

The information contained in Chapter Nine: Guardrail and Roadside Barriers, dated May 2022, has been updated to reflect the January 2023 Errata. The errata addresses errors, changes in procedure, changes in NDOT department titles, changes in other Roadway Design Manual chapters and other reference material citations occurring since the latest publication of this chapter.

Chapter Nine presents guidance for the design of New and Reconstructed projects; design guidance for 3R projects is provided in Chapter Seventeen.

Except as otherwise noted, existing roadside barriers must be reviewed for compliance with the National Cooperative Highway Research Program (NCHRP) Report 350 or the Manual for Assessing Safety Hardware (MASH). Short radius W-Beam guardrail installations (See Section 7.A of this chapter) shall be in compliance with NCHRP Report 230.

Chapter Nine

Guardrail and Roadside Barriers

The **Nebraska Department of Transportation (NDOT)** will use the guidance found in the Roadside Design Guide (Ref. 9.1) for the evaluation and design of the roadside geometry, guardrail, and roadside barriers. This chapter includes additional **NDOT** guidance for New and Reconstructed projects (See Chapter Seventeen: Resurfacing, Restoration and Rehabilitation (3R) Projects, Section 9, of this manual for barrier guidance on 3R projects).

A roadside barrier may be used to shield traffic from critical slopes, cross-median traffic, and other obstacles along the roadside. The barrier is an obstacle itself and should not be used when it presents a greater crash potential than the object or condition being shielded.

Barrier installations at intersections will be reviewed for intersection sight distance (See Chapter Four: Intersections, Section 1.C.2, of this manual). Barrier selection and placement should also take snow drifting into consideration since the barrier may act as snow fence. The designer should check with the **District Engineer (DE)** prior to and on the plan-in-hand field inspection for potential snow drifting areas.

Whenever significant pedestrian and/ or bicycle traffic is anticipated special attention must be paid to the deflection characteristics of the barrier (See Section 3.D.1 of this chapter).

1. BARRIER JUSTIFICATION

A study to determine whether a barrier is desirable should include:

1. Determination of the clear-zone distance
2. Identification of the obstacle(s)
3. Consideration of your options
4. Performance of a cost effectiveness analysis for viable options

1.A Determination of the Clear-Zone Distance

For New and Reconstructed projects the clear-zone distance is the roadside area, starting at the edge of the through lane, which is available for the recovery of vehicles leaving the roadway. The clear-zone distance provides an area free of fixed obstacles and should consist of the shoulder and either a recoverable slope or a traversable slope with a clear runout area.

The minimum required clear-zone width is given in the Nebraska Minimum Design Standards (MDS) (Ref. 9.2) (<http://dot.nebraska.gov/media/5593/nac-428-rules-regs-nbcs.pdf>) as determined by the roadway classification, ADT, and design speed.

For additional information see Chapter Six: The Typical Roadway Cross-Section, Section 9, of this manual.

1.B Identification of the Roadside Condition

The designer should use the survey and/ or photo imagery to identify roadside obstacles.

1.C Consideration of Your Options

The designer should consider the following options when determining the appropriate treatment for an obstacle:

1. Remove the obstacle.
2. Redesign the obstacle so it can be traversed.
3. Relocate the obstacle to a location where it is less likely to be hit, preferably beyond the clear-zone distance.
4. If the obstacle is a sign support, traffic signal support, or utility pole that cannot be relocated, use breakaway devices where feasible.
5. Shield the obstacle if feasible and cost effective to do so.
6. If no other option is practicable, delineate the obstacle to reduce impacts.

EXHIBIT 9.1 is a partial listing of potential roadside conditions and considerations.

Roadside Condition	Decision Considerations
Foreslopes and Backslopes	The slope and the clear-zone distance.
Bridge piers, abutments and end of bridge rail	The location and the clear-zone distance. The end of the bridge rail is typically shielded with guardrail.
Cross-Median Traffic	The median width, traffic speed, traffic volumes, and percentage of heavy trucks.
Boulders	The nature and size of the obstacle and the likelihood of impact.
Culverts, pipes, headwalls	Crossroad culverts 36 inches or less in diameter with flared end sections, round-equivalent culverts 36 inches or less in width with flared end sections, and multiple-pipe installations of culverts 30 inches or less in diameter with flared end sections may be included within the clear-zone distance, typically without protection. Larger culverts may require either a traversable end section, extension outside of the clear-zone distance, or a cost effectiveness analysis to determine if barrier protection is economically warranted. Driveway culvert pipes parallel to the highway are typically placed at the back of the ditch, outside of the clear-zone distance. Headwalls are typically located beyond the clear zone distance.
Ditches (parallel)	The foreslope, backslope, depth, and the clear-zone distance. (See FIGURES 3-6 & 3-7 of the <u>Roadside Design Guide</u> , Ref. 9.1).
Ditches (transverse)	The approach transverse side slope (should be 1:6 or flatter inside of the horizontal clear zone) and the likelihood of impact (See Chapter Six: <u>The Typical Roadway Cross-Section</u> , Section 9.B.2, of this manual and, and Section 3.2.3 of the <u>Roadside Design Guide</u> , Ref. 9.1).
Embankment/ Steep Slopes	The fill height, length of slope, slope geometry, and clear-zone distance. When fixed obstacles exist on the embankment slope the slope may not be the controlling factor: a cost effectiveness analysis should be based on the severity of the fixed obstacle (e.g. large culverts).
Retaining walls	The relative smoothness of the wall, anticipated maximum angle of impact, structural integrity of the wall when impacted, and the cost of repairs.
Sign/ luminaire supports	Locate outside of the clear-zone distance whenever feasible. Shielding is generally required for non-breakaway supports when located within the clear zone.
Trees	Trees within the clear zone are typically removed.
Utility poles	Utility poles are typically relocated outside of the clear-zone distance whenever practicable. When utility poles cannot be relocated, the utility poles may be shielded. See Chapter Ten: <u>Miscellaneous Design Issues</u> , Section 11, of this manual for information regarding coordination with utilities.
Permanent bodies of water	The location and depth of the water and the likelihood of impact.

Exhibit 9.1 Barrier Considerations for Roadside Conditions

1.D Performance of a Cost Effectiveness Analysis

Barrier installation is sometimes based on a cost effectiveness analysis and the premise that a barrier should only be installed if it will reduce the severity of crashes. The cost effectiveness analysis program used by **NDOT** is the “Roadside Safety Analysis Program” (RSAP). RSAP is an encroachment-based computer software tool for cost-effectiveness evaluation of roadside safety improvements. **FHWA** has identified RSAP as a resource in roadside design. RSAP calculates the benefit to cost ratio, comparing the potential costs of impacting roadside obstacles to the expected benefit of shielding them and the lesser costs of impacting the barrier. The analysis can include, but is not limited to, consideration of the costs of:

- Removing or minimizing the obstacle
- The type and length of barrier
- The cost of barrier maintenance
- Crashes involving the barrier
- Crashes involving the roadside obstacle

2. **BARRIER TYPES USED IN NEBRASKA**

Details of the barrier types used in Nebraska are shown in the Standard/Special Plans Book (Standard Plans) (Ref. 9.3) (<http://dot.nebraska.gov/business-center/design-consultant/stand-spec-manual/>). EXHIBIT 9.2 summarizes the guidance for barrier use.

Barrier	Location	Comments
Semi-rigid Guardrail (Midwest Guardrail System (MGS), W-beam, and Thrie-beam)	Used to shield motorists from fixed objects such as bridge piers. Should not be placed on slopes steeper than 1:10. It is preferred that the posts be installed with the shoulder slope continuing for a minimum of two feet behind the system.	Semi-rigid guardrail relies on energy absorption of posts rotating in soil. For additional information, see Section 7, "Special Installations", of this chapter.
Cable Guardrail (Low-Tension)	Typically placed at four feet from the slope break point when the slope is 1:2 or flatter. Should not be placed within four feet of a slope between 1:1.5 and 1:2 or within 12 feet of a fixed object. Preferred over semi-rigid guardrail where snow drifting is likely.	This system relies on tensile forces in cables and the ability of impacting vehicles to ride down weak posts. Should not be placed on the inside of curves with radii less than 1910 feet unless additional space at a 1:10 or flatter slope is provided. Not typically placed on the inside of a curve with a Radius less than 716 feet.
Cable Guardrail (High-Tension)	Used for narrow medians (e.g. Interstate and expressway medians) to guard against cross-over crashes.	May have less deflection than Low-Tension Cable Guardrail and, typically, the installation will still be standing after a hit. Roadway Design Engineer approval is required for this installation.
32 inch Concrete Protection Barrier	Used in areas where barrier deflections are intolerable, truck capacity is required, or barrier repair is difficult. Should only be placed adjacent to surfaced shoulders or medians.	The New Jersey or F shape barrier is typically used in Nebraska.
42 inch or higher Concrete Protection Barrier	Used when the ability to contain large trucks is of primary concern. Locations with high volumes and narrow medians or where widening into a median is planned are the most common applications.	Height helps to reduce headlight glare somewhat and may redirect a semi-trailer to keep it from tipping over.
Vertical Concrete Barrier	Used where barrier deflections are intolerable, truck capacity is required, or barrier repair is difficult. May be higher than 32 inches.	Barrier provides high strength and low repair costs without high rollover rates. When initially taller than 32 inches, overlays may be placed next to it.
Bridge Approach Section/ Special Bridge Approach Section	Typically used when semi-rigid guardrail is transitioned to a bridge rail on approach to a bridge.	Transitions from a semi-rigid guardrail section (W-Beam) to a rigid barrier section (concrete bridge rail).
Bullnose Median Barrier	Used in medians to shield motorists from sign bases, bridge ends, bridge piers, etc.	Requires 66 feet minimum clearance from the tip of the bullnose to the fixed object. The approaching terrain should be graded 1:10 or flatter for 60 feet prior to the bullnose.

Note: For additional information, see TABLE 5-3 of the Roadside Design Guide (Ref. 9.1).

Exhibit 9.2 Nebraska Barrier Summary

3. GUARDRAIL DESIGN PROCEDURES

Once it has been determined that guardrail is the appropriate solution for a given location, its placement, length, type, etc. must be determined. The required length of a guardrail installation is a function of several variables, including:

- Design speed
- Design year ADT
- Runout length
- Lateral extent of the obstacle
- The tangent length of guardrail upstream from the obstacle
- The guardrail's lateral distance from the edge of the traveled way
- The flare rate for the specific type of guardrail installation

The following steps should be followed in guardrail design:

1. Determine the runout length and the lateral extent of the obstacle (See Section 3.A of this chapter).
2. Plot the runout path (See Section 3.B of this chapter).
3. Determine the appropriate guardrail flare rate (See Section 3.C of this chapter).
4. Select the guardrail components (See Section 3.D of this chapter).
5. Graphically locate the guardrail components on the plan (See Section 3.E of this chapter).
6. Design the earthwork around the guardrail (See Section 3.F of this chapter).
7. Determine the details of surfacing under guardrail (See Section 3.G of this chapter).
8. Determine the pay item quantities (See Section 9 of this chapter).

These steps are expanded upon in the following sections.

3.A Determine Runout Length & Lateral Extent of the Obstacle

Runout Length: The distance used to graphically determine the required length of a barrier. The runout length is measured along the edge of the lane from where a vehicle leaves the roadway to the obstacle being shielded as measured along the outside edge of the through travel lane. The runout length may be determined based on the design speed and traffic volume using EXHIBIT 9.3.

Design Speed (mph)	Runout Length (L _R) for Given Traffic Volume (ADT)			
	Over 10,000 veh/ day	5000 to 10,000 veh/ day	1000 to 5000 veh/ day	Under 1000 veh/ day
80	470 feet	430 feet	380 feet	330 feet
70	360 feet	330 feet	290 feet	250 feet
60	300 feet	250 feet	210 feet	200 feet
50	230 feet	190 feet	160 feet	150 feet
40	160 feet	130 feet	110 feet	100 feet
30	110 feet	90 feet	80 feet	70 feet

Exhibit 9.3 Runout Length Values
 (Source: Roadside Design Guide, Ref. 9.1)

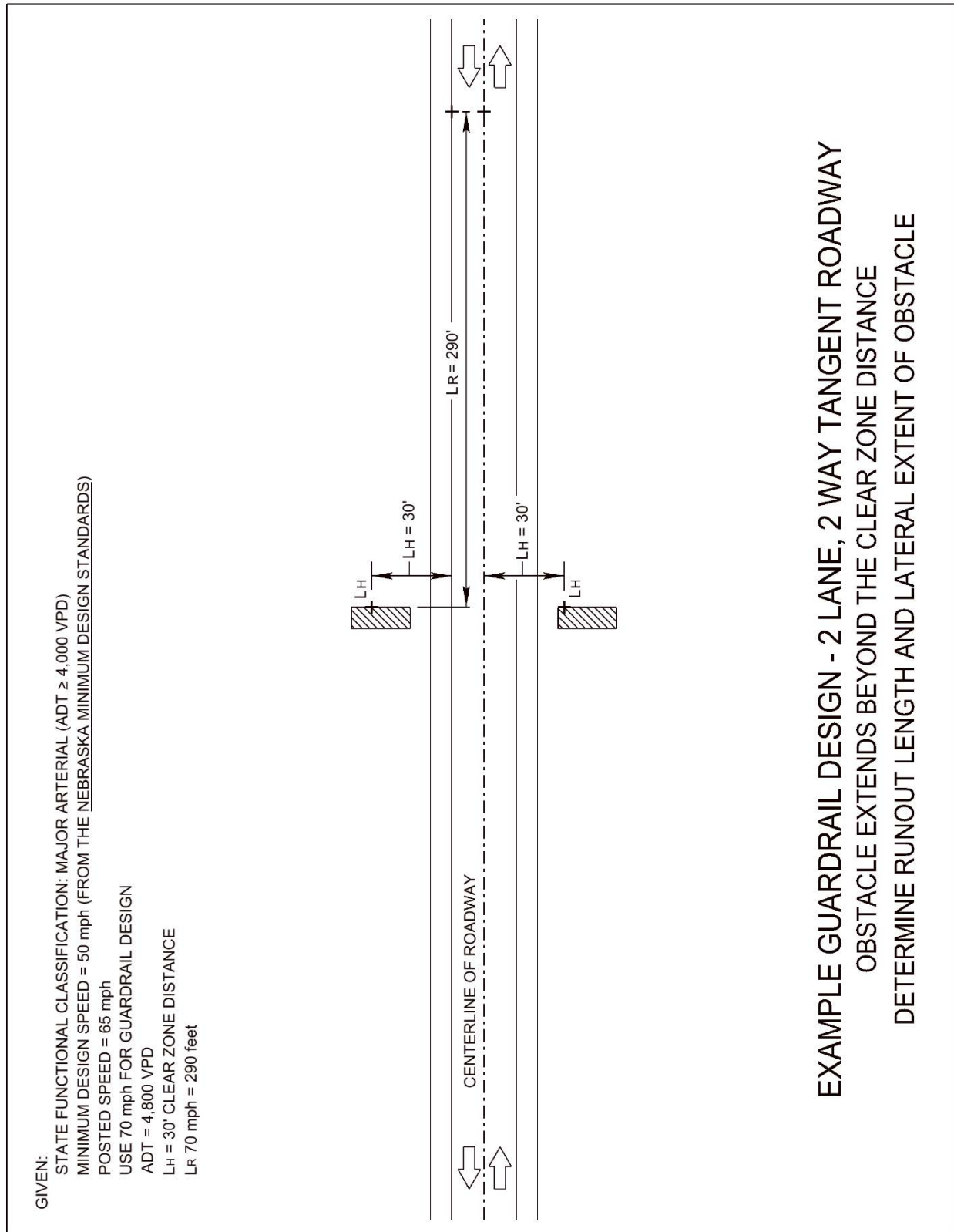
Lateral Extent of the Obstacle: The distance from the edge of the traveled way to the far side of a fixed obstacle. If the obstacle extends beyond the clear-zone distance the lateral extent of the obstacle is measured to the clear-zone distance.

