Standard Drawings D-764-5A to 17A and D-764-33 to 37 have been deleted and moved to the Design Manual as Appendix III-13B. Standard Drawing D-764-2B has been renumbered to D-764-4. Standard Drawing D-764-2C has been renumbered to D-764-6. Standard Drawing D-764-2D has been renumbered to D-764-5. Standard Drawing D-764-2H has been renumbered to D-764-7. Standard Drawing D-764-3 has been renumbered to D-764-9. Standard Drawing D-764-3A has been renumbered to D-764-10. Standard Drawing D-764-5 has been renumbered to D-764-11. Standard Drawing D-764-3B has been renumbered to D-764-13.

III-13.01 Introduction

These design procedures should be used after it has been determined that guardrail is warranted. Standards D-764-1 through D-764-37 should be used to determine the length of need and location of the guardrail and post spacing. The Standard Drawings can be found on the web at http://www.dot.nd.gov/dotnet/standarddrawings/stddrawings.aspx These design procedures should be used to determine the type of guardrail, the length of guardrail, and the position of the guardrail. The AASHTO Roadside Design Guide has been used for guidance in preparing these design procedures.

III-13.02 Design Speed

The design speed should be determined according to the roadway classification. Generally, there are five classifications of roadway; 1) Rural/Urban Interstate; 2) Interregional System; 3) State Corridor; 4) District Corridor, and 5) District Collector.

The design speed should be obtained from Section I-06.

III-13.03 Lateral Clearance

The lateral clearance from the roadway centerline to the edge of the obstacle should be determined.

The distance from the finished shoulder to the roadway centerline should also be determined. For new surfacing projects, this distance should be determined from the typical section for the new surfacing.

III-13.04 Obstacle Type

There are several different types of obstacles. The type of obstacle will determine the type of guardrail to be used. Some of the different types of obstacles are as follows.

III-13.04.01 Bridge Rail Ends

These are near the roadway and should be treated with W-beam guardrail. The bridge rail should be an acceptable type of design and should have been crash tested in accordance with NCHRP Report 350.

The following types of bridge rail are acceptable and should have an acceptable end treatment for guardrail to bridge end connection:

A. **Jersey Barriers:** The Jersey barrier bridge rail should have the W-beam guardrail attached to the bridge rail using the standard W-beam terminal connector and transitioning to the standard W-beam guardrail, as shown on Standard Drawing D-764-3. Further requirements of this design are discussed in Section III-13.05.01.A.

B. **Double Box Beam Rail Retrofit:** Bridges with sloped curb (Code E) bridge rail or other deficient bridge railings, should be retrofitted with a double box beam bridge railing, with thrie beam guardrail connection plates.

   1. Bridge Rail Retrofit: The retrofit bridge rail should have a thrie beam terminal connector plate for transition from the retrofit bridge rail to the thrie beam connector. A 12'-6" thrie beam, with a thrie beam to W-beam transition section, is installed between the thrie beam connector and the W-beam approach rail. These sections should be double thickness. The thrie beam to W-beam transition and connection details are shown in Standard Drawing D-764-3A.

III-13.04.02 Light Standards

These are usually made breakaway by providing a slip base or a frangible transformer base. High mast poles are usually placed outside the clear zone of the particular highway and need no safety treatment. Guardrail warrants would be determined by clearances between driving lane and the pole locations. The offset distance requirement will be discussed later in this design procedure.

III-13.04.03 Utility Poles

These are usually placed outside the clear zone of the particular highway. Guardrail for any poles that are within the clear zone will be discussed later.

III-13.04.04 Bridge Piers

These may be placed within the clear zone and may need guardrail. The type of guardrail will depend on the offset distance between the guardrail and the pier. The type of guardrail required is discussed in Section III-13.05.02.

III-13.04.05 Sign Supports

Sign supports are made breakaway or are a yielding type, except overhead sign structures. The overhead sign structures are treated like piers and will be discussed later.

III-13.04.06 Culverts

A single culvert (or end section) opening larger than 36" or multiple culvert (or end section) openings larger than 30" within the clear zone are considered obstructions. These culverts should be extended to the clear zone or guardrail should be installed. The type of guardrail will depend on the offset distance between the guardrail and the top of the culvert opening.

III-13.04.07 Water

Water is considered an obstacle if it is 2 or more feet deep and within the clear zone. In most cases, 3-cable guardrail is used to shield water areas.

III-13.04.08 Trees

Trees over 4 inches in diameter within the clear zone should have guardrail if they cannot be removed. The type of guardrail will depend on the offset from the guardrail.

III-13.04.09 Rock or Rip Rap

Rock or rip rap within the clear zone should be removed or moved outside the clear zone. If rocks or rip rap cannot be removed or moved, guardrail should be installed. The type of guardrail will depend on available offset between the guardrail and the rock or rip rap. In some instances where there is insufficient room to install guardrail because of a narrow roadway width, it may be necessary to post the area for reduced travel speed.

III-13.04.10 Steep Slopes

Steep slopes are studied during the safety review to determine if guardrail or flattening the slopes is cost effective. When guardrail is required, 3-cable guardrail is used unless there is another obstruction on the foreslope that is within 11 feet of the guardrail in which case W-beam guardrail is required.

III-13.05 Treatment of Obstacle

III-13.05.01 Bridge Rail Ends

The clear roadway distance is obtained from the bridge plans. The bridge plans will also show the type of bridge rail that is in place. The two types of acceptable bridge rail have been specified in Section III-13.04.01.

