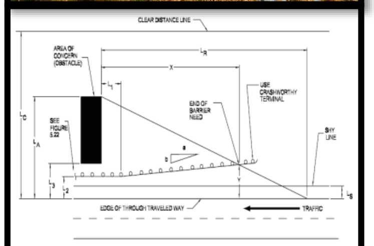



### North Carolina Department of Transportation

# Highway Safety Barrier Design Training

Instructor: Bill Fitzgerald, PE
KLS Engineering, LLC
(703) 858 1356

## Virtual Live Training

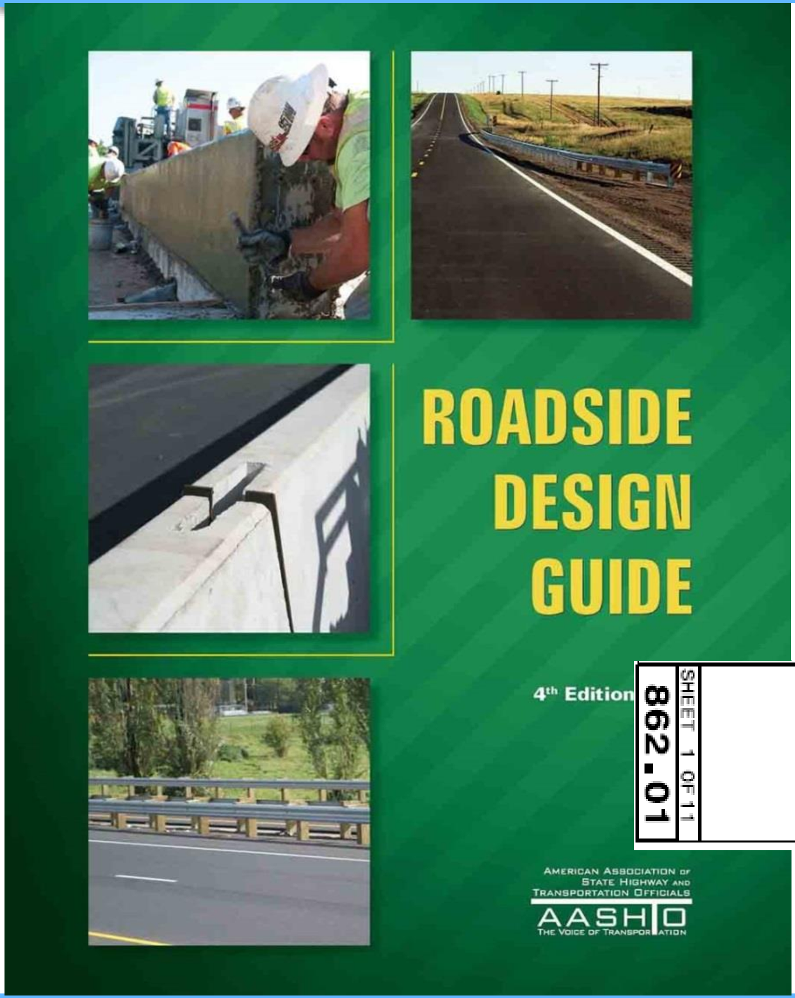
## May 18 – 19, 2021

THE UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER

KLS Engineering

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

# Guidance Presented




ROADWAY DESIGN MANUAL PART 1

CHAPTER THREE

GUARDRAIL, BARRIERS AND ATTENUATORS

GUARDRAIL WARRANTS 3-1

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

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

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

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

(2) Can Guardrail be eliminated?

| | | | |
|---|---|---|---|
| 862.01 | SHEET 1 OF 11 | ROADWAY STANDARD DRAWING FOR<br>**GUARDRAIL PLACEMENT** | 1-18<br>STATE OF<br>NORTH CAROLINA<br>DEPT. OF TRANSPORTATION<br>DIVISION OF HIGHWAYS<br>RALEIGH, N.C. |

862D0 X

And Proposed Update

# Ground Rules

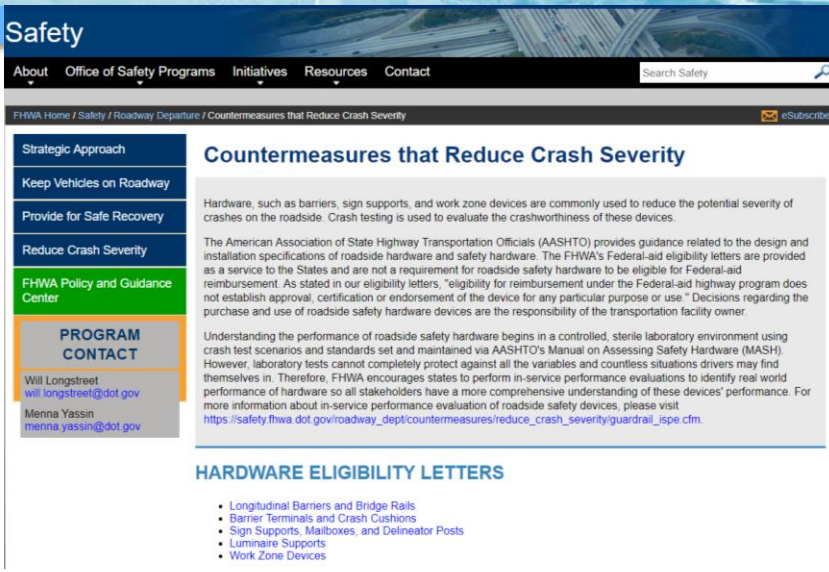
- Be on time
- Participate
- Restrict sidebar conversations
- Turn off cellphones

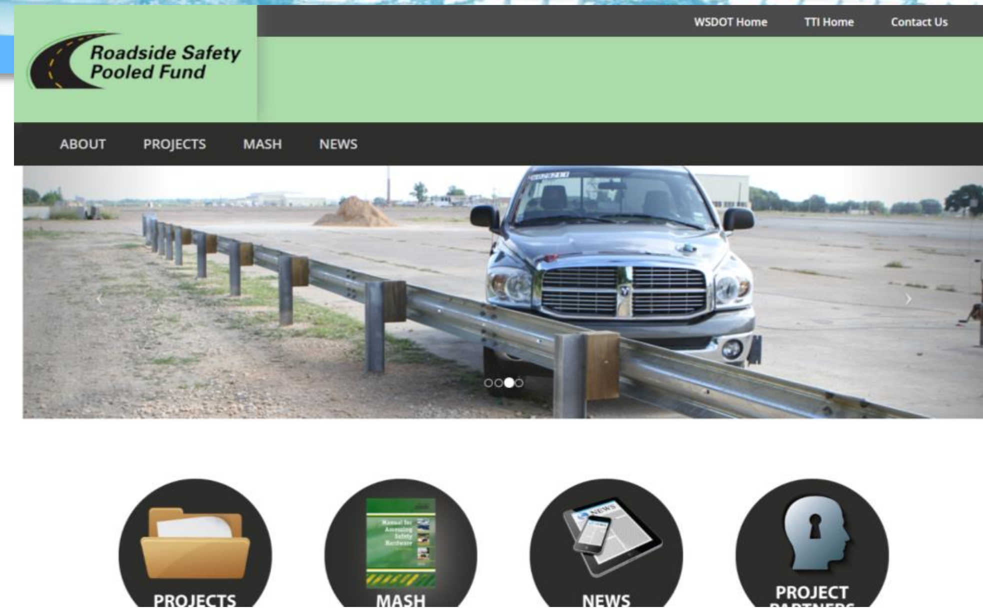
Virtual Training – participate with yes/no answers to questions

Use chat box to submit your questions/comments

Terminology: Page v

# Additional Resources



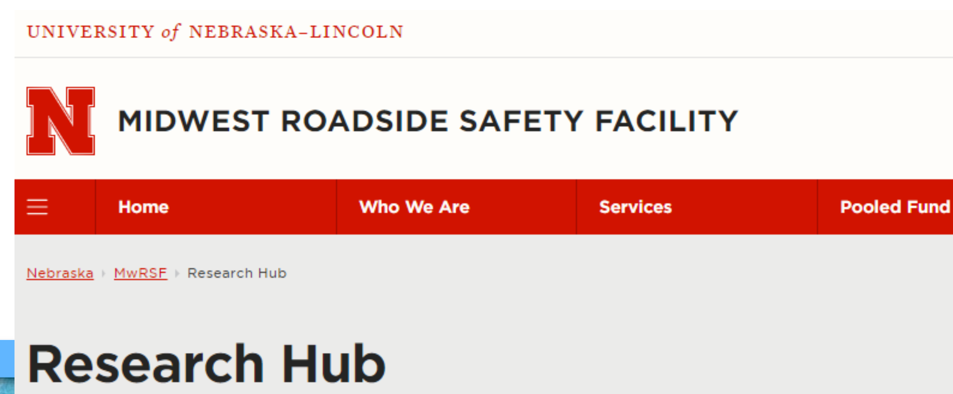

FHWA Eligibility Letters

https://safety.fhwa.dot.gov/roadway_dept/countermeasures/reduce_crash_severity/

TTI Pooled funds, etc.

https://www.roadsidepooledfund.org

https://mwrsf.unl.edu/researchhub →



# Objectives of Course

At the course you will be able to:

- Identify when a traffic barrier MAY be the best treatment to use at a specific site.
- Select a barrier that will adequately shield the identified hazard(s).
- Assess the topography of the site to provide for an optimal barrier system installation.

# Session 1:

# Introduction and Pre-assessment

# Session 1 Learning Outcomes

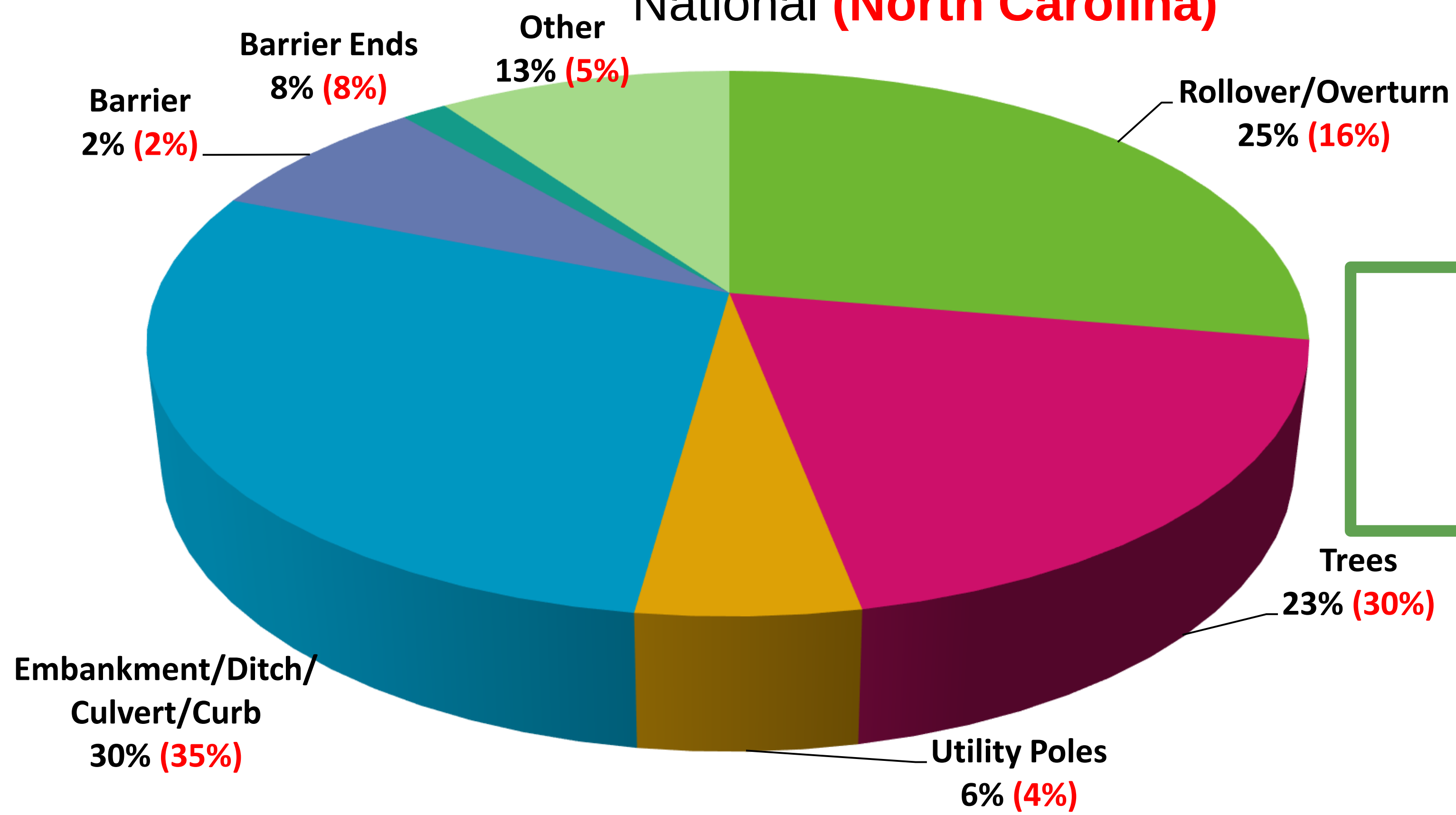
At the end of this session, you will be able to:

- Identify the primary Roadside Safety Concerns in North Carolina.
- Assess your current knowledge of Barrier Design Principles.

# National Roadway Departure Fatalities

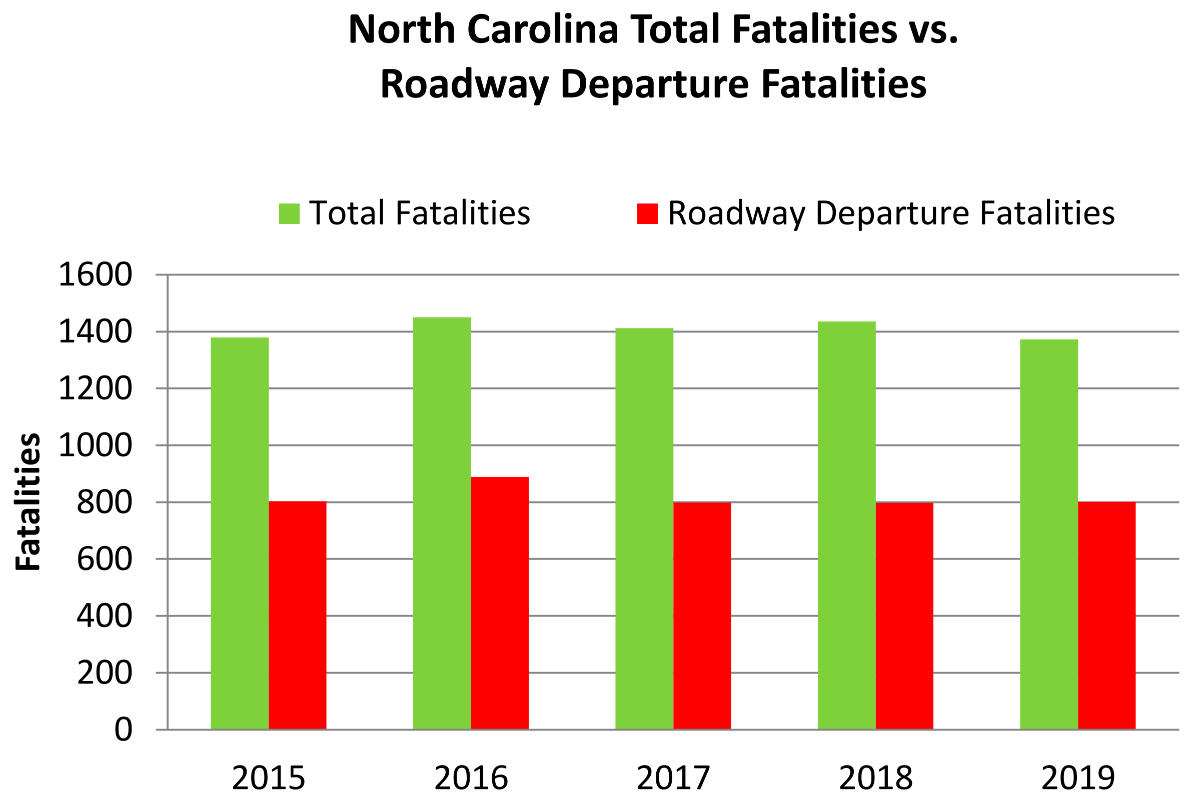
## (Single Vehicle Fatal Crashes)

National **(North Carolina)**



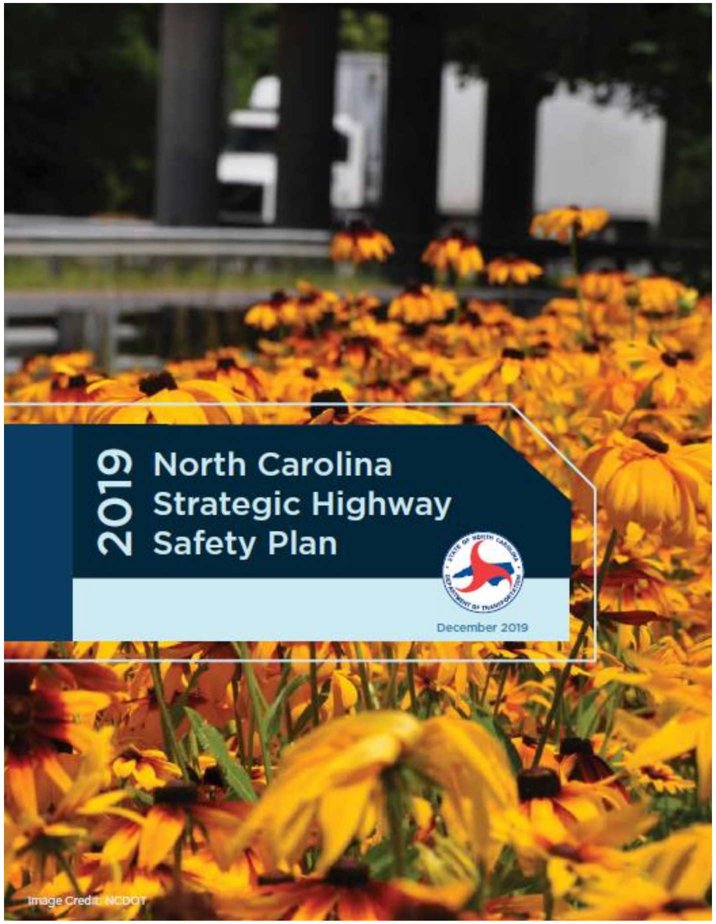

Total US Highway Fatalities 37,143

# North Carolina Crash Data Trend




Ref: FARS Data – 2019

# North Carolina Strategic Highway Safety Plan




**Lane Departure STRATEGIES**

1. Keep vehicles from leaving their travel lane.
2. Reduce the potential for and severity crashes when vehicles leave their lane.
3. Support & enhance driver education & awareness programs.

**Strategy 2:**
**Reduce the potential for and severity of crashes when vehicles leave their lane.**

*Supporting Actions*

- Continue to apply and evaluate the effectiveness of low-cost treatments such as Safety EdgeSM technology, clear zone maintenance, median barriers, and guardrail.

# Real World Crashes

# Real World Crashes

# Need for Training

Potential consequences of poorly designed barrier systems include:

- Systems may not function as designed.
- Crash severities may be increased.


Driving Off Roads
Prohibited

# Need for Training

The next 9 slides show locations where barrier was installed. For each photo, decide at a glance whether you believe it to be:

1. Good example,
2. Bad example, or
3. Cannot decide without more information.

We will discuss these slides in further detail in later applicable sessions, so please record and save your responses.


SHOPPING CENTER
NEXT RIGHT


Childrens Home
NEXT EXIT


EXIT
466


EXIT
265 B

# Review Learning Outcomes

- Identify the primary Roadside Safety Concerns in North Carolina.
- Assess your current knowledge of Barrier Design Principles.

# Session 2:

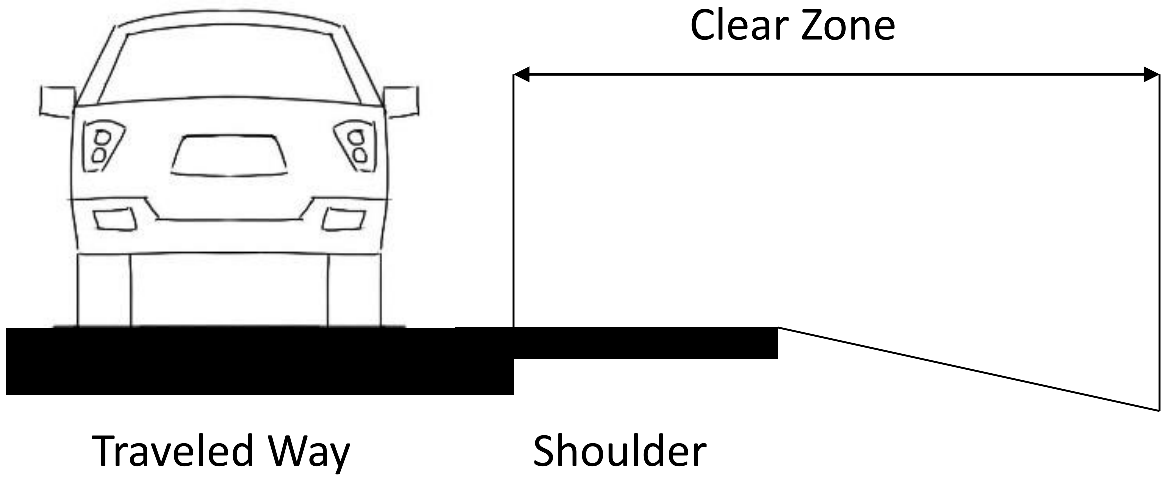
# Clear Zone and Guidelines for Barrier Need

# Session 2 Learning Outcomes

At the end of this session, you will be able to:

- Understand and apply the clear zone concept
- Identify objects and features that may require shielding

# Clear Zone: A Definition




The unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes.

Ref: AASHTO Roadside Design Guide, 4th Edition, Glossary

# Clear Zone Principle

**Get**

**MAXIMUM,**

**COST-EFFECTIVE**

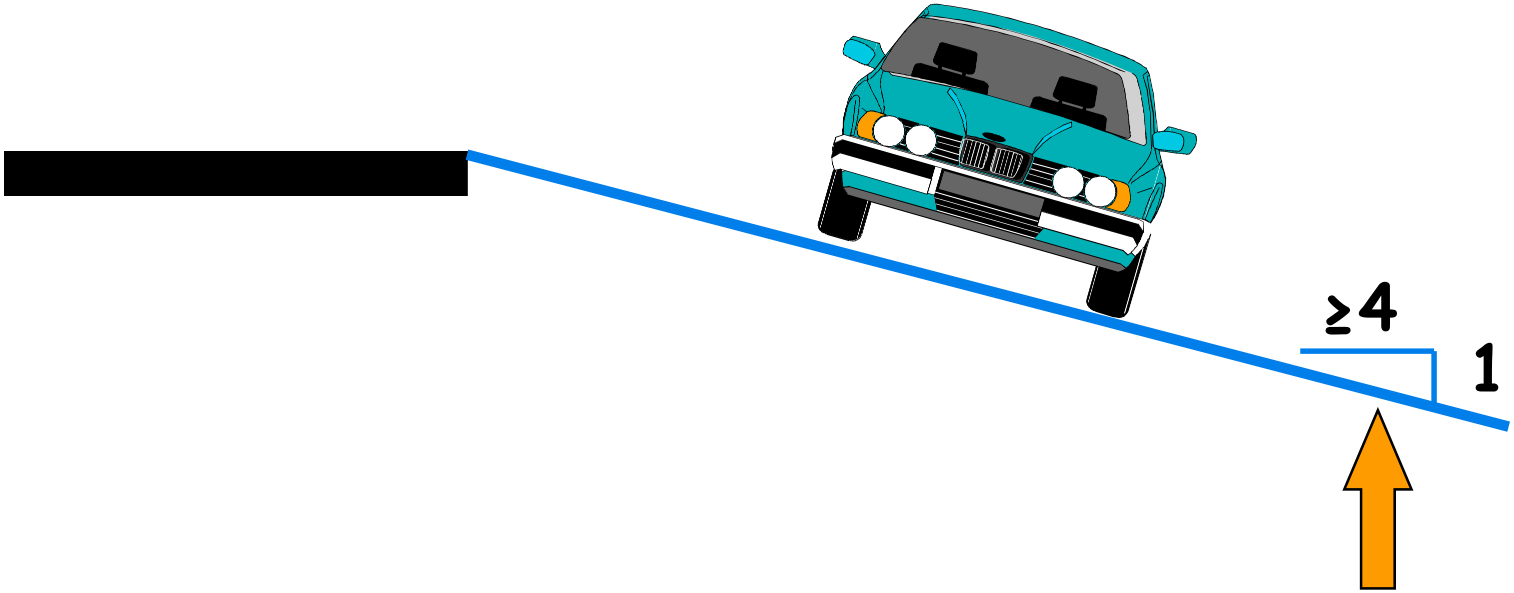
**width**

# As Wide as Practical

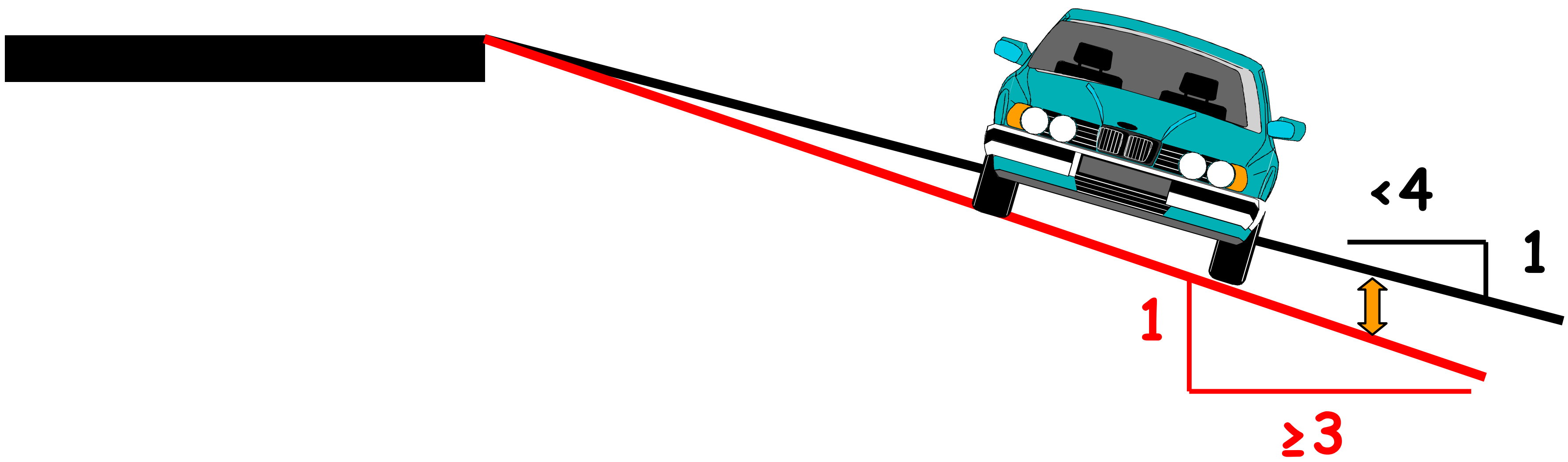
# Clear Zone Factors

- Slope Type and Steepness
- Design Speed
- Traffic Volume
- Horizontal Curvature

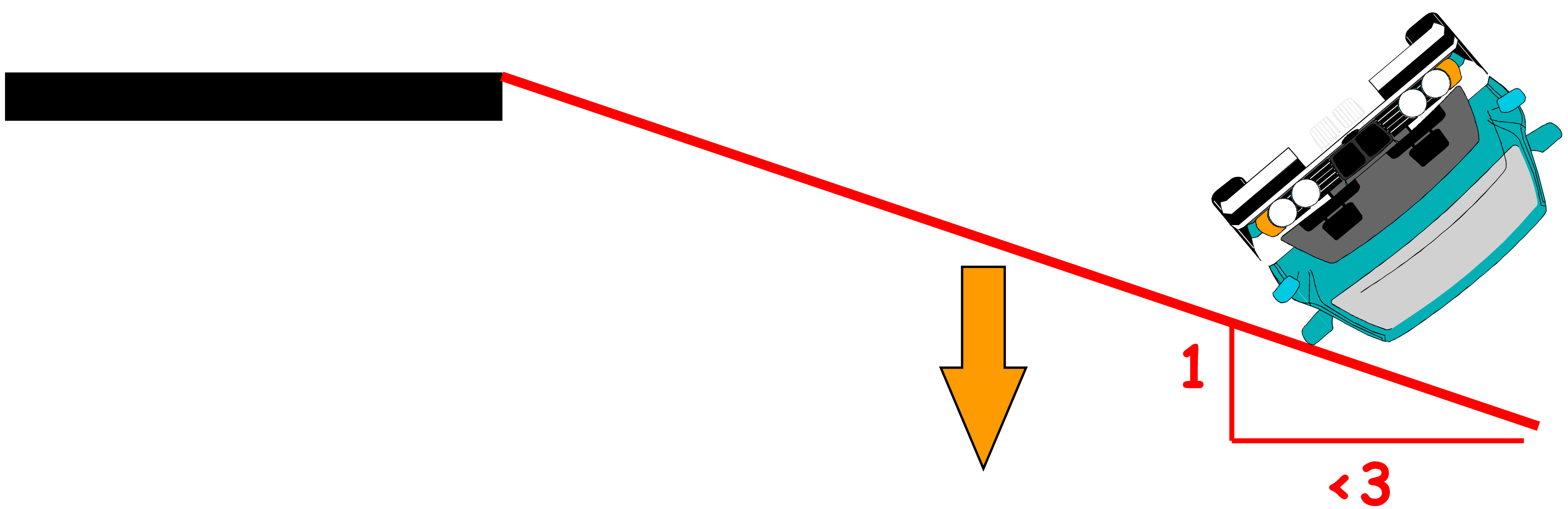
# Recoverable



# Non-Recoverable (but Traversable)



# Critical



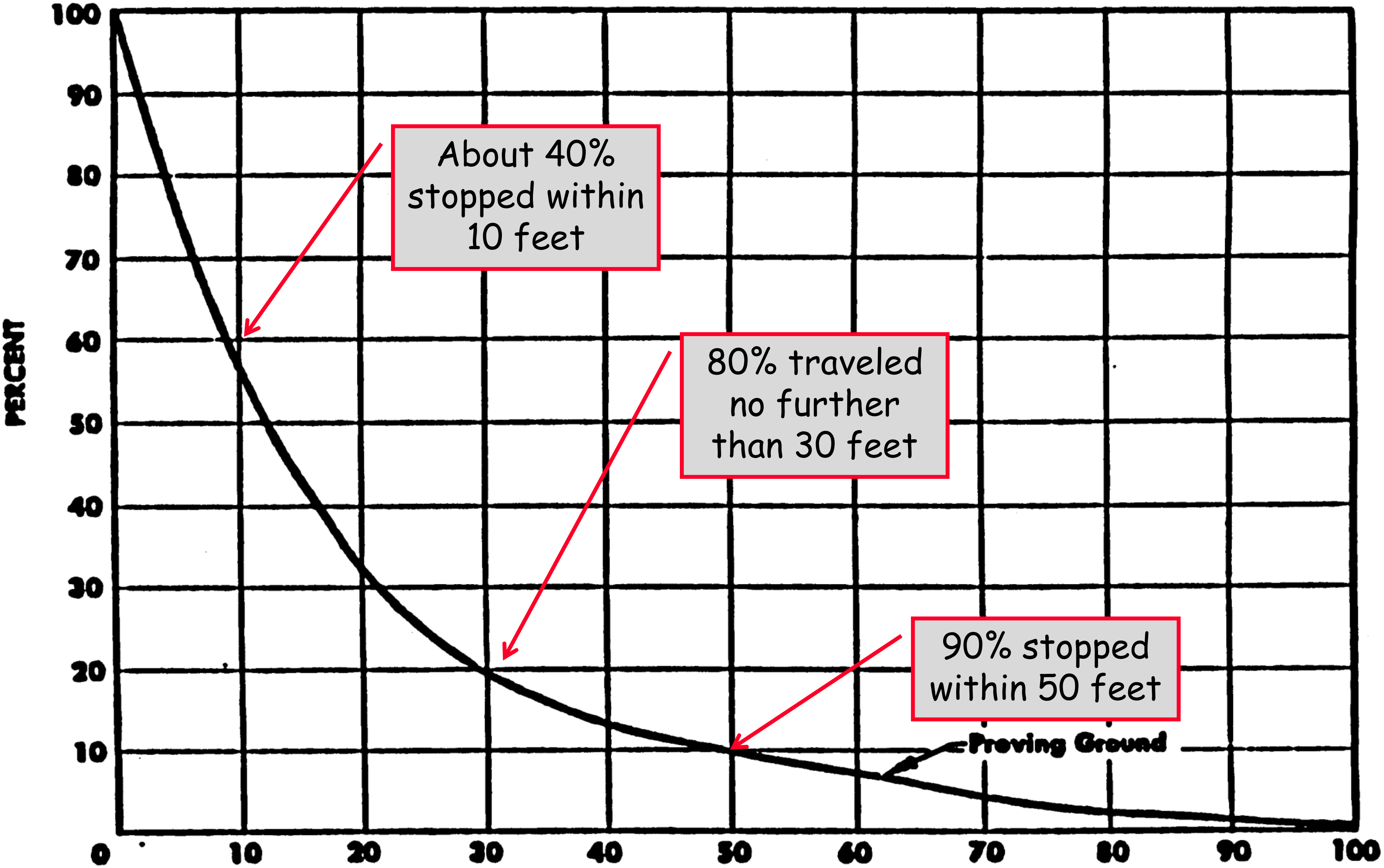
# Clear Zone

THE "MAGIC"

30 FEET

# GM PROVING GROUND ACCIDENTS

## 211 CASES



# NCDOT Design Clear Zone Table

| Design Speed | Design ADT | Foreslopes | | | Backslopes | | |
|---|---|---|---|---|---|---|---|
| | | 1V:6H or flatter | 1V:5H to 1V:4H | 1V:3H | 1V:3H | 1V:5H to 1V:4H | 1V:6H or flatter |
| 40 mph or less | UNDER 750 | 7-10 | 7-10 | ** | 7-10 | 7-10 | 7-10 |
| | 750-1500 | 10-12 | 12-14 | ** | 10-12 | 10-12 | 10-12 |
| | 1500-6000 | 12-14 | 14-16 | ** | 12-14 | 12-14 | 12-14 |
| | OVER 6000 | 14-16 | 16-18 | ** | 14-16 | 14-16 | 14-16 |
| 45-50 mph | UNDER 750 | 10-12 | 12-14 | ** | 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 mph | UNDER 750 | 12-14 | 14-18 | ** | 8-10 | 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 mph | 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 mph | UNDER 750 | 18-20 | 20-26 | ** | 10-12 | 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 |

* Clear zone distances can be limited to 30 feet unless in a high accident rate areas

Ref: Roadway Design Manual, Part I. Clear Zone Distances, 1-4N

# Important Distinction

Available Clear Zone = Area Existing for recovery

Design Clear Zone = A selected value used for design to provide recovery area for a majority of errant drivers

Do not compromise available clear zone

# Example Clear Zones

# Example Clear Zones

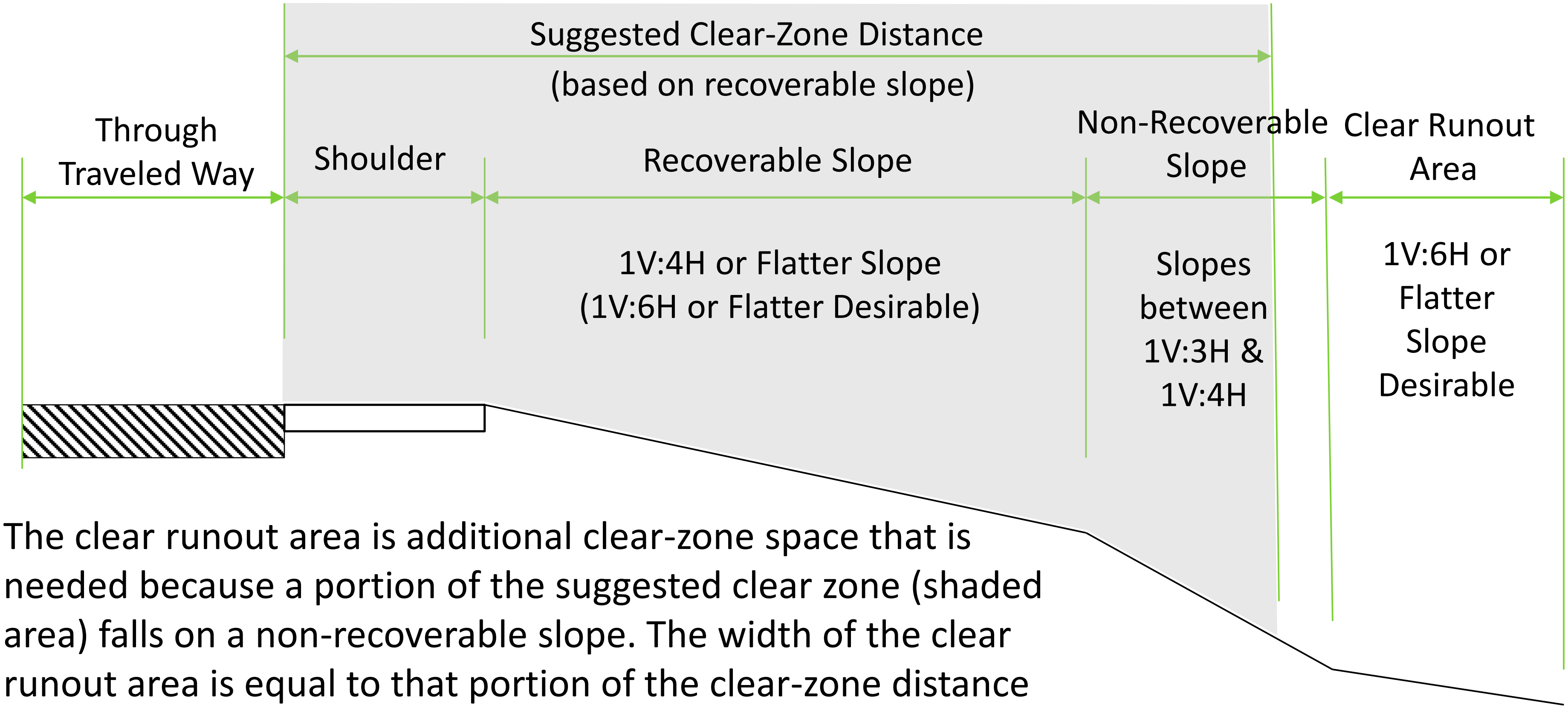
# Example Clear Zones

# Example Clear Zones

# Example Clear Zones

# Example Clear Zones

# Clear Zone Adjustments for Non-uniform Slopes



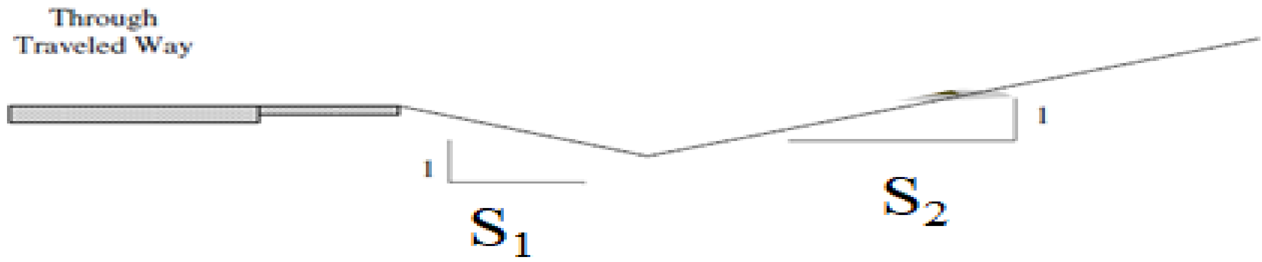

The clear runout area is additional clear-zone space that is needed because a portion of the suggested clear zone (shaded area) falls on a non-recoverable slope. The width of the clear runout area is equal to that portion of the clear-zone distance that is located on the non-recoverable slope – min 10'.

Ref: AASHTO Roadsid

FIGURE 1 SIMILAR 1-4M

F-1

# Clear Zone with a Ditch

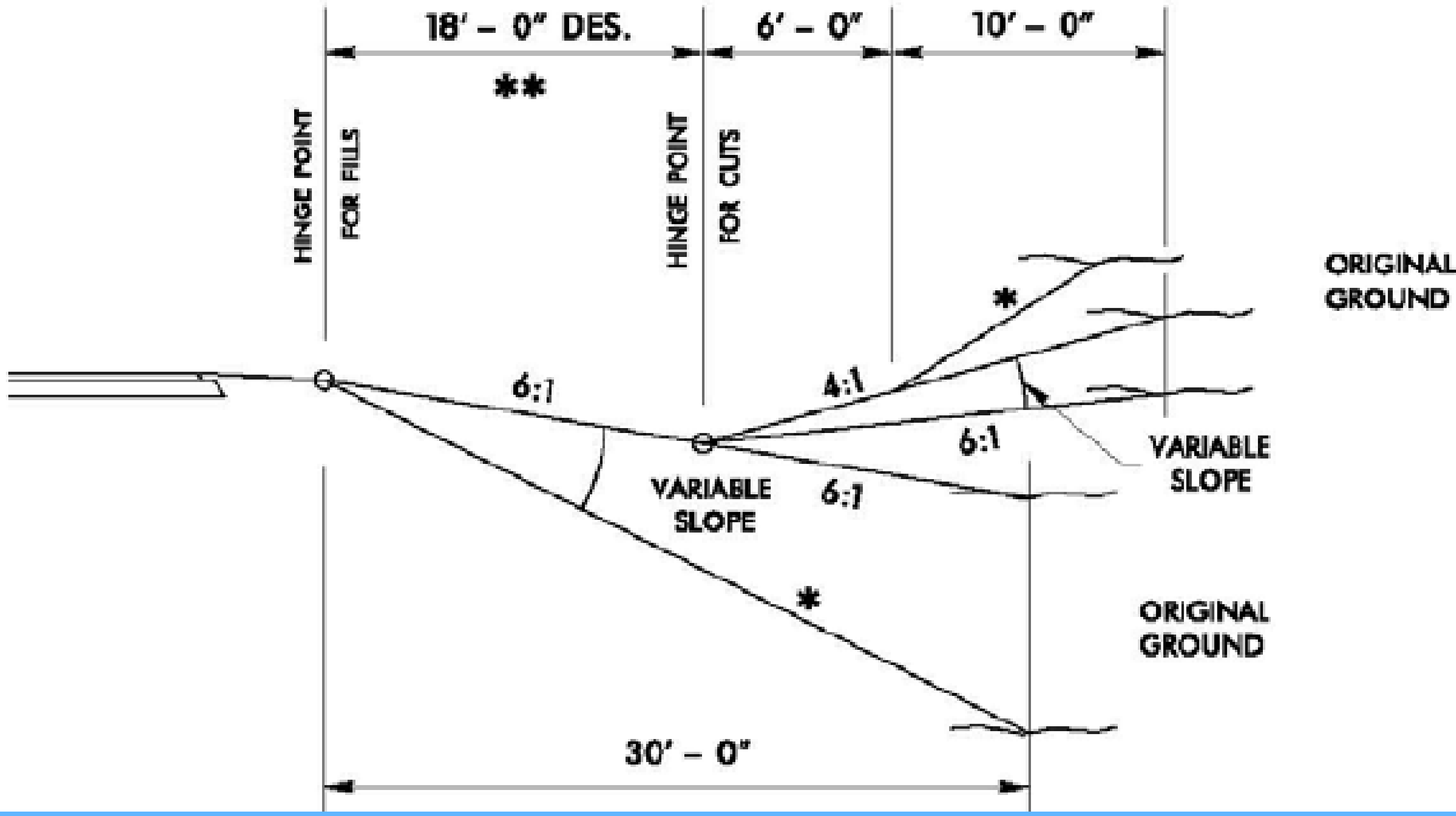



- The combination of $S_1$ and $S_2$ needs to fall within the preferred area of Figure 3.6 of the RDG for the clear zone to extend beyond the ditch bottom
- If the combination is outside and $S_1$ is recoverable, the clear zone stops at the ditch bottom
- If $S_1$ is not recoverable, the clear zone stops at the top of the $S_1$ slope

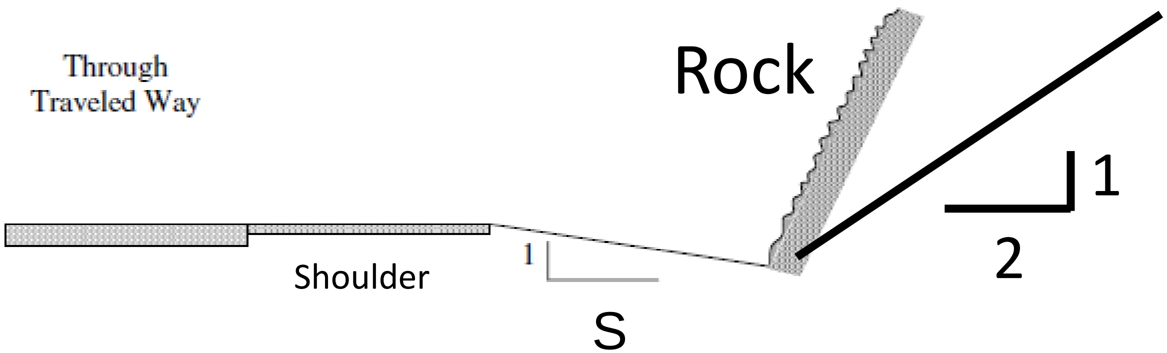
Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 3.6, Pg. 3-9

# Clear Zone with a Ditch - NCDOT

(A) INTERSTATES, FREEWAYS, EXPRESSWAYS, OTHER FOUR LANE FACILITIES, ARTERIALS, COLLECTORS AND LOCALS (OVER 4000 ADT DESIGN YEAR TRAFFIC)



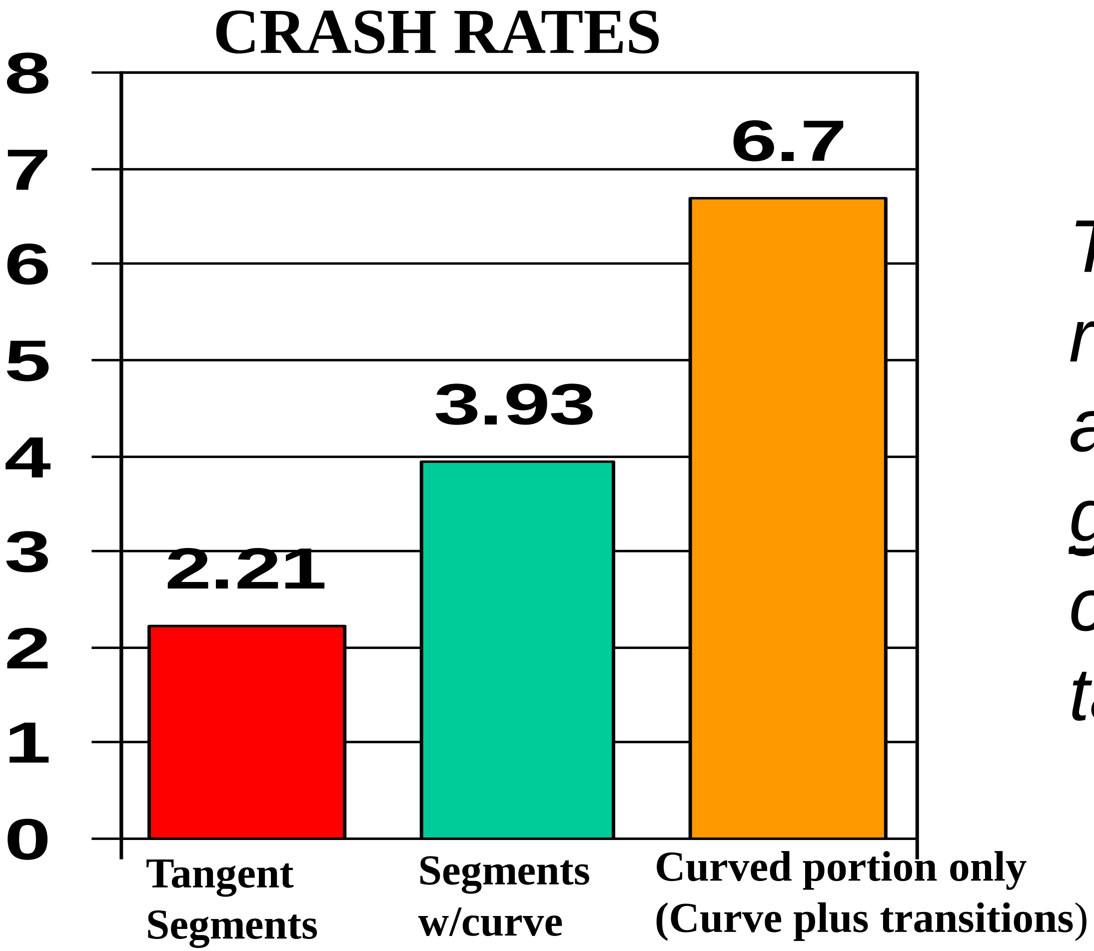
# Clear Zone with a steep Cut Slope




| | |
|---|---|
| S (≥4) Recoverable | Clear Zone extends to the base of the cut.<br>If this distance is less than the design clear zone:<br>• For a **smooth** rock cut – it can be considered a natural barrier. (Note a 2:1 smooth slope is not normally shielded)<br>• For a **jagged** rock cut – it is considered as any other significant obstacle within the design clear zone. |
| S (<4) Non-Recoverable | Clear Zone ends at the edge of shoulder. |

Ref: AASHTO Roadside Design Guide, 4th Edition, Pg.3-24

# ….Curves Present Particular Safety Problems

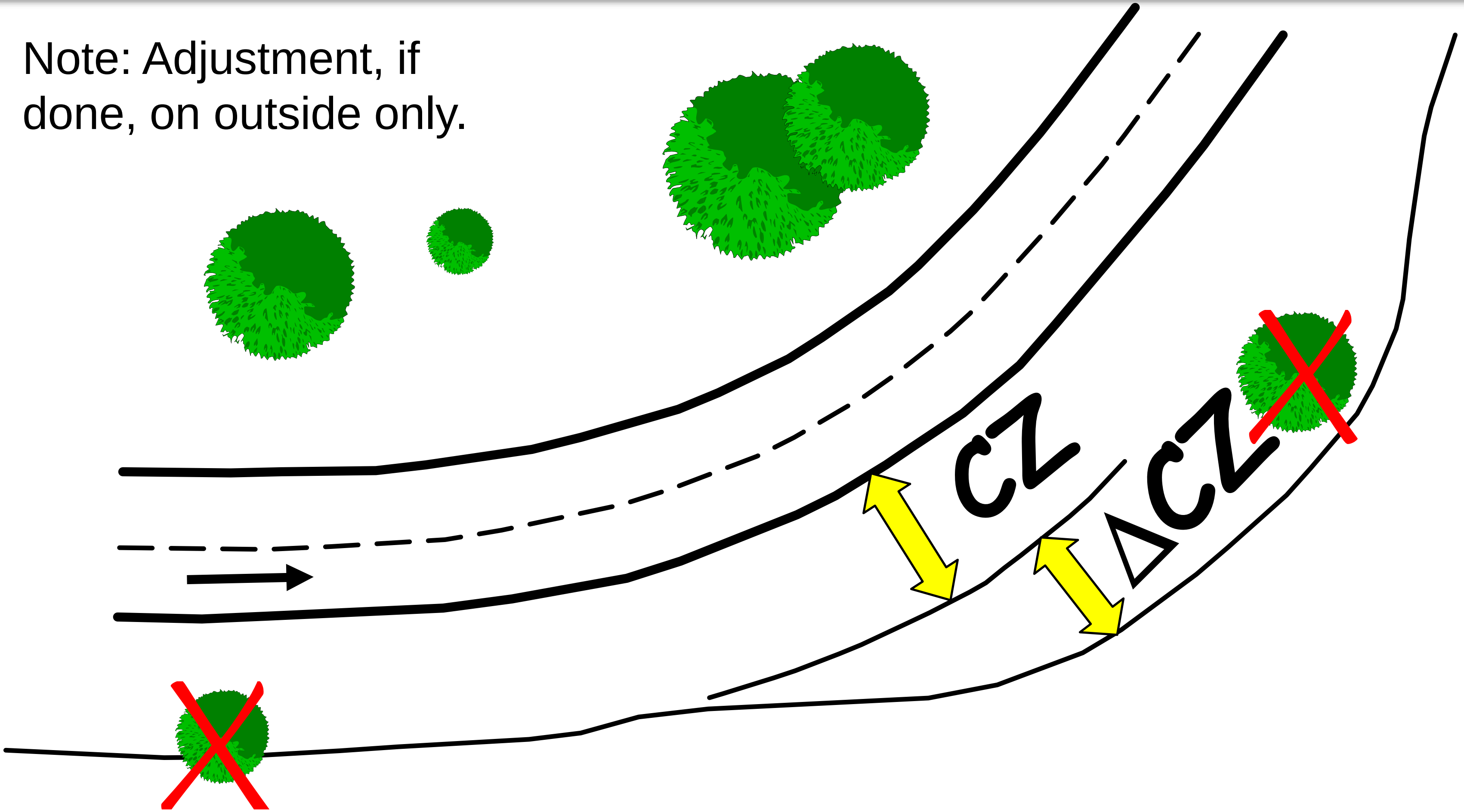



*The risk of a reported crash is about <u>three times greater</u> on a curve than on a tangent*

Source: Glennon, et al, 1985 study for FHWA

# Horizontal Curves - AASHTO

Note: Adjustment, if done, on outside only.




