Guide (non-regulatory)	3.6 Temporary Crossings	A. Where and when to use: When temporary access is required across a river. B. Where not to use: When crossing permanently dry gullies. C. Design: 1. Plan for temporary harvest crossings at the harvest planning phase. 2. Consider factors such as the catchment size, the river's banks, width and substrate, and downstream infrastructure. 3. Aim to minimise the number of crossings needed to safely and productively harvest. 4. Ensure the crossing locations are clearly marked out for the operator. D. Construction 1. Minimise the disturbance of the natural shape of the river. 2. Minimise soil entering the river during construction. 3. Reduce potential sediment entering the water body from the approach tracks: a. Wherever practicable, maintain the track grade over the crossing. b. Consider corduroying the approaches or use slash on the approaches to limit rutting. c. Construct the track approaches so that extracted logs do not sweep off the crossing into the river (e.g. logs can be driven vertically at corners and crossing entrances to keep trees aligned to the crossing). 4. If logs are placed in the bed of the river, a culvert of at least 300 mm diameter must be installed at the base of the crossing. E. Maintenance and removal Maintenance 1. Maintain river crossings and approaches so that stormwater control is effective. River crossings can be difficult to maintain in wet periods. 2. Ensure culverts are not getting blocked with woody debris from the harvest operation. 3. Maintain the integrity of log crossings. 4. During wet weather limit the use of the crossing to minimise mud accumulating on the track leading into and away from the crossing. 5. Stop operations when the approach tracks or the crossing are releasing sediment to the river and divert any track stormwater onto the cut-over. Crossing removal 6. Remove the material used to construct the crossing within one week of finishing the harvesting operation. 7. Crossing material should be placed in a location that minimises the risk of it entering the river. 8. Rehabilitate or decommission the approaches.

5. Temporary log crossings: what does the research say about their benefits and impacts?

A survey of peer-reviewed and grey literature relating to drainage feature crossings in timber harvesting operational areas was undertaken, spanning the period 1970-2021. The review found there is limited published research specifically relating to temporary snig track crossings on headwater streams (Reeves, 2012), and very few papers that explore the use of temporary log crossings. This may reflect difficulties in designing and conducting valid experiments to test their impacts, and the consequent prospect that studies would not yield definitive results. Further, the position of the tracks in watersheds, the temporary use of snig track crossings, and the ephemeral nature of the waterways that are crossed, may be seen as limiting the materiality of risks of impacts, particularly compared with roads and tracks with greater and longer-term use and on-going connection to waterways. Other areas of research may be perceived to offer greater benefit or return on investment.

Due to limited availability of peer-reviewed literature on temporary log crossings, there has been minimal opportunity to quantify impacts for this specific crossing type or to make any direct comparisons to the use of temporary log crossings in NSW native coastal forestry operations. The purpose of this section is therefore to present the findings of studies which discuss the performance of and quantify water quality impacts for watercourse crossing types that are broadly analogous to temporary log crossings. Focus is placed on types of crossings which involve filling a channel to bank height with a stable fill material (log or similar) without the need to deform channel bed or banks through excavation. Porosity to convey flows along the waterway may be provided by gaps between logs, culverts and/or other pipes. The types of crossing considered include:

- Log crossings, where only timber logs are placed in the channel
- Log crossings with pipe culverts, where the channel is filled with logs and with additional pipe culvert(s) to assist in conveying flow
- Pipe bundles, where bundles of connected poly-vinyl chloride (PVC) or high-density polyethylene (HDPE) pipes are placed in the channel rather than logs.

Differences in the crossing structure and use, as well as in physical setting limit the direct comparability of the studies. However, they provide some general insights into the performance and the likely water quality and river health benefits and risks of temporary log crossings.

5.1 Overview of log crossing performance and design

A survey of peer-reviewed and grey literature relating to drainage feature crossings in timber harvesting operational areas was undertaken, spanning the period 1970-2021. The review found there is limited published research specifically relating to temporary snig track crossings on headwater streams (Reeves, 2012), and very few papers that explore the use of temporary log crossings. Of the peer-reviewed literature that could be accessed, only two studies (Carroll, 2008; Aust, *et al*., 2011) quantitatively compare the water quality impacts of temporary log crossings with other crossing types. Both papers draw on the same study of the installation, use and removal of "slash" or timber logs in waterway channels.

Reeves (2012) explores the use of a similar crossing type; however the crossing was constructed from pipe bundles rather than logs. Studies by Wear, *et al*. (2012), Wade, *et al*. (2015) and Vinson, *et al*. (2017) explore the use of slash on the approach to a track crossing but not placed in channel. These papers suggest that best management practices (BMPs) used on stream approaches may be more important to stream water quality than the stream crossing type itself. The results of these studies are discussed further in Section 5.2.

Brief descriptions of the findings of a research project conducted by Tornatore (1995), which specifically studied water quality impacts from the use of a pole bridge (log crossing) and shale back-filled culvert, are provided in Taylor, *et al*. (1999) and Carrol (2008). It was noted that a pole bridge (effectively a log crossing) resulted in significant increases in sediment production compared with a culvert (with shale fill) at the same location. The paper concluded that pole-bridges were a non-preferred method for permanent stream crossings, although are recommended to be installed in ephemeral and intermittent streams as a temporary crossing when there is limited water flow (Tornatore, 1995; as cited by Taylor, *et al*., 1999 and Carrol, 2008).

An earlier paper by Tornatore, *et al*. (1994) compared sediment generation associated with the use of a portable bridge crossing and culverts with log fill or shale fill. Total suspended solids increased at the portable bridge and log fill culvert, but not the shale fill culvert. The effect at the temporary bridge crossing resulted from debris falling through gaps in the bridge planking. Disturbance of the approach to the log fill culvert generated sediment that entered the waterway, rather than the actual crossing.

In keeping with the conclusions made in Tornatore (1995), it is recognised that log crossings are not suitable for long-term or permanent crossings (Blinn, *et al*., 1998; Blinn, *et al*., 1999; Taylor, *et al*., 1999), and it is commonly prescribed in forestry regulations and US state BMPs that log crossings are only to be used on ephemeral channels with no or low flowing water (see Sections 3 and 4). This is not only because log crossings (or their approaches) have the potential to produce high sediment loads during flow (as per Tornatore, 1995), but also due to potential degradation of aquatic habitat, obstruction of fish passage (DPI, 2006), as well as potential to disrupt natural hydrological function during a substantial flow event (Blinn, *et al*., 1998; Reeves, 2012; Taylor, *et al*., 1999).

Conversely, log crossings for temporary use have been described as an environmentally sound alternative to temporary causeways and other crossing types as the variable size and shape of the logs can conform to the shape of the channel, meaning they are able to be installed without significant modification to the stream bed or banks and require minimal earth fill to be placed into the channel (Reeves, 2012; Wisconsin DNR, n.d; Monk, 2009). By reducing the need for significant amounts of fill, as well as minimising bed and bank disturbance during installation and use, temporary log crossings are expected to minimise effects on water quality and aquatic habitat downstream (Wisconsin DNR, n.d; Reeves, 2012; Taylor, *et al*., 1999). Compared to other crossing types, temporary log crossings perform well with regard to protecting water quality downstream following removal of the crossing as the original streambed structure stays intact and often only requires minimal rehabilitation works (Reeves, 2012; Monk, 2009; Wisconsin DNR, n.d).

