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RESOURCE ROAD ASSESSMENTS FOR IMPLEMENTATION OF 9-AXLE LOG B-TRAINS

PROJECT NUMBER: 30101441

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Abstract. British Columbia permits the use of both tandem-drive and tridem-drive B-train configurations for log hauling on approved public highways and Forest Service Roads (FSRs). This report provides general guidance for professionals who assess the adequacy of resource roads (i.e., Road Permit roads, private roads, FSRs, Road Use Permit roads) for use by these 9-axle log B-trains.

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1 INTRODUCTION

British Columbia permits the use of both tandem-drive and tridem-drive B-train configurations for log hauling on approved public highways and Forest Service Roads (FSRs). Bradley (2020) detailed an assessment of B.C. bridge designs and forest road geometric standards to meet the requirements of these trucks which can be referenced for resource road assessments for 9-axle log hauling vehicles, and which is referenced in this document.

This report provides general guidance for professionals who assess the adequacy of resource roads (i.e., Road Permit roads, private roads, FSRs, Road Use Permit roads) for use by these 9-axle B-trains. The reader is referred to (Sinnett and Bradley, 2020) for information about the processes for authorizing 9-axle use on designated FSRs and public highways utilized by the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNR) and the B.C. Ministry of Transportation and Infrastructure (TRAN), respectively.

2 PROFESSIONAL ASSESSMENT OF RESOURCE ROADS FOR USE BY 9-AXLE B-TRAINS

The 9-axle B-train vehicle loads, load distribution, dimensions, wheel tracking, and performance characteristics differ from other highway log hauling vehicles currently in use. It is recommended that a qualified professional assess the intended resource road route prior to its use by 9-axle B-train log hauling vehicles, in order to confirm the adequacy of the road and its structures for safe use. The qualified professional should have adequate training and education associated with resource roads and bridges, including their design, inspection, and maintenance. In addition, they should have sufficient training and experience with vehicle loads, tracking, and dynamics to be able to assess the suitability of a resource road for use by log hauling configurations, and to understand the limitations of any guidance, such as provided in (Bradley, 2020), and implications for safe use. This document references technical guidance in (Bradley, 2020), which a qualified professional may utilize; alternatively, the qualified professional can implement other means to assess the suitability of 9-axle log hauling vehicles for use on a specific resource road route. The qualified professional is expected to follow professional principles and use appropriate best practices in the assessment and preparation of documentation. Following the guidance in this document will support meeting obligations for appropriate professional practice and documentation.

For FSRs, licensees are required to obtain authorization, typically consisting of a Road Use Permit, for 9-axle B-train use from FLNR. Qualified professionals should note that FLNR district managers will review and provide authorizations where appropriate for 9-axle B-train use on FSRs. District managers will review assessments in the context of the long term and not just a single user. The qualified professional's work will be kept on file and may be used in the future by district managers.

Two primary aspects of resource road infrastructure need to be assessed:

1. bridge structural capacity.
2. horizontal and vertical alignment and gradeability.

Office evaluations of bridge capacity and road geometry should be supplemented with field reviews to confirm that there are no problems with bridge and road condition and that they are suitable for industrial log hauling vehicle use.

A reviewing professional also may need to capture other infrastructure or considerations in an assessment, and this will be determined on a road by road basis.

2.1 Assessing Bridge Structural Capacity

Each bridge on a proposed 9-axle route needs to be reviewed according to information provided in Tables 1, 2, and 3 of (Bradley, 2020) to determine whether the bridge has sufficient capacity for 9-axle B-train traffic based on the underlying general analysis and resulting span limits. The span ranges specifically for tridem-drive 9-axle B-train traffic from Tables 1, 2, and 3 of (Bradley, 2020) are reproduced below for the reader's convenience. Bridges that are outside the identified span limits or that are not within the scope of the general analysis will need to be individually assessed for sufficiency by a bridge engineer.

The following data should be determined for each bridge along each 9-axle B-train route:

- The original design vehicle configuration.
- The bridge clear span and configuration (e.g., single or multiple spans, simply supported or continuous spans, single or multiple lane bridges).
- Whether any of the concrete beam bridges longer than 18.5 m were designed using a pre-2000 bridge design code (if designed with a pre-2000 code, the span limits in the report tables do not apply and the shear capacity will need to be determined separately by a bridge engineer using current bridge evaluation methods), and
- Any structural deficiencies that may limit capacity (i.e., structural defects causing the bridge to be down rated).

