Forest Haulage Roads in British Columbia

By Jack Durand *

THE building of roads for timber haulage is a comparative innovation by the B.C. Forest Service. This body administers the Crown forest lands of Canada's most westerly province and its 118 million acres of commercial forest stands. A postwar boom in timber had led the industry and the Forest Service to consider utilization of the less accessible of these stands. The Government then began to implement a blueprint presented to it in 1945 for the gearing of felling to growth in State owned forests and to reject older and less enlightened exploitation methods which gave no thought to the future of an area.

Certain forest areas were designated sustained yield units and management plans were completed for them. The province has continued to elaborate these units and to-day there are 78 covering over 46 million acres of productive forest. These are set an allowable cut which is, incidentally, set deliberately low, averaging 10 cu. ft. hoppus per acre per year. These areas are intended for the operation of sales to several smaller loggers, with a pre-set duration of sale which varies from 3 to 10 years. Larger operators generally arrange "tree farm" licences on long terms and are expected to provide their own development investment capital.

In the public sustained yield units, or working circles, the State is the manager through the agency of the local forest ranger and district management staff, there being five such districts in the province. Accessability being a primary requisite for the introduction of management, a special engineering section was organised in 1950 to provide for this. As the most rational system of haulage was by road the section evolved, as far as roading was concerned, into a highly specialised unit covering planning, design and construction. Its budget to-day exceeds £1 million which can be compared with the total forest industry production of more than £250 million (or roughly 40% of total provincial income) and the total allowable cut per year on State lands of over 650 million cu. ft. hoppus.

Planning.

The area of the unit is chosen from considerations of management, silviculture and access. Thus a large watershed or other naturally bounded area is frequently the unit. As the amount and type of roading is related to the amount and type of traffic, volume of timber, and constructional costs, a knowledge of the volume of timber and direction of haul is advantageously provided in the designed unit for a certain

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* (The author worked some years ago as a project engineer in British Columbia on forest road construction. For information on present day operations he is greatly indebted to Mr. P. J. J. Hemphill, Chief Engineer, Engineering Services Division, B.C. Forest Service.)

Naver-Ahbau Forest Development Road, Class 2 Road. Stand of over 100 year old Douglas fir and Western spruce in foreground. Waelti (1960).

Naver-Ahbau Forest Development Road, Class 2 Road. Waelti (1960).

sustained yield, moving towards a particular point or points. These facts, though helpful to the planner, leave him yet to decide a network of roads which ideally will have the least mean transporation cost and redemption costs. This latter concept stems from consideration of the roading as an industrial investment and a redemption or amortization period set usually at 20 years. For purposes of calculation this is regarded as an oncost to be recovered from sales of timber in the unit and the short period is comparable with private enterprise. This relatively short period has advantages in making an earlier return towards a faster rate of overall forest development and is helped by the fact that the most valuable stands in a unit are first exploited.

The calculation of the most efficient road network involves a summation of various combinations of elemental costs. Experienced judgement is necessary to ensure rapid elimination of the less likely methods in what is essentially a trial and error approach. It is found that networks will depend mainly on topography and layout of the block and generally will consist of main and tributary roads. The road classes, of which six are recognised, will on the other hand depend mainly on the tributary yield, which of course is known.

Road Classes — Minimum Dimensions in Feet

Class	Surface width	Subgrade width	Width of clearing
1	24–28	34	90
2	20–24	30	80
3	18–20	24	70
4	14	20	60
5	12	16	50
6	10	12	40

Classes 1 to 3 are double lane, Class 4 is $1\frac{1}{2}$ lane and Classes 5 and 6 are single lane. Classes 4 to 6 have passing bays built. Cut banks are sloped at $\frac{3}{4}$ to 1 or 1 to 1 and fill embankments are sloped at 1 to $1\frac{1}{2}$. Width of clearing is increased where necessary to provide 10 feet of cleared width above cut banks.

Of the roads constructed to date the ratio of length to area is 1 mile to 3,500 acres approximately and is intended frankly as primary access only, it being left to the operators themselves to lay out their own final haulage routes in keeping with their individual equipment. This allows adjustments in keeping with changing trends in logging practice, but it seems safe to assume that the density of construction of roading by the State will increase in the future.

The costs which must be recovered from the volume of timber transported can be divided into:

(1) yearly redemption costs for the road system,

(2) costs of haulage,

(3) yearly maintenance of the road system.