Ref: AASHTO Roadside Design Guide, 4th Edition, Pg. 3-3

# Horizontal Curve Adjustments

## $K_{CZ}$ (Curve Correction Factor)(U.S. Customary Units)

| Radius (ft) | Design Speed (mph) | | | | | |
|---|---|---|---|---|---|---|
| | 40 | 45 | 50 | 55 | 65 | 70 |
| 2,950 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 |
| 2,300 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 |
| 1,970 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.4 |
| 1,640 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 |
| 1,475 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | 1.5 |
| 1,315 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | - |
| 1,150 | 1.2 | 1.2 | 1.3 | 1.4 | 1.5 | - |
| 985 | 1.2 | 1.3 | 1.4 | 1.5 | 1.5 | - |
| 820 | 1.3 | 1.3 | 1.4 | 1.5 | - | - |
| 660 | 1.3 | 1.4 | 1.5 | - | - | - |
| 495 | 1.4 | 1.5 | - | - | - | - |
| 330 | 1.5 | - | - | - | - | - |

Ref: AASHTO Roadside Design Guide, 4th Edition, Table 3-2.Pg. 3-4

# Horizontal Curves - NCDOT

The Roadside Design Guide states: “The designer **may** choose to modify…”.  Again, not normally done unless crash history indicates a problem.

Need approval by Roadway Design Unit

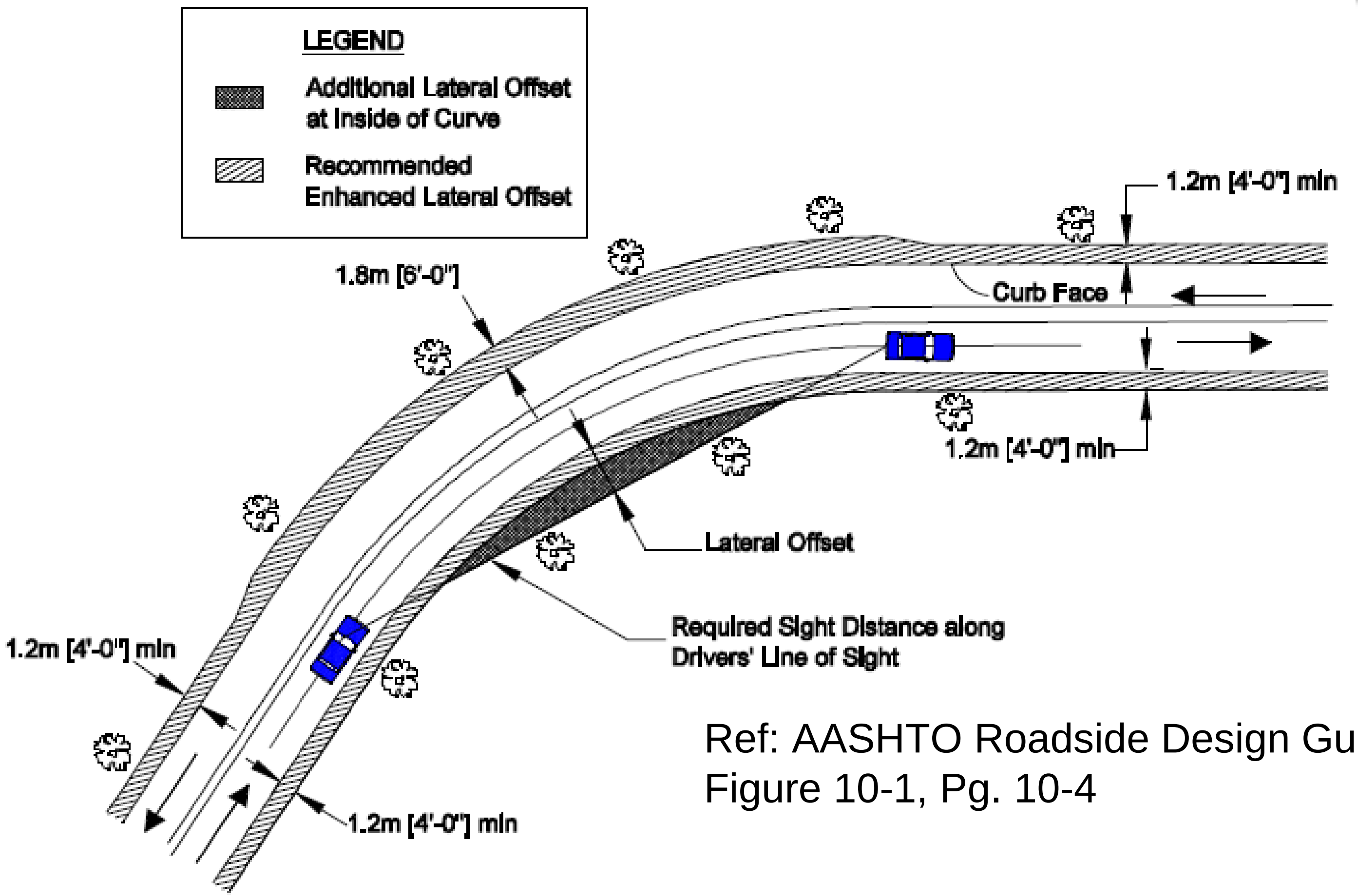
**Remember - As Wide as Practical**

# Clear Zone and Curbs

The minimum lateral offset of 1.5 ft should be provided beyond the face of curbs to any vertical objects.
This is called the Lateral Offset and ***<u>should not be construed as an acceptable clear zone distance</u>*****.**

Ref: AASHTO Roadside Design Guide, Section 10.2.1.1 Curbs

# Clear Zone in an Urban Area




Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 10-1, Pg. 10-4

**Figure 10-1. Lateral Offset for Objects at Horizontal Curves on Curbed Facilities**

# Order of Preference

1. Remove hazard
2. Redesign hazard (make traversable)
3. Relocate hazard (move away from traffic)
4. Reduce Impact Severity ( use breakaway design)
5. SHIELD hazard
6. Delineate hazard so motorist can avoid

Ref: AASHTO Roadside Design Guide, 4th Edition – Pg. 1-4

# Order of Preference - NCDOT

## 4.10 Traffic Barriers
## 4.10.1 General Considerations

The preferred method of addressing roadside hazards is as follows:

1. Remove the hazard;
2. Remove embankment hazard (flatten slopes);
3. Shift hazard away from traffic;
4. Reduce the impact severity by using breakaway posts;
5. Protect the hazard;
6. Delineate the hazard so motorists are aware of the hazard.

# Barriers Must Be Less of a Hazard

# AASHTO Barrier Warrants

| Obstacle | Guidelines |
|---|---|
| Bridge piers, abutments, and railing ends | Shielding generally required |
| Boulders | Judgment decision based on nature of fixed object and likelihood of impact |
| Culverts, pipes, headwalls | Judgment decision based on size, shape and location of obstacle |
| Foreslopes and backslopes (smooth) | Shielding not generally required |
| Foreslopes and backslopes (rough) | Judgment decision based on likelihood of impact |
| Ditches (parallel) | Refer to Figures 3-6 and 3-7 |
| Ditches (transverse) | Shielding generally required if likelihood of head-on impact is high |
| Embankment | Judgment decision based on fill height and slope (see Figure 5-1) |
| Retaining Walls | Judgment decision based on relative smoothness of wall and anticipated maximum angle of impact |
| Sign/Luminaire supports | Shielding generally required for non-breakaway supports |
| Traffic signal supports | Isolated traffic signals within clear zone on high-speed rural facilities may warrant shielding |
| Trees | Judgment decision based on site-specific circumstances |
| Utility poles | Shielding may be needed on a case by case basis. |
| Permanent bodies of water | Judgment decision based on location and depth of water and likelihood of encroachment. |

**Ref: AASHTO Roadside Design Guide, 4th Edition Chapter 5 Table 5-2, Pg. 5-9**

# NCDOT Guidance

ROADWAY DESIGN MANUAL PART 1

CHAPTER THREE

GUARDRAIL, BARRIERS AND ATTENUATORS

GUARDRAIL WARRANTS 3-1

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

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

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

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

(2) Can Guardrail be eliminated?

# NCDOT Guidance - Proposed

| Obstacles* within the Clear Zone | Guideline |
|---|---|
| Embankments | engineering judgment - see note 1 |
| Shoulder Drop-off with slope Steeper than 1:1 - greater than 2 feet height | guardrail required |
| Shoulder Drop-off with slope Steeper than 1:1 - less than 2 feet height | Guardrail not required |
| Bridge Piers, Abutments | Guardrail required - see note 2 |
| Culverts, Pipes, Headwalls | Guardrail required - see note 3 |
| Sign Supports | Guardrail required for non-breakaway supports |
| Traffic Signal Supports | Engineering judgement based on each location |
| Utility Poles | Engineering judgement based on each location |
| Rough Rock Cuts | Guardrail required |
| Large Boulders | Guardrail required |
| Streams or Permanent Bodies of Water less than 2 feet in depth | Guardrail not required |
| Streams or Permanent Bodies of Water greater than 2 feet in depth | Guardrail required |
| Landscaping | Engineering judgement based on each location - see note 4 |

* Obstacles may be nontraversable hazards or fixed objects

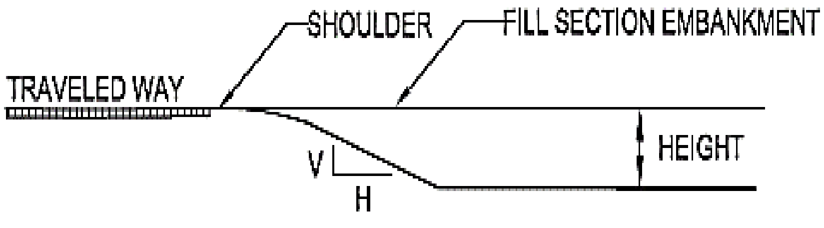
Note 1 - see RDG Figure 5-1

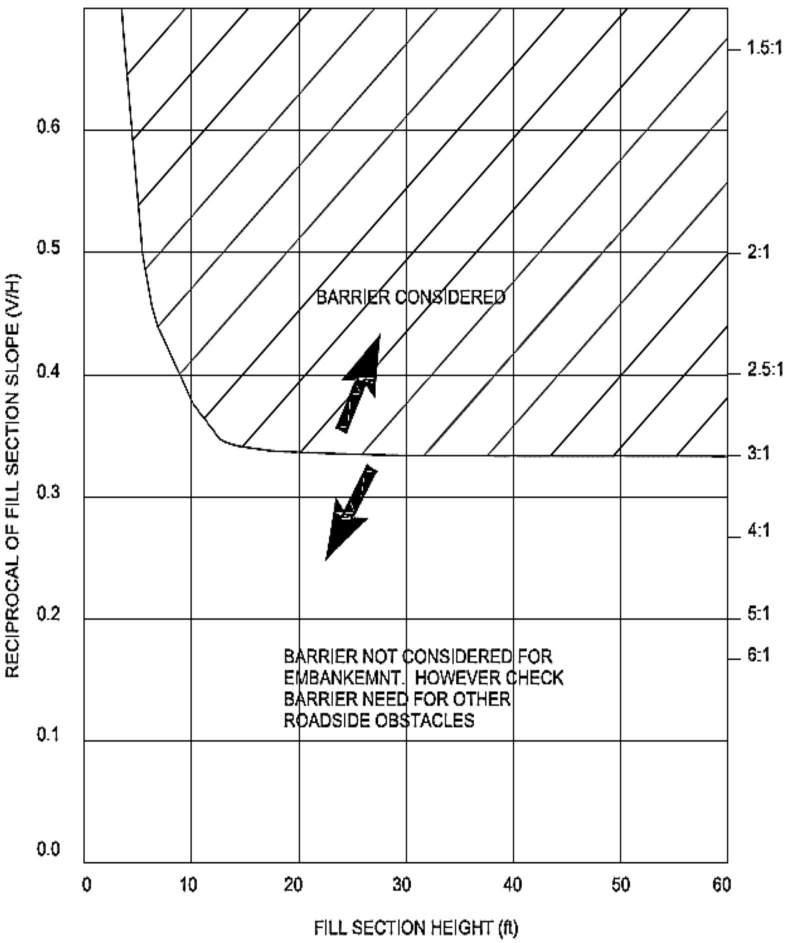
Note 2 - Subregional Tier Guideline allows for reduced lengths (see STG for details)

Note 3 - section 5-2 original RDM need new information location

Note 4 - Landscaping plans should be reviewed for potential hazards

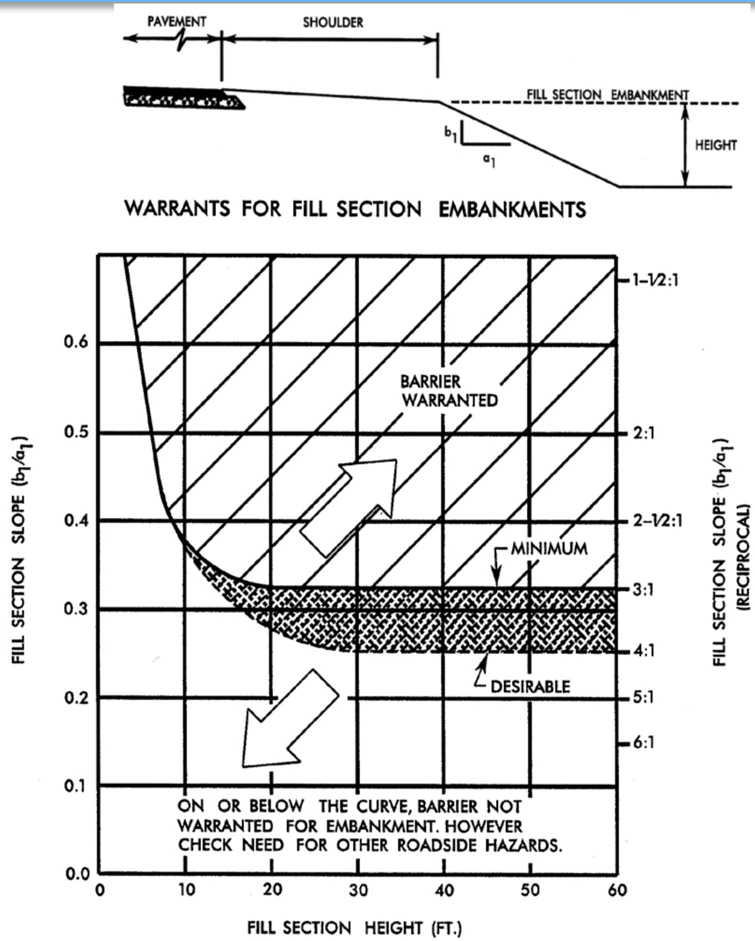
# Embankment Guidelines



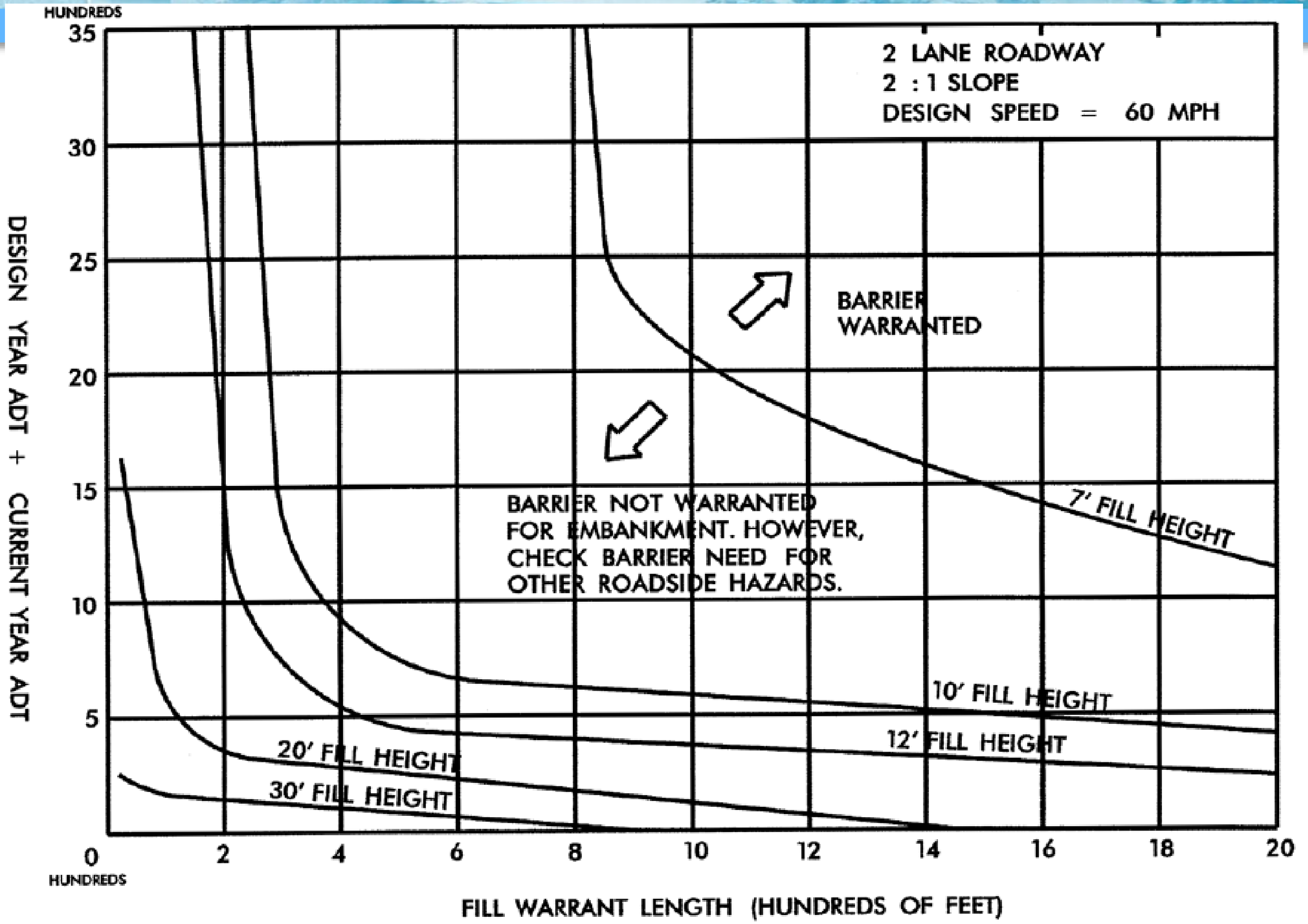

Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 5.1b, Pg. 5-6

# NC Embankment Warrants




Ref: NCDOT Roadway Design Manual, Part 1, Chapter 3

# Modified Embankment Warrants




Ref: NCDOT Roadway Design Manual, Part 1, Chapter 3, Figure 5

Is barrier warranted at the locations shown in the next eight photos?

Do not consider effectiveness of existing barrier (if any).


AVAILABLE

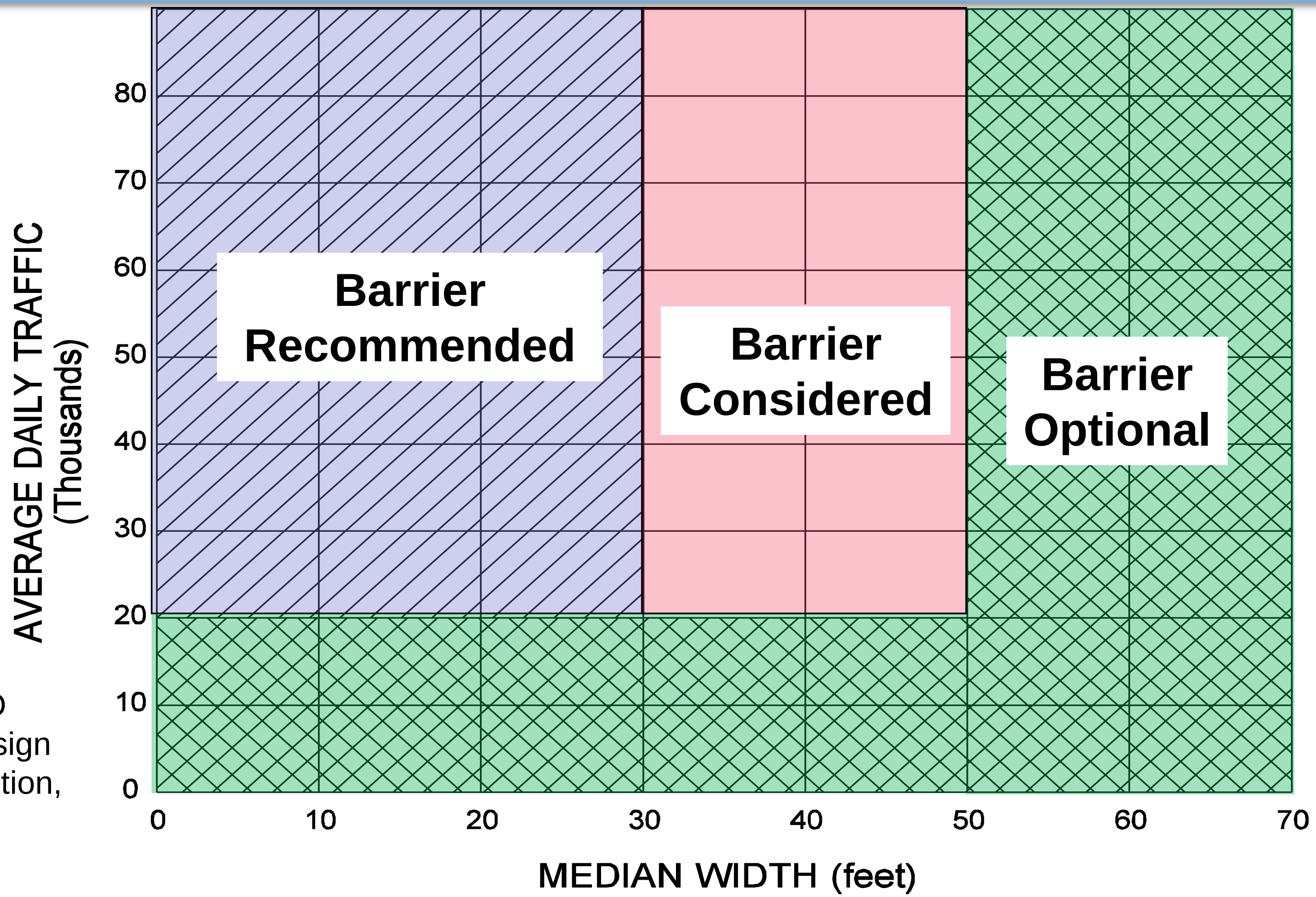

SPEED
LIMIT
45


NORTH
EAST
[redacted]


EXIT 14


Laurel
Fork

# Median Width Guidelines - AASHTO




Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 6-1

# Median Width Guidelines - NCDOT

ROADWAY DESIGN MANUAL PART 1

GUARDRAIL / GUIDERAIL TREATMENT IN MEDIAN LOCATIONS 3-6

**Guidelines for typical Median Guardrail / Guiderail Installations:**

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

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

# Review Learning Outcomes

- Understand and apply the clear zone concept
- Identify objects and features that may require shielding

# Session 3:

# Testing Requirements and Performance Characteristics of Common Barrier Systems

# Session 3 Learning Outcomes

At the end of this session, you will be able to:

- Understand how barriers are tested for crashworthiness
- Identify common barrier systems
- Explain how these barrier systems function
- Define the key components of a transition design

# Crash Testing Guidelines

- In 1993, crash testing and evaluation criteria were published as NCHRP Report 350
- In 2009, the Manual for Assessing Safety Hardware (MASH) was published by AASHTO. It was used by FHWA as the testing standard for all new products
- In 2016, an update to MASH was adopted and a timetable for implementation of new installations complying with this edition was signed between FHWA and AASHTO

# MASH Implementation Timeline

(AASHTO/FHWA Joint MASH Implementation Agreement Issued January 7, 2016)

**11 years**

10 years

9 ½ years

7 years

2 years

**2009**

**2016**

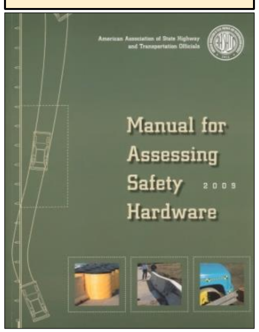
**Dec 31, 2017**

**June 30, 2018**

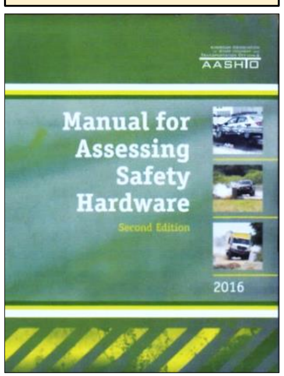
**Dec 31, 2018**

**December 31, 2019**

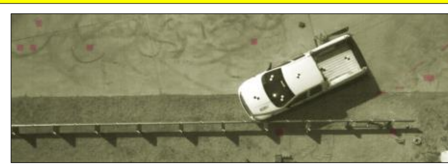
MASH Published




MASH 2016 Published




- **W-Beam Barriers**
- **Cast-in-place Concrete Barriers**



**W-Beam Terminals**
- **Tangent**
- ❖ **Flared**
- ❖ **Median**

- X **Crash Cushions**
- ❖ **Cable Barriers**
- ❖ **Cable Terminals**

- **All Other Terminals**
- **Transitions**
- **All Other Barriers/Portable**
- **Bridge Rails**
- **Sign Supports**
- **Other Breakaway Hardware**

❖ **MOVED TO DEC. 31, 2019**

X **SOME MOVED TO DEC. 31, 2019**

# MASH Test Conditions

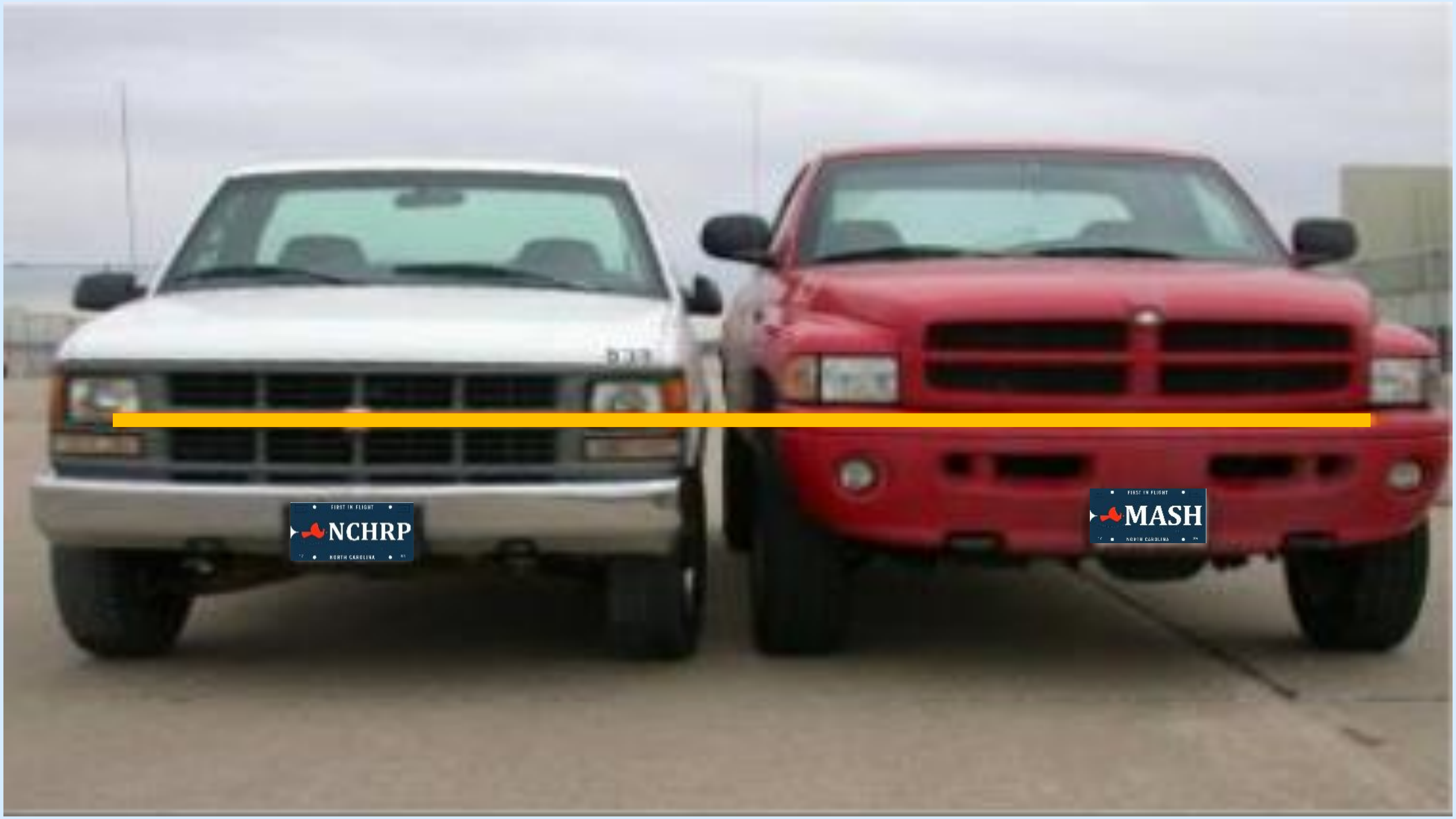
Selection of a performance level is based on speed and traffic mix.

- **TL-1**, **TL-2**, and **TL-3**: crash tests with small car and pickup truck with a 25˚ impact angle at 31, 44, and 62 mph, respectively.

2,420 lbs.
1100C

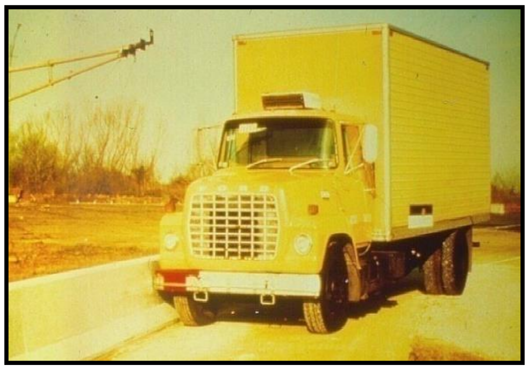
5,000 lbs.
2270P

# NCHRP 350 comparison with MASH Crew Cab Truck



# MASH Test Conditions (cont'd)

- **TL- 4**: TL-3 + 15˚ impact angle, 56 mph Single-Unit Truck
- **TL- 5**: TL-3 + 15˚ impact angle, 50 mph Tractor-Van Trailer
- **TL- 6**: TL-3 + 15˚ impact angle, 50 mph Tractor-Tank Trailer



22,000 lbs.

80,000 lbs.

80,000 lbs.

# Functional Requirement of Barrier

1. Contain Vehicle
   - No Penetration
   - No Vaulting/Under-riding
2. Redirect Vehicle Smoothly (low exit angle) with no snagging/overturning, and no excessive rotation (75 degree max)
3. Tolerable Occupant Impact Forces
4. Minimum Occupant Compartment Deformation and no Debris Intrusion

# Standard Barrier Systems

- Rigid Systems
- Semi-Rigid Systems
- Flexible Systems
- Median Barrier Systems

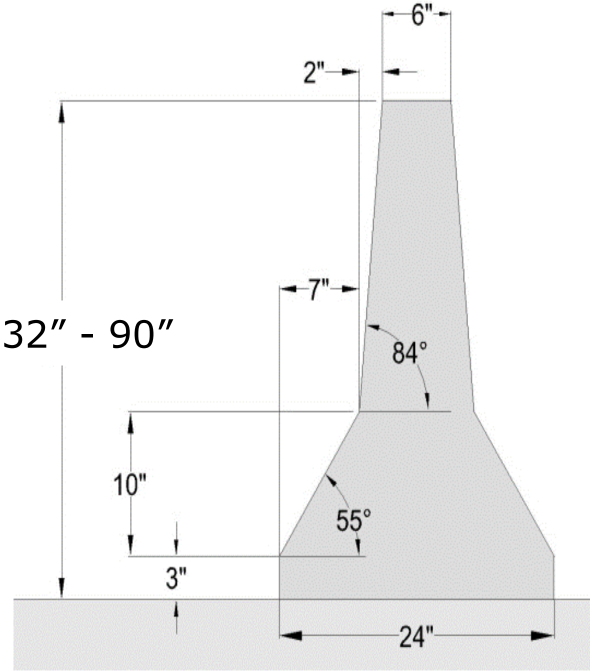
# Barrier Systems: Rigid Barriers

Rigid Barrier Systems have little (between 0 to 1 ft.) deflection under the TL-3 pickup impact. They are generally anchored by some acceptable means.

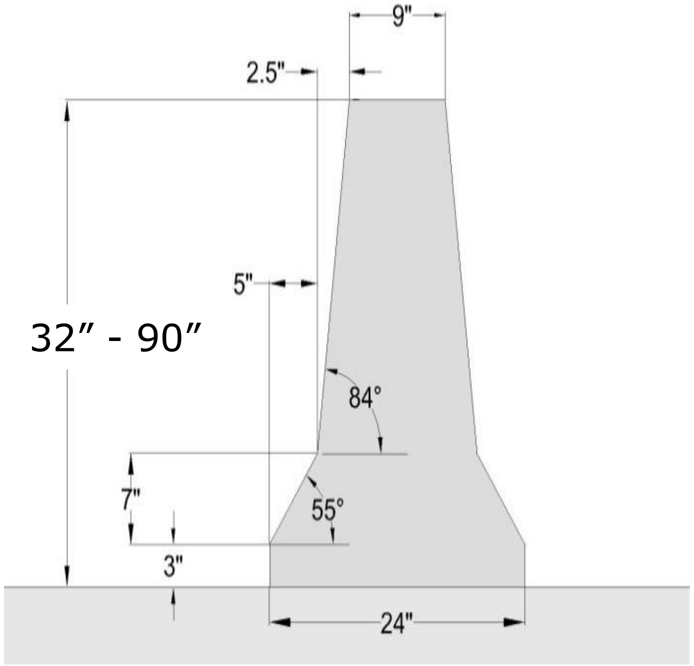
Examples include:

- New Jersey Safety Shape Concrete Barrier
- F-shape Concrete Barrier
- Single or Slope Concrete Barrier
- Vertical Wall

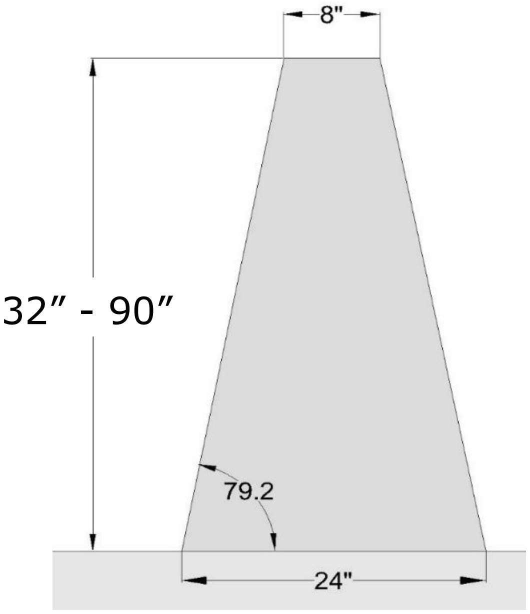
# Rigid Barrier




New Jersey Shape

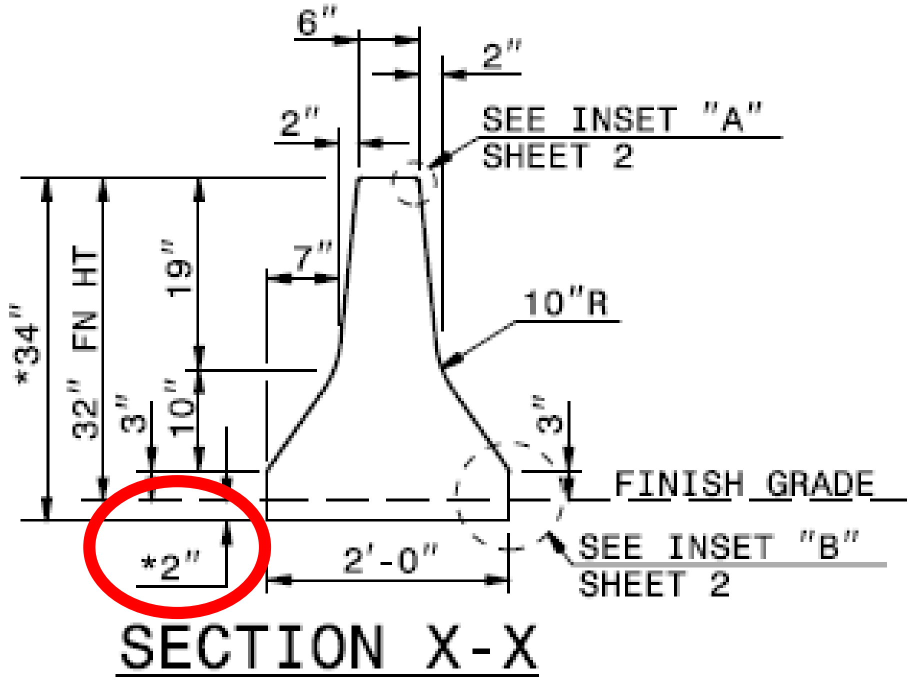



F-Shape




Single Shape

# Rigid Barrier – New Jersey Shape




TYPE IV - NO GLARE SCREEN PERMITTED

Type IV typically used

Types II & III for bifurcated cross-sections

2” min Embedment minimizes Deflection

When large trucks are not an issue

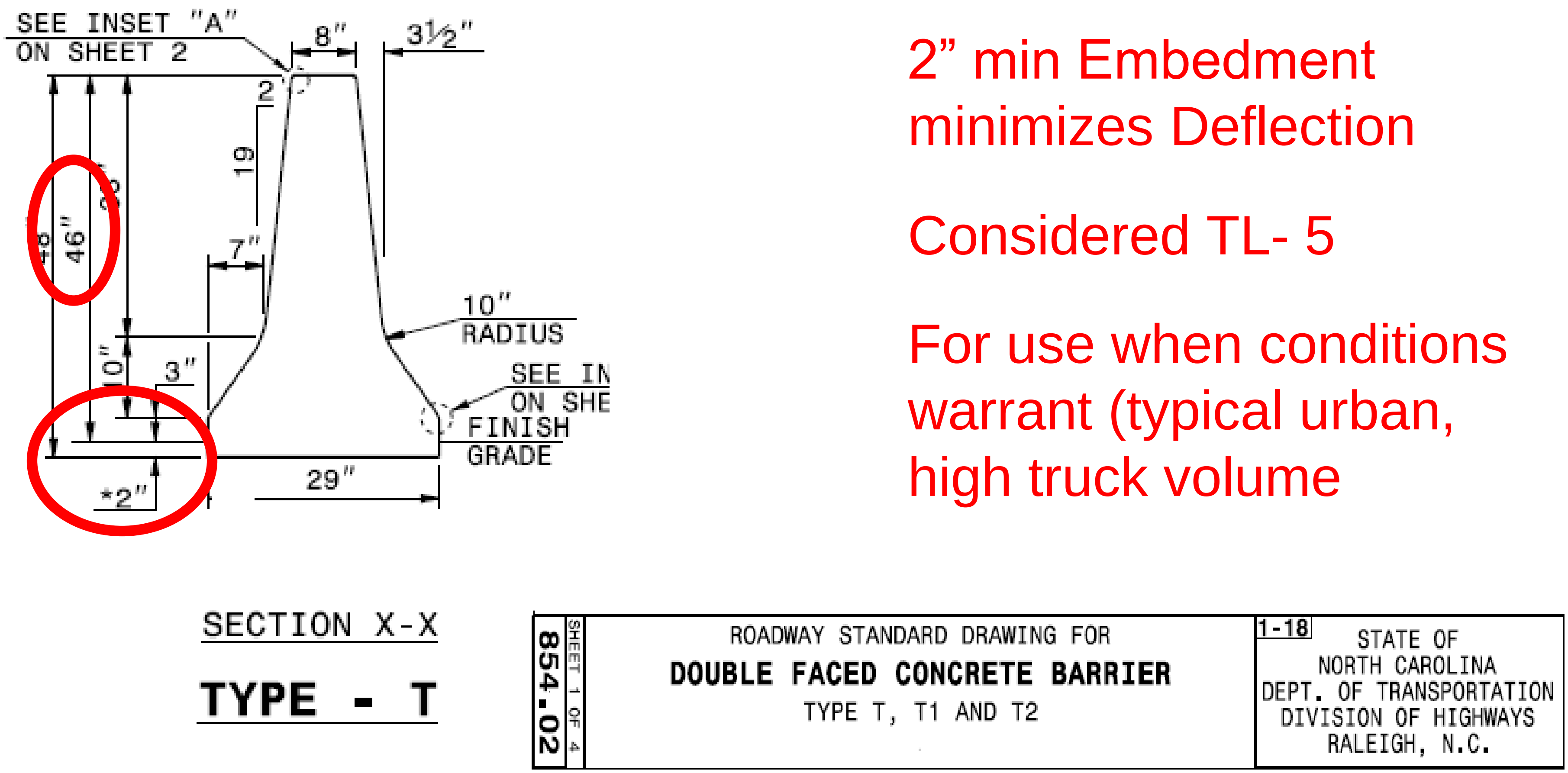
854.01 SHEET 1 OF 4

ROADWAY STANDARD DRAWING FOR
**DOUBLE FACED CONCRETE BARRIER**
TYPES I, II, III & IV

1-18

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

# Rigid Barrier – New Jersey Shape

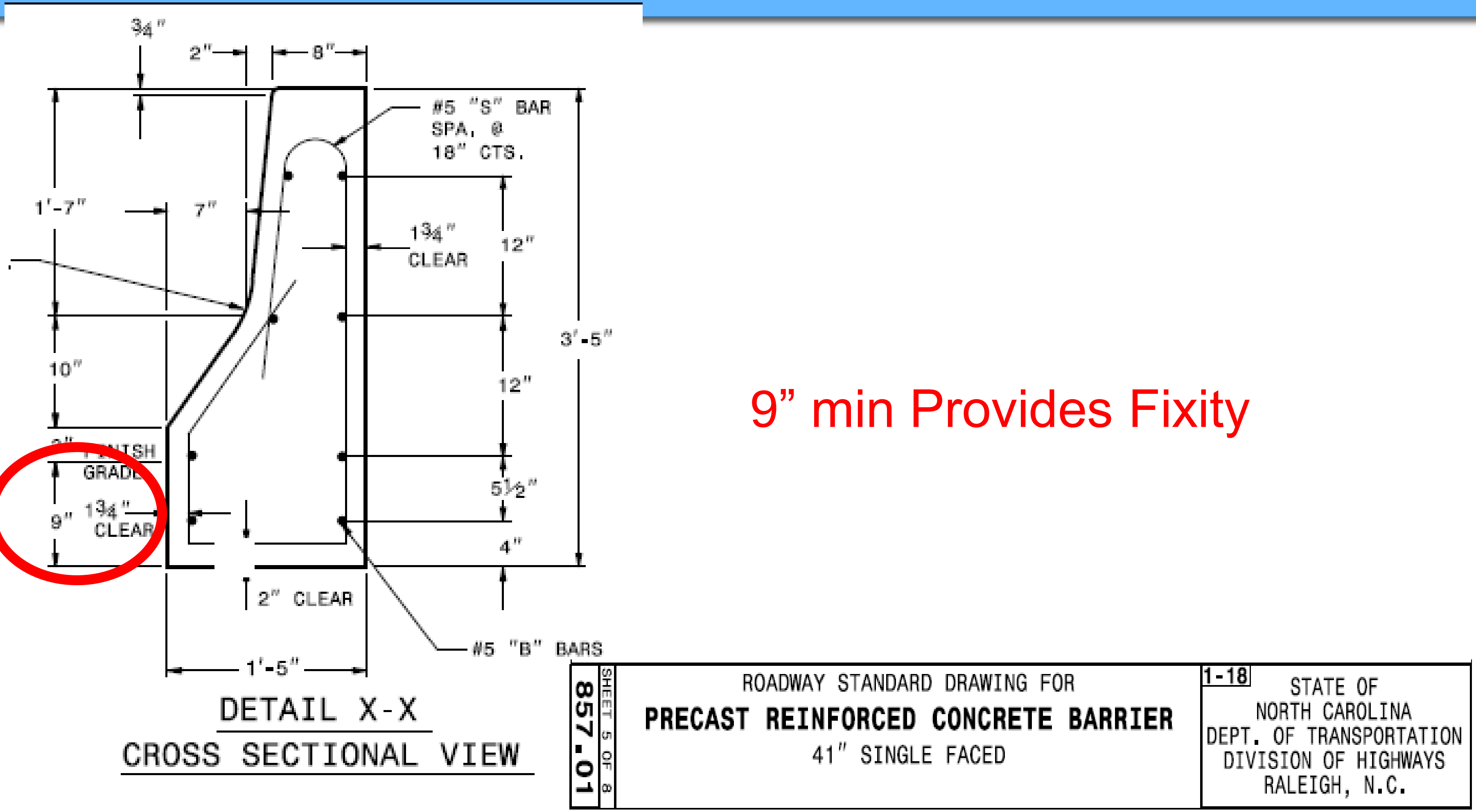



2" min Embedment minimizes Deflection

Considered TL- 5

For use when conditions warrant (typical urban, high truck volume

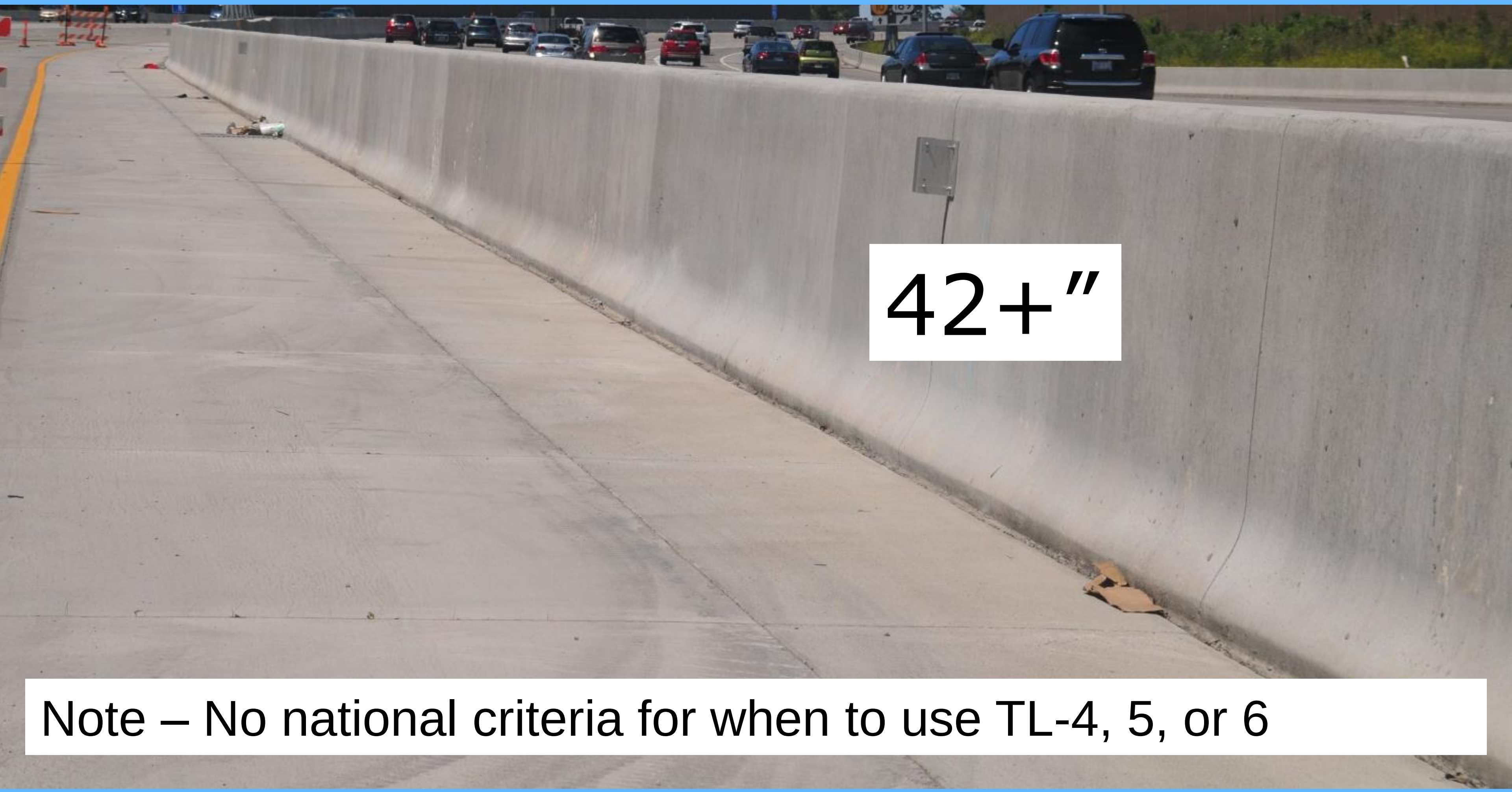
# Rigid Barrier – New Jersey Shape




9” min Provides Fixity

# MASH Testing of 32" New Jersey Shaped Concrete Barrier

# Rigid Barrier




Note – No national criteria for when to use TL-4, 5, or 6

# Rigid Barrier: TL-5

# Zone of Intrusion

<u>Zone of Intrusion (ZOI)</u> - the region measured above and behind the face of a barrier system where an impacting vehicle or any major part of the system may extend during an impact.