A. Jersey Barrier

1. This type of rail requires a transition as shown on Standard Drawing D-764-3. A W-beam terminal connector is bolted directly to the jersey barrier for attachment of the approach guardrail. At each bridge corner where guardrail is required, a 6 inch high curb with height transitions shall be installed. The minimum length of the curb (including height transitions at each end) is 20 feet, and a maximum length of 25 feet may be installed. At the end nearest the jersey barrier, the curb shall transition to match the lower jersey barrier shape. At the end furthest from the bridge, the curb shall taper from 6" to 0" over a distance of 3 feet. Details of the required curb are shown on Standard D-764-3. On roadways where curb and gutter will extend beyond the 20 foot approach curb, the transition curb height shall taper down from 6" to 3" maximum. On roadways where additional curb is required beyond the transition curb, the lower 3" curb height shall be provided for a distance equal to the length of the guardrail embankment area as shown on Standards D-764-9B through D-764-13. At the location where the 4:1 taper for the embankment meets the face of curb, the curb height may then be transitioned back up to a standard 6" curb height. The length of the height transition at this location should be a minimum of 2 feet in length.

    a. Where a bridge approach slab is placed, the Bridge Division will provide the curb on the slab. If no approach slab is to be placed, the guardrail designer will provide for the curb in the guardrail plans.

        1. Where no additional curb is installed beyond the minimum 20 foot long transition curb, drainage shall be carried down the foreslope from the curb end, and the foreslope shall have turf reinforcement mat installed in accordance with Standard Drawing D-708-4.

            a. At locations where the existing foreslope will not be disturbed, and adequate turf exists to prevent erosion, consideration may be given to omitting the turf

reinforcement mat.

2. At some locations, inlets may be provided within the 20 foot long transition curb. Where necessary, these must be carefully sized and located between the guardrail posts, which have a maximum center to center spacing of 3'-1 ½" in the area where the curb is installed. Drainage from inlets installed at these locations shall be carried through underground drains to the bottom of the foreslope.

3. If inlets are required beyond the 6" tall transition curb, they must be of a type which has a curb box that is adjustable to allow installation in the 3" curb required in these areas, or the curb may be transitioned to a mountable type, and mountable inlets may be installed.

4. When no approach slab is in place and curb and gutter is in place, the curb and gutter should be removed, or if possible, modified to conform to the requirements as shown on Standard Drawing D-764-3. When drainage is provided by using drop inlets, the inlets should be treated as discussed in 2 and 3 above.

B. Double Box Beam Bridge Rail Retrofit

Several types of existing bridge rail can be retrofitted with double box beam railing which has been crash tested in accordance with NCHRP 350. The bridge designer provides the plans for retrofit bridge railing. The approach rail for the retrofit bridge rail should start with a thrie beam terminal connector attached to the attachment plate on the retrofit bridge rail. A double thickness, 12'-6" section of thrie beam is attached to the terminal connector using splice bolts. The post spacing on this section of thrie beam is 1'- 6 3/4"except the last space (between the 6th and 7th post) before the thrie to W-beam transition section is 3'-1 1/2". The next section is a 6'-3" thrie beam to W-beam transition section with a post spacing of 3'-1 1/2" and is also double thickness. For details, see Standard Drawing D-764-3A, "Thrie Beam to W-Beam Transition and Connection to Double Box Beam Retrofit." The thrie beam to W-beam transition section is connected to the thrie beam and W-beam with splice bolts.

1. Where a thrie beam to W-beam transition is used in conjunction with double box beam bridge rail retrofit, as described above, any curb and gutter installed within the guardrail area, from the end of the embankment taper to the beginning of the bridge, shall be either curb and gutter having a maximum curb height of 3" or mountable curb having a maximum curb height of 3" When curb and gutter is

installed, the width of the curb should be modified to 5" maximum, to avoid conflict with the installation of guardrail posts. If mountable curb is installed, the location of the curb, and the flow line will require adjustment to avoid conflict with the installation of guardrail posts. The preferred option is generally the standard Type I curb and gutter with a modified 3" curb height.

C. Bridge rails may have to be updated temporarily by placing retrofit bridge rail.

1. The guardrail transition for an installation of this type is as described above in B.

D. Bridge End Treatments with speeds under 30 mph.

1. The type of bridge rail will determine what is required.

a. At design speeds of less than 30 mph, where jersey barrier type bridge rails exist or are to be used, a 20 foot long transition wall can be provided which transitions from the 32" jersey barrier shape to a standard Type I curb shape (6" curb height). This transition is typically provided as part of a bridge approach slab. If no curb exists, the wall transitions to a height of 4" or less. This treatment is for use only at low speed locations such as urban areas where site conditions such as pedestrian facilities adjacent to the roadway, limit the available end protection options.

b. Double box beam bridge rail retrofit does not have an acceptable tapered down transition for speeds of less than 30 mph. It is recommended that guardrail be installed. The transition as described in B. above, and as shown on Standard Drawing D-764-3A should be provided, with approach guardrail length of need provided in accordance with Standard Drawing D-764-5A.

2. Reduction in posted speed to 25 mph for the sole purpose of elimination of guardrail at bridge ends, or other obstructions is generally not recommended. If the prevailing speeds at the bridge are greater than 45 mph, there should be no reduction of speed to eliminate guardrail or reduce guardrail length. Motorists will tend to exceed what they perceive to be over-restrictive speed limits when these speed reductions are not otherwise consistent with the general roadway conditions.

III-13.05.02 Bridge Piers

Bridge piers that are within the clear zone require shielding. Shielding of median piers on divided highways, where they lie within the clear zone of both roadways may be accomplished by

use of vertical concrete walls or jersey barriers with attenuation devices or crash cushions, or by installation of guardrail. The type of guardrail which may be used will depend on lateral clearance from the guardrail to the piers.

A. When piers are less than 1'-3" from the finished shoulder, a Jersey type barrier should be placed directly against the pier and the Jersey barrier should run from outside of the pier to outside of the pier, and be 42" in height. The Jersey barrier should then transition down in 10' to the height of 32". A curb and gutter shall be installed on the approach end of the Jersey barriers as shown on Standard Drawing D-764-3. The W-beam is bolted to a W-beam terminal connector, which is bolted directly to the Jersey barrier as shown on Standard Drawing D-764-3. On non-divided roadways, a height transition, and a curb and gutter shall be placed in both directions. See Figures 1-3 in Appendix III-13 A.