Several examples of the use of temporary log crossings in North American forests are described by Monk (2009). The first example describes a log crossing with a pipe culvert on a minor, but flowing, drainage channel, and the second example describes a log crossing without a pipe culvert on an ephemeral drainage channel with low chance of flows (see Figure 5-1 and Figure 5-2, respectively). Use and rehabilitation of the crossings resulted in limited long-term disturbance and water quality impairment.

The situation was a summer drainage crossing for a forwarder. After installation, the crossing withstood heavy use for a month or more then was removed. The stream course was running water to a depth of 300mm and up to 900mm wide. The crossing was created using a separator material, corrugated plastic pipe, and pulpwood. The separator material kept the logs from being pushed into the soil and resulted in cleaner logs being hauled out of the woods. A previous, nonwoven geotextile was used. After the crossing was no longer needed, the pulpwood was removed and hauled. The separator material and pipe were removed for reuse.

Figure 5-1 Example 1 - Temporary log crossing with culvert in place (left); and after its removal (right). Source: Monk (2009).

The situation was an ephemeral drainage line used during August, when the chance of measurable precipitation was minimal. The crossing was removed by September 1. There was no pipe or separator material used. Whole trees 250-600mm diameter breast height were used in the drainage channel. After the crossing was no longer needed, the material was removed with a heel-boom loader and processed at the landing. Standard erosion control measures where required.

Figure 5-2 Example 2 - drainage channel following removal of the temporary log crossing on an ephemeral drainage line. The ephemeral drainage channel has some ground disturbance following removal of the crossing due to the greater bank slope. Source: Monk (2009).

Similar temporary log crossings (to example 1, Monk 2009) have been used (for forwarding tracks) in native forestry operations in Victoria, with limited apparent impact during operation (Jacobs, 2020; Figure 5-3[3]).

Figure 5-3. Temporary log crossing in use as a forwarding track across a permanent stream in tall, wet eucalypt forests in Victorian Central Highlands region. Source: Jacobs (2020).

The review highlighted that there were various material options which can be utilised in temporary crossings of ephemeral waterways (Blinn, *et al.*, 1998; Carrol, 2008; Monk, 2009; Aust, *et al.*, 2011; Reeves, 2012; Wisconsin, DNR, n.d). These include logs (also referred to as "slash" or "corduroy"; Blinn, et al. 1998), logs with temporary pipe culverts (Monk, 2009; Carrol, 2008; Aust, *et al.*, 2011; Jacobs, 2020), as well as bundles of connected poly-vinyl chloride (PVC) or high-density polyethylene (HDPE) pipes (Blinn, *et al.*, 1998; Reeves, 2012) or PVC or HDPE pipes with wooden panels overlain (Wisconsin, DNR, n.d). Examples of these are provided in Figure 5-4.

[3] Note that no observations were made of crossing construction or rehabilitation to assess water quality impacts at these stages.

Figure 5-4 Examples of temporary log crossing structures with various types of fill-material, including slash only (top left) (Blinn, *et al.*, 1998); slash and pipe culvert (top right) (Aust, *et al.*, 2011), pipe bundle (bottom left) (Blinn, *et al.*, 1998) and pipe bundle with wooden panels overlain (bottom right) (Wisconsin DNR, n.d).

Log crossings and pipe bundles serve a similar function, in that they are both raised crossings, do not require channel bed deformation, and provide varying levels of permeability such that water is able to move through the crossing. While it is possible for pipe bundles to be used as the fill material instead of logs and is a recognised practice in some US jurisdictions, it is expected that the load-bearing capacity for this material may be lower than for logs, and that pipes may be prone to breakage (Blinn, *et al.*, 1998). Further, it is noted that standard PVC pipes lose strength when exposed to sunlight (Blinn, *et al.*, 1998). Importantly, logs sourced from the compartment itself are a renewable material that produces no persistent waste and do not add to greenhouse gas emissions associated with the forestry operation.

Due to the similar function of log crossings and pipe-bundle crossings, we have discussed the results of a study in Section 5.2 which used pipe-bundles as temporary stream crossings (Reeves, 2012), however it is not recommended that pipe-bundles be used as an alternative design to temporary log crossings in NSW coastal State Forests.

5.2 Comparison of water quality impacts from different crossing types

The literature indicates that all crossing types may mobilise sediments and affect water quality downstream of harvest areas. However, there are differences in the level of impact from various crossing types, with impacts dependent on how often a crossing is used and the physical characteristics of the site (Looney, 1981; Thompson and Kyker-Snowman, 1989; Thompson, *et al*., 1996; Tufts, *et al*., 1994; Welch, *et al*., 1998; White Water Associates, 1997; Taylor, *et al*., 1999; Rothwell, 1983; Thompson, *et al*., 1996; Reeves, 2012). The following discussion examines the differing impacts of crossings and highlights the relative performance and impact of temporary log crossings in terms of water quality and levels of sediment generated from erosion.

Carroll (2008) examined four different types of crossings and their associated impacts on water quality. The study was conducted on stream crossings in harvesting areas of natural upland stands of hardwood and pine plantations in the Piedmont physiographic region of central Virginia, United States. The landscape of the region is characterised as rolling hills with small drainage lines, and many of the ephemeral and intermittent streams have unstable banks because they are recovering erosion gullies from previous agricultural land uses. The four stream crossing types analysed were portable steel skidder bridges (bridge), standard earth-fill culverts (culvert), reinforced fords (ford), and pole-filled channel (some with pipe-culverts). Twenty-three stream crossings were monitored over the course of the project, including six bridges, six culverts, four fords and seven pole crossings. Total dissolved solids (TDS), pH, conductivity, water temperature and total suspended solids (TSS) were measured upstream and downstream of the crossings.

Aust, *et al*. (2011) published a follow-up article on Carrol (2008) and provided a clear summary of the work. It was noted in that culvert and ford crossings were primarily associated with permanent roads, whereas bridge and pole crossings were usually found on snig tracks (or 'skid trails'). Catchment areas for bridge and pole crossings averaged 49.7 and 9.4ha, respectively, while culvert and ford catchment areas averaged 282ha and 1059ha, respectively. Culverts and fords were used on permanent roads because of their greater load bearing potential and durability.

The water quality results for different crossing types presented in Aust *et al*. (2011) have been reproduced in Table 5-1 and represent the average concentration difference for each parameter between the upstream and downstream sites.

Table 5-1 Average change of water quality across waterway crossings of various types. Source: Aust *t al.* (2011)

Crossing type	Total number of times the crossings were sampled	Total Dissolved Solids (mg/L)	Conductivity (µS/cm)	pH	Temperature (°C)	Sediment (mg/L)
Bridge	48	22.7	40.3	0	0.5	221.4
Culvert	48	226.9	121.0	0	0.9	252.8
Ford or causeway	32	292.1	421.2	0.3	0.9	249.3
Pole or pipe-filled crossing	56	162.6	194.7	-0.3	0.4	144.6

Results indicated that bridges had the least overall impact on water quality, followed by pole crossings (analogous to log crossings). Fords appeared to have the highest overall impact on water quality across all indicators. Pole crossings resulted in the lowest level of sediment yield compared to the other crossing types. The differences in sediment concentrations were not found to be statistically significant for any of the treatments.

Aust, *et al*. (2011) also summarised findings of erosion potential models for the different crossing types presented in Carrol (2008). Erosion potential for the different crossing types was calculated using the Universal Soil Loss Equation (USLE) and the Water Erosion Prediction Project for forest roads (WEPP). The results are presented in Table 5-2 and demonstrate, overall, that temporary log crossings had the lowest erosion potential using both methods.