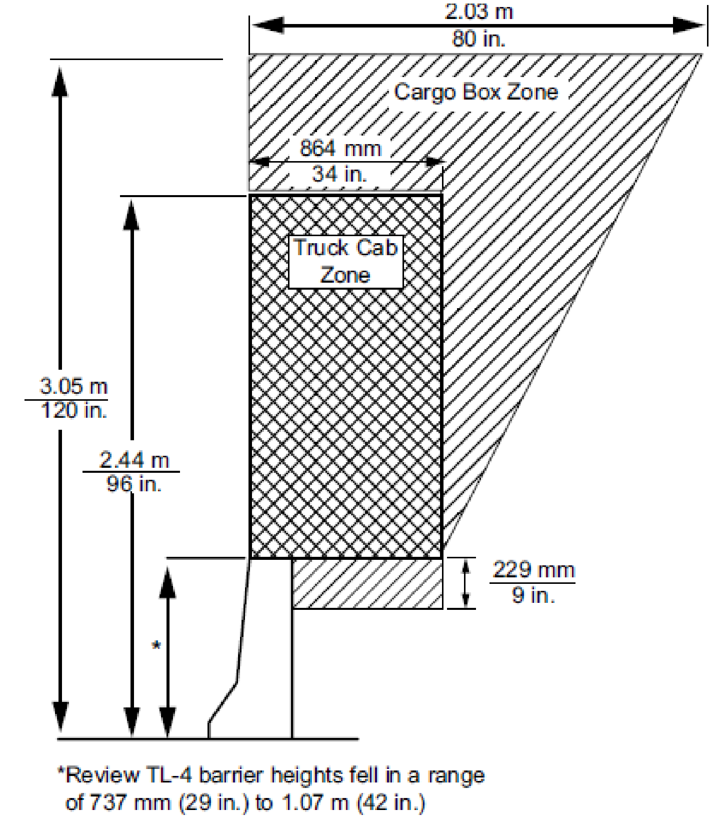



**Figure 5-31. Zone of Intrustion for TL-4 Barriers per NCHRP Report 350**

# AASHTO LRFD Bridge Specification (7th Edition)

**3.6.5.1**

Where the design choice is to redirect or absorb the collision load, protection shall consist of one of the following:

- An embankment;
- A structurally independent, crashworthy ground-mounted 54.0-in. high barrier, located within 10.0 ft from the component being protected; or
- A 42.0-in. high barrier located at more than 10.0 ft from the component being protected.

Such barrier shall be structurally and geometrically capable of surviving the crash test for Test Level 5, as specified in Section 13.

# Barrier Systems: Semi-Rigid

Semi-Rigid Barrier Systems have deflections of a few feet (between 2 to 5 ft.) under the TL-3 pickup impact.

Typically consist of beam and post elements.

TERMINOLOGY: Call new system 31” (shows 2’-1” to bolt on standards)

# Barrier Systems: Semi-Rigid

- W-Beam Steel Guardrail – **350 Guardrail (29")**
  - 12" wide W-beam rail section (12-gauge thickness).
  - Posts are spaced at 6'-3" centers, and the nominal rail height is 27" – 30"
  - Rail splice at the post.
  - Steel posts: W6 x 8.5/9.0 x 6'-0" long.
  - Offset Block: 6" x 8" recycle plastic or composite.

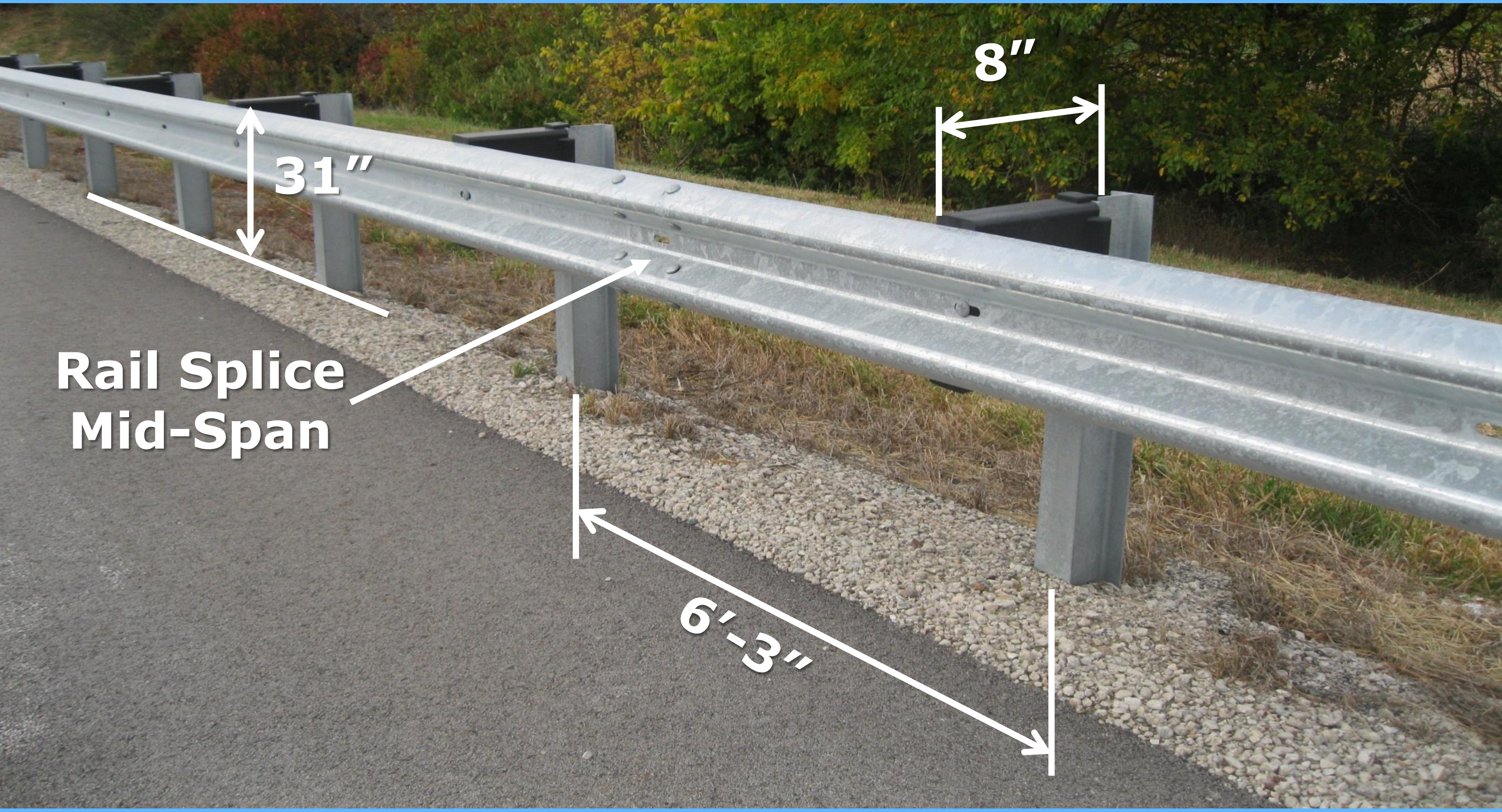
# Guardrail with Wood Post & Wood Offset Block 27 5/8” Height

# Guardrail with Steel Post & Wood Offset Block 27 5/8” Height

# Barrier Systems: Semi-Rigid

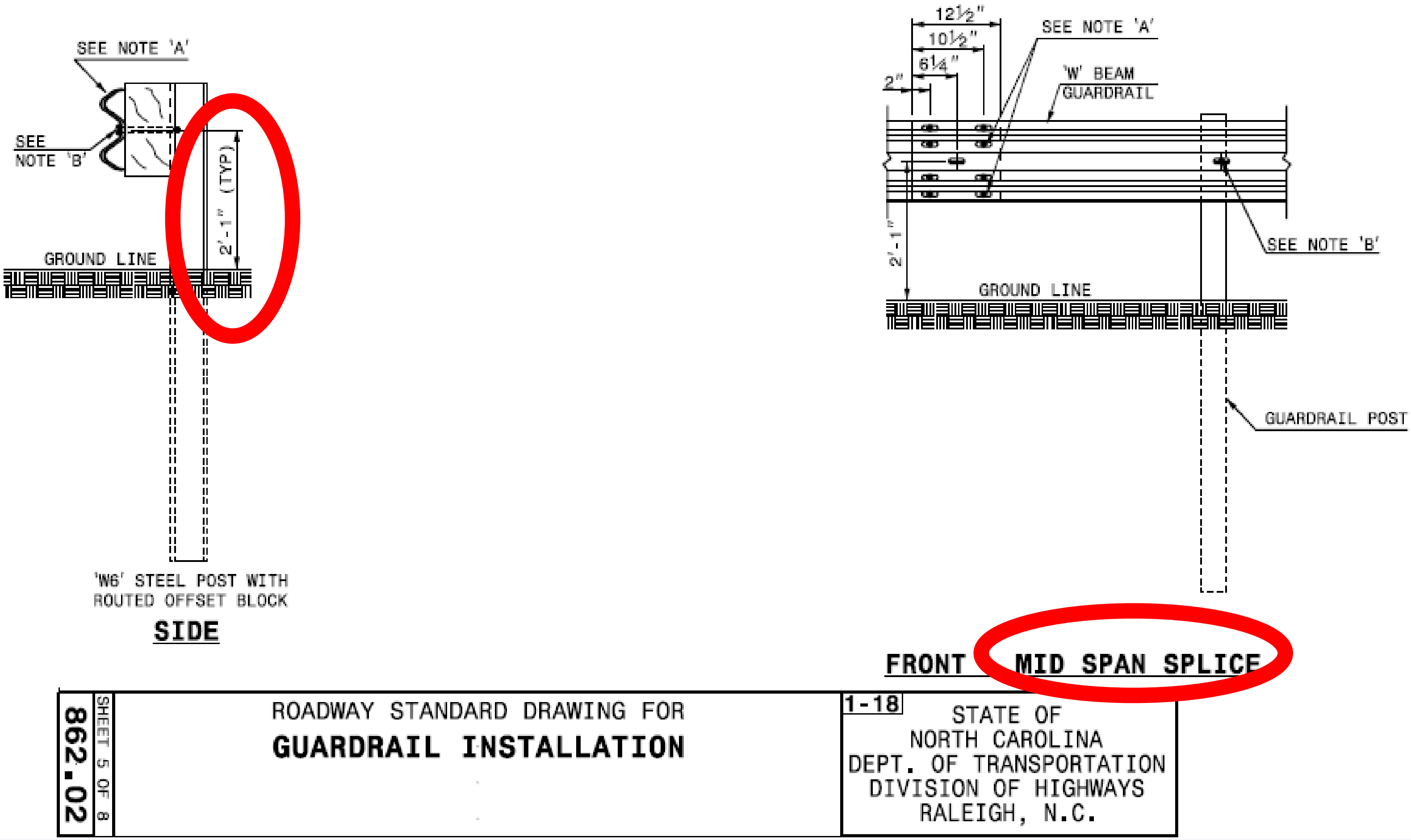
- **31”** (shown in standards as 2’-1”)
  - 31” Height to Top of Rail
  - Rail Splice mid-span.
  - Post spacing 6’-3”
  - Steel posts, W6 x 8.5/9.0 x 6’
  - Offset Block:  8” recycled plastic or composite

# 31” Guardrail



# 31” MASH Test 3-11

# NCDOT 31” Guardrail



# Existing Guardrail Height

Must be ≥ 27” to <u>remain</u> in place within the Transportation Improvement Program (TIP)

# Barrier Systems: Flexible Barriers

Flexible Barrier Systems typically have relatively large deflections

Examples of Flexible Barriers include:

- Weak post W-beam
- Low tension cable
- High tension cable

No longer in standards

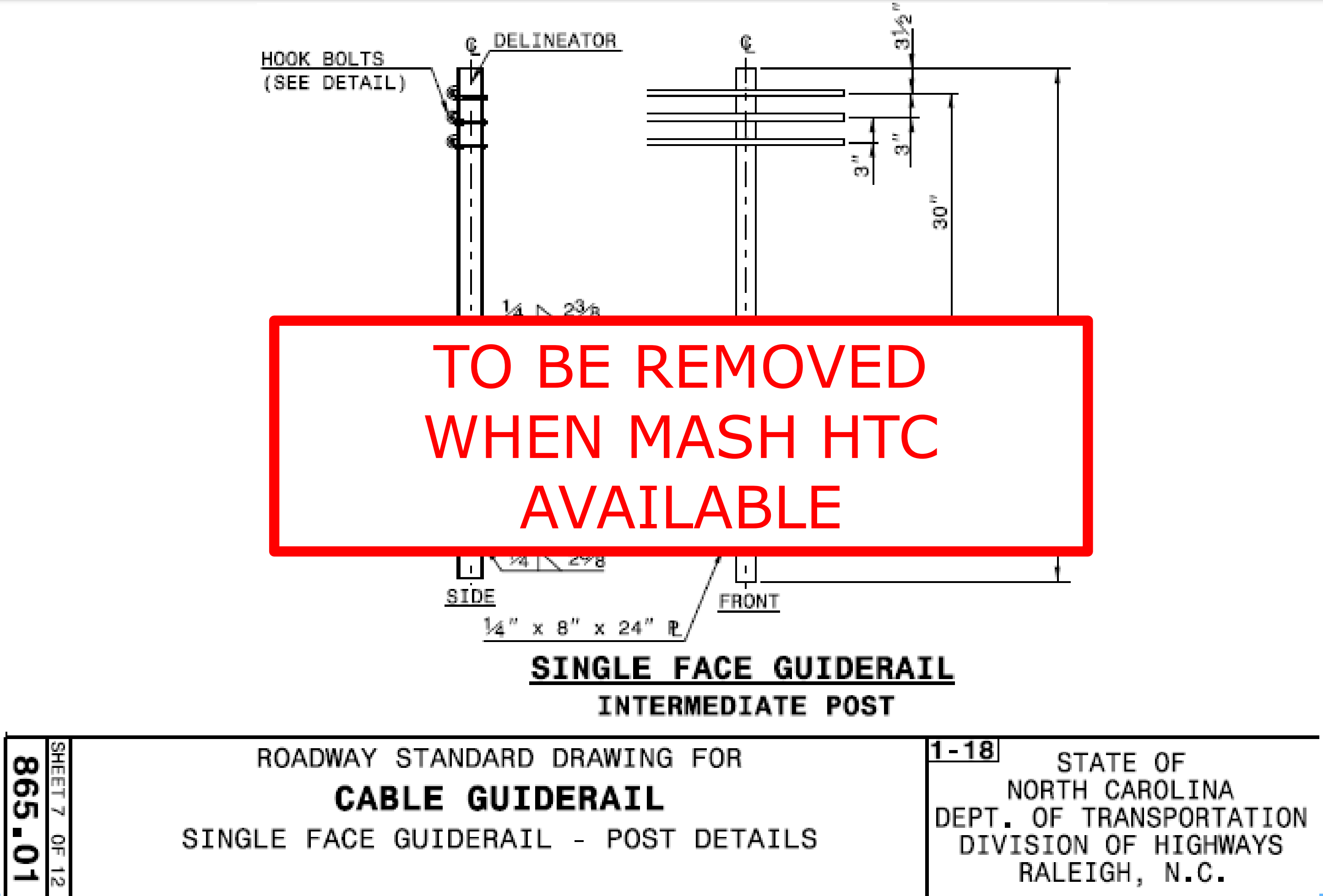
To be removed from standards when MASH available

# Barrier Systems: Flexible Barriers

- Low Tensioned Cable Barrier
  - Generic System
  - 3 cables design (center cable on opposite side of the post for median application).
  - Design deflection of approximately 12 ft.
  - Generic crashworthy terminal.

# Cable Guiderail

# NCDOT Cable Guiderail




TO BE REMOVED
WHEN MASH HTC
AVAILABLE

# Barrier Systems: Flexible Barriers

Advantages of cable systems include:

- Low initial cost
- Lower deceleration forces
- Effective vehicle containment and redirection
- Installation conditions flexibility
- SNOW

# Barrier Systems: Flexible Barriers

- High Tensioned Cable (HTC) Barrier
  - Five different proprietary designs available
  - Each requires a unique proprietary terminal
  - Somewhat reduced deflections
  - Generally easier maintenance
  - Can retain effectiveness after most impacts

# High-Tension Cable (HTC) Systems

- Brifen ★★
- Safence
- CASS (Trinity Steel) ★
- Nucor
- Gibraltar ★

★ = APL

Currently, NO system has passed all MASH 2016 testing

# Brifen USA

http://www.brifenusa.com

- Interweaving cables creates a “mini-anchor” at each post due to friction as the tensioned cables weave past each post.
- 3 or 4 cable design available.

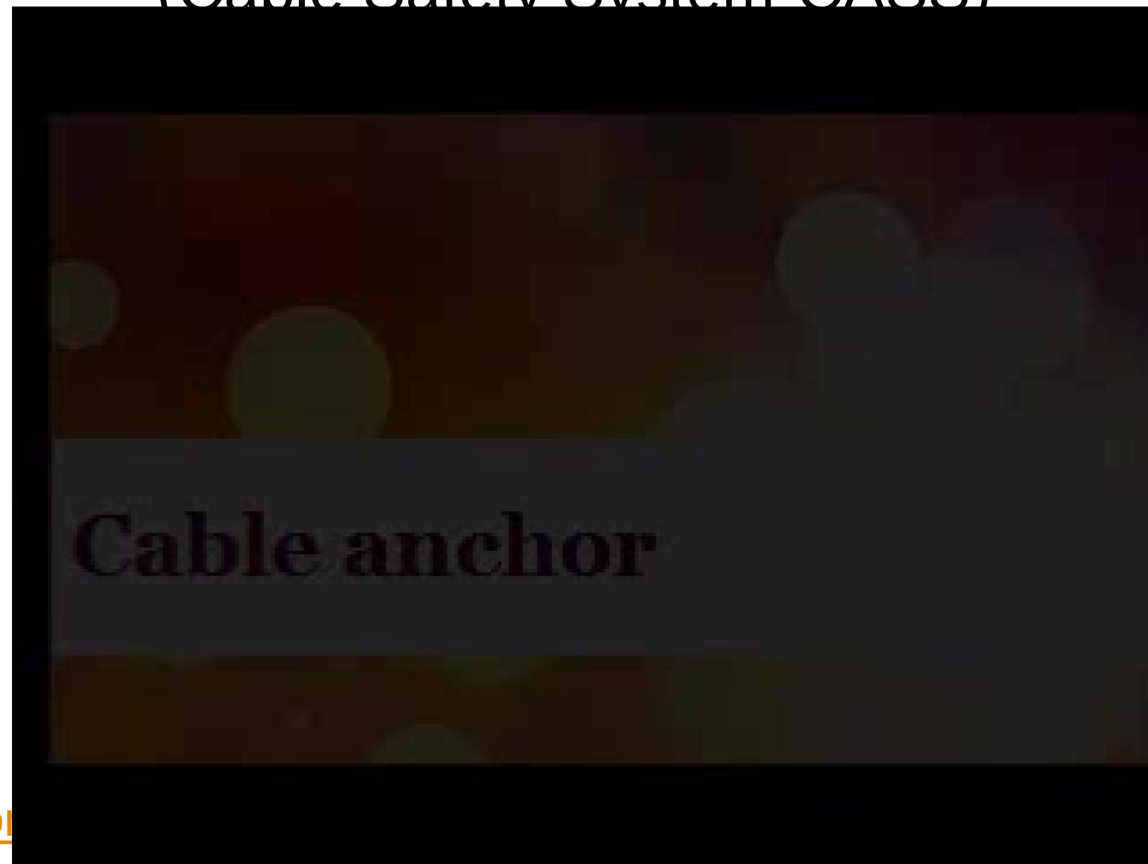
# Gibraltar

http://www.gibraltartx.com

- Has hairpin type connection to post.
- Posts to cable connection is alternate side-to-side
- 3 or 4-cable design available.

# Trinity Industries

(Cable Safety System-CASS)




http://www.highwayguardrail.co

- 3 or 4 cable design available.

# Four Cable System

# Post Foundation and Typical Terminal

# HTC On 4:1 Slope

# Barriers in the Median

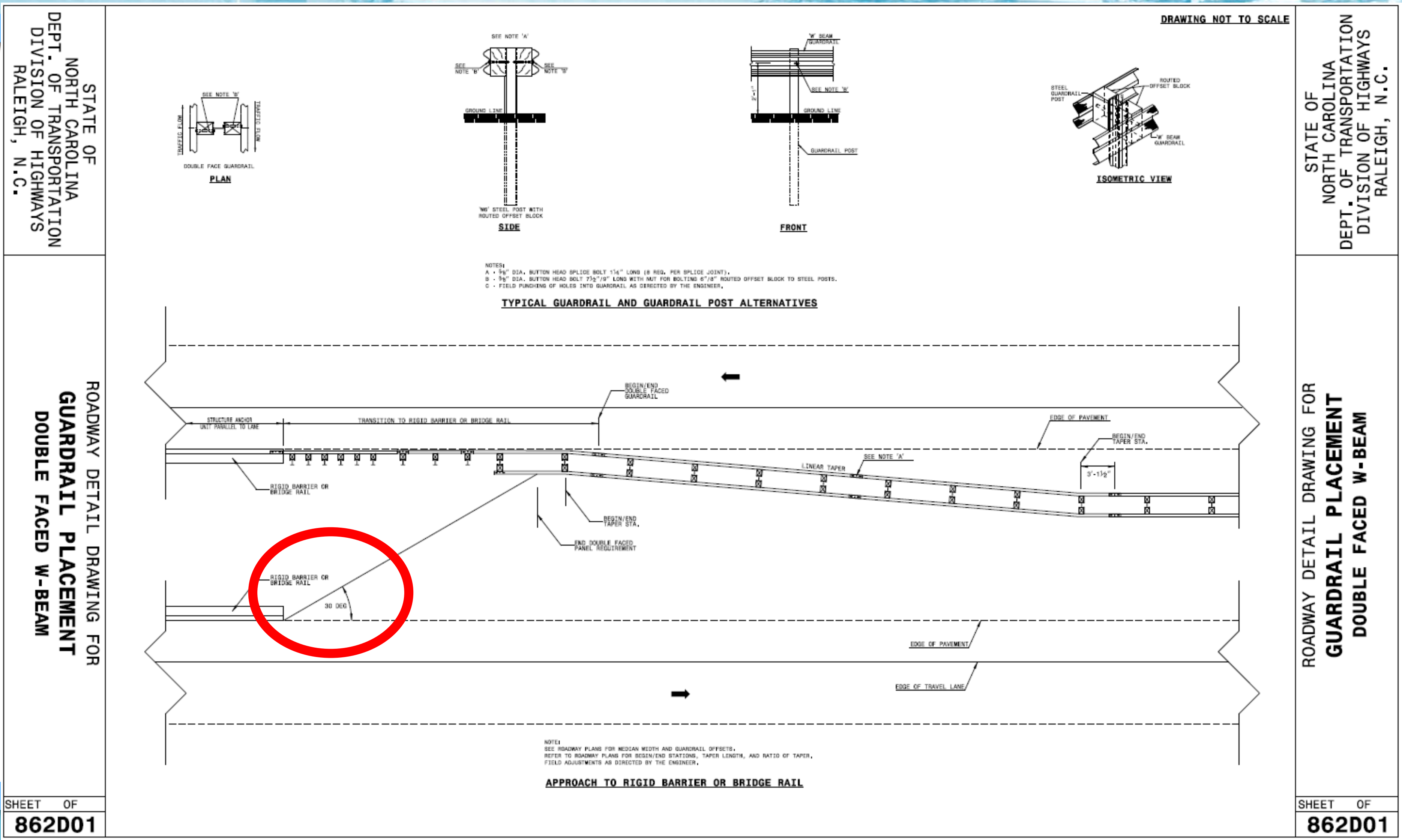
- Used to separate opposing traffic on a divided highway or to separate through traffic from local traffic.
- Many barriers approved for roadside applications can be modified for use in the median.
- Width of the median is an important consideration.
- Also must consider the dynamic deflection of the barrier to avoid intrusion into opposing traffic.
- There are terminals designed specifically to shield the ends of median barriers.

# MASH 27” W-Beam Median Barrier Test

Failed Test!!!

# MASH 31” Median Barrier Test

# MASH 31” Median Barrier



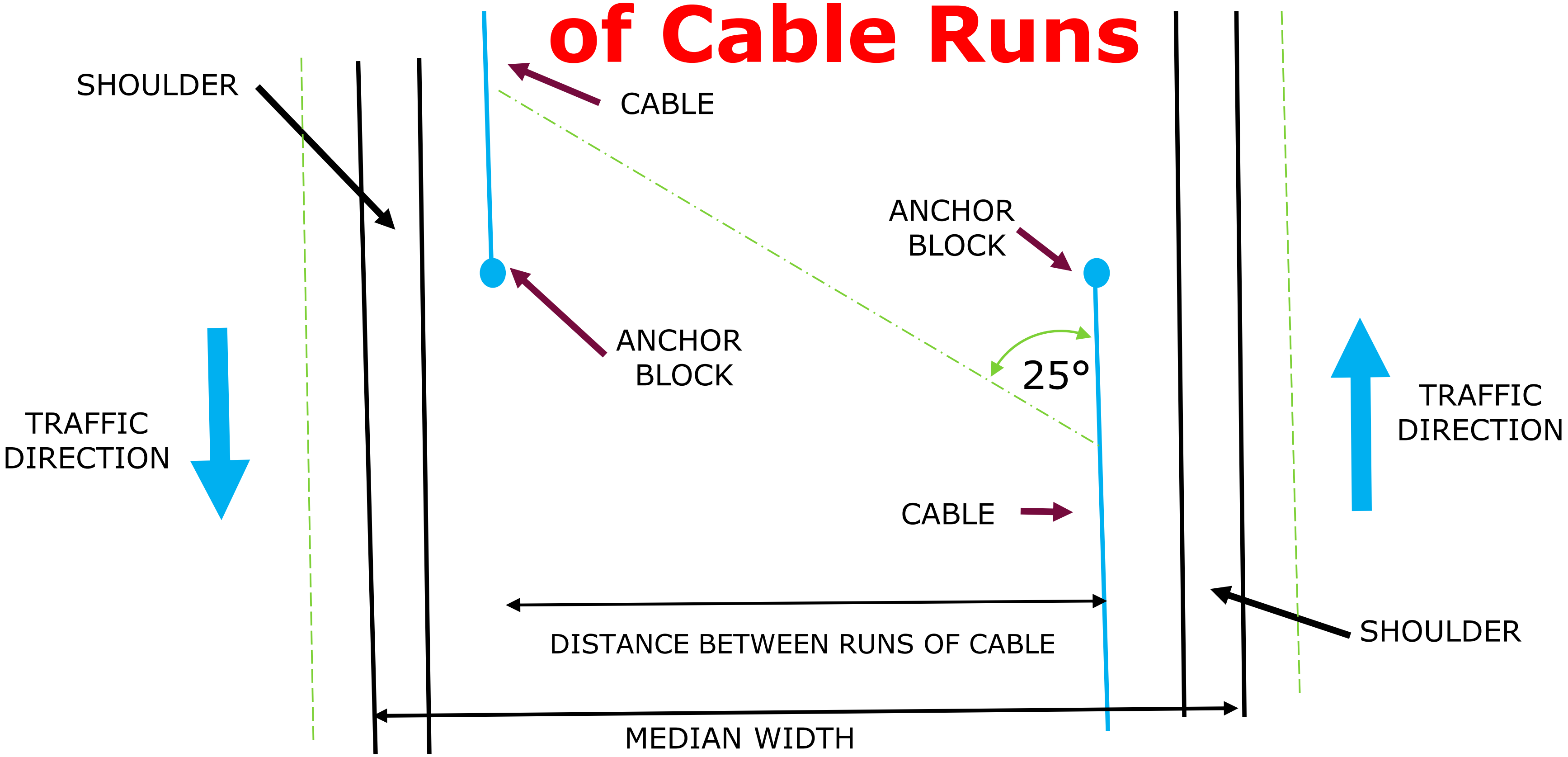
# Flexible Median Barriers

Advantage of high tension cable is it may remain effective after impact.

# Flexible Median Barriers

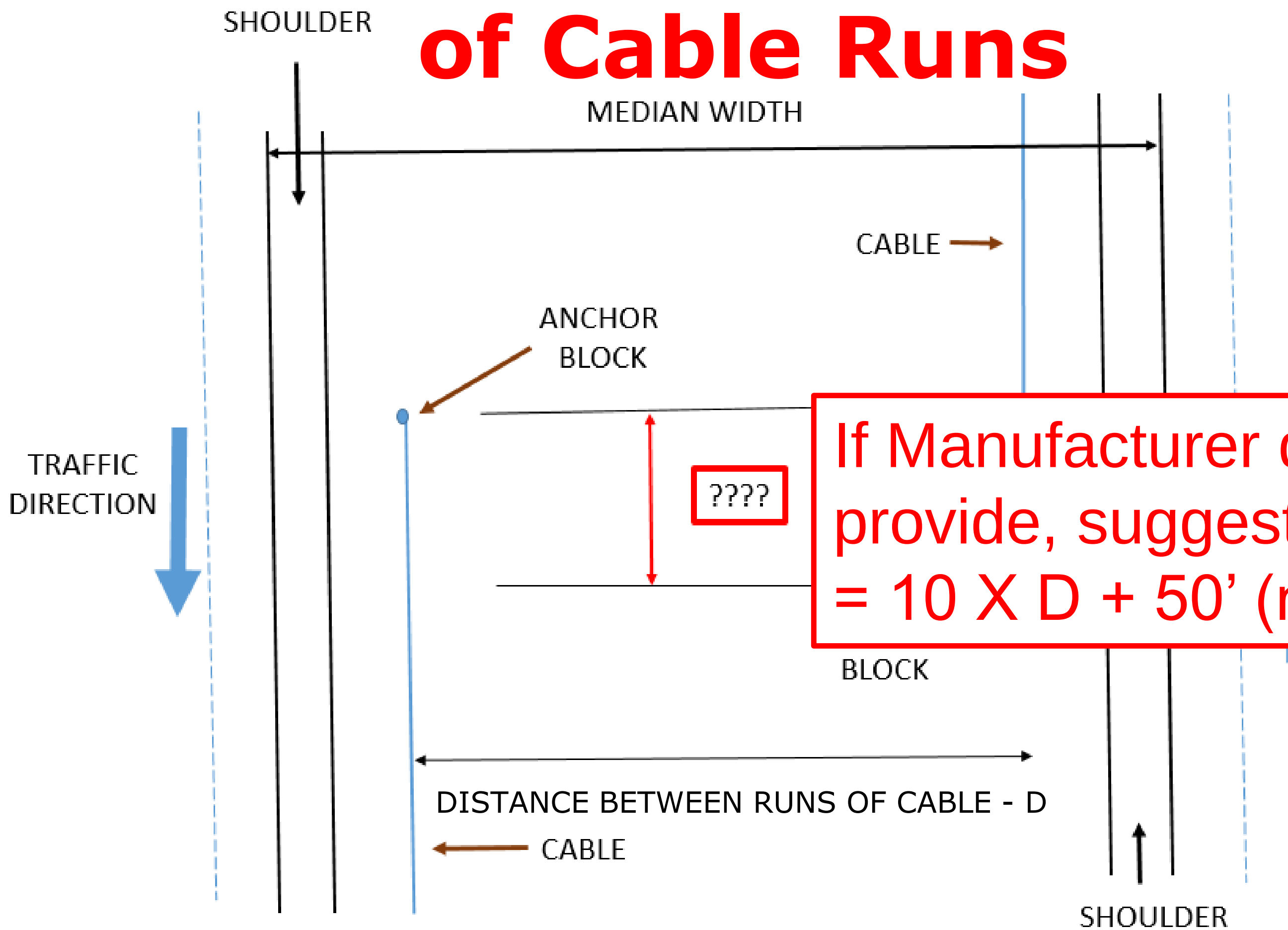
# Treatment at Opening

## Near-Side Overlap of Cable Runs



# Treatment at Opening

## Far-Side Overlap of Cable Runs




If Manufacturer does not provide, suggest
= 10 X D + 50' (max 300')

# Transition Sections

- When a softer (more flexible) barrier precedes a stiffer barrier, a gradual stiffening must occur between the two systems.
- An effective transition must provide the following:
  - Adequate connection (TENSION continuity)
  - Adequate length to gradually increase stiffness.

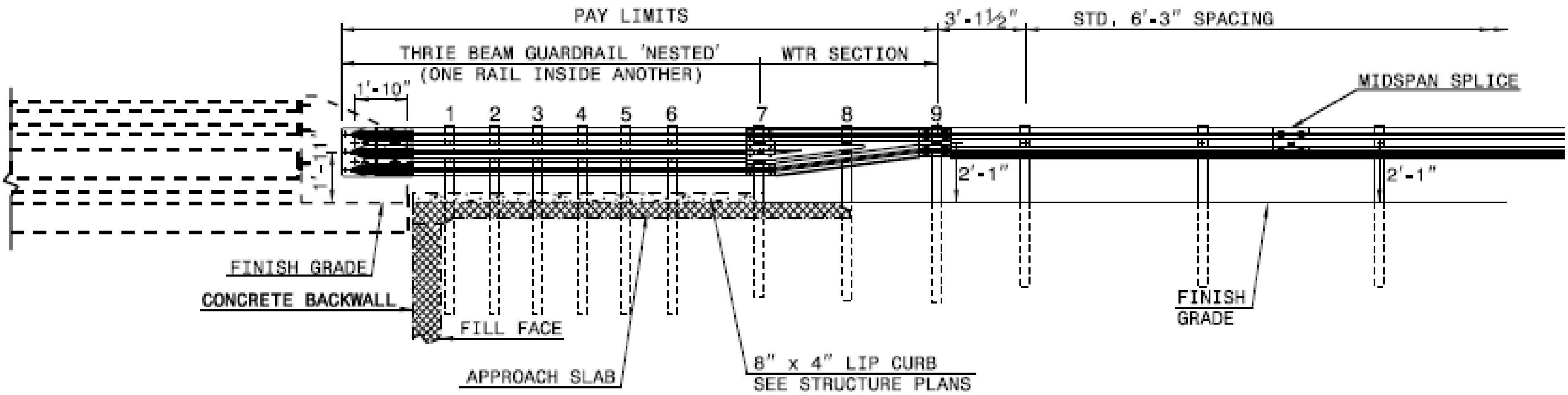
# Inadequate Transition

# Transition Sections

Successfully crash-tested transitions include the following essential elements (in addition to a structural connection):

- Additional and/or Larger Posts
- Nested rail (w-beam or Thrie-beam)
- Curbs (only as crash-tested transition unit), Rub Rails, and/or Flared Parapet Wall to Prevent Snagging

# NCDOT Transition – Thrie-beam

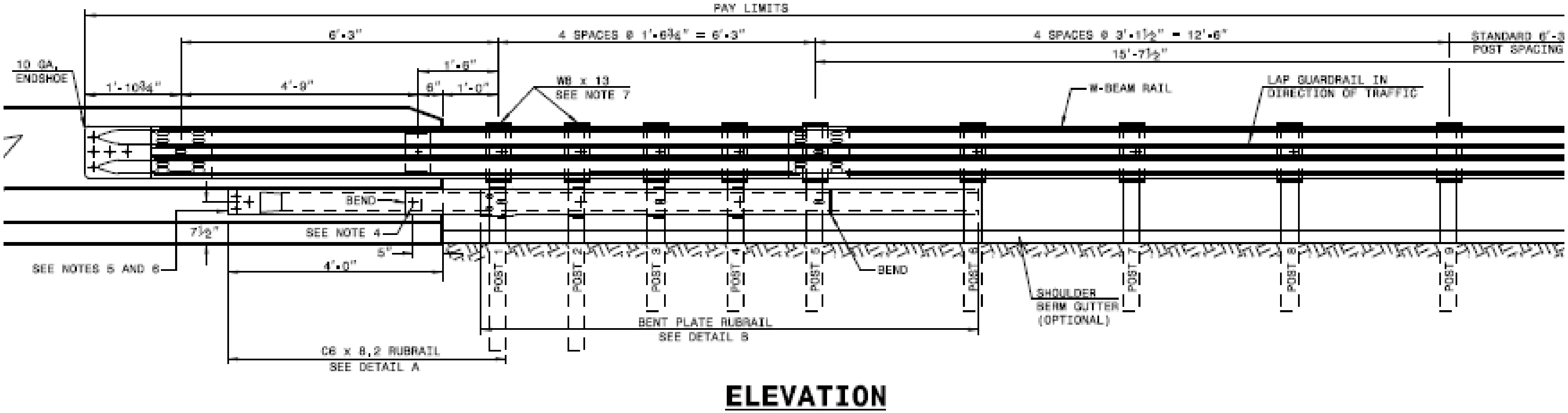



**ELEVATION**

| | | | |
|---|---|---|---|
| 862.03 | SHEET 1 OF 7 | ROADWAY STANDARD DRAWING FOR<br>**STRUCTURE ANCHOR UNITS**<br>GUARDRAIL ANCHOR UNIT, TYPE III<br>FOR ATTACHMENT TO RAIL ON BRIDGE | 1-18<br>STATE OF<br>NORTH CAROLINA<br>DEPT. OF TRANSPORTATION<br>DIVISION OF HIGHWAYS<br>RALEIGH, N.C. |

# NCDOT Transition – Previous Standard

# NCDOT Transition – Direct




SHEET 4 OF 7

862.03

ROADWAY STANDARD DRAWING FOR

**STRUCTURE ANCHOR UNIT**

GUARDRAIL ANCHOR UNIT TYPE B-77

FOR F-SHAPE BARRIER

1-18

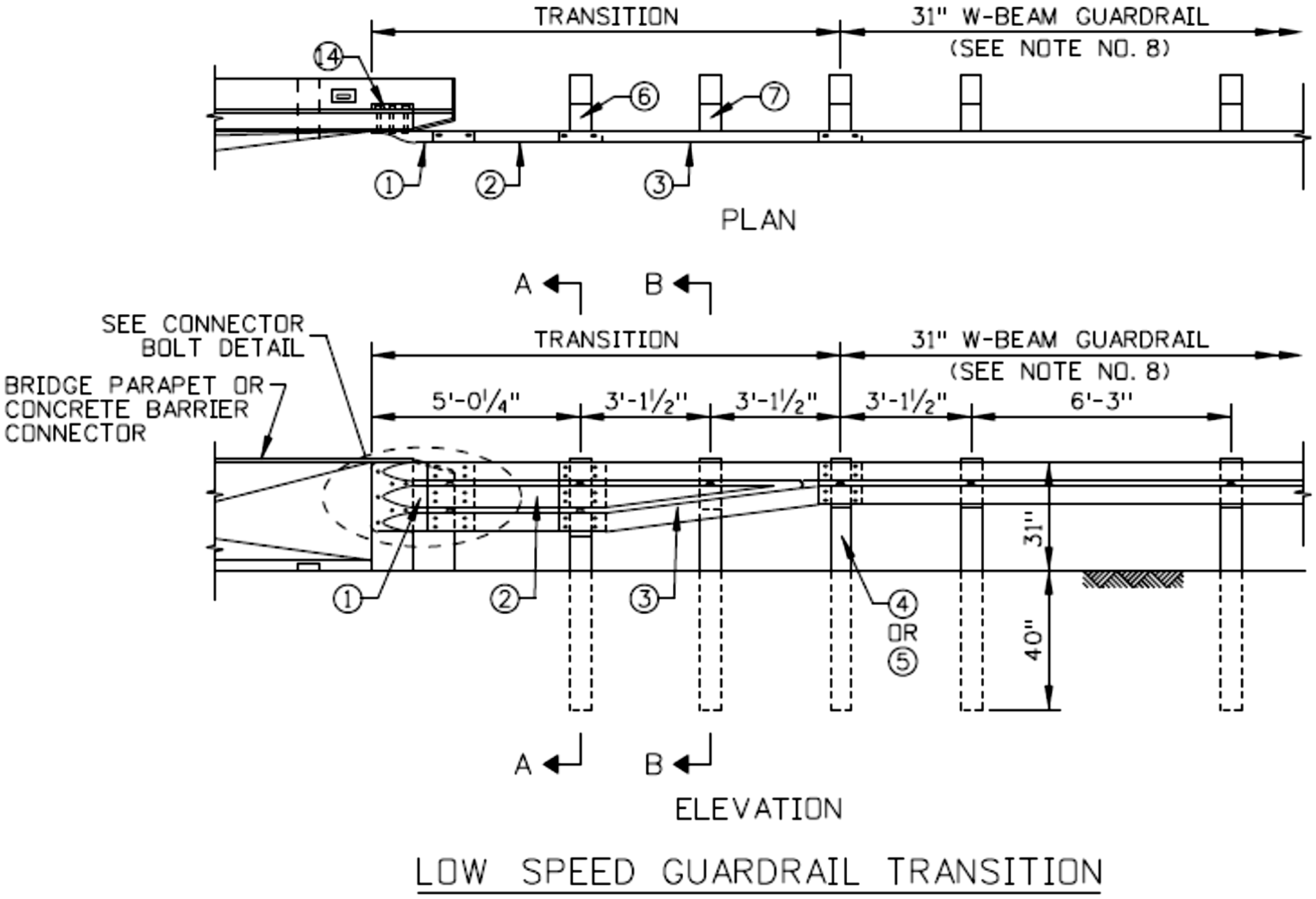
STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

# NCDOT Transition – With Curb

# NPS Transition

# 31” Transition

# Transition – 31”, TL-2



# Connections to Low Parapets or Combination Rails

If the concrete parapet or portion of a combination rail is less than the transition height (31”), a steel plate may be applicable to adjust the height.

