1160. Resurfacing, Restoration, & Rehabilitation Projects (3R)

1160.1. Guidelines

1160.1.1 General

This chapter presents the procedures for development of 3R projects in Alaska, which are cost-effective and enhance highway safety. These procedures are required where projects are federally funded or on federal-aid routes. In nonfederal projects, these procedures represent good engineering, but they are not mandatory.

1160.1.2 Background

Prior to 1976, federal-aid highway funds were generally limited to participation in the new construction of highways. Preservation of the existing highways was a state or local agency responsibility.

By 1975, it became evident that many sections of the existing highway system were reaching the end of design life, and the rate of deterioration was exceeding the funding levels available for preservation. In recognition of this problem, Congress, in the 1976 Federal-Aid Highway Act, broadened the scope of the Federal-Aid Highway Program to include preservation work by adding resurfacing, restoration, and rehabilitation (3R) to the definition of construction under Title 23, USC, Section 101(a).

However, since many existing highways do not meet current design standards and have safety deficiencies, the amount of upgrading to current 3R project standards has been a continuing concern. This concern was recognized in the 1982 Surface Transportation Assistance Act, Section 101(a), which emphasizes safety by stating that 3R projects “shall be constructed in accordance with standards that preserve and extend the service life of the highways and enhance highway safety.” (Emphasis added.)

1160.1.3 Definition

Rehabilitation (3R) projects consist of the resurfacing, restoration, and rehabilitation of an existing roadway on the same alignment or modified alignment. The principal objective of 3R projects is to restore the structural integrity of the existing roadway, thereby extending the service life of the facility. In addition, the safety and capacity of the facility should be enhanced, if required.

Generally, a 3R project consists of the repaving or the asphalt paving of an existing gravel surface. It can also include drainage improvements and reconstruction of the structural section. Safety enhancements include improvement of deficient geometry identified by a performance criterion found in this section. Capacity enhancements include the addition of truck climbing lanes, passing lanes, and slow moving vehicle lanes. Turnouts may be added as safety enhancements where driver fatigue or sightseeing are factors in accidents.

Section 1160.5. describes a modified design procedure for non-NHS road construction projects whose primary purpose is to reduce maintenance costs and improve the quality of life for Alaskans by hard surfacing of gravel roads, but that may include limited shoulder, drainage, and other work related to preserving the road structure.

1160.1.4 Determining the Type of Project

Follow normal project planning and programming procedures for determining the type of improvement: new construction, reconstruction on existing alignment, or restoring the existing facility (3R). This determination is specified on the Design Designation.

Select a design year that at least equals the expected life of the improvement. Designate the design year in five-year increments.

1160.2. Factors

Evaluate the following in determining type and scope of a project:

1. **Pavement Condition**: The existing pavement condition and the scope of needed pavement improvements dictate to a large extent what improvements are feasible. The project analysis should indicate how existing pavement condition...
and the scope of pavement improvements will interrelate with the scope of geometric improvements and the values used for design of geometric improvements.

2. **Physical Characteristics:** The physical characteristics of a highway and its general location often determine what improvements are necessary, desirable, possible, practical, or cost-effective. Consider topography, climate, adjacent development, existing alignment (horizontal and vertical), cross-section (pavement width, shoulder width, cross slope, and sideslopes), and similar characteristics in determining the scope of geometric or safety improvements to be made in pavement-type 3R work.

3. **Traffic Volumes:** Traffic data are needed in the design of all highway improvements, including 3R. Traffic volume is an important consideration in determining the appropriate level of improvement (for example, reconstruction versus 3R) and in the selection of values for the various geometric elements.

4. **Traffic Controls and Regulations:** Signing and marking in all highway projects, including 3R, must conform to the *Alaska Traffic Manual* (ATM). Where roadway geometry or other roadway or roadside features do not meet the drivers’ expectancy and reconstruction is not appropriate, consider additional signs, markings, and other devices beyond the normal requirements of the ATM. While traffic control devices cannot fully mitigate all problems associated with substandard geometric features, they can compensate for certain operational deficiencies. In addition, judicious use of special traffic regulations, positive guidance techniques, and traffic operational improvements can often forestall expensive reconstruction by minimizing or eliminating possible adverse safety and operational features of existing highways.

5. **Accident Records:** Accident records are an integral part of these 3R standards. It is necessary to reference the state reporting system to evaluate existing geometric features for accident performance. Generally, use a three- to five-year period. When evaluating historical accident records, examine each accident as a whole, regardless of the number of vehicles or people involved. Moose accidents and alcohol-related accidents are eligible. Obtain average accident rates from the January 25, 2002, DOT&PF *Highway Safety Improvement Program Handbook*.

6. **Skid Resistance:** A skid-resistant surface should be an essential part of any pavement surface improvement, regardless of the scope of geometric problems or improvements. The Alaska design method for asphalt pavement provides a skid-resistant surface. Portland cement concrete requires a broom or similar finish.

7. **Economics:** By their purpose and definition, 3R projects reflect and emphasize the economic management of the highway system. The purpose of 3R is to prolong and preserve the service life of existing highways and to enhance highway safety to protect the investment in, and derive the maximum economic benefit from, the existing highway system. Economic considerations should be a major factor in determining the priority and scope of 3R work.

8. **Potential Impact of Various Improvements:** Often, development and effects on the land influence the scope of geometric improvements made by 3R projects. Typically, social, environmental, and economic impacts severely limit the scope of 3R projects, particularly where the existing right-of-way is narrow and there is considerable adjacent development.
1160.3. 3R Geometric Design Standards

1160.3.1 General (Design Exceptions)
Design all 3R-type projects using the 3R design criteria found in this section. Design standards for 3R projects that are not in this section shall be dictated by the remaining applicable sections of Chapter 11 and the current AASHTO A Policy on the Geometric Design of Highways and Streets 2001. All signing and pavement markings must conform to the Alaska Traffic Manual. Upgrade all warranted guardrail terminals and bridge rail terminal connections to current standards (see Table 1130-12 of this manual for guardrail terminal replacement guidance). If an engineering analysis indicates that a section of existing guardrail is not warranted for obstacle protection or other operational factors, it may be removed. Design exceptions, in accord with Section 1100.3, shall be required when the results or determinations of the 3R design procedures require a feature improvement and the proposed project does not include that improvement.