Field review of the bridge condition will identify maintenance or structural issues that may require addressing before industrial activities commence.

It is recommended that a table listing all the bridge assets to be used by the 9-axle B-train traffic be included in the report. The table should include basic details about each structure. In addition, it should demonstrate and confirm that each bridge meets the structural requirements for the type of 9-axle B-train traffic (tridem-drive and (or) tandem-drive). Table 2 provides an example of how these data might be arranged.

Table 1. Span length of single lane B.C. forest bridges that can support tridem-drive 9-axle B-trains [compiled from Tables 1, 2 and 3 in (Bradley, 2020)][a]

Bridge Design	Maximum Bridge Length that can be Support Tridem-drive 9-Axle B-Trains (m)		
	Simply Supported Single-Span Bridges	Simply Supported Two-span Bridges	Continuous Two-Span Bridges
L-45	5.5 (9.5 – 11 m length OK also)	11.0 (5.5 + 5.5) (16 to 17.5 lengths OK also)	10.0 (5.0 + 5.0)
L-60	23.0	22.5 (11.25 + 11.25)	20.0 (10.0 + 10.0)
CL-625	32.5	31.0 (15.5 + 15.5)	30.0 (15.0 + 15.0)
BCL-625	37.5	37.5 (18.75 + 18.75)	30.0 (15.0 + 15.0)
L-75	80	83 (41.5 + 41.5)	60 (30 + 30) Exception: bridges with spans of 18 – 22 m require a detailed analysis
L-100	80	160 (80 + 80)	100 (50 + 50)

[a]This table is offered as a general guide. Specific bridges may have higher load limits if they are evaluated individually. The calculated length limits assume that the bridge is in good condition with no deterioration that would reduce its structural capacity

Table 2. Sample bridge asset report table for 9-axle tridem-drive B-trains

Structure number	Location	Bridge type	Superstructure type	Span length (m)	Original bridge design vehicle	Load rating / field condition [a]	Applicable bridge length limit (m) [b]	Meets 9-axle B-train criteria?
CR-1488	5 km on Green Lake FSR	Simple, one lane, one span	Concrete panels on two steel girders	23.4	BCL-625	64 tonnes/ good condition	37.5	YES
CR-1403	16 km on Green Lake FSR	Simple, one lane, one span	Concrete slab	8.0	L-75	68 tonnes/ good condition	80	YES
CR-2204	35 km on Green Lake FSR	Continuous, one lane, two spans	Concrete panels on two steel girders	48.4 (24.2, 24.2)	L-75	68 tonnes/ good condition	60 (30, 30)	YES

[a]Field condition of key structural elements

[b]Refer to Table 1

2.2 Assessing Horizontal and Vertical Alignment, and Gradeability

9-axle B-trains are well suited to use in flat and gently rolling terrain. They are suitable for replacing log hauling configurations that are currently used in this type of terrain (i.e., 6- and 7-axle tractor/ semi-trailer 'hayracks', and 8-axle B-trains) and have comparable gradeability limitations and swept path requirements. Given their limitations, however, 9-axle B-trains are likely not suitable for replacing log hauling configurations that are commonly used in steep terrain, such as 8-axle tridem-drive/ quad wagon trailers.

The most expedient method for assessing the suitability of a road network for 9-axle B-trains is to consider the vehicles that are already using the network. Bradley (2020) lists the geometric requirements of 7 common highway-configured reference vehicles for making this kind of comparison:

- 8-axle tridem-drive B-train (25 m-long),
- 8-axle tridem-drive B-train (27.5 m-long),
- 8-axle tridem-drive tractor/ tridem lowbed trailer with a single axle booster,
- 6-axle tractor/ tandem-axle semi-trailer (6-axle 'hayrack'),
- 7-axle tractor/ tandem-axle semi-trailer (7-axle 'hayrack'),
- 8-axle tridem-drive tractor/ quad wagon trailer.

For example, if 8-axle tridem-drive tractor/ tridem lowbed trailers with single booster axles and (or) 8-axle tridem-drive B-trains have or are currently operating safely on a resource road network, this is strong evidence for a qualified professional to conclude that the network would be suitable for 9-axle B-train traffic. When reporting on the geometric fit of a network of resource roads to 9-axle B-trains, therefore, the qualified professional could simply indicate that the network roads have been or are currently used by trucks with comparable gradeability and horizontal and vertical alignment requirements.