B. When bridge piers are between 1'-3" and 3' from the finished shoulder, W-beam guardrail should be used. The post spacing of the W-beam guardrail should be reduced to 3'-1 1/2" from 25' in advance of the piers and past the pier area. The last section beyond the piers should have 6'-3" post spacing and a breakaway cable treatment should be used in the last 6'-3" post spacing section. See Figure 13 in Appendix IIIB13 A.

C. When bridge piers are 3' to 11' from the guardrail, W-beam guardrail should be used with 6'-3" post spacing throughout. The last 6'-3" post spacing past the pier should have a breakaway cable treatment. See Figure 13 in Appendix III-13 A.

D. When piers are over 11' from the finished shoulder, 3-cable guardrail should be used because of reduced installation cost and reduced snow accumulations.
The 3-cable guardrail should be placed 9' from the driving lane on the median side of divided roadways as long as 11' or more minimum clearance can be maintained between the cable and the face of the pier. The 3-cable guardrail should be placed on a slope of 10:1 or flatter when placed in this position. The 10:1 or flatter slope should be carried 3' behind the guardrail (measured from the cable). The area outside the 10:1 slope should be graded to drain away from the piers. Some culvert extension or installation may be needed.

E. Where there are median piers and both roadways are at nearly the same elevation, one of the following treatments should be installed:

1. Where piers are set on top of a rectangular footing having a continuous, smooth face, the top of which is at least 42" above the final finished surface after the median is filled:

   The median should be filled to provide a flat area wide enough to provide a minimum of 5 feet of flat area (measured perpendicularly from the device toward

the roadway) adjacent to a Type B attenuation device when this type of end protection is installed. Where a crash cushion will be used to shield the barrier end, provide a minimum width of 5 feet of flat area adjacent to the median bridge pier for the entire length of the median pier protection embankment. From this point the fill should be placed at a 12:1 or flatter slope to the finished edge of the shoulders.

Vertical faced transition walls shall be installed at each end of the pier footing, having a height of 42" or higher at the face of the pier foundation, and tapering down to a height of 32" above the finished surface, and a width of 24". The top of the transition wall shall taper at a rate of 10:1 or flatter slope. The traffic faces of the transition wall shall have a taper rate consistent with, or flatter than, the suggested flare rates for barrier design for rigid barrier systems, as given in Table 5.7 of the 2002 AASHTO Roadside Design Guide. The values in Table 5.7 are given for design speeds from 30 mph to 70 mph. Where a design speed of 75 mph applies, the taper rate for concrete transition walls shall be 23:1 or flatter. An additional 2 feet of wall 32" high by 24" wide shall extend beyond the end of the height transition, and the last 5 feet of the transition wall shall be 24" wide, to accommodate the rearward movement of crash cushion side panels when impacted. The barrier walls and transitions shall be reinforced.

The end of these types of transition walls may be shielded by either an attenuating crash cushion meeting the crash test requirements of NCHRP Report 350 (TL3), installed on a concrete pad, or a Type B attenuation device, as shown on Standard Drawing D-704-1. The type B attenuation device when permanently installed shall be placed on a concrete pad. Permanent installations of this type are described with pay items "Barrel Attenuation Device Type B-(speed, mph)." Concrete pads for attenuating crash cushions shall be specified to be as recommended by the crash cushion manufacturer.

See Figures 3B7 in Appendix IIIB13 A.

2. Where piers are set on footings below the ground, or where the pier footing is less than 42" above the final finished surface:

The median should be filled to provide a flat area wide enough to provide a minimum of 5 feet of flat area (measured perpendicularly from the device toward the roadway) adjacent to a Type B attenuation device when this type of end protection is installed. Where a crash cushion will be used to shield the barrier end, provide a minimum width of 5 feet of flat area adjacent to the jersey barrier for the entire length of the median pier protection embankment. From this point

the fill should be placed at a 12:1 or flatter slope to the finished edge of the shoulders.

A 42" high Jersey barrier will be placed from end of pier to end of pier on both sides of the piers. The 42" high Jersey barrier walls shall be tapered down to a 32” height, and the traffic faces shall be tapered at a rate consistent with, or flatter than the suggested flare rates for barrier design for rigid barrier systems, as given in Table 5.7 of the 2002 AASHTO Roadside Design Guide. The values in Table 5.7 are given for design speeds from 30 mph to 70 mph. Where a design speed of 75 mph applies, the taper rate for concrete barrier walls shall be 23:1 or flatter. The length of the barrier transition will vary depending upon the width of the pier foundation. The top width of the Jersey barrier face (at the pier) shall be tapered to 1'-8" near the end of the transition. The barrier then transitions, over a distance of 7’-6 ¾” to a 24” wide by 32” tall rectangular shape. Two additional feet of the rectangular wall shape are required at the end of the transition. The barrier walls and transitions shall be reinforced.

The end of these types of barrier walls may be shielded by either an attenuating crash cushion meeting the crash test requirements of NCHRP Report 350 (TL3), installed on a concrete pad, or a Type B attenuation device, as shown on Standard Drawing D-704-1. The type B attenuation device when permanently installed shall be placed on a concrete pad. Permanent installations of this type are described with pay items “Barrel Attenuation Device Type B-(speed, mph).” Concrete pads for attenuating crash cushions shall be specified to be as recommended by the crash cushion manufacturer.

See Figures 8-12 Appendix IIIB13 A

III-13.05.03 Sign Supports

Sign supports usually are made of breakaway or yielding type material. In some cases, overhead sign structures are utilized and their end towers and foundations may need guardrails or have Jersey barrier and crash cushion placed when the end towers and foundations are within the clear zone. The overhead sign structure end tower and foundation should be shielded by guardrail, or have Jersey barriers and crash cushions installed, when warranted, using the same criteria as used for bridge pier protection.