Continuity may require that routes be analyzed as a whole with respect to lane, shoulder widths, and cross-section geometry. Apply 3R standards to individual projects, but regional policy may be required for minimum acceptable geometry on individual routes.

Urban and Multilane Rural Highways
Less is known about the safety cost-effectiveness of widening urban and multilane rural highways, and minimum values have not been proposed that highway agencies can adopt as standards. Use the minimum widths recommended for rural two-lane highways as a guide to safety cost-effective improvements for multilane rural and urban highways. However, routinely upgrading lane and shoulder widths in urban areas to the minimum widths recommended for rural two-lane highways is likely to produce some widening projects that are not safety cost-effective, particularly when there are physical constraints or high right-of-way costs. In such situations, determine the scope of widening improvements on a case-by-case basis.

Gravel Surfaced Roads
Roads in this class do not have to be analyzed for routine safety enhancement unless a prodigious accident history at specific locations warrants an improvement.

Design Volume
Determine ADT for the design life of the project. The design ADT shall equal the mid-design period ADT. Generally, design life periods for 3R projects are equal to the pavement design periods and should be compatible with the service life of the improvement.

Design Speed
The recommended minimum design speed is the 85th percentile speed. You should consider that the actual 3R improvement may increase the operating or measured 85th percentile speed over that currently posted.

On lower volume roadways, AADT less than 2,000, it may be cost prohibitive to obtain a sample size that provides a statistically valid speed study to define 85th percentile speeds for design. In these cases, the engineer should drive the project and use operating speeds observed during field investigations for the design speed, or use the safe speeds defined by existing geometrics.

Where AADT is greater than or equal to 2,000, it is likely that the Department has speed studies for the roadway on file and these should be used to estimate the 85th percentile speeds for 3R evaluation and design. If not, speed studies at these locations are usually economically feasible. Consider additional speed studies or field observations to estimate speeds in areas where there are significant accident clusters.

1160.3.2 Lane and Shoulder Widths

Rural Two-Lane Paved Highways
Select lane and shoulder width improvements in accordance with a performance evaluation based on historical accident rates versus a predicted rate A. Compilation of actual accident rates and computation of a predicted accident rate A are required. Calculate the actual accident rate for the previous three- to five-year period for comparison to the predicted rate A.

If the historical accident rate is equal to or less than the predicted rate A, then the existing total lane and shoulder width may remain unchanged.

If the historical accident rate exceeds the predicted rate A, widen the total lane and shoulder width, in each direction, by 1 foot on each side for every 10 percent increment the historical accident rate exceeds A. The widening shall not exceed the values required for new construction.
Study accident data to identify accident clusters that may result from high hazard locations atypical to the route or project. You may remove the accident data from these locations for the determination of lane and shoulder widths, but analyze them on an individual basis as required by the 3R Procedure Outline shown in Figures 1160-1 and 2.

When evaluating lane and shoulder widths, consider route continuity. Adjoining projects could have a bearing on the width selection.

\[ A = 0.0019 \ ADT^{0.882} \times 0.879^W \times 0.919^{PA} \times 0.932^{UP} \times 1.236^H \times 0.882^{TER1} \times 1.322^{TER2} \]

(Ref. Transportation Research Board Special Report 214, Appendix C)

\( A = \) number of run-off road, head-on, opposite-direction sideswipe, and same-direction sideswipe accidents per mile per year. Does not include intersection accidents

\( ADT = \) two-directional average daily traffic volume for the study period

\( W = \) existing lane width in feet

\( PA = \) existing width of paved shoulder in feet

\( UP = \) existing width of unpaved (gravel, turf, earth) shoulder, in feet

\( H = \) median roadside hazard rating for the highway segment, measured subjectively on a scale from 1 (least hazardous) to 7 (most hazardous). See Figures 1160-1 through 1160-7.

\( TER1 = 1 \) for flat terrain, 0 otherwise

\( TER2 = 1 \) for mountainous terrain, 0 otherwise

This accident model is limited because it applies only to:

- Lane widths of 8 to 12 feet and shoulder widths of 0 to 10 feet. Combinations of lane and shoulder widths that can be reasonably modeled are limited to those shown in Figure 3-2, Chapter 3 of TRB Special Report 214.
- Two-lane, two-way paved rural roads
- Homogeneous roadway sections. It does not include the additional accidents expected at intersections.
### Table 1160-1
3R Procedure Outline (Case I)

**3R PROCEDURE OUTLINE**

**CASE I**

**EXISTING ROADWAY TOP WIDTH IS LESS THAN REQUIRED FOR NEW CONSTRUCTION**

#### Site Specific Accidents or Anomalies

- Accident site specific geometry or obstacles shall be evaluated in accord with Section 1160.03.

#### Lane & Shoulder Width Selection (total top width)

- General accident rate for segment or project equal or less than the predicted accident rate.
- General accident rate for segment or project greater than the predicted accident rate.

- Top width widening is not required.
- Widen top width 1 ft each side (2 ft total) for each 10 percent increment that the actual accident rate exceeds the predicted rate up to but not exceeding the width required for new construction.

#### Cross Sectional Elements

- Evaluation not required.
- Reduce the actual accident rate by ten percent for each 1 ft of top widening each side (2 ft total).

- If adjusted accident is equal or less than the predicted then the cross sectional evaluation is not required.
- If adjusted accident exceeds the predicted then the cross sectional elements require evaluation in accord with Section 1130.
3R Procedure Outline (Case II)

3R PROCEDURE OUTLINE

CASE II

EXISTING ROADWAY TOP WIDTH IS EQUAL OR GREATER THAN REQUIRED FOR NEW CONSTRUCTION

Site Specific Accidents or Anomalies

Accident site specific geometry or obstacles shall be evaluated in accord with Section 1160.03.

Lane & Shoulder Width Selection (total top width)

Top width widening is not required.

- General accident rate for segment or project equal or less than the predicted accident rate.
- General accident rate for segment or project greater than the predicted accident rate.

Cross Sectional Elements

Evaluation not required.