Table 5-2 Potential erosion estimates of approaches to different crossing types. Source: Aust *t al.* (2011)

Crossing type	Number of samples	USLE (tonnes/ha/year)	WEPP (tonnes/ha/year)
Bridge	48	39.0	49.0
Culvert	48	95.8	60.2
Ford	32	31.1	42.9
Pole crossing	56	9.2	35.0

The erosion potential estimates for culverts were higher than for bridges, fords and temporary log crossings. The paper attributed this to the need for more significant amounts of earth-fill (on permanent roads) and that culverts generally had longer, wider approaches with bare soil than other crossing types. Pole crossings typically had smaller approaches and were filled with slash (logs).

The estimated sediment load for ford crossings was approximately 3.4 times higher (using the USLE method) and 1.2 times higher (using the WEPP method) than for pole crossings. As previously noted, pole crossings tended to be used for temporary crossings on narrower roads that crossed smaller streams (and not for snigging), whereas ford crossings tended to be located in areas with wide, shallow streams and larger catchment areas. Nevertheless, both crossing types were constructed on channels with similarly gentle sloping banks and results indicated that erosion potential was significantly higher for fords compared with log crossings.

Reeves (2012) also explored the effectiveness of different elevated skid trail crossing types in minimising sediment loading downstream, although this experiment used pipe bundles instead of “slash” or timber logs for the crossings. The study was conducted at the University of Kentucky’s Robinson Forest in south-eastern Kentucky within the Cumberland Plateau physiographic region. The experiment was conducted on headwater streams within the 1,700ha Cole’s Fork watershed of Robinson Forest. Pipe bundles were applied to 3 crossings with drainage areas ranging from 12.6-33.9ha. Other crossing types which were evaluated were fords, bridges and culverts. Catchment areas for fords ranged between 21 and 119ha, bridges ranged from 15 to 89ha, and culverts ranged from 9.3 to 29ha. The study examined the effectiveness of temporary crossing structures on various water quality parameters, including suspended sediments, throughout the installation, use, removal and post-removal of the crossing.

Overall, the results of the study found a statistically significant difference among treatments, with average suspended sediment production over all elevated crossing types (204kg ± 65) being significantly less than the average for fords (7888kg ± 1614). While the pipe bundles’ mean total sediment (154kg ± 71) was not significantly different from culverts (432kg ± 38) or bridges (28kg ± 15), results did indicate that pipe bundles performed significantly better than fords and could be recommended as an improved crossing type to mitigate sediment from headwater streams (Reeves, 2012; refer to Figure 5-5).

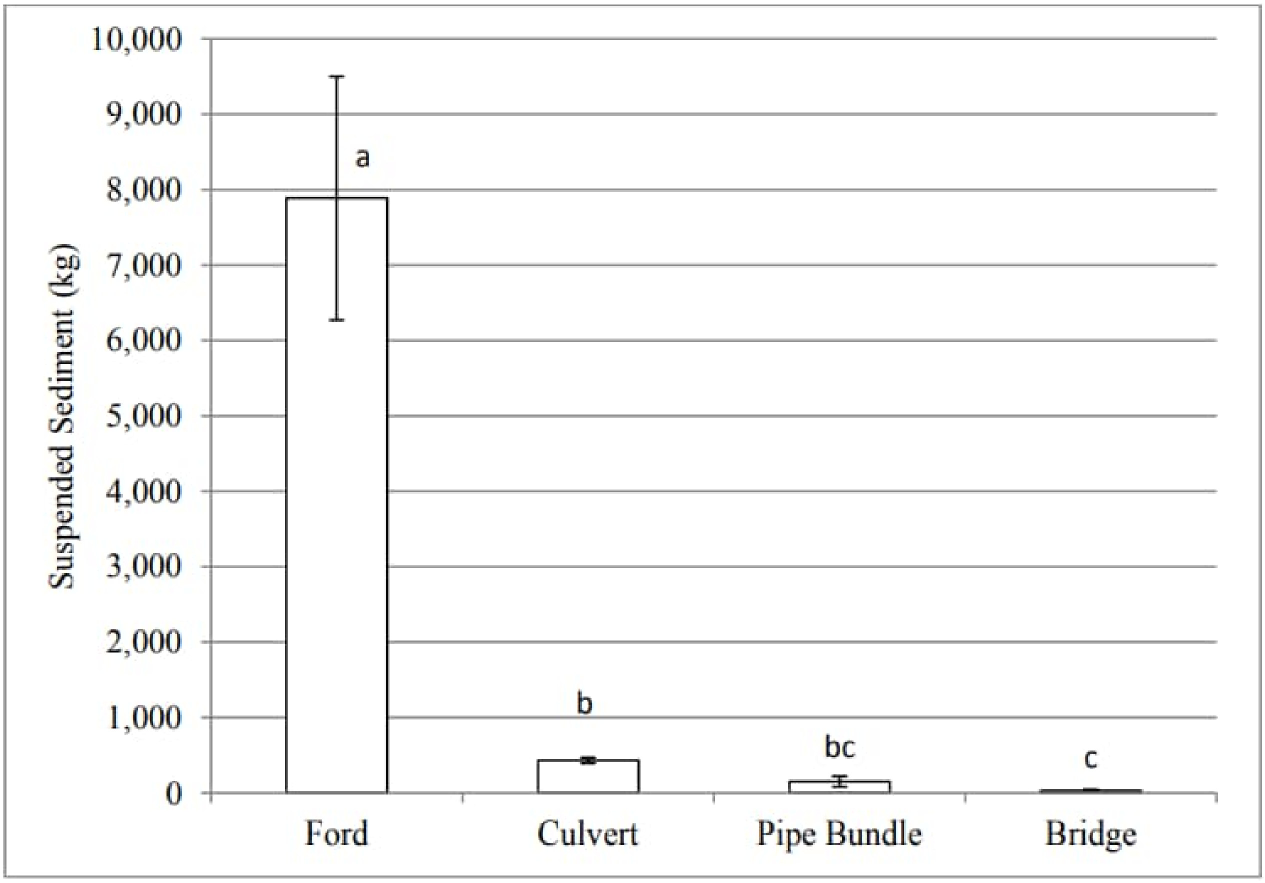


Figure 5-5 Total suspended sediment (mean and standard error) among all crossing types. Different letters indicate significant differences ($p \leq 0.05$) using least squares difference. Source: Reeves (2012)

Reeves (2012) also showed that even during low flows, having the snig track directly enter the stream channel increased the suspended sediment. Fords generated a total of 6556 kg (± 2521) of suspended sediment during the 22 passes over the structure. This was significantly higher than the overall average of 50kg (± 23) for all of the elevated crossing types. There was no significant difference among the elevated crossing types during the actual passes by the loaded cable skidder, which indicated that once the elevated structures were in place, they successfully mitigated suspended sediment introduction into streams.

Further, during removal and post-removal activities, fords produced significantly more suspended sediment than elevated crossing structures (Reeves, 2012). Fords generated 396kg (± 189) compared to 96kg (± 33) for all elevated crossing types. Even though there was no disturbance occurring after removal and skidder ruts and streambanks were stabilised, fords continued to contribute suspended sediment to streams. Among elevated crossing types, bridges and pipe bundles produced significantly less suspended sediments than culverts during both removal and post-removal periods.

Results from each of these experiments indicated that water bars alone were not the most effective treatment for preventing erosion and are not the best choice in areas that are prone to erosion. Seed treatments (with water bars) offered some erosion control but are only slightly better than water bars alone. Overall, the best erosion control was offered by the hardwood slash, pine slash and mulch treatments (all in combination with water bars).

