CHAPTER THREE

GUARDRAIL, BARRIERS AND ATTENUATORS

GUARDRAIL WARRANTS 3-1

Warrants for guardrail are to be in accordance with the "Roadside Design Guide" and with the guardrail warrant curves included in this Chapter.

In the preliminary design stage, the designer will establish the location and grade of the project so as to eliminate as much guardrail as possible using these warrants.

After location data is received, plans plotted, grades set, and initial templates determined, the following procedures should be followed:

(1) Determine Guardrail Locations
- (a) Is guardrail warranted in accordance with Figure 1 in this Chapter? If not required, go to (c). If required, go to (b).
- (b) Is guardrail required in accordance with Figures 4 through 6 of this Chapter? If not required, go to (c).
- (c) Is guardrail warranted in accordance with Table 2 and 3 in this Chapter? Refer to Sheet 1-4M and 1-4N in Chapter 1 of this manual.

(2) Can Guardrail be eliminated?
- (a) Can hazard be removed, relocated, or made breakaway?
- (b) Does a cost effectiveness analysis justify flattening slopes? (Be sure to include the additional costs for right of way, drainage, borrow, erosion control, and clearing, in the initial cost of the slope-flattening alternative.)
- (c) Will there be an impact on additional wetlands?

(3) Determine safety-clearing limits for areas unprotected by guardrail. Refer to Sheet 1-4N in Chapter 1 of this manual.

(4) Using the safety clearing limits:
- (a) See pipe end treatment guidelines (5-20 of this manual) for cross drainage pipe within the safety zone.
- (b) For large pipes or culverts that have openings within the safety zone, economically justify by use of the cost effectiveness program, either (1) extending the pipes or culverts beyond the safety limits, (2) leaving the drainage as it is without guardrail protection, or (3) using guardrail to protect the hazard.
- (d) Check the ditch sections for any front slope or back slope located within the clear zone, which is a non-traversable slope. The ditch may remain unshielded if the back slope is smooth and free from hazards.

(e) Check to see that all obstructions within the clear zone are removed, modified for safety, or protected by guardrail.

(f) Check landscape plans to be sure that reforestation is not proposed within the safety clearing limits.

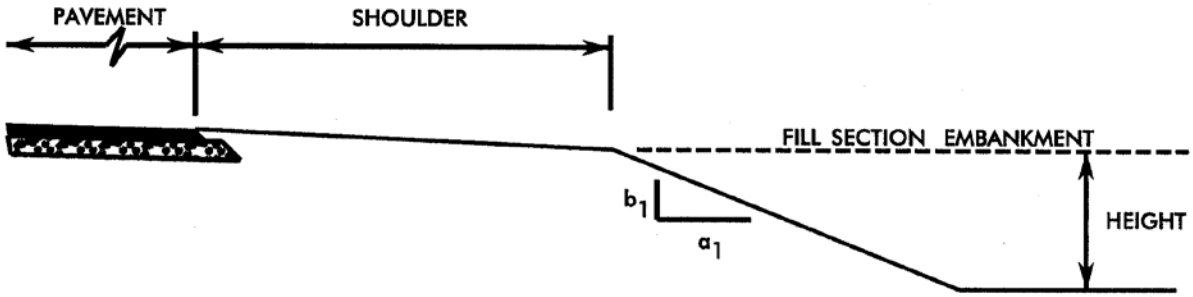
(g) On low volume, unpaved roadways, guardrail is generally warranted only for bridge rail protection. Refer to Part 1, Section 6-6C of this Manual for further information.

The following 3 charts (Figures 4 through 6) present two-lane roadway and divided highway guardrail warrant curves for various heights of 2:1 embankments.

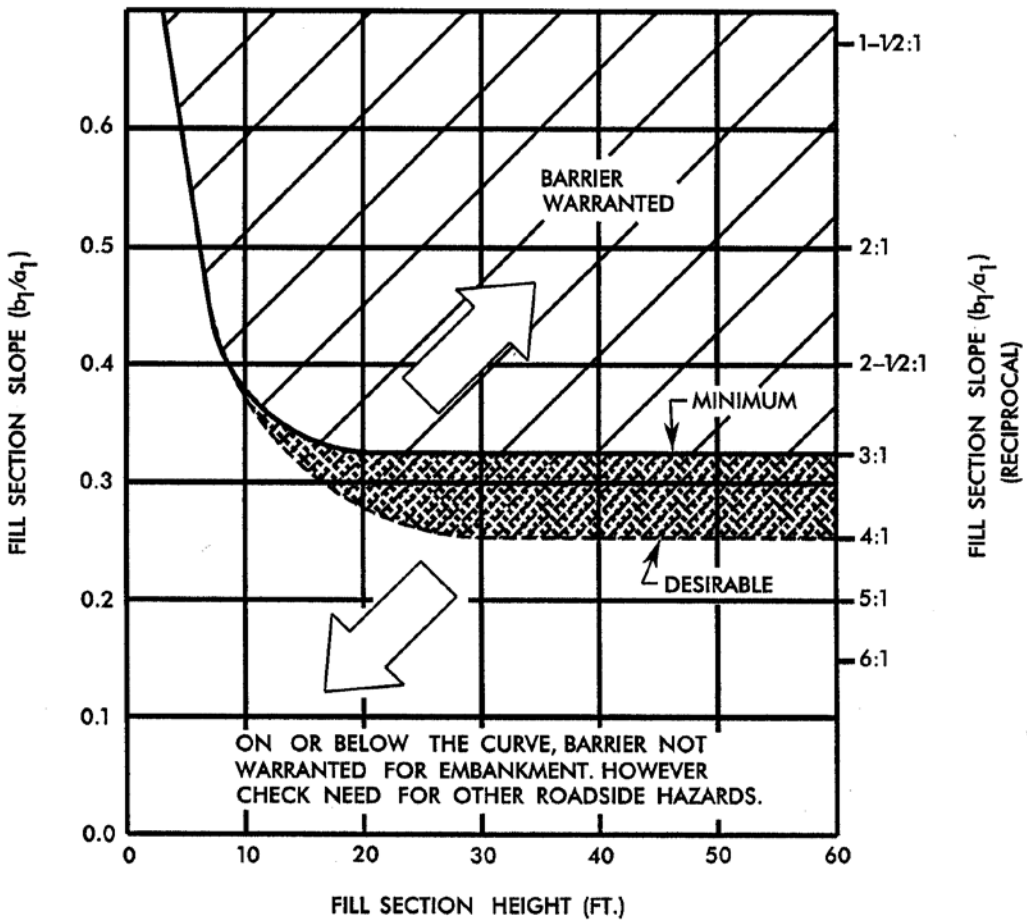
Each curve represents points of equal cost for the unshielded slope and guardrail. Therefore, a combination of average ADT and warrant slope length which falls above and to the right of a particular curve warrants guardrail. A combination, which falls below and to the left of a particular curve, does not warrant guardrail provided there are no other roadside hazards, which would require a traffic barrier.

These curves are based on a design speed of 60 mph.

FIGURE 1 3 - 1 / F - 1



WARRANTS FOR FILL SECTION EMBANKMENTS



TABLES 2 & 3 **3- 1**

WARRANTS FOR NONTRAVERSABLE HAZARDS T - 2

* NONTRAVERSABLE HAZARD WITHIN CLEAR ZONE – SEE PART 1,1-4N IN THIS MANUAL	TRAFFIC BARRIER REQUIRED	
	YES	NO
Rough rock cuts	X	
Large boulders	X	
Streams or permanent bodies of water less than 2 ft. in depth		X
Streams or permanent bodies of water more than 2 ft. in depth	X	
Should drop-off with slope sleeper than 1:1 and		
(a) Height greater than 2 ft.	X	
(b) Height less than 2 ft.		X

* All roadside obstacles within the clear zone should be removed if possible, otherwise provide barrier protection.

WARRANTS FOR FIXED OBJECT T - 3

* FIXED OBJECTS WITHIN CLEAR ZONE SEE PART 1,1-4N IN THIS MANUAL	TRAFFIC BARRIER REQUIRED	
	YES	NO
Sign, traffic signal, and luminaire supports **		
(a) Concrete base extending 6 in. or more above ground		
(1) Less than 1,100 lb-sec		X
(1) Greater than 1,100 lb-sec	X+	
(b) Breakaway or yielding design with linear impulse	X	
Rough rock cuts	X	
Large boulders	X+	
Streams or permanent bodies of water less than 2 ft. in depth	X+	
Streams or permanent bodies of water more 2 ft. in depth	X+	
Shoulder drop-off with slope steeper than 1:1	X+	

* Fixed object should be removed or relocated so that a barrier is unnecessary, if practical.
** Breakaway or yielding design is desirable regardless of distance from traveled way.
\+ A Judgment decision.