Cross Sectional Elements

The roadside cross sectional elements require evaluation in accord with Section 1130.
Figure 1160-1
Rural Roadside Hazard Rating of 1
Figure 1160-2
Rural Roadside Hazard Rating of 2
Figure 1160-3
Rural Roadside Hazard Rating of 3
Figure 1160-4
Rural Roadside Hazard Rating of 4
Figure 1160-5
Rural Roadside Hazard Rating of 5
Figure 1160-6
Rural Roadside Hazard Rating of 6
Figure 1160-7
Rural Roadside Hazard Rating of 7
**1160.3.3 Horizontal Curves**

**Radius of Curvature**

The existing horizontal curvature may be used if superior (or equal) to the values required for new construction, or if the actual number of accidents for the previous three- to five-year period on the section of road under consideration is less than $A_h$. If the number of accidents is equal to or greater than $A_h$, improve the horizontal curvature to the standards of new construction unless it is not cost-effective. Horizontal curves that have no accident history do not require an evaluation and may remain unmodified.

$$A_h = AR_r(LV) + [0.0336 * D * V] \quad \text{for} \; L \geq L_c$$

(Ref. Transportation Research Board, Special Report 214, Appendix C)

where:

- $A_h =$ predicted total number of accidents on the segment
- $AR_r =$ accident rate on comparable straight segments in accidents per million vehicle miles
- $L =$ length of highway segments in miles
- $V =$ total traffic volume in millions of vehicles
- $D =$ curvature in degrees
- $L_c =$ length of curved component in miles

Consider in the cost-effective analysis the historic accident rate for the previous three- to five-year period and the related societal costs (See Example 1160-4). An annual accident cost can be calculated and compared to the annual cost of the improvement.

An annual accident cost savings should be determined as the product of the accident reduction factor (ARF) (Equation 4 in Appendix D, TRB 214; Table D-7, TRB 214; or DOT&PF’s Highway Safety Improvement Program Handbook, January 25, 2002) produced by the improvement and the historic annual accident cost over the study period. The improvement is considered cost-effective if the annual accident cost savings exceeds the annual cost of the improvements.

When it is not cost-effective to improve curve alignment, consider other safety improvement measures. These improvements can consist of widening and paving shoulders, widening the clear zone, flattening steep sideslopes, removing or relocating roadside obstacles, and installing traffic control devices such as raised pavement markings or reflective guideposts.

**Superelevation**

Superelevation may remain unchanged if there are no related accidents. When accidents are related to the existing superelevation, modify it to conform to the requirements for new construction. In unusual cases, it may be possible to show by a cost-effective analysis, based on a three- to five-year accident history, that an existing cross slope may remain.

**Superelevation Transition Length**

Transition length requirements generally control driver comfort and roadway appearance rather than safety, so existing transition lengths that do not meet the requirements for new construction may remain.

**Minimum Length of Curve**

Curve length requirements generally control driver comfort and roadway appearances rather than safety, so existing curve lengths that do not meet the requirements for new construction may remain.

**1160.3.4 Vertical Curvature and Stopping Sight Distance**

**Sag Vertical Curves**

An analytical method is not available to analyze accidents at sag vertical curves. Generally, sag vertical curves that do not meet AASHTO requirements may remain. If a grouping of accidents at a sag vertical curve appears to be an anomaly when compared to similar curves, an improvement may be needed if cost-effective.

**Crest Vertical Curves**

Existing crest vertical curvature may be used if superior or equal to the values required for new construction, or if the actual number of accidents for the previous three- to five-year period on the section of road under consideration is less than $N_c$. If the number of actual accidents is equal to or greater than $N_c$, then improve the crest vertical curvature to the standards of new construction unless it can be shown not cost-effective. Vertical curves that have no actual accident history do not require an evaluation and may remain unmodified.

$$N_c = AR_h(L_c) + AR_h(L_r)(V)(F_{ar})$$
where:

\[ N_c = \text{number of predicted accidents attributable to the crest vertical curve segment} \]

\[ A_{th} = \text{average accident rate for the highway in consideration in accidents per million vehicle miles} \]

\[ L_{vc} = \text{length of vertical curve (highway segment) in miles} \]

\[ V = \text{total traffic volume in millions of vehicles} \]

\[ L_r = \text{length of restricted sight distance in miles (The length of restriction is the distance over which the available sight distance is less than that considered adequate by AASHTO procedures for the actual highway operating speed.)} \]

\[ L_r = \frac{[a_0 + (a_i \times A)]}{5280} \]

\[ A = \text{the absolute value of grade difference in percent} \]

\[ F_{ar} = \text{accident rate factor. See Table 1160-3 and Table 1160-4.} \]

Equation 7 in Appendix E of TRB 214 predicts the change in accidents resulting from lengthening crest vertical curves. An annual cost savings can be estimated using the historic annual accident cost over the study period. The improvement is considered cost-effective if the annual accident cost savings exceeds the annual cost of the improvements.

### 1160.3.5 Bridges

#### Width

Improve bridge widths to the minimums established in the *AASHTO A Policy on the Geometric Design of Highways and Streets 2001* when the length is less than 100 feet and the usable width is less than the following values:

<table>
<thead>
<tr>
<th>Mid Design Period ADT</th>
<th>Usable Bridge Width (ft)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-750 751-2,000</td>
<td>Width of Approach Lanes</td>
</tr>
<tr>
<td></td>
<td>Width of Approach Lanes plus 2 feet</td>
</tr>
</tbody>
</table>

You may leave qualified bridges above in place if no improvement is necessary based on a cost-effective analysis considering the previous 10-year accident history.

Bridges longer than 100 feet that are substandard in width generally are not considered for width improvement under 3R standards.

#### Structural Capacity

If any existing structural member has a design capacity less than HS 15 (HS 20 for interstate bridges), replace that member.

#### Bridge Rail and Transitions

On projects containing major bridge rehabilitation (widening, strengthening, and/or deck replacement), ensure all bridge rail and rail transitions meet strength and crash test criteria for the appropriate rail performance level. In lesser rehabilitation projects, determine by a cost-effective analysis the appropriate rail upgrade (previously discussed in this chapter). The Bridge Section will be responsible for maintaining the procedures to be used and for applying the current bridge rail upgrade guides.