III-13.05.04 Culverts

The location of the culvert end openings will determine the type of guardrail. The same criteria used for piers will determine the type of guardrail to be used. Single centerline culverts having openings of greater than 36” in width, or multiple culverts having greater than 30” width

openings that are within the clear zone, will require either extension of the culvert, or the installation of guardrail. Centerline culvert ends 15 to 36 inches in diameter can be within the clear zone if they have a traversable end section. Culverts installed parallel to the roadway, such as those through approaches, can be within the clear zone if they have a traversable end section. The details for traversable end sections can be found on Standard Drawing D-714-1A on the NDDOT web site at:

http://www.dot.nd.gov/docs/design/Design%20Standards/D714-01A.pdf

III-13.05.05 Water

Water areas may be shielded by 3-cable type guardrail in most cases, provided that rip rap or other obstructions are outside the 11-foot deflection distance. W-beam guardrail must be used where obstructions lie within 3 to 11 feet of the railing.

III-13.05.06 Rock Outcroppings

The location of the obstacle will determine the type of guardrail to be used. The same criteria used for guardrail at piers should be used.

III-13.05.07 Steep Slopes

Steep foreslopes warranting guardrail will normally require the use of 3-cable guardrail. Foreslopes 3:1 or steeper require guardrail. A foreslope steeper than 2:1 will require shielding with W-beam guardrail because errant vehicles could under-ride the cables of the 3-cable guardrail system at or near the maximum deflection on slopes steeper than 2:1.

III-13.06 Guardrail Location

A. W-beam guardrail should be placed at bridge ends or barrier walls. The straight sections should be aligned with the face of the barrier wall or the flat plate of the retrofit bridge rail.

B. W-beam guardrail installed at locations other than bridge ends should be placed at the finished shoulders with the front face of the guardrail aligned with the finished shoulder. In no case should the slope in front of the W-beam guardrail be greater than a 10:1 slope. Where piers are close to the roadway, and a barrier wall is to be installed, the alignment should be as stated above for W-beam guardrail placed at bridge ends.

C. W-beam guardrail may be flared away from the roadway at the flare rate shown on the standard drawings, dependent on the design speed. In all cases, a curved section will transition the straight section to the flared section. A minimum length of 25 feet of

tangent railing shall be installed in advance of an obstruction, such as a pier, culvert, rock outcrop, overhead sign structure, steep slope, etc., before the curved rail section and flared rail are installed. See Standard Drawings D-764-13B through D-764-17A.

D. Some locations may have conditions that will not allow W-beam guardrail to be flared at the standard taper rates. When conditions such as drainage, right of way, or possible clear zone violation for opposing traffic lanes (such as at median installations on divided highways) will not allow the W-beam guardrail to be flared at the taper rates given on the standard drawings, the guardrail should be installed either straight along the shoulder, parallel with the traveled lane, or wherever possible, should be flared at a rate flatter than the standard taper rates. A 50:1 taper rate has been used at many locations by NDDOT to accommodate unusual field conditions such as those discussed above.

E. Box beam guardrail should be placed at the finished shoulder with the front face of the guardrail aligned with the finished shoulder break. In no case should the slope in front of the box beam guardrail be greater than a 10:1 slope. The box beam guardrail shall have an NCHRP Report 350 crash-tested end terminal installed, such as the Wyoming Box Beam End Terminal (WYBET). Presently, box beam guardrail is rarely used on North Dakota highways. It is not currently supported by the NDDOT standard drawings.

F. 3-cable guardrail should be placed 2' from the finished shoulder, but should be at least 2' inside of the graded shoulder. Where the roadway slough is steeper than 10:1, fill should be placed, at a 10:1 slope, from the finished shoulder to 3' behind the 3-cable guardrail. On divided highways where piers are protected with 3-cable guardrail, the 3-cable guardrail should be placed 9' from the edge of the driving lane on the median side, but no closer than 11' from the face of the pier. In most cases, fill will be required for placement of the 3-cable guardrail at that point. The fill area between the finished shoulder and 3' beyond the 3-cable guardrail location should be 10:1 or flatter. Drainage may have to be modified for installation of the 3-cable guardrail at the 9' offset. 3-cable guardrail will only be used in the median where the finished elevations of the two roadways differ to the extent that median protection using either the vertical concrete wall or the jersey barrier installation cannot be installed. The wide flat area required for the installation of these systems, especially when attenuation devices are installed, will in some cases prohibit their use when roadway elevations differ.

III-13.07 Length of Need

III-13.07.01 Bridge End Treatment

A. The W-beam guardrail should be carried 39'- 4 3/4" straight as shown on the layouts for the various design speeds, on Standard Drawings D-764-5A through D-764-9A. The end terminal should be one of those shown in Standard Drawings D-764-2B, D-764-2C, or D-764-2H. The acceptable end terminal type or types will be specified in the plans depending upon guardrail taper rate, or length of the installation. The criteria for determining the proper end terminal options at a given location is discussed in section III-13.11.

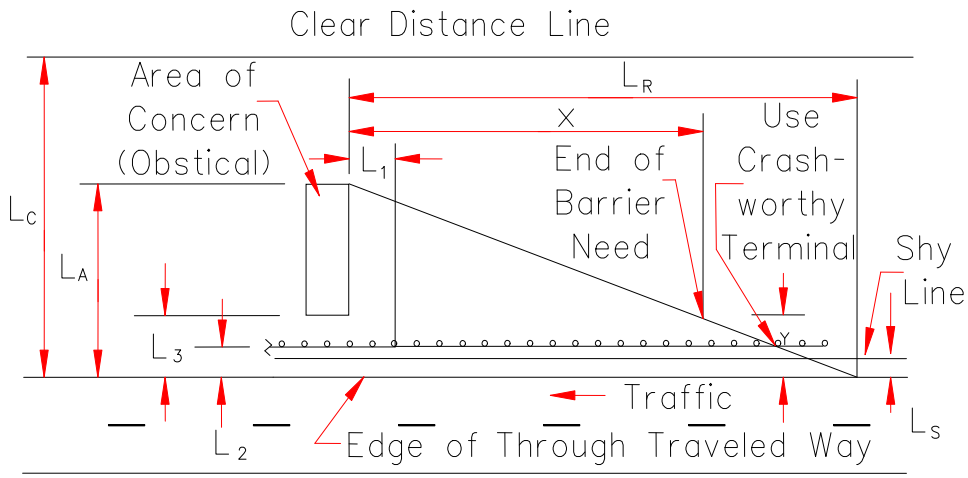
B. The bridge end connection will depend on the bridge rail. Jersey barrier bridge rails should have the W-beam bolted to a W-beam terminal connector which is bolted directly to the Jersey barrier as shown on Standard Drawing D-764-3.