FIGURE 4 **3 - 1**

F - 4

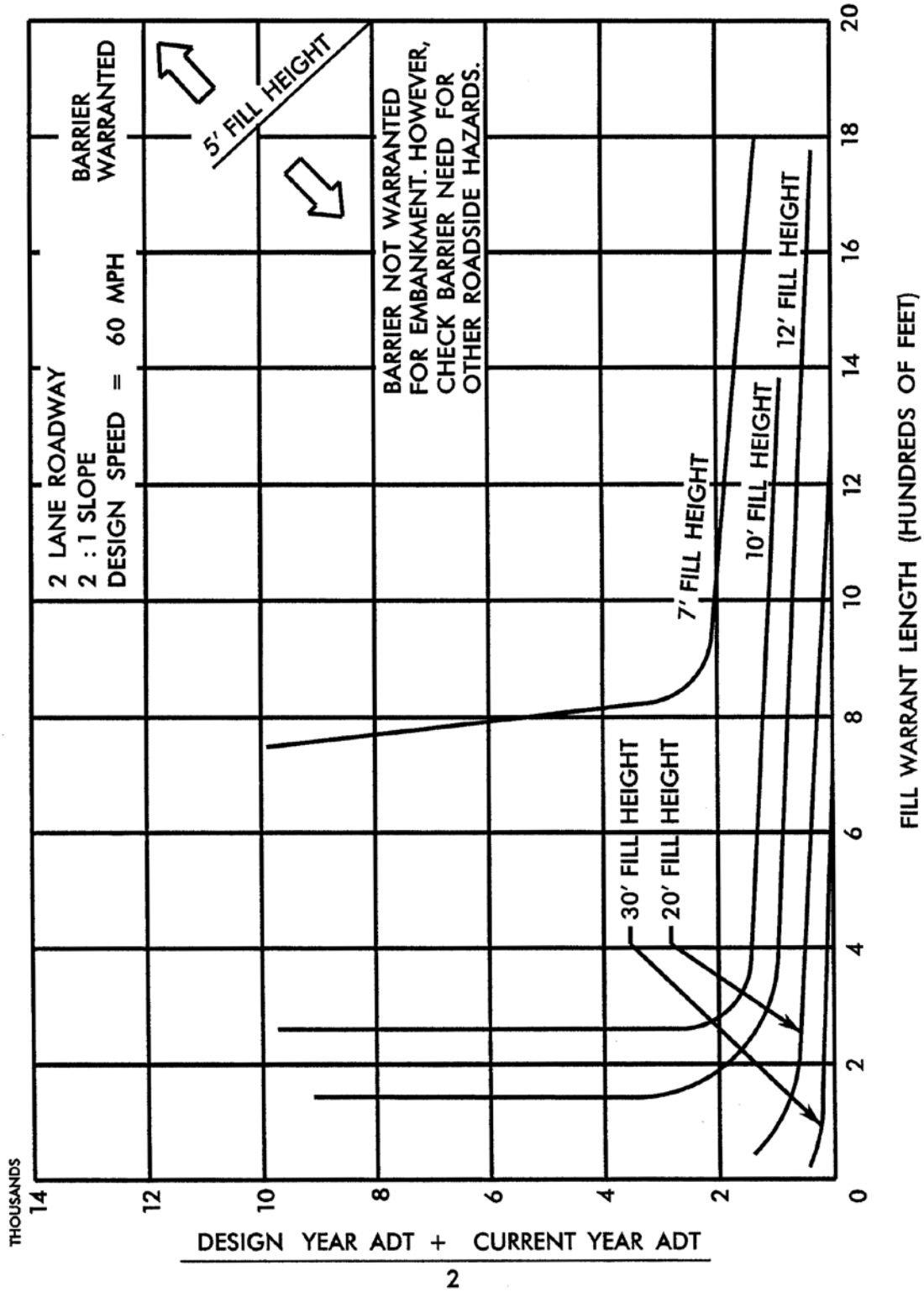


FIGURE 5 **3 - 1**
F - 5

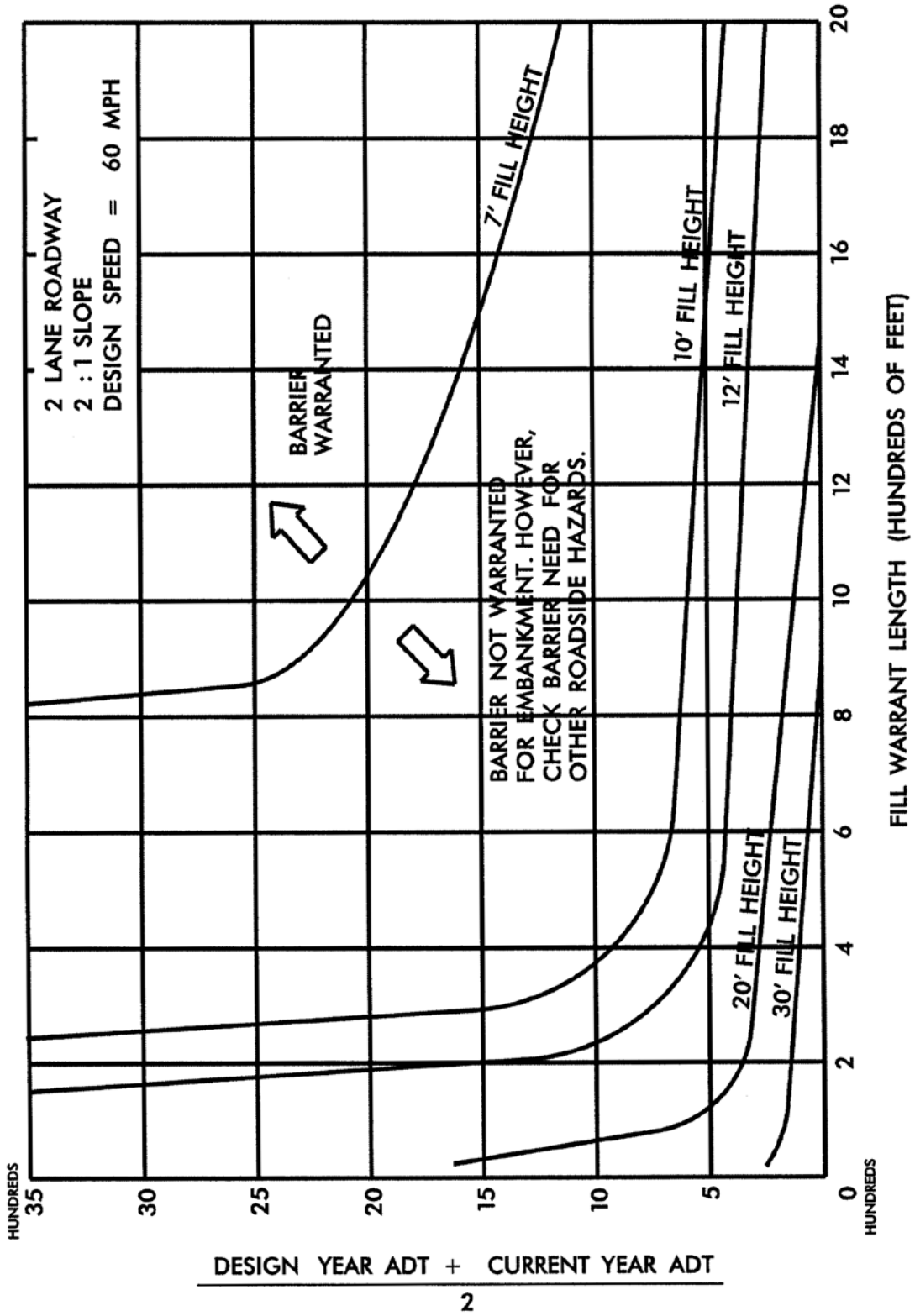
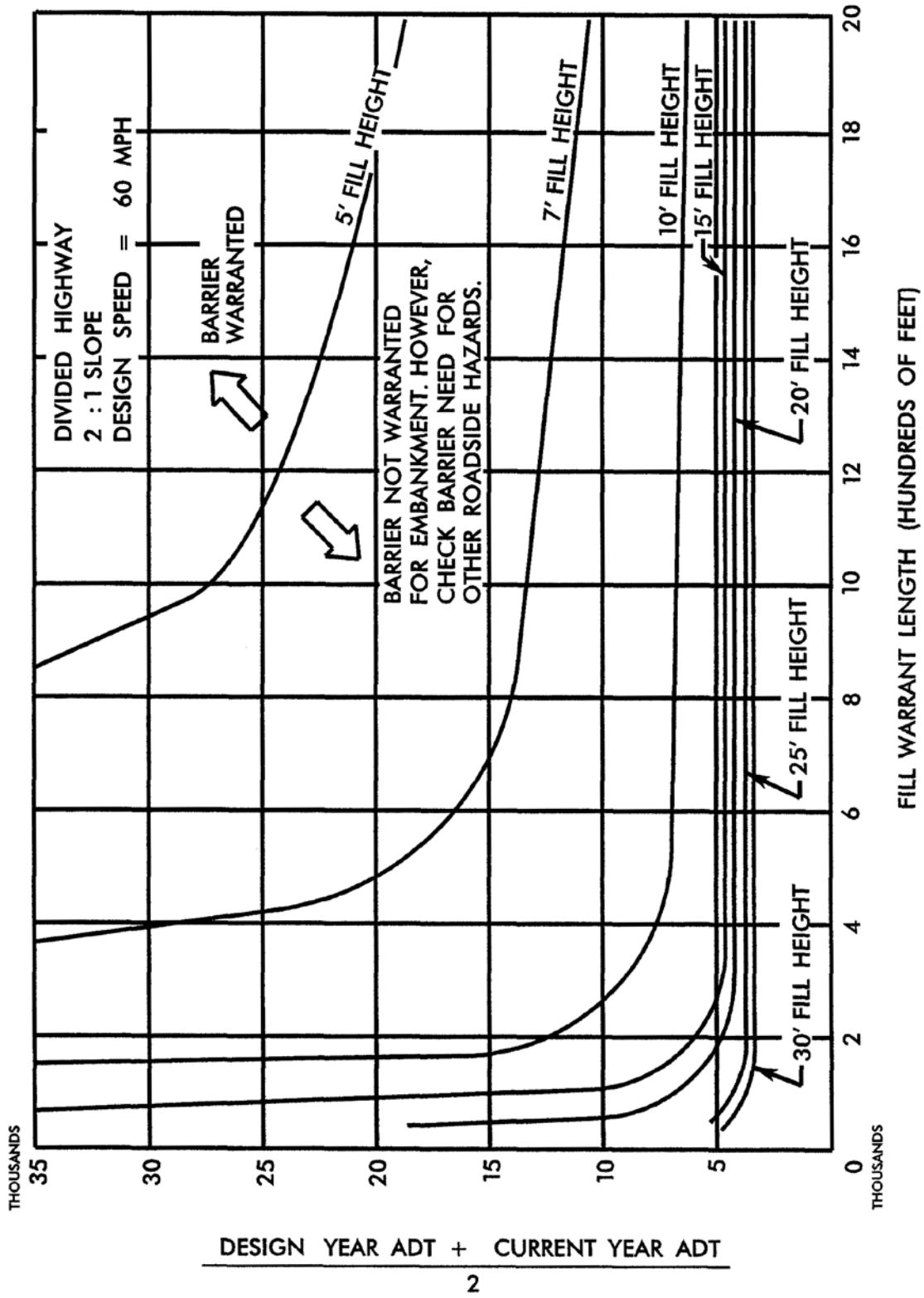