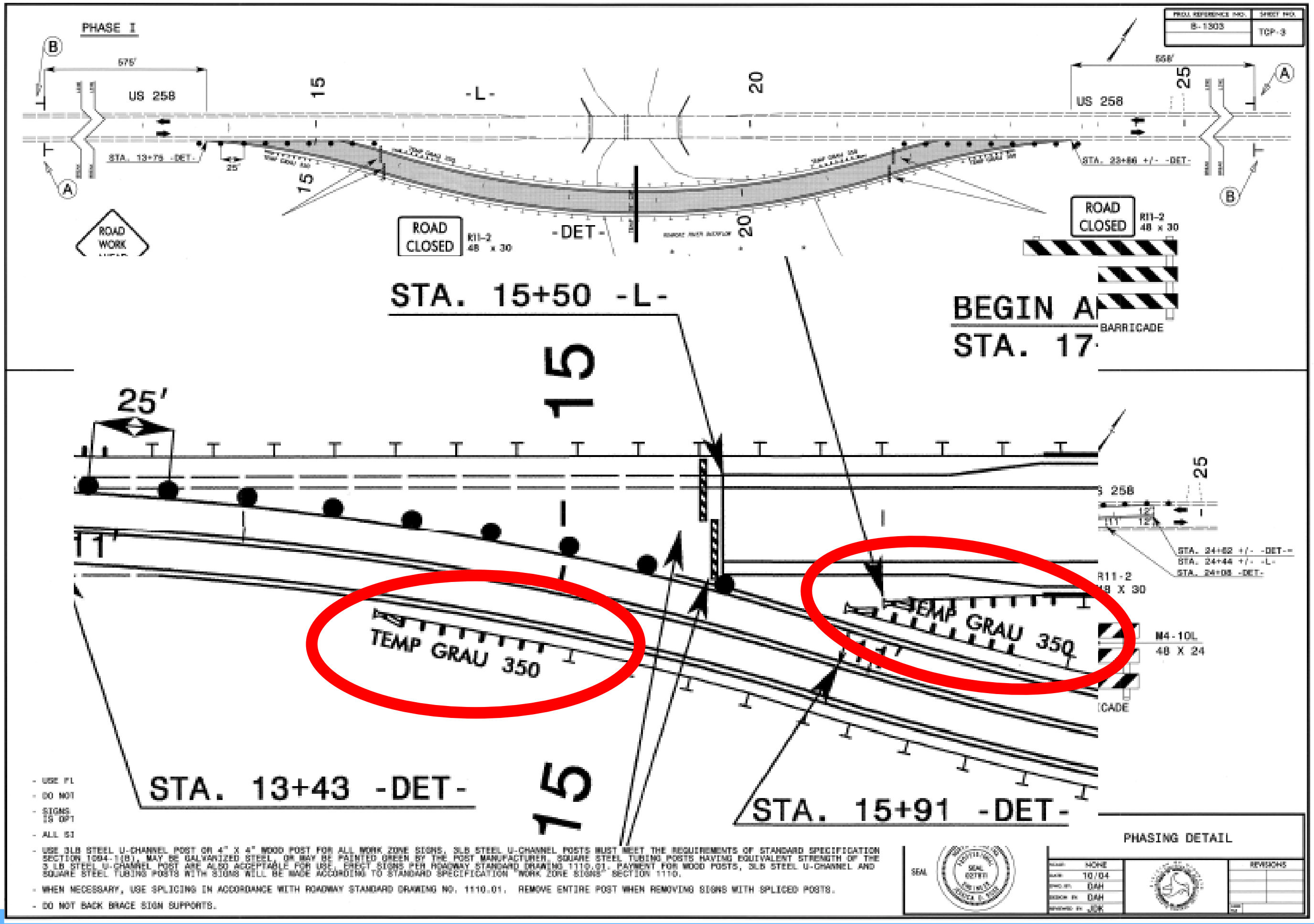
# Transition: HTC to Guardrail (Spatial)

# HTC or LTC - Cable to W-Beam Transition

Probably not going to be available with MASH

# HTC - Cable to W-Beam Transition

# Temporary Barrier – Need for Tension




Traffic Management Plan

COMPUTED BY: K.N.WASHINGTON DATE: 05/26/2005
CHECKED BY: T. F. DUNCAN, PE DATE: 06/2/2005

| PROJECT NO. | SHEET NO. |
|---|---|
| B-1303 | 3-B |

# STATE OF NORTH CAROLINA
# DIVISION OF HIGHWAYS

## SUMMARY OF EARTHWORK

| Station | Station | Uncl. Excav. CY | Embank. +% CY | Borrow CY | Waste CY |
|---|---|---|---|---|---|
| -L- | | | | | |
| 13+00.00 | 17+89.94 | 74 | 1,398 | 1,324 | |
| 19+72.06 | 24+44.63 | 32 | 1,332 | 1,300 | |
| | | | | | |
| -DET- | | | | | |
| 15+00.00 | 22+50.00 | | 23,877 | 23,877 | |
| | | | | | |
| SUBTOTALS: | | 106 | 26,607 | 26,501 | |
| | | | | | |
| -DET- REMOVAL | | 18,445 | | | 18,445 |
| | | | | | |
| | | | | | |
| PROJECT TOTALS: | | 18,551 | 26,607 | 26,501 | 18,445 |
| EST. 5% TO REPLACE TOP SOIL OF BORROW PIT | | | | 1,325 | |
| | | | | | |
| EST. SHOULDER MATERIAL | | | 672 | 672 | |
| GRAND TOTALS: | | 18,551 | 27,279 | 28,498 | 18,445 |
| | | | | | |
| SAY: | | 18,600 CY | | 28,600 CY | |
| | | | | | |
| | | | | | |

UNDERCUT EXCAVATION = 500 CY
SELECT GRANULAR MATERIAL = 5000 CY
FABRIC FOR SOIL STABILIZATION = 1500 SY

## SUMMARY OF EXISTING ASPHALT PAVEMENT REMOVAL

| LINE | Station | Station | LOC LT/RT/CL | AREA SY |
|---|---|---|---|---|
| -L- | 17+40.00 | 18+14.00 | CL | 263 |
| -L- | 19+20.00 | 20+28.00 | CL | 356 |
| | | | | |
| -DET- | 14+73.68 | 22+87.55 | CL | 2,351 |
| | | | TOTAL: | 2,970 |
| | | | SAY: | 3,000 SY |

APPROXIMATE QUANTITIES ONLY. UNCLASSIFIED EXCAVATION, FINE GRADING, CLEARING AND GRUBBING, AND REMOVAL OF EXISTING PAVEMENT WILL BE PAID FOR AT THE LUMP SUM PRICE FOR "GRADING".

"N" = DISTANCE FROM EDGE OF LANE TO FACE OF GUARDRAIL.
TOTAL SHOULDER WIDTH = DISTANCE FROM EDGE OF TRAVEL LANE TO SHOULDER BREAK POINT.
FLARE LENGTH = DISTANCE FROM LAST SECTION OF PARALLEL GUARDRAIL TO END OF GUARDRAIL.
W = T[illegible] BEGINNING OF TAPER TO END OF GUARDRAIL.
[illegible]ATING IMPACT ATTENUATO[illegible] 350
NG = NON-GATING IMPACT ATTENUATO[illegible]PE 350

## GUARDRAIL SUMMARY

| LINE | BEG. STA. | END STA. | LOC. | LENGTH: STRAIGHT | LENGTH: TEMP STRAIGHT | LENGTH: DOUBLE FACED | WARRANT POINT: APPR. END | WARRANT POINT: TRAIL. END | "N" DIST FROM E.O.L. | TOTAL SHLDR WIDTH |
|---|---|---|---|---|---|---|---|---|---|---|
| -L- | 13+82.94 | 17+[illegible]4 | RT | 475.00 | | | 13+03.00 | 17+77.94 | 10 | 13 |
| -L- | 13+82.94 | 17+7[illegible]4 | LT | 475.00 | | | 17+77.94 | 13+00.00 | 10 | 13 |
| -L- | 19+84.06 | 23+0[illegible] | RT | 325.00 | | | 19+84.06 | 23+50.00 | 10 | 13 |
| -L- | 19+84.06 | 22+[illegible] | LT | 300.00 | | | 21+50.00 | 19+84.06 | 10 | 13 |
| -L- | 16+00.00 | | RT | | | | | | 10 | 13 |
| -L- | | 21[illegible]00 | RT | | | | | | 10 | 13 |
| -DET- | 14+44.15 | [illegible].15 | RT | | 875.00 | | 15+00.00 | 23+00.00 | 6 | 8 |
| -DET- | 15+87.50 | [illegible]50.00 | LT | | 562.50 | | 20+50.00 | 17+00.00 | 6 | 8 |
| SUBTOTAL: | | | | 1,575.0 | 1,437.5 | | | | | |
| | | | | | | | | | | |
| [illegible]NCHORS DEDUCT[illegible] | | | | | | | | | | |
| GRAU [illegible] | [illegible] | @ | 50.00 | -200.00 | | | | | | |
| TYPE III | 4 | @ | 18.75 | -75.00 | | | | | | |
| TEMP GRAU | 4 | @ | 50.00 | | -200.00 | | | | | |
| ANCHOR TOTALS: | | | | -275.00 | -200.00 | | | | | |
| | | | | | | | | | | |
| GRAND TOTAL: | | | | 1,300.00 LF | 1,237.50 LF | | | | | |
| | | | | | | | | | | |
| SAY: | | | | 1,300.00 LF | 1,237.50 LF | | | | | |
| | | | | | | | | | | |
| ADDITIONAL GUARDRAIL POST: | | | | 5 EA | | | | | | |

| LINE | FLAIR LENGTH: APPR. END | FLAIR LENGTH: TRAIL. END | W: APPR. END | W: TRAIL. END | ANCHORS: TYPE III | ANCHORS: GRAU 350 | ANCHORS: TEMP GRAU 350 | IMP. ATTEN. TYPE 350: EA | G | NG | REMOVE EXISTING GRDRAIL | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -L- | 50 | | 1 | | 1 | 1 | | | | | 137.50 | GR WARRANTED ALONG ENTIRE RT SIDE BEFORE BR. |
| -L- | | 50 | | 1 | 1 | 1 | | | | | 137.50 | GR WARRANTED ALONG ENTIRE LT SIDE BEFORE BR. |
| -L- | | 50 | | 1 | 1 | 1 | | | | | 137.50 | |
| -L- | 50 | | 1 | | 1 | 1 | | | | | 137.50 | |
| -L- | 50 | | 1 | | | | 1 | | | | | REQUESTED BY TRAFFIC CONTROL |
| -L- | | 50 | | 1 | | | 1 | | | | | REQUESTED BY TRAFFIC CONTROL |
| -DET- | 50 | 50 | 1 | 1 | | | 2 | | | | | REMOVE -DET- TEMP GR |
| -DET- | 50 | 50 | 1 | 1 | | | 2 | | | | | REMOVE -DET- TEMP GR |
| SUBTOTAL: | | | | | 4 | 4 | 6 | | | | | |
| GRAND TOTAL: | | | | | 4 | 4 | 6 | | | | 550.00 LF | |
| SAY: | | | | | 4 | 4 | 6 | | | | 550.00 LF | |

# Quantity Summary Sheet

# Quantity Summary Sheet – blow-up

| LINE | BEG. STA. | END STA. |
|---|---|---|
| -L- | 13+02.94 | 17+77.94 |
| -L- | 13+02.94 | 17+77.[illegible]4 |
| -L- | 19+84.06 | 23+09.[illegible]6 |
| -L- | 19+84.06 | 22+84.[illegible]6 |
| -L- | 16+00.00 | |
| -L- | | 21+5[illegible].00 |
| -DET- | 14+44.15 | 23+[illegible]9.15 |
| -DET- | 15+87.50 | 21+50.00 |
| SUBTOTAL: | | |

| W | | ANCHORS | | | | | |
|---|---|---|---|---|---|---|---|
| APPR. END | TRAIL. END | | TYPE III | GRAU 350 | TEMP GRAU 350 | | |
| 1 | | | 1 | 1 | | | |
| | 1 | | 1 | 1 | | | |
| | 1 | | 1 | 1 | | | |
| 1 | | | 1 | 1 | | | |
| 1 | | | | | 1 | | |
| | 1 | | | | 1 | | |
| 1 | 1 | | | | 2 | | |
| 1 | 1 | | | | 2 | | |
| | | | 4 | 4 | 6 | | |
| | | | | | | | |

Need to re-establish tension in any altered guardrail – include in plan sheets

- Placement of GRAU (GREU) must abide by standard application criteria (Deflection and LON)

# Review Learning Outcomes

- Understand how barriers are tested for crashworthiness
- Identify common barrier systems
- Explain how these barrier systems function
- Define the key components of a transition design

# Session 4:

# Testing Requirements and Performance Characteristics of End Treatments and Impact Attenuators

# Session 4 Learning Outcomes

At the end of this session, you will be able to:

- Understand how end treatments and impact attenuators are tested for crashworthiness
- Identify common end treatments and impact attenuators
- Understand how these systems function
- Choose the appropriate system for a specific site

# Guardrail End Treatments

A barrier end treatment must serve two functions:

- Provide the necessary TENSION of the guardrail system for downstream impacts
- Be crashworthy when impacted end-on.

# Cable Anchor Terminal – MASH

- 2 Design Tested
- Both have a strut between last 2 posts

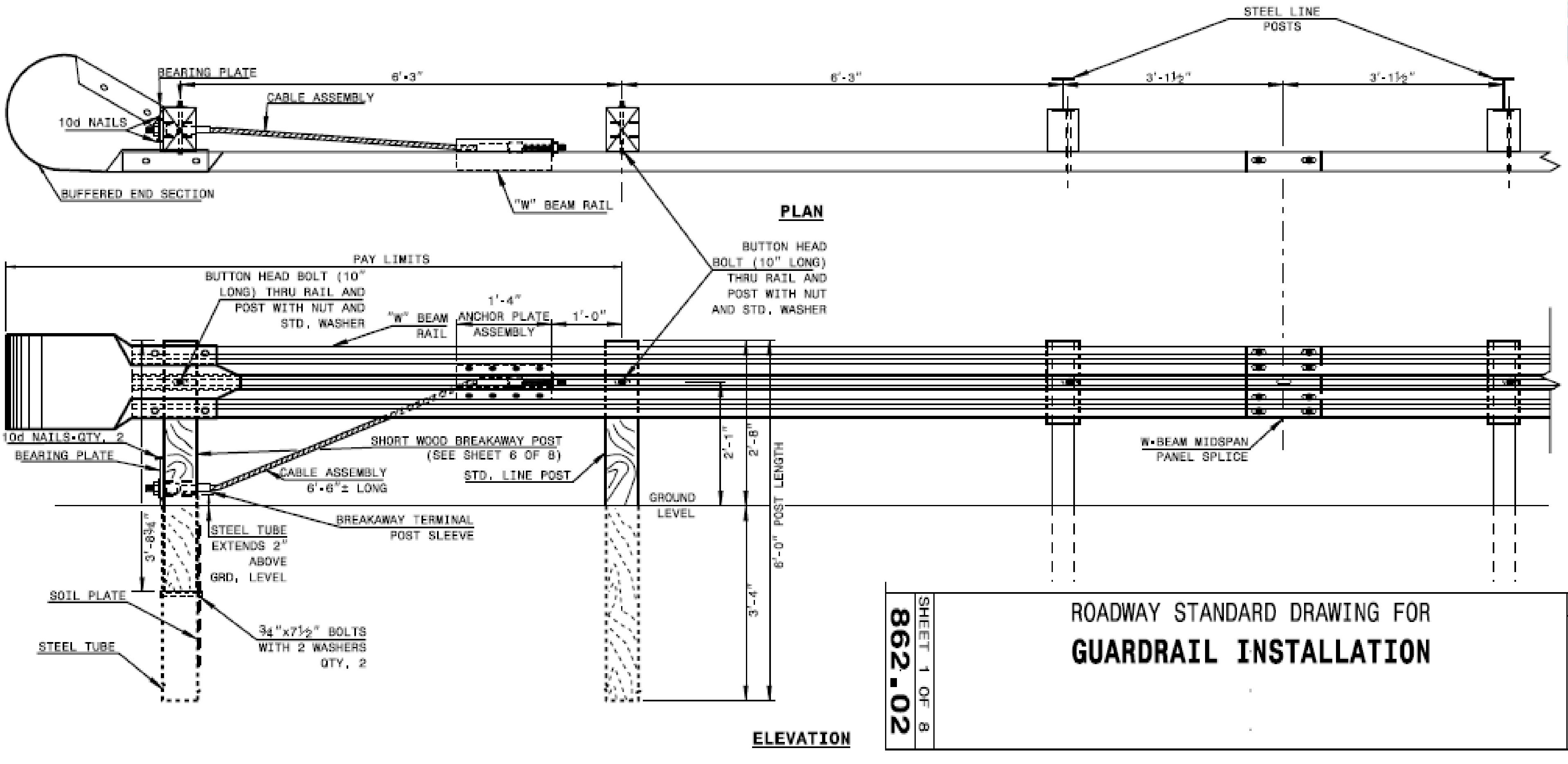
TxDOT Design
9'- 4 ½ " rail element
Rail ends at last post

Eligibility Letter B-256

MwRSF Design
12'- 6" rail
Rail extends past last post

# Cable Anchor Terminal - Tension

# NC Cable Anchor – Not tested




**TRAILING END UNIT ASSEMBLY**

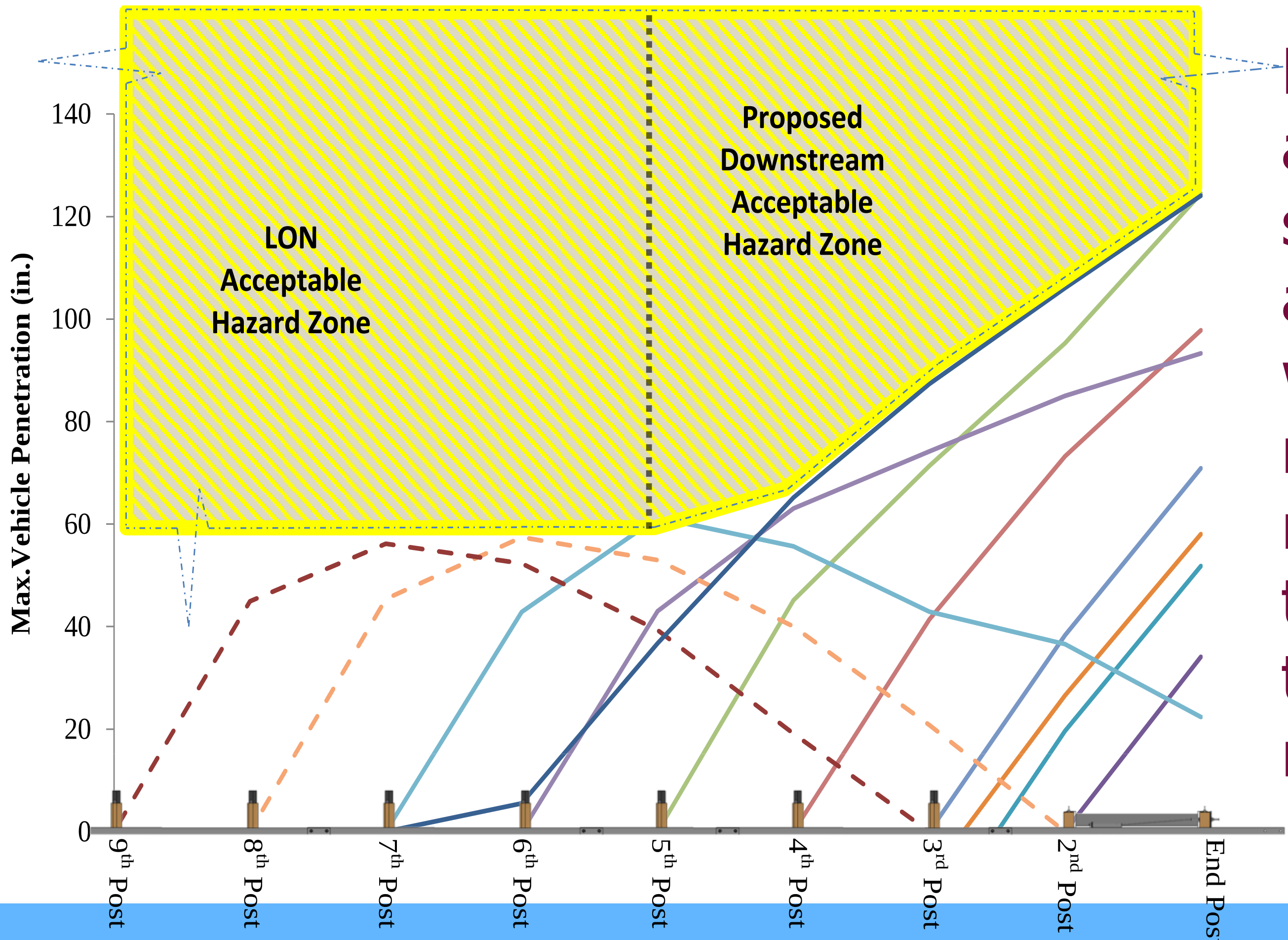
**C.A.T.-1 SYSTEM**

# Guardrail Cable Anchor Terminal Test

Impacted at 6th post from the end

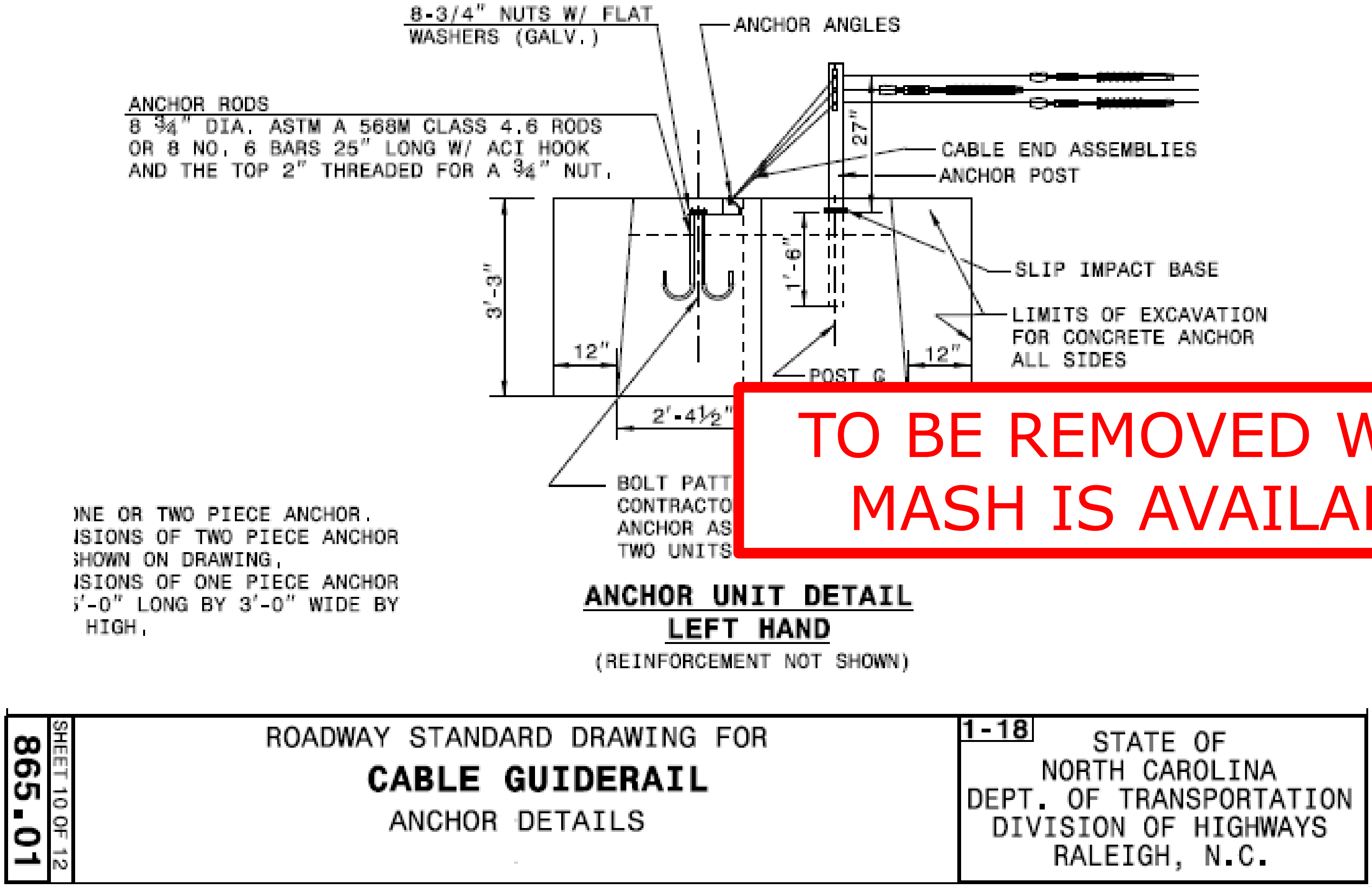
Vehicle deflected up to 10′ behind the barrier

# Guardrail Cable Anchor Terminal Test Analysis




Based on test and simulations, additional working width may be needed from the 6th post to the end of the rail.

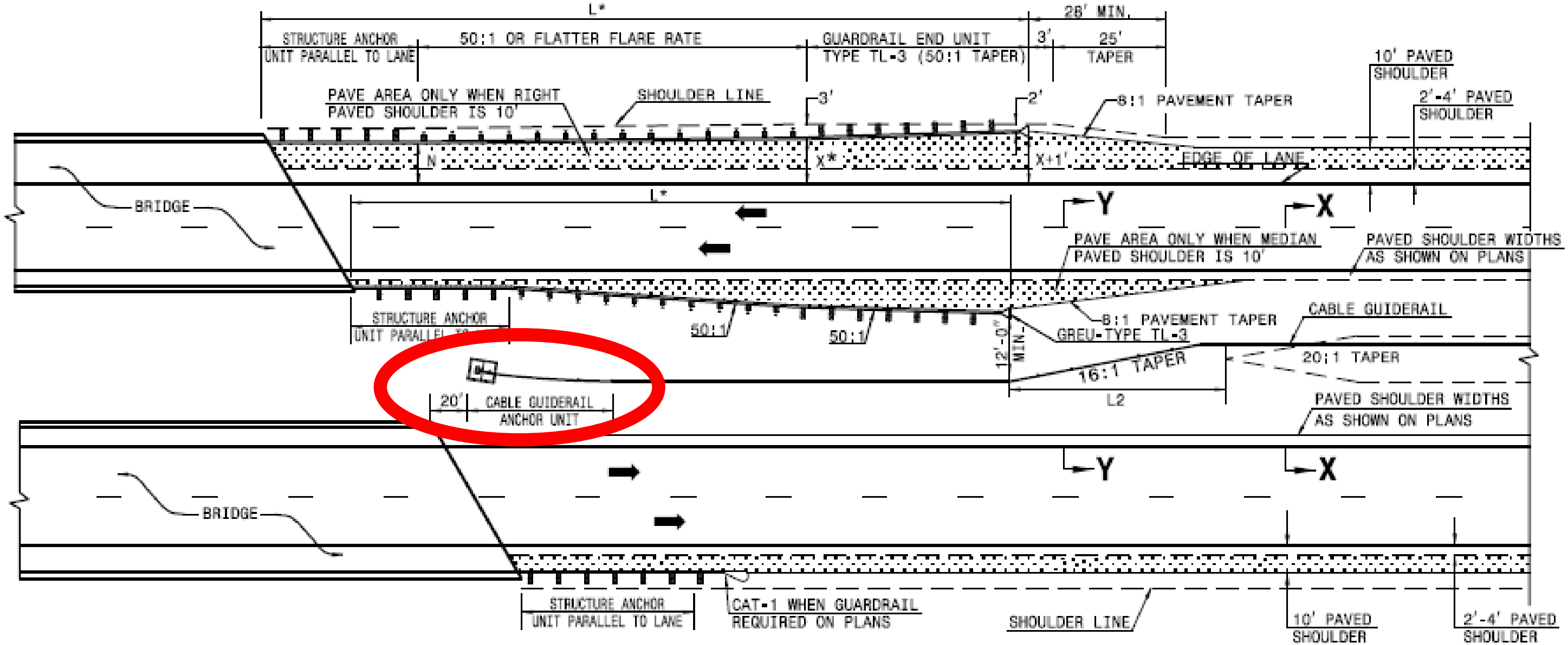
# Cable Guiderail terminal - LTC



# Cable Guiderail terminal - HTC

# PRE-ASSESSMENT PHOTO

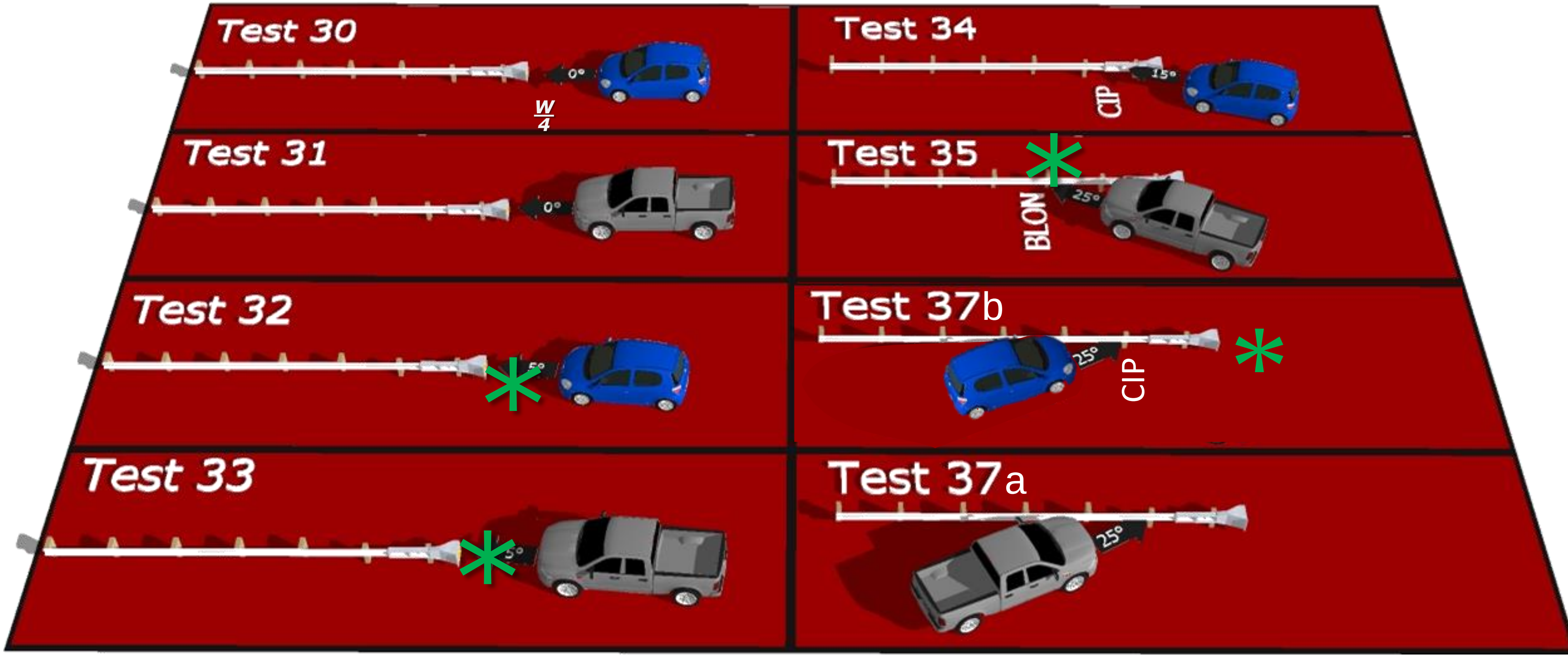
# Cable Guiderail Anchor Unit Placement




| 865.01 | SHEET 2 OF 12 | ROADWAY STANDARD DRAWING FOR<br>**CABLE GUIDERAIL**<br>DUAL LANE BRIDGES GUIDERAIL LAYOUT | 1-18<br>STATE OF<br>NORTH CAROLINA<br>DEPT. OF TRANSPORTATION<br>DIVISION OF HIGHWAYS<br>RALEIGH, N.C. |
|---|---|---|---|

# PRE-ASSESSMENT PHOTO

# End Treatment MASH Test Matrix




* Significant Change

* Small Car 1100C (2420 #)

* Pickup Truck 2270P (5000 #)

BLON – Beginning Length of Need

# Guardrail End Treatments

Types of End Treatments

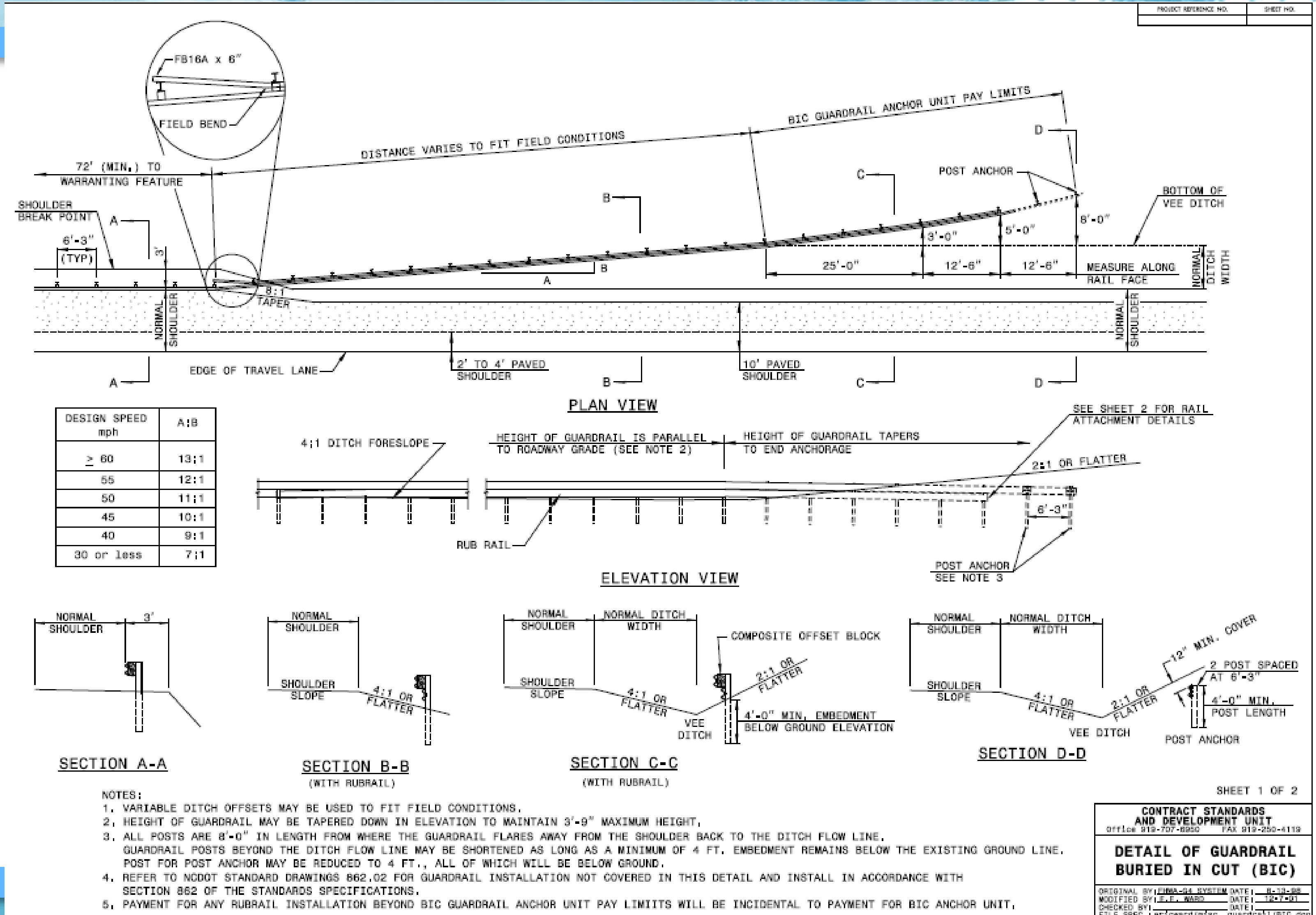
- Buried-in-Cut (Detail, not in Standards)
- Tangent terminals – terminal is parallel to the roadway or has a straight flare with a "slight" offset; all are Energy-absorbing
- Flared terminals – terminal is placed on a flare to the roadway typically 3' or 4'; both non-energy- and energy-absorbing

# Buried in Cut End Treatment

- Key design considerations:
  - For slopes steeper than 10:1, keep the height of the w-beam rail constant relative to the roadway grade until the barrier crosses the ditch flow line (but a max height of 47")
  - Use a flare rate, either 13:1 or appropriate for the design speed,
  - Add a w-beam rubrail when the distance between the bottom of the w-beam rail and the ground exceeds ~19",
  - Use an anchor of steel posts capable of developing the full tensile strength of the w-beam rail and buried 1' below ground

# MASH
# Buried in Cut End Treatment

# Buried in Cut (350 – to be Updated)



# BIC Looking Across Roadway

# Single Rail BIC

# BIC Considerations – 10:1 Slope for Single

# BIC Considerations - LON

Any concerns with this installation?

# PRE-ASSESSMENT PHOTO

# End Treatments - Terminology

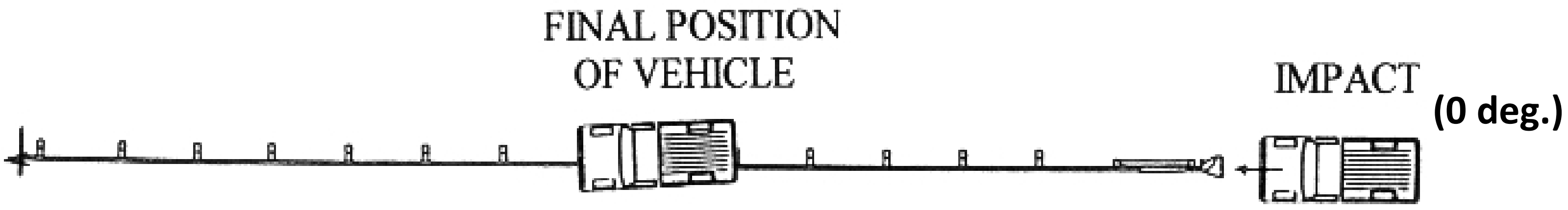
CAT-1 – Cable Anchor Terminal – non-crashworthy device to develop Tension where there is no opportunity for end-on impacts

(AT-1 – Anchor Terminal – no cable)

GREA – Guardrail End Anchor – crashworthy Pre-MASH devices

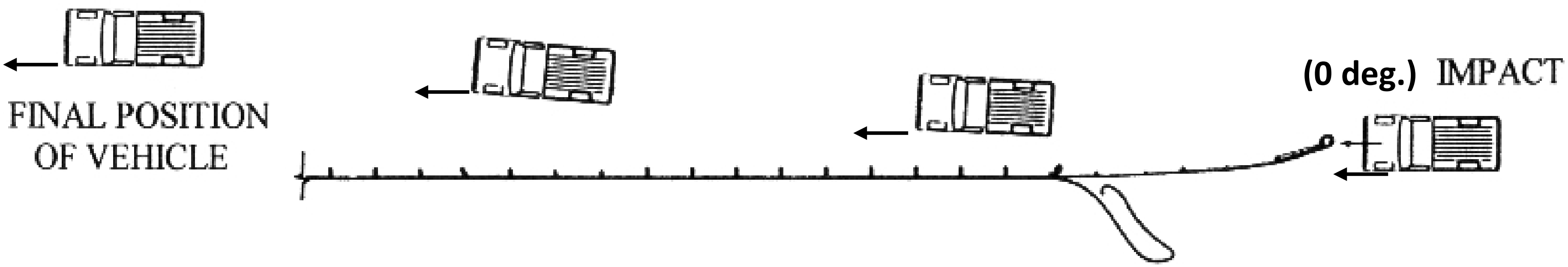
GREU – Guardrail End Unit – crashworthy MASH approved devices

# End Treatments




**Energy Absorbing Terminal**

(vehicle is brought to a controlled stop in a short distance)




**Non-Energy Absorbing Terminal**

Controlled Buckling Terminal

(vehicle may travel hundreds of feet before stopping)

# Flared End Treatments

## Historically used, most recently the SRT and FLEAT

Business »

### Approved Products List

Product ID (ex. NPYY-xxxx):

Company Name:

Product Name:

Product Group: Guardrail and Delineators (862)(1088)

Product Category: End Treatments

Product Status:

| Product ID | Plant ID | Company Name | Product Group | Product Category | Product Name | Model Number | Product Status | Description |
|---|---|---|---|---|---|---|---|---|
| NP11-5773 | | Road Systems, Inc. | Guardrail and Delineators (862)(1088) | End Treatments | MFLEAT | | Approved | MASH tested, Guardrail End Terminal |

https://apps.ncdot.gov/vendor/approvedproducts/

# Flared End Treatment:  Energy Absorbing

- **MFLEAT** *MASH Version of FLEAT (MASH 16)*
  - Curls the rail (by kinking) tightly towards the roadway.
  - Steel post system; BLON at 4th Post
  - TL-3 at 39' 7" straight flared length. 3-ft. offset.
  - Cable-anchored, compression system

**BLON – Beginning Length of Need**

Ref: FHWA Eligibility Letter CC-143 dated 04/10/19

# MASH MFLEAT

# Flared End Treatment: Non-energy-Absorbing

- MASH SRT (Slotted Rail Terminal)
  - W-Beam rails on a straight line and horizontal slots in rail
  - Offset - 4'; 31" Height
  - 37'-6" long, BLON at Post 4
  - Cable-anchored system


Not currently on APL

Ref: FHWA Eligibility Letter CC-140 dated 12/19/17

# **MASH** Test 3-31: SRT

Because of the non-energy absorption, no hazard should exist within 150’ downstream of post #1

NOT GOOD!!!!!

# Flared End Treatments on Flared Standard Run

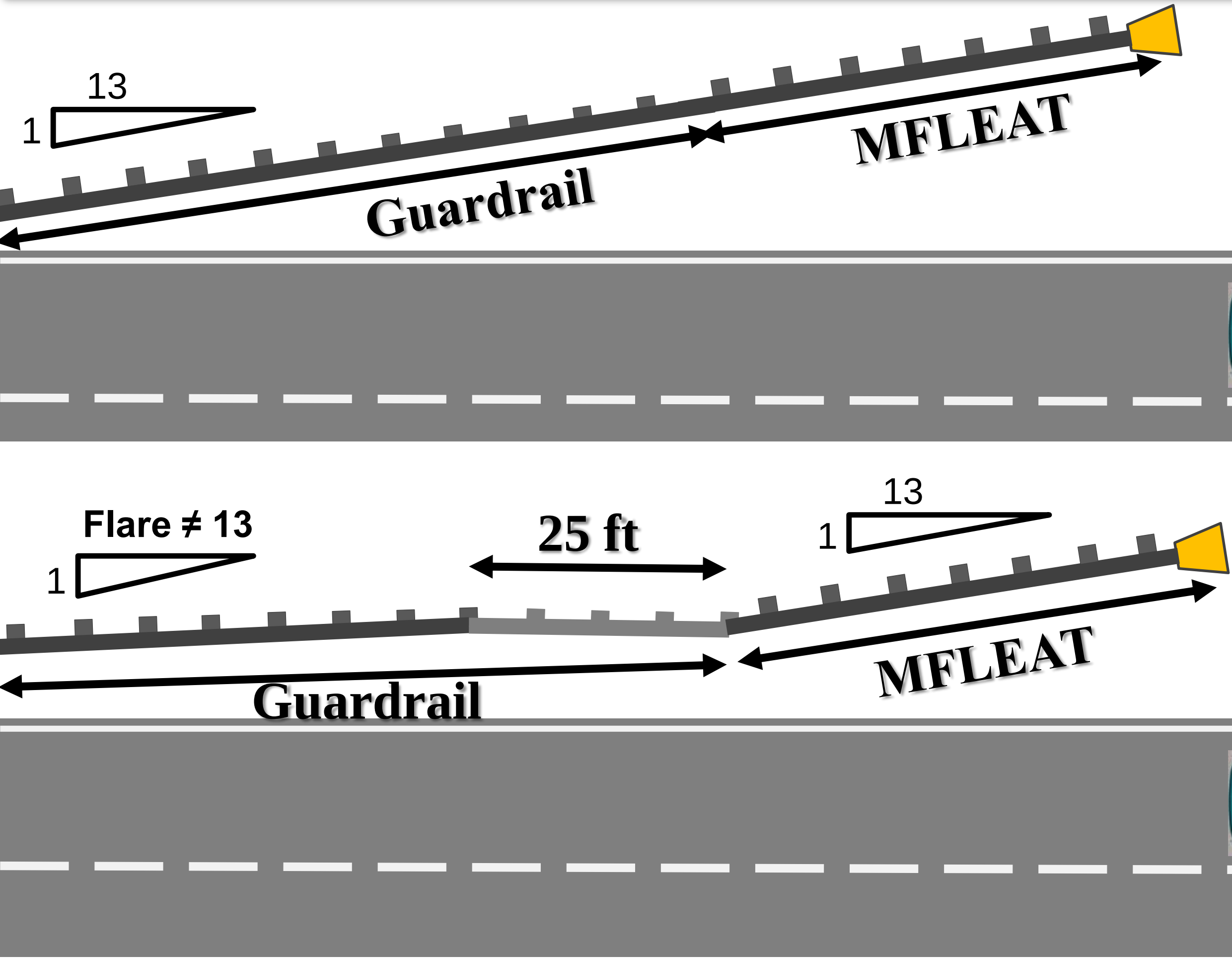
The flare of the end treatment is measured from a line parallel to the ROADWAY:

For Energy Absorbing (MFLEAT) which has a 13:1 flare, there may need to be a "kink" either toward or away from the roadway, depending on the flare of the standard guardrail

For the SRT MASH, the offsets are measured from a line parallel to the roadway.

NCDOT guidance is to provide 25' of parallel guardrail in advance of any end treatment requiring a kink.

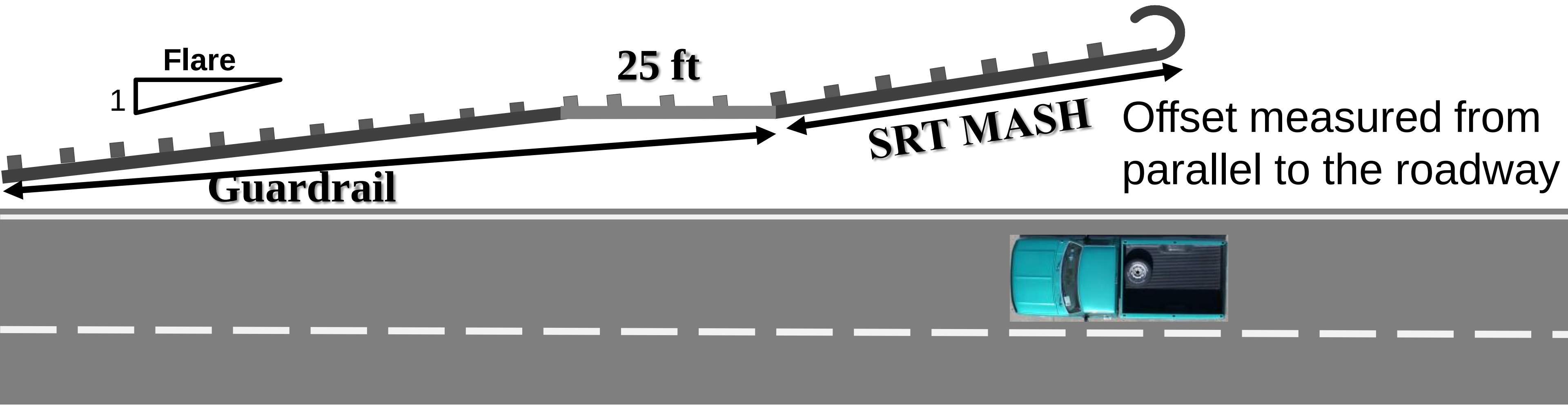
# Flared End Treatment on Flared Standard Run MFLEAT - Schematic




Flare of standard guardrail is 13:1

Flare of standard guardrail is not 13:1

# Flared End Treatments on Flared Standard Run SRT MASH - Schematic



# Flared End Treatment Selection

- The contractor may choose any system on the Approved Product List meeting the design requirements
  - One is energy absorbing (currently MFLEAT)
  - One could be non-energy absorbing (SRT)

What is **important** is to understand how the system works –a **FLARED** system should only be allowed if criteria have been met (LON and grading)

# Tangent End Treatment

**NCDOT** NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

*Connecting people, products, and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina.*

Business | DMV | Newsroom | Programs

**Approved Resources**

- Product Listing
- Seeds
- Producer/Supplier
- Technician Certification
- Minimum Sampling Guide

Business »

## Approved Products List

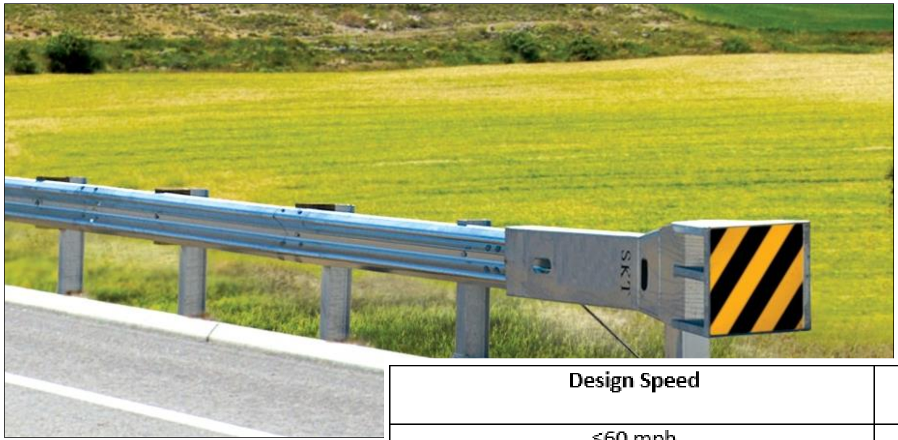
Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: End Treatments, Type MASH-16
Product Status:

Search Reset

| Product ID | Plant ID | Company Name | Product Group | Product Category | Product Name | Model Number | Product Status | Description |
|---|---|---|---|---|---|---|---|---|
| NP17-7819 | | Trinity Highway Products | Guardrail and Delineators (862)(1088) | End Treatments, Type MASH-16 | SoftStop Mash End Terminal | | Approved | MASH tested;All steel galvanized tangent end terminal for use with 31" W-Beam system. |
| NP17-7851 | | Road Systems, Inc. | Guardrail and Delineators (862)(1088) | End Treatments, Type MASH-16 | MSKT | | Approved | MASH tested;Guardrail End Terminal |
| NP18-8257 | | SPIG Industry, LLC | Guardrail and Delineators (862)(1088) | End Treatments, Type MASH-16 | SGET | | Approved | The SGET (SPIG Gating End Terminal) is a gating guardrail end terminal system in which an impact upon the head causes the head to move down the guardrail and dissipate the energy of the impact. The SGET system also deflects vehicles back onto the roadway |

# Tangent End Treatment: Energy Absorbing

- **MSKT** *MASH Version of SKT (MASH 16)*
  - Kinks Guardrail when hit head-on or at a shallow angle
  - Steel post system; BLON at 3rd Post
  - TL-3 at 47' long; attachment to 31" Guardrail
  - Cable-anchored system, Compression system




| Design Speed | Minimum Length of Steel Beam Guardrail Between Structural Anchor and GREU |
|---|---|
| ≤60 mph | 12.5 feet |
| > 60 mph (Interstates, Freeways, Major Arterials | 25 feet |

# MASH MSKT

# Tangent End Treatment: Energy Absorbing

- Soft Stop (MASH 16)
  - Impact head slides along panels, crushing them vertically, absorbing the energy of the vehicle in shallow angle impacts – **works in tension**
  - TL-3 at 51' long; BLON at 16'-6"; 31" only

| Design Speed | Minimum Length of Steel Beam Guardrail Between Structural Anchor and GREU |
|---|---|
| ≤60 mph | 12.5 feet |
| > 60 mph (Interstates, Freeways, Major Arterials | 25 feet |

# MASH Soft Stop

# MASH SGET

| Design Speed | Minimum Length of Steel Beam Guardrail Between Structural Anchor and GREU |
|---|---|
| ≤60 mph | 12.5 feet |
| > 60 mph (Interstates, Freeways, Major Arterials | 25 feet |

# MASH SGET – Test 3-31

# Tangent End Treatment: Energy Absorbing

- MAX-Tension (MASH 16)
  - The MAX system utilizes tensioned cables, telescoping panels, and a cutting tooth to absorb the kinetic energy and safely contain or redirect impacting – **works primarily in tension**
  - TL-3 at 50’ long; BLON at 9’-4 ½”; 31” only

Not on current APL

| Design Speed | Minimum Length of Steel Beam Guardrail Between Structural Anchor and GREU |
|---|---|
| ≤60 mph | 12.5 feet |
| > 60 mph (Interstates, Freeways, Major Arterials | 25 feet |

# MASH MAX-Tension

# Tangent End Treatments – End Offset Proposed

## 4.10.9 Guardrail Anchor Units

The following are commonly used anchor units with a brief description.