C. When the bridge railing is a double box beam rail retrofit, the straight section should begin on the bridge with the thrie beam terminal connector, which attaches to the retrofit attachment plate. The thrie beam and thrie to W-beam transition should be installed as shown on Standard Drawing D-764-3A. The straight section, from the beginning of the thrie beam terminal connector to the curved section shall be at least 45'-7 ¾."

D. When drainage or other constraints won=t allow the W-beam guardrail to be flared at the standard taper rates, with the required 10:1 sloped embankment slope, the W-beam guardrail should be installed either at a flatter than standard taper rate, or straight, as was discussed in III-13.06. The length of need should be determined by the traffic volume, design speed, bridge clear roadway, and clear zone.

When guardrail is to be installed straight (non-flared), the length of need can be determined from the following equation:

$$X = (L_A - L_2)/(L_A/L_R)$$



Where L_A is the clear zone because at most bridge structures, steep slopes, water, or other obstacles lie behind the bridge railing, so shielding to protect out to the clear zone is necessary. L_2 is the clearance between the edge of the travel way and the guardrail. L_R is the runout length.

Traffic Volumes (ADT)				
Design Speed (mph)	Over 6000 vpd	2000-6000 vpd	800-2000 vpd	Under 800 vpd
	Runout Length L_R (ft)	Runout Length L_R (ft)	Runout Length L_R (ft)	Runout Length L_R (ft)
75	520	485	430	395
70	475	445	395	360
65	450	425	370	345
60	425	400	345	330
55	360	345	315	280
50	330	300	260	245
45	260	245	215	200
40	230	200	180	165
30	165	165	150	130

Suggested Runout Lengths for Barrier Design

Design Speed (mph)	DESIGN ADT	FORESLOPES					BACKSLOPES					
		Flatter than 6:1	6:1	5:1	4:1	3:1	Steeper than 3:1	3:1	4:1	5:1	6:1	Flatter than 6:1
40 or less	Under 750	7 - 10	7 - 10	7 - 10	7 - 10	**	7 - 10	7 - 10	7 - 10	7 - 10	7 - 10	7 - 10
	750 - 1500	10	12	12	14	**	10 - 12	10 - 12	10 - 12	10 - 12	10 - 12	10 - 12
	1500 - 6000	12	14	14	16	**	12 - 14	12 - 14	12 - 14	12 - 14	12 - 14	12 - 14
	OVER 6000	14	16	16	18	**	14 - 16	14 - 16	14 - 16	14 - 16	14 - 16	14 - 16
45 - 50	Under 750	10	12	12	14	**	8 - 10	8 - 10	8 - 10	8 - 10	10	12
	750 - 1500	14	16	16	20	**	10	12	12	14	14	16
	1500 - 6000	16	18	20	26	**	12	14	14	16	16	18
	OVER 6000	20	22	24	28	**	14	16	18	20	20	22
55	Under 750	12	14	14	18	**	8	10	10 - 12	10 - 12	10 - 12	10 - 12
	750 - 1500	16	18	20	24	**	10	12	14	16	16	18
	1500 - 6000	20	22	24	30	**	14	16	16	18	20	22
	OVER 6000	22	24	26	32	**	16	18	20	22	22	24
60	Under 750	16	18	20	24	**	10	12	12	14	14	16
	750 - 1500	20	24	26	32	**	12	14	16	18	20	22
	1500 - 6000	26	30	32	40	**	14	18	18	22	24	26
	OVER 6000	30	32	36	44	**	20	22	24	26	26	28
65 - 70	Under 750	18	20	20	26	**	10	12	14 - 16	14 - 16	14 - 16	14 - 16
	750 - 1500	24	26	28	36	**	12	16	18	20	20	22
	1500 - 6000	28	32	34	42	**	16	20	22	24	26	28
	OVER 6000	30	34	38	46	**	22	24	26	30	28	30
75	Under 750	19	22	24	29	**	12	14	14	17	17	19
	750 - 1500	25	30	32	40	**	15	17	20	22	25	27
	1500 - 6000	32	36	39	49	**	17	22	22	27	29	32
	OVER 6000	37	39	44	54	**	24	27	29	32	32	34

Clear Zone Table
For Guardrail Length of Need Determination

The length of need tables in the Standard Drawings for guardrail were developed based upon the clear zone values given above, for 6:1 foreslope, in all cases. It was found that the weighted average foreslope rate that an errant vehicle travels across a runout path consisting of a 4:1 slope in advance of the guardrail embankment area, and the 10:1 foreslope of the embankment in advance of the guardrail was very nearly 6:1. Therefore, for standardization, the 6:1 values were used in developing the lengths of need for guardrail. Since a 10:1 foreslope is provided in advance of flared guardrail, the use of the 6:1 clear zone values, for graphical analysis, when the Standard Drawings are not used, or not applicable, should provide results comparable to the lengths of need provided by the Standard Drawings.

III-13.07.02 Obstacles

The treatment of the various types of obstacles will depend on the lateral clearance.