FIGURE 6

3 - 1
F – 6



DETERMINING GUARDRAIL LENGTHS OF NEED 3-2

After it has been determined, that guardrail is warranted through use of the previous tables and graphs, the next step is to determine the total length of guardrail needed. Guardrail will be warranted throughout the entire length of the hazard. To provide adequate protection for errant motorists, guardrail will, in several cases, be extended beyond the hazard. The extension of guardrail will be taken through a specified "Length of Need" area.

The "Length of Need" will vary depending on traffic volume, design speed and the type of hazard present. When determining the "Length of Need" or "L" for protection of a fill slope or rigid obstacle, Details 3-2A through Detail 3-2D should be followed.

NOTE: A space of less than 300' should not be left between guardrail installations. If less than 300' remains between installations, the guardrail should be extended through the area.

The formulas and details are derived from Chapter 5 in the Roadside Design Guide.

DETAIL OF GUARDRAIL PLACEMENT ON APPROACH END OF RIGID OBSTACLE WARRANT 3-2A

Detail 3-2A should be used when determining the “Length of Need” or "L" on the approach end of a rigid obstacle warrant. (A rigid obstacle can be a tree, culvert, headwall, retaining wall, etc.) Detail 3-2A can also be used to determine the length of guardrail needed at bridge pier locations located on the outside shoulder. For guardrail installations at bridges, please refer to the Roadway Standard Drawings, Std. No. 862.01, "Standard Guardrail Placement", Sheets 1 thru 4.

To determine the “Length of Need” on the approach end of the rigid obstacle warrant, the following variables are used:

LC = Clear zone distance for the roadway listed in the table.

LH = Distance from the edge of the travel lane to the backside of the hazard.

Note: LC will be used as LH value if the hazard extends beyond the clear zone.

LR = Runout length or theoretical distance needed for a vehicle which has left the roadway to come to a complete stop.

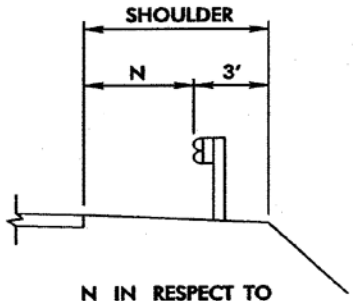
N = The distance from the edge of the travel lane to the face of the guardrail.
N = Minimum shoulder width for locals and collectors.
N = Usable shoulder width plus 2' for arterials, interstates and freeways.

The above values are listed on Detail 3-2A and can be used in the following formula:

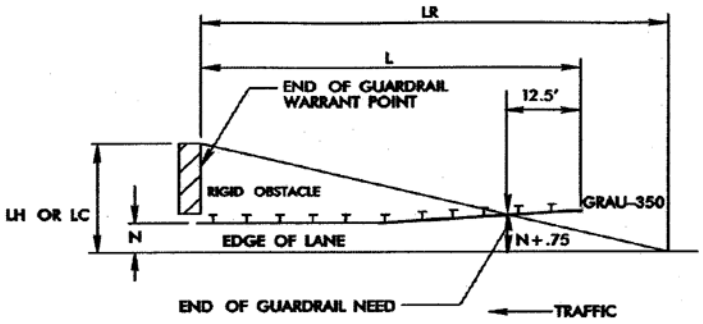
$$L = \frac{LH - (N + 0.75)}{LH/LR} + 12.50$$

Note: This formula is for use on Tangent Alignments. A graphic solution is more suitable for Curve Alignment.

L = Length of Need which will be measured from the approach end of the hazard to the Guardrail Anchor Unit Type 350.



N IN RESPECT TO SHOULDER WIDTH



DETAIL OF BEGINNING GUARDRAIL AT APPROACH END OF RIGID OBSTACLE

LH = DISTANCE FROM EDGE OF TRAVEL LANE TO BACK SIDE OF HAZARD. IF LH DISTANCE EXCEEDS CLEAR ZONE VALUES IN TABLE BELOW, USE LC VALUE AS LH.

DESIGN SPEED (MPH)	TRAFFIC VOLUME (ADT)							
	OVER 4000		2000 - 4000		800 - 2000		UNDER 800	
	LC	LR	LC	LR	LC	LR	LC	LR
	FT	FT	FT	FT	FT	FT	FT	FT
70	30	480	30	440	28	400	20	360
60	30	400	28	360	22	330	16	300
50	22	320	20	290	16	260	12	240
40	18	240	14	220	12	200	10	180

LC = CLEAR ZONE DISTANCE
LR = RUNOUT LENGTH
N = NORMAL SHOULDER WIDTH (WIDTH OF SHOULDER FROM EDGE OF TRAVEL LANE TO FACE OF GUARDRAIL)

TO DETERMINE "L" USE THE FOLLOWING FORMULA ON TANGENT ALIGNMENTS (GRAPHICALLY SOLVE CURVED ALIGNMENT)

$$L = \frac{LH - (N + 0.75)}{LH / LR} + 12.50'$$

"N" WIDTH FOR LOCALS AND COLLECTORS

ADT	DESIGN YEAR			
	UNDER 400	400-1500	1501-2000	OVER 2000
LOCALS AND COLLECTORS	2'	5'	6'	8'

USABLE SHOULDER WIDTHS FOR ARTERIALS, INTERSTATES AND FREEWAYS.