Table 5-3 summarises the total sediment load calculated for each crossing type at each stage of the process. As can be seen, bridges performed best with regards to protecting water quality followed by pipe bundles (an analogue to temporary log crossings with through flow via pipes).

Research has also been conducted to assess the effectiveness of material being applied at the approach of a track crossing to minimise erosion and sedimentation. Studies by Wear *et al*. (2012), Wade *et al*. (2015) and Vinson *et al*. (2017) all compared the use of slash material being applied to snig tracks at the approach to a crossing. These experiments all adopted a similar approach to their assessment by evaluating the performance of various treatment types including 1) water bar only (control); 2) applying grass seed (seed); 3) applying grass seed with mulch (mulch); 4) piling hardwood slash on trails (hardwood slash); and 5) piling pine slash on trails (pine slash). The effectiveness of treatments was analysed using both onsite field measurements and by use of soil erosion models USLE, WEPP and the Revised Universal Soil Loss Equation version 2 (RUSLE2).

Results from each of these experiments indicated that water bars alone were not the most effective treatment for preventing erosion and are not the best choice in areas that are prone to erosion. Seed treatments (with water bars) offered some erosion control but are only slightly better than water bars alone. Overall, the best erosion control was offered by the hardwood slash, pine slash and mulch treatments (all in combination with water bars).

Table 5-3 Total sediment load summary for different drainage feature crossing types. Source: Reeves (2012).

Sediment levels (kg)	Ford	Culvert	Pipe Bundle	Bridge
Installation	38.9	84.9	13.67	3.6
Passes over	6556	63.6	79.9	6.8
Rain events during installation	879	68.8	1.42	4.28
Removal and post-removal	396	215	59.1	14.9
Total Suspended Sediment	7888	432	154	29.7

5.3 Summary of findings

While the body of literature on the relative performance of temporary log and other forms of waterway crossing is limited, it supports the general conclusion that temporary log crossings are likely to result in less downstream sediment movement than causeways. Other key findings of the literature review include:

- Log crossings should only be applied to temporary track crossings on low-order, ephemeral waterways. Use on higher order, flowing waterways can result in increased sediment load (Tornatore, 1995), as well as other hydrological and ecological impacts (Taylor, *et al*., 1999; Wisconsin DNR, n.d; DPI, 2006), relative to some other crossing types.
- Temporary log crossings can be constructed so that they result in limited bed and bank disturbance during installation, use and following removal of the structure from the channel (Monk, 2009).
- Causeways tend to have more significant impacts on water quality than other crossing types, including temporary log crossings (or similar structures), because streamflow passes over the snig track, introducing sediment directly into the stream during construction and use (Looney 1981, Thompson and Kyker-Snowman, 1989; Thompson, *et al*., 1996; Tufts, *et al*., 1994; Welch, *et al*., 1998; White Water Associates, 1997; Carrol, 2008; Aust, *et al*., 2011; Reeves, 2012).
- The physical setting, and operational use of the track crossing significantly influences the estimated erosion potential and volume of sediment generated (Carrol, 2008; Aust, *et al*., 2011).
- Well-constructed bridge crossings typically yield the lowest downstream sediment load (Carrol, 2008; Aust, *et al*., 2011; Reeves, 2012). Where they have gaps in the decking, sediment loads may exceed log crossings (Tornatore, *et al*., 1994).
- Estimated erosion potential for log crossings is lower than other crossing types (excluding bridges) and significantly lower than for causeways in a similar physical setting (Carrol, 2008; Aust, *et al*., 2011).
- During and following removal of a temporary track crossing, causeways produce significantly more suspended sediment than other elevated crossing types, including log crossings (Reeves, 2012). Causeways continue to contribute suspended sediment to streams after their removal and rehabilitation.
- Temporary log crossings (or analogues) were shown to produce significantly less suspended sediments than causeways and culverts during both removal and post-removal periods (Reeves, 2012).
- Placing slash material on the approach to temporary crossings can significantly reduce the erosion potential at the crossing (Wear, *et al*., 2012; Wade, *et al*., 2015; Vinson, *et al*., 2017).

6. Use of temporary log crossings in NSW coastal hardwood forests

6.1 Rationale for the use of temporary log crossings

Causeways have traditionally been used for temporary track crossings of ephemeral waterways in the coastal native forests of New South Wales. Temporary log crossings were introduced into the CIFOA on the basis they could, in at least some settings, provide improved environmental performance compared with causeways. The rationale for their introduction was that they would reduce deformation of the drainage features' bed and banks during construction, use and removal and hence preserve their stability (as illustrated in Figure 6-1). This would, in turn, reduce sedimentation and downstream water quality impacts.

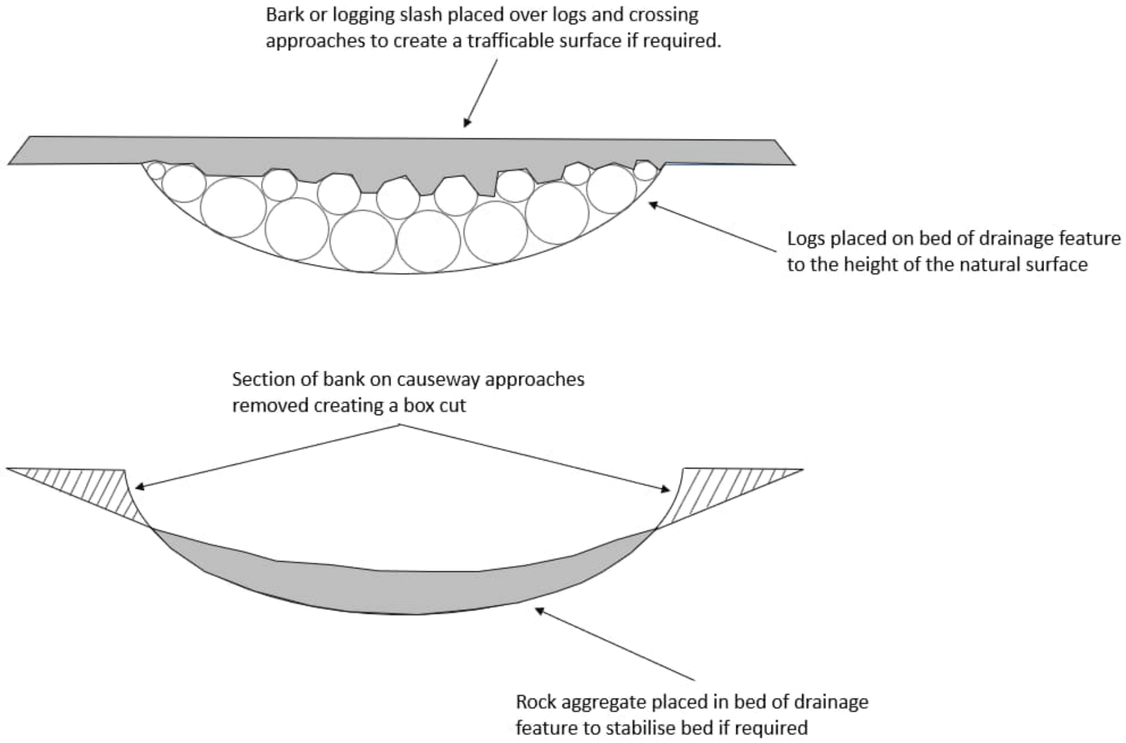


Figure 6-1. Conceptual models of temporary log crossings and causeway crossings for snig tracks (adapted from NSW Forestry Corporation, 2021).