The clear-zone distance listed in the *MDS* (Ref. 9.2) also applies to curved roadway segments in the following cases:

- When the obstacle is located outside a curve with a radius greater than 2,950 feet and there is no crash history
- When the obstacle is located inside the curve

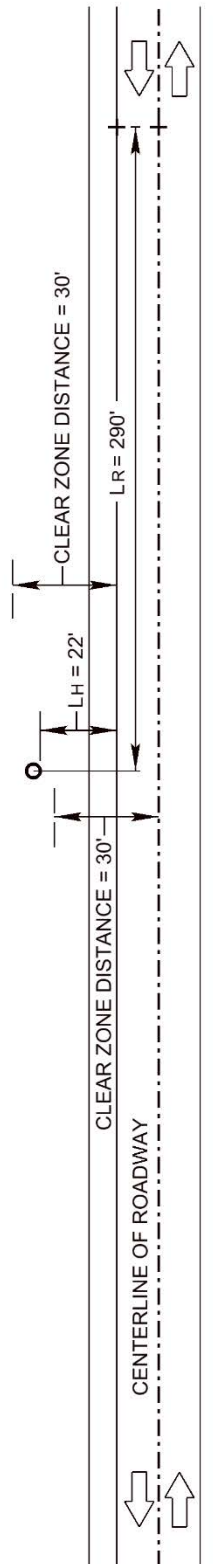
When the obstacle is located on the outside of a curve with a radius of 2,950 feet or less, the clear-zone distance for the tangent roadway may be multiplied by the appropriate curve correction factor to arrive at an adjusted clear-zone distance to be used in plotting the runout path. For additional information see Section 3.B of this chapter and **TABLE 3-2** of the Roadside Design Guide (Ref. 9.1).

On two-way two-lane roadways guardrail is typically used to shield opposing traffic at bridge rails. The same guardrail design procedures are used for the opposing traffic but the lateral extent of the obstacle and the runout length will be measured from the centerline of the two-way roadway (See EXHIBIT 9.4).



**Exhibit 9.4a Determine the Runout Length & Lateral Extent of Obstacle
 (Obstacle Extends Beyond the Clear Zone Distance)**

GIVEN:
 STATE FUNCTIONAL CLASSIFICATION: MAJOR ARTERIAL (ADT \geq 4,000 VPD)
 MINIMUM DESIGN SPEED = 50 mph (FROM THE NEBRASKA MINIMUM DESIGN STANDARDS)
 POSTED SPEED = 65 mph
 USE 70 mph FOR GUARDRAIL DESIGN
 ADT = 4,800 VPD
 L+H RIGHT LANE = 30' CLEAR ZONE DISTANCE (OBSTACLE BEYOND CLEAR ZONE)
 L+H LEFT LANE = 22'
 L+R 70 mph = 290 feet



EXAMPLE GUARDRAIL DESIGN - 2 LANE, 2 WAY TANGENT ROADWAY
OBSTACLE INSIDE CLEAR ZONE DISTANCE
DETERMINE RUNOUT LENGTH AND LATERAL EXTENT OF OBSTACLE

Exhibit 9.4b Determine the Runout Length & Lateral Extent of Obstacle (Obstacle Inside Clear Zone Distance)

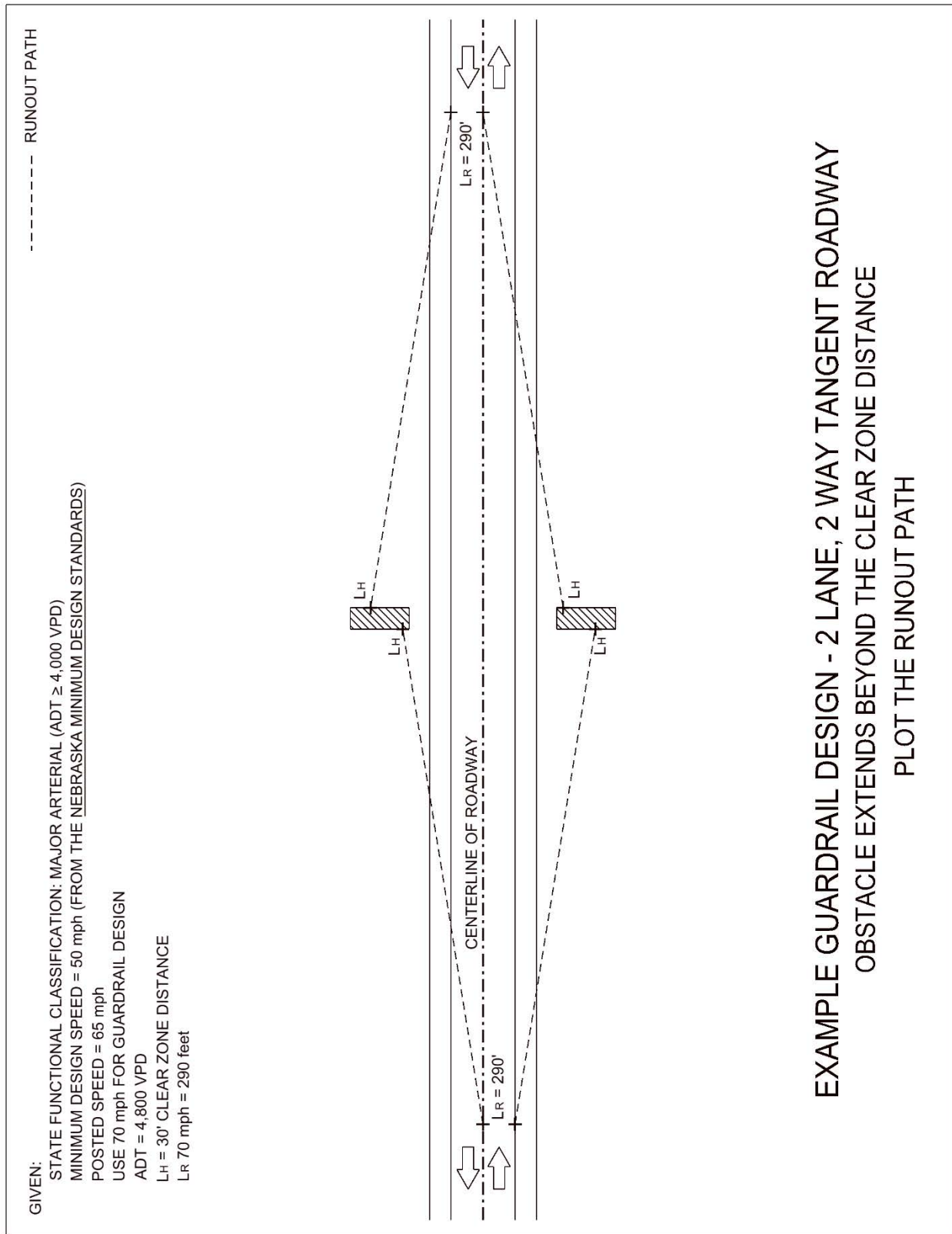
3.B Plot the Runout Path

On tangent roadway segments, the runout path runs from the lateral extent of the obstacle to a point on the outside edge of the nearest driving lane which is at the runout length distance from the obstacle as measured along the edge of the lane (See [EXHIBIT 9.5](#)). The same procedure should be used on curved roadway segments where the curve radius is greater than 2,950 feet and for obstacles on the inside of the curve (See [EXHIBIT 9.7](#)).

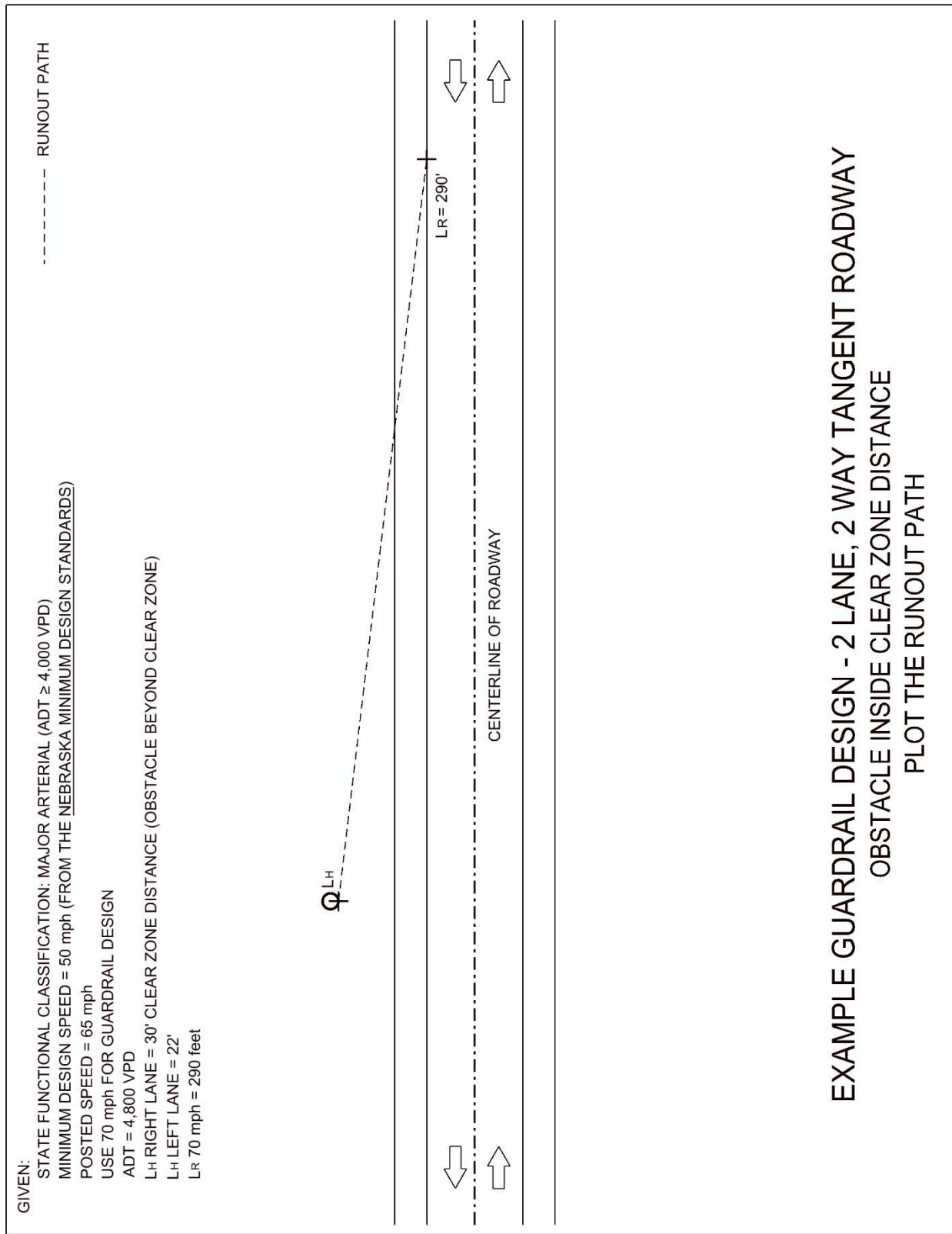
On curves with a radius of 2,950 feet or less, the runout path is plotted tangent to the outside edge of the driving lane so that it intersects the obstacle at the adjusted lateral extent of the obstacle (See Section 3.A of this chapter and [EXHIBIT 9.8](#)).

For MGS, W-beam, and Thrie-beam guardrail installations, a portion of the guardrail end treatment will not be included in the length of need. The runout path must intersect these end treatments at the beginning of length of need point as specified by the end treatment's manufacturer (See [EXHIBIT 9.6](#)).

For a low-tension cable guardrail installation, the runout path must intersect the guardrail at a distance of 15 feet or more from the end post of the in-line terminal anchorage system when used to shield a fixed object (See [EXHIBIT 9.9](#)).



**Exhibit 9.5a Plot the Runout Path
 (Obstacle Extends Beyond the Clear Zone Distance)**



**Exhibit 9.5b Plot the Runout Path
 (Obstacle Inside Clear Zone Distance)**

3.C Determine the Appropriate Flare Rate(s)

Typically, flare is used in guardrail installations to place the terminal section at a greater distance from the roadway and to shorten the required length of the barrier. Flare rate is a function of design speed and barrier type.

- A 25:1 flare rate is generally used for a Guardrail End Treatment, Type I (primarily installed with Midwest Guardrail System (MGS) and W-beam guardrail on multi-lane divided roadways)
- A 15:1 flare is used for a Guardrail End Treatment, Type II (generally used on MGS and W-beam guardrail on two-lane, two-way roadways).

Parallel installations or flatter flare rates are often used on projects with right-of-way constraints, to reduce environmental impacts, to reduce impacts to utilities, and/ or where a limited amount of earthwork is desired. A parallel installation or a flatter flare rate increases the required length of the barrier.

The *Standard Plans* (Ref. 9.3), Standard Plan 743, includes guardrail post locations for the various flare rates.

3.D Select the Guardrail Components

Factors influencing guardrail selection include but are not limited to:

- Design speed
- Design year ADT
- Length and lateral offset of the obstacle
- Roadway geometry
- Median width (consider back-side impacts)
- Allowable deflection distance
- Cost
- The guardrail's lateral distance from the edge of the traveled way
- The flare rate for the specific type of guardrail installation

The following guidelines should be followed:

- Guardrail, when justified, should be connected to concrete bridge rail with an appropriate transition section (See Section 5 of this chapter). MGS or W-beam guardrail may be used on the off-end of one-way bridges when an obstacle is required to be shielded.
- MGS, W-beam, and Thrie-beam guardrail may be designed in multiples of 6.25 feet due to site restrictions, if that satisfies the required runout length.
- Use the appropriate terminal sections based on:
 1. Flare rate,
 2. The guardrail system,
 3. The roadway classification,
 4. The design speed, and
 5. **District** preference.

3.D.1 Deflection Distance

Selection and placement of guardrail is a function of the distance it will deflect upon impact. If the guardrail is shielding a rigid object, the distance between the guardrail and the object must be sufficient to avoid a vehicle contacting the object. Guardrail may not function properly in protecting traffic from a rigid object if the guardrail post(s) come in contact with the obstacle. See **TABLE 5-6** of the Roadside Design Guide (Ref. 9.1) for the required guardrail clearances and deflections.

- Low-tension cable guardrail deflects the greatest distance, by as much as 11.5 feet in crash testing. Low-tension cable guardrail should be designed with a 12 feet minimum deflection.
- High-tension cable guardrail systems have lower deflection distances, seven feet to nine feet in crash testing.
- Deflection characteristics of semi-rigid systems (MGS, W-beam, or Thrie-beam guardrail) vary.
- Concrete (rigid) barriers are designed for virtually no deflection and may be used where space is limited between the obstacle and the travel lanes.

See the Roadside Design Guide (Ref. 9.1), Section 5.5.2, “Barrier Deflection Characteristics” for further information.

3.E Graphically Locate the Guardrail on the Plan

The designer should lay out the guardrail components on the plan (See EXHIBIT 9.6). For MGS, W-beam, and Thrie-beam installations, the components typically include the bridge approach section, the appropriate guardrail radius section for the design flare rate, the tangent guardrail section, and the applicable guardrail end treatment(s) (See Section 4 of this chapter). The runout path will intersect the guardrail, at a minimum, at the beginning of length of need point as specified by the end treatment’s manufacturer.

Cable guardrail installation components are the cable guardrail and the terminal anchorage sections. The runout path will intersect the low-tension cable guardrail at a distance of 15 feet or greater from the end of the in-line terminal anchorage section (See EXHIBIT 9.9).

For unique installations (e.g. on a curved roadway where the guardrail is curved in the opposite direction) the designer should provide the station and offset at the ends of the guardrail and at intermediate points as appropriate.

See the *Standard Plans* (Ref. 9.3) for details of the guardrail components.