ADT	DESIGN YEAR			
	UNDER 400	400-1500	1501-2000	OVER 2000
ARTERIALS	4'	6'	6'	8' **

** 10' ON FREEWYAS, EXPRESSWAYS, AND INTERSTATES AND 12' ON FREEWAYS AND INTERSTATES WHEN TRUCK DHV EXCEEDS 500.

NOTE: SEE PART 1-4B F2, IN CHAPTER ONE FOR THE MAJOR ARTERIAL MAP.

N = USABLE SHOULDER WIDTH + 2'-0" FOR ARTERIALS, FREEWAYS, INTERSTATES AND EXPRESSWAYS.

DETAIL OF GUARDRAIL PLACEMENT ON APPROACH END OF RIGID OBSTACLE WARRANT

DETAIL 3-2A

DETAIL OF GUARDRAIL PLACEMENT ON TRAILING END OF RIGID OBSTACLE WARRANT 3-2B

Detail 3-2B will be used to determine the “Length of Need” or "L" on the trailing end of a rigid obstacle warrant. The variables used in determining the length of need are as follows:

LH = Distance from the edge of the opposing travel lane to the back of the hazard. (Note Diagram on Detail 3-2B)

As on the approach end, if LC is less than LH, use LH.

LC = Clear zone distance which can be obtained from Detail 3-2A.

L1 = Distance from edge of opposing travel lane to the face of the guardrail.

LR = Runout length from Detail 3-2A.

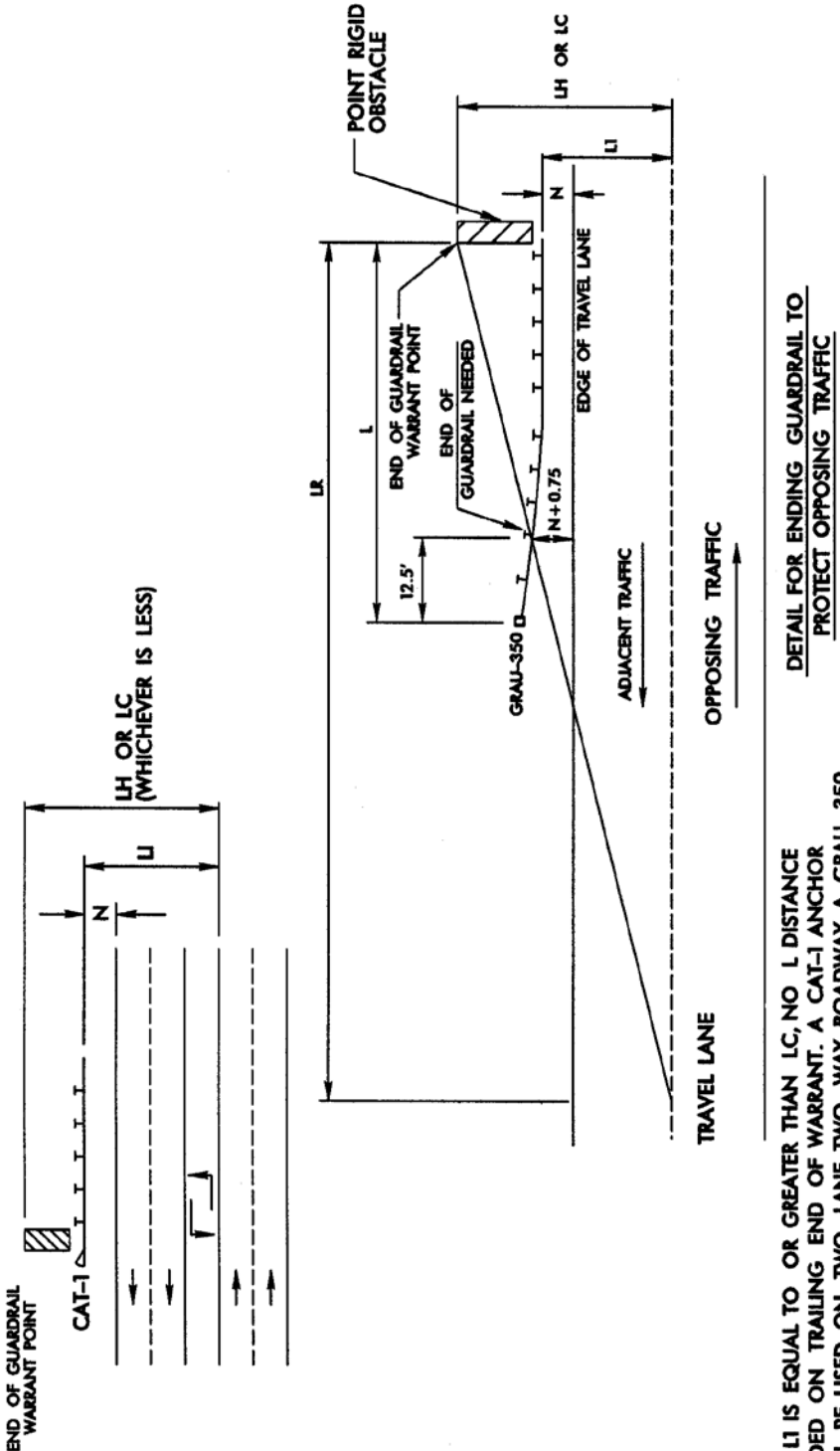
On multi-lane highways (3 or more lanes), no additional length of guardrail is required beyond the warrant point on the trailing end of the hazard, and a CAT-1 Anchor Unit will be used. On two lane, two-way roadways, a Guardrail Anchor Unit, Type 350, should be used on both the approach and trailing end.

DETAIL OF GUARDRAIL PLACEMENT ON APPROACH AND TRAILING END OF A FILL SLOPE WARRANT 3-2C

Detail 3-2C should be used in determining the “Length of Need” or "L" on the approach and trailing end of a fill slope warrant.

The table provided on Detail 3-2C gives Recommended “L” values. For two-lane, two-way roadways, the “L” distance is the same on both the approach and trailing end. On a multi-lane facility of three or more lanes, no additional guardrail will be warranted on the trailing end beyond the fill slope warrant. A CAT-1 Anchor Unit will be used.

DETAIL 2B **3 – 2B**



NOTE: WHEN L1 IS EQUAL TO OR GREATER THAN LC, NO L DISTANCE IS NEEDED ON TRAILING END OF WARRANT. A CAT-1 ANCHOR UNIT CAN BE USED. ON TWO LANE, TWO WAY ROADWAY, A GRAU 350 SHOULD BE USED IN ALL CASES.

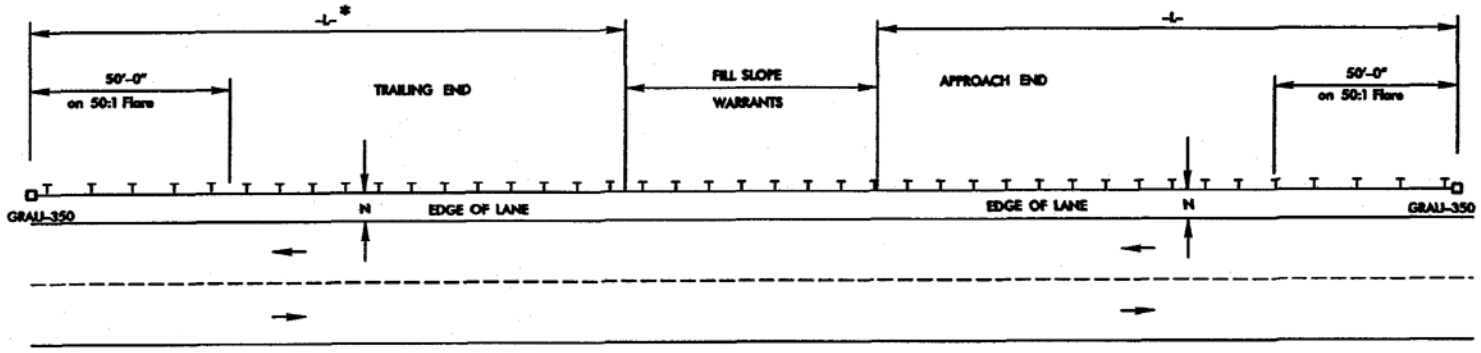
DETAIL FOR ENDING GUARDRAIL TO PROTECT OPPOSING TRAFFIC

TO DETERMINE "L" USE THE FOLLOWING FORMULA ON TANGENT ALIGNMENTS (GRAPHICALLY SOLVE CURVED ALIGNMENTS)
$L = \frac{LH - L1}{LH / LR} + 12.50'$

NOTE:
FOR LH VALUES, REFER TO PREVIOUS DETAIL SHEET

$L1 = N + 0.75 +$ TRAVEL LANE WIDTH

DETAIL OF GUARDRAIL PLACEMENT ON TRAILING END OF RIGID OBSTACLE WARRANT



"L" OR LENGTH OF NEED ON THE APPROACH SIDE OF THE GUARDRAIL FOR A FILL SLOPE WARRANT FOR ANY CLASSIFICATION OF ROADWAY

DESIGN SPEED (MPH)	70	60	50	40
*L (FT.)	150'	125'	100'	75'

NOTE: * FOR TWO LANE, TWO WAY ROADWAYS, THE ABOVE "L" DISTANCE IS USED ON THE TRAILING END OF THE FILL SLOPE WARRANT.