If used properly, woody material should reduce the amount of damage to the bed and banks of drainage features compared with construction of causeways. For example, in comparison to dragging material across the natural surface of the channel bed in a causeway (which is usually bare soil), corduroy spreads the weight of the load and separating machine tyres and logs from direct soil contact thereby reducing ground pressure, disturbance and rutting. In addition, the channel bed sediment is invariably displaced by the dragged logs resulting in the continual pulling back of the material to ensure a stable running surface is maintained, which is neither efficient nor practical. By raising the level of the crossing to the natural surface on either side of the channel, log crossings eliminate the need to cut into channel banks which may be required to construct the approaches to a causeway crossing (see Figure 6-1).

6.2 Observations on the use of temporary log crossings and causeways in NSW coastal hardwood forests

Despite being permitted under the CIFOA, there is limited NSW native forest experience in the use of temporary log crossings as a form of temporary track crossing. We conducted two site visits to the Wauchope region to inspect and evaluate the use of temporary log crossings within the NSW coastal native forest setting. Our first site visit did not coincide with the active use of temporary log crossings and we were unable to inspect crossings that were in place. However, we were able to visit a site where a temporary log crossing had recently been used and rehabilitated, and photographic evidence of the use of that temporary log crossing was provided by NSW Forestry Corporation (Figure 6-2) . Video footage of another temporary log crossing (Figure 6-3 and Figure 6-4) was also provided by NSW Forestry Corporation which also allowed useful observations.

During our second site visit, a temporary log crossing was in place and a demonstration of the use of the crossing to transport logs was provided by the harvesting contractor and NSW Forestry Corporation (Figure 6-5 and Figure 6-6). Video footage and site photographs of the temporary log crossing being removed, as well as following rehabilitation were also provided by NSW Forestry Corporation (Figure 6-7, Figure 6-8).

We also revisited the rehabilitated temporary log crossing site inspected in the first site inspection to evaluate the condition of the site several months after rehabilitation (Figure 6-2).

The temporary log crossings depicted in Figure 6-2 to Figure 6-8 support several inferences (by the authors) about the benefits and risks in using temporary log crossings for snig tracks that cross small ephemeral waterways:

- Temporary log crossings reduce the physical impacts of skidders and snigged logs on the bed and banks of ephemeral waterways relative to conventional causeways constructed under Condition 106 and operated in accordance with Protocol 9.7 and 17 of the CIFOA. There are three main mechanisms involved, each of which is likely to reduce disturbance to the waterway and reduce the risk that sediments are mobilised in subsequent rainfall events:
    - The skidder and logs pass across the log fill and so do not directly disturb or deform the bed or banks of the waterway
    - For locations where the stream bed is incised, the log fill lifts the traffic above the incised channel, where a causeway would require excavation and disturb the channel and banks. Excavation to construct a causeway crossing could allow sediments to be mobilised into the waterway during a rainfall event
    - The log fill acts to at least partly intercept any soil or other debris dragged onto the crossing. This function would be enhanced by placing bark and possibly other debris over the logs.
- Temporary log crossings can be rehabilitated, often with minimal rehabilitation effort or residual risk of sediment generation from the crossing point.
- Where the approach to the crossing point is relatively steep (as depicted in Figure 6-2 to Figure 6-9) the main potential sources of sediment into the waterway (both during crossing operation and following rehabilitation) are from the snig track. During operation of the track, the snigged logs (particularly) drag soil onto the crossing. While the logs help to intercept that material, if they do not have a full cover of bark or other debris, that soil may fall through to the waterway bed. If a rainfall event causes runoff while the crossing is in place, this soil may be mobilised along the waterway. If the track does not have appropriately constructed cross drains on the approach to the crossing (required post-rehabilitation), water may run along the track and deposit sediment into the waterway.

Crossing in use (NSW Forestry Corporation)	Rehabilitated and stabilised crossing and its approach (Jacobs)	Bed of rehabilitated log crossing. (Jacobs)	Bed of rehabilitated log crossing 9 months after rehabilitation (Jacobs)

The temporary log crossing was constructed to ease the pass of a skidder and logs across a small ephemeral waterway. Both approaches to the crossing were relatively steep (~15°) and the bed of the waterway channel was incised 50-100cm at the crossing point. While no soil was deliberately placed onto the crossing, machine traffic and snigging resulted in soil accumulating on the logs. Following removal of the logs, there is minimal evident disturbance of the bed and banks of the channel nor of the approaches to the crossing. The bed of the waterway appeared stable and no more likely to erode during a flow event than adjacent undisturbed areas. Potential flow of water along the compacted track is intercepted by a cross-drainage structure (constructed at rehabilitation) placed about 5 m from the crossing. The bed and banks appeared to have remained stable during the months following rehabilitation (despite significant rainfall). Cross drainage has also remained intact. A significant amount of forest litter (leaves, bark, branches and twigs) had fallen into the channel since rehabilitation. A small amount of vegetation had grown in the riparian buffer zone either side of the crossing along the snig track approach.

Figure 6-2. Temporary log crossing in use and following rehabilitation, Wauchope region, NSW. Sources: NSW Forestry Corporation, Jacobs

Crossing following use | Water in ephemeral stream below crossing

As in Figure 6-2, this temporary log crossing was constructed to ease the pass of a skidder and logs across a small ephemeral waterway. Both approaches to the crossing were relatively steep and in active use, the snig track is compacted and would channel any overland flow towards the waterway. The bed of the waterway channel was incised up to 100cm at the crossing point. Soil was again dragged onto the crossing by machine traffic and logs. Rainfall following construction of the crossing has passed through the logs and, some remained in a pool on the downstream side of the crossing.

Figure 6-3. Temporary log crossing, Wauchope region, NSW. Source: NSW Forestry Corporation

Skidder with logs approaching the crossing | Skidder dragging logs over the crossing

This is the same log crossing as shown in Figure 6-3. The skidder approaches and passes over the crossing slowly, without any obvious wheel slippage. The snigged logs leave ruts in the snig track and drag soil and bark onto the crossing. The logs are lifted as the skidder passes the crossing to prevent the logs from digging into the track. The presence of logs in the crossing prevents direct contact between the waterway bed and the logs being snigged. Had the crossing been via a causeway, it is assumed that the ruts in the snig track would have continued across the crossing.

Figure 6-4. Temporary log crossing, Wauchope region, NSW. Source: NSW Forestry Corporation

Crossing in-situ (Jacobs)	Cross-sectional profile of crossing (Jacobs)	Slash and bark build up on far side of the crossing (Jacobs)

Similar to crossings shown in Figure 6-2 to Figure 6-4, this temporary log crossing was constructed to ease the pass of a skidder and logs across a small ephemeral waterway. The channel head was approximately 200 metres upstream of the crossing location. Both approaches were relatively steep and in active use. The bed of the waterway was incised approximately 50cm at the crossing point, although the grade of the approaches to the waterway were only 5-10°. One layer of logs had been placed in the channel. Soil and debris were again dragged onto the crossing by the machine traffic and logs. There was a significant amount of bark and slash located on the far side of the crossing which had been deposited during the log drag. This also provides some protection to the soil from machinery traffic.

Figure 6-5 Temporary log crossing in-situ during second site visit, Wauchope region, NSW. Source: Jacobs

		
Crossing in use, showing skidder travelling over crossing (NSW Forestry Corporation)	Crossing in use, showing log being pulled over crossing by skidder (Jacobs)	Approach to the crossing, showing ruts and disturbance of the soil caused by log drag (NSW Forestry Corporation)

This is the same log crossing as shown in Figure 6-5. A demonstration of the use of the crossing was provided by the harvesting contractor with a skidder machine. The log crossing in use demonstrated the same observations as were evident in the video footage provided by NSW Forestry Corporation of the log crossing shown in Figure 6-3 and Figure 6-4. The snigged logs leave ruts in the snig track and drag soil and bark onto the crossing. The logs are lifted as the skidder passes the crossing to prevent the logs from digging into the track. The presence of logs in the crossing prevents direct contact between the waterway bed and the logs being snigged. Had the crossing been via a causeway, it is assumed that the ruts in the snig track would have continued across the crossing.

