2. D. C. Oliver. Liability in the 1980s: Construction Zones, Intersections, and the MUTCD. *ITE Journal*, Vol. 56, No. 4, Institute of Transportation Engineers, April 1986, pp. 27-32.
3. G. L. Gittings. Tort Liability in the Pennsylvania DOT. *Proc., Effectiveness of Highway Safety Improvements Conference*, American Society of Civil Engineers, New York, 1986, pp. 102-116.
4. R. S. Hostetter, K. W. Crowley, H. W. McGee, Sr., and W. E. Hughes. *Driver Needs on Two-Lane Rural Highways*. Vol. I—Technical Report. FHWA, U.S. Department of Transportation, April 1985.
5. D. L. Ivey, R. M. Olson, N. E. Walton, G. D. Weaver, and L. W. Furr. *NCHRP Report 203: Safety at Narrow Bridge Sites*. TRB, National Research Council, Washington, D.C., June 1979.
6. J. K. Kihlberg and K. J. Tharp. *NCHRP Report 47: Accident Rates as Related to Design Elements of Rural Highways*. HRB, National Research Council, Washington, D.C., 1968.
7. K. Perchonok. *Hazardous Effects of Highway Features and Roadside Objects*. Vols. 1 and 2. Reports FHWA-RD-78-201 and 202. FHWA, U.S. Department of Transportation, Sept. 1978.
8. R. S. Hostetter, K. W. Crowley, H. W. McGee, Sr., and W. E. Hughes. *Driver Needs on Two-Lane Rural Highways*. Vol. II—Simplified Location of Information Deficiencies. FHWA, U.S. Department of Transportation, April 1985.

Development of Geometric Design Standards for Low-Volume Roads in Canada

D. BEWS, G. SMITH, AND G. TENCHA

Approximately 76 percent of the road system in Canada has been classified as rural local roads that carry low traffic volumes. In the past, a uniform set of geometric design standards for roads was not available in Canada. The lack of national standards for low-volume roads resulted in agencies developing their own. These standards may not have been compatible with the required function of the road and also had the effect of nonuniform treatment of roads between road jurisdictions. Transportation planners and designers were faced with the problem of reducing national standards, which were originally developed for a higher classification of roads, to meet economic constraints. It became evident that there was a need to find ways to construct these roads more economically and to maintain their safety and effectiveness. As a result, the Roads and Transportation Association of Canada initiated a project to develop a national set of geometric design standards for low-volume roads. A separate chapter for low-volume roads is now included in the *Manual of Geometric Design Standards for Canadian Roads*. A discussion is presented of the approach used to develop the geometric design standards for low-volume roads, the results and findings, and future research that should be performed to further refine the standards.

The Canadian Road Network consists of over 800 000 km of roads that serve a population of approximately 25.6 million. Approximately 610 000 km, or 76 percent, of these roads can be classified as rural local roads that carry low traffic volumes. In addition, 490 000 km of these rural local roads have either earth or gravel surfaces.

In the past, geometric design standards for these types of roads were not specifically addressed in Canada. Both road planners and designers were faced with either using national standards that were developed for a higher classification of roads, which resulted in roads being built at a great cost that was unrelated to their function, or reducing these higher classification standards to meet economic constraints, usually without a logical basis for doing so.

In many instances, the lack of national design standards for these roads and the pressure to reduce costs resulted in agencies developing their own design standards or, in certain instances, in constructing roads without regard for any design standards. This has resulted in the creation of standards that are not compatible with the road function, nonuniformity of standards between jurisdictions, arbitrary selection of standards, and in many cases an unsafe road.

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It was therefore evident that there was a need within the Canadian road system for a set of national geometric design standards that recognized the unique qualities of these rural roads with low traffic volume.

The Roads and Transportation Association of Canada (RTAC) is a nonprofit, nonpartisan association of 600 corporate members including federal, provincial, territorial and municipal governments; a wide range of carriers and suppliers of transportation goods and services; and the academic community. In 1983, RTAC approved the establishment of a project steering committee to research and develop a set of geometric design standards for low-volume, rural roads that would be the product of a consensus of the majority of users in Canada.

These standards would be incorporated as a separate chapter in the RTAC *Manual of Geometric Design Standards for Canadian Roads*, which was currently in the process of being updated (*1*). The objectives of the project were defined as follows:

- To establish uniform national standards for the classification of low-volume roads to meet the special services requirements of road agencies across Canada,
- To provide standards compatible with the present economic requirements without jeopardizing the safety or effectiveness of the road, and
- To provide standards for road agencies that relate to the type of road function and that will ensure standardization.

The project steering committee, which consisted of representatives from federal, provincial, territorial, and county road authorities, and the private sector, established terms of reference and selected a consultant to perform the work. Funding for the project was provided by the Council on Highway and Transportation Research and Development (CHTRD) of the Roads and Transportation Association of Canada and the Federal Department of Indian Affairs and Northern Development.

METHODOLOGY

A literature review was undertaken to determine present practices in Canada, the United States, and selected foreign countries and to identify available, related research data.

Existing design standards used by the various Canadian federal, provincial, and municipal agencies, and agencies in other countries were reviewed and documented.

A questionnaire was developed and distributed to a representative sample of Canadian road agencies, and to private companies that were engaged in resource development. The questionnaire included a number of questions related to draft design standards to determine the reaction of potential users. It also included questions designed to obtain opinions, suggestions, experience, and comments related to low-volume roads to assist in establishing the design standards.

Design standards were developed for low-volume roads through a synthesis of existing standards that were in use by the various road agencies in Canada. Adjustments were made when appropriate, based on standards used by other agencies and available research.

Low-volume roads in Canada were defined by the Committee as roads with an average daily traffic (ADT) of 200 vehicles or less, the service functions of which were oriented to rural road systems, roads to or within isolated communities, recreational roads, and resource development roads.