FOR ROADWAYS WITH THREE OR MORE LANES, NO-LENGTH IS NEEDED BEYOND FILL SLOPE WARRANT ON THE TRAILING END. A CAT-1 ANCOR UNIT CAN BE USED AT WARRANT POINT.

DETAIL 3 - 2C

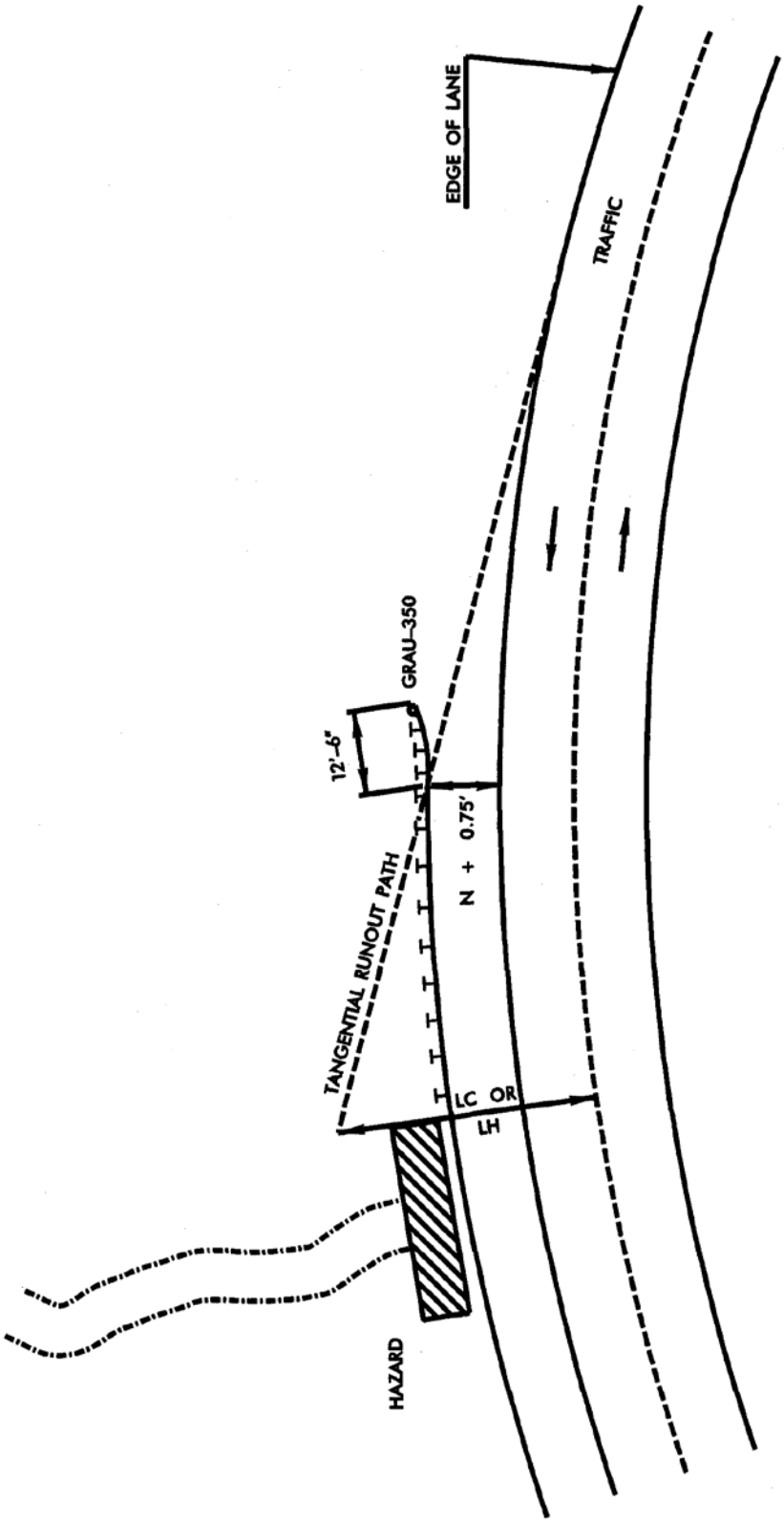
DETAIL OF GUARDRAIL PLACEMENT ON APPROACH AND TRAILING END OF FILL SLOPE WARRANT

DETAIL OF GUARDRAIL PLACEMENT ON THE APPROACH END OF A HAZARD WHICH IS LOCATED ON A CURVE 3-2D

The previous details 3-2A through 3-2C have been applicable to tangent alignments. Detail 3-2D will be used when either a rigid obstacle or fill slope hazard exists on a curved alignment.

On curved alignments, a vehicle which leaves the roadway, will generally follow a tangential runout path. Therefore, the tangent runout is extended from the edge of the travel lane to either the backside of the hazard (LH) or clear zone distance (LC). A distance of 12.5' will be added to the distance to obtain the total length of need.

DETAIL 2D **3 – 2D**



DETAIL OF GUARDRAIL PLACEMENT ON APPROACH END OF HAZARD LOCATED ON A HORIZONTAL CURVE

The anchor units most commonly used are listed and their usage is described below:

Guardrail Anchor Unit Type 350: (GRAU-350)

The GRAU-350 is a crashworthy tangential end section, which is used along the outside shoulders in instances where there is a chance of hitting the guardrail "head-on" within the vehicle's clear zone. Locations where this end section is used are as follows:

On the approach ends of guardrail along the outside shoulders.

On the trailing ends of guardrail along two lane two way roadways.

On the trailing ends of guardrail along outside shoulders where the end of the guardrail is within an opposing vehicle's clear zone.

As stated previously, the GRAU-350 is a tangential end unit. However, these units will be flared over the last 50 feet to provide a 1-foot offset. This minimal flare allows the terminal to be offset so that no component of the unit extends beyond the face of the guardrail. The tangential end unit should not be flared greater than a 50:1 flare rate.
No curb is allowed within the limits of this unit.

Median Anchor Unit Type 350: (M-350)

M-350 anchor units are flared end sections. Within the medians along dual lane bridge approaches, there is a need to flare the guardrail to move it away as quickly as possible from the inside travel lane. The flared guardrail must be anchored with a flared end section. Therefore, the M-350 Anchor unit is used in the following situations:

Within the median on the approach to a dual lane bridge.

Within the median on the trailing end of a dual lane bridge if the backside of the approach anchor unit is within the clear zone. (See Roadway Standard Drawings, Std. No. 862.01, Sheet 2)

The M-350 has a flare and is flared for a distance of 37.5 feet. The unit has a 4 foot offset.
No curb is allowed within the limits of this unit.

Cable Anchor Terminal: (CAT-1)

The Cable Anchor Terminal (CAT-1) end treatment is not crashworthy and should only be used at locations where there is not an opportunity to have a "head-on" hit within a vehicle's clear zone.

Typically, the CAT-1 is used on the trailing end of guardrail along multi-lane highways. (Exceptions would be in the median as noted in the previous discussion of the M-350).

Anchor Terminal: (AT-1)

The Anchor Terminal's (AT-1) usage is limited to anchoring the shop curved guardrail at intersections, which have radii between 20 to 75 feet. Typically, vehicles will be approaching the intersection at a lower speed in order to stop. Therefore, this anchor system is appropriate for this condition. (Refer to Roadway Standard Drawings, Std. No. 862.01 Sheet 7 for an example of this application).

Terminal End Section:

This end section is not an anchor unit. As its name implies, it is an end section, which is placed at locations where an anchor unit is not needed. Typically, the terminal end section is placed on sections of guardrail that are used to terminate or "dead-end" roadways.

Structure Anchor Units:

Type III:

This anchor unit is used to anchor guardrail to bridges with metal bar railing or any other rail design that has a vertical shape allowing the Type III attachment (See Roadway Standard Drawings, Std. No. 862.03). The 4" curb adjacent to the anchor unit is not required in locations where the bridge rail is behind the sidewalk. This anchor unit can be used on temporary bridges.