Figure 6-6 Temporary log crossing in use during second site visit, Wauchope region, NSW. Sources: Jacobs, NSW Forestry Corporation

		
Log crossing extraction following use (NSW Forestry Corporation)	Channel bed immediately following log extraction (prior to rehabilitation) (NSW Forestry Corporation)	Channel bed following rehabilitation (NSW Forestry Corporation)
This is the same log crossing as shown in Figure 6-5 and Figure 6-6. The logs were extracted by a tracked harvesting machine. The logs were collected and lifted out of the channel. No channel bank reformation works were required following extraction as the banks had remained intact. The sediment, debris and slash that had accumulated on the crossing fell into the channel bed when the logs were extracted but was removed during rehabilitation works. The bark and debris which had accumulated on the far side of the crossing during operation was moved out of the riparian buffer zone. Cross banks were constructed on the snig track approaches (to intercept overland flows along the tracks) approximately 5m from the channel banks. The channel bed required minimal rehabilitation efforts to restore the channel to a stable state.		

Figure 6-7 Temporary log crossing during extraction, prior to and following rehabilitation, Wauchope region, NSW. Source: NSW Forestry Corporation

This is the same log crossing as shown in Figure 6-5 to Figure 6-7. The photographs show the state of the crossing and snig tracks approximately one month after rehabilitation. A cross bank is in place and slash and grass have been placed / sown across the snig track to assist in stabilisation. Leaf litter has accumulated in the stream channel and been moved by a small flow. The flow event also appears to have redistributed a small amount of the loose soil present in the rehabilitated crossing., which otherwise appears stable.

Figure 6-8 Temporary log crossing following rehabilitation and subsequent rainfall, Wauchope region, NSW. Source: NSW Forestry Corporation

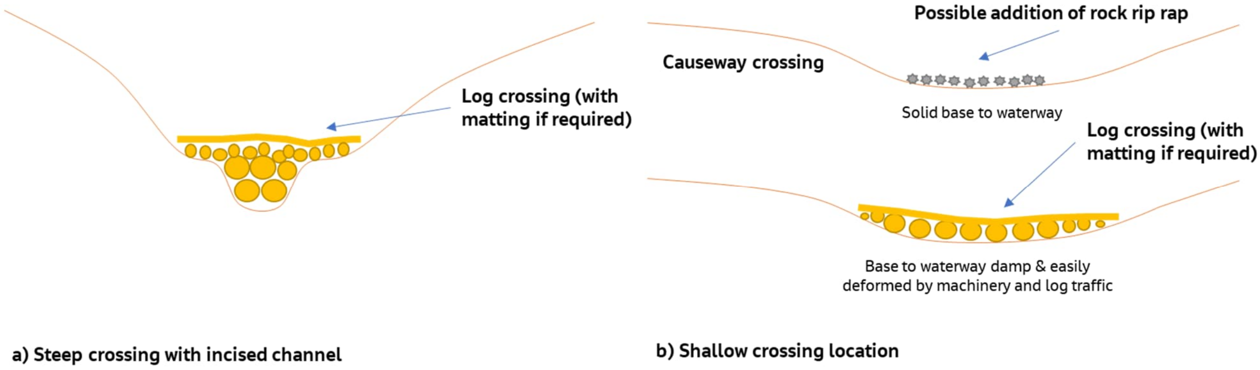
Two causeway crossings were observed during our first field trip (Figure 6-9). Both were used to access hardwood forestry plantations and were not subject to the IFOA Conditions or Protocols. Although they were not direct analogues of causeways that would be constructed in native forests, both images highlight that causeways have potential to act as an on-going sediment source. This risk is exacerbated if used when wet and machinery traffic disturb soils in a drainage feature.

Causeway crossing in on-going use, with evidence of sediment generated following vehicle passage. Note that this is a road rather than temporary track crossing.

Causeway crossing showing disturbance associated with traffic during harvesting and site preparation for replanting. Soil in the drainage feature has been disturbed and could be mobilised during a significant rain event

Figure 6-9. Causeway crossings in/near hardwood forestry plantations, Wauchope region, NSW. Source: Jacobs

Temporary log crossings appear to be most appropriate in settings where the approaches to a crossing point on an ephemeral waterway are relatively steep and there is an incised channel (Figure 6-10a). Use of log fill reduces the grades, elevates traffic above the channel and reduces disturbance to the bed and banks of the waterway, relative to a causeway. Causeways would normally be a more appropriate form of crossing for ephemeral drainage features with lower approach slopes and minimal channel incision (Figure 6-10b), or crossings where the bed substrate is highly resistant to erosion or deformation (i.e., rock or gravel). Temporary log crossings could reduce disturbance in areas with damp soils that would not be able to resist machinery and log traffic.



Potential advantages in using temporary log crossings are greater for waterways with steep approaches and/or incised low flow channels. Causeways (with or without rip rap) are suitable for use in settings with lower slope and dry and solid soils that are less likely to be deformed by machinery traffic.

Figure 6-10. Conceptual landscape settings for causeway and temporary log crossings.

6.3 Analysis of the regulatory framework for temporary track crossings of ephemeral waterways

Planning and operational requirements for temporary log crossings and causeways used as (temporary) track crossings are summarised in Table 6-1, with specific details of the requirements given in Table 3-2 to Table 3-5. Many of the differences in operational requirements reflect unique features of temporary log crossings and the locations in which they are to be used. Beyond that, planning and design specifications are stronger for causeway crossings and some operational requirements for temporary log crossings are more restrictive.

The former most likely reflects that causeways may be for tracks and roads and may therefore be used in a wider range of settings than temporary log crossings. Unlike temporary log crossings, there are no limits on the number of temporary causeway track crossings within a compartment and no time-based restrictions on their use, closure and/or rehabilitation.

Table 6-1. A comparison of the planning and operational requirements for temporary track crossings of ephemeral waterways by log crossings and causeways

Temporary log crossings	Temporary causeway track crossing
Operational planning	
Protocol 9.4	Protocols 9.4, 9.7 Protocol 17.5 if causeway located in class 1 aquatic habitat
Key differences: ▪ No specific planning requirements for temporary log crossings in class 1 aquatic habitat, noting that given their restriction to first and second order ephemeral drainage lines, it is unlikely that temporary log crossings would be able to be constructed in class 1 aquatic habitat ▪ No specific design requirements for temporary log crossings to ensure disturbance to bed and banks of drainage feature is minimised (as per Protocol 9.7 b,d,e)	
Operational requirements	
Condition 106 Protocol 32	Condition 106
Key differences (other than unique features of location and construction of temporary log crossings): ▪ Only one temporary log crossing may be operational in a compartment at a time ▪ Temporary causeways on ephemeral waterways are not subject to similar time restrictions to temporary log crossings, namely: - A temporary log crossing must not be used after the date that is two weeks from the date of construction (Protocol 32h) - A temporary log crossing must be removed within five days of the completion of snigging at that crossing, and following removal, the area in which the crossing was located must be stabilised and rehabilitated prior to opening another crossing in that area (Protocol 32i) - Where a temporary log crossing causes a diversion of the drainage feature or erosion, such as undercutting, the crossing must be removed within five business days of the occurrence of the diversion or erosion (Protocol 32k) ▪ A temporary log crossing must not be used in an area of a compartment that is subject to seasonality restrictions	

The more restrictive operational requirements for temporary log crossings provided by Protocol 32[4], reduces flexibility in their use and may diminish their attractiveness to harvesting contractors, relative to temporary causeway crossings. This may have contributed to their apparent slow uptake and the realisation of any environmental benefits from their introduction.