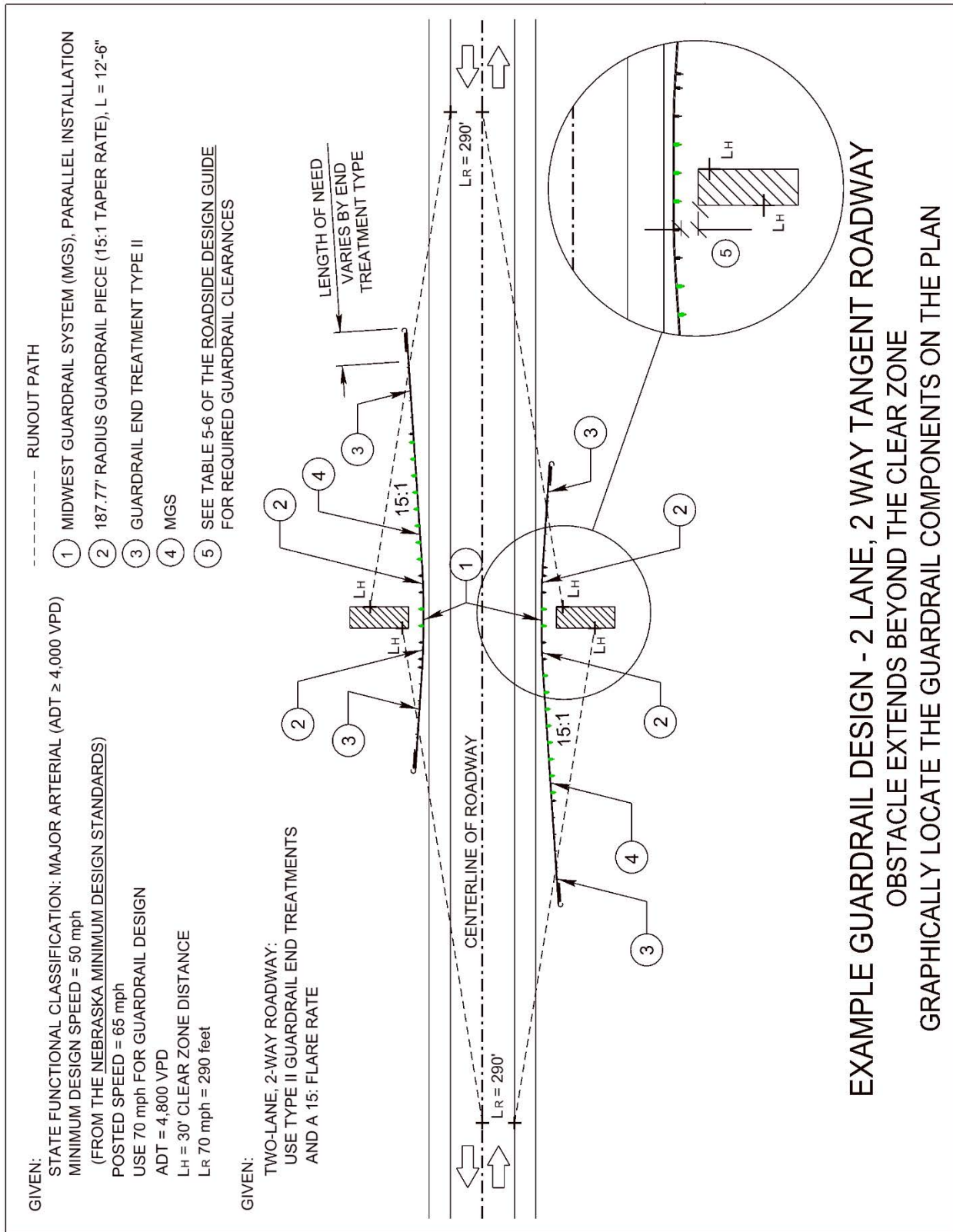


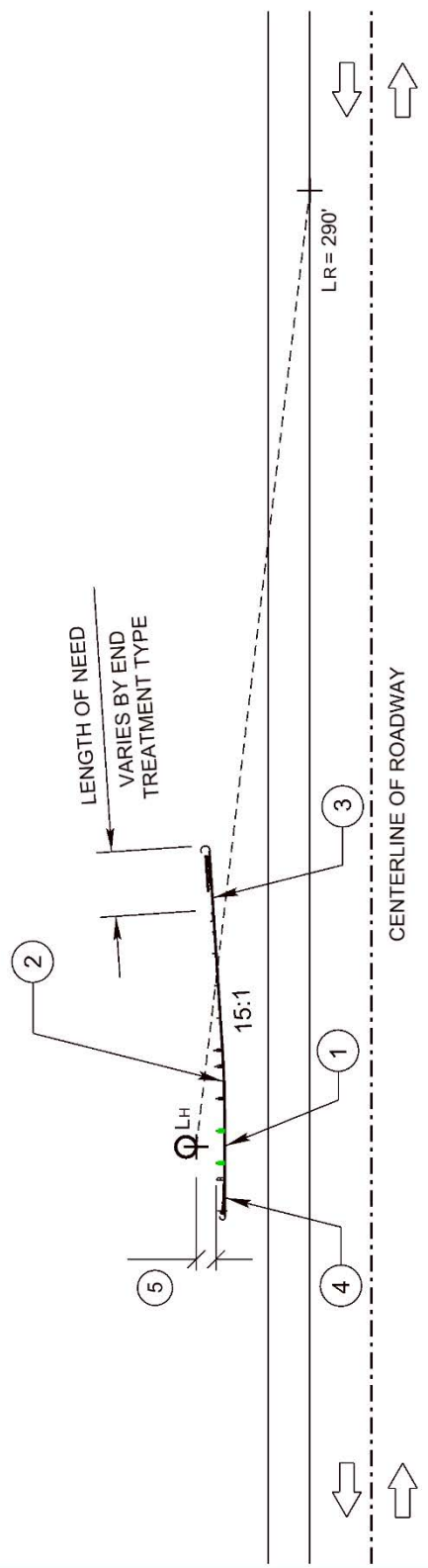
Exhibit 9.6a Graphically Locate the Guardrail Components on the Plan (Obstacle Extends Beyond the Clear Zone Distance)

GIVEN:

- STATE FUNCTIONAL CLASSIFICATION: MAJOR ARTERIAL (ADT ≥ 4,000 VPD)
- MINIMUM DESIGN SPEED = 50 mph
 (FROM THE NEBRASKA MINIMUM DESIGN STANDARDS)
- POSTED SPEED = 65 mph
- USE 70 mph FOR GUARDRAIL DESIGN
- ADT = 4,800 VPD
- L_H RIGHT LANE = 30' CLEAR ZONE DISTANCE
 (OBSTACLE BEYOND CLEAR ZONE)
- L_H LEFT LANE = 22'
- L_R 70 mph = 290 feet

- RUNOUT PATH
- ① MIDWEST GUARDRAIL SYSTEM (MGS), PARALLEL INSTALLATION
- ② 187.77' RADIUS GUARDRAIL PIECE (15:1 TAPER RATE), L = 12'-6"
- ③ GUARDRAIL END TREATMENT TYPE II
- ④ END ANCHORAGE ASSEMBLY
- ⑤ SEE TABLE 5-6 OF THE ROADSIDE DESIGN GUIDE FOR REQUIRED GUARDRAIL CLEARANCES

GIVEN:
 TWO-LANE, 2-WAY ROADWAY;
 USE 1 - TYPE II GUARDRAIL END TREATMENT,
 1- END ANCHORAGE ASSEMBLY
 AND A 15:1 FLARE RATE



EXAMPLE GUARDRAIL DESIGN - 2 LANE, 2 WAY TANGENT ROADWAY
 OBSTACLE INSIDE CLEAR ZONE DISTANCE
 GRAPHICALLY LOCATE THE GUARDRAIL COMPONENTS ON THE PLAN

Exhibit 9.6b Graphically Locate the Guardrail Components on the Plan (Obstacle Inside Clear Zone Distance)

3.F Design the Earthwork Around the Guardrail

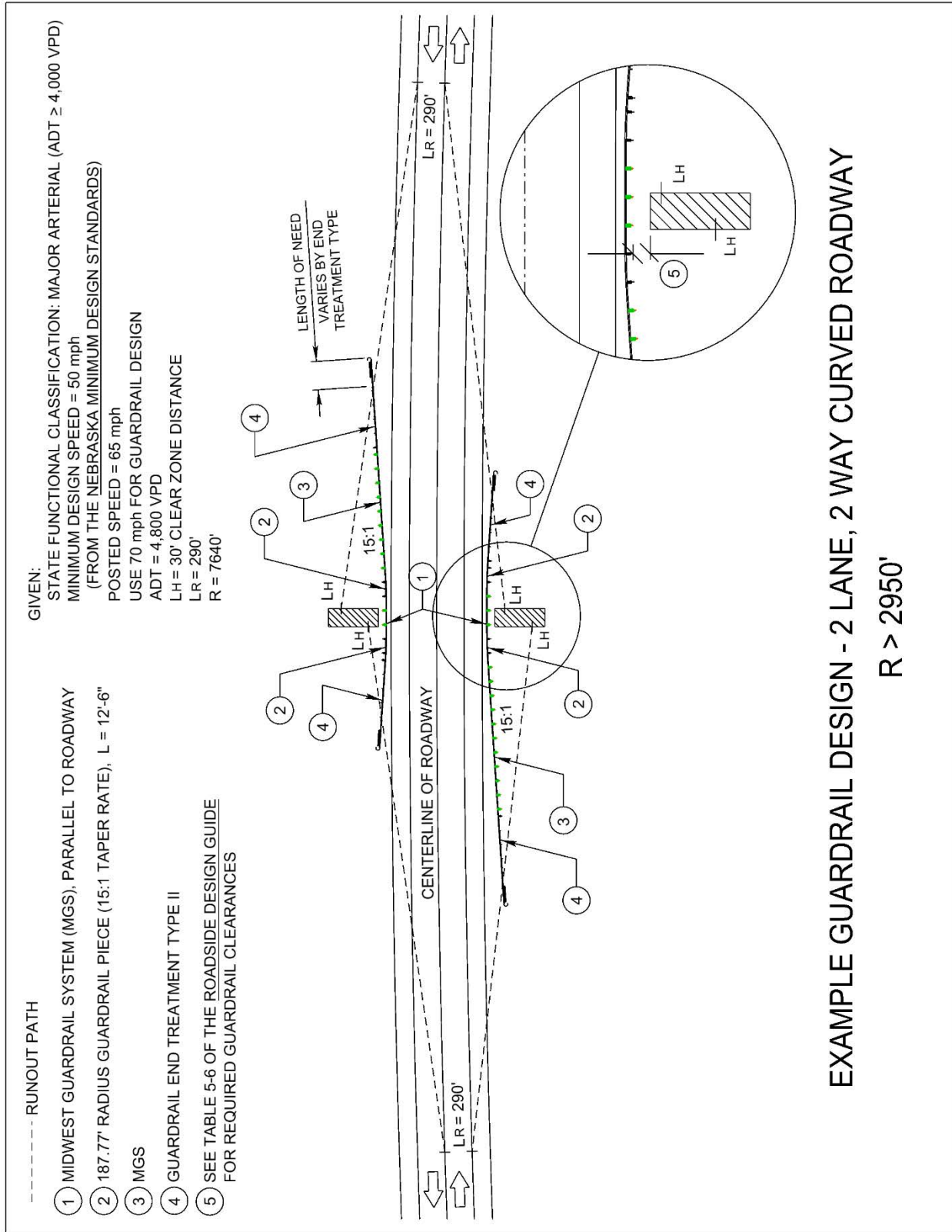
The designer should refer to the “Design Guides” section of the *Standard Plans* (Ref. 9.3) for guidance in designing earthwork for guardrail. Details of earthwork around the guardrail should be provided on guardrail plan sheets and on the project cross-sections for the benefit of the contractor and inspector (see Chapter Eleven: Highway Plans Assembly, of this manual). This earthwork will be included in the earthwork quantities.

3.G Determine the Details of Surfacing Under the Guardrail

Surfacing is placed under guardrail as a method to control weeds. The designer should consult with the **DE** or the **District Construction Engineer (DCE)** during the plan-in-hand field inspection to determine if surfacing under guardrail is desired, the choice of material to be used will be determined by the contractor. Surfacing may be concrete, asphaltic concrete, or millings. When concrete or asphaltic concrete surfacing is used the posts will be blocked out and backfilled with suitable materials (See the *Standard Plans* (Ref. 9.3), Standard Plan 743, and the Standard Specifications for Highway Construction (*Spec Book*) (Ref. 9.4) (<http://dot.nebraska.gov/media/10343/2017-specbook.pdf>).

Typical sections of asphalt surfacing under guardrail for non-curbed and curbed conditions are shown in Plan 1731 in the “Standard Details” section of the *Standard Plans* (Ref. 9.3). Designers will submit detailed plans, typical sections, and estimates for all asphalt surfacing under guardrail locations to the **Materials and Research Division (M&R)** for inclusion in the asphalt quantities; the designer is responsible for calculating concrete surfacing quantities.

Further examples of typical guardrail installations may be found in EXHIBITS 9.7 THROUGH 9.9.



**Exhibit 9.7 Example W-Beam or Thrie-Beam Guardrail Design:
 2-Lane, 2-Way Curved Roadway: R > 2950'**

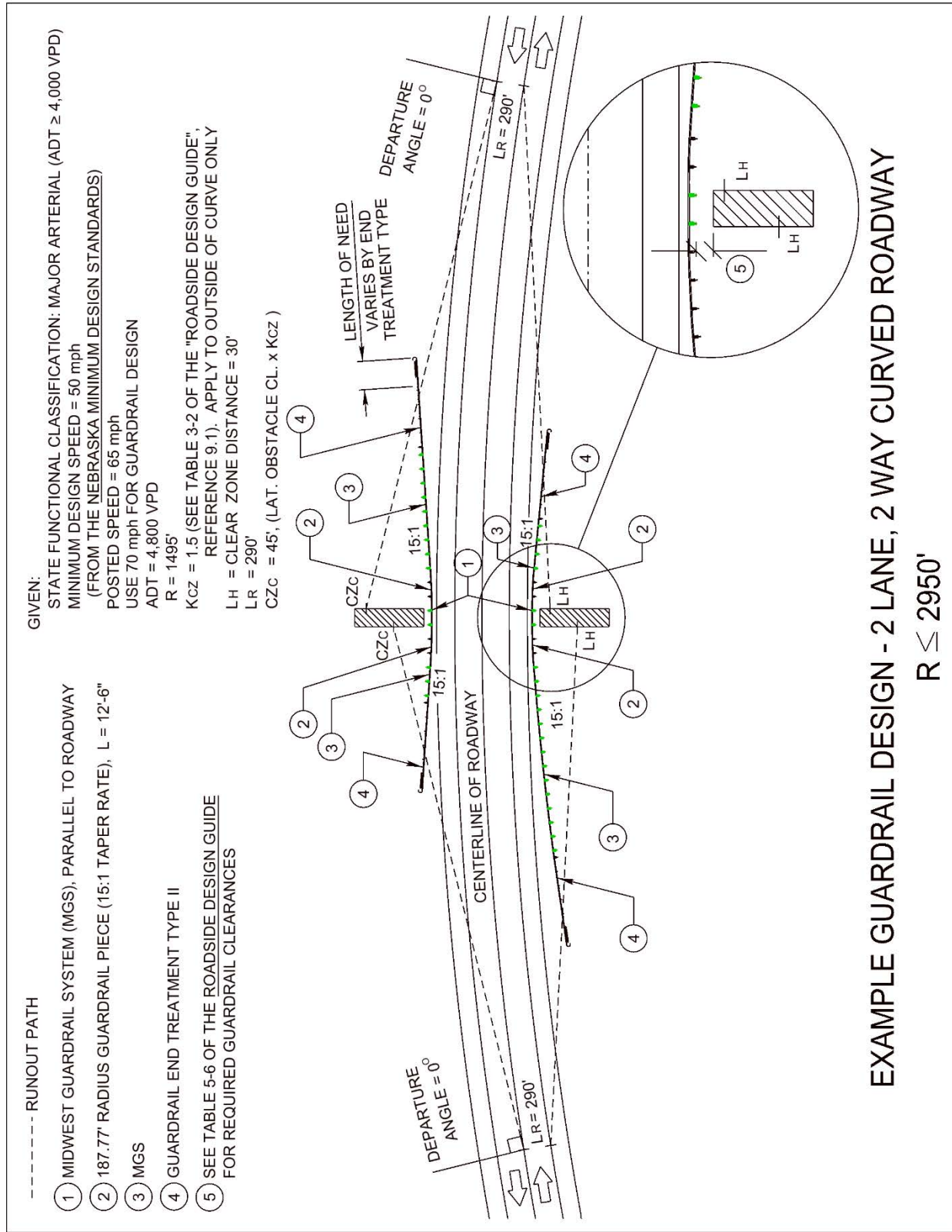
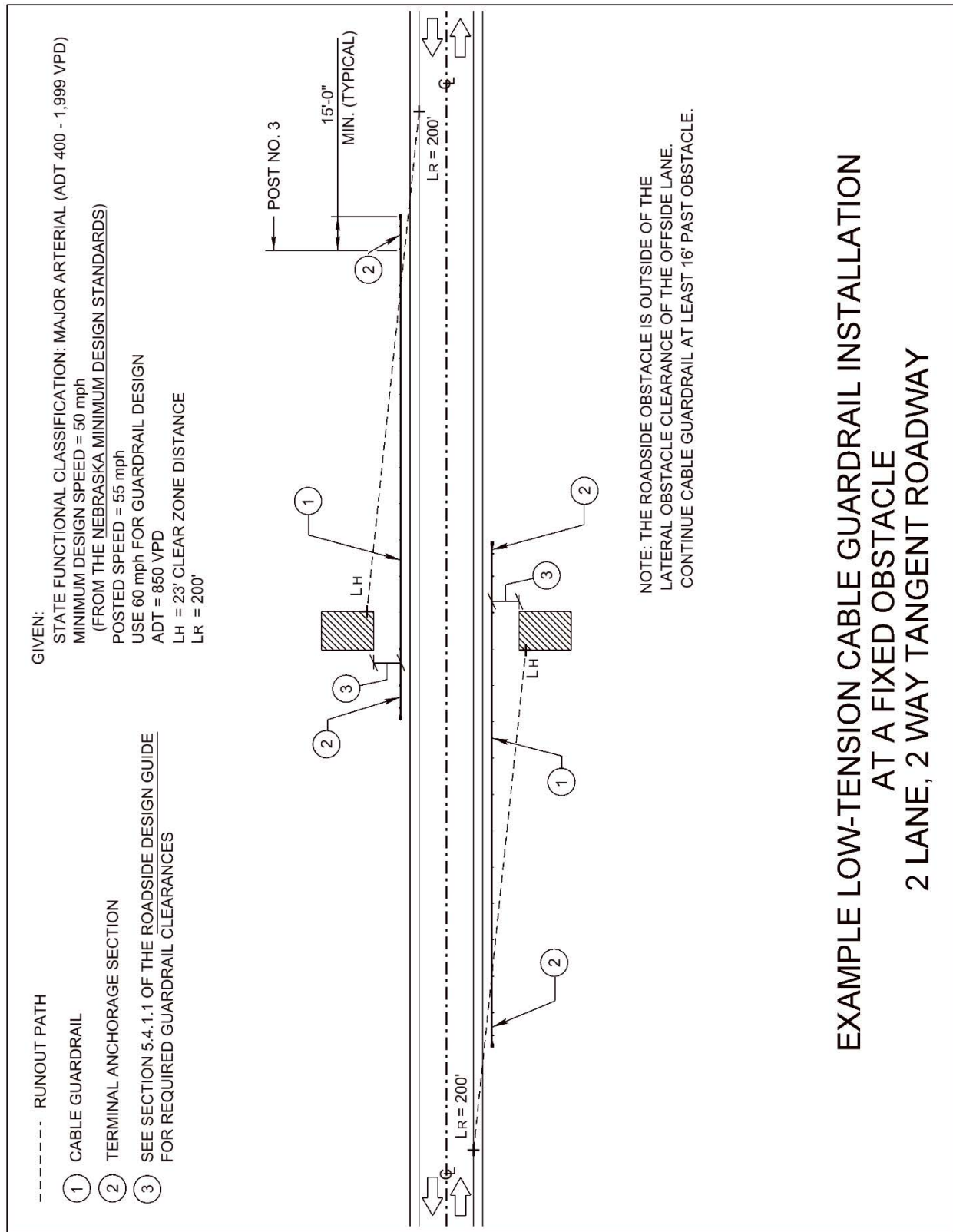