<u>Guardrail End Unit – Test Level 2 and Test Level 3 (GREU-TL-2 and TL-3) -</u> the GREU – TL-2 and TL-3 are tangential end units. These units will be flared over the last 50 feet to provide a 1-foot offset.

# Tangent End Treatments on Flared Standard Run

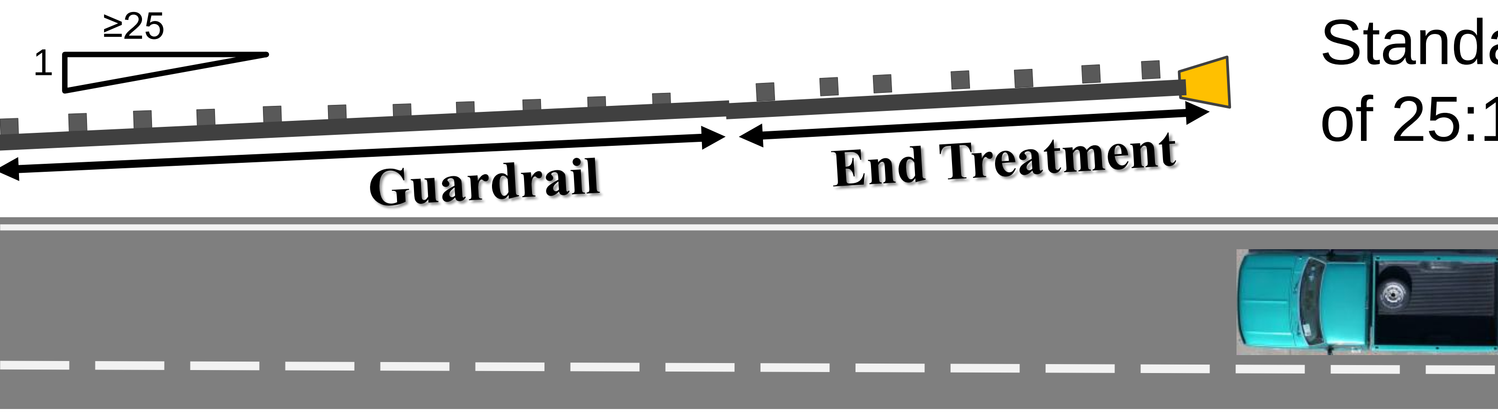
The offset of the end treatment is measured from a line parallel to the ROADWAY:

If the standard flare is 25:1 or flatter, the end treatment may be placed on the standard flare line extended

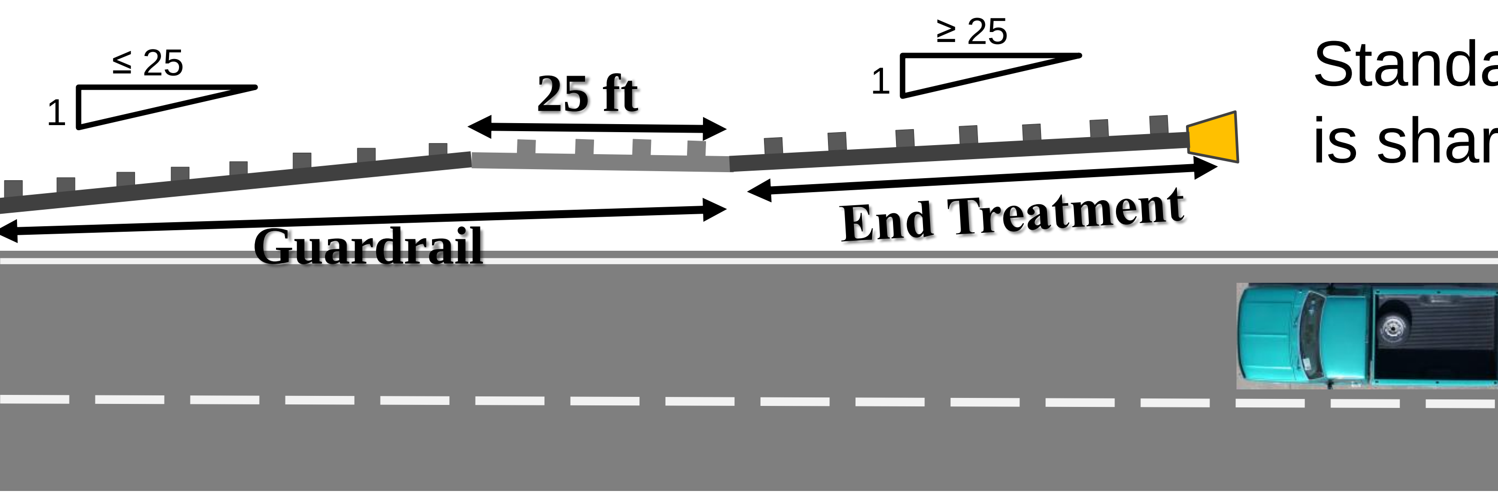
If the standard flare is sharper than 25:1, a kink in the run must be provided so the end treatment is no sharper than 25:1

NCDOT guidance is to provide 25’ of parallel guardrail in advance of any end treatment requiring a kink.

# Tangent End Treatments on Flared Standard Run Schematic




Standard Run Flare of 25:1 or flatter



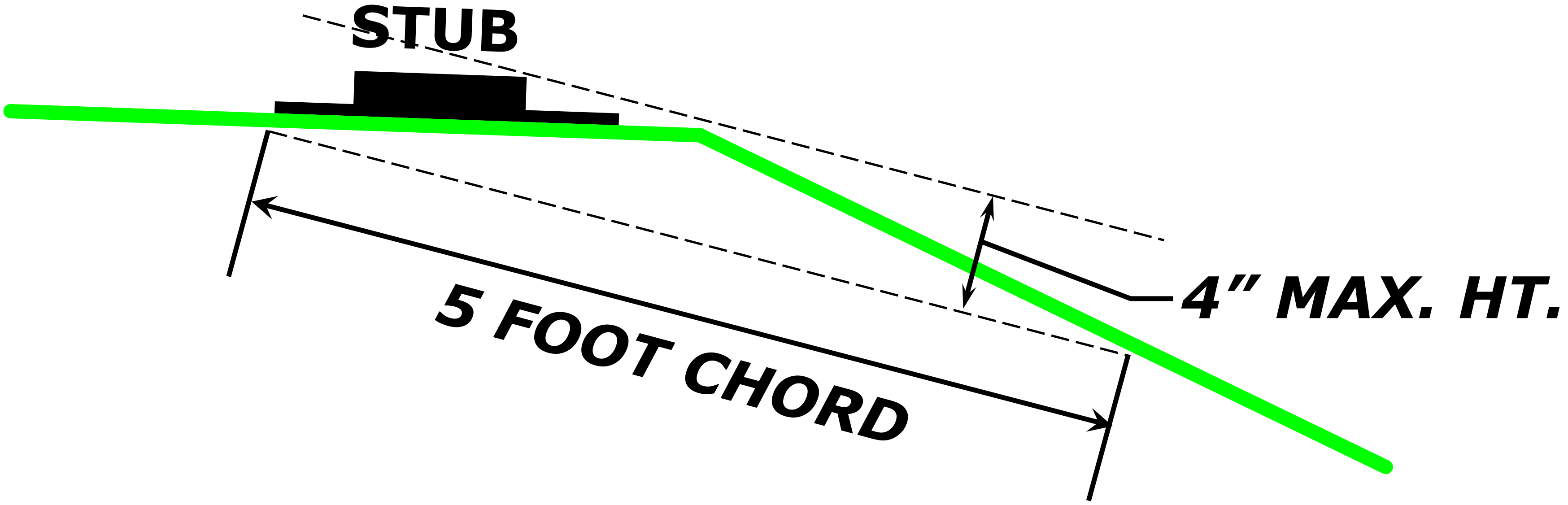

Standard Run Flare is sharper than 25:1

# End Treatment Grading

- Special grading requirements for guardrail end treatments:
  - Flat terrain (10:1 or flatter) is required *in* **ADVANCE** *of all end treatments* so that vehicles are relatively stable on approach
  - Flat grading must extend *behind* post 1 (**ADJACENT**) so vehicle is stable at impact ***and*** stub height criteria is satisfied

Ref: FHWA Memorandum, Roadside Safety Hardware, May 26, 2015 with attachment and
Ref: AASHTO Roadside Design Guide, 4th Edition, Section 8.3.3.

# Stub Height Criteria



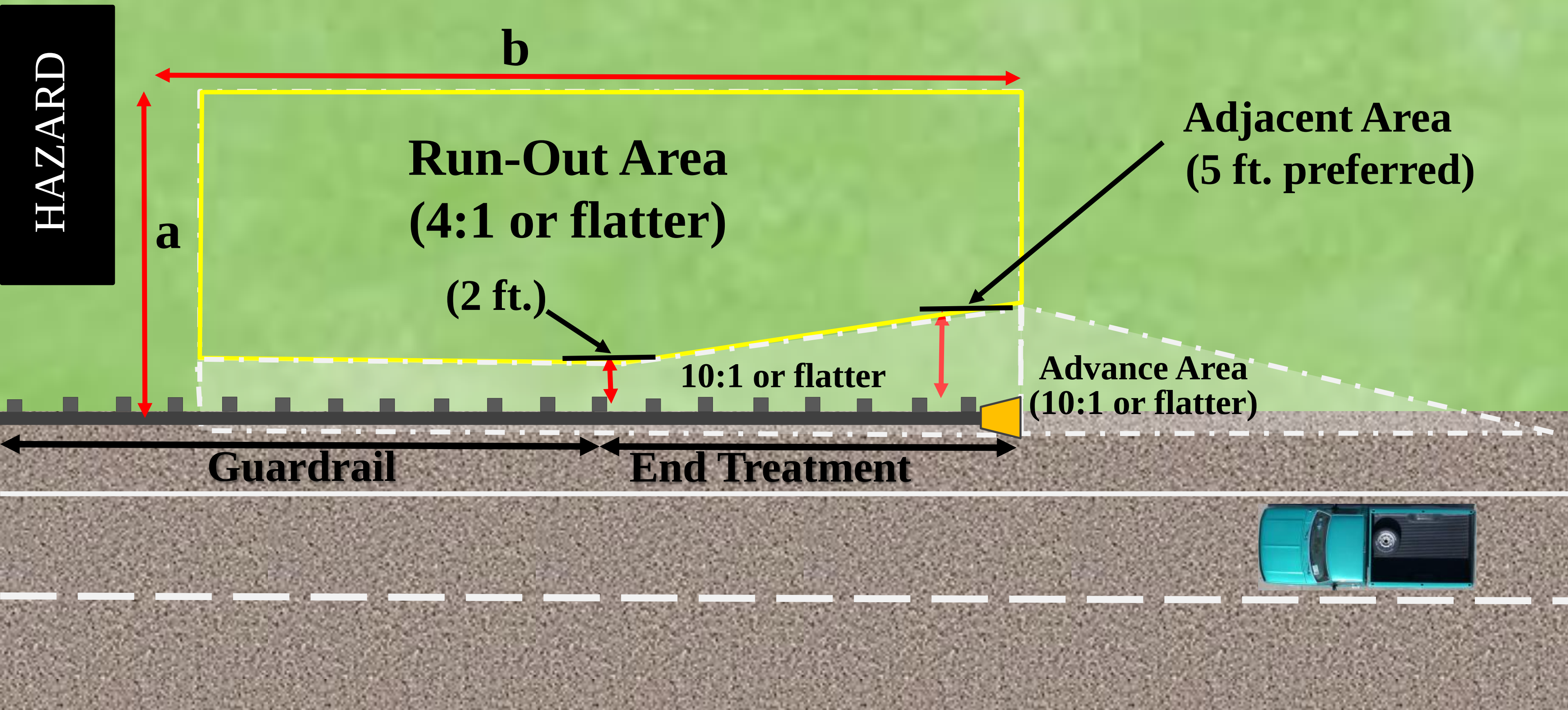

***RDG Figure 4.1***

Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 4.1

# End Treatment Grading Requirements

- **Runout Distance Grading** - refers to the area into which a vehicle may travel after impacting a terminal ahead of its length-of-need point.
  – The lateral runout distance directly behind a terminal ideally should be at least as wide as the roadside clear distance immediately upstream of terminal.
  – The minimum recovery obstacle-free area behind and beyond a terminal should be approximately 75 ft. long.

Ref: AASHTO Roadside Design Guide, 4$^{th}$ Edition, Section 8.3.3.




a – Extend out to clear zone when practical; if not, it should be at least as wide as area upstream of the end treatment.

b – LON Required; when LON cannot be provided due to site conditions, a minimum of 75' from post 1 may be acceptable

# Flared End Treatment Grading - AASHTO

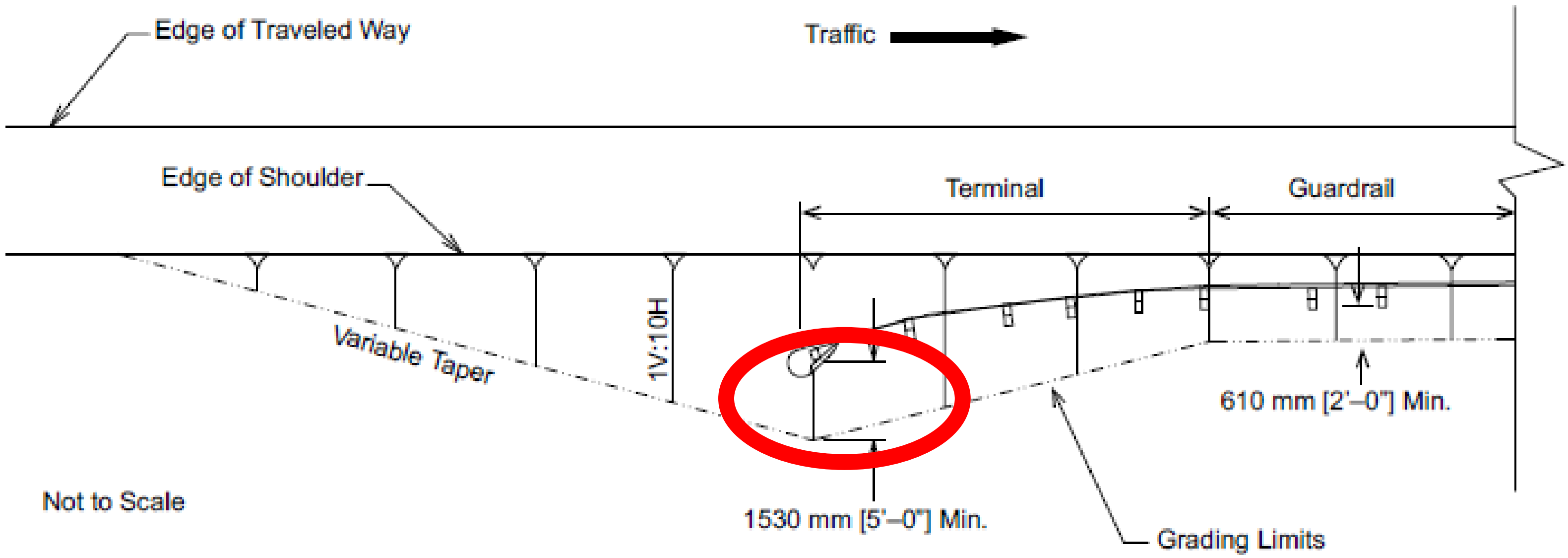
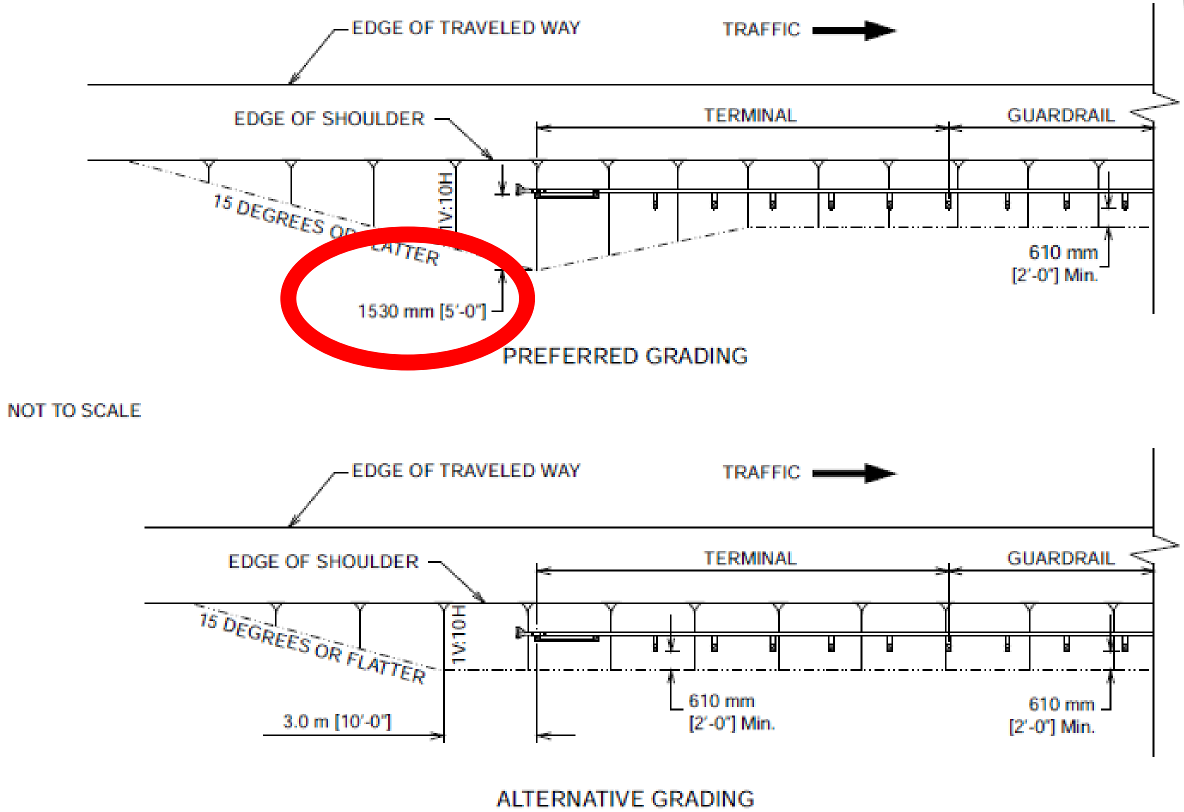



**Figure 8-2. Grading for Flared Guardrail Terminal**

*End Treatments (Anchorages, Terminals, and Crash Cushions)* 8-5

Must have this full grading if a flared end treatment is used

# Tangent End Treatment Grading - AASHTO

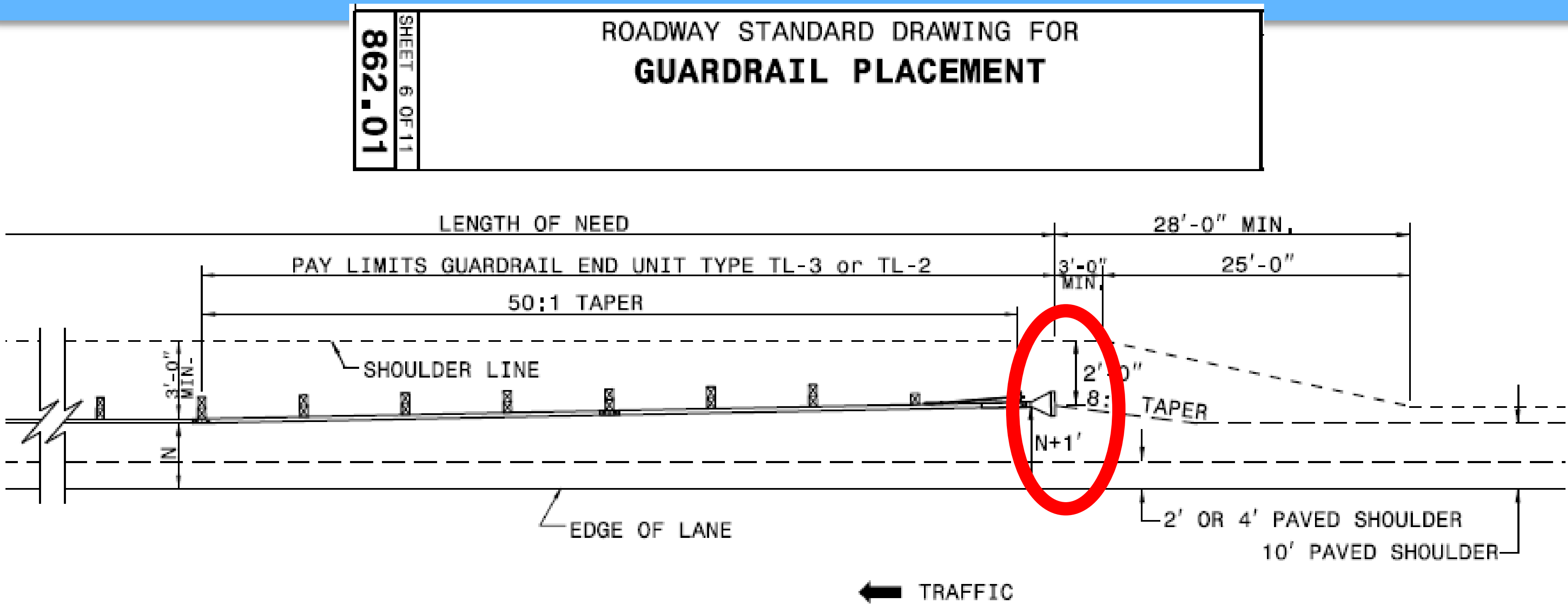



Note: The preferred grading layout should be used when practical. However, if necessary because of site limitations, the alternative grading layout may be used when upgrading an existing terminal.

**Figure 8-3. Grading for Tangent Guardrail Terminal**

# PRE-ASSESSMENT PHOTO

# Tangent End Treatment Grading - NCDOT




Need special Borrow bid item for 3R projects

Need Special Provision for Density

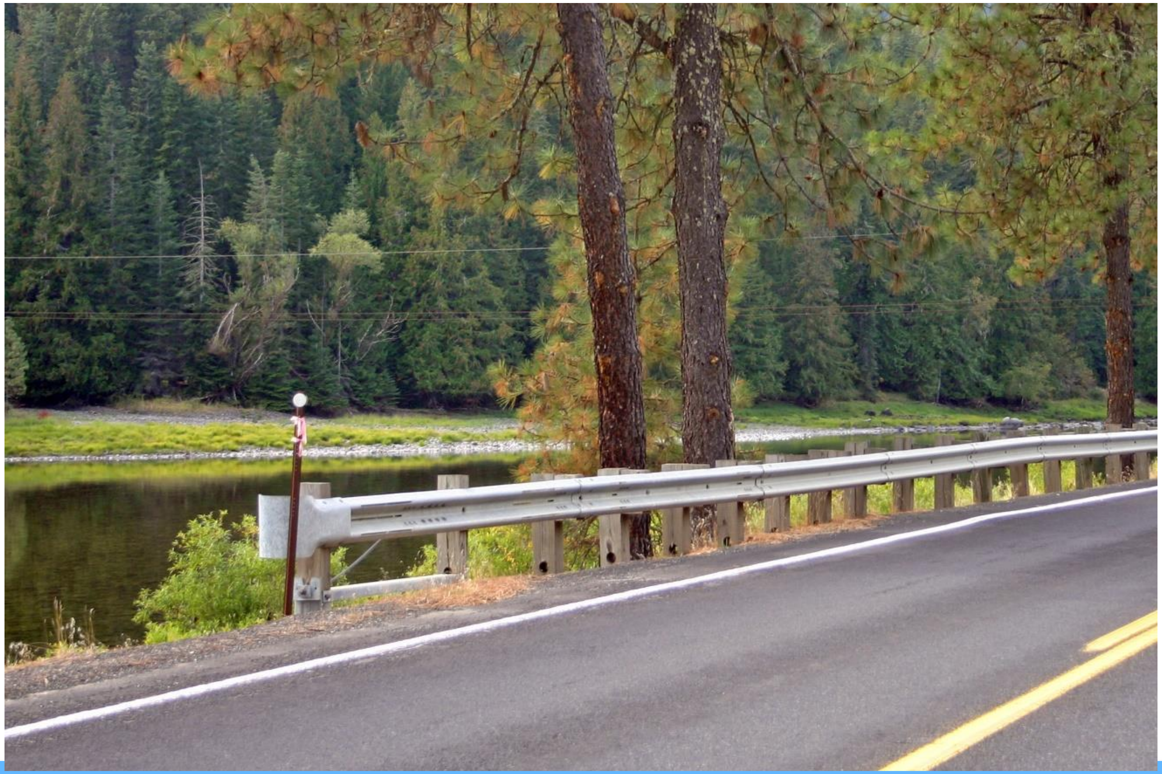
# PRE-ASSESSMENT PHOTO

## No Stub problem, but could be better

# Substandard Grading – DOCUMENT

# Thing to Remember about End Treatments

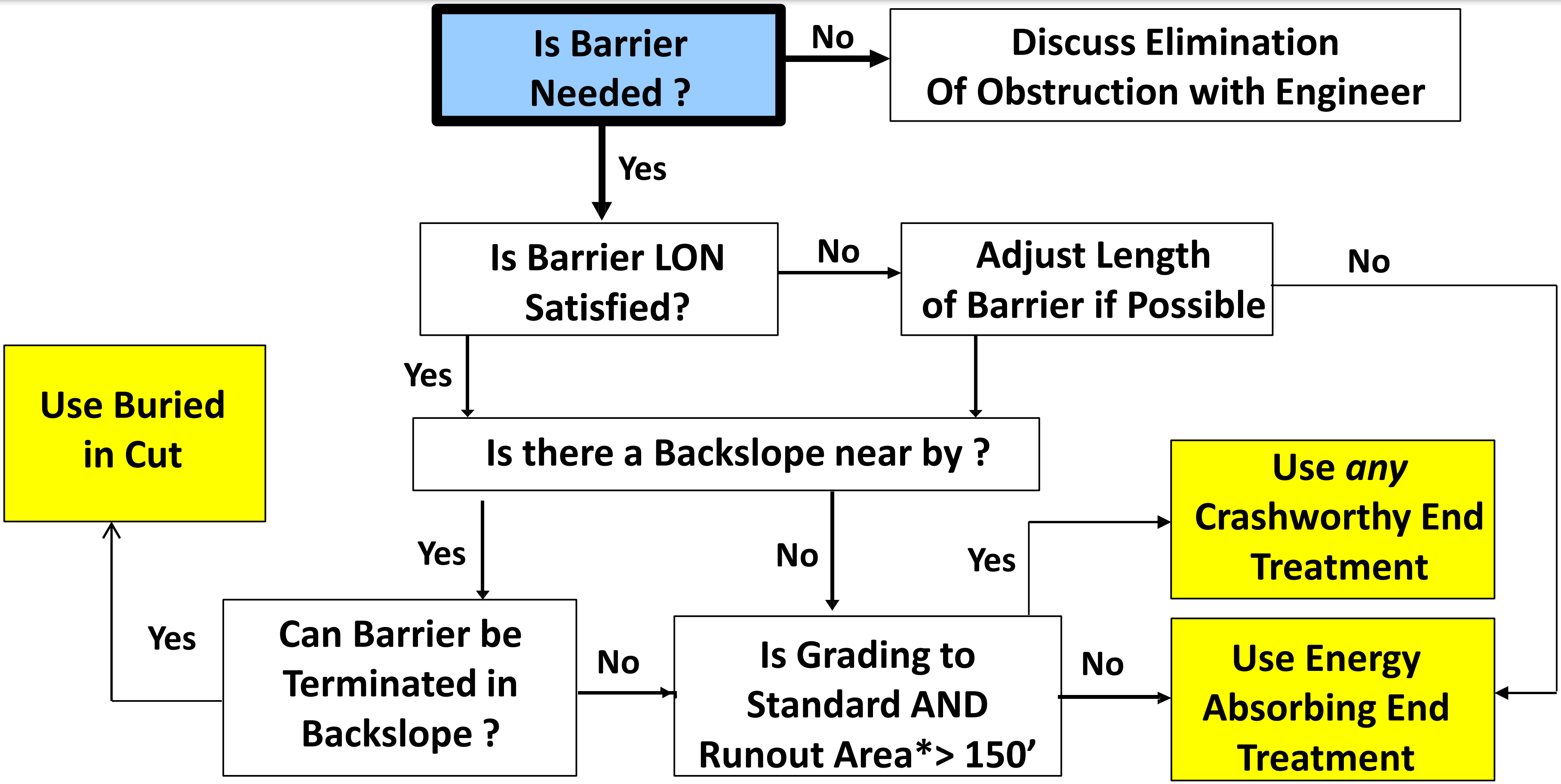
Non-Energy Absorbing End Treatments will not shield objects directly behind and within End Treatment limits



# Thing to Remember about End Treatments

Even Energy Absorbing End Treatment will not shield objects directly behind and within End Treatment limits

# Suggested FHWA End Treatment Selection Flow Chart



# EXISTING END TREATMENTS

# Tangent Guardrail End Treatment Energy Absorbing

- SKT 350 (Sequential Kinking Terminal)(NCHRP 350)
  - Kinks panels when hit head-on or at a shallow angle
  - Wood or Steel post system (many options)
  - TL-3 at 50’ long;  BLON at 3rd Post
  - Cable-anchored, Compression system

Ref: FHWA Eligibility Letter CC-88 dated 3/8/05

# Tangent Guardrail End Treatment Energy Absorbing

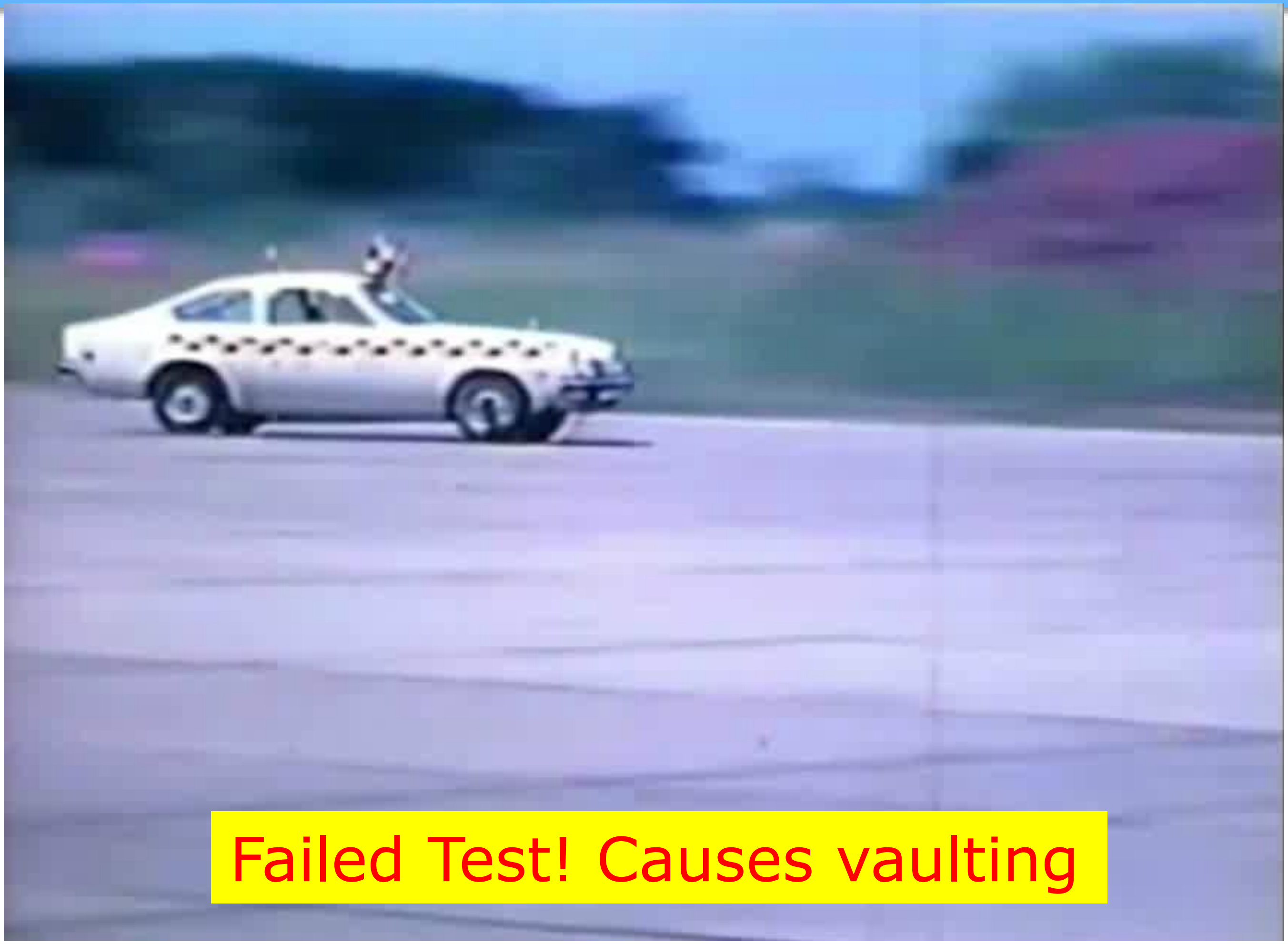
- ET Plus (Guardrail Extruder Terminal)(NCHRP 350)
  - Flattens the rail element when hit head-on
  - Weakened wood or steel posts (several options available)
  - 50’ long; attaches to either height w-beam system
  - BLON at 3rd Post
  - Cable-anchored, compression system

Ref: FHWA Eligibility Letter CC-12Q dated 3/15/10

# Non-crashworthy End Treatment
## Blunt End

# Non-crashworthy End Treatment
## Turndown

# Turndown



# Non-crashworthy End Treatment
## BCT Terminal

- Breakaway Cable Terminal (BCT) NCHRP 230
  - W-Beam rail with a parabolic curve and 4-ft offset.
  - No impact head or ground strut between the two end posts.
  - Only two breakaway posts.
  - Rail bolted to all posts.

For Identification Only

# Non-crashworthy End Treatment
## BCT Terminal

Failed Test! Causes spearing

# Guardrail End Treatments: Non-energy Absorbing – For Identification Only

- MELT – Modified Eccentric Loader Terminal
  - W-Beam rail with an accentuated parabolic curve and 4-ft offset.
  - Strut between the steel tubes foundation of the two end posts.
  - 37'-6" long with 8 breakaway posts; BLON at Post #3.
  - No rail-to-post bolts except at posts 1 and 8 and beyond.

For Identification Only

(NCHRP 350 TL-2)

# Guardrail End Treatments: W-Beam Median

Only one MASH gating, double sided end treatment available on the market

No longer on NCDOT APL

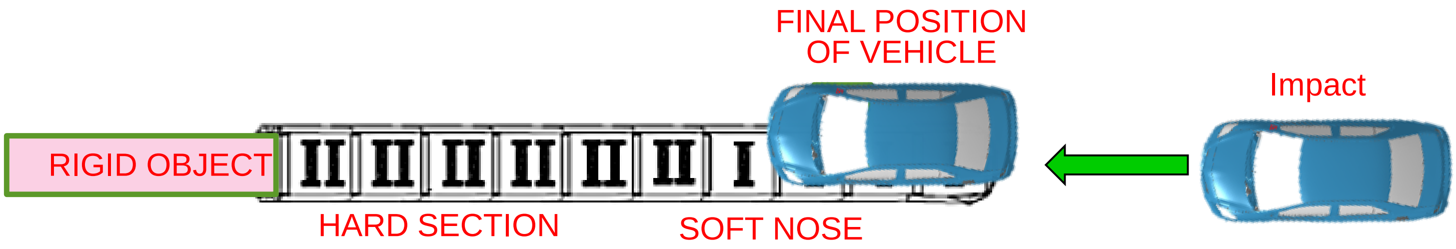
# Impact Attenuator

Crash test with blunt end:

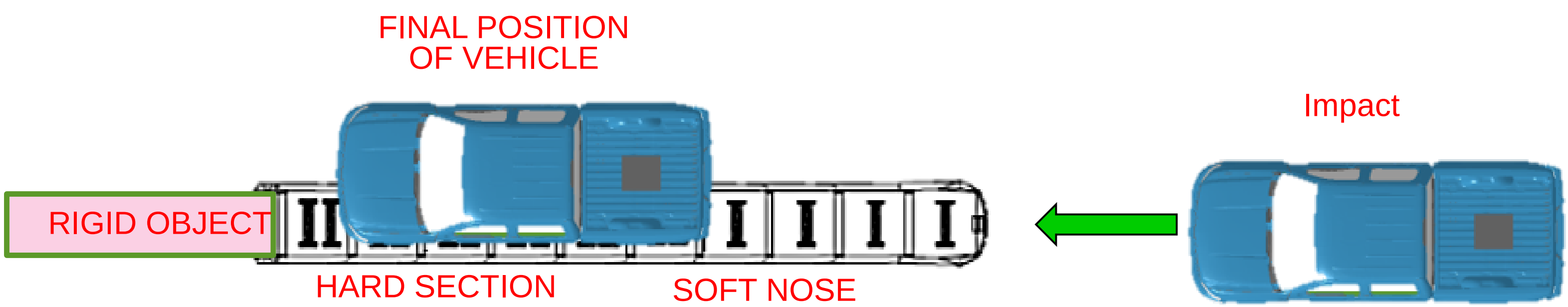
# Impact Attenuator

Crash test with ramped end:

# Impact Attenuator Theory




**Soft nose to bring a small car to a controlled stop**




**Harder back section to bring a pick-up truck to a controlled stop**

# Impact Attenuator, Sacrificial - Water Filled

- Water-filled Barriers

  **<u>Absorb M (MASH)</u> / <u>Sled(MASH</u>) / ACZ 350** / **TRITON CET**

  - Individual crash cushion designs vary by manufacturer, but they all function in a similar manner.
  - Vehicles impacting the nose at an angle will **not** be redirected.
  - No appreciable re-directive capability under most impact conditions.
  - Typically used in work zones to shield temporary concrete barrier.

# Impact Attenuator, Sacrificial - Water Filled

## Approved Products List

Product ID (ex. NPYY-xxxx):

Company Name:

Product Name:

Product Group:

Product Category: WZTC - Category III

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NP11-5771 | | Lindsay Transportation Solutions | Work Zone Traffic Control | WZTC - Category III | Absorb 350 | | Approved for Provisional Use | *Must be approved by Steve Kite (919-814-4937) prior to use on NCDOT project.* The ABSORB 350 is a non-redirective, gating water filled crash cushion that has been successfully tested to NCHRP Report 350 TL-2&3. |
| NP11-5884 | | TrafFix Devices, Inc. | Work Zone Traffic Control | WZTC - Category III | SLED | Series 45044 | Approved | PE Water Filled Crash Cushion w/Galvanized Steel Cables molded inside.NCHRP-350 for Test Level 1,2or3.Use as end treatment/crash cushion. |
| NP16-7335 | | Trinity Highway Products | Work Zone Traffic Control | WZTC - Category III | ACZ-350 Water Filled Crash Cushion | ACZ-350 | Approved for Provisional Use | The ACZ-350 is a narrow, non-redirecting TL-2 and TL-3 impact attenuator |
| NP99-3106 | GR10 | Energy Absorption Systems, Inc. | Work Zone Traffic Control | WZTC - Category III | Triton Barrier | Triton Barrier | Approved | The Triton Barrier® is a highly portable, water-filled barrier. Performance meets the FHWA NCHRP 350 TL-2 or TL-3 (with TL-3 kit) standard for longitudinal re-directive barrier. The Triton Barrier is certified as its own end treatment. |

# Impact Attenuator, Sacrificial - Water Filled

Absorb M (MASH)

ACZ-350

Sled (MASH)


TRITON barrier CET

# Water Filled

# Impact Attenuator, Sacrificial – Sand Barrel

## Non-Redirective and Gating

- Individual barrel designs vary in shape by manufacturer, but they all function the same
- Arrays of sand barrels may be designed to shield any shape hazard
- Impacting vehicles will not be redirected.
- Since no re-directive capability, the corner of the hazard must be reasonably shielded.

# Impact Attenuator, Sacrificial – Sand Barrel

➢ Sand Barrels:

Energite

TrafFix Big Sandy (MASH)

Not Normally Used

CrashGard (MASH)

# Sand Barrels – Good Application

# Sand-Filled Array

# Impact Attenuators, Non-Gating

Non-gating as follows:

- Contains and redirects vehicles impacting along the sides of the device essentially its entire length
- Contains vehicles impacting the nose either head-on or at a 15º angle.
- Approved for TL-2 (350) & TL-3 systems.
- Designed to shield a point hazard; either attached or stand alone.

# Impact Attenuators, Non-Gating

**Approved Products List**

Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: Impact Attenuators, Non-Gating

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| NP19-8389 | Lindsay Transportation Solutions | Guardrail and Delineators (862)(1088) | Impact Attenuators, Non-Gating | Universal TAU-M | | Approved | MASH compliant re-directive, non-gating anchored, partially reusable compression-based crash cushion |

MASH

NCHRP 350 - Allowed if Conditions Mandate

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| NP02-1527 | Lindsay Transportation Solutions | Guardrail and Delineators (862)(1088) | Impact Attenuators, Non-Gating | Universal TAU-II | | Approved | The Universal TAU-II is a redirective, non-gating crash cushion. The system is available in lengths and capacities for both low and high speed applications |
| NP03-4111 | Trinity Highway Products | Guardrail and Delineators (862)(1088) | Impact Attenuators, Non-Gating | WIDE TRACC | N/A | Approved for Provisional Use | the WideTRACC is test level 3 crash cushion and is avaliable in varying lengths and widths. can be configured for any appropriate width application. |

# Impact Attenuators, Non-Gating

- TAU-M (MASH) and TAU IIR Systems (NCHRP 350)
  - Can be attached directly to a W-beam or Thrie-beam median barrier as well as to a concrete safety shape.
  - Designed to attach to a median barrier.
  - Common set of parts for 36” to 102” widths in 6” increments (350)
  - Consists of Thrie-beam panels, expendable (MASH) or self-restoring (R) (350) absorbing cartridges, steel diaphragms and two cables at the bottom to provide redirection.

# Impact Attenuators, Non-Gating - Typical

# Impact Attenuators, Life Cycle

## Approved Products List

Product ID (ex. NPYY-xxxx):
Company Name:
Product Name:
Product Group:
Product Category: Impact Attenuators, Life Cycle

MASH

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| NP16-7403 | Energy Absorption Systems, Inc. | Guardrail and Delineators (862)(1088) | Impact Attenuators, Life Cycle | Quadguard Elite | N/A | Approved for Provisional Use | **Contact NCDOT Mobility and Safety Field Operations prior to use at 919-773-2800**The QuadGuard Elite System offers the added value of reusable cylinders for applications with above average impact frequency. After a typical design impact, the system is |
| NP16-7404 | Hill and Smith | Guardrail and Delineators (862)(1088) | Impact Attenuators, Life Cycle | Smart Cushion Innovations Crash Cushion | SCI100GM | Approved | Test Level III Crash Attenuator |
| NP16-7405 | Hill and Smith | Guardrail and Delineators (862)(1088) | Impact Attenuators, Life Cycle | Smart Cushion Innovations Crash Cushion | SCI70GM | Approved | Test Level II Crash Attenuator |
| NP16-7406 | TrafFix Devices, Inc. | Guardrail and Delineators (862)(1088) | Impact Attenuators, Life Cycle | Compressor System Crash Cushion | 55000 Series | Approved | Low Maintenance, Severe-Duty, Self-Restoring, Re-Directive Impact Attenuator. NCHRP-350 approved as TL-3. Designed for repeated impacts with no need for repair. For use in Uni-directional or Bi-Directional applications up to 96 wide |

MASH

# Impact Attenuators, Life Cycle

- SCI Smart Cushion (MASH)
  - Variable Reaction Force
  - Re-usable with minimal component replacement
  - Needs repair before next hit

# Example – Low Cost

# Impact Attenuators, Life Cycle

- QuadGuard Elite (MASH)
  - Uses High Density Polyethylene cylinders to absorb energy
  - Essentially for use in locations where a high number of hits is anticipated.

REF: FHWA Eligibility Letter CC-57E dated 12/18/15

# Example - Self Restoring

# Very Appropriate Use

# Review Learning Outcomes

- Understand how end treatments and impact attenuators are tested for crashworthiness
- Identify common end treatments and impact attenuators
- Understand how these systems function
- Choose the appropriate system for a specific site

# Session 5:
# Design Principles

# Session 5 Learning Outcomes

At the end of this session, you will be able to:

Understand the design principles affecting an optimal barrier installation.

# Order of Preference - NCDOT

**4.10 Traffic Barriers**

**4.10.1 General Considerations**

The preferred method of addressing roadside hazards is as follows:

1. Remove the hazard;
2. Remove embankment hazard (flatten slopes);
3. Shift hazard away from traffic;
4. Reduce the impact severity by using breakaway posts;
5. Protect the hazard;
6. Delineate the hazard so motorists are aware of the hazard.

# Barriers Must Be Less of a Hazard

# Guardrail Placement

**Place AS FAR AWAY as Possible**

*without affecting function*

# Barrier Design Principles

1. Deflection
2. Slope in Front of Barrier
3. Guardrail and Curb
4. Soil Backing for Fill Locations
5. Flare Rate

# Principle 1: Deflection

Adequate room must be left behind the barrier to allow for lateral deflection in an impact.

- If the barrier is shielding a vertical rigid object, the distance between the barrier and the object should be sufficient to avoid the vehicle impacting or snagging on the object.
- Note that, even for rigid barriers with no lateral deflection, large vehicles may roll behind the top of the barrier even if the barrier itself does not deflect.