#### Earthquake Capacity

All bridges on rural or urban arterials and rural or urban collectors, where there are no feasible detour routes, are essential. In addition, classify bridges as essential if they provide the only feasible access to:

- Military bases, supply depots, and National Guard installations
- Hospitals, medical supply centers, and emergency depots
- Major airports
- Defense industries and those that could easily or logically be converted to them
- Refineries, fuel storage, and distribution centers
- Major railroad terminals, railheads, docks, and truck terminals
• Major power plants, including nuclear power facilities and hydroelectric centers at major dams
• Major communication centers
• Other facilities that the state considers important from a national defense viewpoint or during emergencies resulting from natural disasters or other unforeseen circumstances

Bridges on 3R projects shall be assigned to a Seismic Performance Category in accordance with the current AASHTO Specifications for Seismic Design of Highway Bridges.

You do not have to investigate bridges rated SPC “A” for earthquake retrofitting.

Investigate bridges rated SPC “B,” “C,” or “D” for bearing width, bearing height, joint restraint, bearing restraint, support width, and other evident areas of potential seismic motion distress. Retrofit those structures that do not conform to the AASHTO Specifications for Seismic Design in the above areas in accord with the Federal Highway Administration publication FHWA-RD-94-052, Seismic Retrofitting Manual for Highway Bridges.

The Headquarters Bridge Section will be responsible for the retrofitting investigation. If required, the Bridge Section will also prepare retrofitting plans and specifications for inclusion in the 3R project documents.

The estimated cost of any individual bridge earthquake retrofit shall not exceed 10 percent of the estimated total structure value. If the cost exceeds 10 percent, qualify the structure for retrofitting under another funding source.

1160.3.6 Sideslopes and Clear Zones
Evaluate section geometry and obstacles within the clear zone when required by the 3R Procedure Outline shown in Tables 1160-1 and 2.

1160.3.7 Pavement Edge Drop
Edge drops at the edge of the traveled way are a recognized safety hazard. These drops generally occur with degradation of unpaved shoulders. Paving shoulders is the best solution for eliminating the edge drop. If shoulders won’t be paved, bring the existing shoulders to a grade with new material that matches the top edge of the driving surface.

1160.3.8 Intersections
The relative risk of accidents at intersections is high. It is normal to observe accident clustering at intersections. Study the accident history of an intersection to determine if accidents are caused by a design deficiency or operator error. Correct a geometric deficiency related to accidents to the new design standards of this manual or the AASHTO A Policy on the Geometric Design of Highways and Streets 2001, if cost-effective or corrected by actions such as signing, signaling, or channelization.

Sight distance is of primary importance at intersections to allow operators sufficient time to observe and react to conflicts. The sight triangle shown in Figure 1160-8 is the minimum allowable at any existing intersection (driveway). The sight distances required (Sd) are the minimum stopping sight distances required by Section 1120.1. of this manual.

1160.3.9 Driveways
Existing driveway geometry may remain except if accident records indicate an anomaly. In that case, the driveway requires an engineering evaluation for improvement to meet the requirements of Section 1190 of this manual.
**MINIMUM INTERSECTION SIGHT DISTANCE**

![Diagram of intersection sight distance](image)

Note: Minimum sight distances are stopping sight distances for level grades, between -3% and +3%. Refer to AASHTO A Policy on Geometric Design of Highways and Streets 2001, for desirable intersection sight distances and for grade adjustments.

**Figure 1160-8**

 Minimum Intersection Sight Distance

<table>
<thead>
<tr>
<th>DESIGN SPEED or POSTED SPEED LIMIT (mph)</th>
<th>SD MINIMUM (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>115</td>
</tr>
<tr>
<td>25</td>
<td>155</td>
</tr>
<tr>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>35</td>
<td>250</td>
</tr>
<tr>
<td>40</td>
<td>305</td>
</tr>
<tr>
<td>45</td>
<td>360</td>
</tr>
<tr>
<td>50</td>
<td>425</td>
</tr>
<tr>
<td>55</td>
<td>495</td>
</tr>
<tr>
<td>60</td>
<td>570</td>
</tr>
<tr>
<td>65</td>
<td>645</td>
</tr>
</tbody>
</table>
### Table 1160-3
**Accident Rate Factor ($F_{ar}$)**

<table>
<thead>
<tr>
<th>Severity of sight Restriction (mph)</th>
<th>Degree of Hazard in Sight Restricted Area</th>
<th>Minor</th>
<th>Significant</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>0</td>
<td>0.4</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>(0.3)</td>
<td>(0.8)</td>
<td>(1.4)</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>0.5</td>
<td>1.1</td>
<td>1.8</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>1.2</td>
<td>2.0</td>
<td>2.8</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>2.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

*a*: See Table 1160-4

**Note:** Numbers in parentheses were interpolated from J.C. Glennon “Effects of Alignment on Highway Safety: A Synthesis of Prior Research” In TBR State of the Art Report. TRB, National Research Council, Washington D.C.

### Table 1160-4
**Relative Hazard**

<table>
<thead>
<tr>
<th>Relative Hazard</th>
<th>Geometric condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor</td>
<td>Tangent horizontal alignment</td>
</tr>
<tr>
<td></td>
<td>Mild curvature (less than 3 degrees)</td>
</tr>
<tr>
<td></td>
<td>Mild downgrade (less than 3 percent)</td>
</tr>
<tr>
<td>Significant</td>
<td>Low-volume intersection</td>
</tr>
<tr>
<td></td>
<td>Intermediate curvature (3 to 6 degrees)</td>
</tr>
<tr>
<td></td>
<td>Moderate downgrade (3 to 5 percent)</td>
</tr>
<tr>
<td></td>
<td>Structure</td>
</tr>
<tr>
<td>Major</td>
<td>High-volume intersection</td>
</tr>
<tr>
<td></td>
<td>Y-diverge on road</td>
</tr>
<tr>
<td></td>
<td>Sharp curvature (greater than 6 degrees)</td>
</tr>
<tr>
<td></td>
<td>Steep downgrade (greater than 5 percent)</td>
</tr>
<tr>
<td></td>
<td>Narrow bridge</td>
</tr>
<tr>
<td></td>
<td>Narrow pavement</td>
</tr>
</tbody>
</table>
Table 1160-5
Constants for $L_r$