A. Objects within 0 to 1'-3" from the roadway finished shoulder should have a barrier wall installed with the W-beam guardrail as was discussed in III-13.05.02 A. The guardrail length of need should be determined from Standard Drawings D-764-5A through D-764-9A for bridge ends.

1. On divided highways, the 42" barrier wall should be installed only to the end of the obstacle on the exiting end.

2. The W-beam should be attached to the 32" barrier wall at both ends on two-way roadways and on the upstream, approach end on divided highways.

B. Obstacles 1'-3" to 3' from the roadway finished shoulder should have W-beam guardrail installed with reduced post spacing. The post spacing for the railing in front of, and for 25 feet in advance of the obstruction, shall be 3'-1 ½ ".

1. On non-divided highways, the straight portion of the W-beam rail in the vicinity of the obstacle shall be determined by taking the length of the obstacle, and rounding this up to the nearest length which is divisible by 12'-6". An additional length of 25 feet is added to each end. This total straight portion is installed symmetrical about the centerline of the obstacle. This is illustrated in the W-beam guardrail dimension layout, on Standard Drawings D-764-13B through D-764-17A.

2. On divided highways, the straight portion of the W-beam rail in the vicinity of the obstacle shall be determined by taking the length of the obstacle, and rounding this up to the nearest length which is divisible by 12'-6". This portion of the straight railing is installed symmetrical about the centerline of the obstacle, and shall have 3'-1 ½" post spacing. An additional length of 25 feet of railing, having 3'-1 ½" post spacing is added to the upstream, approach end, before a curved rail section and flared rail with end terminal is installed. At the downstream end, an additional 12'-6" section with 6'-3" post spacing is installed, just beyond the obstacle, with a breakaway cable terminal end in the last 6'-3".

See Figure 13 in Appendix III-13 A.

C. Obstacles 3' to 11' from the roadway finished shoulder should have W-beam guardrail installed.

1. The guardrail along the obstacle should have the length calculated as specified in B 1 above, except all post spacings may be 6'-3" for obstacles 3' or more behind the face of the W-beam guardrail.

2. The guardrail for divided highways should be as specified in B 2 above, except all post spacings may be 6'-3" for obstacles 3' or more behind the face of the W-beam guardrail.

D. Objects over 13' from the roadway finished shoulder should have 3-cable guardrail installed.

1. 3-cable guardrail should be placed 2' from the finished shoulder, but not closer than 2' to the graded shoulder. To ensure the 2' to the graded shoulder, the distance from the 3-cable guardrail to the finished shoulder could be less than 2'.

E. On divided highways where median piers are protected with 3-cable guardrail, the 3-cable guardrail should be placed 9' from the edge of the driving lane on the median side but no closer than 11' from the face of the pier. In most cases, fill will be required for placement of the 3-cable guardrail at that point. The fill area between the finished shoulder and 3' beyond the 3-cable guardrail location should be 10:1 or flatter. Drainage may have to be modified for installation of the 3-cable guardrail at the 9' location. 3-cable guardrail will only be used in the median where the finished elevations of the two roadways differ to the extent that median protection using either the vertical concrete wall or the jersey barrier installations cannot be installed. The wide flat area required for the installation of these systems, especially when attenuation devices are installed, will in some cases prohibit their use when roadway elevations differ.

III-13.08 Guardrail Design

The design of the guardrail for a particular type of obstacle uses each of the above sections to obtain the proper design. The following information should be obtained for each location.

A. The designer should determine the type of obstacle.

1. Bridge ends: Obtain bridge rail plans.

2. Piers and bridge layout: Obtain bridge layouts and pier plans.

3. Culverts: Obtain plan and profile sheets.

4. Steep slopes: Obtain plan and profile sheets.

5. Water: Obtain plan and profile sheets.

6. Other: Obtain plan and profile sheets.

B. The designer should obtain the design speed for the roadway. Guardrail design speeds used by NDDOT are: 30 mph, 40 mph, 45 mph 50 mph, 55 mph, 60 mph, 65 mph, 70 mph and 75 mph.

C. Lateral clearance from the roadway centerline to the obstacle should be determined. Obtain the cross sections of the roadway in the area that guardrail is warranted.

D. The traffic volumes should be obtained from the plan title page or from the Planning and Programming Division.

III-13.09 Design Procedures

The following design procedures should be followed, dependent on the type of obstacle, using the above information.

III-13.09.01 Bridge Ends

The designer should use W-beam guardrail at these locations and the length of need should be obtained from Standard Drawings D-764-5A to D-764-9A, dependent on design speed.

A. The type of bridge end treatment should depend on whether the bridge has a jersey barrier rail or a double box beam rail retrofit.

1. **Jersey Barrier**

a. The requirements for the transition railing, including curb requirements, were discussed in III-13.05.01 A, and the transition is shown on Standard Drawing D-764-3.

2. **Double Box Beam Bridge Rail Retrofit**

a. The requirements for the guardrail transition railing, including curb requirements, if curb is needed, were discussed in III-13.05.01B, and the transition is shown on Standard Drawing D-764-3A.

B. The length of need is taken from Standard Drawings D-764-5A to D-764-9A, dependent on design speed.

1. Entering the table on the appropriate standard drawing with the bridge width and traffic volume, read across the standard drawing to determine the various guardrail dimensions for that bridge width and traffic volume.

2. The bridge on a two-way roadway should have the length of guardrail shown on the approach side and opposite side. The guardrail should have the end terminals as shown on Standard Drawings D-764-2B, D-764-2C or D-764-2 H. Dimensions C or C1 give the length of the end terminal.

3. Where an approach falls within this length, the approach should be moved. The district office should determine if the approach can be moved.