Exhibit 9.8 Example W-Beam or Thrie-Beam Guardrail Design: 2-Lane, 2-Way Curved Roadway; $R \leq 2950'$



**Exhibit 9.9 Example Low-Tension Cable Guardrail Design:
 2-Lane, 2-Way Tangent Roadway**

4. END TREATMENTS

Guardrail end treatments used in Nebraska may be found in the Design Guides section of the *Standard Plans* (Ref. 9.3).

4.A Guardrail End Treatment, Type I

A Guardrail End Treatment, Type I is Test Level 3 approved and is typically used for parallel guardrail installations or for installations with a 25:1 taper. This end treatment is used primarily for the Interstate System, freeways, and expressways.

4.B Guardrail End Treatment, Type II

A Guardrail End Treatment, Type II is Test Level 3 approved and is primarily installed on high-speed (≥ 50 mph) two-lane, two-way roadways with a guardrail installation with a 15:1 taper.

4.C Guardrail End Treatment, Type TL2 (for Low-Speed Roadways)

The Guardrail End Treatment, Type TL2 is Test Level 2 approved and is installed on low-speed (≤ 45 mph) two-lane, two-way roadways with guardrail installations, typically with a 25:1 taper. The minimum guardrail installation at a low-speed bridge connection consists of the Guardrail End Treatment, Type TL2 connected directly to a Bridge Approach Section, Type TL2. See the *Standard Plans* (Ref. 9.3) for details.

4.D End Anchorage Assembly

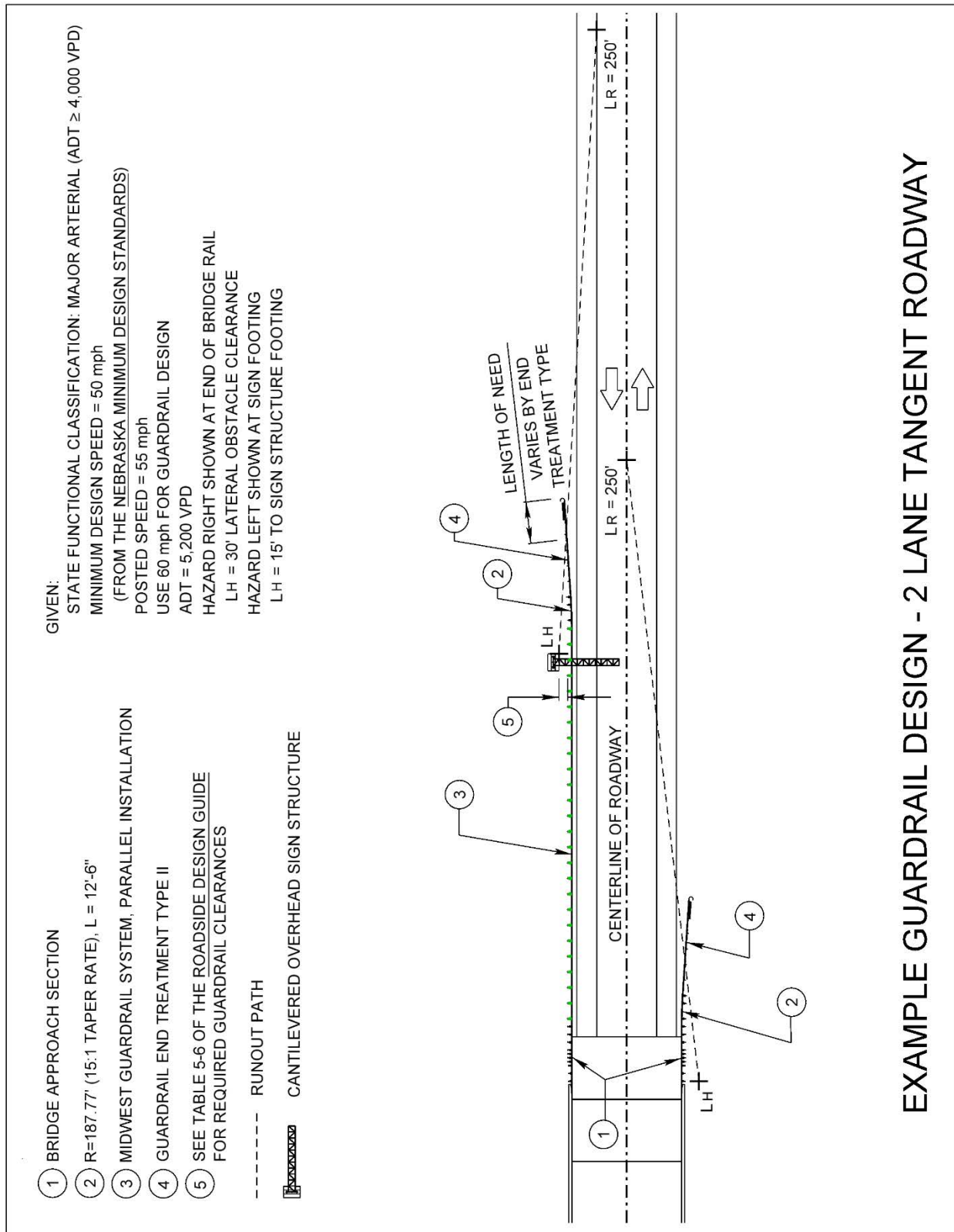
The end anchorage assembly is permitted on the trailing ends of guardrail installations that are not exposed to oncoming traffic and on curved beam guardrail installations (with control releasing terminal posts) terminating on driveways to provide tension to the guardrail system. See the *Standard Plans* (Ref. 9.3), Standard Plan 745, for details.

4.E Bullnose

See Section 6.B of this chapter.

5. BRIDGE APPROACH SECTIONS

The bridge approach section is a transition section used where semi-rigid guardrail joins to a rigid bridge rail. Transition sections are designed to produce a gradual transition between the deflection capabilities of the two types of rail, reducing the potential of a vehicle pocketing, snagging, or penetrating the rail in the transition area. The bridge approach sections for both high-speed installations (≥ 50 mph, 25 feet in length) and low-speed installations (≤ 45 mph, 9 feet - 4.5 inches in length) in Nebraska may be found in the *Standard Plans* (Ref. 9.3). For examples of typical guardrail installations at a bridge, see EXHIBITS 9.10 THROUGH 9.12 AND EXHIBITS 9.15 & 9.16.



EXAMPLE GUARDRAIL DESIGN - 2 LANE TANGENT ROADWAY

Exhibit 9.10 Example Guardrail Design at a Bridge:
 2-Lane, 2-Way Tangent Roadway

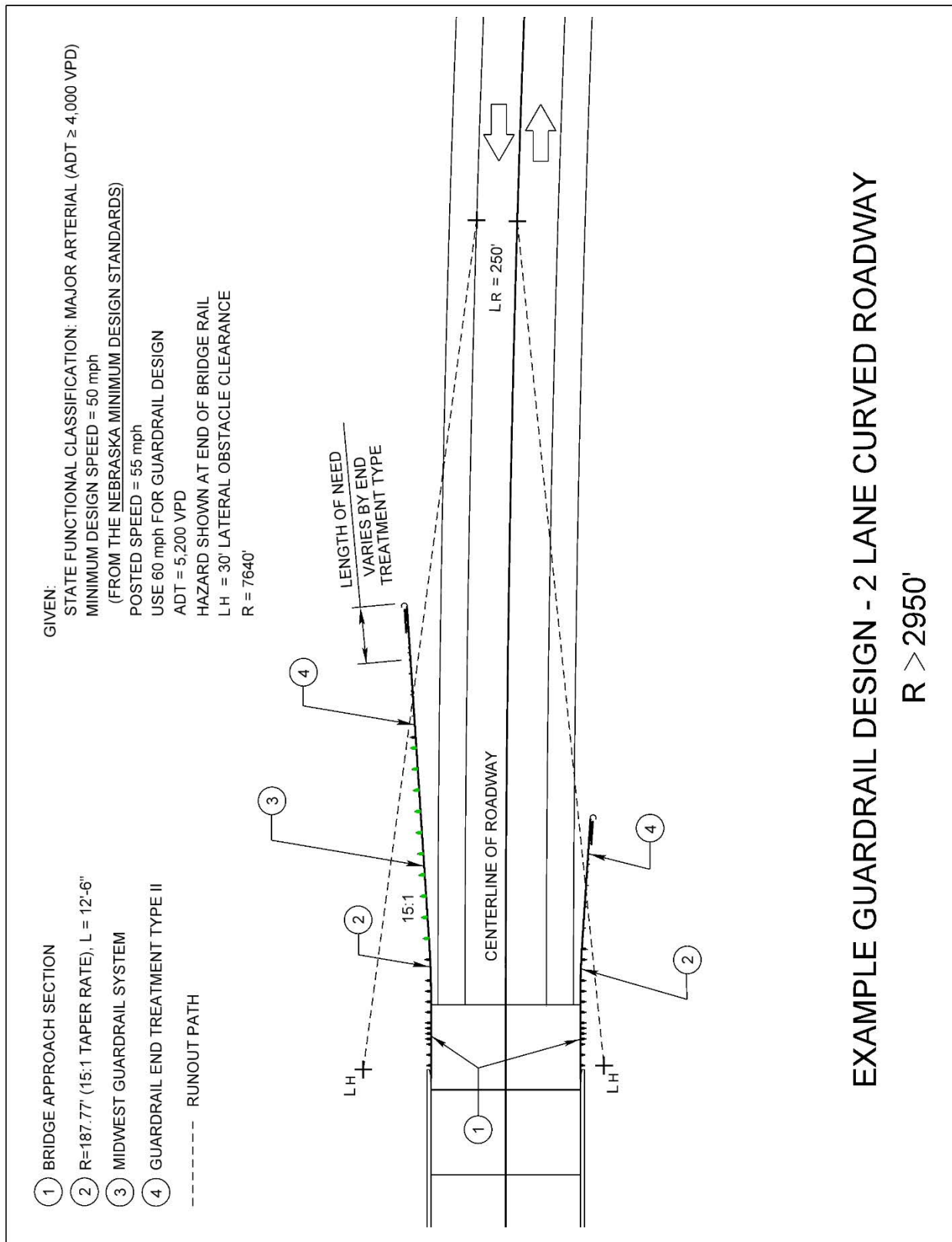
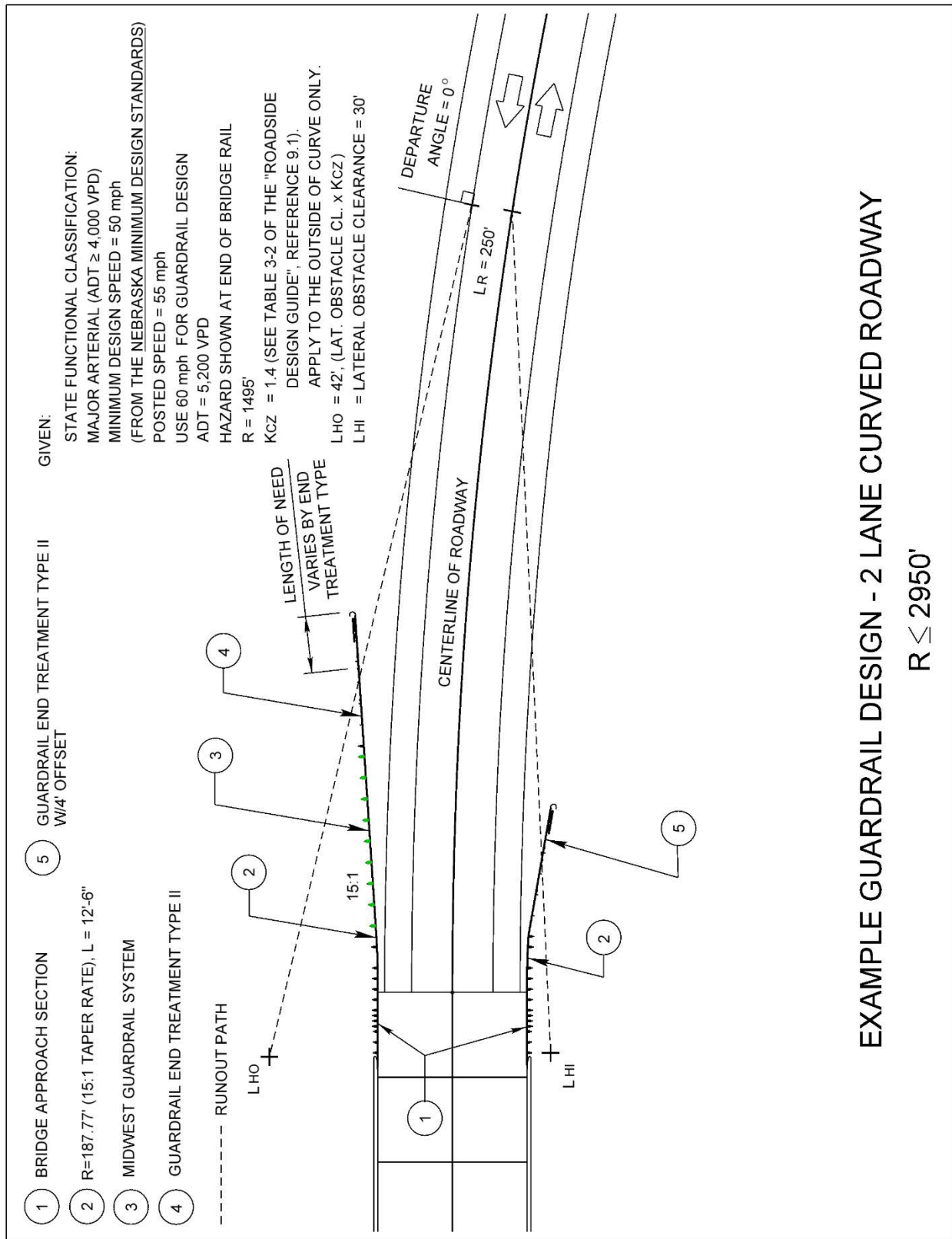


Exhibit 9.11 Example Guardrail Design at a Bridge:
 2-Lane, 2-Way Curved Roadway; R > 2950'



**Exhibit 9.12 Example Guardrail Design at a Bridge:
 2-Lane, 2-Way Curved Roadway; $R \leq 2950'$**

6. MEDIAN BARRIERS

A barrier is placed in the median of a divided highway to reduce crossover head-on crashes and to redirect vehicles striking from either side of the barrier. The design, height, and lateral placement of the median barrier is critical for proper performance.