<table>
<thead>
<tr>
<th>Operating Speed on Vertical Curve (mph)</th>
<th>Equivalent speed to existing crest Vertical curve stopping sight distance (mph) (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60</td>
</tr>
<tr>
<td>60</td>
<td>-524</td>
</tr>
<tr>
<td>55</td>
<td>-452</td>
</tr>
<tr>
<td>50</td>
<td>-405</td>
</tr>
<tr>
<td>45</td>
<td>-332</td>
</tr>
<tr>
<td>40</td>
<td>No sight restriction</td>
</tr>
<tr>
<td>35</td>
<td>-231</td>
</tr>
<tr>
<td>30</td>
<td>-193</td>
</tr>
<tr>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

**Values of $a_0$**

$$L_r = \frac{[a_0 + (a_1 \times A)]}{5280}$$

$A =$ the absolute value of grade difference in percent

(1) TRB Special Report 214 uses the definition Highway Design Speed of the existing vertical curve.
1160.3.10 Passing Sight Distance
Operational and passing sight distances are given in Section 3B of the Alaska Traffic Manual. Improvements of passing distances are not required within the context of 3R projects.

1160.3.11 Grades
Grades that do not meet new construction standards should be evaluated as a potential contributing factor where there are clusters of accidents on or in the vicinity of the grade section. Grade-related accidents might include single or multiple vehicle accidents where a vehicle lost control and leaves the travel lane or is unable to stop. Countermeasures for steep grades may include warning signs or realignment.

1160.3.12 Safety Mitigation
Even though these 3R standards may not require a geometric improvement, the designer should anticipate circumstances where mitigating improvements could be made at minimum cost. For example, geometric changes at an intersection or horizontal curve to increase sight distance may not be cost-effective, but cutting brush or trees can partially alleviate the problem.

1160.4. Studies
1160.4.1 Design Study Report
Prepare a Design Study Report in accord with Chapter 4, Section 450. In addition to the Section 450 requirements, include the following in the report:
- A list of all existing horizontal and crest vertical curves that do not meet the current minimum design requirements of AASHTO for new construction
- A discussion of the design speed determination in accord with Section 1160.3.3
- A discussion of the determination of lane widths in accord with Section 1160.3.4 and the clear zone requirements as determined by Section 1160.3.8
- A discussion of horizontal curve treatments in accord with Section 1160.3.5
- A discussion of vertical curve treatments in accord with Section 1160.3.6
- A discussion of bridge features that require improvement
- A discussion of accidents at intersections and what improvements may be made

Include supportive calculations for the above items in the report.

1160.5. Gravel to Pavement
1160.5.1 General
Section 1160.5, Gravel to Pavement, applies to non-NHS road construction projects whose primary purpose is reducing maintenance costs and improving the quality of life for Alaskans by hard surfacing of gravel roads, but which may include limited shoulder, drainage, and other work related to preserving the road structure.

The existing alignment, profile, and sideslopes may remain as long as the project does not degrade any existing safety or geometric aspects. Guardrail, guardrail terminals, and bridge rail terminal connections will not routinely be upgraded to more current standards.

Signing and Markings
Inventory and evaluate all existing signing for sign placement and condition. Conform signing to the requirements of the Alaska Traffic Manual (ATM) and the Alaska Sign Design Specifications (ASDS). Install regulatory speed limit signing conforming to the chosen design speed of the roadway. Install curve, grade, advance intersection, and other warning signs as required to warn of conditions where the safe speed is lower than the posted speed limit. Other regulatory signing requirements include stop signs at side street approaches.

Upgrade signposts that do not conform to current safety standards.

1160.5.2 Design Year
The design year should at least equal the expected surface life of the selected surface type.

1160.5.3 Design Speed
Use the current posted as a minimum design speed. In the absence of posted speeds, use the criteria in A Policy for the Geometric Design of Highways and Streets 2001, to establish a minimum design speed.

In selecting the design speed, consider the anticipated speed of traffic traveling on the newly surfaced roadway. You may use the speed limit on paved roads of similar character in selecting design speed.
1160.5.4  **Lane and Shoulder Widths**

Rural Two-Lane Paved Highways
Table 1160-6 shows minimum lane and shoulder width improvements.

**Table 1160-6**
Two-Lane – Two-Way Traffic
Combined Roadway Minimum Lane & Shoulder Widths
For Use With Gravel to Pavement Modified Procedure

<table>
<thead>
<tr>
<th>Minimum Lane and Shoulder Width (ft)</th>
<th>Design Year ADT 0-2000 vpd</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-250</td>
</tr>
<tr>
<td>Design Year Traffic Volumes (ADT) in vpd</td>
<td></td>
</tr>
<tr>
<td>20 mph</td>
<td>18</td>
</tr>
<tr>
<td>30 mph</td>
<td>18</td>
</tr>
<tr>
<td>45 mph</td>
<td>18</td>
</tr>
<tr>
<td>50 mph</td>
<td>22</td>
</tr>
</tbody>
</table>
Waiver of Roadway Width
For roadway width less than shown in Table 1160-6, obtain a design waiver in accordance with Alaska Preconstruction Manual Section 1100.3. guidelines.

The minimum width for two-lane roads is 18 feet.

1160.5.5 Grades
Grades do not require improvement under these standards.

1160.5.6 Horizontal Curves
Radius of Curvature
No change is required under these standards.

Superelevation
Superelevation should match the design speed for the project. Follow AASHTO A Policy on the Geometric Design of Highways and Streets 2001. Maximum superelevation is 6 percent cross-slope.

Superelevation Transition Length
When possible, provide minimum superelevation transition length in accordance with the AASHTO A Policy on the Geometric Design of Highways and Streets 2001.

Minimum Length
No change is required under these standards.

1160.5.7 Vertical Curvature and Stopping Sight Distance
Sag and Crest Vertical Curves
No change is required under these standards.

Stopping Sight Distance
No change is required under these standards.

Intersection Sight Distance for Side Streets
No change is required under these standards.

Consider clearing to the right-of-way limits to improve sight distance that does not meet AASHTO minimum sight distance standards.

Driveway Sight Distance
No change is required under these standards.

Consider clearing to the right-of-way limits to improve sight distance that does not meet AASHTO minimum sight distance standards.