4. If the approach cannot be moved, the guardrail should be broken, with a minimum of either 39'-4 ¾" (at bridges with Jersey barrier) or 45'-7 ¾" (at bridges with double box beam rail retrofit) straight section and an end terminal, as shown on Standard D-764-2B, D-764-2C or D-764-2H, installed in the vicinity of the radius of the approach roadway as a minimum. If additional guardrail can be installed, then extend the rail with additional straight W-beam rail sections, to place the end terminal in the vicinity of the approach radius The guardrail length need should be provided by placing a length of guardrail on the other side of the approach to the required length, and an end treatment as shown on Standard D-764-2B, D-764-2C, or D-764-2H shall be installed on both ends of the guardrail. The length of need shall include the end treatments minus the first 12.5 feet from the end of the terminal ends that may be hit by errant vehicles. The end treatment at the approach should begin at a point approximately 5 feet from the vehicle turning radius. The end treatment shall have the offsets as shown on the standard drawings. For private drives or field drives, a general rule of thumb is that the access opening between the guardrail ends should be approximately 60 feet. Adjacent land use, skew angle of the approach, and turning movements should be considered in determining the opening.

   On low-volume, low-speed roadways a curved rail may be placed as shown on Standard Drawing D-764-3B. The speeds on the main roadway shall be 55 mph or less and the 750 ADT or less.

5. Where roadside constraints, such as drainage, do not allow for flaring the guardrail at standard taper rates (10:1 for 30 mph to 45 mph, 11:1 for 50 mph, 12:1 for 55 mph, 14:1 for 60 mph, 15:1 for 65 mph and 70 mph, and 16:1 for 75 mph), the guardrail should be installed at a flatter taper rate. Any taper rate which is flatter than that prescribed for a given design speed is acceptable. The standard taper rates are maximum taper rates. This means that if right of way restrictions limit the available guardrail offset, a flatter taper rate could be used to install the rail. However, the length of the railing would likely require adjustment. This can best be accomplished by graphical means. Refer to Section 5.6.4 of the 2002 AASHTO Roadside Design Guide. A 50:1 taper rate has been used by NDDOT at many high speed locations, to allow for a reasonable length of guardrail to be installed which satisfies length of need requirements. Alternately, straight guardrail can be installed, which further increases the length of rail required. This type of installation is not preferred, as increased nuisance hits are likely, and snow buildup on the roadway may be increased.

If an approach is encountered in this length, it should be treated as stated above. Wherever possible, approaches should be relocated rather than providing breaks in the guardrail installation.

6. For length of guardrail needed for double box beam rail retrofit installations, the straight approach length is revised from the 39.4' shown in the length of need tables, to 45.65'. This increases the total length given in the table, by 6.25 feet.

C. Flared guardrail (and most straight guardrail installations) will require fill material provided to place the guardrail on, as shown on Standard Drawings D-764-9B through D-764-13A. It should be noted that this fill area should be installed from the finished shoulder to 3' behind the guardrail, and this area should be 10:1 or flatter. The foreslope in advance of the end treatment should be equal to the foreslope it is matching. The foreslope behind the guardrail, between the downstream end of the end terminal (beginning of flared W-beam rail) and the beginning of the bridge may be steepened if necessary to accommodate the fill.

D. Where guardrail is provided on divided highway bridges, the guardrail length is determined as stated above. However, the distance from the approach roadway centerline to the bridge rail face (lowest face of jersey barrier), times two, should be the clear roadway width used for that side of the roadway. Use this and the traffic volumes. For example, if an interstate highway bridge has two twelve foot lanes, an outside shoulder of 10 feet, and a passing lane (median side) shoulder of 4 feet, then the clear roadway width to use for the outside driving lane is: (12 +10) * 2 = 44 feet. The clear roadway width to use for the passing lane is: (12 + 4) * 2 = 32 feet. Both of these would be considered an approach side, because traffic is using both lanes entering the bridge, and length of need is taken for each side, from the appropriate clear roadway width lines in the length of need table.

III-13.09.02 Obstacles

The designer should use the guardrail type, dependent on guardrail offset from the roadway driving lane, and the clear distance from the obstacle. The W-beam guardrail should be flared, if possible. All obstacles should have a minimum of 25' of straight guardrail in advance of the obstruction and 25' past, except on divided highways, the length past the obstacle can be reduced to 12'-6" when a cable anchor is installed. 3-cable guardrail should not be placed on the inside of curves with curvature of more than 4 degrees. Intermediate anchors should be installed as specified on the standard drawings.

III-13.10 Design Procedures For Guardrail On The Outside of Horizontal Curves

The design of W-beam guardrail on the outside of horizontal curves depends upon the degree of curvature of the roadway.

A. For all curves of 1 Degree 15 minutes (R= 4583.66') or flatter, the layout of the W-beam guardrail for the outside of the curve may be established in accordance with the Standard Drawings for guardrail length of need. Adjustments to the longitudinal dimensions (measured parallel to centerline of roadway) given by the standard drawings will be required, to correct for the difference between the roadway curvature and the tangent lengths given, to allow for proper layout in the field. The offset dimensions determined from the standard drawings may be used, however the dimension "D" given for the offset of the approach end of the W-beam guardrail end terminal should be adjusted, to allow the end terminal to be installed tangent to the downstream flared (or straight) guardrail. This may be done graphically by establishing the straight tapered portion of the rail relative to the roadway using the offset dimension "B" given in the standards, and extending a line coincident with the rail for a distance of 50 feet. The offset measured from the end of this 50 foot extension, (which is coincident with the end of the end terminal) to the centerline of the roadway is the appropriate offset dimension to use in lieu of utilizing the "D" offset dimension given in the standard drawings. In this way, the end terminal will remain tangent to the downstream guardrail.

B. Guardrail to be installed on the outside of curves sharper than 1 Degree 15 minutes (R < 4583.66') will require a graphical design procedure to assure that length of need is provided, and that the anticipated vehicle impact angle with the guardrail does not exceed 10 degrees.