- 1) **NDOT** follows the guidance found in Chapter 6 of the Roadside Design Guide (Ref. 9.1).
- 2) EXHIBIT 9.13 Presents Benefit/Cost ratios for the installation of cable guardrail median barriers in relatively flat, unobstructed medians. These criteria may be used in the absence of cross median crash data for a specific site.
- 3) EXHIBIT 9.14 presents guidelines for median barrier installations on high-speed controlled access roadways that have relatively flat, unobstructed medians. These criteria may be used in the absence of cross median crash data for a specific site.
- 4) For median widths between 30 feet and 50 feet, **NDOT** will analyze the crash history and determine if median barrier installation is warranted.

Median Width (ft.)	Traffic Volume at B/C =2.0 (1000 ADT)	Traffic Volume at B/C = 4.0 (1000 ADT)
10	15	17
20	19	22
30	24	28
40	31	37
50	42	51
60	60	74
70	97	121

Traffic Volumes are based on two-way traffic.

Cable barrier should be installed at a B/C ratio of 4.0 and above, may be considered at B/C ratios between 2.0 and 4.0, and is generally not cost effective at a B/C ratio below 2.0.

For additional information, refer to the Cable Median Barrier Guidelines at <https://mwrsf.unl.edu/researchhub/files/Report75/TRP-03-206-08.pdf>

Exhibit 9.13 Cable Barrier B/C Ratios

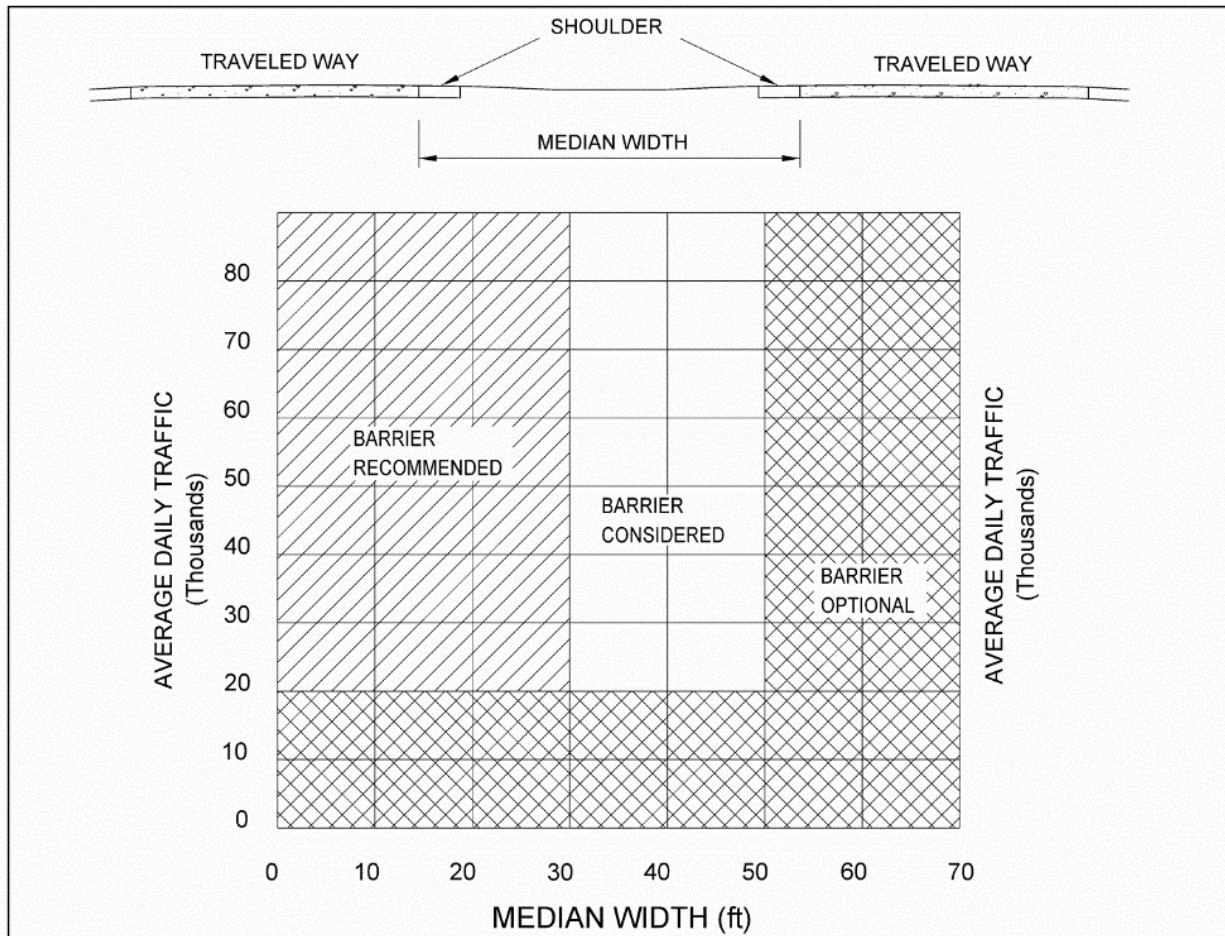


Exhibit 9.14 Guidelines for Median Barriers
 Source: Roadside Design Guide (Ref. 9.1)

6.A Median Barrier Systems

Concrete Protection Barrier

The concrete protection barrier (32 inch or 42 inch) should be used in narrow flush medians, depending upon the traffic speed, ADT, and percentage/ number of heavy truck traffic and the crash history. Both the 32 inch and 42 inch heights provide for a future three-inch overlay to be placed against the barrier. Concrete median barriers may be precast or cast in place. The barrier ends should be treated with an appropriate terminal section or tapered away beyond the clear zone. See the *Standard Plans* (Ref. 9.3), Standard Plan 870, for details.

Semi-Rigid Guardrail

Guardrail may be installed in the median to deflect vehicles from hitting specific obstacles, such as piers, and at dual bridges on divided highways. The preferred installation at a bridge in a median with a width of 40 feet or greater may include a bridge approach section, MGS, W-Beam, or Thrie-Beam guardrail, and a guardrail end treatment (See Section 4.A of this chapter and [EXHIBITS 9.15 & 9.16](#)).

The preferred installation for pier protection in a median with a width of 40 feet or greater will consist of two parallel runs of semi-rigid guardrail with one guardrail end treatment and one end anchorage assembly each, located so that the back of the end treatments are beyond the clear zone of the opposing traffic (See [EXHIBIT 9.17](#)). The **District** may want surfacing under the guardrail for weed control.

Cable Guardrail

Cable guardrail may be installed in medians which are of sufficient width to allow for the greater deflection of the cable, 12 feet for a low-tension installation. Crash tests on high-tension cable guardrail systems have exhibited reduced deflection distances, as specified by the manufacturer. The installation of high-tension cable guardrail requires **Roadway Design Engineer** approval.

Bullnose

The bullnose guardrail installation may be used on multilane divided highways to protect the motorist from hitting sign bases, bridge ends, bridge piers, or other obstacles in the median or gore area (See [EXHIBIT 9.18](#)).

When a bullnose installation is used to protect bridge ends in medians of 40 feet or less in width some **Districts** prefer to connect the bullnose installation to both of the paired parallel bridges; other **Districts** prefer the away side to be unattached so that maintenance has easy access for mowing behind the bullnose. The designer should contact the **DE** or **DCE** to ascertain the preferred installation method (See [EXHIBITS 9.19 THROUGH 9.23](#) for design examples).

Bullnose attenuators are designed so that the front end of vehicles impacting the installation head-on will be wrapped by the guardrail and will decelerate to a stop; side-impacting vehicles will be redirected. The bullnose installation shall have a minimum 66 feet of clearance from the tip of the bullnose to the fixed object. The approaching terrain should be unobstructed and graded 1:10 or flatter for a minimum of 60 feet prior to and under the bullnose for proper performance (See the *Standard Plans*, Ref. 9.3, Standard Plans 712 & 713).

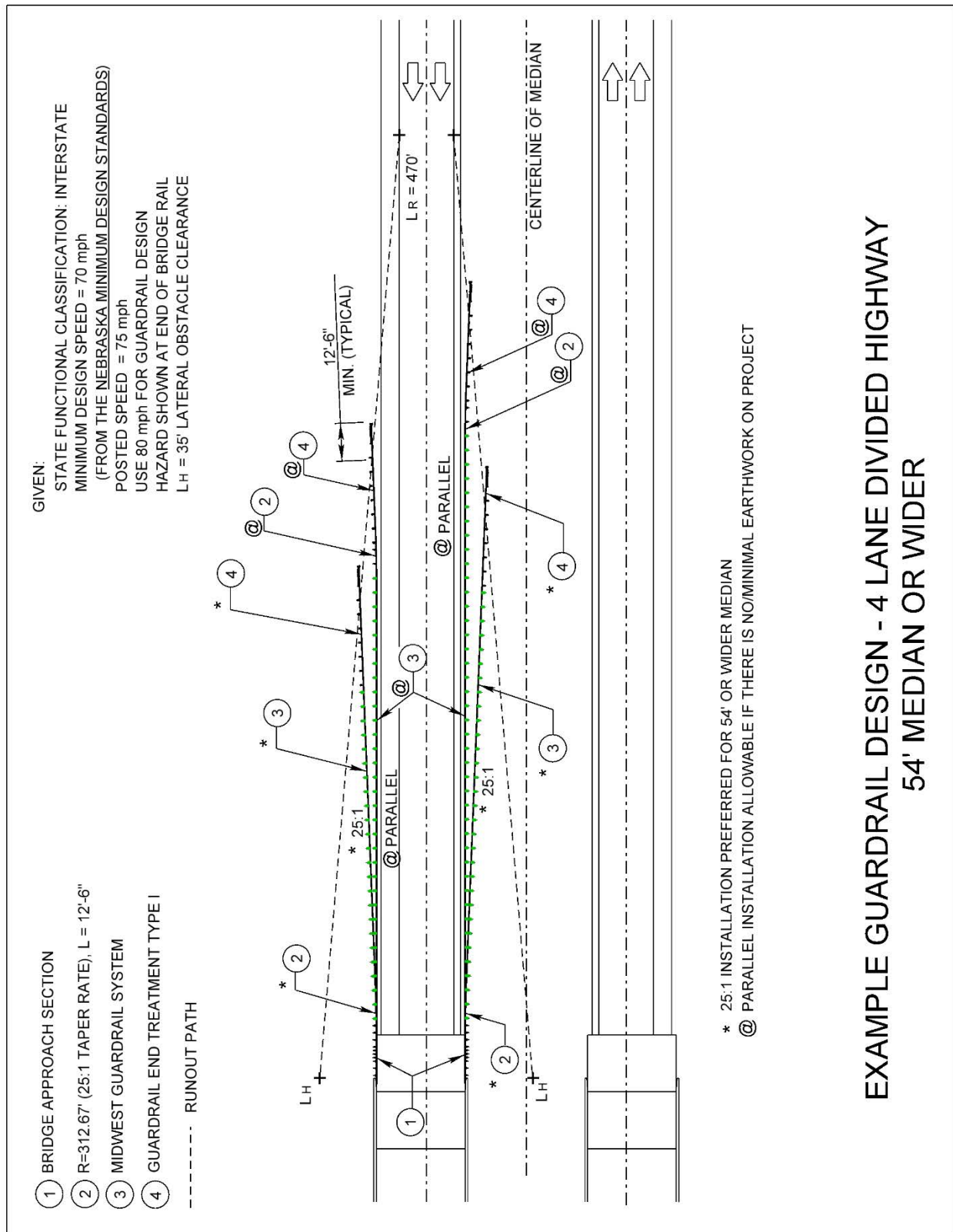


Exhibit 9.15 Example Guardrail Design – 4 Lane Divided Highway:
 54 Foot and Wider Median Width

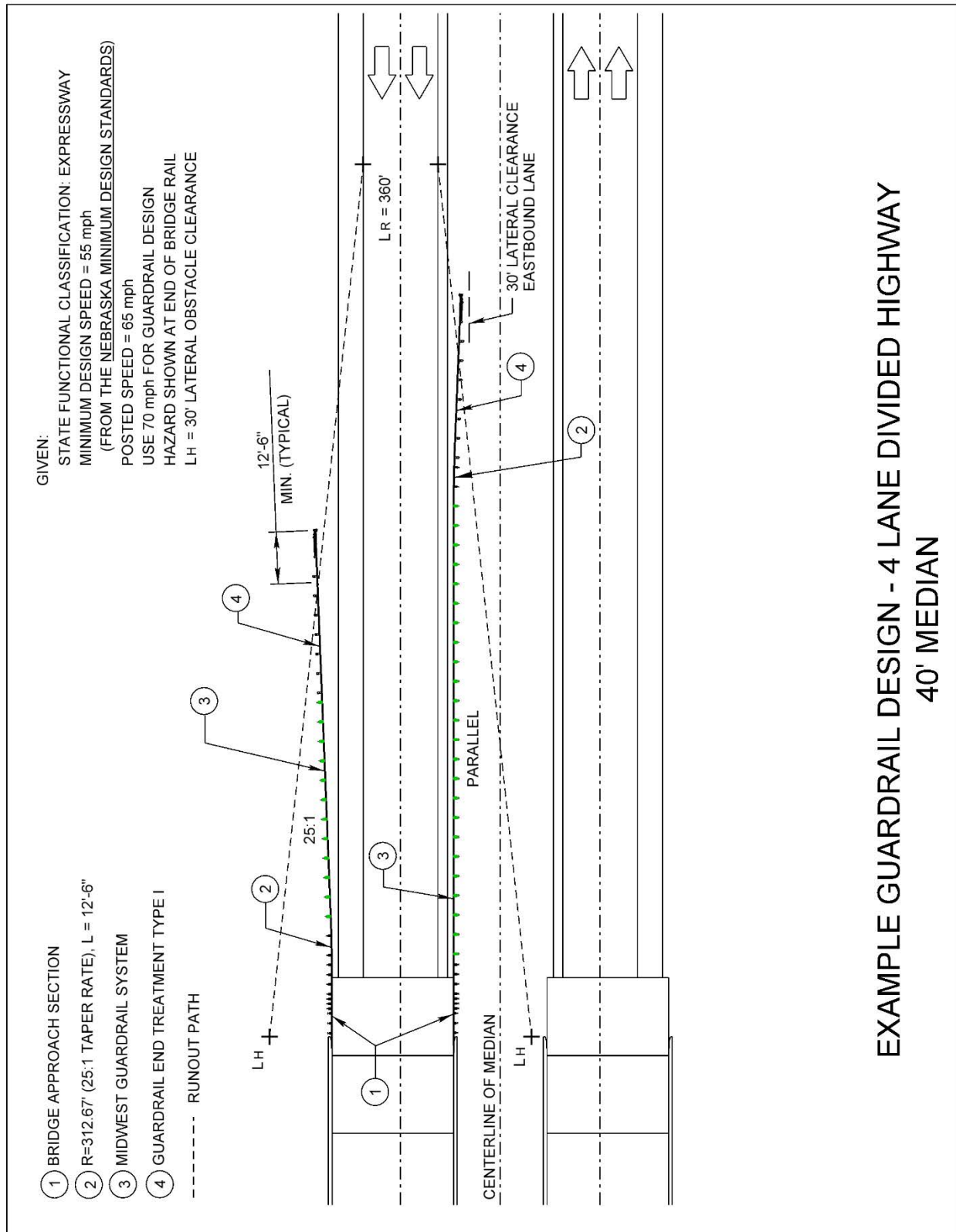


Exhibit 9.16 Example Guardrail Design – 4 Lane Divided Highway:
 40 Foot Median Width