# Deflection Distance

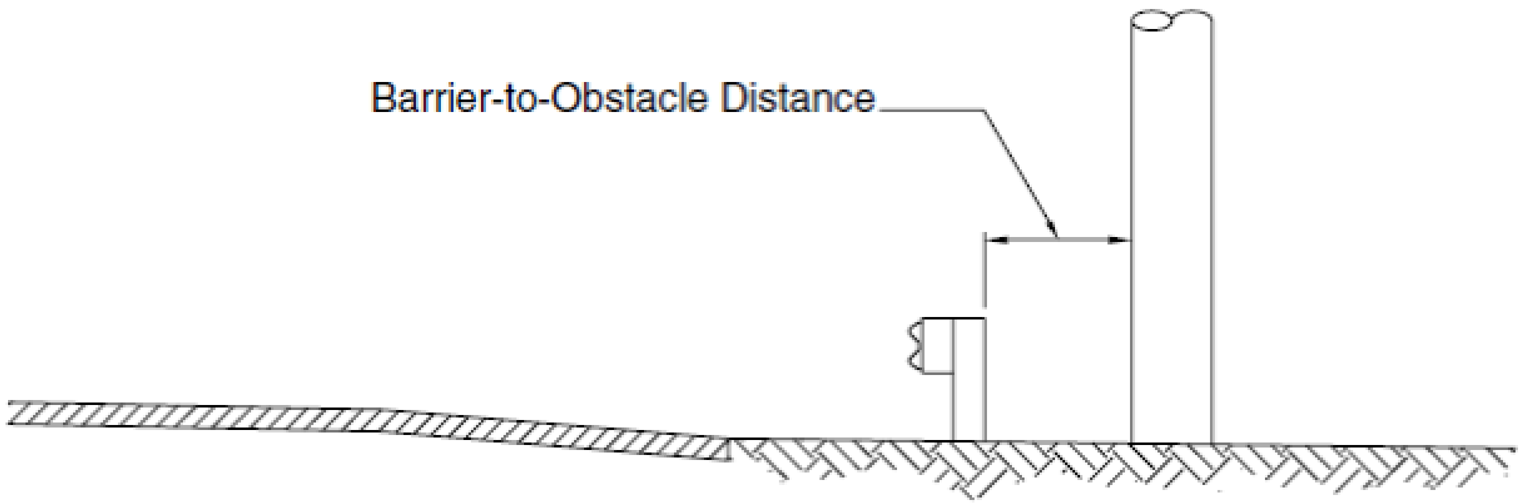
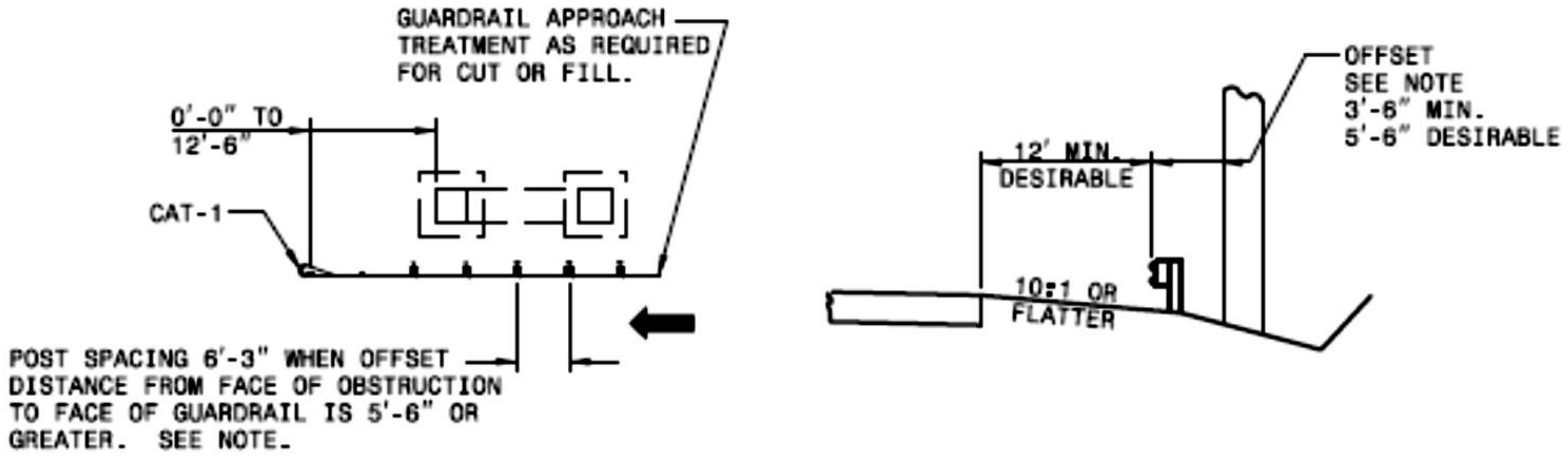



**Figure 5-33. Recommended Barrier Placement for Optimum Performance**

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – Figure 5-33

# Deflection

# Deflection Distance - NCDOT




NOTE: WHEN OFFSET DISTANCE FROM FACE OF OBSTRUCTION TO FACE OF GUARDRAIL IS BETWEEN 3'-6" AND 5'-6", BEGIN 3'-1½" POST SPACING AT A POINT 25' BEFORE REACHING THE OBSTRUCTION AND CARRY THROUGHOUT ITS LENGTH. IF THE OFFSET IS LESS THAN 3'-6" USE CONCRETE BARRIER.

**DETAIL OF RIGHT SIDE GUARDRAIL AT UNDERPASS**

Ref: NCDOT Standard Drawing 862.01, Sht 1

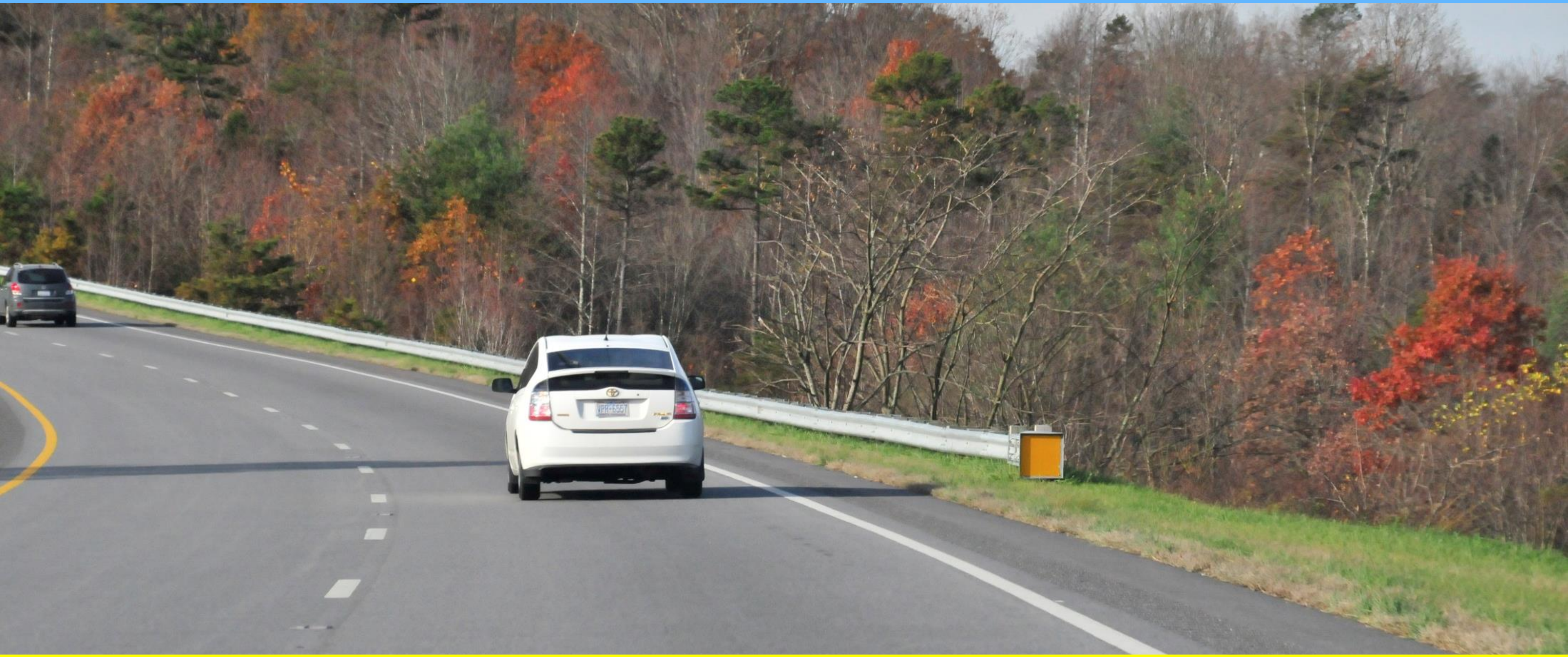
# Quarter Post Spacing

Successfully tested to MASH

Deflection distance = 19”; therefore offset from face of rail is 3’

Must start stiffening at 50’ before hard point: 25’ of half post guardrail; 25’ of quarter post guardrail

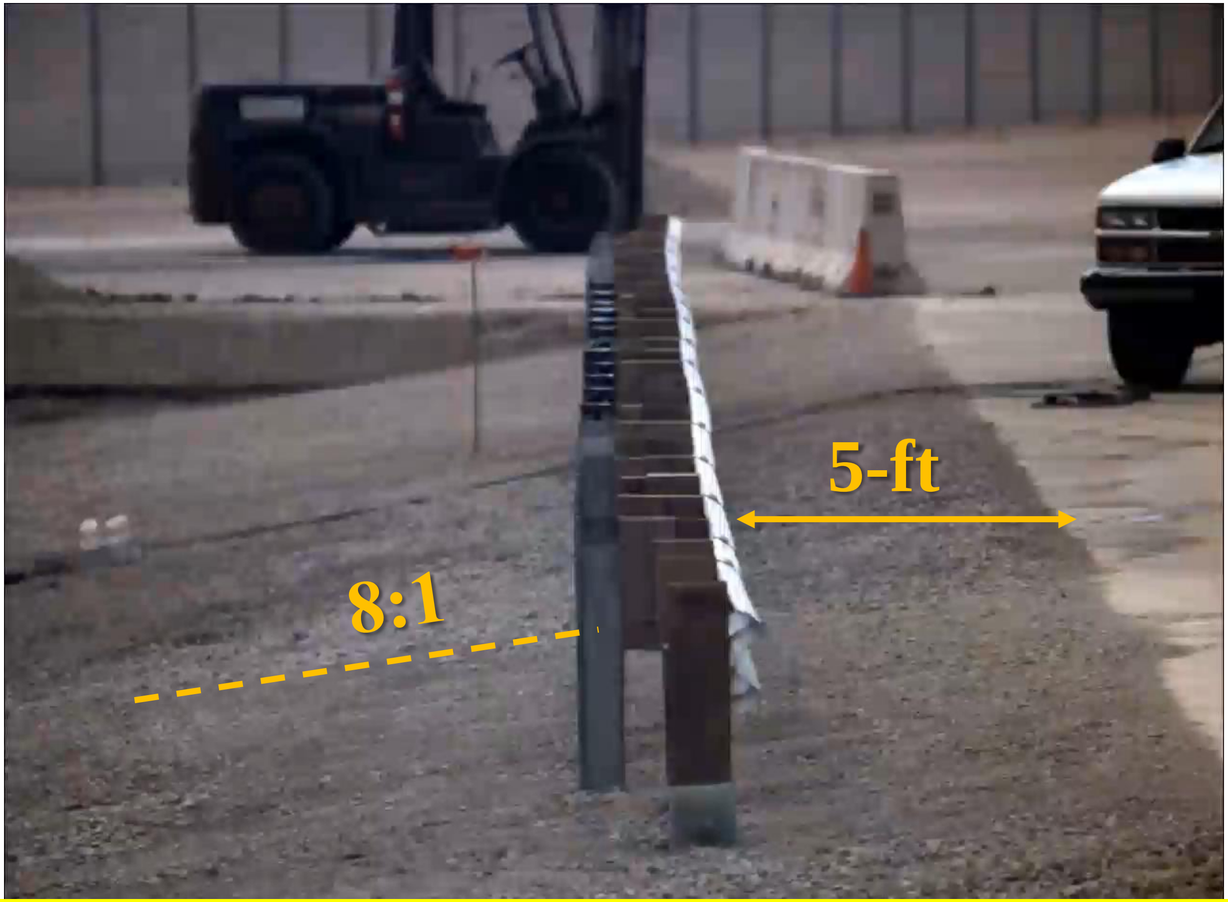
# Principle 2: Slope in Front of Barrier



Any barrier may be placed anywhere on a 10H:1V or flatter slope.

# Principle 2: Slope in Front of Barrier

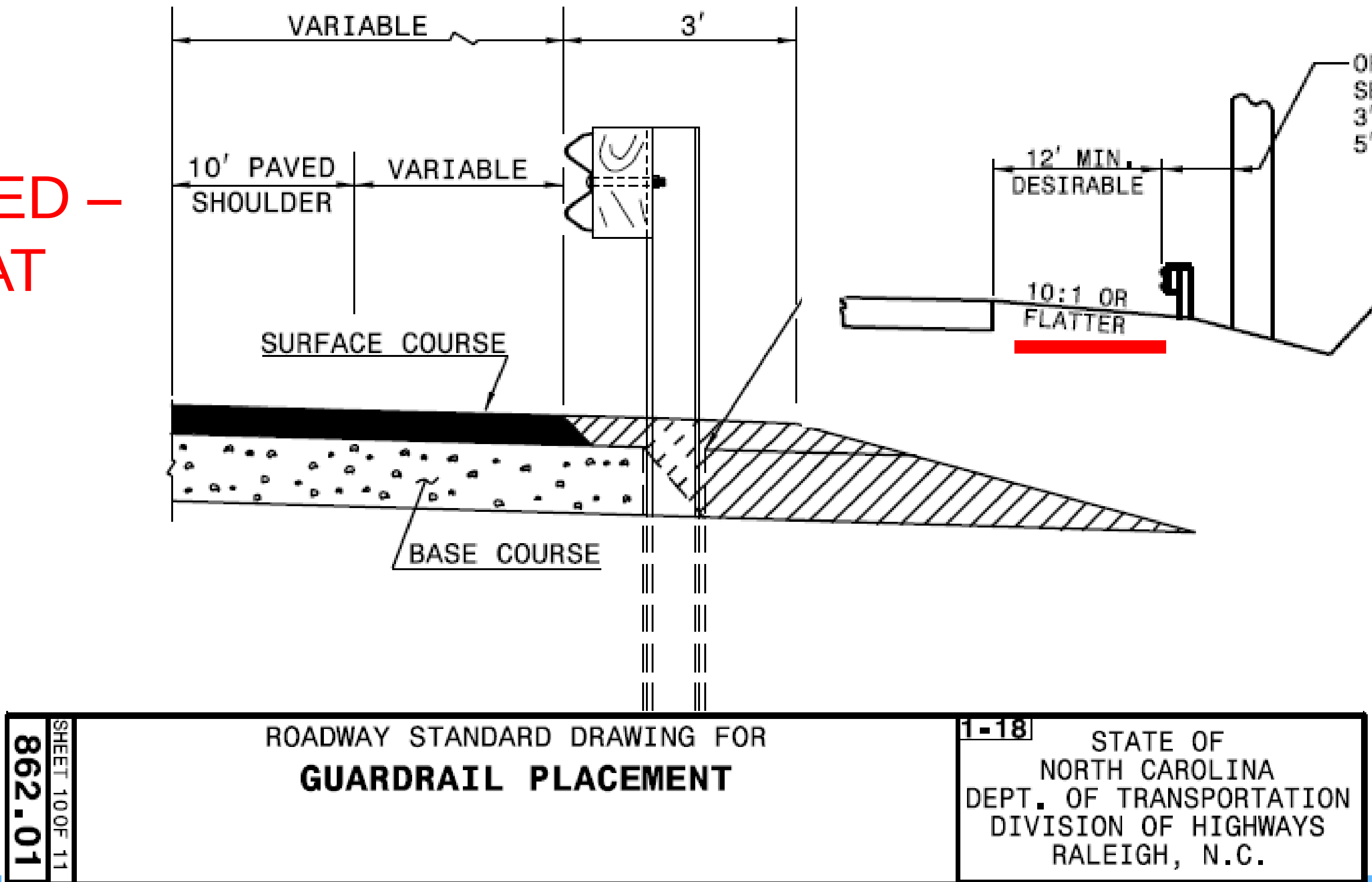
# NCHRP 350 TL-3 31” on 8:1 Slope




Vehicle is contained and redirected but shows instability

# Slope in Front of Barrier

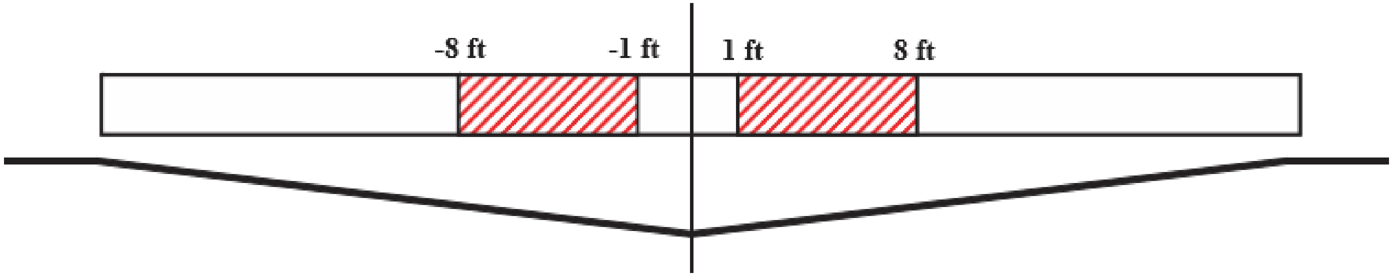
IMPLIED – FLAT



# Barrier in Sloped Median - Old System (29") ONLY -

# Slope in Front of Cable Barrier

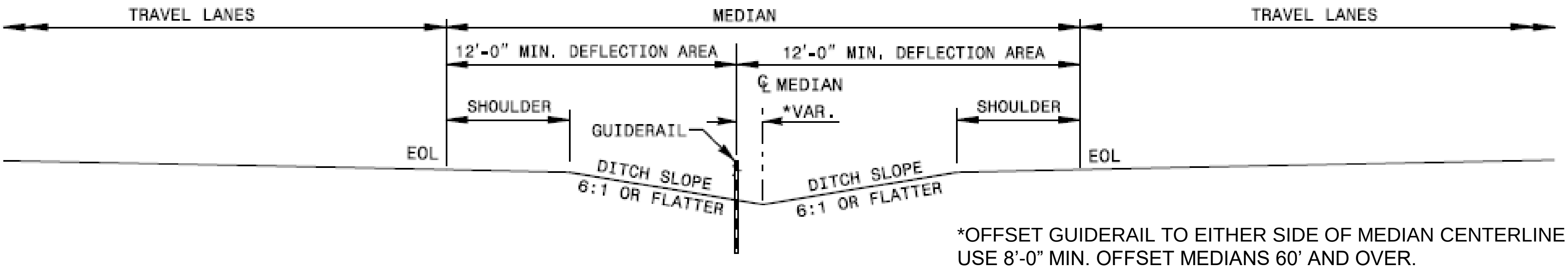
- Cable barrier may be placed anywhere on a 10:1 or flatter slope.
- Cable barrier may be placed on slopes of 6:1, but not in the area from 1 ft.  to 8 ft. from the ditch bottom.




(a) Medians shallower than 6H:1V slope (NCHRP Report 711)

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – 6.6.1.1, Pg. 6-18

# NCDOT Slope/Swale Guidance - LTC




*OFFSET GUIDERAIL TO EITHER SIDE OF MEDIAN CENTERLINE
USE 8'-0" MIN. OFFSET MEDIANS 60' AND OVER.
USE 4'-0" MIN. OFFSET FOR MEDIANS LESS THAN 60'

**TYPICAL SECTION**
(DEFLECTION AREA ON MEDIAN SLOPES)
**DOUBLE FACE GUIDERAIL APPLICATION**

USE 4'-0" MIN. OFFSET FOR MEDIANS LESS THAN 60'.

Strongly Discouraged

| | |
|---|---|
| 865.01 SHEET 4 OF 12 | ROADWAY STANDARD DRAWING FOR **CABLE GUIDERAIL** DESIGN AND PLACEMENT |

# Location of Cable in Swales

MASH 2016 requires testing with a mid-sized vehicle because of this problem (NC experience)

CABLE SHOULD NOT BE PLACED BETWEEN 1' AND 8' BEYOND THE BOTTOM OF A DITCH

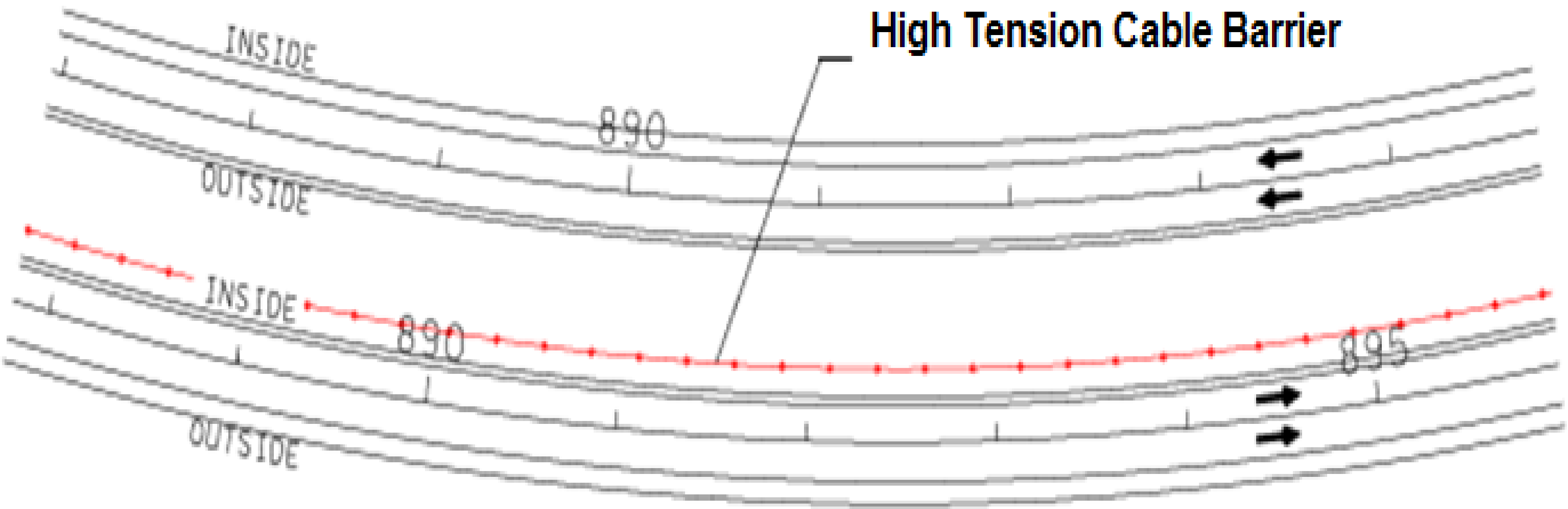
Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – 6.6.1.1, Pg. 6-18

# PRE-ASSESSMENT PHOTO

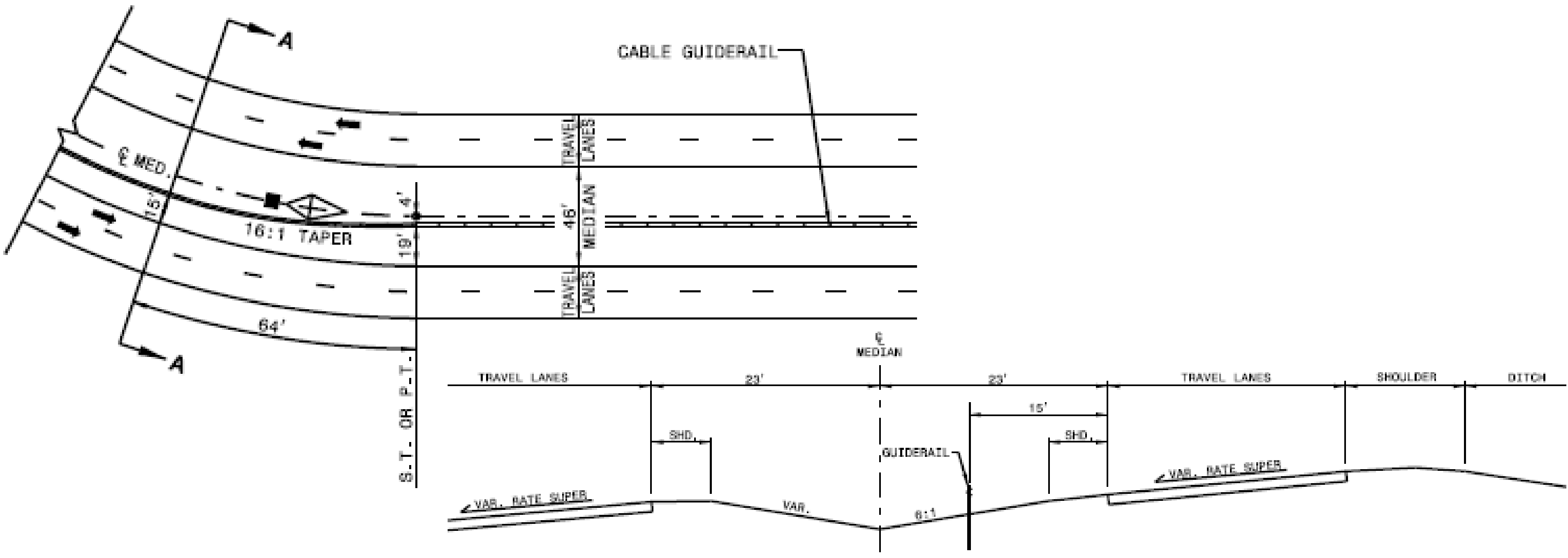
# Barrier in Sloped Median

# Barrier in a Curved Median

## Which Side of the Median Should the Cable Barrier be Placed?



# Barrier in a Curved Median




**SECTION A-A**

865.01

SHEET 3 OF 12

ROADWAY STANDARD DRAWING FOR

**CABLE GUIDERAIL**

46' MEDIAN GUIDERAIL TRANSITIONS WITH SUPERELEVATION AND/OR FALSE SUMPS

# Principle 3: Guardrail and Curbs

# PRE-ASSESSMENT PHOTO

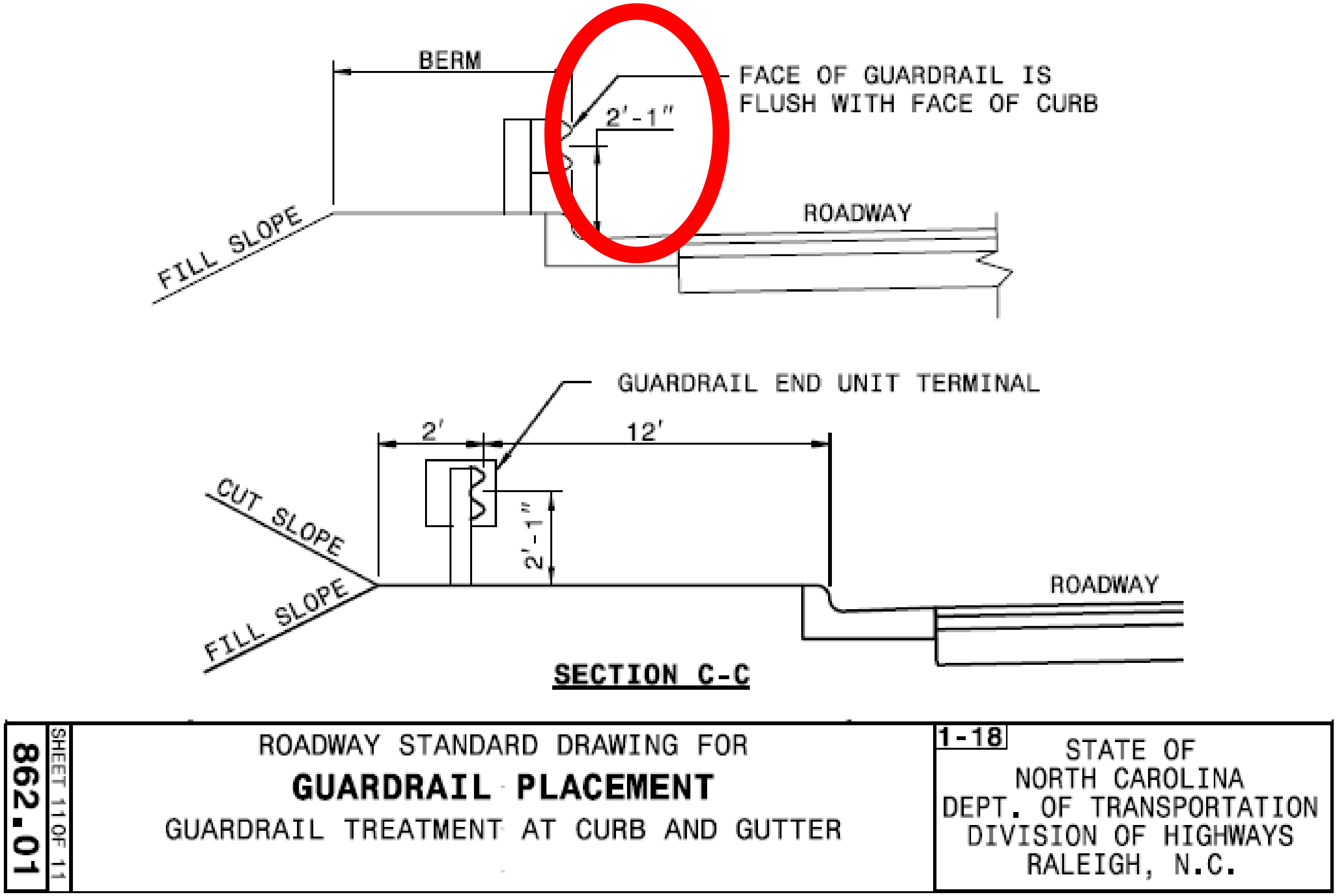

6” Curb not acceptable for old 29” System on HS

# Guardrail and Curbs

- Curbs may function to channelize traffic, to control drainage, improve delineation, control access, and reduce erosion.
- Curbs are not adequate to prevent a vehicle from leaving the roadway; they are not a barrier.
- Use of any guardrail/curb combination where high-speed, high-angle impacts are likely should be discouraged.

# Guardrail and Curbs – 29”

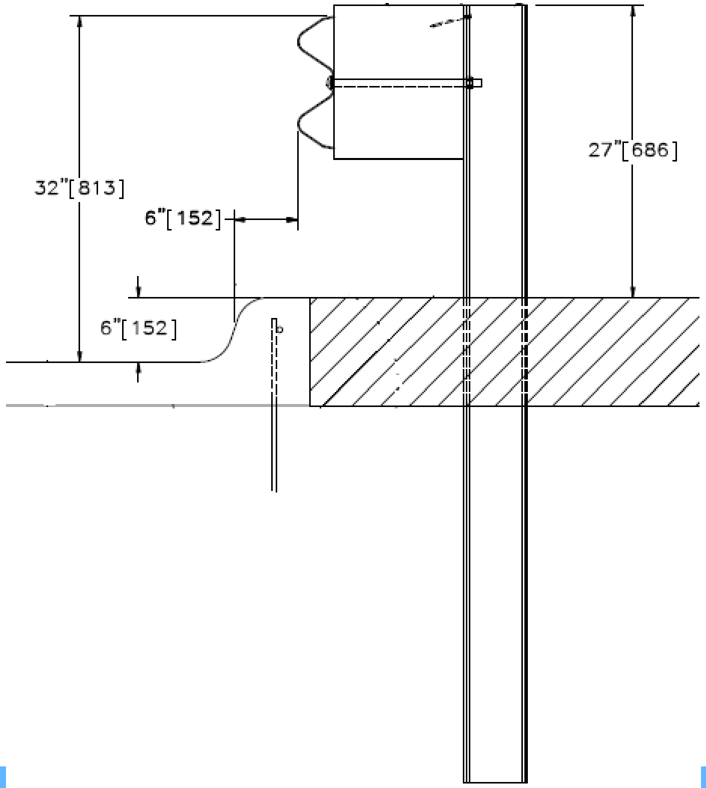
# NCDOT Guardrail and Curbs




Ref: NCDOT Standard Drawings, 862.01 Sht. 11

# 31” and Curbs

Successfully tested to MASH placed 6” behind a 6” high curb at TL-3



# MASH TL-3 31”
# Placed 6” behind 6” high Curb

# 31” and Curbs

- The 31” was tested with a 6” curb, 8’ in front of the rail at MASH TL-3

unsuccessful

# End Treatments and Curbs

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

No curb is allowed within the limits of this unit.

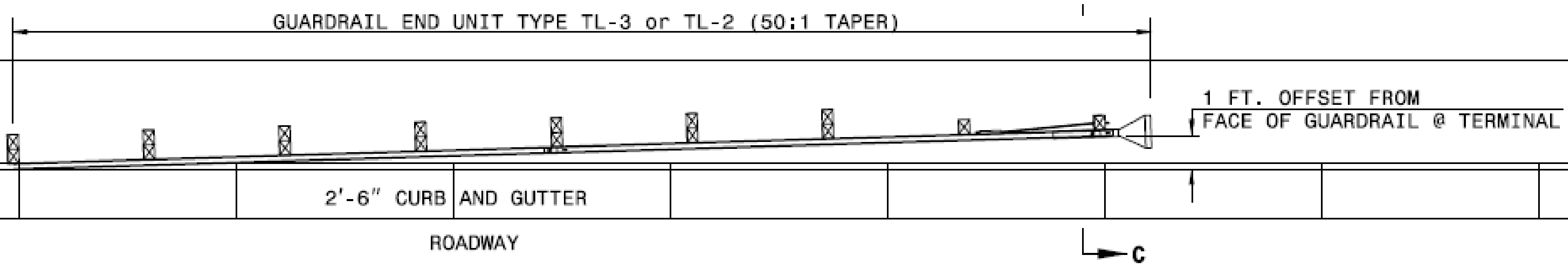
GUARDRAIL ANCHOR UNITS 3-2E

# End Treatments and Curbs

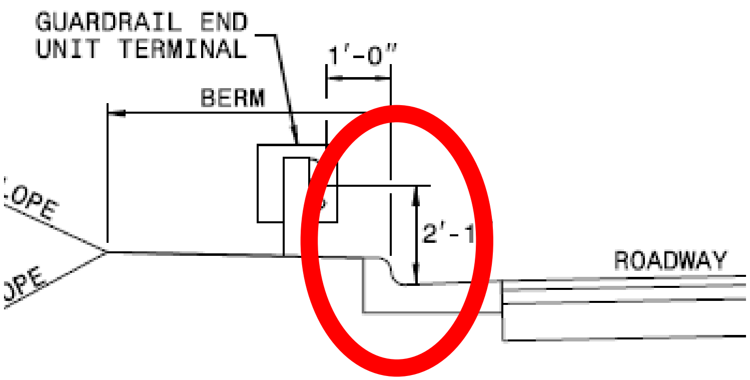
CURRENTLY UNDER STUDY –
DO NOT BURY BEARING PLATE

**2" maximum height recommended**

# End Treatments and Curbs - NCDOT




**GUARDRAIL AT FACE OF CURB**




**SECTION C-C**

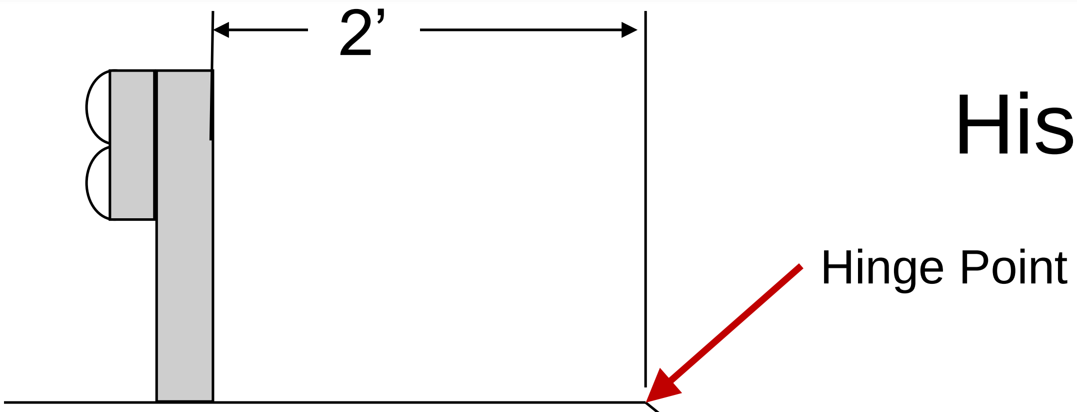
Ref: NCDOT Standard Drawings, 862.01 Sht. 11

Careful with BCA Terminal Anchor – Don't let Bearing Plate be buried

# MASH TL-2 31” 6 ft. behind curb

# Principle 4: Soil Backing For Fill Locations

# Soil Backing Recommendation



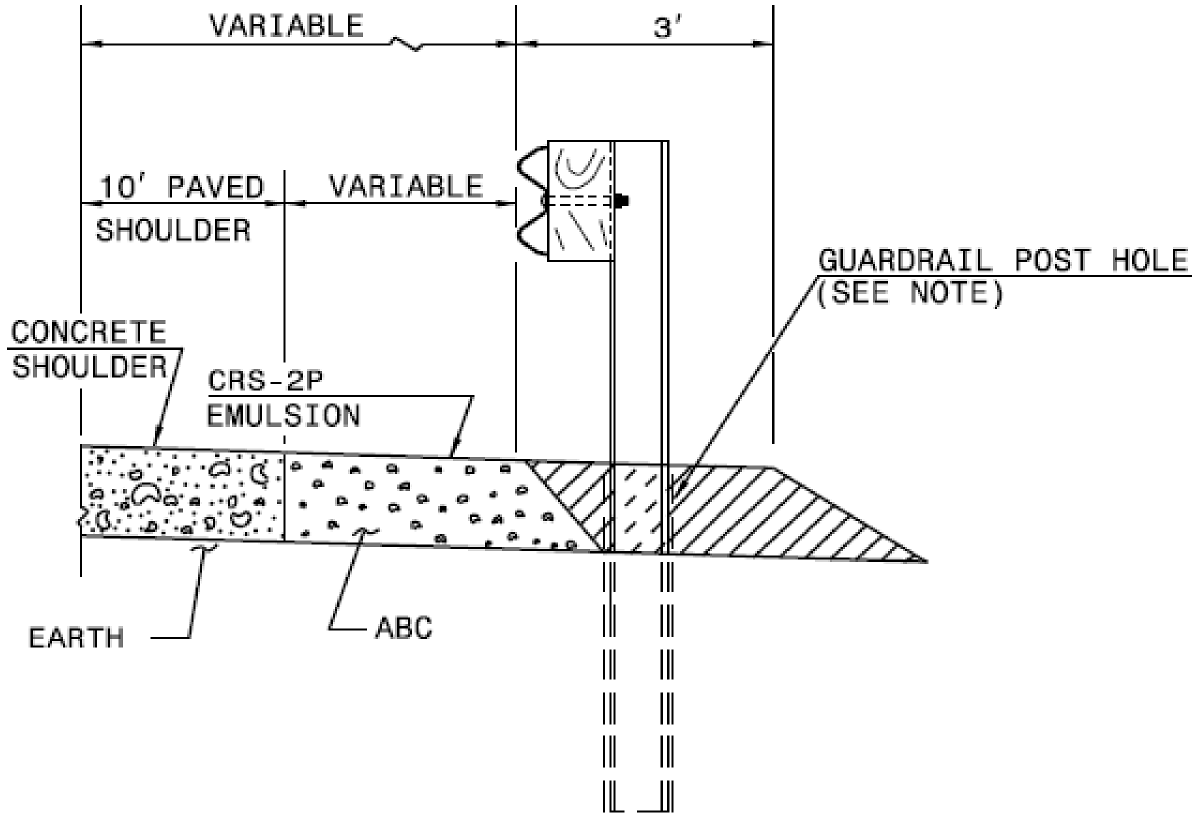

## Historical Guidance

1. Slope can be as steep as 2:1 with 2-ft. backing in strong soil with 6 ft. posts.

2. Backing can be less than 2 ft. with 2:1 slope in strong soil with 7 ft. posts. NCHRP 350 requires half post spacing – ONLY applies to 29” system

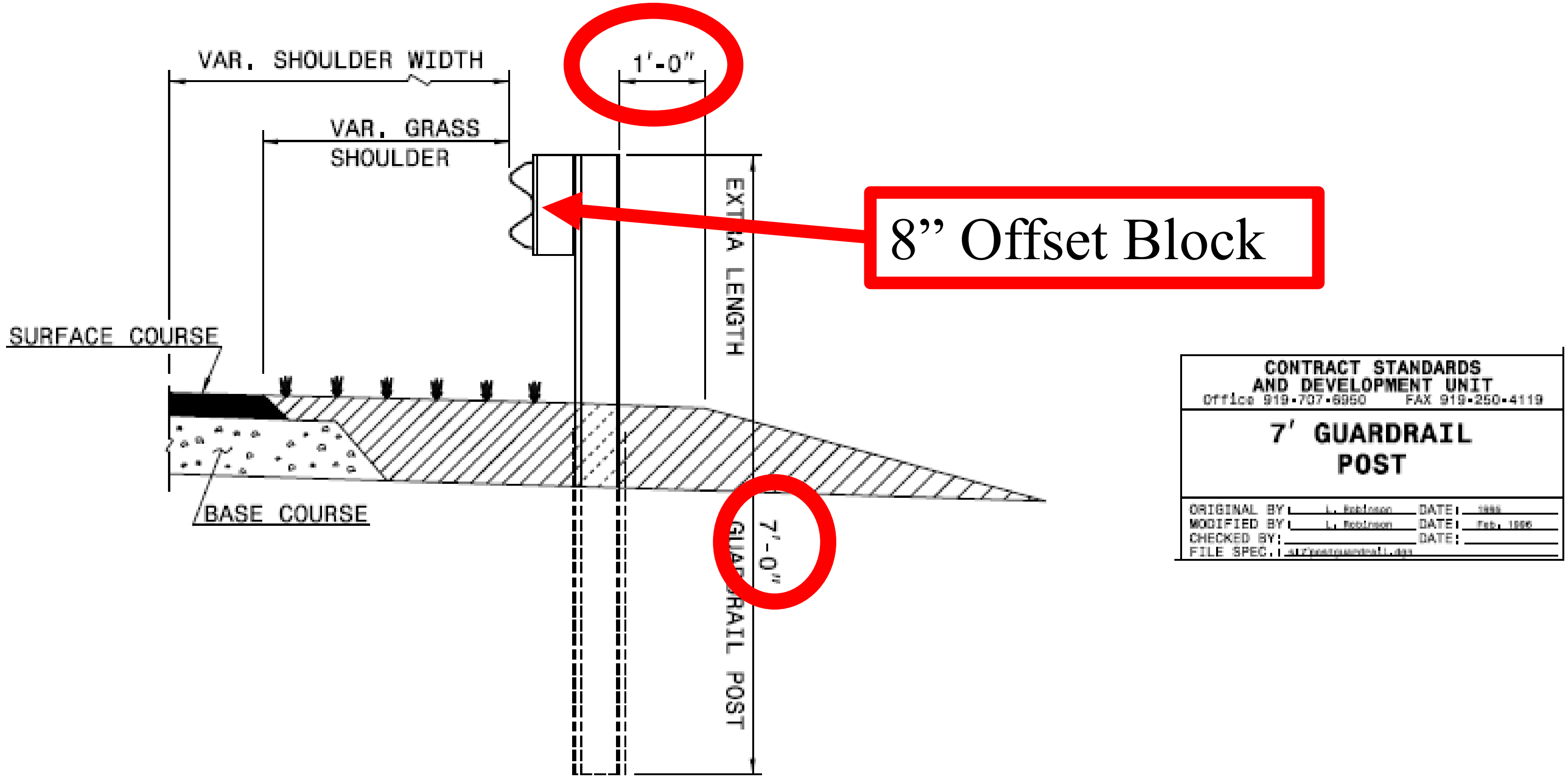
Ref: AASHTO Roadside Design Guide, 4th Edition – Figure 5.33, Pg. 5-41

# Soil Backing – NCDOT

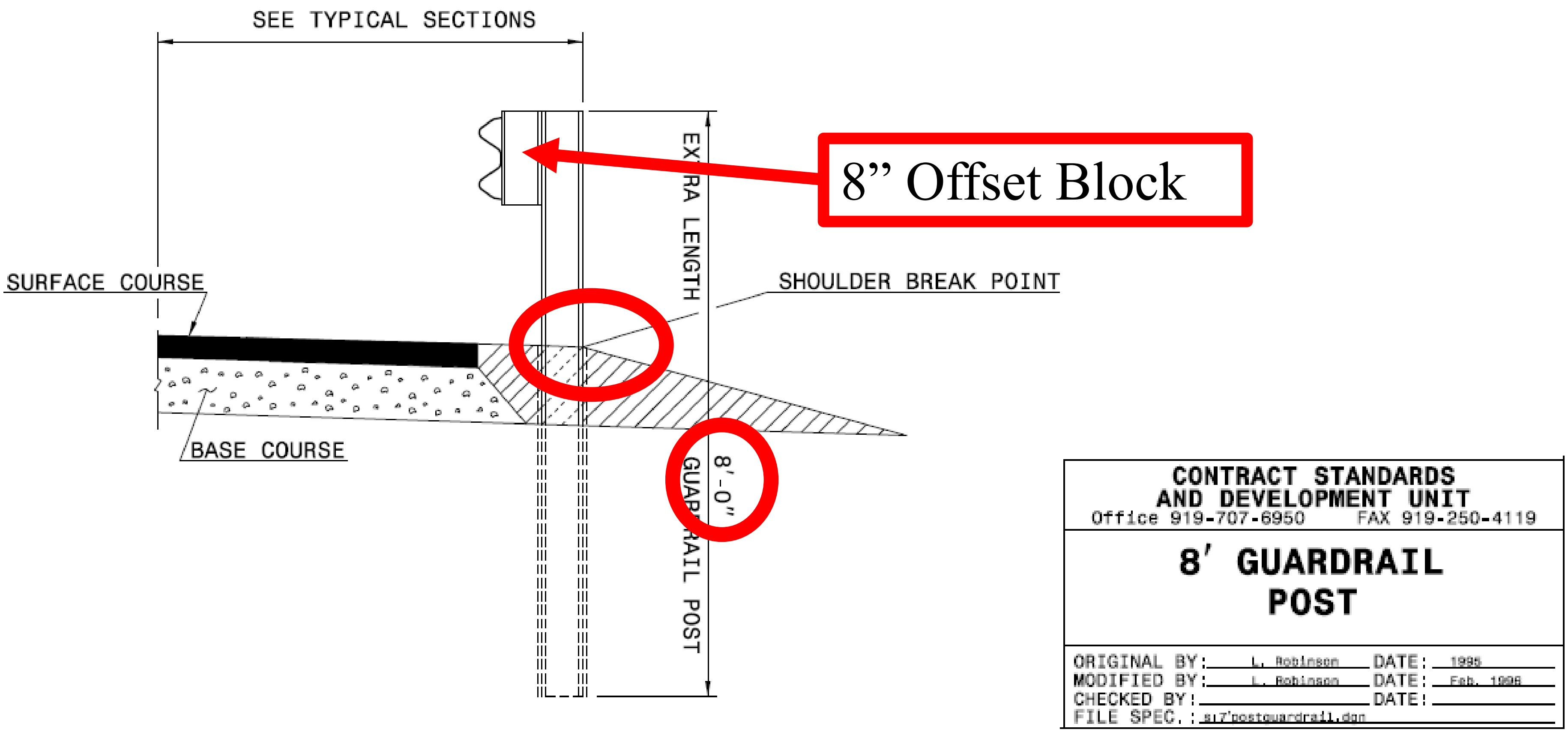



| 862.01 | SHEET 10 OF 11 | ROADWAY STANDARD DRAWING FOR **GUARDRAIL PLACEMENT** | 1-18 STATE OF NORTH CAROLINA DEPT. OF TRANSPORTATION DIVISION OF HIGHWAYS RALEIGH, N.C. |
|---|---|---|---|

# Soil Backing – NCDOT



# Soil Backing – NCDOT



# 31” with Posts on a 2:1 Slope

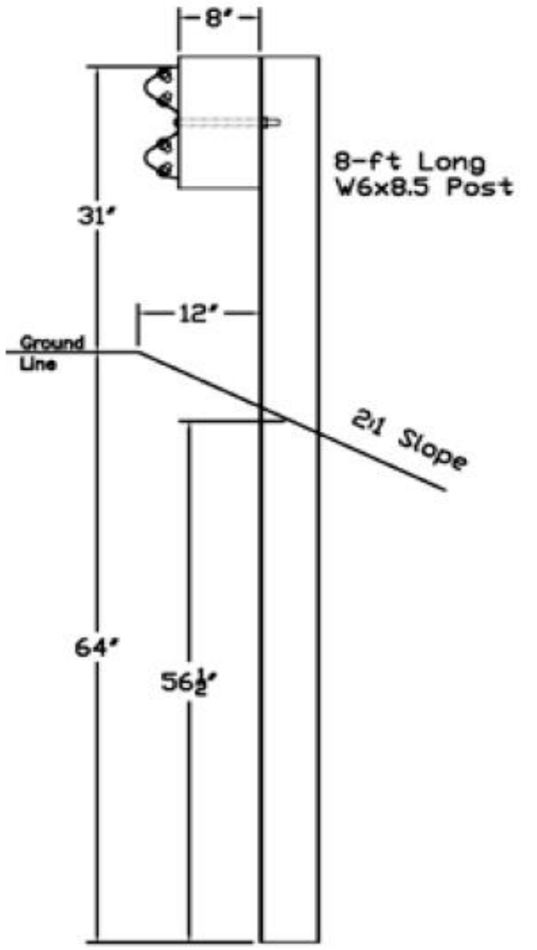
31” with face of rail at slope break point of 2:1 slope

**Posts**

- 8’ long W6x9 posts tested
- Not recommended with Wood posts at this time
- 6’-3” post spacing

**Offset Blocks**

- 8” Offset block tested
- Not recommended without offset block at this time



# 31” with Posts on a 2:1 Slope

MASH Testing of
MGS adjacent to a
2:1 Slope
8" blockout
8' long posts at
6'-3" spacing

Working Width – 55.2”
Eligibility Letter B-261

# Principle 5: Flare Rate

# Flare Rate

*Flared barriers* are those that are not parallel to the edge of the traveled way. They are used to:

- Locate end treatments farther from the roadway.
- Lessen driver reaction to a roadside obstacle.
- Reduce total length of rail needed.
- Reduce nuisance hits.
- When tying to a bridge rail from a farther offset (in advance of transition)

# Flare Rate

Trade offs and restrictions of flared barriers:

- Flare increases the angle at which the barrier can be hit.
- Flare may increase the angle of redirection after an impact.
- Flared barriers can only be placed on 10:1 or flatter slopes.
- Maximum flare rate varies with design speed
  NCDOT flare rate typically 50:1

# Tangent End Treatments on Flared Standard Run - Repeat

The offset of the end treatment is measured from a line parallel to the ROADWAY:

- If the standard flare is 25:1 or flatter, the end treatment may be placed on the standard flare line extended

- If the standard flare is sharper than 25:1, a kink in the run must be provided so the end treatment is no sharper than 25:1

NCDOT guidance is to provide 25’ of parallel guardrail in advance of any end treatment requiring a kink.