DISCUSSION OF STANDARDS

Classification

A separate classification system was developed for low-volume roads that recognized their unique characteristics and function or use. The system enabled the designer to select a set of geometric design standards that were related to the use of the road and were economically compatible with the low volumes. The system was based on service function, traffic volume, and design speed.

Service Function

Because low-volume roads serve different functions, and in order to address their different design requirements, the roads were divided into the following three functional categories:

- Rural road systems and roads to or within isolated communities,
- Recreational roads, and
- Resource development roads.

These functional categories reflect the differences in traffic and land service that influence the selection of design standards, particularly roadway width. The three categories, which are similar to the categories used in the new design manual of the American Association of State Highway and Transportation Officials, were confirmed through the questionnaire as being appropriate for low-volume roads in Canada (*2*).

Rural roads and roads to or within isolated communities provide access to farms, residences, and businesses or other abutting properties. Traffic consists of light and medium vehicles with occasional heavy trucks.

Recreational roads provide access to and within all types of recreational areas. Traffic generally consists of cars, trailers, camper-truck units, and maintenance vehicles. Recreational roads are further subdivided into primary roads, perimeter roads, and internal roads, which essentially reflect differences in expected operating speeds. This category is similar to the classification system for recreational roads of both Parks Canada and AASHTO (*2, 3*).

Resource development roads include all resource-related roads such as forest roads, mining roads, and roads required for energy development. Traffic on these types of roads is predominantly large, heavily loaded trucks.

Traffic Volume

An ADT of 200 vpd was selected as the maximum volume for which the design standards are intended. This was based on the fact that the majority of low-volume roads in Canada have traffic volumes below this value, and was confirmed through responses to the questionnaire. The design standards satisfy safety requirements for an ADT of up to 200 vpd.

The ADT value is used for design instead of Average Annual Daily Traffic (AADT), which is normally used in the design of the higher classification roadways, to account for the variation in traffic volumes that can be expected due to seasonal use. The ADT is defined as the total volume of traffic during a given time period, in whole days, greater than 1 day and less than 1 year, divided by the number of days in that period. Other road agencies that use ADT for design traffic volume include AASHTO, the U.S. Department of Agriculture Forest Service, and the Zambia Roads Department in Africa (*2, 4, 5*).

The current ADT is established as the design ADT if low growth is expected. If higher growth is expected, the projected 10-yr ADT is used as the design ADT. If the design ADT is greater than 200 vpd, the designer must use the design standards for the higher classification road.

As is the case with roads of higher classification, traffic volumes do not directly influence design standards for sight distance, horizontal alignment, or vertical alignment. They do, however, influence road cross-section elements.

Road cross-section elements were developed for the following:

- Two-lane roads for ADTs less than 100 vpd, and for ADTs between 100 and 200 vpd;
- One-lane, one-way roads for ADTs up to 200 vpd;
- One-lane, two-way roads for ADTs up to 50 vpd; and
- One-lane, two-way resource development roads for ADTs up to 150 vpd.

The Average Daily Truck Traffic (ADTT) also influences roadway widths. When the ADTT is greater than 15 vpd, roadway widths are increased. This was based on the research presented in a study by the National Cooperative Highway Research Program (*6*).

Design Speed

The design speed concept is used to select design standards for low-volume roads. The design speed ranges for low-volume roads are shown in the following table.

Service Function	*Design Speed (km/h)*
Rural road systems and roads to or within isolated communities	30-100
Recreational roads	
Primary	30-100
Perimeter	30-50
Internal	30-50
Resource development roads	30-100

Design speeds higher than 100 km/h for low-volume roads were not considered justifiable in terms of the cost of meeting the higher design standards. Design speeds of 50 km/h or less are recommended for perimeter and internal recreational roads to satisfy environmental constraints and aesthetic considerations. Design speeds of 50 km/h or less are recommended for one-lane, two-way roads in the interest of safety.

The most important factors considered in selecting design speed include terrain type, trip length, and service function. Lower design speeds are considered appropriate in rolling or mountainous terrain because of horizontal and vertical constraints. Under these conditions, drivers will generally accept a lower operating speed. Higher design speeds are appropriate in level terrain in which higher design standards can be provided without a major increase in cost. Safety could be jeopardized if high design standards are not provided in flat terrain, because drivers tend to overdrive the road.

In remote areas in which trips are long, it is perceived that drivers tend to drive at higher speeds. Higher design speeds should generally be selected for roads that constitute a long trip. However, there are difficulties in defining a long trip and in identifying the relationship between trip length and design speed. Research is required on this aspect of design speed selection.

Service function also influences the selection of design speed. Roads that serve adjacent developments, with numerous access points, should have a lower design speed. Recreational roads generally have lower design speeds because of environmental or aesthetic considerations, or because of adjacent development.

Although the design speed concept has been used in these standards, its application to the design of low-volume roads is subject to question by many. It is considered unrealistic and uneconomical to attempt to balance all of the physical features of the road to a consistent design speed, particularly in rolling or mountainous terrain. If low-volume roads are to be low-cost roads, they should be designed to fit the terrain and conditions instead of being designed to some preselected design speed. However, until more research is performed on this aspect of low-volume roads, the design speed concept will continue to be used for low-volume roads.

Alignment Elements

The alignment elements developed for low-volume roads are primarily determined from the design speed using the same physical relationships developed for other road classifications. However, some modifications have been made to the RTAC standards developed for roads of higher classifications to satisfy specific requirements for low-volume roads. These modifications relate to vertical curvature, gradients, and the development of superelevation.

Minimum Stopping Sight Distance

Minimum stopping sight distances for low-volume roads are based on a fixed brake reaction time of 2.5 sec and on friction values for wet pavement in poor condition, as for roads of a higher classification. Although friction values for gravel and earth roads have been developed through research, the results have not been translated into usable standards. This is of particular concern because although the friction values for wet pavement in poor condition may reflect some gravel surface conditions, they do not reflect all the variations in surface type and conditions that occur on gravel and earth roads. Until further research is undertaken, wet pavement friction values will continue to be used to establish the minimum stopping site distances on gravel and earth roads.