If log hauling configurations other than those evaluated as reference vehicles are used on the proposed road network, the qualified professional could assess the road fit of 9-axle B-trains by alternative, more intensive analyses, such as:

- Comparing the geometric requirements of their specific trucks (log hauling and/or equipment transport) to those of 9-axle B-trains using the same approach as in (Bradley, 2020). These calculations may best be made using specialized path tracking software (e.g., AutoTurn from Transoft Solutions).
- Assembling data on the maximum grades, tightest vertical curves (including at bridge approaches), and narrowest road widths in horizontal curves on the subject road network and comparing these data to the grade limitations and vertical and horizontal curve requirements of 9-axle B-trains. These data might be the geometric standards specified by FLNR for FSRs (FLNR, 2018) or by TRAN (TRAN, 2007), be as-built road dimensions, or be a combination of both.

Tables 3 to 5 are reproduced from Tables 4 to 9 in (Bradley, 2020) for the reader's convenience and summarize the horizontal and vertical curve and gradeability requirements for 9-axle tridem-drive B-trains.

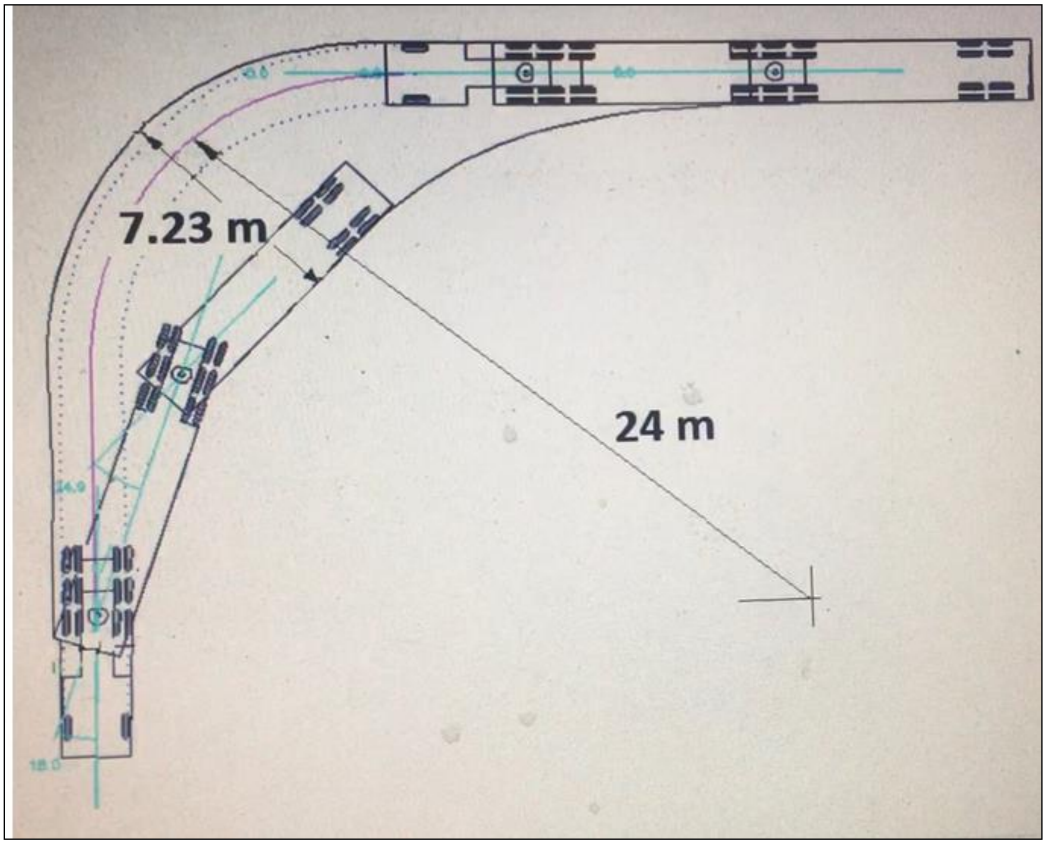

Figure 1. A 9-axle tridem-drive B-train has a 7.23 m swept path (occupied road width) when negotiating a 24 m-radius, 90° angle, curve.