# Suggested Flare Rates

Table 5-9. Suggested Flare Rates for Barrier Design

| Design Speed km/h | Design Speed [mph] | Flare Rate for Barrier Inside Shy Line | Flare Rate for Barrier at or Beyond Shy Line: Rigid Barrier | Flare Rate for Barrier at or Beyond Shy Line: Semi -Rigid Barrier |
|---|---|---|---|---|
| 110 | [70] | 30:1 | 20:1 | 15:1 |
| 100 | [60] | 26:1 | 18:1 | 14:1 |
| 90 | [55] | 24:1 | 16:1 | 12:1 |
| 80 | [50] | 21:1 | 14:1 | 11:1 |
| 70 | [45] | 18:1 | 12:1 | 10:1 |
| 60 | [40] | 16:1 | 10:1 | 8:1 |
| 50 | [30] | 13:1 | 8:1 | 7:1 |

Notes:

A = Suggested maximum flare rate for rigid barrier system.

B = Suggested maximum flare rate for semi-rigid barrier system.

The MGS has been tested in accordance with NCHRP Report 350 TL-3 at 5:1 flare.

Flatter flare rates for the MGS installations also are acceptable. The MGS should be installed using the flare rates shown or flatter for semi-rigid barriers beyond the shy line when installed in rock formations.

# Example of Benefit of Flare

# PRE-ASSESSMENT PHOTO

# Review Learning Outcomes

Understand the design principles affecting an optimal barrier installation.

# Session 6:
# Length of Need and Special Considerations

# Session 6 Learning Outcomes

At the end of this session, you will be able to:

- Define the Length of Need and apply the design principles for an optimal installation
- Modify guardrail for special situations

# Order of Preference - NCDOT

## 4.10 Traffic Barriers
## 4.10.1 General Considerations

The preferred method of addressing roadside hazards is as follows:

1. Remove the hazard;
2. Remove embankment hazard (flatten slopes);
3. Shift hazard away from traffic;
4. Reduce the impact severity by using breakaway posts;
5. Protect the hazard;
6. Delineate the hazard so motorists are aware of the hazard.

# Length of Need (LON) Definition

## AASHTO

The length of effective barrier needed IN ADVANCE OF the hazard to intercept and redirect an encroaching vehicle.

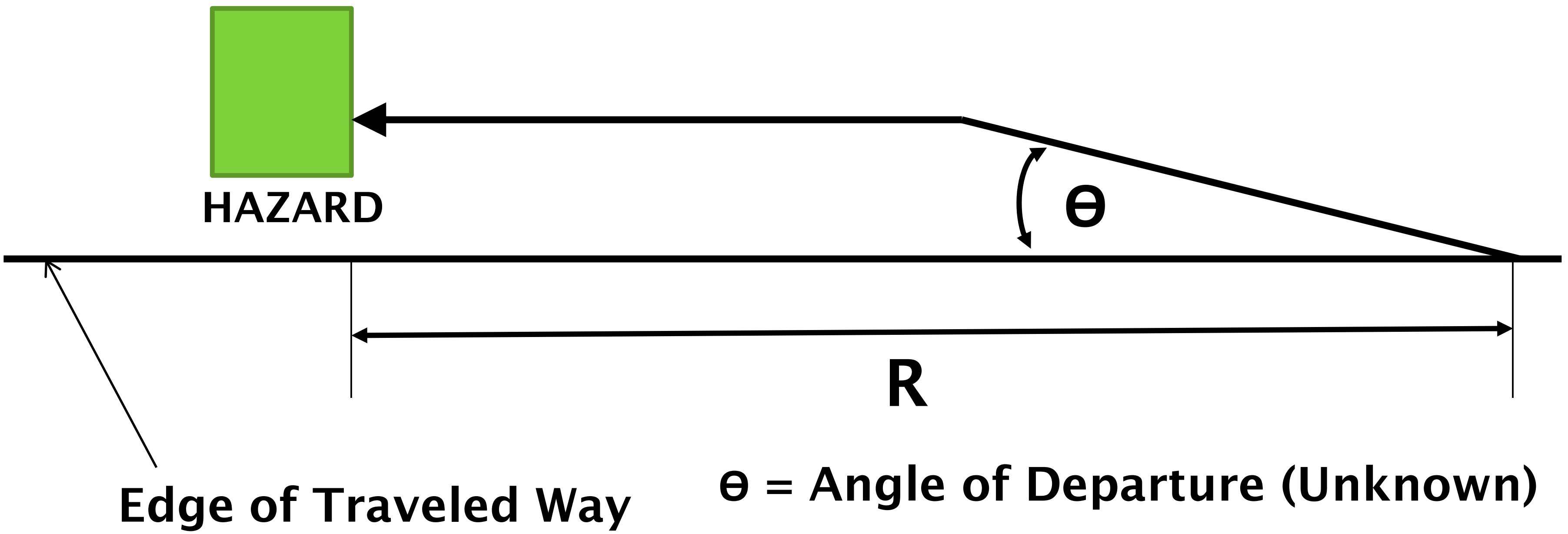
# Length of Need (LON) Definition

NCDOT

The length of effective barrier in advance of the obstacle **NOT TO INCLUDE ANY** of the GREU.

# Length of Need (LON) Theory

## AASHTO




**ϴ = Angle of Departure (Unknown)**

**R = Runout Length**

# Runout Lengths - NCDOT

Proposed - replace with AASHTO RDG values

LR = RUNOUT LENGTH
N – NORMAL SHOULDER WIDTH (WIDTH OF SHOULDER FROM EDGE OF TRAVEL LANE TO FACE OF GUARDRAIL)

DETAIL 3–2A

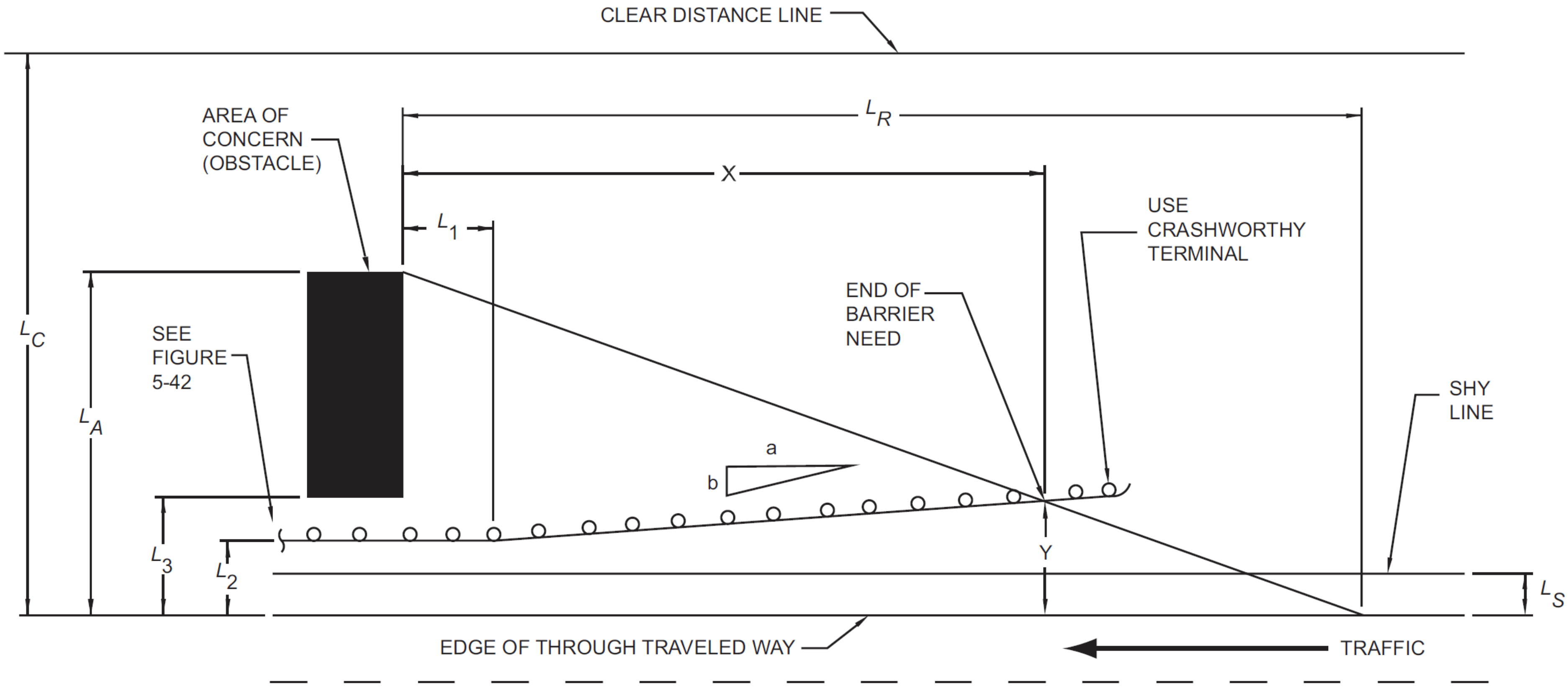
# Runout Lengths - AASHTO

Table 5-10(b). Suggested Runout Lengths for Barrier Design (U.S. Customary Units)

| Design Speed (mph) | Runout Length ($L_R$) Given Traffic Volume (ADT) (ft) | | | |
|---|---|---|---|---|
| | Over 10,000 | 5,000 to 10,000 | 1,000 to 5,000 | Under 1,000 |
| 80 | 470 | 430 | 380 | 330 |
| 70 | 360 | 330 | 290 | 250 |
| 60 | 300 | 250 | 210 | 200 |
| 50 | 230 | 190 | 160 | 150 |
| 40 | 160 | 130 | 110 | 100 |
| 30 | 110 | 90 | 80 | 70 |

Ref: AASHTO ROADSIDE DESIGN GUIDE, 4th EDITION – TABLE 5.10, Pg. 5-50

# LON Design Procedure for Approach Barrier Layout




Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.39, Pg. 5-49

# Length of Need – AASHTO

- Calculating the length of need (X) for straight or nearly straight sections of roadway:
  - For <u>flared</u> guardrail installations:

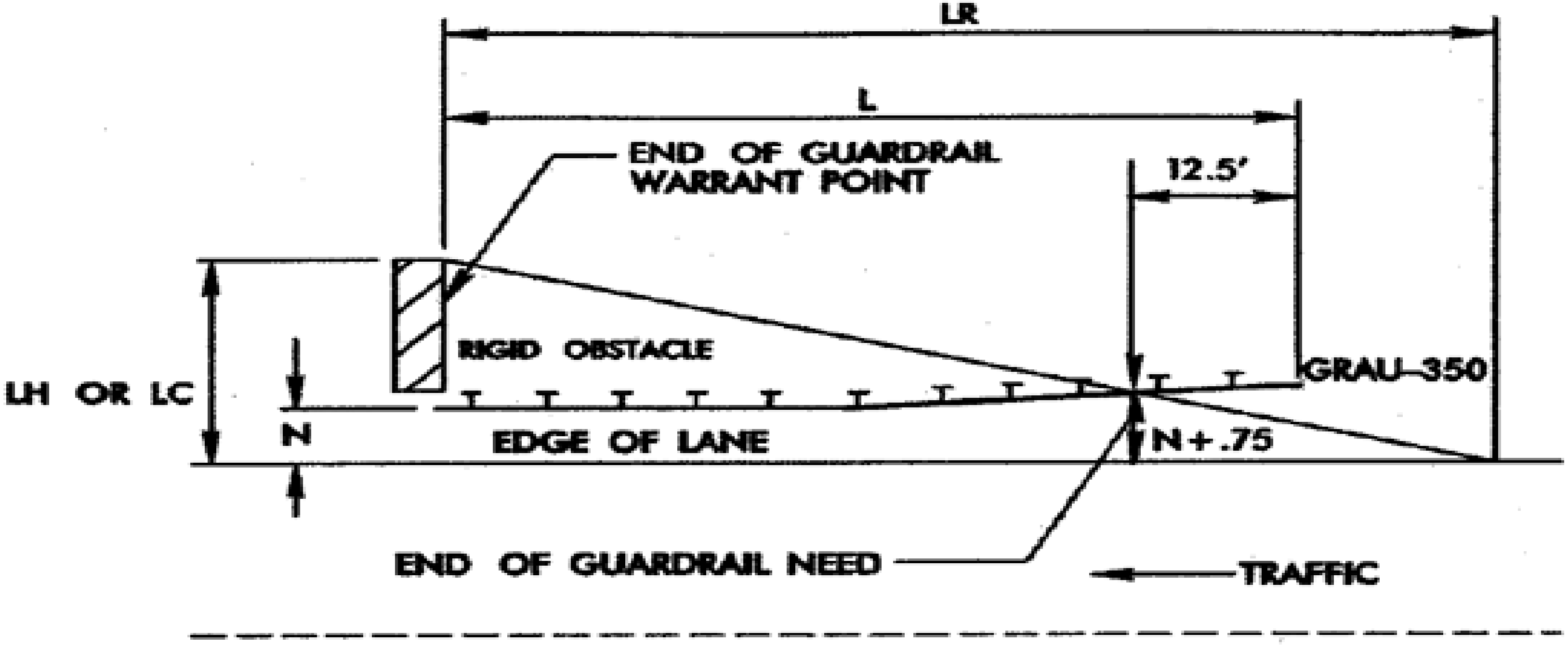
$$X = \frac{L_A + (b/a)(L_1) - L_2}{(b/a) + (L_A/L_R)}$$

  - For <u>parallel</u> guardrail installations:

$$X = \frac{L_A - L_2}{L_A/L_R}$$

Ref: AASHTO Roadside Design Guide, 4th Edition, Equation 5-1 and 5-2, Pg 5-51

# Length of Need – NCDOT




ROADWAY DESIGN MANUAL PART 1

DETAIL 3-2A

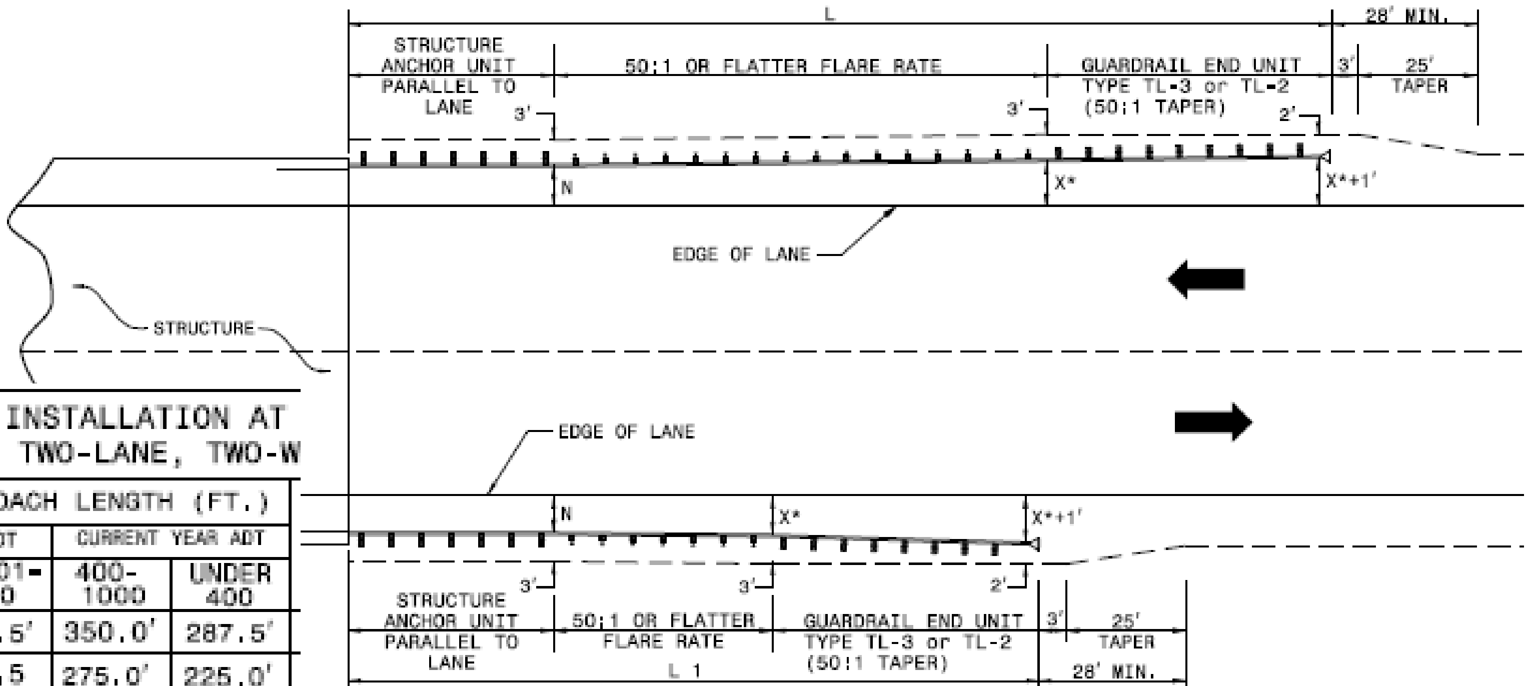
# Length of Need – NCDOT

- Calculating the length of need (L) for straight or nearly straight sections of roadway (parallel installation):

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

The formulas and details are derived from Chapter 5 in the <u>Roadside Design Guide</u>.

# Length of Need for Bridge Approach NCDOT



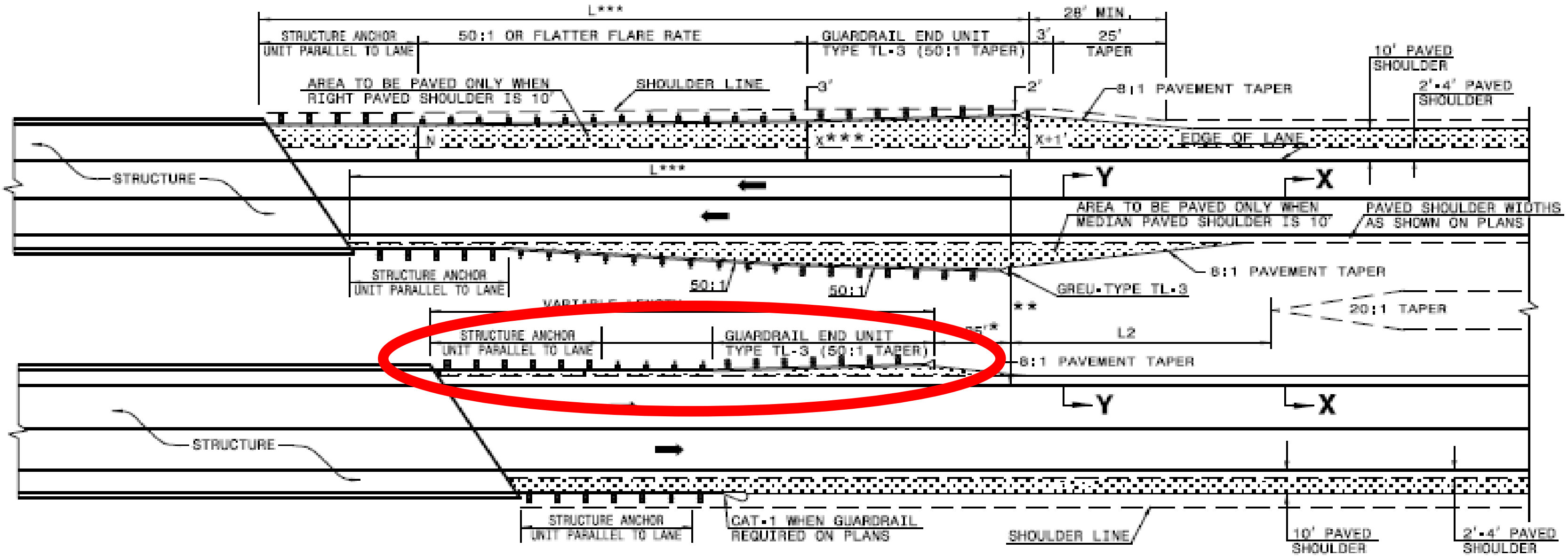

GUARDRAIL INSTALLATION AT
FOR TWO-LANE, TWO-W

| DESIGN SPEED (MPH) | "L" APPROACH LENGTH (FT.) | | | |
|---|---|---|---|---|
| | DESIGN YEAR ADT | | CURRENT YEAR ADT | |
| | OVER 2000 | 1001-2000 | 400-1000 | UNDER 400 |
| 70 | 362.5' | 362.5' | 350.0' | 287.5' |
| 60 | 300.0' | 287.5 | 275.0' | 225.0' |
| 50 | 212.5' | 212.5' | 200.0' | 162.5' |
| 40 | 175.0' | 150.0' | 137.5' | 112.5' |
| | | | | |
| X * | 8' | 6' | 4' | 4' |

SHEET 4 OF 11

862.01

# Length of Need for Bridge Approach NCDOT – Dual Bridges




DIMENSIONS FOR LENGTH OF GUARDRAIL APPROACHING DUAL LANE BRIDGES

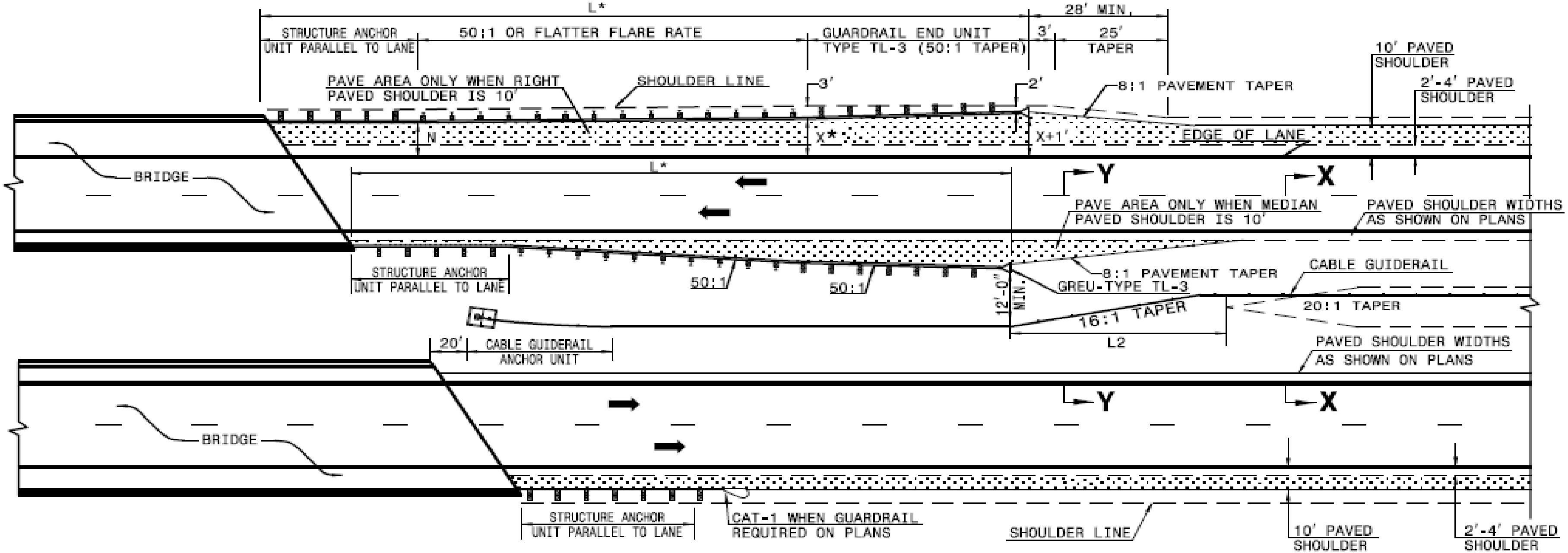
| MEDIAN WIDTH | -L-*** | | | | | | -L2- DIM. |
|---|---|---|---|---|---|---|---|
| | 70 MPH | 60 MPH | 50 MPH | | | | |
| 30' | 300.0' | 250.0' | 150.0' | | | | 80.0' |
| 36' | 300.0' | 250.0' | 150.0' | | | | 60.0' |
| 40' & ABOVE | 300.0' | 250.0' | 150.0' | | | | 40.0' |

SHEET 3 OF 11

862.01

THE DESIGN LAYOUT FOR LENGTHS SHOWN ON THIS STANDARD ARE MINIMUM DESIGN LENGTHS.

# Length of Need for Bridge Approach NCDOT – with Cable Barrier

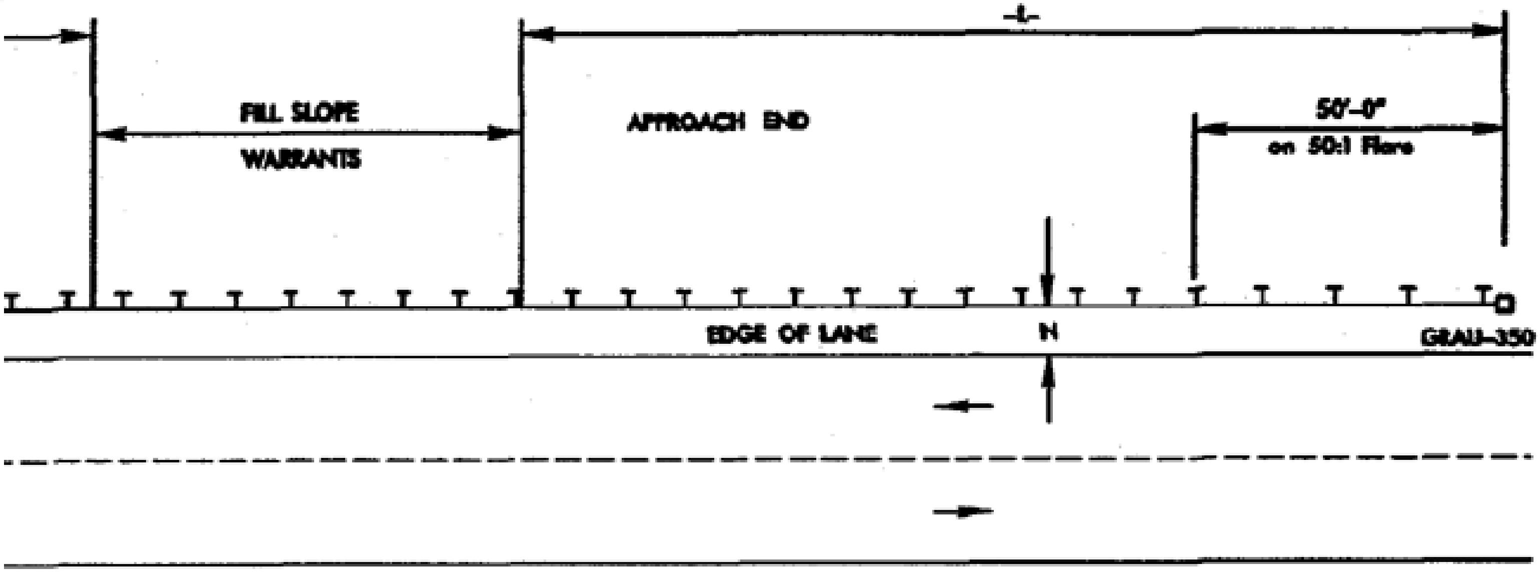



| DIMENSIONS FOR LENGTH OF GUARDRAIL APPROACHING DUAL LANE BRIDGES | | | | | | | |
|---|---|---|---|---|---|---|---|
| MEDIAN WIDTH | -L-* | | | | | | -L2- DIM. |
| | 70 MPH | 60 MPH | 50 MPH | | | | |
| 46' & ABOVE | 300.0' | 250.0' | 150.0' | | | | 40.0' |

SHEET 2 OF12
865.01

THE DESIGN LAYOUT FOR LENGTHS SHOWN ON THIS STANDARD ARE MINIMUM DESIGN LENGTHS.

# Length of Need for Fill Slope NCDOT



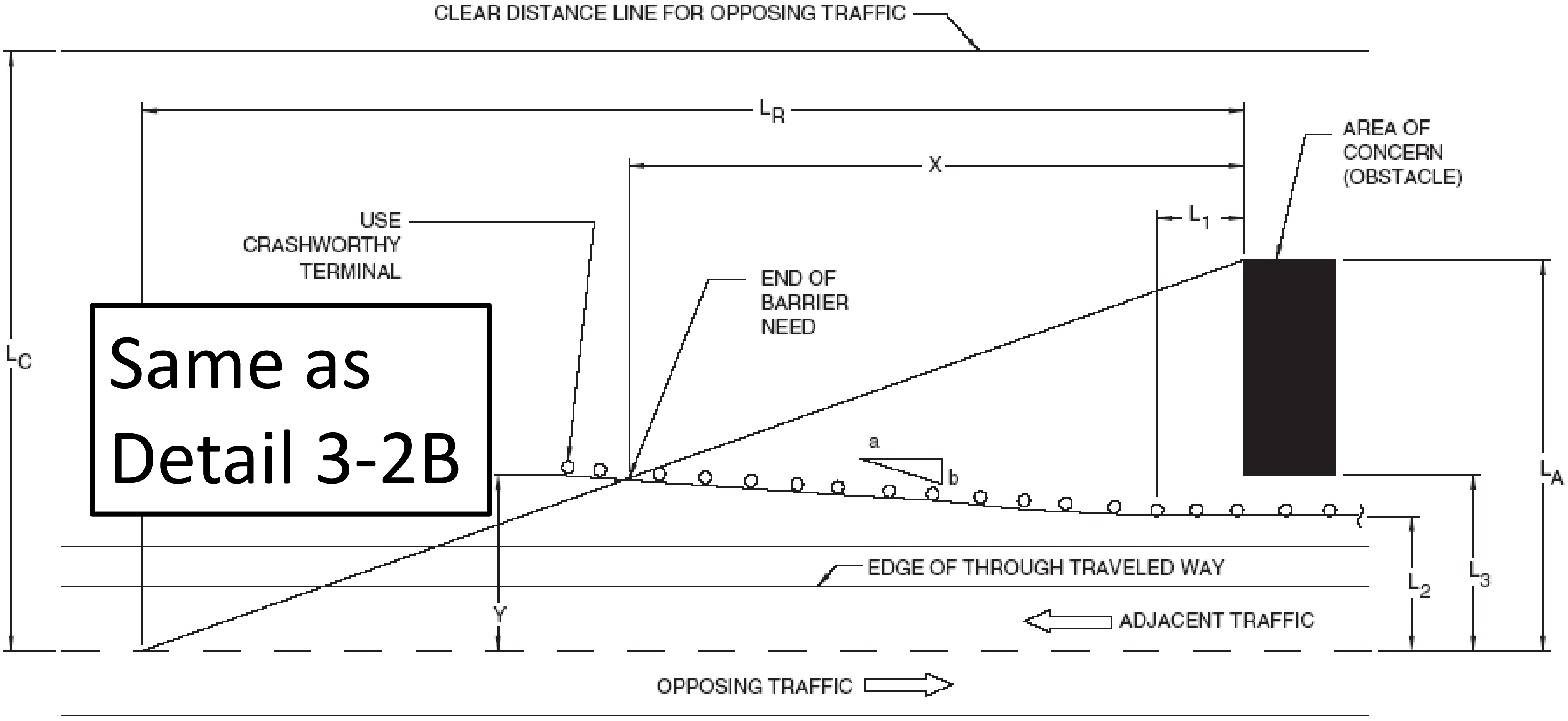

"L" OR LENGTH OF NEED ON THE APPROACH SIDE OF THE GUARDRAIL FOR A FILL SLOPE WARRANT FOR ANY CLASSIFICATION OF ROADWAY

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

DETAIL 3 - 2C

**These are quite short compared to AASHTO**

# LON Design for Opposing Traffic

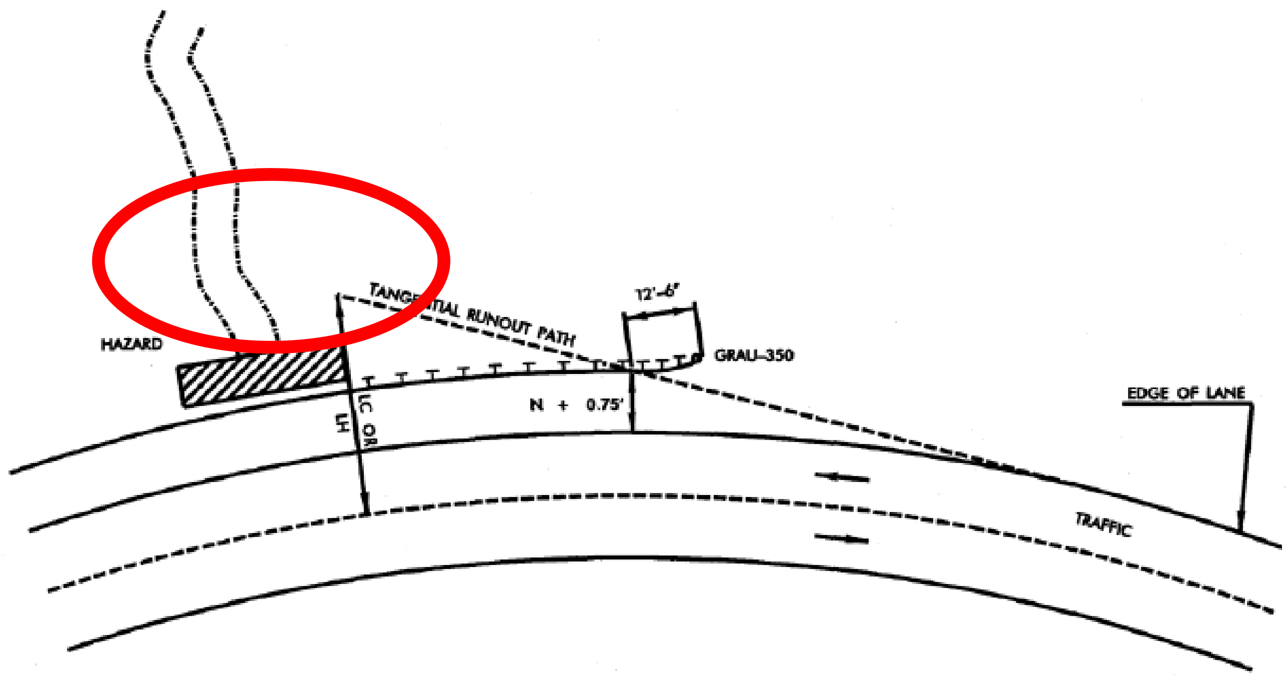



Same as Detail 3-2B

Ref: AASHTO Roadside Design Guide, 4th Edition, Figure 5.42, Pg. 5-54

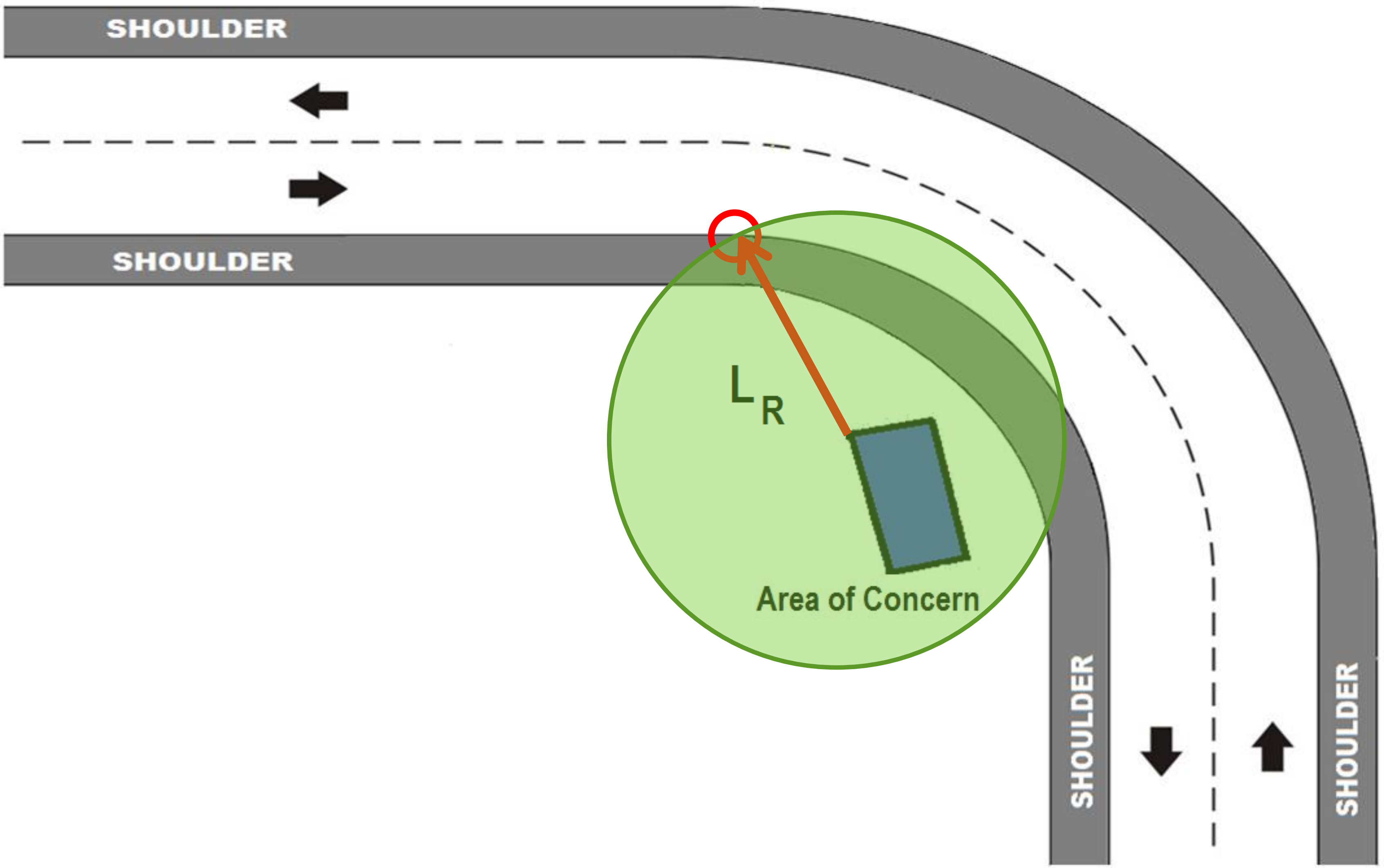
# Length of Need on the Outside of a Horizontal Curve

REV. 01/02/02




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

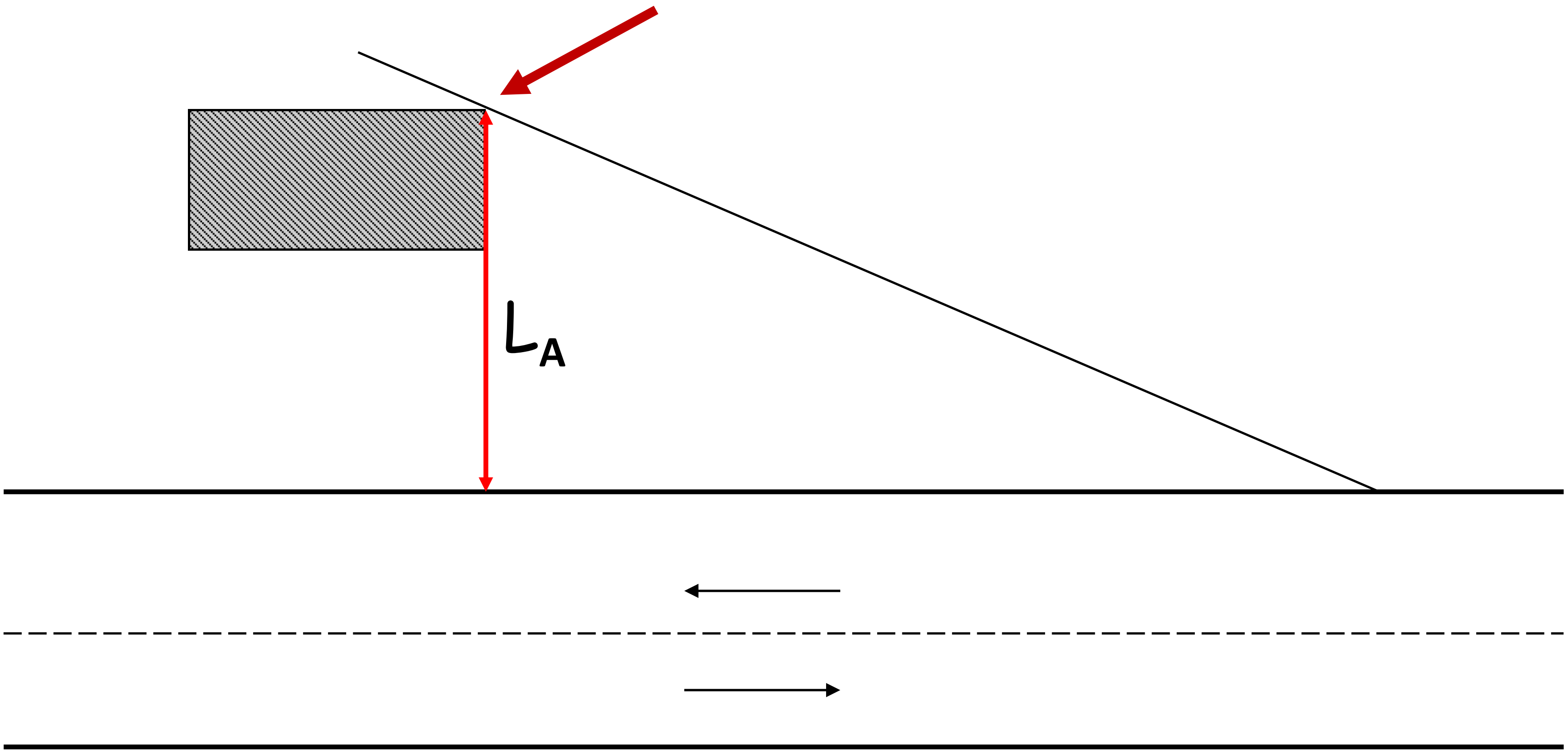
# Length of Need on the Inside of a Horizontal Curve



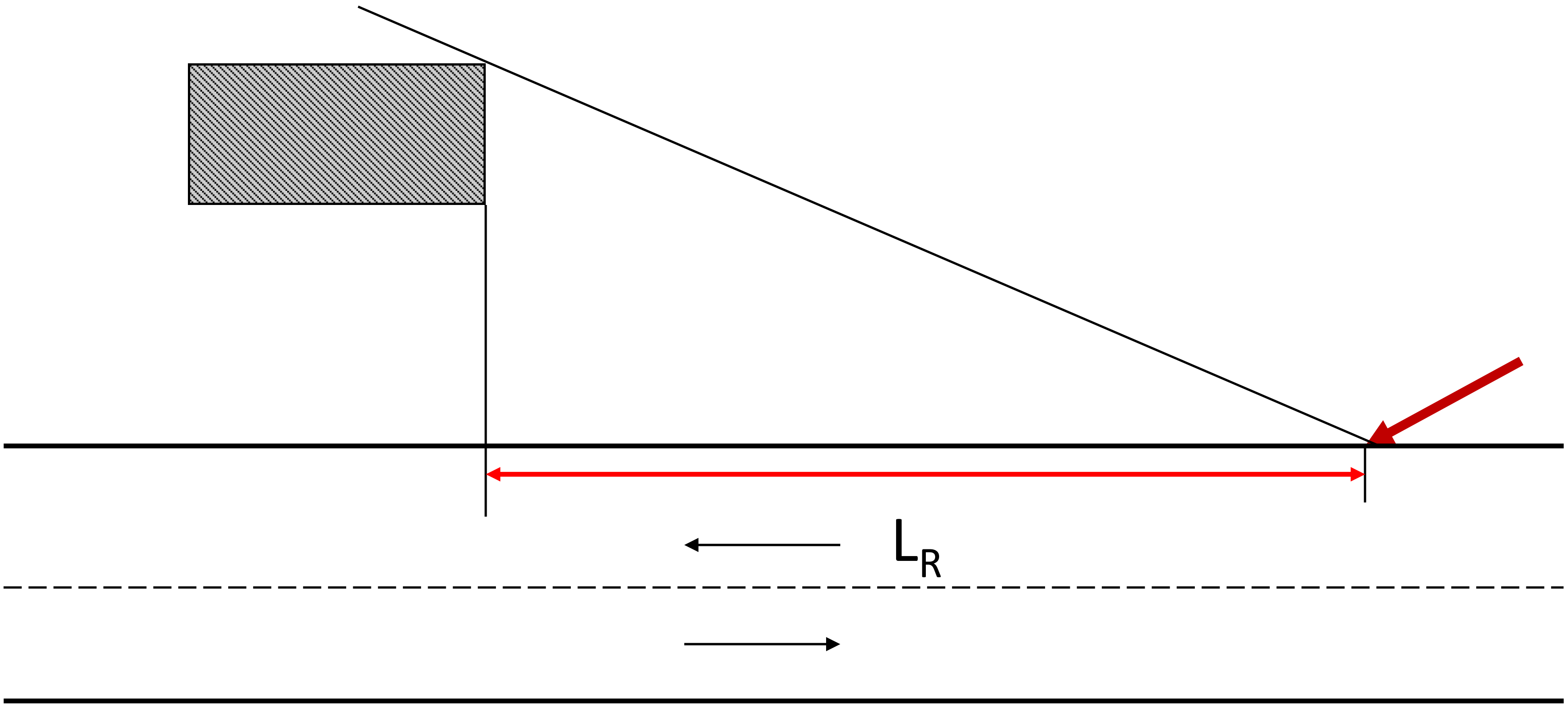
# Energy–Absorbing terminal on a curve

Energy-Absorbing terminals must be installed in a straight line over the length of the terminal proper. This may require the barrier to be extended in advance of the curve.