The minimum stopping sight distance on one-lane, two-way roads is twice that required on two-lane roads based on the assumption that both drivers use the same brake reaction time and are traveling at the same speed. Both AASHTO and the U.S. Forest Service have adopted this standard (*2, 4*).

Horizontal Alignment

Lateral friction factors for gravel roads and earth roads are assumed to be the same as for wet pavements in poor condition. Like the development of stopping site distance, lateral friction values for gravel roads and earth roads have not been translated into usable standards.

A maximum relative gradient for tangent runoff of 1:200 is recommended for superelevating roadways. A value of 1:400 is generally used on roads of a higher classification. However, on low-volume roads in which surface type may be of a lower quality, 1:200 minimizes the length of roadway that has less than the desirable cross-slope for storm water runoff. The AASHTO values for all two-lane highways vary from 1:133 at 30 km/h to 1:222 at 100 km/h (*2*).

The distribution of superelevation rates has been developed for low-volume roads for maximum superelevation rates of 0.08 mm/mm and 0.06 mm/mm, and for normal cross-slopes of 0.02 mm/mm and 0.04 mm/mm. Rates were developed for the 0.04 mm/mm cross-slopes because superelevation is required at a larger radius than when the cross-slope is 0.02 mm/mm for the same design speed.

Vertical Alignment

Crest vertical curvature for stopping sight distance of low-volume roads is based on a fixed object height of 150 mm instead of a fixed tail-light height of 380 mm, which is used for roads of a higher classification. On low-volume roads in which there may be an absence of continuous maintenance, vehicles are more likely to stop for a fixed object, such as logs and washouts, instead of another vehicle. This increases the k-values over that required for roads of a higher classification, as shown in Table 1.

In roads in which maintenance activities are performed on a regular basis, consideration can be given to using k-values developed for the 380-mm object height.

The k-values for one-lane, two-way roads are based on the height of the opposing vehicle, which is assumed to be 1.30 m, because two vehicles approaching each other is the governing condition for minimum stopping sight distance instead of a vehicle approaching a fixed object.

Grades

A review of Canadian road agency standards showed that the maximum gradients used for low-volume roads were similar to the maximum gradients recommended for the RTAC rural local undivided (RLU) road classification. When compared with the AASHTO suggested maximum gradients for local rural roads, the Canadian road agency standards were quite conservative, and because of the low volumes, inappropriate.

The selection of the design maximum gradient depends on many factors including topography, volume of traffic, traffic mix, truck size, and construction costs. An economic analysis should ideally be undertaken to determine the maximum gradient for the design speed and traffic mix.

Until further research is performed on the relationship between gradient and maintenance costs, road user costs, and stopping distance, the suggested maximum gradients will be based on the suggested AASHTO maximum gradients for local rural roads (*2*).

A comparison between recommended gradients for low-volume roads and those of the next highest road classification, RTAC RLU, is shown in Table 2 (*1*).

Cross-Section Elements

Cross-section elements for low-volume roads were developed based on traffic volume, traffic mix, design classification, design speed, and surface type for two-lane earth roads; two-lane gravel roads; two-lane surfaced roads; one-lane, two-way roads; and one-lane, one-way roads.

The cross-section elements for two-lane earth and gravel roads and two-lane surfaced roads are shown in Figures 1 and 2, respectively. The cross-section elements for one-lane, two-way and one-lane, one-way low-volume roads are shown in Figures 3 and 4, respectively.

Roadway Width

The development of roadway widths for two-lane low-volume roads was based on an analysis of roadway widths currently used by Canadian road agencies, and those recommended by AASHTO and NCHRP (*6*). The following assumptions were made in the analysis:

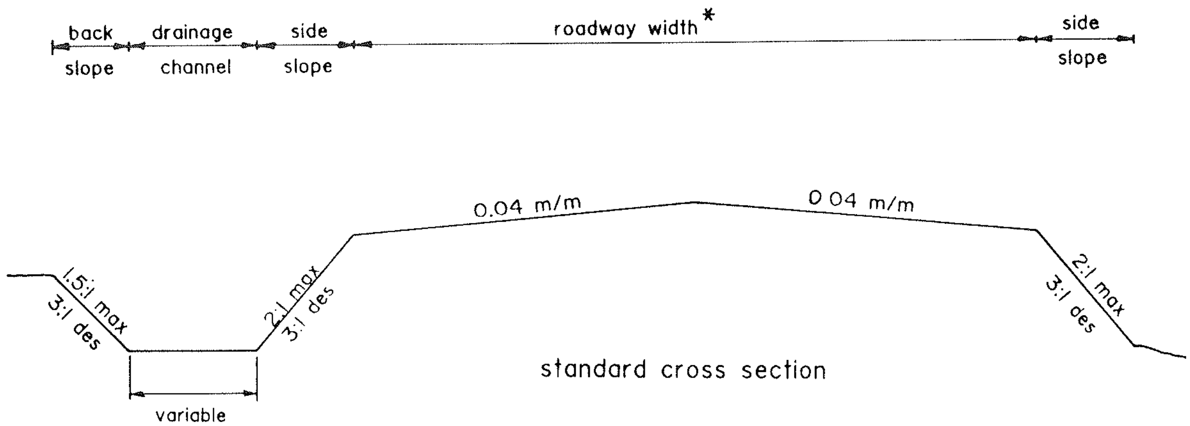
- Some road agencies have roadway width standards for ADTs less than 200 vpd, whereas others have standards for ADTs less than 250 vpd, less than 400 vpd, and 100 to 500 vpd. Roadway widths in these ranges were assumed valid in the analysis.
- Agencies that did not specify ADTs submitted standards for rural local roads, which were also included in the analysis.
- Most agencies do not consider truck volumes in their roadway width standards. Therefore, the roadway widths used by Canadian road agencies were assumed to be applicable to all truck volumes.