[4] Noting that these conditions were proposed by/agreed with Forestry Corporation NSW.

7. Research gaps and monitoring recommendations

7.1 Research gaps

There are few studies (and none from Australia) that compare water quality impacts from log and other types of ephemeral waterway crossings in forestry settings. Limited research evidence and scant NSW field experience with temporary log crossings in native forests contributes to uncertainty regarding our findings in relation to their appropriate use.

Water quality in natural streams is highly variable, being significantly influenced by their physical setting (including climate and weather) and treatment. Designing and executing a research program to definitively test and compare water quality implications of temporary log crossings and causeways within the CIFOA area would be inherently difficult. Key issues to resolve include:

- Sampling the diversity of landforms, soils, forest types and prevailing climatic conditions
- Achieving uniformity of crossing setting, construction and rehabilitation
- Accounting for weather conditions during use of the crossing and following its rehabilitation, as well as any post-harvest fuel reduction or regeneration burning
- Cost, expense and physical disruption associated with installing water quality and flow measurement equipment up and downstream of the crossing location
- Establishing baseline conditions prior to construction of the crossing
- Limited use of either crossing type in native forest operations, given the preference to avoid construction of any form of snig track crossing.

It would therefore be difficult to design a study that would successfully control for key variables and hence allow proper attribution of any observed impacts on water quality to crossing type.

While there are significant research gaps relating to the use of temporary log crossings and causeways in CIFOA forests, these challenges suggest that research to address these would be expensive (particularly when compared to the potential benefit), take several years and likely not yield definitive results. It is therefore not recommended that such research be directly commissioned. Collaborative research with universities and government agencies in other states could be considered.

7.2 Monitoring

Protocol 38: Monitoring Program of the CIFOA specifies that the approval’s monitoring program must be designed to monitor and evaluate the effectiveness of the conditions of the approval, including those relating to drainage feature crossings. This review is a response to that requirement and provides an evaluation of the effectiveness of conditions relating to temporary log crossings and causeways for snig track crossings of ephemeral waterways. However, as previously noted, confidence in that evaluation is constrained by the limited relevant research and dearth of monitoring.

It is recommended that monitoring be undertaken prior to construction, during use and following removal of temporary log crossings and causeways. The monitoring program is suggested to include two components, as follows.

Temporary track crossing monitoring network

This would involve establishment of a network of 15-20 temporary log crossing and causeway monitoring sites (each) across NSW Coastal State Forests. The sites would be set up to monitor temporary track crossings of both types over a range of forest types, landforms, climate zones and operators. Monitoring would continue for one to two years on each site and, depending on resourcing, sites could be “retired” and new temporary track crossing monitoring sites added.

Monitoring at these sites would include two elements:

- *Photo point monitoring:* establishment of a series of photo points in the vicinity of the crossing site to capture its initial condition, state during use and conditions following rehabilitation. Monitoring would continue approximately quarterly during the two years following rehabilitation, as well as episodically, following major rainfall events (e.g., any event greater than 50 mm/d or 100 mm/week). The monitoring points might be configured as depicted in Figure 7-1.

Photographic records would be reviewed, as follows:

- Immediately post-rehabilitation: to identify differences from the original bed and bank conditions following rehabilitation, identify any necessary corrective actions to stabilise the crossing and provide a baseline for post-rehabilitation comparisons
- Quarterly and post-event reviews: to identify how bed and bank conditions have changed post-rehabilitation and rainfall events, instigate any corrective actions that might be needed and evaluate the effectiveness and durability of rehabilitation measures and cross drains on the approaches to the crossing.

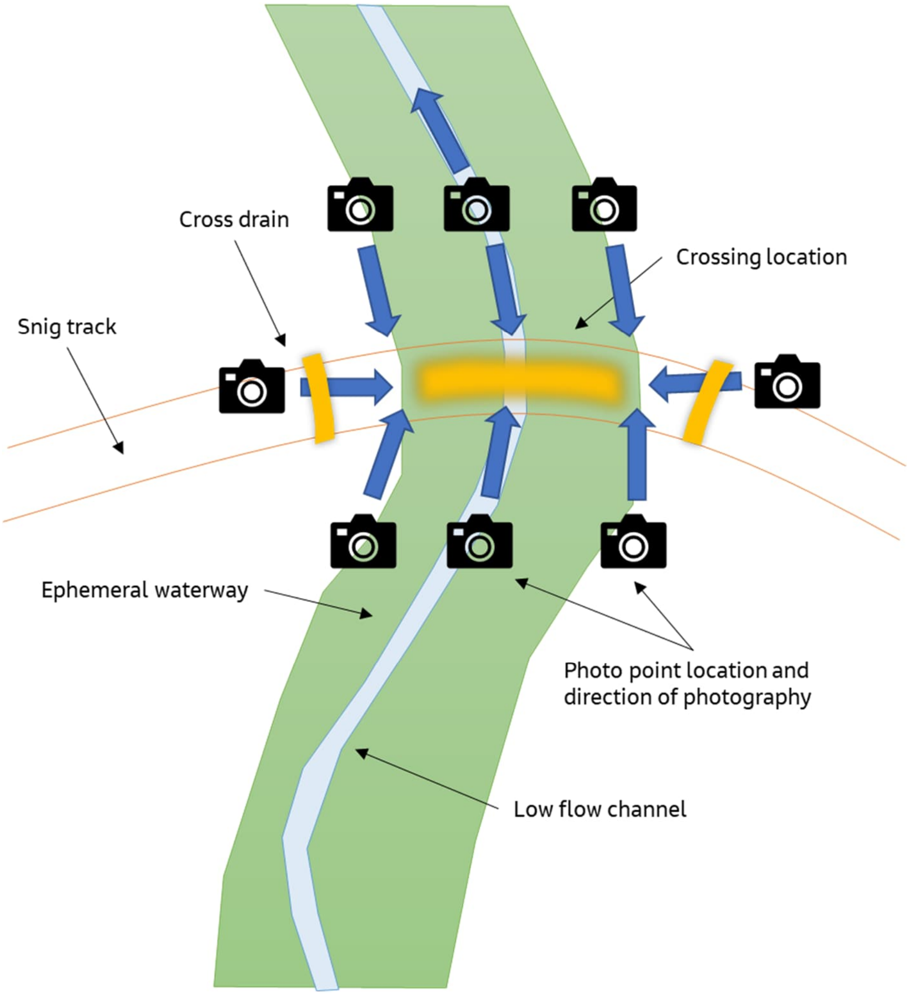


Figure 7-1. Depiction of potential photo point layout for monitoring temporary log crossings

- *Waterway stability classification:* a visual assessment of waterway / channel stability would be completed in conjunction with the photo-point monitoring. This assessment would be undertaken with reference to a set photographic standards and descriptions that scale the stability of the crossing point and success in rehabilitation (e.g., 1-5, low stability/poor rehabilitation to high stability/good rehabilitation). Categorisation would account for vegetation regrowth, erosion within the channel, and the effectiveness of the cross bank in diverting overland flows from the snig track. Monitoring would be undertaken quarterly (by NSW Forestry Corporation personnel) for two years post-rehabilitation (in conjunction with photo point monitoring.
  This form of monitoring would require photographic standards and descriptions to be developed.