1160.5.8 Bridges
No change to the existing structure or railing is required, except as necessary to keep structures serviceable through the design period.

1160.5.9 Clear Zones
No change is required under these standards.

1160.5.10 Bicycles
No enhancements required.

1160.5.11 ADA
Do not construct anything that will diminish the access to, or use of the facility by, a disabled person.

1160.5.12 Design Study Report
For gravel to pavement projects, the requirements of Chapter 4 of this manual concerning preparation of the Design Study Report are modified to include the following:

- Structural section, addressing embankment suitability. Reference section 1180.8.
- Materials sources
- A copy of the Design Study Report to the regional maintenance director/chief
Example 1160-1
Lane-Shoulders & X-Section

Glacier Highway, North Lena Loop Road to Point Stephens Road

Design Period       20
Current ADT          1027
Design Year ADT      1383
Mid Period ADT       1205
Percent Trucks       6.4%
Average Running Speed 45 mph
Terrain Values       Use “0”

Existing Lanes = 11 feet and Shoulders = 0 feet

Accident Study Period

1977 to 1987
Mid-study Period ADT 900

Cross-Section Elements

Roadside Hazard Rating selected as 6, see Figures 1160-1 through 1160-7

\[ A = 0.0019 \times ADT^{0.882} \times 0.879^W \times 0.919^{PA} \times 0.932^{UP} \times 1.236^H \times 0.882^{TER1} \times 1.322^{TER2} \]

\[ A = 0.0019 \times (900)^{0.882} \times 0.879^{11} \times 0.919^0 \times 0.932^0 \times 1.236^6 \times 0.882^0 \times 1.322^0 \]

= 0.7 accidents /mi /year

Route No. 296000
CDS mile points from Alaska DOT&PF General Road Log: 22.93 to 21.68 = 1.25 miles

See accidents for Period = 1977 through 1987 (shown on next page)

(Note: Category 7, 8, 10, 11, & 12 intersection accidents do not qualify)
Example 1160-1
Lane-Shoulders & X-Section, continued

<table>
<thead>
<tr>
<th>ACCNBR</th>
<th>ACCDTE</th>
<th>TIME</th>
<th>ROUTE</th>
<th>MI</th>
<th>ACC DIA</th>
<th>NBR VEH</th>
<th>TOT MAJ</th>
<th>MIN INJ</th>
<th>DAMAGE</th>
<th>ACC TYPE</th>
<th>ROAD CHAR</th>
<th>ROAD COND</th>
</tr>
</thead>
<tbody>
<tr>
<td>7912635</td>
<td>791125</td>
<td>1630</td>
<td>296000</td>
<td>21.95</td>
<td>9</td>
<td>1</td>
<td>1,200</td>
<td>17</td>
<td>2</td>
<td>1400</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>7815249</td>
<td>780509</td>
<td>1539</td>
<td>296000</td>
<td>21.72</td>
<td>9</td>
<td>1</td>
<td>800</td>
<td>40</td>
<td>4</td>
<td>01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8012890</td>
<td>801124</td>
<td>0640</td>
<td>296000</td>
<td>22.57</td>
<td>9</td>
<td>2</td>
<td>800</td>
<td>08</td>
<td>1</td>
<td>01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7709900</td>
<td>770707</td>
<td>1630</td>
<td>296000</td>
<td>22.14</td>
<td>9</td>
<td>1</td>
<td>2,000</td>
<td>25</td>
<td>5</td>
<td>01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8200598</td>
<td>820110</td>
<td>0230</td>
<td>296000</td>
<td>21.71</td>
<td>9</td>
<td>3</td>
<td>1,400</td>
<td>12</td>
<td>1</td>
<td>04</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8202582</td>
<td>820221</td>
<td>1520</td>
<td>296000</td>
<td>21.75</td>
<td>7</td>
<td>3</td>
<td>3</td>
<td>9,000</td>
<td>06</td>
<td>1</td>
<td>04</td>
<td>0</td>
</tr>
<tr>
<td>8218451</td>
<td>821129</td>
<td>0750</td>
<td>296000</td>
<td>22.57</td>
<td>2</td>
<td>2</td>
<td>200</td>
<td>07</td>
<td>5</td>
<td>04</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8400740</td>
<td>840110</td>
<td>0745</td>
<td>296000</td>
<td>22.55</td>
<td>9</td>
<td>1</td>
<td>900</td>
<td>29</td>
<td>5</td>
<td>05</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8521909</td>
<td>851226</td>
<td>1530</td>
<td>296000</td>
<td>21.82</td>
<td>9</td>
<td>1</td>
<td>2</td>
<td>8,000</td>
<td>17</td>
<td>4</td>
<td>04</td>
<td>0</td>
</tr>
<tr>
<td>8606011</td>
<td>860422</td>
<td>2057</td>
<td>296000</td>
<td>21.92</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>3,000</td>
<td>29</td>
<td>4</td>
<td>02</td>
<td>0</td>
</tr>
<tr>
<td>8606208</td>
<td>860429</td>
<td>1426</td>
<td>296000</td>
<td>22.53</td>
<td>1</td>
<td>40</td>
<td>40</td>
<td>4</td>
<td>01</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8702618</td>
<td>870214</td>
<td>2154</td>
<td>296000</td>
<td>21.71</td>
<td>9</td>
<td>1</td>
<td>4,000</td>
<td>17</td>
<td>1</td>
<td>04</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8712934</td>
<td>871104</td>
<td>0825</td>
<td>296000</td>
<td>21.68</td>
<td>9</td>
<td>1</td>
<td>17</td>
<td>5</td>
<td>04</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8715589</td>
<td>871216</td>
<td>2249</td>
<td>296000</td>
<td>21.94</td>
<td>9</td>
<td>2</td>
<td>600</td>
<td>08</td>
<td>5</td>
<td>04</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Roadway Character
1. Straight and level
2. Straight and grade
3. Straight and hillcrest
4. Curve and level
5. Curve and grade
6. Curve and hillcrest

Roadway Surface Condition
1. Dry
2. Wet
3. Muddy
4. Snow/Ice
5. Slush
6. Other

Type of Accident
Collision With
1. Pedestrian
2. Pedacycle
3. Train
4. Animal
5. Moose