Type B-77 (with rubrail):

This guardrail anchor unit is used to attach guardrail to concrete Jersey shape barrier as illustrated in Roadway Standard Drawings, Std. No. 857.01. This anchor unit should also be use on bridges with Jersey shaped barrier rail that has 4" curb or no approach curb. The anchor unit has a rubrail which prevents vehicles from "snagging" the barrier (See Roadway Standard Drawings, Std. No. 862.03). This anchor unit can be used on temporary bridges.

Type B-83

This anchor unit should be used on existing bridges with a Jersey shape barrier and an 8" or higher curb on the approach slab. The curb must extend the full pay limits of the guardrail anchor unit. This may require additional curb construction. This anchor unit is mainly used in retrofit situations replacing the old Type X, XI, XII, and XIII anchor units (See Roadway Standard Drawings, Std. 862.03).

DETERMINING TOTAL GUARDRAIL LENGTH 3-2F

The total length guardrail needed at an installation is obtained by adding the length of need to the guardrail length which is needed throughout the limits of the hazard, and then deducting the applicable anchors' unit length. Anchor unit deductions, to be used in calculations, are listed below: The total length of guardrail should be rounded so it is divisible by 12.5 ft.

ANCHOR DEDUCTIONS

ANCHOR	DEDUCTIONS
GRAU-350	50.0′
M-350	37.5′
CAT-1	6.25′
AT-1	6.25′
*Type III	18.75′
*B – 77	18.75′
*B – 83	25.0′

*Measured from the end of the bridge or approach slab rail.

GUARDRAIL INSTALLATION AT INTERSECTIONS 3-3

When installing guardrail around intersections, care must be taken to ensure adequate sight distance is maintained at the intersection. Also, the guardrail should not impede the turning path of a vehicle. When guardrail is warranted around an intersection, provide as much offset as possible from the edge of the travel lane to the face of the guardrail. This will ensure adequate sight distance and place the guardrail farther from a vehicle's turning path.

In installations along curb and gutter facilities, the guardrail should preferably be placed 12 feet from the face of the curb instead of at the face of the curb. If 12 feet is not available, place the guardrail, as far away from the face of the curb as the berm width will allow. When guardrail is placed at the face of the curb, sight distance and the vehicle's turning ability is impeded.

See Roadway Standard Drawings, Std. No. 862.01, Sheet 7, for a pictorial view showing placement of guardrail at intersections.

GUARDRAIL ON -Y- LINES 3-4

The addition of guardrail where warranted should be considered throughout the construction limits along a Y-line. Remember lower speeds on the Y-line may negate the need for guardrail.

Whenever guardrail is used to shield bridge ends on Y-lines with three (3) or more lanes, no guardrail is warranted on the trailing end of the bridge when fill slopes are 4:1 or flatter. The elimination of the guardrail on the trailing end of the bridge will improve sight distance at ramp intersections, which are downstream of the bridge.

GUARDRAIL INSTALLATIONS ADJACENT TO CURBS AND/OR GUTTERS 3-5

On curb and gutter facilities with a traveling speed of 35 mph or less, guardrail is generally not required. On low speeds, the vehicle is not likely to vault the curb so the curb itself tends to act as a barrier.

On curb and gutter facilities with traveling speeds of greater than 35 mph, guardrail is warranted to protect motorists from fill slope hazards or fixed object hazards, which exist within the clear zone. Methods of placement for guardrail in each situation are described below:

Fill Height and Slope Warrant, Preferred Placement: The preferred treatment is to place the face of the guardrail 12 feet from the face of the curb. The 12 feet width provides ample sight distance for any intersecting streets or driveways near the guardrail installation. This placement method will also accommodate for sidewalk installation. The guardrail will be placed behind the sidewalk.

To provide for the above installation, the berm width would have to be 14 feet. (See Roadway Standard Drawings, Std. No. 862.01 Sheet 11.

Fill Height and Slope Warrant: When right of way restrictions prohibit the use of the preferred treatment, the guardrail should be placed so the face of the guardrail aligns with the face of the curb. If sidewalk exists or is proposed, the sidewalk may have to be flared at the anchor unit installation.

High–Speed facilities frequently require a curb/guardrail combination, on outside shoulders, to control surface drainage and reduce erosion of fill slopes. The expressway gutter/guardrail combination is only to be used when the Hydraulics Unit recommends it on freeways with 3 or more lanes of pavement sloped in the same direction. The situation generally occurs on the low side of a superelevated curve in a fill section. Use the shoulder berm gutter/guardrail combination to meet this requirement at all other locations.

Guidelines for typical Median Guardrail / Guiderail Installations:

Incorporate median guardrail / guiderail on all freeway projects with median widths of 70 feet or less.

Two types of installations will be used: Cable guiderail or steel beam guardrail with 6'- 3" post spacing (semi-rigid guardrail).

Cable guiderail can be used when slopes of 6:1 or flatter exist in the median. Cable guiderail deflects up to 12'. When using cable guiderail, insure that the deflection of the rail does not extend within the opposing travel lane.

Steel beam guardrail has to be placed on 10:1 or flatter slopes. Steel beam guardrail (6'-3" post spacing) normally deflects 3'. When using steel beam guardrail (6′3″ post spacing) to protect from rigid obstacles, insure the face of the guardrail is placed 5'6″ from the face of the hazard. (Refer to offset distance note on Roadway Standard Drawings, Std. No. 862.01, Sheet 1.)

Weak post steel beam guardrail will be used in freeway medians that have adjoining segments of weak post guardrail in place at each end of the project. Currently, NCDOT is not proposing to use weak post guardrail in any other locations. This guardrail is flexible and has 12'-6" post spacing. The normal deflection of this guardrail is 7'. Weak post guardrail has to be placed on slopes 10:1 or flatter.

It is desirable to place the guardrail as far from the edge of the travel lane as the above guidelines will allow.

Typical Placement in Various Median Widths:

30 feet: **Typically, use two rows of semi-rigid guardrail. (Assuming slopes steeper than 6:1 exist in the median)

36 feet: **Two rows of semi-rigid guardrail if slopes are steeper than 6:1.

One line of cable guiderail (approximately 4' from the centerline of the ditch) if median slopes are 6:1 or flatter.

46 feet: One line of cable guiderail if slopes are 6:1 or flatter. (Place approximately 4' from the centerline of the ditch).

**Two lines of semi-rigid guardrail if slopes are steeper than 6:1.

60 feet and above: one line of cable guiderail placed approximately 8' from the center of the ditch.

**If two lines of guardrail are required, place semi-rigid guardrail. (The two lines of steel beam guardrail should not pose as much maintenance problems as two lines of cable guiderail.)

The above are guidelines only and will not cover every possible situation that will be encountered. Each location will have to be studied and evaluated in conjunction with the previous information, to determine an appropriate median guardrail treatment.

Roadway Standard Drawings have not been developed for the following conditions. These conditions can be detailed on the plan view itself.

Two Rows of Semi-Rigid Guardrail at Median Piers(30’-36’ MED):

The semi-rigid guardrail will serve as pier protection. Ensure that the semi-rigid guardrail (3’-1 ½”) can be placed at a minimum distance of 3.6' from the face of the bridge piers (See note on Roadway Standard Drawings, Std. No. 862.01, Sheet 1 which describes minimum offset to piers).

Use of Cable Guiderail with Earth Berm Protection:

It is still desirable to use earth berm protection in median widths of 68' and 70'. When using the earth berm, stop the cable guiderail at an approximate distance of 225' from the beginning of the concrete slope protection.
(Refer to Roadway Standard Drawings, Std. No. 225.08 for Earth Berm Protection. The cable rail will stop between sections D and E as shown on this standard. The distance from the concrete slope protection will be 225' as calculated from the Roadway Standard Drawings, Std. No. 225.08.)

Guardrail is not required in medians wider than 80', when the bridge pier is located in the center of the median.

If the earth berm is not feasible or cost effective, concrete barriers, guardrail, guiderail and/or impact attenuators should be used.