This total cost is usually expressed as dollars per hundred cubic feet of annual cut per mile of road. The general formula is stated as

$$y = ax + \frac{b}{x} + c \quad \text{(i)}$$

where ax = redemption costs

$\frac{b}{x}$ = haul costs

c = road maintenance costs.

Figure 1 shows this concept graphically.

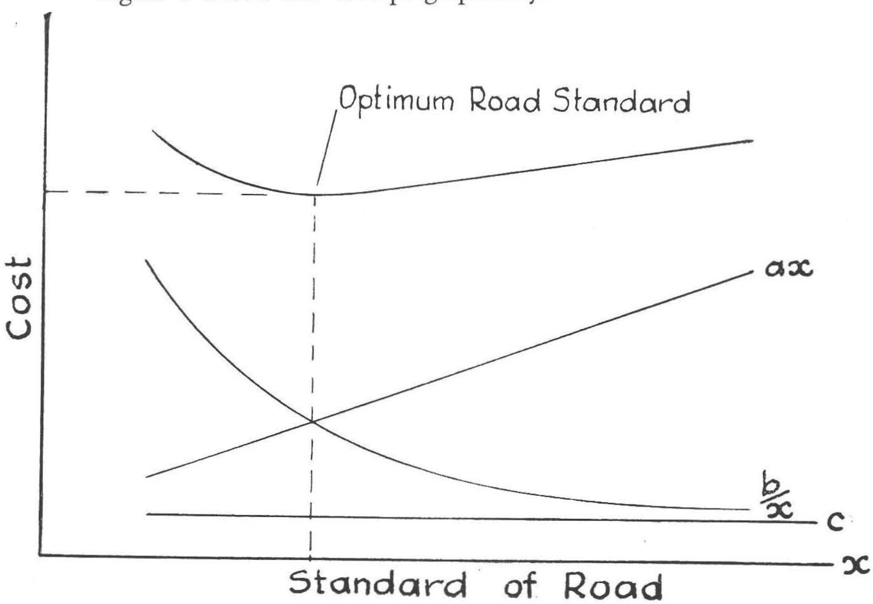


Figure 1

To find the optimal road class the formula is differentiated and then solved for x.

This gives $x = \frac{b}{a}$ showing that the optimal road class is that for which redemption costs and transportation costs are equal. The following table shows the general trend of these figures for the six classes of roads.

(i) Sundberg, U. Studier i Skogsbrukets Transporter
Svenska Skogsvordsforeningens Tidskrift No. 4 1952 and No. 1 1953.

Road Class	Average Tributary Annual Cut in cubic feet hoppus.
1	8 million
2	4—8 ,,
3	2—6 ,,
4	1—2½ ,,
5	½—1½ ,,
6	less than ½ ,,

As can be seen, a deal of flexibility and assumption exists and experience is relied upon to choose between alternative evaluations provided by examination of all known factors.

Finally, the development estimates are tabulated and a decision on a programme of gradual construction is made. This allows for immediate access to over-mature stands and also for priorities between different units depending on availability of fiscal funds and management requirements. The Canadian Federal Government contributes a small proportion of the cost to the Government of B.C.

Procedure in Development Planning.

The first stage is office work, comprising a study of forest statistics —annual cut, age distribution etc., provided by forest surveys—and of maps and data giving existing means of access to the area. Aerial photographs are used extensively at all stages of the work.

The second stage is undertaken in the field in summertime. There is first an aerial reconnaissance, by helicopter where practicable, to mark critical points on the photos and to record on tape descriptions of terrain and generally to get the feel of the area. Secondly there comes the ground inspection on foot. This can be an arduous pursuit as the engineer packs supplies and equipment to cover a trip of some days' duration.

Points from the photographs are picked up on the ground and notes made on all points of interest in determining final route layout, gradients, bridge sites, costs and so on. A reliable and experienced observer can progress at 2-3 miles per day on this type of work and furnish information on which rather accurate estimates can be based. This, the third stage, is a tedious operation, involving estimation of earth quantities and construction costs, bridging and culverting costs and transport times on any proposed route. The correlation of these various factors yields the road class and so the system. Should the answer lie between two road classes the higher order one is chosen as it is to be expected that annual increment will increase with management.

Road Design.