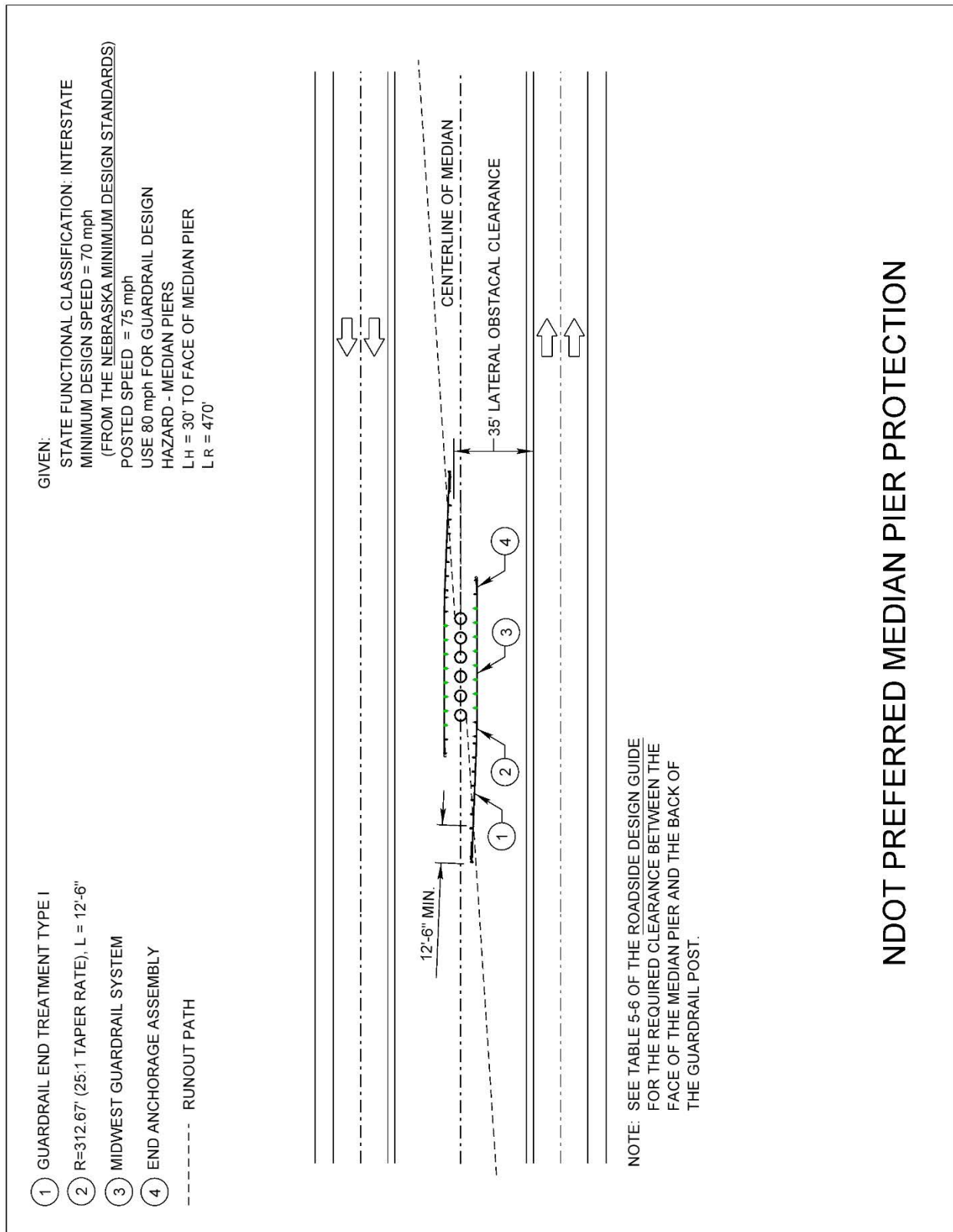


Exhibit 9.17 Example Pier Protection Guardrail Design – 4 Lane Divided Highway: 40 Foot and Wider Median Width

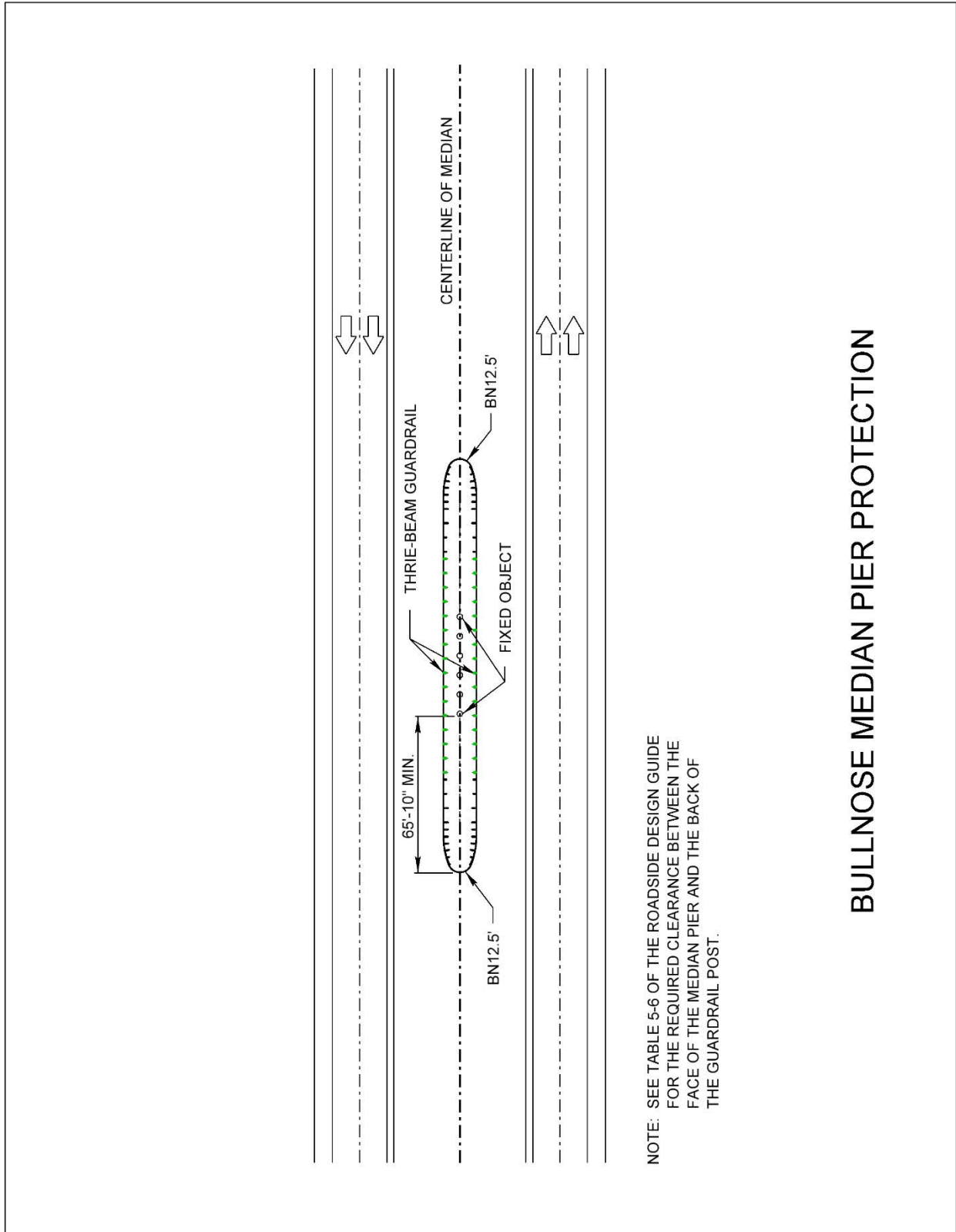
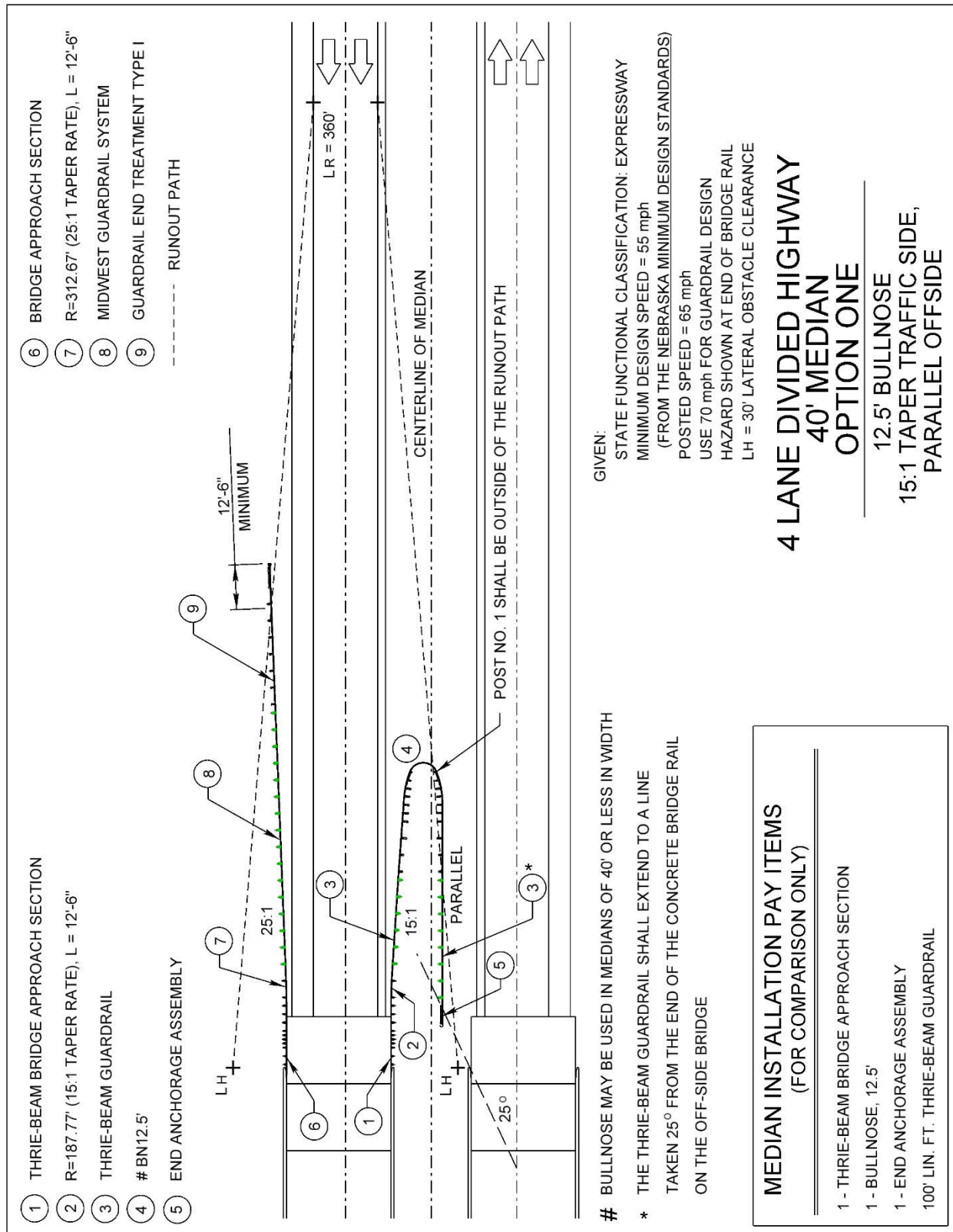


Exhibit 9.18 Example Bullnose Installation for Median Bridge Pier Protection



**Exhibit 9.19 Example Bullnose Bridge Connection in a 40 Foot Wide Median:
 Tapered Bullnose, Bridges not Connected**

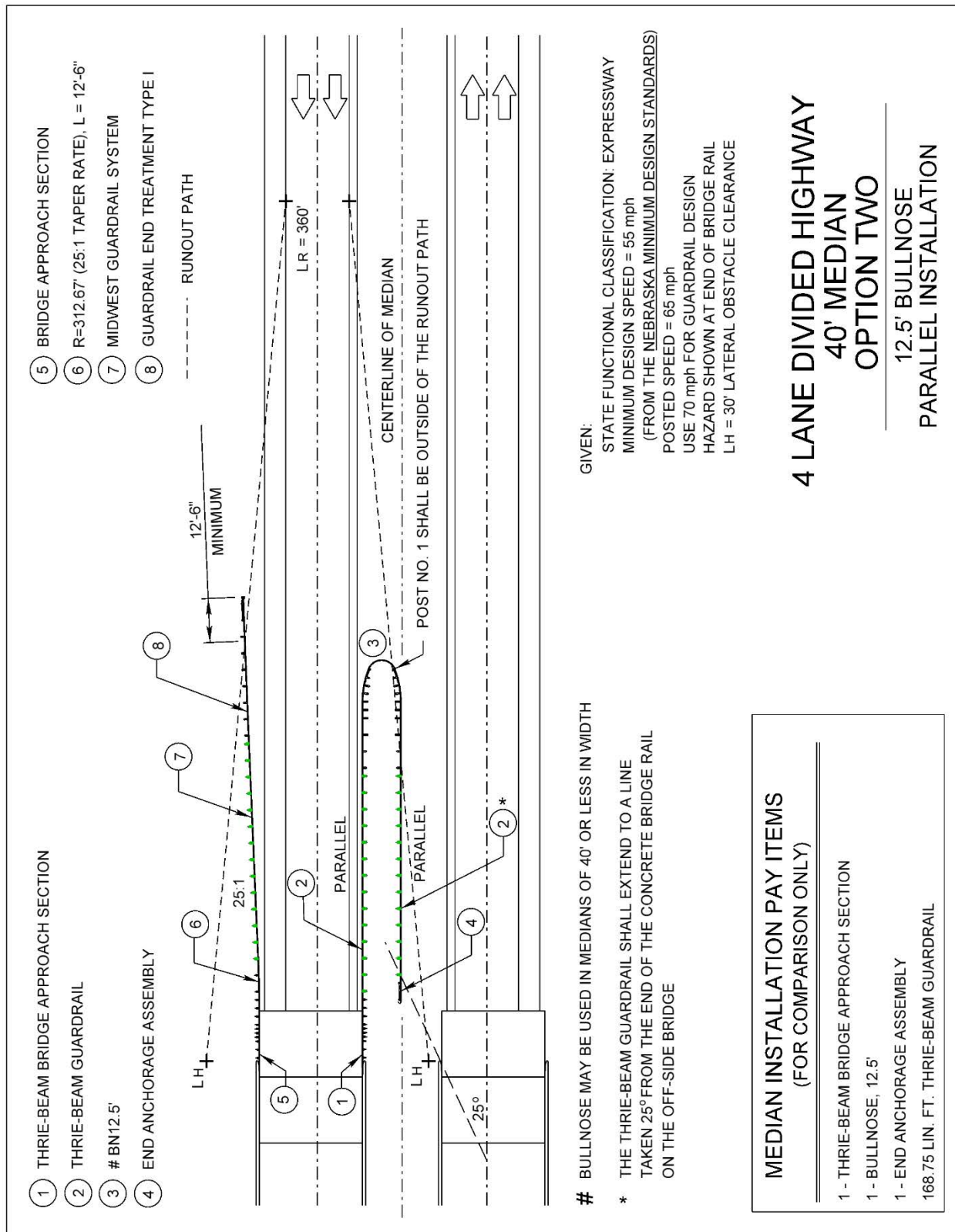
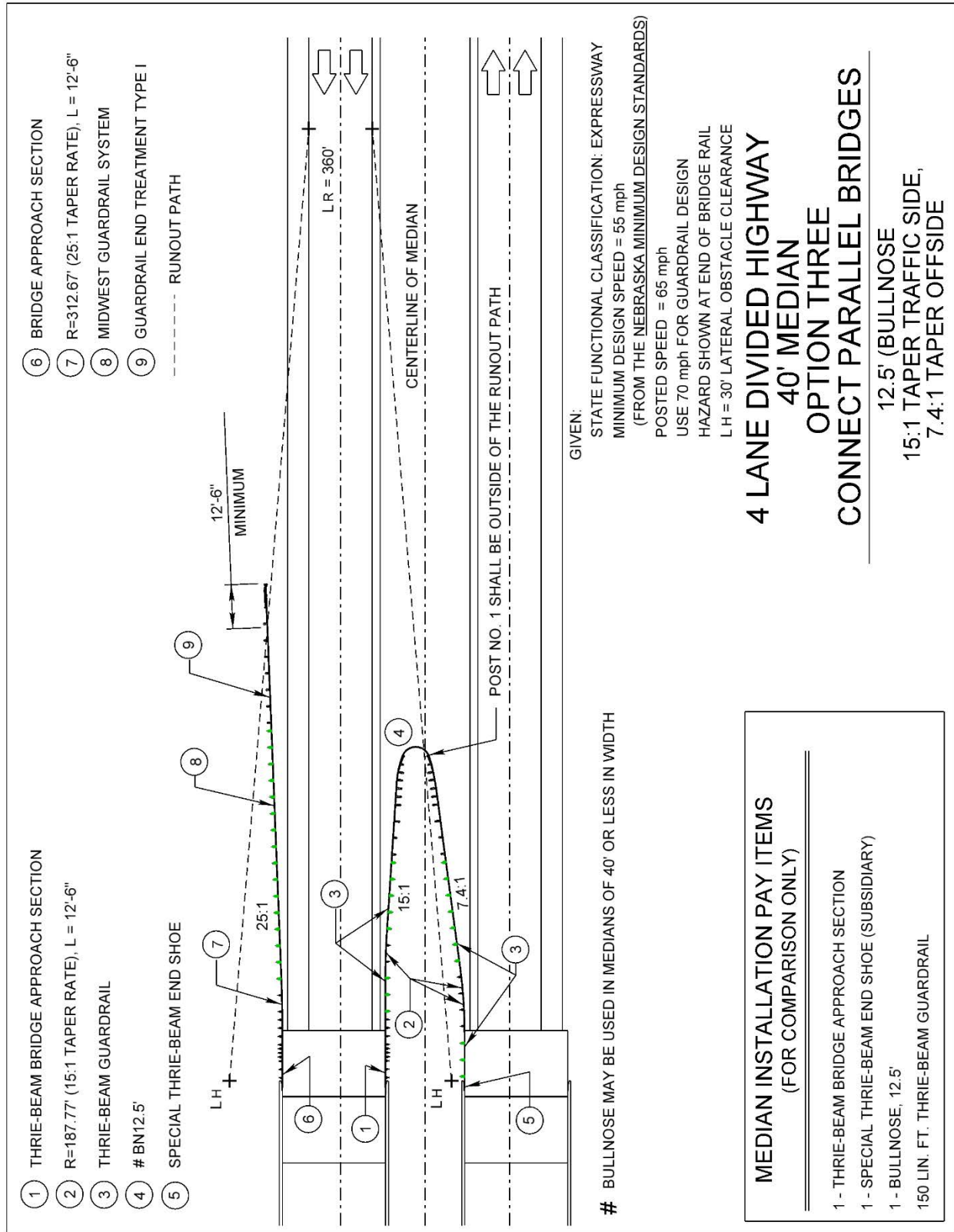