MV in Transport
6. Head on
7. Rear end
8. Angle

MV in Other Roadway
9. Head on
10. Rear end
11. Angle

Parked MV
12. Parked

Fixed Object
13. Bridge/Overpass
14. Building
15. Culvert
16. Curb/Wall
17. Ditch
18. Divider
19. Parking meter
20. Traffic light
21. Light support
22. Sign post
23. Utility post
24. Other support
25. Embankment
26. Fence
27. Guardrail
28. Machinery
29. Tree/Shrub
30. Other object
31. Aircraft

Non-Collision
40. Overtum
41. Fire/Explosion
42. Immersion
43. Gas inhalation
44. Other

Total 14 accidents, 10 accidents qualify.
Actual = \frac{10 \text{ acc}}{(1.25 \text{ mi} \times 10 \text{ yrs})} = 0.8 \text{ acc/ mi / yr}

\left(\frac{\text{Actual}}{\text{Predicted}} - 1\right) \times 100 = \left(\frac{0.8}{0.7} - 1\right) \times 100 = 14.3

- Round 14.3 percent to the nearest 10 percent increment, or 10 percent
- The 10 percent increment requires an increased traveled way width by 2 feet.
- Clear zone need not be addressed after 4-foot widening. The widening reduces the accident rate sufficiently to preclude clear zone investigation.
Example 1160-2
Lane-Shoulders & X-Section

Denali Highway Rehabilitation

Design Period 10
Current ADT 100
Design Year ADT 150
Mid Period ADT 125
Percent Trucks 4.0%
Average Running Speed 50 mph
Terrain Values “0”

Existing Lanes = 10 feet and Shoulders = 2 feet

Accident Study Period

1975 to 1985
Mid-study Period ADT 80

Roadside Hazard Rating selected as 5, see Figures 1160-1 through 1160-7

\[ A = 0.0019 (80)^{0.882} \times 0.879^{10} \times 0.919^{2} \times 0.932^{0} \times 1.236^{5} \times 0.882^{0} \times 1.322^{0} \]

= 0.1 accidents / mi / year

Route No. 140000
CDS mile points from Alaska DOT&PF General Road Log: 0.0 to 21.5 = 21.5 miles

See below accidents for the Period = 1975 through 1985

<table>
<thead>
<tr>
<th>ACCNBR</th>
<th>ACCDTE</th>
<th>TIME</th>
<th>ROUTE</th>
<th>MI</th>
<th>ACC NBR</th>
<th>TOT VEH</th>
<th>TOT INJ</th>
<th>MAJ</th>
<th>MIN</th>
<th>DAMAGE</th>
<th>ACC TYPE</th>
<th>ROAD CHAR</th>
<th>ROAD COND</th>
</tr>
</thead>
<tbody>
<tr>
<td>7712183</td>
<td>770722</td>
<td>2340</td>
<td>140000</td>
<td>5.18</td>
<td>9 1 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,000</td>
<td>40 4</td>
<td>01</td>
<td></td>
</tr>
<tr>
<td>8106618</td>
<td>810704</td>
<td>0901</td>
<td>140000</td>
<td>15.90</td>
<td>9 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30,000</td>
<td>40 4</td>
<td>01</td>
<td></td>
</tr>
<tr>
<td>8106947</td>
<td>810712</td>
<td>1000</td>
<td>140000</td>
<td>21.50</td>
<td>1 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,700</td>
<td>07 2</td>
<td>03</td>
<td></td>
</tr>
</tbody>
</table>

Total 3 accidents, 2 accidents qualify (Note: Category 7 accident does not qualify)

\[
\text{Actual} = \frac{2 \text{ acc}}{21.5 \text{ mi} \times 10 \text{ yrs}} = 0 \text{ acc/mi/yr}
\]

A > Actual Lane ⇒ shoulder improvements not required.

Cross-Section Elements
Investigation not required by accident rate, see Tables 1160-1 and 2.
**Example 1160-3**  
**Horizontal Curve**

**Alaska Highway, Mile 1303 to 1285**

**Project Parameters**
- **Project Length**: 17.52 miles
- **Design Speed**: 60 mph  
  (as defined in Section 1160.3.3)
- **Design Period**: 20
- **ADT 1985**: 485
- **ADT 2005**: 750

**Curve Location**  
CDS mile 68.1 to 68.4

**Curve Data**  
- **D**: 5° - 45°
- **L**: 1502.07 ft

**Accident Record for curve**  
10-year period 1975 to 1985, 3 recorded accidents

\[ A_h = [A_{Rs} \times L \times V] + [0.0336 \times D \times V] \]

Solve \( A_{Rs} \)

**Project Length** = 17.5 mi, CDS mile 62.6 to 80.1

**Period**: 1975 to 1985, 33 qualified accidents  
(Total non-intersection accidents on straight roadway segments only)

**Mid Period ADT (1980)** = 300

**Total Vehicle Miles** = 300 ADT x 365 days x 10 yrs. x 17.5 mi. = 19.2 mvm

\[ ARs = \frac{33 \text{ accidents}}{19.2 \text{ mvm}} = 1.7 \text{ acc/mvm} \]

\[ V = 300 \text{ ADT} \times 365 \text{ days} \times 10 \text{ yrs.} = 1,095,000 \text{ vehicles} \]

\[ A_h = [1.7 \text{ acc/mvm} \times 0.3 \text{ mi} \times 1.095 \text{ Milveh}] + [0.0336 \times 5.75\degree \times 1.095 \text{ Milveh}] = 0.8 \text{ accidents} \]

Actual accidents (3) exceeds predicted \( A_h \) (3 > 0.8)

Therefore, improve curve to new construction minimums or check with cost-effective analysis  
See following Example 1160-4.
Example 1160-4  
Cost-Effective Analysis

Horizontal Curve; See Previous Example 1160-3

**Given:** Typical cut section  
- Shoulder: 6 feet from new typical section  
- Cut height: 50 feet  
- Horizontal line shift to accommodate new alignment: 100 ft  
- Excavation cost: $3 per yd³

First cost: Curve length = 1502.07 ft from previous example 1160-3

Excavation EFC = \[
\frac{1502.07 \times 50' \times 100'}{2 \times 27} \times 3.00 = 417,242
\]

CRF = Capital Recovery Factor, to compare present cost of multi-year cost of improvement

\[
CRF = \frac{(1.07)^{20} \times 0.07}{(1.07)^{20} - 1} = 0.0944
\]

Annual First Cost = 0.0944 X $417,242 = $39,388 per yr.