SPECIAL MEDIAN GRADING

The Roadway Engineers and Hydraulics Engineers must consider Special Median Grading. Highway plans submitted to the Hydraulics Unit shall include information as follows:

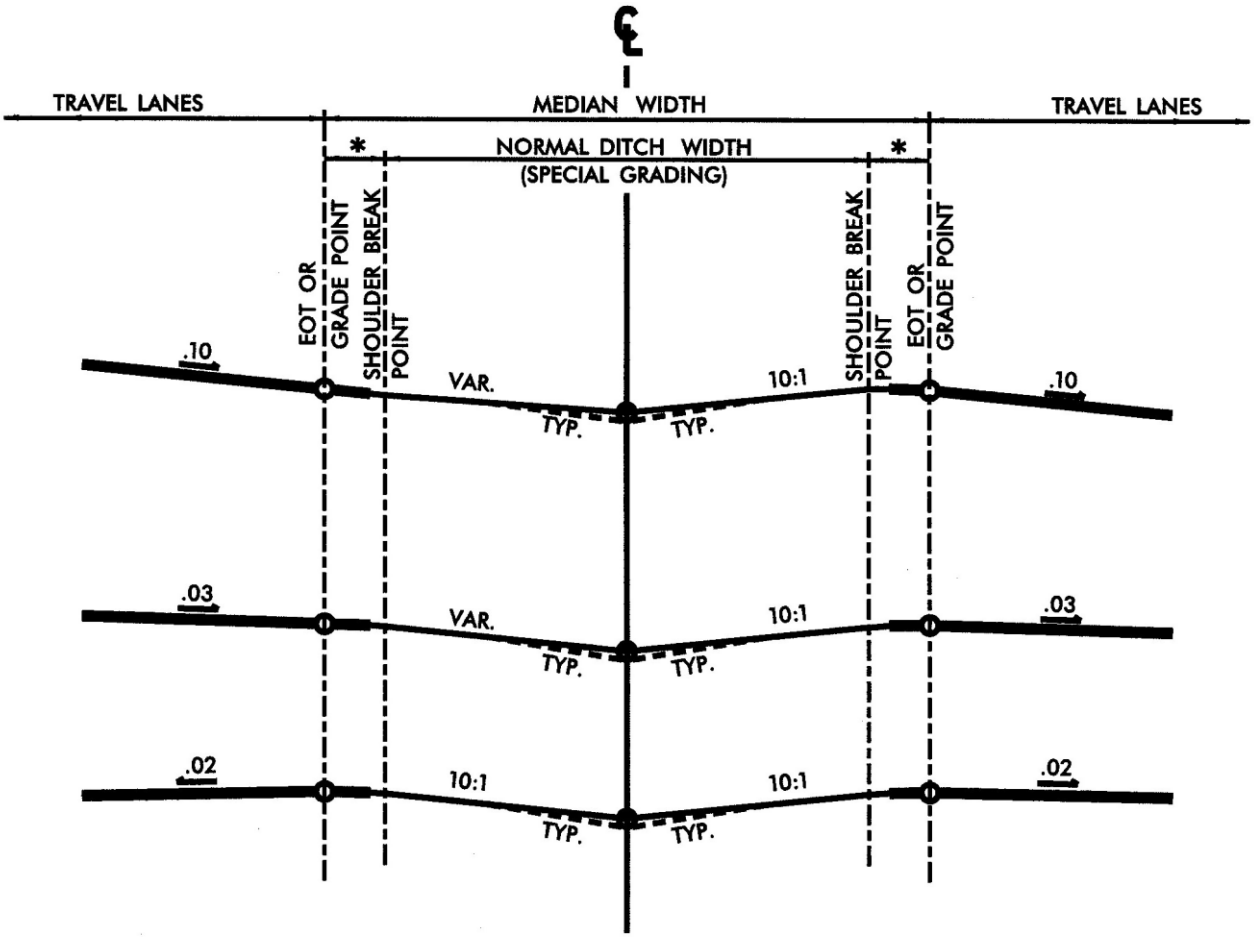
1. Modified Cross-Sections as specified by Roadway Standard Drawings;
   a. STD. No. 22508, Sheet 1
   b. STD. No. 86201, Sheet 1
   c. STD. No. 86201, Sheet 2
   d. STD. No. 86501, Sheet 2
2. Cross reference the plan sheets to the applicable standard by showing, "Note: See Cross-Sections and Roadway Standard Drawings, STD. No. _____, Sheet _____for Special Median Grading."
3. The plan sheets shall show Guardrail and/or Impact attenuators requiring special grading. Use the longest Impact attenuator, permitted by the Special Provisions, for grading limits, (See Part 1, 3-12, Table 1 of this manual for lengths.)
4. Label beginning and ending of Special Grading on plan sheets.
5. Inform the Hydraulics Engineer of altered drainage patterns or low points created by Special Median Grading.

Special grading in Superelevated locations shall have Standard Median Shoulder slopes (See Roadway Standard Drawings Nos. 560.01 and 560.02). Use a 10:1 slope from the higher median shoulder break point to establish the elevation at the center of the median. Next extend a slope from the lower median shoulder break point to the center of the median elevation, as established above, to complete the Median Cross-Section (See Part 1, 3-6, Figure 1, of this manual for further information)

FIGURE 1 **3–6**

F–1

SPECIAL GRADING IN SUPERELEVATED LOCATION



* MEDIAN SHOULDER WIDTH–
SEE STANDARDS 560.01 AND 560.02 FOR
METHOD OF SHOULDER CONSTRUCTION.

1. With Outside Bridge Piers:

   A. With a Concrete Barrier:
   If the outside pier is 15'-6" or less from the edge of the main travel lane, use a concrete barrier and guardrail (Roadway Standard Drawings, Std. No. 857.01).

   The guardrail should be extended from the concrete barrier according to the length of need requirements as outlined in Section 3-2 of this manual.

   B. Without a Concrete Barrier:
   If the face of the bridge pier is greater than 15'-6" from the edge of the main travel lane but within the clear recovery area, then use guardrail to protect the pier. The face of the guardrail will normally be placed 5'-6" from the face of pier, but usually no less than 12' from the edge of the main travel lane. (See Roadway Standard Drawings, Guardrail Placement Std. No. 862.01, Sheet 1).

   The guardrail should be extended based on the length of need requirements as outlined in Section 3-2 of this manual.

2. Without Outside Bridge Piers:

   A. Approach With a Natural or False Cut:
   No guardrail is needed if the 6' vertical curve is used with Roadway Standard Drawings, Std. No's. 225.07 and 610.03.

   B. Approach in a Fill without a False Cut:
   Guardrail is normally placed 6' to 12' from the edge of a local, collector, or auxiliary lane, and 12' to 20' from the edge of a main travel lane. Guardrail spacing at the end bent slope will typically be 6'-3". The guardrail should be extended based on the length of need requirements as outline in Section 3-2 of this manual.

3. With Curb and Gutter:

Note: For curb and gutter facilities with traveling speeds greater than 35 mph, guardrail will be warranted for the protection of bridge piers. The guardrail should be placed so the face of the guardrail aligns with the face of the curb.

ELIMINATION OF BRIDGE SHOULDER PIERS

In order to facilitate future widening and increase safety and aesthetics, shoulder piers should be eliminated at grade separations.

For a copy of the Guardrail Summary Sheet "sample", Please contact NCDOT Transportation Program Management Office

GUARDRAIL ANCHOR UNITS ON STRUCTURES 3-8

For additional information on Guardrail Anchor Units on Structures, see Part I, Chapter 6-6C of this manual. Also, refer to Roadway Standard Drawings, Std. No. 862.03.

GUARDRAIL ON CURB AND GUTTER BRIDGE APPROACHES 3-9

The guardrail should be placed at the back of the sidewalk so that it ties directly into the bridge rail as shown on Roadway Standard Drawings, Std. No. 862.01 Sheet 4.

The bridge rail used with the sidewalk installation is the bar metal rail. A Type III Guardrail Anchor Unit will be used to anchor the guardrail to the end of all bridges. The Type III Guardrail Anchor is shown on Roadway Standard Drawings, Std. No. 862.03, Sheet 2.

GUARDRAIL ATTACHMENT AND RETROFIT MANUAL 3-10

The Guardrail Attachment and Retrofit Manual has been prepared for use as a guide in the Structure Design Unit and Roadway Design Unit. The Roadway Design Project Engineer will coordinate guardrail attachments required at existing bridges with the Structure Design Project Group Engineer assigned to the project. If the project has not been assigned to a Structure Design Project Group Engineer, coordinate with the Assistant State Bridge Design Engineer.

The manual contains examples or special details of guardrail attachment used on previous projects. If a required detail is not in the manual, the Structure Design Project Group Engineer will prepare the detail and the finalized detail will be sent to the Engineering Development Section in the Structure Design Unit for distribution. At times, measurements from the Bridge Maintenance Unit will be necessary before the details can be finalized.

NOTE: The Structure Design Project Group Engineer is responsible for determining the appropriate design detail to be used or if a new design is required.