Exhibit 9.20 Example Bullnose Bridge Connection in a 40 Foot Wide Median: Parallel Bullnose, Bridges not Connected



**Exhibit 9.21 Example Bullnose Bridge Connection in a 40 Foot Wide Median:
 Tapered Bullnose, Bridges Connected**

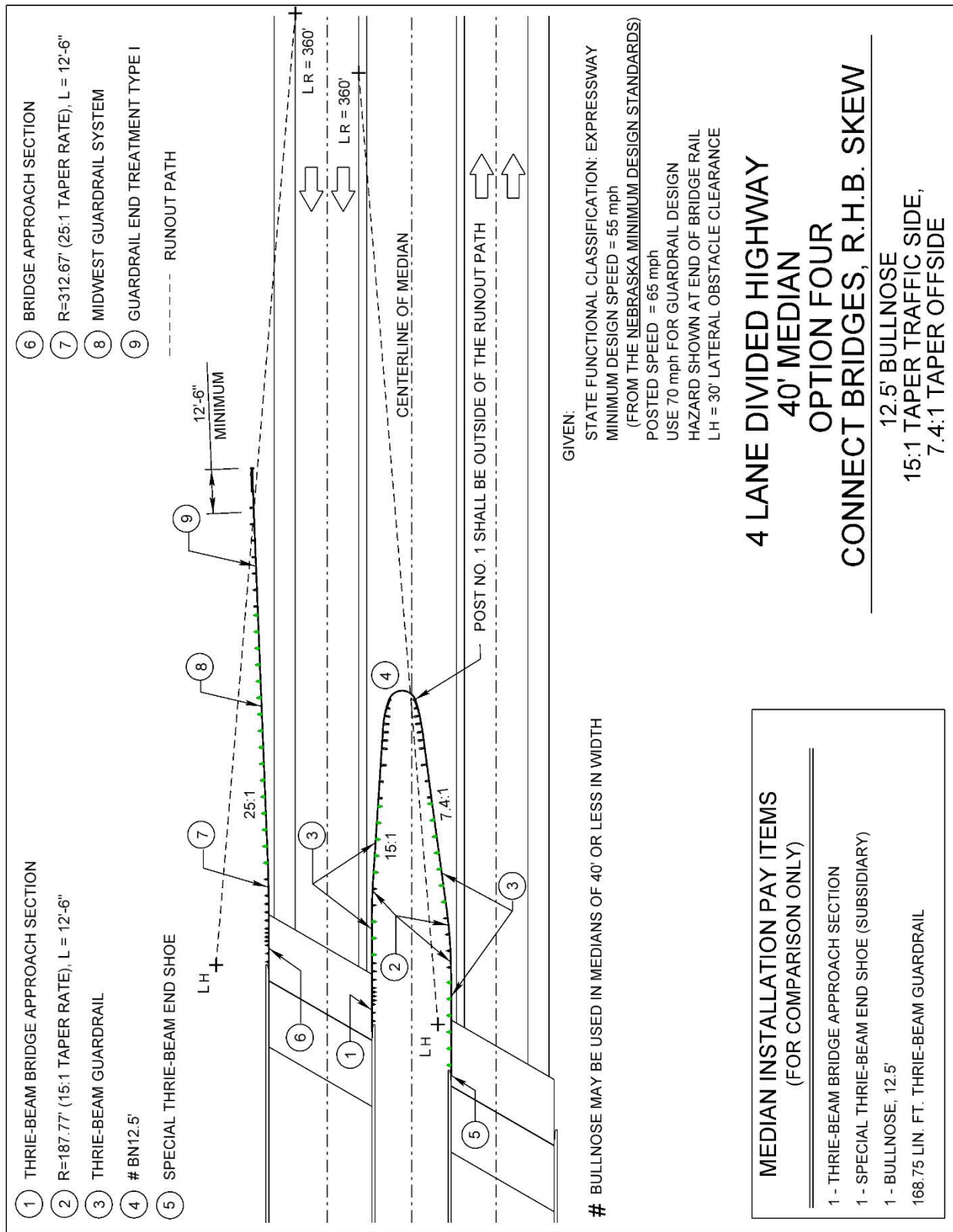
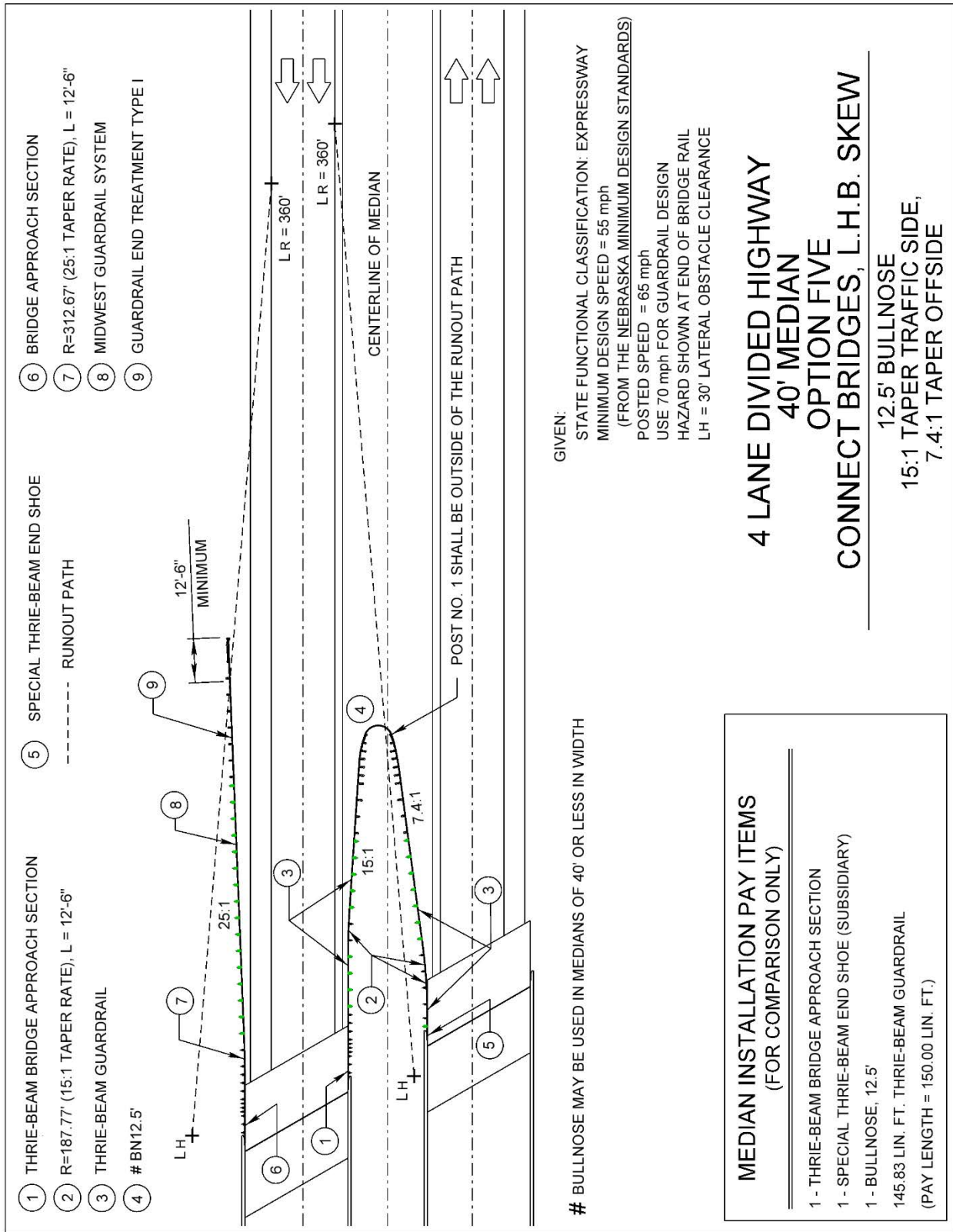


Exhibit 9.22 Example Bullnose Bridge Connection in a 40 Foot Wide Median: Right-Hand-Back Skew, Tapered Bullnose, Bridges Connected



**Exhibit 9.23 Example Bullnose Bridge Connection in a 40 Foot Wide Median:
 Left-Hand-Back Skew, Tapered Bullnose, Bridges Connected**

7. SPECIAL INSTALLATIONS

7.A Guardrail at Intersections

When a minor road or driveway intersects a main roadway near a bridge it may not be possible to shield the bridge rail end with a standard guardrail installation. If it is not feasible to relocate the intersecting road, a crash cushion or an impact attenuator could be installed to protect the end of the bridge rail or a short radius W-Beam guardrail installation may be used with **Roadway Design Unit Head** approval. An area behind the guardrail, based on the radius of the curved beam, should be free of fixed objects. The standard bridge approach section or bridge approach section Test Level 2 (on low-speed roadways, ≤ 45 mph) should be used to transition to a concrete bridge rail. Controlled releasing terminal (CRT) posts are used through the curved section. Low-speed guardrail end treatments (See Section 4.C of this chapter) may be used for the terminal on the minor road, an end anchorage assembly may be used for the terminal on driveways, and a guardrail end treatment or a Test Level 2 guardrail end treatment should be used for the terminal on state highways. See the "Standard Details" section of the *Standard Plans* (Ref. 9.3), Plan 7046, for an example of this design and for plans of the guardrail components. Further information may be found in the Roadside Design Guide (Ref. 9.1).

7.B Guardrail Over Low Fill Culverts

The *Standard Plans* (Ref. 9.3), Standard Plans 747 & 748, illustrates the culvert mounted guardrail post details to be used when full embedment of a guardrail post is not possible, such as over low-fill culverts. Designers should graphically lay out the guardrail post location to use the minimum number of special posts. Posts can be attached directly to the top of the Concrete Box Culvert or to the face of the parapet.

7.C Guardrail Spans with Posts Eliminated

The "Standard Details" section of the *Standard Plans* (Ref. 9.3), Plan 7049, illustrates the MGS design to be used for long spans of two missing posts (up to 25 feet) where guardrail posts are eliminated, such as over low fill culverts or in places where two or three posts cannot be placed; three breakaway wood posts are placed on each side. Where a single guardrail post cannot be placed it may be skipped (12.5 foot gap between posts) with no other change; MGS W-Beam does not need to be nested.

7.D MGS Installed Near Slopes

While MGS should be installed on slopes of 1:10 or flatter, there are circumstances where installing guardrail near a steeper slope may be warranted. Currently four W-beam guardrail configurations installed near slopes have been successfully crash tested to MASH Test Level 3 (See EXHIBIT 9.24). All four configurations utilize a 31 inch tall guardrail, a 6.25 foot post spacing, and should be limited to slopes of 1:2 or flatter.

<p>Installation Type A</p>	<p>Installation Type B</p>	<p>Installation Type C</p>	<p>Installation Type D</p>
<p>Installed adjacent to the slope using:</p> <ul style="list-style-type: none"> • 9 foot long posts centered on the slope break point • 12 inch blockouts (8 inch and no blockouts are acceptable options) 	<p>The only system with the posts installed on the slope using:</p> <ul style="list-style-type: none"> • 8 foot long posts placed at 12 inches to the face of the post down a 1:2 slope (placing the face of the guardrail at the slope break point) • 8 inch blockouts (12 inch blockouts may be used) 	<p>Developed specifically for use on top of MSE walls using:</p> <ul style="list-style-type: none"> • Standard 6 foot long posts which extend through the mesh, strengthening the system • No blockouts 	<p>A standard MGS installation with</p> <ul style="list-style-type: none"> • 6 foot long posts centered on the slope break point • 12 inch blockouts (8 inch and no blockouts are acceptable options) <p>This installation exhibits greater deflection than the other installations.</p>

Exhibit 9.24 Details for 31 inch MGS Near Slopes

(Source: Adapted from A Synthesis of MASH Tested 31-in. Tall, Non-Proprietary, W-Beam Guardrail Systems, Transportation Research Board, October 2017)

7.E Guardrail and Curbs

If a curb is used in conjunction with a guardrail installation on a high-speed facility (≥ 50 mph), the curb will be either a three-inch or four-inch concrete slope curb or a three-inch asphaltic concrete mountable curb. The desirable curb location will place the back of the curb a minimum distance of two feet behind the back of the guardrail post. If curb must be placed in front of a guardrail installation, the back of the curb should be flush with the front face of the guardrail posts.

On low-speed roadways (≤ 45 mph), six-inch curbs can be located with the back of the curb at the face of the semi-rigid guardrail (See [EXHIBIT 9.25](#)).

On low-speed roadways (≤ 45 mph), six-inch curbs should not be either in front of or for a distance in advance (upstream) of the guardrail end treatment (See [EXHIBIT 9.26](#)). The minimum curb-free distance should be 25 feet in advance of the first post of the guardrail end treatment.

For further information, see the [Roadside Design Guide](#) (Ref. 9.1) and the *Standard Plans* (Ref. 9.3), Standard Plan 743.