Data and observations from monitoring should be collated and reviewed annually until two-years of post-rehabilitation monitoring has been obtained for all sites. Preliminary reviews would be undertaken to assess the appropriateness of data collection and refine monitoring methods (if required). They would also be used to assess the relative impacts of the two crossing types (log crossings and causeways) and identify opportunities to improve construction and rehabilitation of crossings and reduce any soil or water quality impacts.

An annual independent audit or review of site conditions and the waterway rehabilitation categorisation data and accompanying photographs is also recommended.

Once the data collection program has been completed, data would be reviewed and analysed, and the results comprehensively reported. As necessary, additional monitoring or research may be recommended.

Routine compartment monitoring

A crossing establishment and management record would be added to routine compartment monitoring undertaken by NSW Forestry Corporation personnel. The types of data gathered would include:

- Siting: photograph of crossing site, comments on the rationale for selection, any specific soil or water quality risk factors and how these are to be controlled.
- Construction: photographs of site post-construction, comments on implementation of any soil or water quality risk controls. Date of construction to be noted.
- Operation: record of days in use, comments on any observed impacts associated with use of crossing, rainfall events etc. Date of final use to be noted.
- Rehabilitation: photographs of site before and after rehabilitation, including of cross banks to intercept runoff along snig track. Documentation of planned rehabilitation approach, including of risks to soils and water and their mitigation. Documentation of rehabilitation implementation. Description of level of disturbance of bed and banks from use and rehabilitation of crossing. Date of completion of rehabilitation to be noted.

8. Potential modifications to Protocol 32 Temporary log crossings

Based on the limited available literature on temporary track crossings of ephemeral waterways, first principles consideration of the relative potential effects of temporary log crossings and causeways on such waterways and our review of relevant CIFOA protocols and conditions, we suggest consideration of several potential amendments to Protocol 32: Temporary log crossings (Table 8-1). They only apply to 32.2 Management requirements.

Table 8-1. Suggested modifications to Protocol 32 Temporary log crossings and associated rationale.

Current text	Proposed modified text	Rationale
32.2 Management requirements		
a) A temporary log crossing must only be constructed on a drainage depression, first order ordered drainage feature, second order ordered drainage feature, class 1 classified drainage line or class 2 classified drainage line that is no more than one metre deep.	a) A temporary log crossing must only be constructed on a drainage depression, first order ordered drainage feature, second order ordered drainage feature, class 1 classified drainage line or class 2 classified drainage line that is no more than one metre deep **at bankfull level as per Protocol 16.5**.	The amendment is proposed to clarify how 1m depth is to be measured. A similar amendment to Condition 106 Track crossings is recommended to prevent the construction of temporary track crossings by causeways or temporary log crossings of larger drainage features. Beyond 1m, alternative crossing locations should be sought.
b) Water must not be flowing at the time of temporary log crossing construction	-	-
c) Only one track with a temporary log crossing can be used in a compartment at any time.	Propose removing this rule.	There are no limits on the number of causeway crossings that may be used in a compartment at any time. If temporary log crossings are appropriate for use, which we consider to be the case, they should be permitted to be used as required.
d) Earth fill is not permitted to be used in a temporary log crossing.	-	-
e) A temporary log crossing must be capable of withstanding snigging	-	-
f) No branches or tree heads are to be used in the construction of a temporary log crossing	f) No branches or tree heads are to be used in the construction of a temporary log crossing. **Bark may be used as matting on the trafficked surface of the crossing.**	The amendment is proposed to clarify that matting is not proscribed and may catch soil that would otherwise work its way between the logs and into the waterway as the crossing is used. Matting, logs and any other material deposited in the waterway would need to be removed when the crossing is rehabilitated (consistent with Condition 106 and Protocol 32.2 I,j).
g) The location of a temporary log crossing must be approved and shown on the operational map.	-	-

Current text	Proposed modified text	Rationale
h) A temporary log crossing must not be used after the date that is two weeks from the date of construction.	Propose removing this rule.	There is no similar restriction on the duration of use of causeways and no obvious reason to limit use to two weeks from construction. Temporary log crossings and causeway track crossings should be open only for the time required to complete snigging at that location and then rehabilitated.
i) A temporary log crossing must be removed within five days of the completion of snigging at that crossing, and following removal, the area in which the crossing was located must be stabilised and rehabilitated prior to opening another crossing in that area.	i) A temporary log crossing must be removed **and rehabilitated as soon as practicable and** within five days of the completion of snigging at that crossing. ~~Following removal, the area in which the crossing was located must be stabilised and rehabilitated prior to opening another crossing in that area~~	Temporary log crossings should generally be rehabilitated as soon as practicable after log extraction has been completed in the area accessed by the crossing. Five days has been retained as the upper limit. It is suggested that Condition 106 is amended to ensure that all forms of temporary track crossing are rehabilitated over a consistent timescale. There is no apparent justification for causeway track crossings to remain unrehabilitated for longer than temporary log crossings. Since there is no similar restriction on the number of causeways that may be open at one time, it is proposed that this restriction be removed for temporary log crossings.
j) When removing a temporary log crossing, logs must be lifted out of the drainage feature.	-	-
k) Where a temporary log crossing causes a diversion of the drainage feature or erosion, such as undercutting: ▪ the crossing must be removed within five business days of the occurrence of the diversion or erosion; and if the soil is: - not saturated, soil stabilisation measures must be put in place within five days of the occurrence of the diversion or erosion to achieve a stable cross-section; or - saturated, then the saturated soil condition in condition 98 of the approval applies.	-	-
l) A temporary log crossing must not be used in an area of a compartment that is subject to seasonality restrictions.	Propose removing this rule.	Forestry operations continue to be subject to seasonality restrictions. If temporary log crossings are the most appropriate form or crossing at a location and can be constructed, used and rehabilitate safely, they should be used. There is no similar restriction on the use of causeway track crossings.
m) Where a temporary log crossing is removed, the crossing must be reshaped and: if the soil is not saturated, soil	-	-

Current text	Proposed modified text	Rationale
stabilisation measures put in place within five days to achieve a stable cross-section; or if the soil is saturated, saturated soil conditions apply.		
n) Following the removal of a temporary log crossing, material used to construct the temporary log crossing must not be left in the riparian exclusion zone or ground protection zone.	-	-
	Propose including a new rule, whereby temporary log crossings would be removed, and the site temporarily rehabilitated when rainfall exceeding the 1:10y event prescribed in Condition 106.8 is forecast to be exceeded.	Condition 106.8 requires all track crossings to be capable of withstanding peak flows from a 1:10 year storm event. When larger events are forecast and temporary log crossing sites might be disturbed by high flows, they should, where practicable, be removed before the event. This will allow the site to safely pass the flows and avoid the soil disturbance and debris movement that may result from failure of a crossing. Temporary cross banks should also be put in place to prevent drainage from the snig track flowing directly into the waterway. Photographic evidence suggests that temporary log crossings can be removed with minimal disturbance to the waterway and hence crossing removal prior to a forecast heavy rainfall event is preferable to leaving it in place and risk it not safely passing water flows. Given the low frequency of recurrence of the rainfall event specified and the brief period of operation of the temporary log crossing, there would likely be only rare instances where temporary removal would be required. This proposal is suggested as a theoretical concept. Its practicability, value in reducing environmental risk to ephemeral waterways and wording should be subject to further analysis and discussion among stakeholders.

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