Table 3. Horizontal curve requirements for 9-axle tridem-drive B-trains [from Tables 4, 5, and 6 in (Bradley, 2020)]

Curve description	Minimum road width in curve (m) [a]	Design speed (km/h)	Minimum curve radius (m)	9-axle tridem-drive B-train swept path through curve (m)				
				Curve angle				
				15º	20º	30º	45º	90º
Low-speed, tight-radius, curve	9	20	15	5.46	6.57	7.6	8.48	9.15
	7.6	20	24	5.43	6.29	6.74	7.03	7.23
Moderate-speed, curve	7	30	35	4.1	4.46	5.07	5.52	5.91
	6.7	40	65	3.88	4.11	4.31	4.42	4.45
High-speed curve	6	50	100	3.66	3.77	3.83	3.85	3.85
	5.8	60	140	3.47	3.52	3.55	3.55	3.55

[a]Recommended minimum value from FLNR (2018)

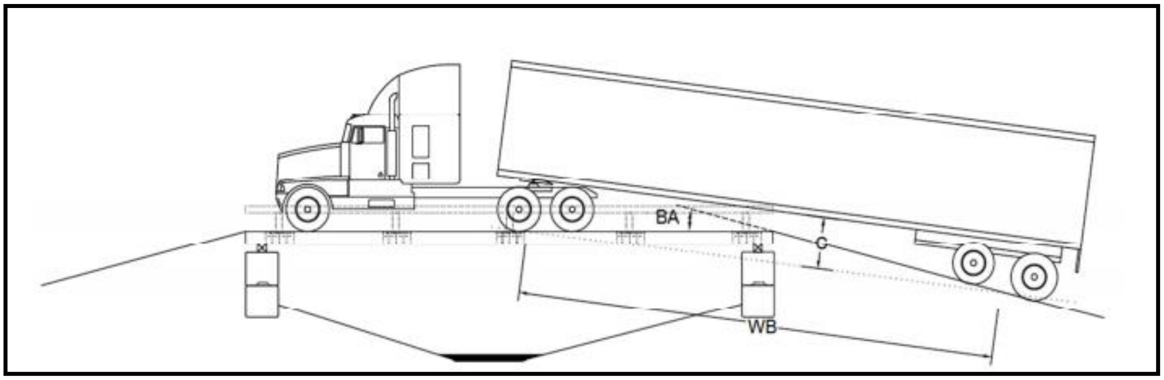

Figure 2. Schematic of tractor/ semi-trailer in the vertical curve of a bridge approach illustrating definitions of ground clearance (c), wheelbase (WB), and break over angle (BA).

Break over angle is defined as the maximum angle that a vehicle can drive over without the ground touching the vehicle's undercarriage. Break over angle can be derived from the vehicle's ground clearance and wheelbase as follows:

$$\mathbf{BA\ (°) = 2 \times tan^{-1}\ [2 \times C\ /\ WB]}$$

Grade break is the break over angle expressed as the percent grade (Grade break = BA x 2π / 360°).

The K value of a vertical curve is defined as the horizontal distance along which a 1% change in grade occurs on the vertical curve. It is calculated as horizontal length of curve divided by the absolute difference of the tangent grades (%):

$$\mathbf{k = L_C\ /\ |g1 - g2|}$$

where, *k = K value*

L_C = horizontal length of curve (from tangent 1 to tangent 2) (m)

g1 = percent grade of tangent 1 (%)

g2 = percent grade of tangent 2 (%)

In the following table, the K values are calculated for each component vehicle of the 9-axle B-train (tractor, lead trailer, and rear trailer) using that vehicle's wheelbase as the length of curve (L_C).

Table 4. Sample bridge asset report table for 9-axle tridem-drive B-trains

	Clearance (m)	Wheelbase (m)	Break over angle	Grade break	K value [a]
Tridem-drive tractor	0.56	6.60	19.3º	33.62%	0.20
3-axle B-train lead trailer	0.84	9.68	19.7º	34.37%	0.28
2-axle B-train rear trailer	0.98	7.00	31.3º	54.60%	0.13

[a]If sag and crest curves are constructed with K values that meet or exceed the minimum values given in (TRAN, 2007) or are calculated from the stopping sight distances given in (FLNR, 2018), then this will meet the requirements of 9-axle tridem-drive B-trains.