TABLE 1 COMPARISON OF K-VALUES FOR LOW-VOLUME ROADS AND HIGHER CLASSIFICATION ROADS

	Crest K-Value (m)	
Design Speed (km/h)	Low-Volume Roads (Object Height = 150 mm)	Higher Classification Roads (Object Height = 380 mm)
30	3	-
40	5	4
50	12	7
60	18	15
70	30	22
80	50	35
90	70	55
100	100	70

TABLE 2 COMPARISON OF GRADIENTS

Design Speed (km/h)	Low-Volume Road (Maximum Gradient %)	RLU (Maximum Gradient %)
30	11-16	7-11
40	11-15	7-11
50	10-14	7-11
60	10-13	7-11
70	9-12	6- 9
80	8-10	6- 8
90	7- 9	5- 7
100	6- 8	5- 7



class LVR (all categories)	roadway width** m: ADT less than 100, trucks less than 15 ADTT	ADT less than 100, trucks greater than 15 ADTT	ADT 100-200, trucks less than 15 ADTT	ADT 100-200, trucks greater than 15 AADTT
100	7.4	7.8	7.4	7.8
90	7.0	7.4	7.4	7.8
80	7.0	7.4	7.0	7.4
70	6.6	7.0	7.0	7.4
60	6.6	7.0	6.6	7.0
50	6.0	6.4	6.2	6.6
40	6.0	6.4	6.2	6.6
30	5.6	6.0	6.0	6.4

* To allow for future gravelling of earth roads, consideration should be given to constructing the initial roadway width to accommodate the gravel thickness.

** Where traffic barrier is used, increase roadway width by 0.5 m on traffic barrier side of roadway. Roadway widths do not include roundings.

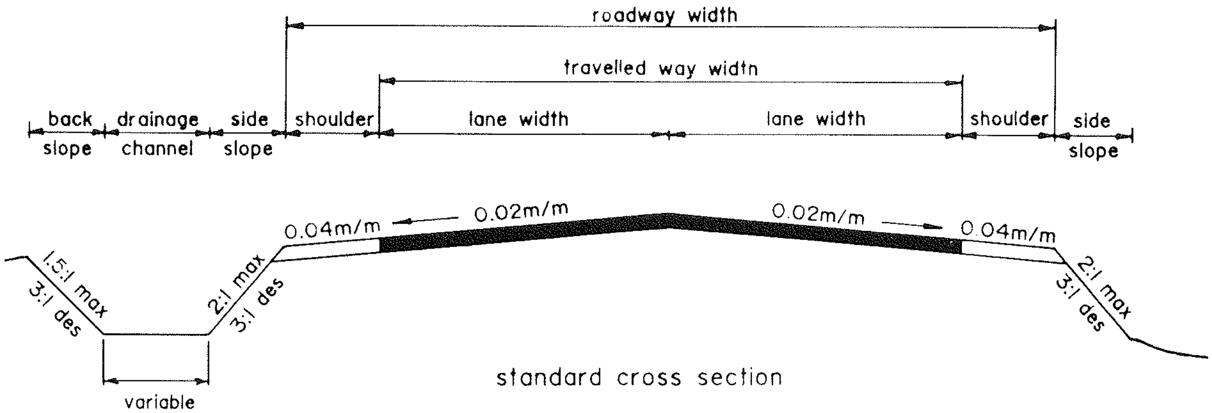
FIGURE 1 Roadway width versus design speeds of various road agencies (ADT <50).

The average roadway widths of the Canadian road agency for gravel roads with ADTs of less than 100 vpd and 100 to 200 vpd are shown in Table 3. Also shown are minimum roadway widths recommended by AASHTO for ADTs less than 250 vpd, and NCHRP for ADTs less than 400 vpd (*2, 6*)

Some agencies further broke the ADT volumes down into 0 to 50 vpd, 50 to 100 vpd, 100 to 150 vpd, and 150 to 200 vpd. However, the differences in roadway widths between 0 to 50 vpd and 50 to 100 vpd and between 100 to 150 vpd and 150 to 200 vpd were negligible. The roadway widths used by Canadian road agencies are shown in Figures 5 to 8. Also shown are the roadway widths recommended by AASHTO, NCHRP, and the National Association of Australian State Road Authorities (NAASRA) for design speeds from 30 km/h to 100 km/h for ADTs of 50 vpd, 50 to 100 vpd, 100 to 150 vpd, and 150 to 200 vpd, respectively.

As can be seen from Table 3, the average of the Canadian road agency road widths is substantially higher than that of AASHTO for all design speeds and that of NCHRP for design speeds of 60 km/h and less (*2, 6*). The NCHRP roadway widths satisfy safety requirements for tracking and lateral clearance and are significantly higher than those of AASHTO and Canadian road agencies for design speeds higher than 60 km/h. However, they apply to ADT volumes up to 400 vpd.