This procedure is largely equivalent to the procedure discussed in the Roadside Design Guide 2002, page 5-42. The fundamental difference between this procedure and the Roadside Design Guide method, is that, for most horizontal curves, when using the method described here, some limited flaring of the guardrail is achieved relative to the roadway curvature. The use of a shallow flare for the guardrail results in a decrease in guardrail length of need, as compared to a parallel guardrail installation. The advantages of this type of installation include decreased snow accumulation and fewer nuisance hits. The flaring provided by this method shall be limited to provide an anticipated vehicle impact angle with the guardrail of no more than 10 degrees. Most often, an impact angle ranging between 7 and 8 degrees has been used by NDDOT. This angle is determined most easily by simple graphical means. A design example is illustrated below.

1. **Design Example**

See Figure 14 in Appendix III-13 A

In this example, a bridge is located within a 2 degree 10 minute horizontal curve (R=2644.42'). The roadway inslopes are 6:1. Design speed is 70 miles per hour and forecast ADT = 1000. The bridge has a clear roadway width of 40 feet.

First, the clear zone is determined. Since the horizontal curve is 2 degrees, 10 minutes, a clear zone correction factor of 1.3 (See Table 3.2, Roadside Design Guide, 2002, or NDDOT Design Manual) is applied to the value obtained from Table 3.1 of the Roadside Design Guide or from the Clear Zone table in the NDDOT Design Guide . Clear zone for a tangent roadway with the above design values, is given as 26 feet. With horizontal curve correction, the clear zone at this location is: 1.3 X 26' = 33.8 feet from the edge of the driving lane, or 45.8 feet from the roadway centerline.

The method for determining the design runout path is as follows: First, a line is drawn perpendicular from roadway centerline, at the beginning of the bridge, toward the outside of the curve, for a distance of 33.8'+12' = 45.8 '. A curve is drawn or offset 12 feet from the centerline, to establish the edge of the driving lane in advance of the bridge end. Next, from the end of the perpendicular line, at the clear zone, a line is drawn upstream to meet the edge of the driving lane on a tangent. This line is known as the Tangential Runout Path. The distance from the point of tangency is measured, along the edge of the driving lane, to the beginning of the bridge. This distance is then compared to the Suggested Runout Length, given in Table 5.8, page 5-33 of the Roadside Design Guide, 2002, or NDDOT Design Manual. If the measured distance is less than the Suggested Runout Length, then the Tangential Runout Path shall be used to determine the guardrail length of need. However, if the distance measured along the edge of the driving lane, from the point of tangency to the beginning of the bridge is greater than the Suggested Runout Length, then the Suggested Runout length shall be used to determine the guardrail length of need. This is accomplished by drawing an arc of a length equivalent to the Suggested Runout Length, from the beginning of the bridge upstream along the edge of the driving lane. From the end of this arc, a line is drawn to the clear zone point previously established, on the outside of the curve, adjacent to the bridge end.

Once the runout path has been established, as described above, the approach guardail is extended parallel to the roadway for a portion of its length, then continued on a tangent, resulting in a shallow flare relative to the curving roadway. The distance that the rail is required to run parallel to the horizontal

curve is determined graphically, by measuring the angle between the runout path and the guardrail. This angle must be 10 degrees or less. Generally, flatter angles of 7 to 8 degrees are preferred, and can be achieved without providing excessive guardrail length.

In this example, the guardrail was run parallel to the curved roadway for the first 64.4 feet, then continues on a tangent. The angle between the runout path and the approach guardail in this example is 7 degrees 45 minutes. Since this is less than 10 degrees, this is would be considered an acceptable design.

The length of the rail is adjusted by 12'-6" rail section increments until the approach end of the end terminal (last post) is 12'-6" or more beyond the design runout path. Because the first 12'-6" of the end terminal is yielding, and redirection takes place beginning at the third post, this portion of the end terminal is not considered part of the length of need.

The opposite side guardrail for the inside of the horizontal curve is dimensioned off of the roadway centerline in accordance with the offset dimensions provided in the standard drawings, and longitudinal dimensions are adjusted to account for the horizontal curvature.

III-13.11 W-Beam Guardrail End Terminal Installation Requirements

Four W-beam guardrail end terminals are used by NDDOT. These end terminals have varying site location and guardrail installation configuration requirements. The type or types of end terminals which may be installed at a given location shall be specified in the guardrail plans.

A. ET-2000, as shown on Standard D-764-2B: The ET-2000 end terminal shall be installed on straight guardrail installations, or installations having a flare rate no greater than 25:1 relative to the approaching traffic. Where necessary, the ET-2000 may be installed straight, tangent to the approach guardrail (and parallel to the traveled way), however it is preferred, (and typical NDDOT practice) that this end terminal be tapered at 50:1 to allow clearance for snow removal equipment, and to reduce the likelihood of nuisance hits.

B. Flared Energy Absorbing Terminal (FLEAT) as shown on Standard D-764-2C: The FLEAT end terminal shall be installed with either the 2'-6" or 4'-0 flare as shown on Standard D-764-2C, when it is installed on the end of a straight (parallel to traveled way) W-beam guardrail installation. When the FLEAT is installed to the end of a flared guardrail installation having standard flare rates of 10:1 to 16:1, the end terminal shall be installed with only the flare rate of the downstream guardrail.

C. Sequential Kinking Terminal (SKT), as shown on Standard D-764-2D: The SKT end terminal shall be installed on straight guardrail installations, or installations having a flare rate no greater than 25:1 relative to the approaching traffic. Where necessary, the SKT may be installed straight, tangent to the approach guardrail (and parallel to the traveled way), however it is preferred, (and typical NDDOT practice) that this end terminal be tapered at 50:1 to allow clearance for snow removal equipment, and to reduce the likelihood of nuisance hits.

D. Slotted Rail Terminal (SRT), as shown on Standard D-764-2H: The SRT end terminal shall be installed with the 4'-0 flare as shown on Standard D-764-2H, whether it is installed on the ends of straight W-beam guardrail or flared W-beam guardrail. The Slotted Rail Terminal shall not be installed at locations where the distance from the upstream end of the end terminal to the obstruction being shielded is less than 175 feet.