Table 5. Gradeability requirements of 9-axle tridem-drive B-trains [from Table 8 and Table 9 in (Bradley, 2020)]

Form of grade	Loading condition	Estimated traction-limited gradeability [a]			
		With tire chains on packed snow		On good gravel surfaces	
		< 200 m long	< 50 m long	< 200 m long	< 50 m long
Traction-limited, momentum-assisted, gradeability	unloaded	11% (11.5%)	14.5% (15%)	15.5% (17%)	19% (20.5%)
	loaded	10% (10.5%)	13.5% (14%)	14% (15.5%)	17.5% (19%)
Traction-limited, sustained, gradeability	unloaded	10% (10.5%)		14.5% (16%)	
	loaded	8.5% (9.5%)		13% (14.5)	

[a]Values in brackets are the gradeability with the inflation of the drive tires reduced (using a Tire Pressure Control System).

It is recommended that a table listing the geometric assessment results for each of the main resource roads be included in the report. This table should include basic details about each road and a reasoning why each road's geometry is suitable for use by 9-axle B-trains. An example of reasoning might be that FLNR minimum horizontal curve widths were used for the road design, 8-axle B-trains currently use the bridge approaches without issue, and maximum road grades are less than the 9-axle tridem-drive B-train limits given in (Bradley, 2020). Table 6 provides an example of how these data might be arranged.

Table 6. Sample of a resource road reporting table entry

	Maximum grade over 200 m long	Horizontal curve design standard	Vertical curve design standard	Historic or current truck configurations in use on the route	Reasoning for judgment that road is suitable for 9-axle B-trains
Green Lake FSR	7.50%	FLNR (2018)	unknown	8-axle B-trains, 7-axle tridem-drive hayracks	**1**. 9-axle B-trains OK for FLNR standard. Some widening of tight curves done after construction. **2**. 8-axle B-trains use bridges without issue, so 9-axle B-trains will too. **3**. Grades are less than 9-axle B-train limits.

Field reviews of the resource road routes will confirm office findings for suitability of 9-axle log haul vehicle use or confirm issues that require addressing before proceeding.

3 REPORT AND ASSURANCE STATEMENT

Both the ABCFP and EGBC professional practice guidelines require members to document their projects such that the work is measurable or verifiable, and so they can provide a rationale as to the methods used in measuring or verifying. In order to demonstrate professional reliance, therefore, project reports for resource road assessments should include key field and office review data, applicable qualifiers or limitations of the assessment, and an assurance statement from the qualified professional who prepared the report.

The assessment report should include:

- Identification of the subject truck (e.g., 9-axle tridem-drive B-train).
- A description of the assessment methodology.
- Clear identification of the road(s) and bridges being assessed. This may best be done on a map(s) showing the proposed haul route, the location of specific resource roads and bridges, and any other elements pertinent to the assessment.
- A table detailing, for each bridge on the haul route, key data including bridge number, location, bridge type, superstructure type, original design vehicle, current load rating, bridge length, field condition of key structural elements, and rationale for concluding the bridge is sufficient for 9-axle traffic.
- Tables summarizing the alignment of the haul route resource roads and the reasoning for concluding that it is suitable for 9-axle traffic. These tables may best be arranged to separately detail maximum grades, horizontal curves, and vertical curves.

Applicable qualifiers of the assessment may include seasonal restrictions of the haul route or be contingent on planned road or bridge work. Designation of a haul route for use with 9-axle B-trains (or other future configurations) is likely to be long term and, therefore, the assessment report should acknowledge that the client can rely on the assessment for an extended period. If disclaimers are attached to the report, they, too, should allow for the long-term use of the route by 9-axle B-trains (or other future configurations). Disclaimers concerning confidentiality, copyright, and liability limitations also may be warranted.

The report should include the qualified professional's assurance statement. This statement is an assurance that the work was conducted by the qualified professional, or under their direct supervision, such that they can take responsibility for all key aspects of the work. Finally, the statement should include an assurance that, in the professional's opinion, the analysis clearly indicates that the resource road(s) and its bridge infrastructure can be expected to remain within acceptable operating conditions when subject to 9-axle B-train use, subject to the limitations provided in the report.

4 MORE INFORMATION

Should the reader have questions or require clarification about technical aspects of conducting a resource road assessment, please contact the author Allan Bradley at allan.bradley@fpinnovations.ca; Brian Chow, Chief Engineer, FLNR at Brian.Chow@gov.bc.ca; or your local FLNR District Manager.

Further information about the TRAN and FLNR route authorization processes can be found in (Sinnett and Bradley, 2020).

5 REFERENCES

Bradley, A. 2020. *9-axle B-trains for log hauling on B.C. resource roads.* Technical Report No. 11, Version 2.1, Vancouver, B.C.: FPInnovations. December 2020.

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