The roadway widths used by Canadian road agencies are greater than those of AASHTO for all design speeds and those of NCHRP for design speeds 60 km/h and less (*2, 6*). This is because many of these agencies provide wider lanes and wider

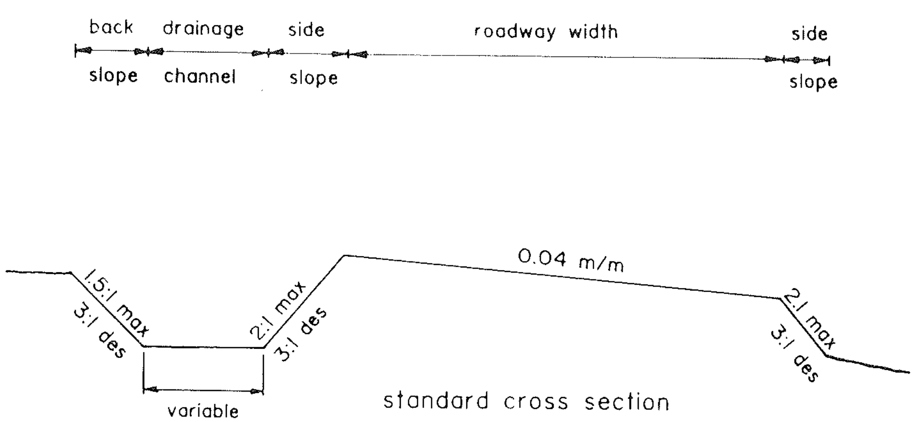


	ADT less than 200			
class LVR (all categories)	roadway width** m	travelled way width m	lane width m	shoulder width* m
100	8.4	7.4	3.7	0.5
90	8.4	7.4	3.7	0.5
80	8.0	7.0	3.5	0.5
70	8.0	7.0	3.5	0.5
60	7.6	6.6	3.3	0.5
50	7.2	6.2	3.1	0.5
40	7.2	6.2	3.1	0.5
30	7.0	6.0	3.0	0.5

* where traffic barrier is used, increase shoulder width by 0.5 m
** roadway widths do not include roundings

Note: Surfaced roads are roads on which the travelled lanes have been physically delineated by some form of bituminous or concrete surface.

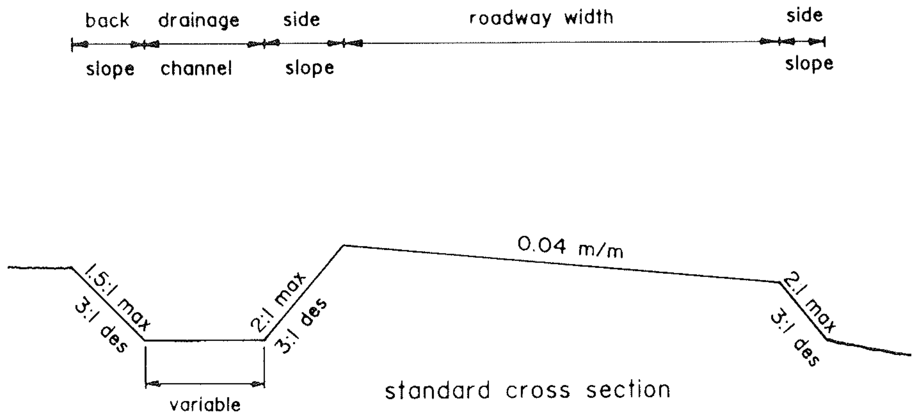
FIGURE 2 Roadway width versus design speeds of various road agencies (ADT 50 to 100).



category	maximum ADT	maximum design speed km/h	roadway width* m
rural road systems and roads to or within isolated communities	50	50	4.0
recreational roads	50	50	4.0
resource development roads	100	50	4.0

* where traffic barrier is used, increase roadway width by 0.5 m on traffic barrier side of roadway. roadway widths do not include roundings.

FIGURE 3 Roadway width versus design speeds of various road agencies (ADT 100 to 150).



category	maximum ADT	design speed km/h	roadway width* m
recreational roads	200	30-100	5.5

* where traffic barrier is used, increase roadway width by 0.5 m on traffic barrier side of roadway.
roadway widths do not include roundings.

FIGURE 4 Roadway width versus design speeds of various road agencies (ADT 150 to 200).

TABLE 3 ROADWAY WIDTHS FOR TWO-LANE GRAVEL ROADS

	Roadway Width									
	Average of Canadian road agencies		AASHTO	NCHRP Report 214		Recommended roadway widths				
design speed	ADT less than 100	ADT greater than 100	ADT less than 250	ADT less than 400		ADT less than 100		ADT 100-200		
				ADTT less than 14	ADTT greater than 14	ADTT less than 15	ADTT greater than 15	ADTT less than 15	ADTT greater than 15
km/h	m	m	m	m	m	m	m	m	m
100	8.4	9.0	7.3	-	-	7.4	7.8	7.4	7.8
90	8.5	8.6	7.3	-	-	7.0	7.4	7.4	7.8
80	7.8	8.0	7.3	9.1	9.1	7.0	7.4	7.0	7.4
70	7.2	7.4	7.3	7.9	7.9	6.6	7.0	7.0	7.4
60	7.4	7.6	-	6.7	7.3	6.6	7.0	6.6	7.0
50	7.2	7.4	6.7	6.1	6.7	6.0	6.4	6.2	6.6
40	7.7	8.0	6.7	6.1	6.7	6.0	6.4	6.2	6.6
30	6.8	7.1	6.7	5.5	6.1	5.6	6.0	6.0	6.4

Note: Roadway width of gravel roads is the distance between the intersections of the side slopes and the roadway surface.

shoulders and, in many cases, include rounding as part of the roadway width. This additional width is not considered appropriate for low-volume roads because volumes are low, the frequency of traffic conflicts is minimal, and, in practice, drivers tend to travel down the center of the roadway until they meet an oncoming vehicle.

The recommended roadway widths for gravel roads shown in Table 3 do not consider shoulder widths or rounding widths. The roadway widths were developed for two volume categories, for ADT volumes of less than 100 vpd and between 100 and 200 vpd, to reflect the slight increase in roadway widths found in the analysis of Canadian road agency standards in which the ADTs exceeded 100 vpd.

The roadway widths were developed to account for truck traffic, based on the information given in the NCHRP report. They do not provide for emergency or leisure stops because the frequency of traffic conflicts on low-volume roads associated with stopped vehicles does not justify the additional width for sheltering them.

The roadway widths for two-lane surfaced roads include a 0.5-m shoulder adjacent to the traveled way for lateral support of the roadway structure. The recommended traveled way width provides adequate tracking and lateral clearance for all ADT volumes less than 200 vpd and for all truck volumes.