The road classes having been defined, the detailed survey and design of the route is next undertaken. In keeping with general American standards, field costs of survey are of the order of 5% of construction cost, with an additional 2% covering draughting and estimating, so that the standard of survey is matched to the road class. Just as distinction is made in road classes, there are also design classes. Class 1 is a specific design with the highest standards of accuracy and is not stated in general terms. Class 2 is a formal design requiring the plotting of plans, profiles, cross sections and a tentative grade line. Contours at 5 foot intervals for up to 100 feet wide must be established along the accurately laid out centre line to allow of calculation of earth movements. Class 3 design employs generalised graphs for the computation of quantities. It is used in road classes 4, 5 and 6 and requires only plans, profile and a tentative grade line. Class 4 design is used in development planning described above and is again a graph design.

For the various road classes there are specified design speeds and gradients which are set as standard for each project. The following table is observed.

Design Speed (M.P.H.)	Minimum Radius feet	Road Class
50	900	1 & 2
40	600	2 to 4
30	340	3 to 5
25	240	4 to 6
20	140	5 & 6

In specifying grades, allowance is made for the fact that laden trucks will generally be travelling in one direction so that a distinction can be made between favourable and adverse grades. Allowance is likewise made for the capability of a laden truck to develop top speed on grades of up to 1 in 25 or 4%, and grades for the higher order roads are kept within this limit.

Table of Maximum Grades allowable

Road Class	*Favourable*		*Adverse*	
	Less than 600 ft. long	More than 600 ft. long	Less than 600 ft. long	More than 600 ft. long
1	8% or 1 in 12½	6%	4%	4%
2	8	6	4	4
3	10	8	6	4
4	10	8	6	5
5	12	8	8	6
6	14	10	8	6

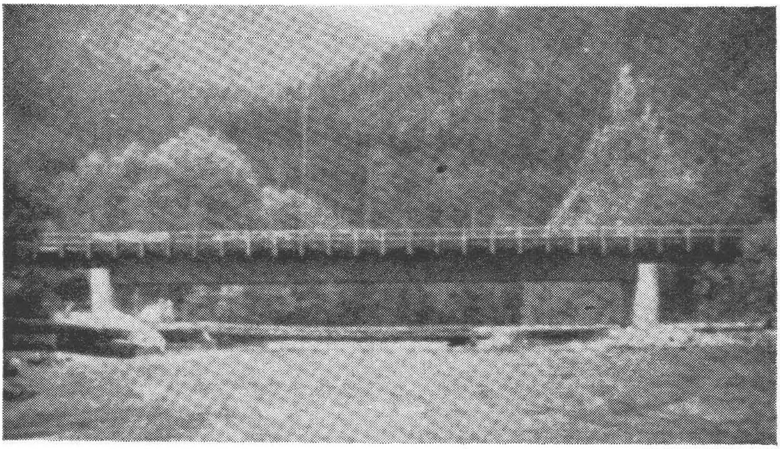
The necessity of ensuring an adequate sight distance to give a driver time to stop when noticing an obstacle on the road ahead must also be considered. For a single lane road this distance will be twice that calculated for the double lane type. In the same context, minimum radii for vertical curves are observed. All of these factors must be considered in design and location and all brought to the same order of consistency to avoid anomaly.

Field Survey and Location.

The field survey is undertaken in the summer months by a party of 6 to 8 men. The party chief may be a university student in his final year of civil or forest engineering and his crew may be composed largely of high school students earning holiday money. The isolation of the camps provide difficulties of supply but trail motorcycles developed for use in the forest are proving of advantage in this type of work.

Perhaps 20 miles of road may be located in the 4 or 5 month season. Use is again made of aerial photographs to first establish the tentative line recommended by the development report. The usual survey instruments are staff compass, steel band and Abney level and they give lines and levels of sufficient accuracy.

The survey results are draughted as the survey proceeds, on the scale of 1″ = 200 feet horizontal, and 1″ = 20 feet vertical, and the proposed horizontal alignment draughted and marked on the ground. Cross sections, earth and stand samples are then recorded. The computation of clearance costs and earthworks in balancing cut and fill, where applicable, are done later in the office. This eventually yields the final grade line to be used in construction. In these computations greater use of the ubiquitous computer and punched card machine is being introduced.



Crossing the Chilliwack river at Mile 12.2, this Forest Development Road Bridge spans 102 feet, and has four main glulam girders, each $12\frac{1}{2}''$ wide × 65″ deep. The total length of the bridge is 158 feet, having approach spans also on glulam girders. Built in 1959 for heavy log-truck loads, the deck measures 22′ 5″ between curbs. Note the old temporary log bridge in the background. Scarisbrick (1959).

Road Construction.