POSITIVELY ANCHORED TEMPORARY PRECAST CONCRETE BRIDGE BARRIER – TYPE S 3-11

During staged construction, widening or specific rehabilitation projects, Work Zone Traffic Control Unit may require a temporary bridge rail. In general, the pay item for temporary bridge barrier will be a traffic control item. Close coordination between Structure Design, Roadway Design and Work Zone Traffic Control Unit is extremely important.

POSITIVELY ANCHORED TEMPORARY PRECAST
CONCRETE BRIDGE BARRIER – TYPE S (cont.) 3-11

The following procedure shall be followed:

(a) The Structure Design Project Group Engineer will contact the Roadway Project Group Engineer and the Traffic Control Project Engineer to determine the width of the bridge deck needed to maintain traffic during construction. This will determine the location of the temporary barrier. The offset distance shall be the distance from the back of the barrier to the edge of the slab.

(b) If the offset distance is from 0'-0" to 3'-11", the Type S barrier will be positively anchored to the slab. Roadway Design will include the detail of the Type S barrier in their plans. This barrier will be a Traffic Control pay item. Work Zone Traffic Control Unit will be responsible for determining pay limits and estimating pay item quantities for the Engineer's Estimate. The Structure Design Project Group Engineer will include a sketch of the Type S barrier with the offset distance dimensioned and a note to see the Traffic Control plans for location and pay items of the positively anchored temporary pre-cast concrete bridge barrier - Type S.

The Structure Design Project Group Engineer will furnish the beginning and ending approach slab stations to the Traffic Control Project Engineer and the Roadway Design Project Engineer.

(c) If the offset distance is from 4'-0" to 5'-11", the standard precast temporary concrete median barrier Roadway Standard Drawings, Std. No. 1170.01 shall be used.

The Structure Design Project Group Engineer will furnish the beginning and ending approach slab stations to the Traffic Control Project Engineer and the Roadway Design Project Engineer. This will be used to determine the pay limits for the barrier. The Work Zone Traffic Control Engineer puts the following note in their plans.

> THE TEMPORARY PRECAST MEDIAN BARRIER ON THE BRIDGE SHALL BE RESTRAINED AGAINST LATERAL MOVEMENT BY THE ANGLE AND ANCHOR SYSTEM. SEE THE BRIDGE PLANS FOR DETAIL AND PAYMENT FOR THE ANGLE AND ANCHOR SYSTEM.

(d) If the offset distance is 6'-0" or greater, the standard precast temporary concrete median barrier Roadway Standard Drawings, Std. No. 1170.01 shall be used. No attachment to the bridge deck is required. This will be a Traffic Control pay item.

POSITIVELY ANCHORED TEMPORARY PRECAST
CONCRETE BRIDGE BARRIER – TYPE S (cont.) 3-11

(e) If a bridge member is over stressed due to the use of the barrier specified in paragraph (b), (c) or (d), the Structure Design Project Group Engineer will coordinate with Work Zone Traffic Control Unit and Roadway Design to use an alternate type of rail.

PROPRIETARY IMPACT ATTENUATORS AND TERMINAL END UNITS 3-12

Impact attenuators are installed to shield rigid objects or hazardous conditions that cannot be removed, relocated or made breakaway. Terminal end units are installed when standard guardrail anchor units will not work or for experimental purposes.

For warrants, see the "AASHTO Roadside Design Guide".

When use of an impact attenuator or terminal end unit is indicated, the following guidelines need to be considered:

1. Only those items that have been crash tested and found to meet the requirements of NCHRP-350 will be considered for use where there is a chance of hitting the guardrail " Head on " within the vehicle's clear zone.

2. Each location must be evaluated to determine the appropriate width and type of attenuator which will meet the site needs, geometric conditions, expected frequency of impact, and economy of installation and maintenance. (See 3-12, Table 1)

3. The effects of impacts with respect to the safety of subsequent vehicles.

TABLE 1 **3 - 12**

FHWA APPROVED, TYPE 350
(IMPACT ATTENUATORS & GUARDRAIL ANCHOR UNITS)

DESCRIPTION				IMPACT ATTENUATORS		GR. ANCH.	
UNIT	WIDTH	LENGTH	SUPPLIER	*DF	MED. BARRIER	UNITS *SF	FIXED OBJECT
ADIEM	1'-8" to 2'-4"	30'	TRINITY		X		X
BRAKEMASTER	1'-6"	32'	ENERGY ABSORPTION	X	X		X
CAT	2'-3"	32'	TRINITY	X	X		X
REACT 350	3'	30'-8"	ENERGY ABSORPTION		X		X
**QUADGUARD	2' 2'-6" 3'-0"	8'-6" to 41'-6"	ENERGY ABSORPTION		X		X
**TRACC	2'-7"	21'-0"	TRINITY		X		
BEST (No Offset)	1'-8"	50'	INTERSTATE STEEL CO.			X	X
ET-2000 (No Offset)	1'-6"	50'	TRINITY			X	X
SKT 350	1'-6"	50'	ROAD SYSTEMS, INC.			X	X
SENTRE	2'	17'	ENERGY ABSORPTION			X	X
SRT 350	1'-6"	37'-6"	TRINITY			X	X
FLEAT	1'-6"	37'-6"	ROAD SYSTEMS, INC.			X	X
REGENT	1'-6"	37'-6"	ENERGY ABSORPTION			X	X

* DF = DOUBLE SPACE
SF = SINGLE SPACE
**NON-GATING UNIT

a. Water-filled units should not be placed where expelled water will stand on or flow across the travel way.

b. Sand-filled units should not be placed where the sand from impacted containers will spill into the travel way.

4. There may be a need for additional delineation to reduce the frequency of impacts (refer to TRR 1111, "Traffic Accident Analysis, Visibility Factors, and Motorists Information Needs" in the Transportation Program Management Unit).

5. The availability and storage of repair parts should be evaluated.

6. Proprietary devices require special attention during final plan process on both State and Federal projects. Three comparable alternatives are desired for the final plans. If only one alternative is used, then written approval must be given by the FHWA Division Administrator (NHS projects) or State Highway Design Engineer (state funded or non-NHS projects). The approvals must be requested based on one of the following criteria:
   1) The device is the only alternative available to do the job and its use is in the Public interest.

   2) The device is to be used for experimental purposes.

   TABLE 1 provides basic information on known systems as an aid to initial selection.

This chapter should provide the Engineer guidelines for selecting an efficient and cost-effective barrier system. Past performance will highly affect the Engineer's decisions. Therefore, Divisions are encouraged to record and document maintenance experience with traffic barriers and provide this information to the Value Management Section, Alternative Delivery Unit.

Example of Guardrail Summary 3-13 Example

I. Protection at Median Bridge Piers (Roadway Standard Drawings, Std. No. 862.01 Sheet 1)

Assume:

1. 46' median
2. 12' median shoulders
3. 6.56' = face of guardrail to face of guardrail under bridge
   a. 3' + (2x1.5) + (2x0.28') = 6.56'

Note: 3' = width of pier
1.5' = width of barrier and offset
0.28' = width of guardrail

4. 6.56' – 2' = 4.56' this is the width that has to be closed

Note: 2' = assumed width of impact attenuator (this is the narrowest width impact attenuator)

5. 4.56' X 7.5 (assuming 15:1 taper on both sides) = 34.20' say 37.5' taper

6. 37.5' taper + 25' GRAU Type XI Modified = 62.5' per attachment

7. 250' guardrail per bridge location (4 Attachments @ 62.5')

8. 2 impact attenuator units, Type 350 per location

9. 60' pier spacing

10. 120' single face concrete barrier (60' x 2 sides of median piers)

II. Guardrail Approaching Dual Lane Bridge (Roadway Standard Drawings, Std. No. 862.01 Sheet 2)

Assume:

1. 40' wide bridges
2. 12' outside shoulders
3. 6' inside shoulders
4. 70 miles per hour design speed
5. 46' median
6. 100' guardrail required by fill height on right shoulder on trailing end of bridge

III. Guardrail at Two Lane – Two Way Bridges **(Roadway Standard Drawings, Std. No. 862.01 Sheet 3)**

Assume:

1. 32' wide bridge
2. over 2000 ADT (Design Year)
3. 60 miles per hour design speed

IV. Guardrail at Bridges with 2' – 6" Curb and Gutter and Sidewalk (Roadway Standard Drawings, Std. No. 862.01 Sheet 4)

Assume:

1. 64' face to face curb and gutter
2. 10' berm
3. 50' miles per hour design speed
4. Bridge has three bar metal rail
5. Bridge is 175' in length

V. Beginning of Guardrail in Cut or Fill (Roadway Standard Drawings, Std. No. 862.01 Sheet 5)

Assume:

1. four lane divided section
2. 70 miles per hour design speed
3. 12' shoulder