One-lane, two-way roads were introduced for low-volume, low-speed conditions. For rural road systems, roads to or within isolated communities, and recreational roads, one-lane, two-way roads can be used when the ADT is less than 50 vpd and for design speeds of 50 km/h or less. On roads used exclusively for resource development, one-lane, two-way roads can be used when the ADT is less than 100 vpd, and for design speeds of 50 km/h or less. For reasons of safety, one-lane, two-way roads should only be considered when the following conditions can be satisfied:

- Operating speeds are limited to 50 km/h or less,
- The road is short in length,
- The road serves a single purpose,

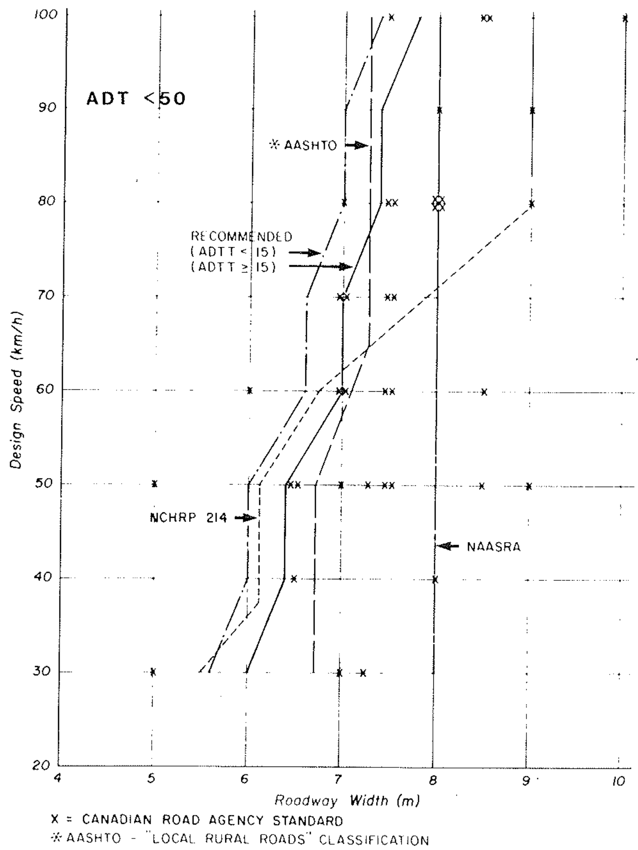


FIGURE 5 Cross-section elements for two-lane, low-volume earth and gravel roads.

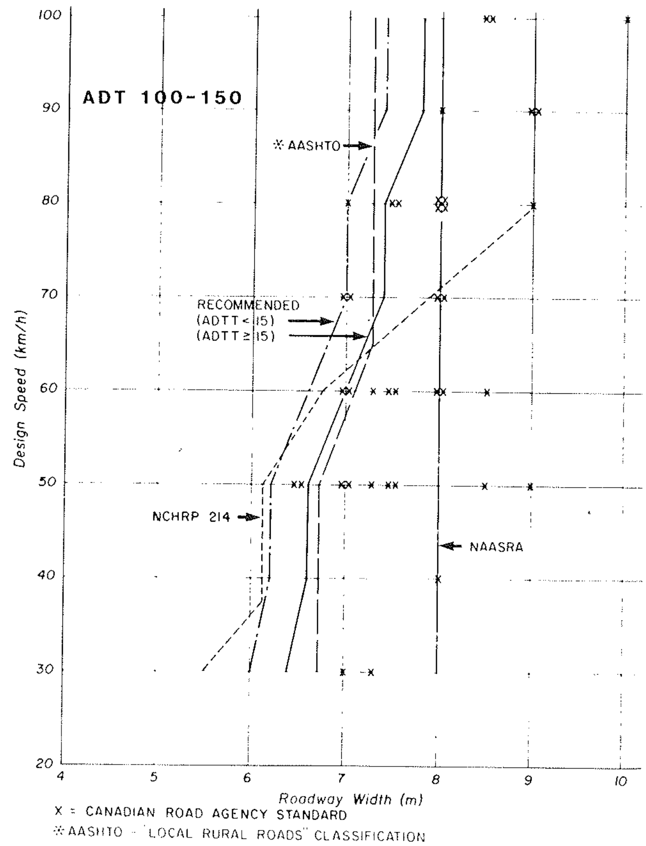


FIGURE 7 Cross-section elements for one-lane, two-way, low-volume roads.

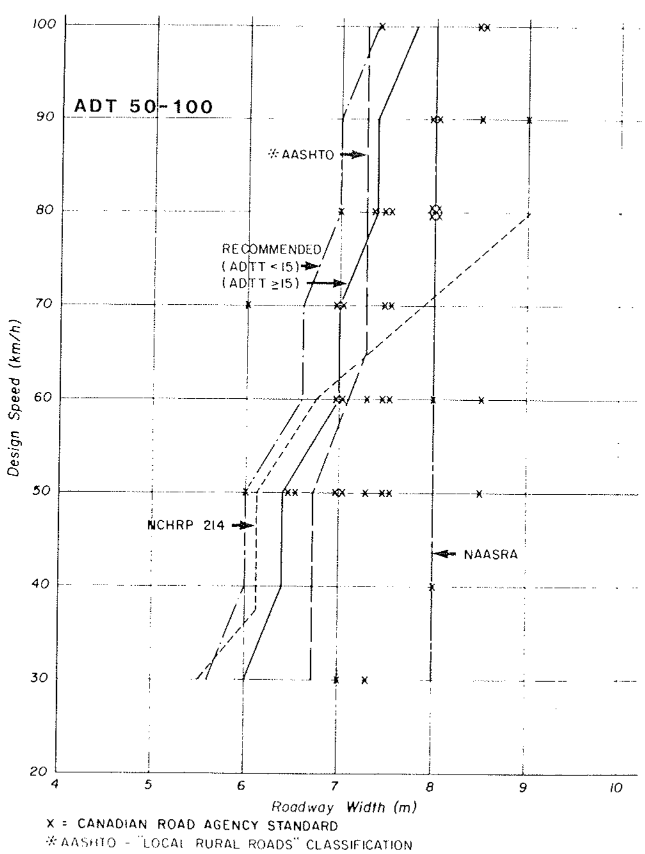


FIGURE 6 Cross-section elements for two-lane, low-volume surfaced roads.