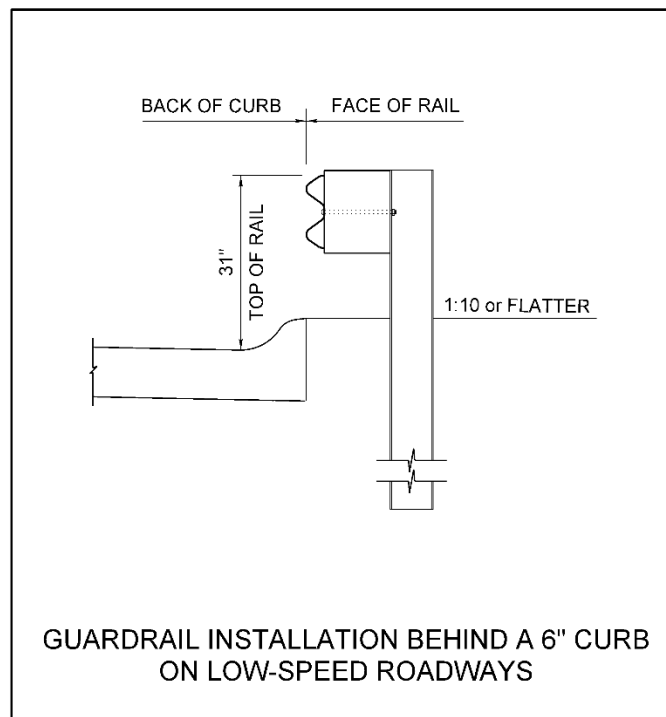
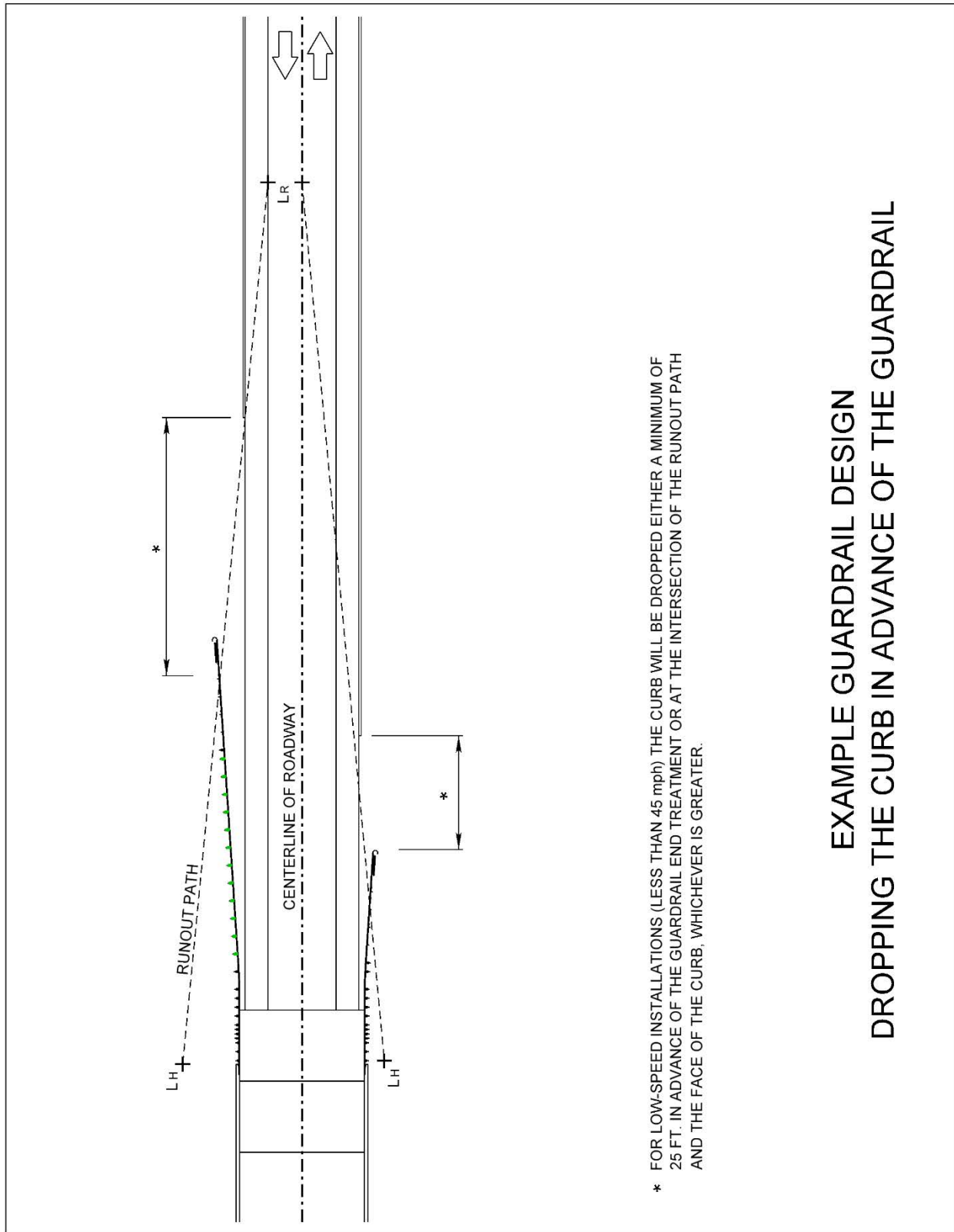


Exhibit 9.25 Guardrail Installed Behind a Six-Inch Curb on a Low-Speed (≤ 45 mph) Roadway



* FOR LOW-SPEED INSTALLATIONS (LESS THAN 45 mph) THE CURB WILL BE DROPPED EITHER A MINIMUM OF 25 FT. IN ADVANCE OF THE GUARDRAIL END TREATMENT OR AT THE INTERSECTION OF THE RUNOUT PATH AND THE FACE OF THE CURB, WHICHEVER IS GREATER.

EXAMPLE GUARDRAIL DESIGN DROPPING THE CURB IN ADVANCE OF THE GUARDRAIL

Exhibit 9.26 Dropping the Curb in Advance of the Guardrail

8. CRASH CUSHIONS AND IMPACT ATTENUATORS

Crash cushions are designed to decelerate a vehicle to a stop in head-on impacts and to redirect a vehicle away from rigid objects in side impacts. Crash cushions may be used alone or in conjunction with longitudinal barriers. Crash cushions may also be used in construction and work zones. See the Roadside Design Guide (Ref. 9.1) for further information on crash cushions and impact attenuators.

EXHIBITS 9.27 & 9.28 and the “Design Guides” section of the *Standard Plans* (Ref. 9.3) contain plans and examples of the crash cushions and impact attenuators used by **NDOT**.

8.A Inertial Barriers

Inertial barriers are sand-filled barrel modules arranged with increasing amounts of sand in the barrels as they are placed closer to the obstacle. Standard module mass varies from 200 to 2100 lbs. Inertial barriers operate by dissipating the energy of an impacting vehicle, transferring the vehicle’s momentum to the variable weights of sand in the barrels. Inertial barriers may be used to shield a variety of fixed object obstacles and are used primarily for protection of pole and column bases, lighting supports, and other rigid objects on the ground.

Inertial barriers should be set as far from the travel lanes as possible to avoid nuisance hits. The width of the last row of modules should be greater than the shielded object. The individual manufacturers supply design details for barrel layout. See the Roadside Design Guide (Ref. 9.1) for additional information.

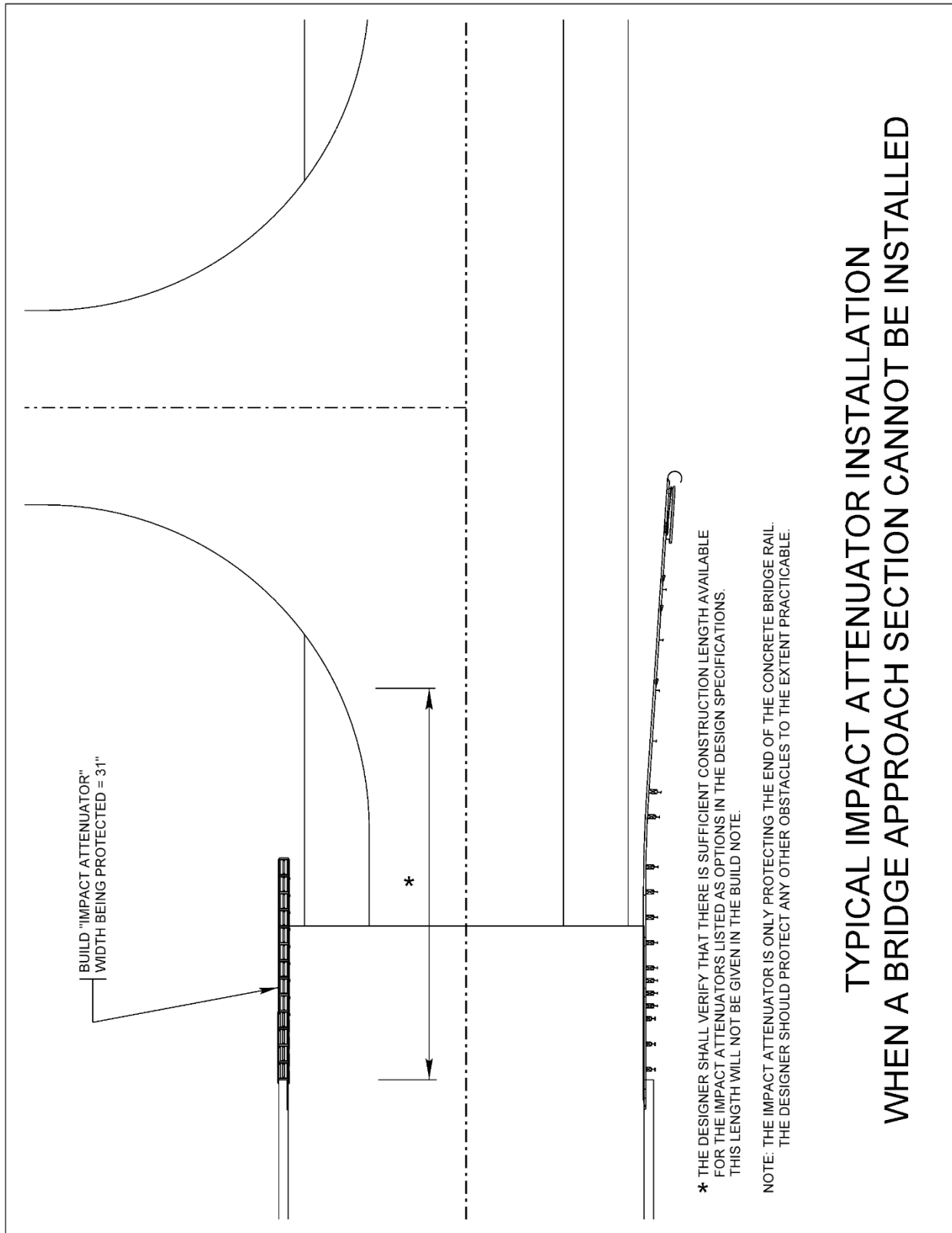


Exhibit 9.27 Impact Attenuator Installation at a Bridge Adjacent to an Intersection or Driveway (Protection of Bridge Railing Only)

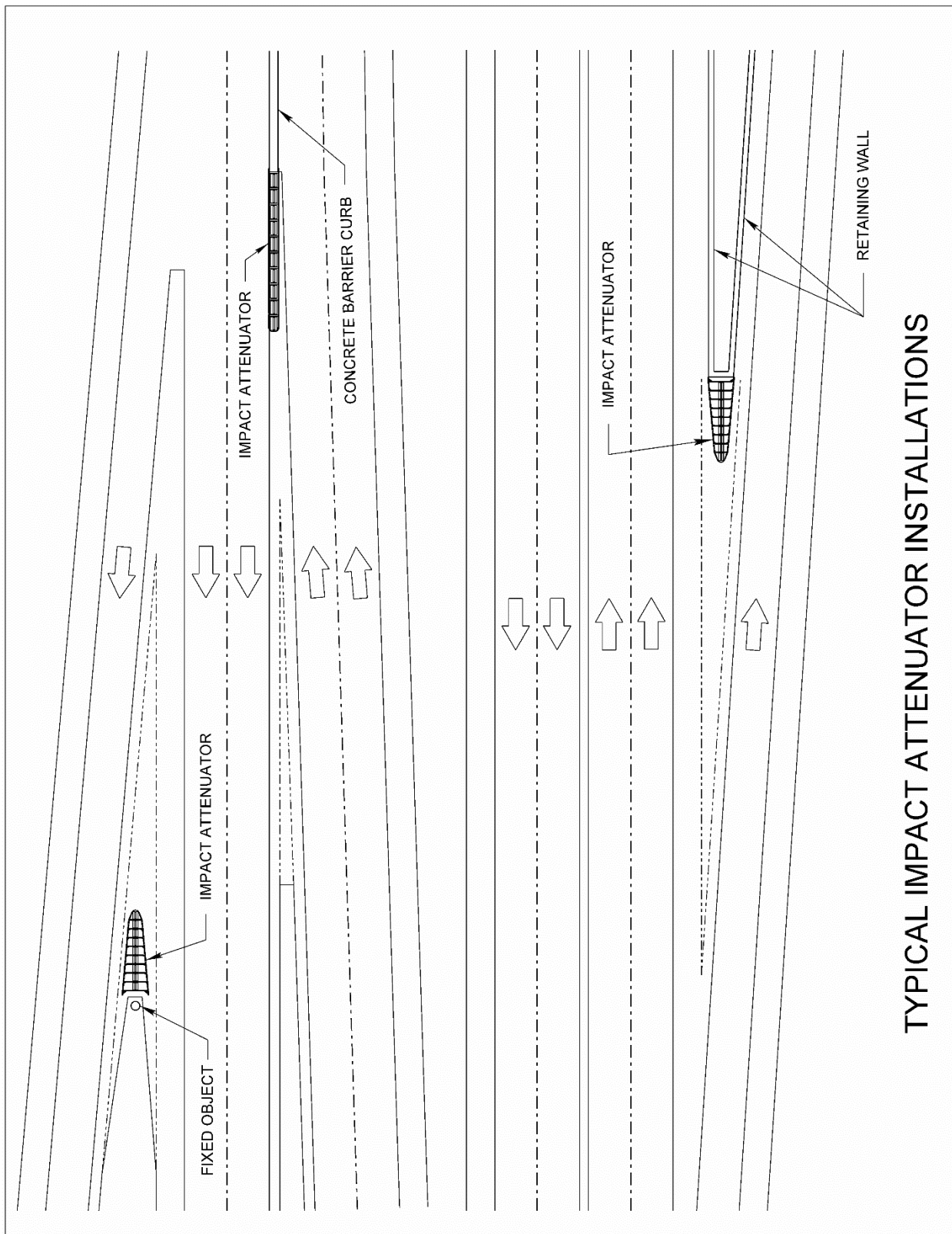


Exhibit 9.28 Typical Impact Attenuator Installations

9. DETERMINE THE PAY ITEM QUANTITIES

Guardrail pay items include, but are not limited to, the following:

- Mid-span Rail Support: Paid for by each. The Bridge Approach Section standard plan shows when the first post at the bridge rail sometimes hits a footing and cannot be placed; the fix is to change Post No. 2 to a larger post and place a 4x4 steel tube connecting to the bridge rail and Post No. 2 to support the back of the rail where Post No. 1 would be.
- Remove Guardrail: Paid for by the linear foot. Used for the removal of both cable and semi-rigid guardrail. The removal length includes the approach and terminal sections for each continuous length of guardrail.
- Remove Existing Surfacing: Paid for by the square yard.
- Semi-Rigid Guardrail (MGS, W-Beam, and Thrie-Beam): Paid for by the linear foot. Measure the semi-rigid guardrail from the bridge approach section to the end treatment(s). The semi-rigid guardrail pay length will include the guardrail radius section, if applicable. This pay item includes the guardrail posts, offset blocks, and hardware required for installation. The pay item for MGS and W-Beam is W-Beam Guardrail; the pay item for Thrie-Beam is Thrie-Beam Guardrail.
- Cable Guardrail: Paid for by the linear foot. Measure the cable guardrail from terminal anchorage section to terminal anchorage section. This pay item includes the guardrail posts and hardware required for installation.
- Bridge Approach Section Test Level 3 and Bridge Approach Section Test Level 2: Paid for by each (Length = 25 feet for Test Level 3 and 9 feet - 4.5 inches for Test Level 2).
- W-Beam to Thrie-Beam Transition Section: Paid for by each. Used to connect MGS or W-Beam guardrail to Thrie-Beam guardrail. This is a separate pay item when it is used separately from a BAS.
- Guardrail End Treatments: Paid for by each. Divided into the pay items Guardrail End Treatment Type I, Guardrail End Treatment Type II, and Guardrail End Treatment Type TL2.
- End Anchorage Assembly: Paid for by each. The end of the W-beam guardrail used at the off end of one-way bridges, includes two posts and the cable tie-down.
- Cable Guardrail Anchorage: Paid for by each.
- Culvert Mounted Guardrail Posts: Paid for by each. When the designer specifies culvert mounted guardrail posts, the posts are a separate pay item from the semi-rigid guardrail.
- Crash Cushions and Impact Attenuators: Paid for by each.
- Concrete Median Barriers: Paid for by the linear foot.
- Bullnose: Paid for by each. The pay item refers to the entire system from Post No. 10 on the left to Post No. 10 on the right and includes all Thrie-Beam guardrail, posts, cables, blockouts, and hardware necessary to complete the Bullnose installation.
- Surfacing Under Guardrail: Paid for by the square yard.

The designer will coordinate with **Bridge** to verify that all pay items are accounted for (e.g. Preparation of Structure).

For further information, see the *Standard Plans* (Ref. 9.3), the *Spec Book* (Ref. 9.4), and Chapter Twelve: Cost Estimating & Funding of this manual.

10. REFERENCES

- 9.1 American Association of State Highway and Transportation Officials, Roadside Design Guide, Washington, D.C., 2011.
- 9.2 Board of Public Roads Classifications and Standards, Nebraska Minimum Design Standards (MDS), Current Edition. (<http://dot.nebraska.gov/media/5593/nac-428-rules-regs-nbcs.pdf>)
- 9.3 Nebraska Department of Transportation, Standard/Special Plans Book (Standard Plans), Current Edition. (<http://dot.nebraska.gov/business-center/design-consultant/stand-spec-manual/>)
- 9.4 Nebraska Department of Transportation, Standard Specifications for Highway Construction (Spec Book), 2017. (<http://dot.nebraska.gov/media/10343/2017-specbook.pdf>)