The removal of the timber from the line of the road is the first and one of the most costly operations, absorbing as much as 1/3 of the total cost. It will be noted from a table earlier that widths of up to 100 feet are cleared. It is generally difficult to sell the timber and controlled burning or burying is adopted to reduce the serious fire risk from slash. The heaviest of machines are employed at this stage of clearing and de-stumping.

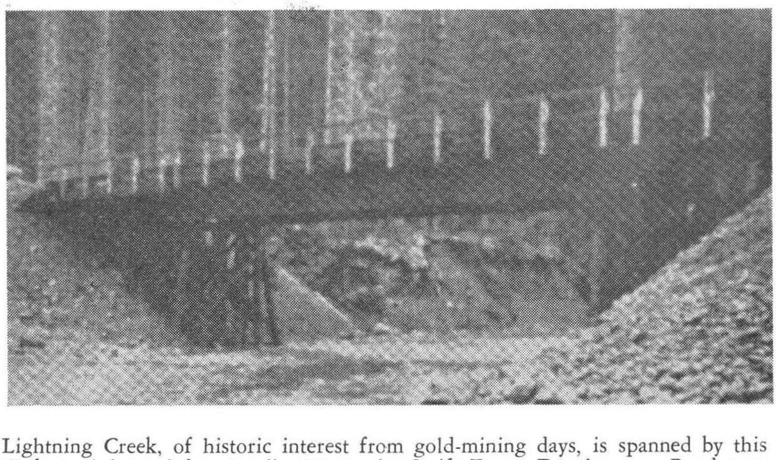
Road construction proper then begins with the large scale movement of earth to its designed and compacted position. Culverts are placed at this stage of the work. Construction is made easier by the presence of easily workable gravels in the main valleys which are glaciated. On higher ground, however, alternative methods of construction and soil stabilization are being employed to an increasing degree. As axle loadings 50% in excess of Public Highway limits are allowed, subgrade compaction is most necessary. These loads in the coastal forest area reach 100 tons on five axle units and in the interior area a load of 50 tons is assumed in design.

The final road surface is intended to be an "all weather" road and may consist of naturally occurring gravel or of crushed stone. As areas come into regular management and consequent heavy traffic, the means of surface binding is receiving attention. Chemical additives are being tested as a first stabilizer in this connection.

Bridges and Culverts.

In designing culvert sizes, maximum periodic run off is expected in order to avoid costly washouts. In areas of heavy snowfall special attention is given to spring thaw conditions.

A particular design section deals with bridges. These are designed as permanent structures on the basis of minimum annual costs, including redemption, as in road calculations. Spans of up to 100 feet are not



Lightning Creek, of historic interest from gold-mining days, is spanned by this 60-foot glulam girder at mile 0.3 on the Swift Forest Development Road near Quesnel, B.C. The one-lane bridge, built in 1957, is on a 17-degree skew. Pressure creosoted pile bents support the main girders. Scarisbrick (1959).

infrequently encountered and superstructure technique has gone some way towards standardization. Creosoted timber is preferred to either concrete or steel on grounds of lower initial cost and less dependence on good maintenance practice than in the case of the latter.

For longer spans transverse decking is laid on glued laminated timber girders. For short spans longitudinal laminated decking may be employed directly or sawn stringers used to carry transverse laminated decking. All timber used is treated under pressure with up to 10 lbs. of creosote per cubic foot and all work possible is done in the shop to aid accuracy and treatment.

Wherever possible, bridges are carried on treated timber piles. These are economical as they eliminate costly underwater construction and abutments and can be driven using conventional road making plant. Freedom from corrosion and security from scouring are also advantages. Protection of the pile bents against ice floes and log jams is necessary in some cases and they may thus be sheeted with planks or steel and pile dolphins driven upstream of the bents.

The erection of bridges is undertaken by the normal road construction crew. The main girder may be walked out by power shovels or other machines or pulled across the river by overhead cable. The experience so far with timber bridges has been very satisfactory and it is natural that this type is encouraged. Although timber is not selected merely because it is timber, design in some cases goes to considerable length to plan timber structures that are competitive in the particular conditions. Close attention is paid to cost records of bridges during construction and information regarding maintenance is being accumulated.

Conclusion.

To date 670 miles of roadway have been constructed in 21 managed units and 24 major bridges have been built. The increasing rate of construction leaves little doubt that these development roads are providing the best solution to present day access problems of B.C's forest industries. Each year great areas of forest are moved from the column headed "inaccessible" to that headed "potentially usable" in forest statistics, and the forest development road is expected to continue to play a vital role in that desirable transformation.

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