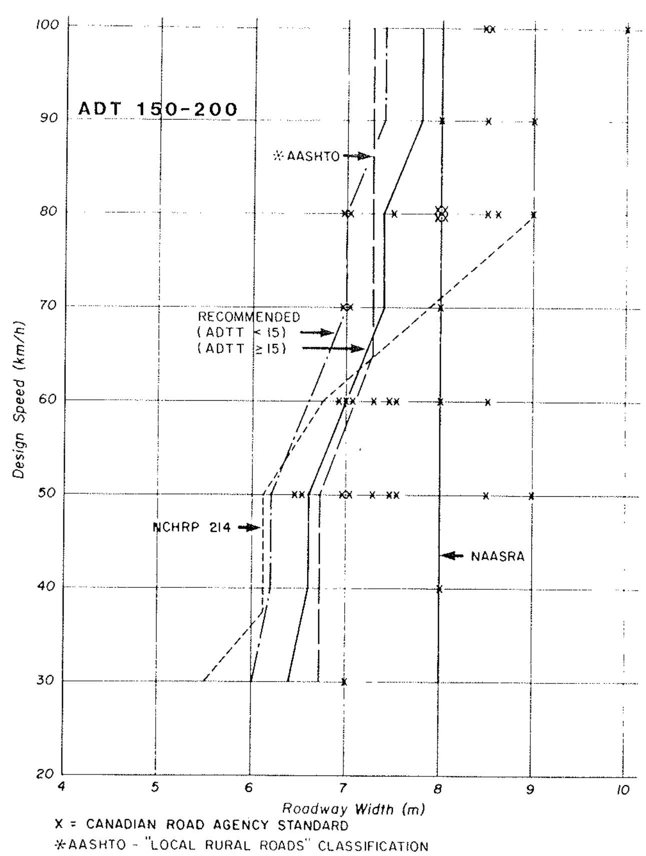


FIGURE 8 Cross-section elements for one-lane, one-way, low-volume roads.

- The road is clearly signed as to its configuration, and
- Turnouts for passing are provided.

Respondents to the questionnaire generally favored the use of one-lane, two-way roads under low-speed, low-volume conditions. AASHTO recommends one-lane, two-way roads for recreational and resource development roads when the ADT is less than 100 vpd and for design speeds of 50 km/h or less (*2*). The U.S. Forest Service also has standards for one-lane, two-way roads (*4*).

The recommended roadway width for one-lane, two-way roads is 4.0 m. The width of 4.0 m prevents the road from being used as a two-lane facility. AASHTO recommends a roadway width for one-lane, two-way roads of 3.7 m or 4.0 m (*2*).

Turnouts must be provided for passing. They should be intervisible with a spacing of approximately 300 m. On roads used exclusively for resource development, turnout spacing can be increased if the vehicles are equipped with two-way radio communication.

The National Association of Australian State Road Authorities (NAASRA) recommends one-lane, two-way roads for AADT volumes less than 150 vpd for all design speeds (*7*). However, the cross-section consists of a 3.5-m sealed lane and 1.5-m to 2.5-m shoulders for a total roadway width of 6.5 m to 8.5 m. Turnouts are not provided, because the total roadway width is ample for passing.

One-lane, one-way roads have been included for use in recreational sites. AASHTO recommends one-way roads in recreational sites and Parks Canada recommends one-way roads for internal and perimeter campground roads (*2, 3*). The recommended roadway width of 5.5 m is based on Parks Canada's recommended cross-section arrangement, which consists of a 4.5-m lane and 0.5-m shoulders to allow other vehicles to pass a stopped vehicle. Standards have been developed for one-lane, one-way roads for all design speeds up to 100 km/h and for an ADT of up to 200 vpd in one direction because head-on conflicts are eliminated.

Other design considerations that affect roadway width are parking, leisure stops, and overwidth trucks. In some cases, low-volume roads may be located in an area in which vehicle parking on the roadway is a requirement. These roads generally have a low design speed and, therefore, a narrow roadway width. Consideration should be given to widening the roadway to accommodate vehicle parking on one side. In such cases, the suggested maximum roadway width is 8.0 m.

Frequent leisure stops may occur in recreational areas such as historic sites or scenic viewpoints. As a safety requirement, consideration should be given to either widening the roadway or constructing turnouts. In such cases, the suggested minimum widening is 3.0 m.

The roadway widths developed for resource development roads meet the safety requirements necessary to accommodate truck widths of 2.6 m. However, in cases in which truck widths greater than 2.6 m are prevalent, it is suggested that the roadway width be increased by the amount the design vehicle width is in excess of 2.6 m for one-lane, two-way roads and by twice this amount for two-lane roads to satisfy safety requirements.

Cross-Slopes

The majority of the respondents to the questionnaire indicated that a cross-slope of 0.04 m/m is preferred on gravel roads to provide effective cross-drainage. AASHTO recommends cross-slopes in the range of 0.02 m/m to 0.06 m/m for earth roads and gravel roads, and 0.015 m/m to 0.030 m/m for surfaced roads (*2*). Cross-slopes of 0.04 m/m are recommended for earth roads and gravel roads, and 0.02 m/m to 0.04 m/m for surfaced roads.