Accident cost:

<table>
<thead>
<tr>
<th>ACCNBR</th>
<th>ACCDTE</th>
<th>TIME</th>
<th>ROUTE</th>
<th>MI</th>
<th>ACC</th>
<th>NBR</th>
<th>VEH</th>
<th>TOT FA</th>
<th>MAJ</th>
<th>MIN</th>
<th>DAMAGE</th>
<th>ACC</th>
<th>TYPE</th>
<th>ROAD CHAR</th>
<th>ROAD COND</th>
</tr>
</thead>
<tbody>
<tr>
<td>7910447</td>
<td>791203</td>
<td>1345</td>
<td>180000</td>
<td>68.25</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>25,000</td>
<td>06</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8012908</td>
<td>801115</td>
<td>1630</td>
<td>180000</td>
<td>68.25</td>
<td>9</td>
<td>1</td>
<td>3,000</td>
<td>40</td>
<td>5</td>
<td>04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7811753</td>
<td>781002</td>
<td>1145</td>
<td>180000</td>
<td>68.25</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>800</td>
<td>17</td>
<td>6</td>
<td>04</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Fatality = 1 = $2,600,000
- Major injury = 0
- Property Damage = 3 = $25,000 + $3,000 + $800 = $28,800

Total accident cost = $2,628,800

10-year period (from Example 1160-3)  
Annual accident cost = $2,628,800/10 = $262,800

Annual accident cost greater than annual first cost of improvement; therefore, the curve geometry should be changed.

**Discussion**

There is the question of whether the fatality was an anomaly. Was high speed involved, an object in the traveled way, or some other factor not related to the curvature? In this case, two vehicles were involved, and it is possible that the accident cause was unrelated to the curvature. If the fatality was an anomaly, then it may be reasonable to only consider the remaining accidents. In that case, the annual accident cost would be $380 (\([$3,000 + $800]/10\)), and the curve would not require improvement.
Example 1160-5  
Vertical Curve  

Unknown Highway, Mile 31 to 44  

Project Parameters  
Project Length = 13.8 miles, CDS mile 31 to 44.8  
Design Speed (as defined in Section 11603.3) = 50 mph  
Design Period = 20  
ADT 1990 = 804  
ADT 2010 = 981  
Sight Distance = 475 ft (See AASHTO Policy on Design)  

Curve Location  
CDS mile 31.6 to 31.7.  

Curve Data  
g_1 = 2.00%  
g_2 = -3.00%  
Length = 500.00 ft  

Existing Sight Distance  
Select the following value for “S” which meets the stated relationship of “S” to “L.”  

\[ S > L \]

\[ S = \frac{1}{2} \left( \frac{L + \frac{1329}{A}}{\frac{1}{A}} \right) = \frac{1}{2} \left( \frac{500}{5} + \frac{1329}{5} \right) = 383 \text{ ft} \]  
Not OK; less than “L”  

\[ S < L \]

\[ S = \left( \frac{1329 \times L}{A} \right)^{\frac{1}{2}} = \left( \frac{1329 \times 500}{5} \right)^{\frac{1}{2}} = 364 \text{ ft} \]  
OK; less than “L”  

Existing sight distance = 364 ft and is substandard to the required 475 ft.  

See Section 1160.3.6, Vertical Curvature and Stopping Sight Distance.  

Accident Record for curve  
10-year period 1978 to 1987, three recorded accidents  
Mid Period ADT(1983) = 600  

\[ N_c = \left[ AR_h \times L_{vc} \times V \right] + AR_h \left( L_c \right) \left( V \right) \left( F_{ar} \right) \]  
See 1160.3.6a, Sag Vertical Curves  

Determine AR  

Project Length = 13.80 mi, CDS mileage 31 to 44.8  
Period: 1978 to 1987, 27 qualified non-intersection accidents  
Mid Period ADT (1983) = 600  
(continued on next page)
Example 1160-5
Vertical Curve, continued

Total vehicle miles = \( (600 \text{ ADT} \times 365 \text{ days} \times 10 \text{ yrs} \times 13.8 \text{ mi})/1,000,000 = 30.2 \text{ mvm} \)

\[
AR_h = \frac{27 \text{ accidents}}{30.2 \text{ mvm}} = 0.9 \frac{\text{acc}}{\text{mvm}}
\]

**Solve for \( L_r \)**

Equivalent speed to existing crest vertical curve stopping sight distance of 364 ft = 45 mph (nearest 5 mph) from Table 1160-5, value for \( a_o \)

From Table 1160-5, using a design speed of 45 mph
\( a_o = -65 \)
\( a_1 = 80.2 \)

\[
L_r = (a_o + (a_1 \times A)) \left( \frac{1}{5280} \right) = (-65 + (80.2 \times 5)) \left( \frac{1}{5280} \right) = 0.064 \text{ miles}
\]

**Find \( F_{ar} \)**

From Tables 1160-3 and 4
\( F_{ar} = 0.8 \)

Severity of sight restriction = (50 mph) - (45 mph) = 5 mph
Moderate down grade @ -3% = significant

**Find Vertical Curve Volume**

\( V = (600 \text{ ADT} \times 365 \text{ days} \times 10 \text{ yrs})/1,000,000 = 2.190 \text{ mv} \)

Solve \( N \) (Number of accidents for ten year period in question.)

\[
N_c = \left[ AR_h \times L_{vc} \times V \right] + AR_h \left( L_r \right) \left( V \right) \left( F_{ar} \right)
\]

\[
N_c = \left[ 0.9 \frac{\text{acc}}{\text{mvm}} \times \frac{500}{5280} \text{ ft} \times 2.19 \text{mv} \right] + 0.9 \frac{\text{acc}}{\text{mvm}} \left( 0.064 \text{ mi} \right) \left( 2.19 \text{mv} \right) \left( 0.8 \right) = 0.29 \text{ acc}
\]

Actual accidents (3) exceeds predicted \( N_c \)

Therefore, improve curve to appropriate minimums or check with cost-effective analysis.