Side-Slopes and Back-Slopes

Maximum earth side-slopes of 2:1 are suggested, depending on the stability of local soils. In mountainous terrain, maximum side-slopes of 1.5:1 may be appropriate in high fill areas to minimize costs. Side-slopes of 3:1 are recommended in the interest of safety. Side-slopes of 2:1 and 3:1 are commonly used by Canadian road agencies. If it is economically feasible, flatter side-slopes should be used.

Maximum back-slopes of 1.5:1 are suggested for low-volume roads, depending on the stability of local soils. Back-slopes of 3:1 are recommended in the interest of safety. Some Canadian road agencies use 1.5:1 back-slopes.

For local rural roads, AASHTO states that side-slopes should not be steeper than 2:1 in cut sections, and back-slopes should not exceed the maximum required for stability.

FUTURE RESEARCH

During the development phase of the standards, several topics were identified by the Project Steering Committee as requiring further research either because research was lacking on the subject, or because available research was only applicable to roads of a higher classification. Areas that require future research are described in the following sections.

Friction Factors

As previously stated, stopping sight distance and circular curve radii calculations have been based on friction factors applicable to paved surfaces. Because many low-volume roads have surfaces that consist of earth or granular material, they may require the use of different stopping distances and circular curve radii to account for the different friction factors that can be expected. The friction factors can vary substantially, particularly on granular surface roads. Friction factors would have to be determined for loose gravel and compacted gravel under both wet and dry conditions. Other factors that would affect the friction values are the gravel gradation and maintenance practices, and these would have to be considered in the research.

Review of Maximum Grades and Superelevation Rates

Factors that govern the determination of maximum grades and rates of superelevation are friction of the road surface, surface type, vehicle characteristics and performance, and the desired level of service. Although these factors have been determined experimentally, they have not been sufficiently translated for use in determining Canadian geometric design standards. Maximum design grades for various classes of roads and vehicle type, and desirable superelevation rates in various climatic conditions should be determined to develop Canada-wide standards for these two design elements.

One-Lane, Two-Way Roads

Research on one-lane, two-way roads is required to determine their cost- and safety-effectiveness as opposed to two-lane roads. One-lane, two-way roads have been widely used in European and Scandinavian countries, but their use is limited in Canada and the United States. Under certain traffic volume and road use situations, they could provide an economic alternative to two-lane roads. There is, however, a need to develop more information on their operation, including appropriate traffic volume levels and accident potential, to support and expand their use.

Developing Optimum Widths for Structures on Low-Volume Roads

The widths and clearances for bridge structures shown in the current RTAC *Manual of Geometric Design Standards for Canadian Roads* may not be appropriate for low-volume roads (*1*). Reduction of bridge widths and clearances may be possible without adversely affecting operation or safety. Optimizing widths for structures on low-volume roads would balance cost savings against the safety and operational requirements. The feasibility of one-lane bridges and the requirements to accommodate farm machinery in agricultural areas would be part of the process.

Safety, Performance, and Costs of Low-Volume Roads

Data are lacking to adequately assess the safety and performance of low-volume roads. Research should include the collection and evaluation of operating, maintenance, and construction cost data from road agencies across Canada as they relate to design speed, road width, and surface type.

Accident data, including the cost of accidents, should also be collected to determine accident rates on low-volume roads and to pinpoint the major cause of the accidents as they relate to horizontal and vertical curvature, sight distance, grades, road width, and surface type.

Economic Analysis Program

A Canadian methodology for the economic analysis of low-volume road projects is required. The methodology would assist road agencies in developing the most economic roadway that satisfies both the road agency and road user requirements. Factors that should be included in the methodology are capital costs, maintenance costs, design life, vehicle operating and travel time costs, and accident costs as they relate to the geometric design elements and road surface type.

Design Speed Related to Trip Length

Although it has not been substantiated, many believe that trip length is a pertinent consideration in selecting design speed. The longer the trip, the greater the desire to travel at higher speeds. The selection of low design speeds for a substantial length of road in flat topography may create unsafe driving conditions because drivers may become impatient and travel at excessive speeds. Conversely, selecting high design speeds for a short length of road may prove to be an uneconomical design. Research is required to establish the relationship between trip length and design speed so that roads may be designed to a safe and economical standard.

Assessment of Design Speed Concepts and Development of an Alternative Approach

The use of the traditional design speed approach may not be appropriate for low-volume roads. It is unrealistic and uneconomical to attempt to balance all of the physical features of a low-volume road to a consistent design speed, particularly in rolling or mountainous terrain. Research should be performed to develop an alternative approach to the design speed concept, such as designing the low-volume road to fit the terrain and estimated desired speed of travel.

Review Volume Level for ADT

The selection of 200 ADTs to define low-volume roads was based on the perception that the majority of lower-volume roads in Canada have traffic volumes less than 200 vpd. Other road agencies classify roads with less than 250, 400, or as high as 1,500 vpd as low-volume. The next volume category for which design standards have been developed in the RTAC manual is less than 1,000 vpd (*1*). Additional research is required to determine if the present design standards for low-volume roads satisfy safety requirements for volumes between 200 and 1,000, or if an intermediate set of standards is required.

REFERENCES

1. *Manual of Geometric Design Standards for Canadian Roads: 1986 Metric Edition.* Roads and Transportation Association of Canada.
2. *A Policy on Geometric Design of Highways and Streets.* American Association of State Highway and Transportation Officials, 1984.
3. *Parks Canada Road Classification System and Geometric Design Standards 97.3.1.* Parks Canada.
4. *Roads Pre-Construction Handbook.* FSH 7709.56. U.S. Department of Agriculture Forest Service (Draft).
5. *Highway Design Standards.* Republic of Zambia, Ministry of Works and Supply, Roads Department.
6. J. C. Glennon. Design and Traffic Control Guidelines for Low-Volume Rural Roads. *National Cooperative Highway Research Report 214*, 1979.
7. *Interim Guide to the Geometric Design of Rural Roads.* National Association of Australian State Road Authorities, 1980.