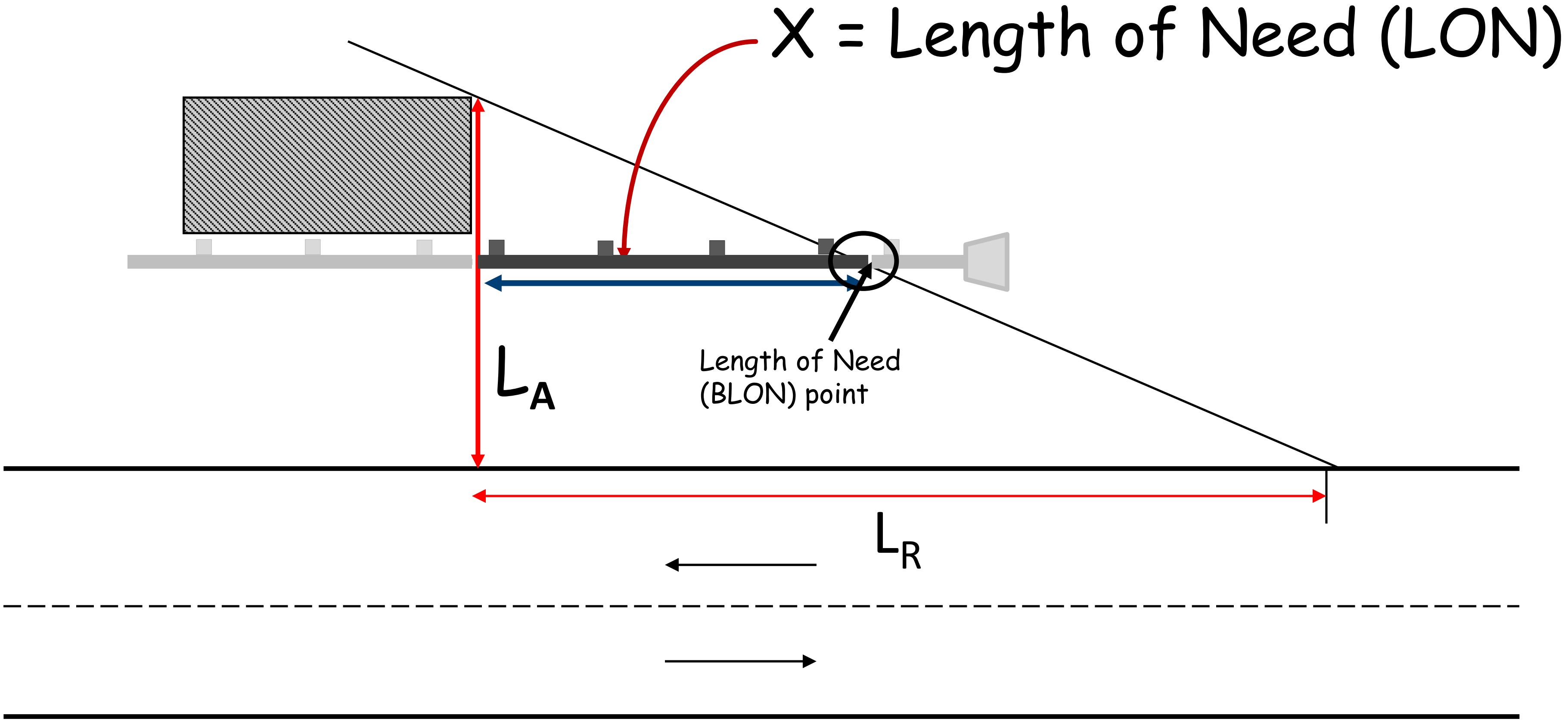
# Step 1: Identify the Hazard



# Step 2: Define the Point of Departure



# Step 3: Intersect the Hypotenuse



# Length of Need – Adequate?

# Length of Need – Adequate?

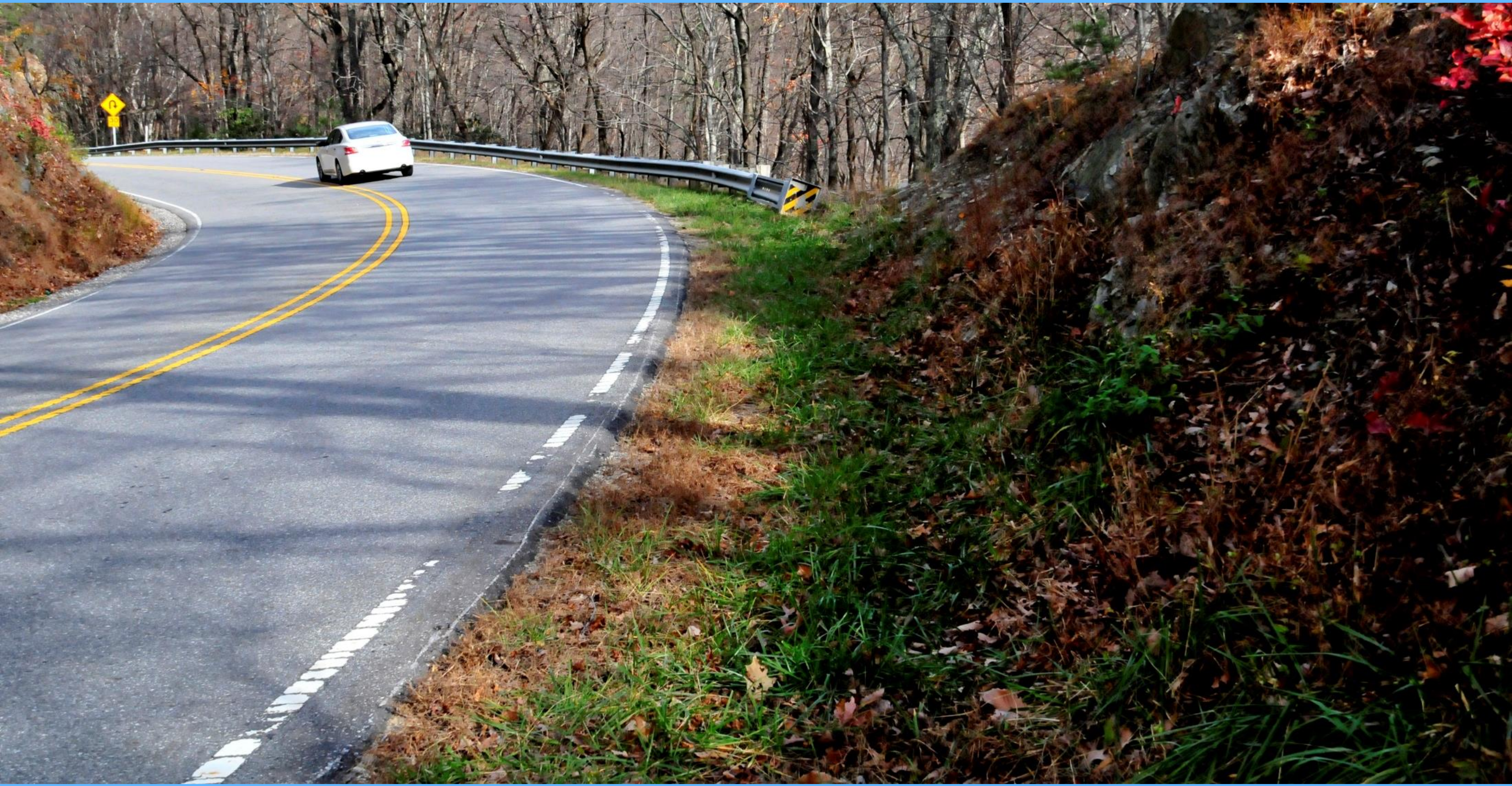
# Length of Need – Adequate?

# Length of Need – Adequate?

# Length of Need – Adequate?


PRE-ASSESSMENT PHOTO

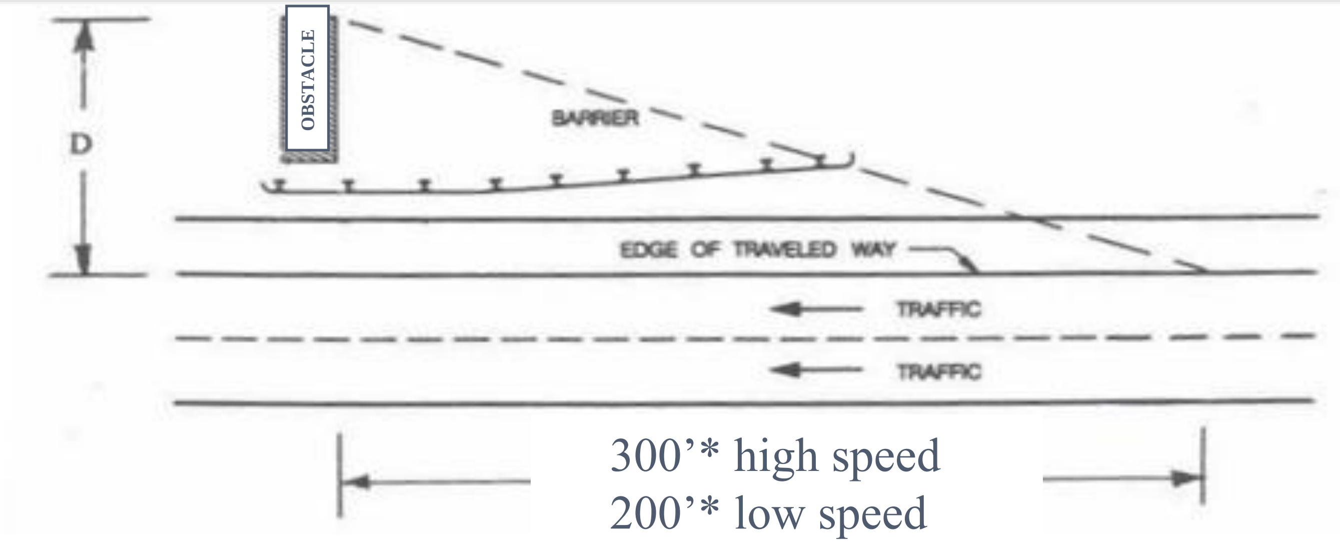
# Length of Need – Adequate?



# Quick Field Check of LON

1. Stand on roadway edgeline opposite the upstream edge of the hazard.
2. Pace upstream along edgeline appropriate runout length (based on speed of roadway and traffic volume).
3. Turn and look at far lateral edge of hazard.
4. If planned (or existing) guardrail run intercepts this line of sight, it satisfies basic design length of need.
5. Check for ALL hazards that should be shielded in this area
6. Check for better terminal location by extending barrier a short distance (especially on curves!!!)

# Length of Need Field Check

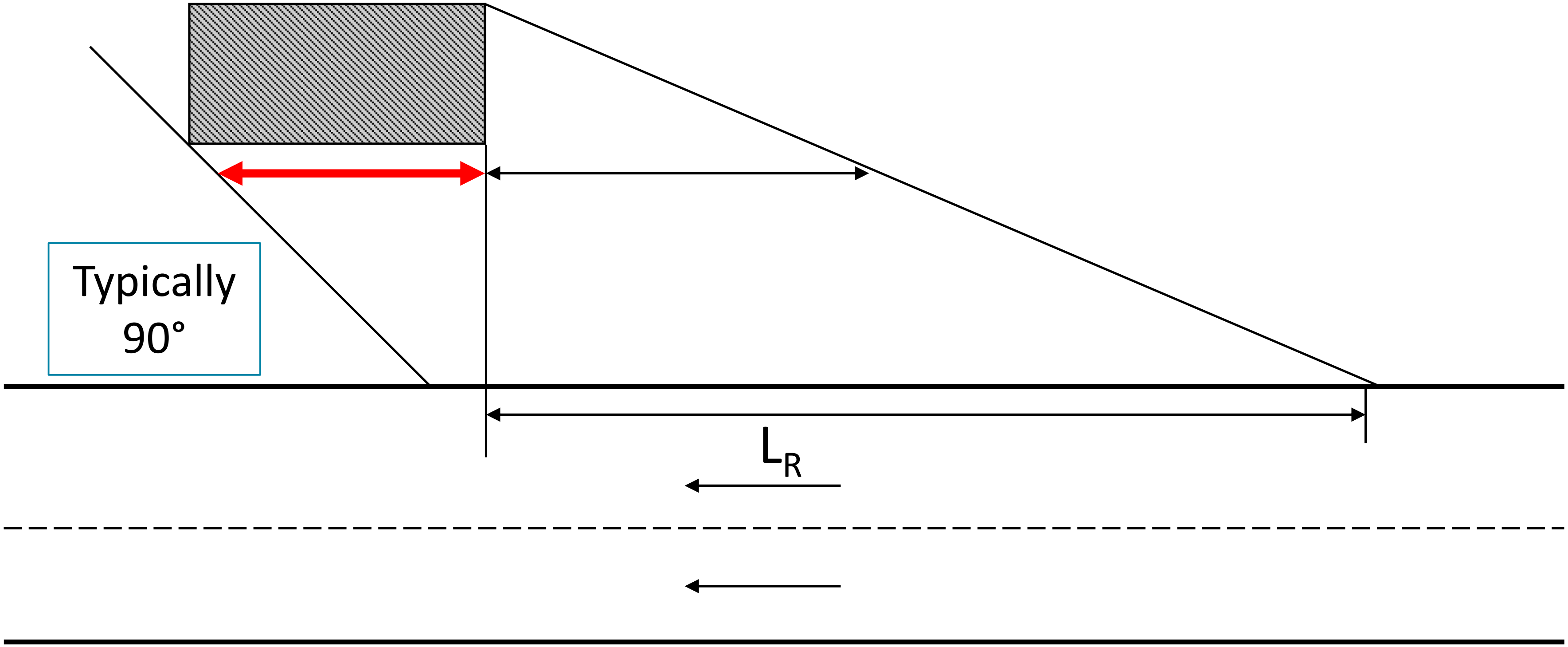



Procedure

- Identify upstream face of hazard
- Identify back of hazard D – limit to 30'
- Walk upstream along the white edge line, beginning at the upstream side of the hazard, 300'* for high speed, or 200'* for low speed (45 mph or less)
- Sight from this position to the upstream face, back edge of hazard (limited to 30')
- End of terminal should intercept line of sight (± ≈30')

# Downstream Termination One Direction Traffic

An anchor (CAT-1) plus 25’ of rail must be ADDED at the end



# Guardrail Placement

Place as far from traffic as practical

(without affecting performance)

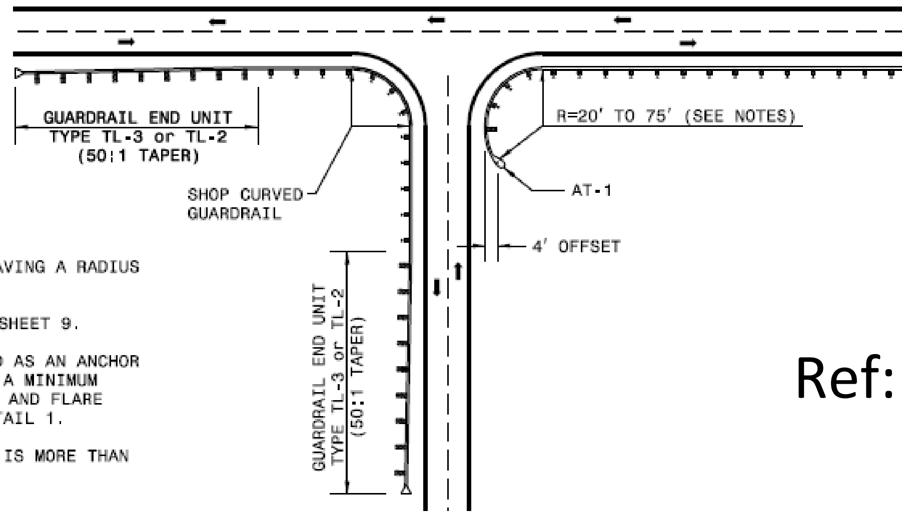
# Guardrail Placement in Special Situations

- Guardrail Placement at Intersections
- Long Span (Omitted Post{s})
- Gaps between runs of barrier
- Extra Offset Blocks
- Leaveouts for Posts in Structural Pavement
- Guardrail Post in Rock

# Guardrail Placement at Intersections


HWY 221

# Guardrail Placement at Intersections




**DETAIL-1**

NOTES:

SHOP CURVED GUARDRAIL IS DEFINED AS HAVING A RADIUS OF 150′ OR LESS.

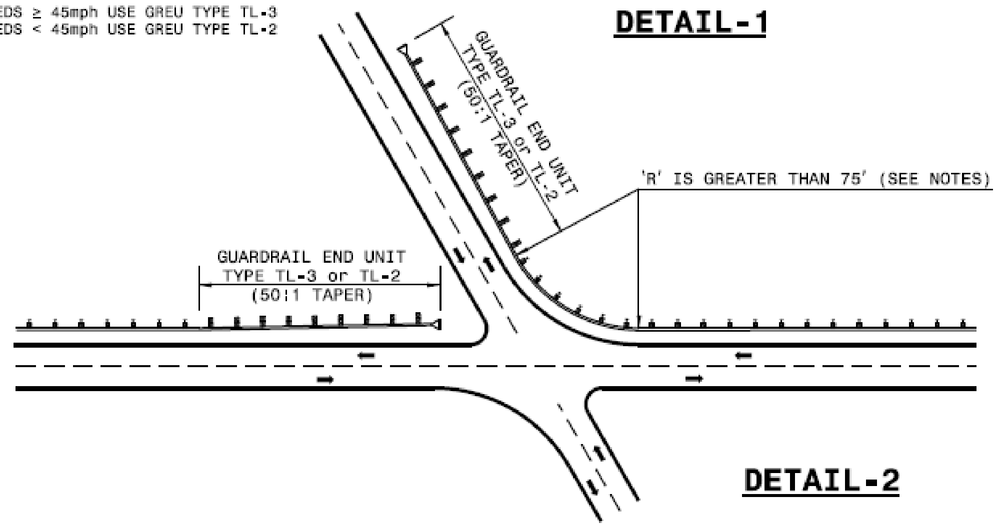
WHEN RADIUS IS LESS THAN 20′ REFER TO SHEET 9.

WHENEVER SHOP CURVED GUARDRAIL IS USED AS AN ANCHOR AND THE RADIUS IS FROM 20′ TO 75′, USE A MINIMUM LENGTH OF 50′ OF SHOP CURVED GUARDRAIL AND FLARE WITH AN AT-1 ANCHOR UNIT. REFER TO DETAIL 1.

WHENEVER SHOP CURVED GUARDRAIL RADIUS IS MORE THAN 75′, REFER TO DETAIL 2.

MAINTAIN CLEAR SIGHT DISTANCE.

FOR POSTED SPEEDS ≥ 45mph USE GREU TYPE TL-3
FOR POSTED SPEEDS < 45mph USE GREU TYPE TL-2

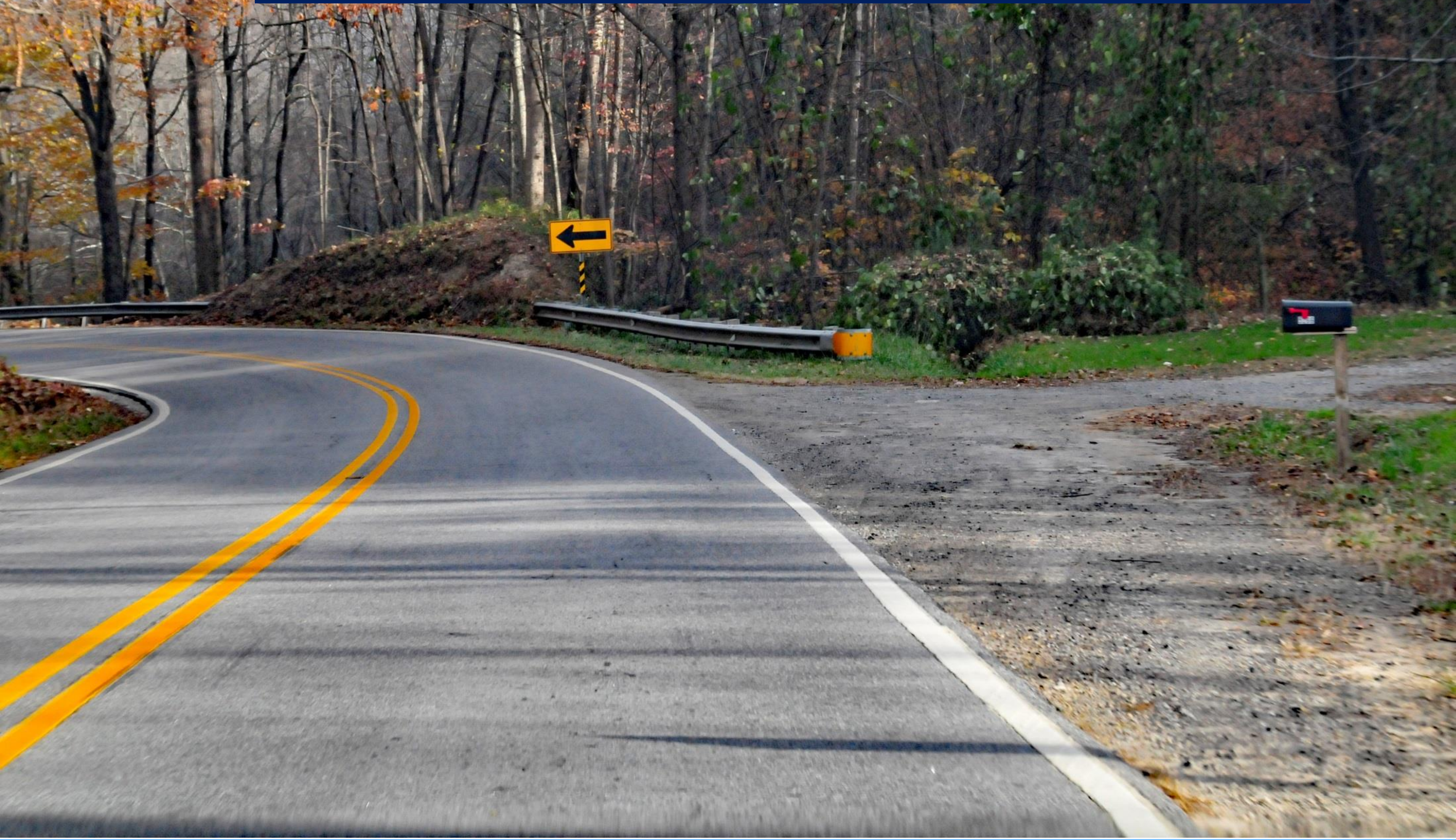



**DETAIL-2**

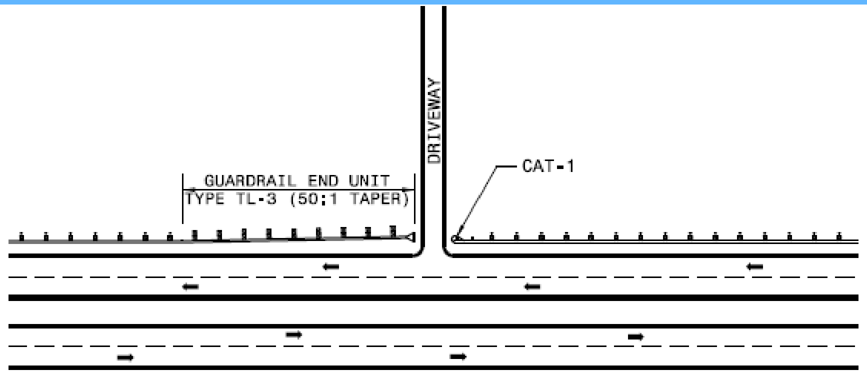
**GUARDRAIL TREATMENT AT INTERSECTIONS**

Ref: NCDOT Standard 862.01, Sht 8

# PRE-ASSESSMENT PHOTO



# Guardrail Placement at Driveways

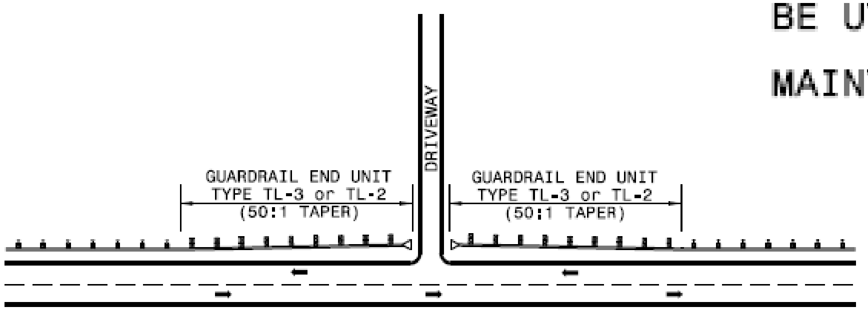



**DETAIL-3**
DIVIDED HIGHWAY

Ref: NCDOT Standard 862.01, Sht 9

NOTE: USE DETAIL 3 & 4 WHENEVER 20′ OR LARGER RADIUS CANNOT BE UTILIZED.

MAINTAIN CLEAR SIGHT DISTANCE.

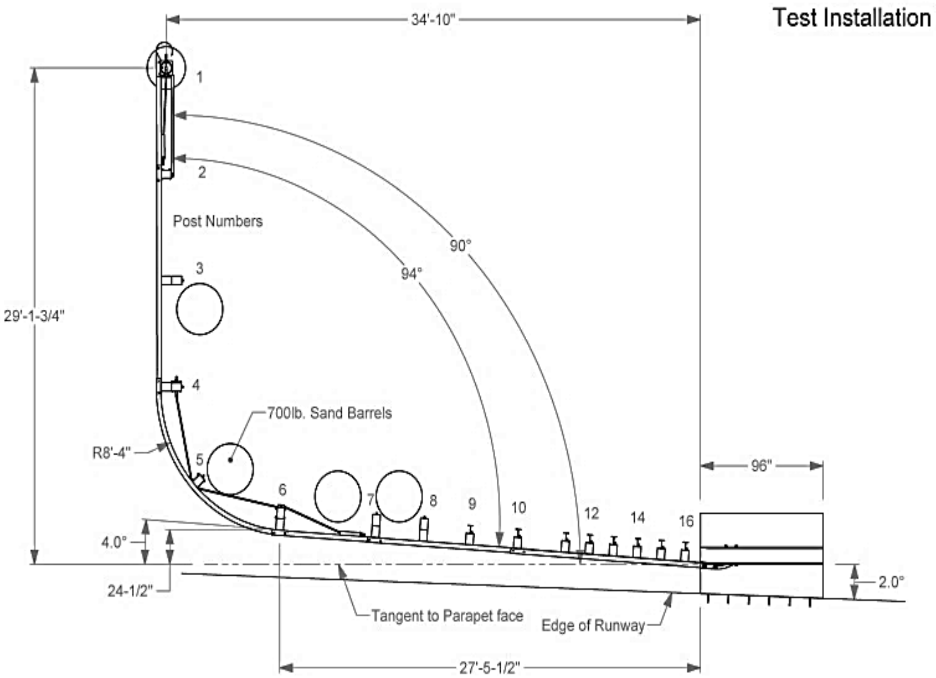



**DETAIL-4**
UNDIVIDED HIGHWAY

**GUARDRAIL TREATMENT AT DRIVEWAYS**


14-1
55

# TxDOT MASH TL-3 Short Radius



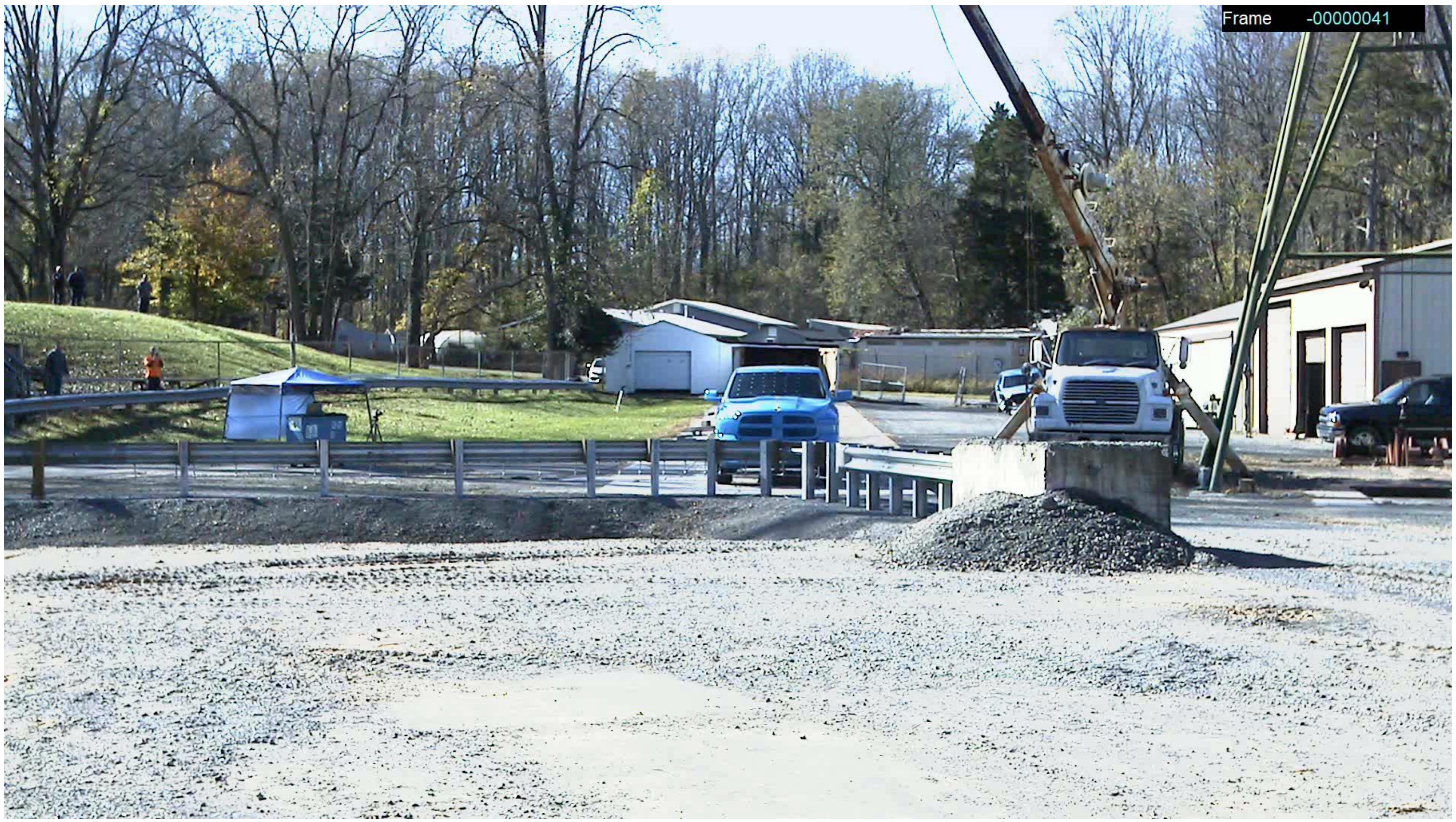

On-going Research by Pool Fund – No Eligibility Letter

# TxDOT MASH TL-3 Short Radius


NCDOT Investigating further developments

# MASH TL-3 Short Radius - NCHRP

# Test 3-33 on a 2:1 Slope at **50 mph** <u>ONLY</u>

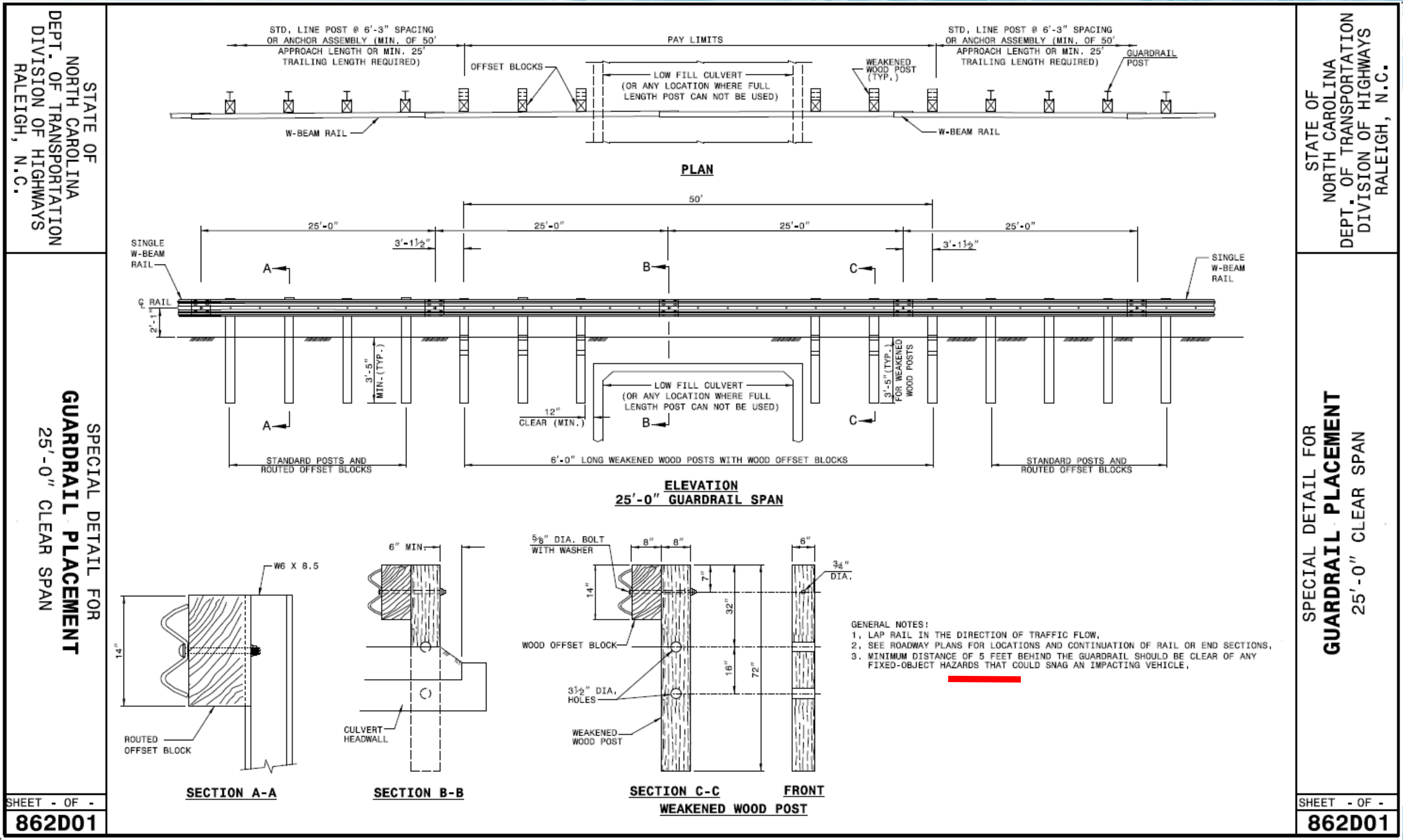


# Omitting posts – old 29" guardrail

# 31” – Omitting 3 posts

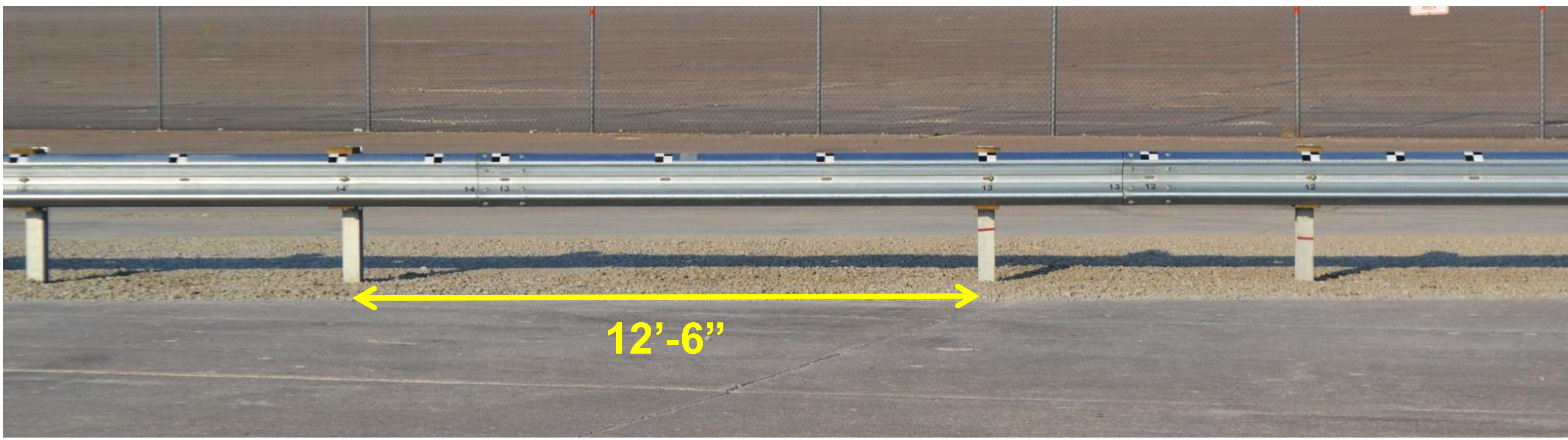
Working Width – 94”
Eligibility Letter B-189

# 31" – Omitting 3 posts

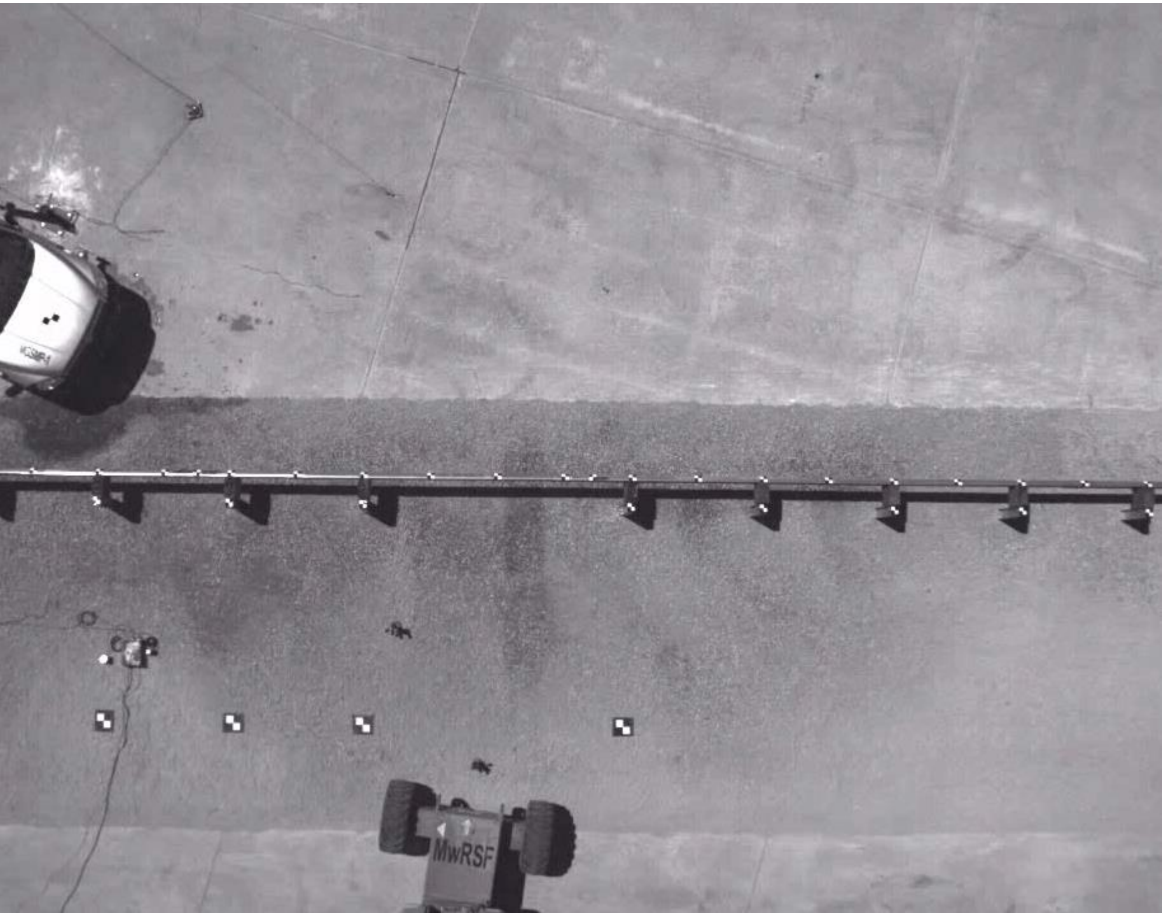


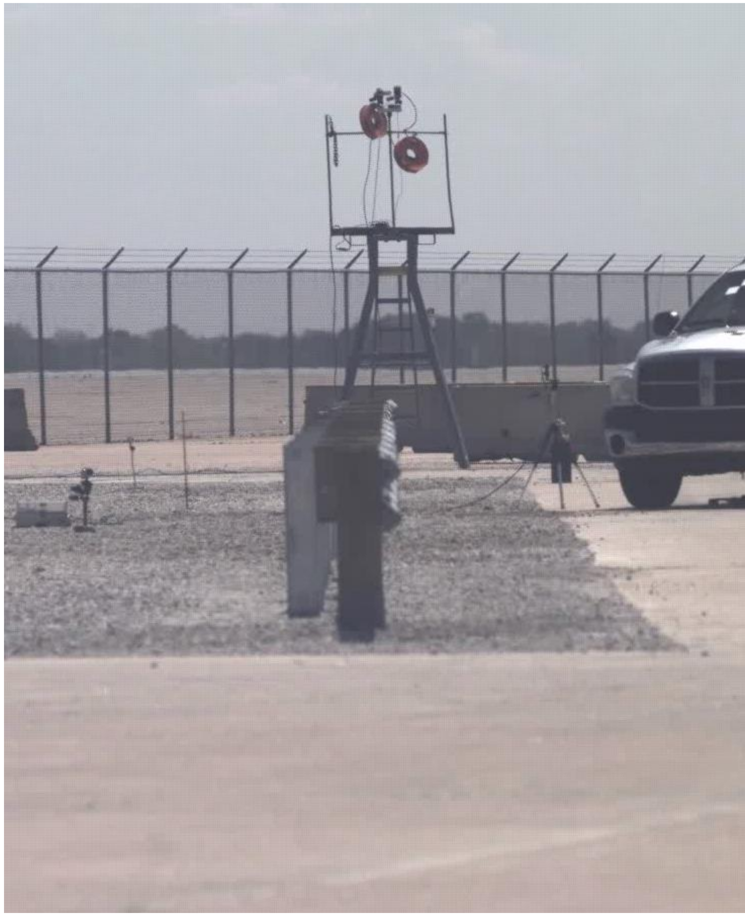
# MGS - Omitting 1 post – Future??

- No post modifications
- Can be used with wood or steel posts
- Can be used with 8” and 12” blockouts but not with the non-blocked system



# MGS - Omitting 1 post – Future??



Working Width 50.1”
Limit 1 per 50’

# Openings in Barriers

Check with maintenance, ROW, etc

# Openings in Barriers - NCDOT

Proposed – Same criteria (4.10.2.2)

ROADWAY DESIGN MANUAL PART 1

DETERMINING GUARDRAIL LENGTHS OF NEED 3-2

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

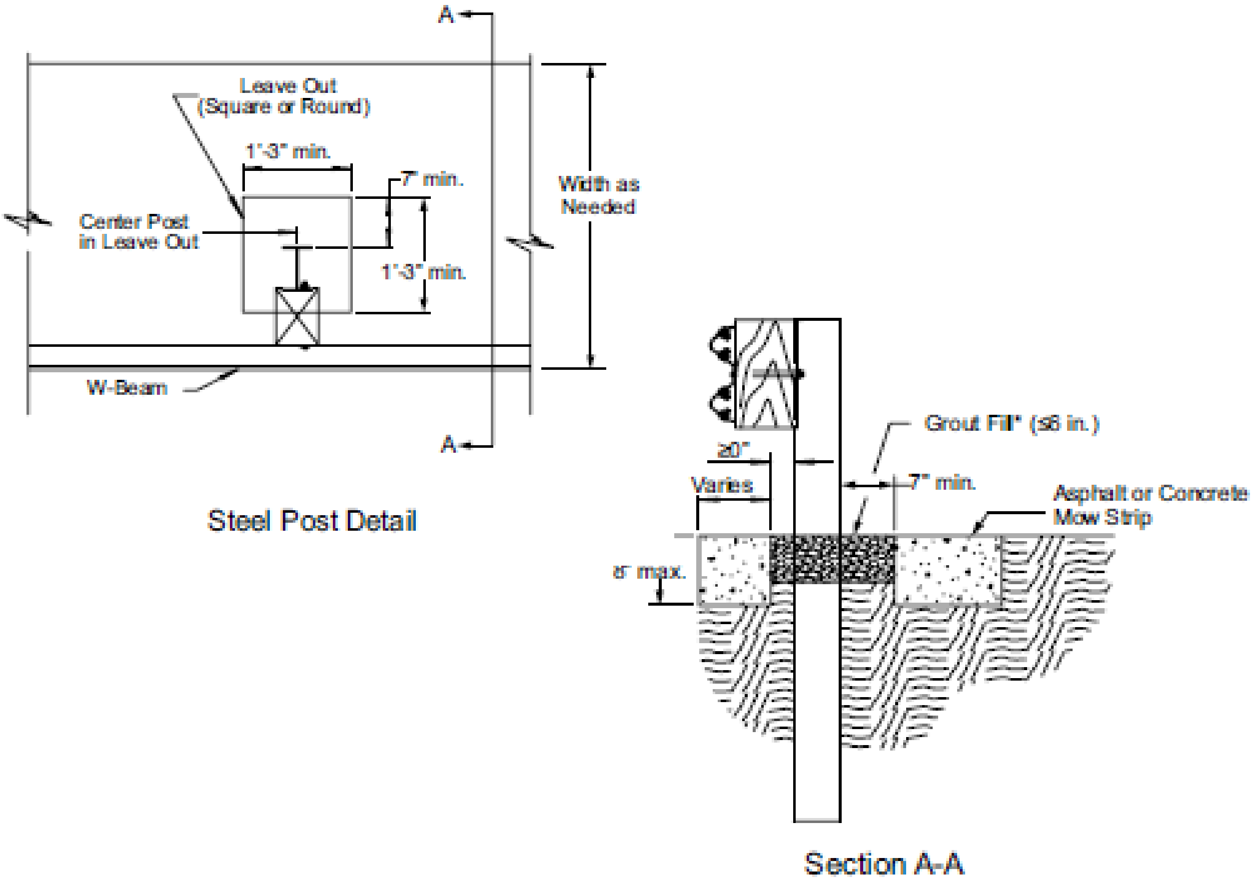
Again, be sure there are no conditions that would preclude closure

# Extra Offset Blocks – National Guidance

- Two Offset blocks (up to 16” deep) may be used at any time, for any number of posts.
- Three Offset blocks may be used at one or two posts in a section of guardrail.

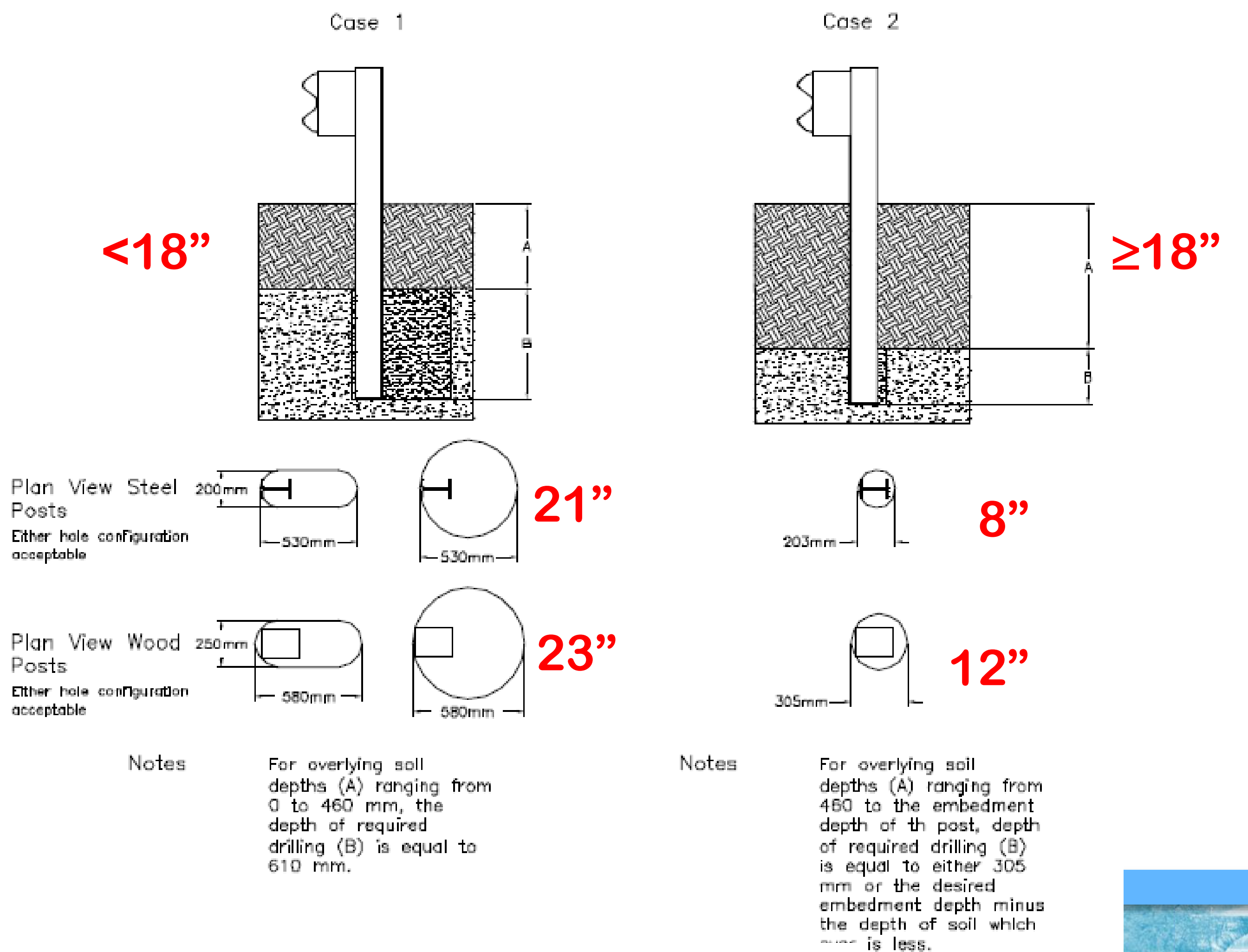
Ref: AASHTO Roadside Design Guide – 3rd Edition, Section 5.4.1.6

# Leaveouts in Structural Pavement




Ref: AASHTO Roadside Design Guide – 4th Edition, Figure 5-52

# Guardrail Posts in Rock AASHTO




Eligibility Letter B-64B

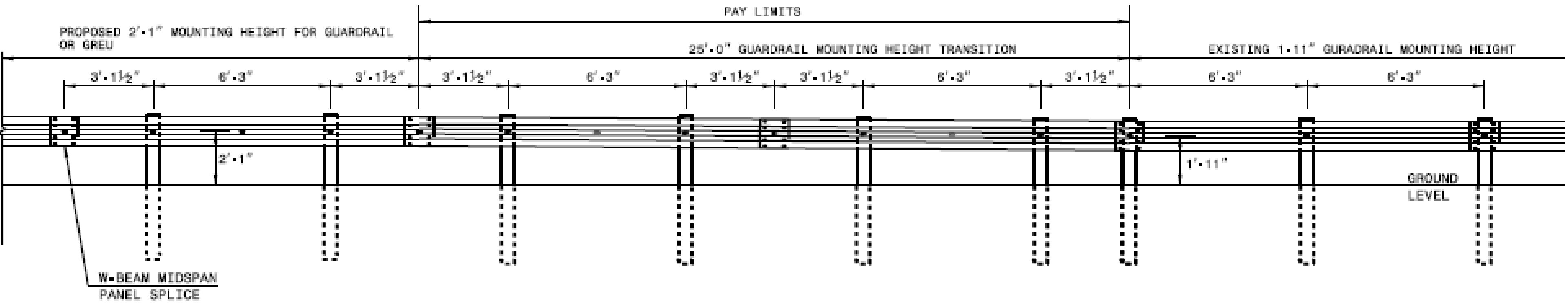
# Guardrail Posts in Rock - NCDOT

**SECTION 862**
**GUARDRAIL**

**862-3 CONSTRUCTION METHODS**

Where rock interferes with the proper installation of the post, excavate a shaft in the rock at least 9 inches wide, parallel to the roadway, by 23 inches long, perpendicular to the roadway and 24 inches deep. Place the post against the roadside edge of the shaft and fill in behind the post with Class VI select material, up to the top elevation of the rock. Fill the remainder of

# Height Transition – 31” to/from Old Guardrail

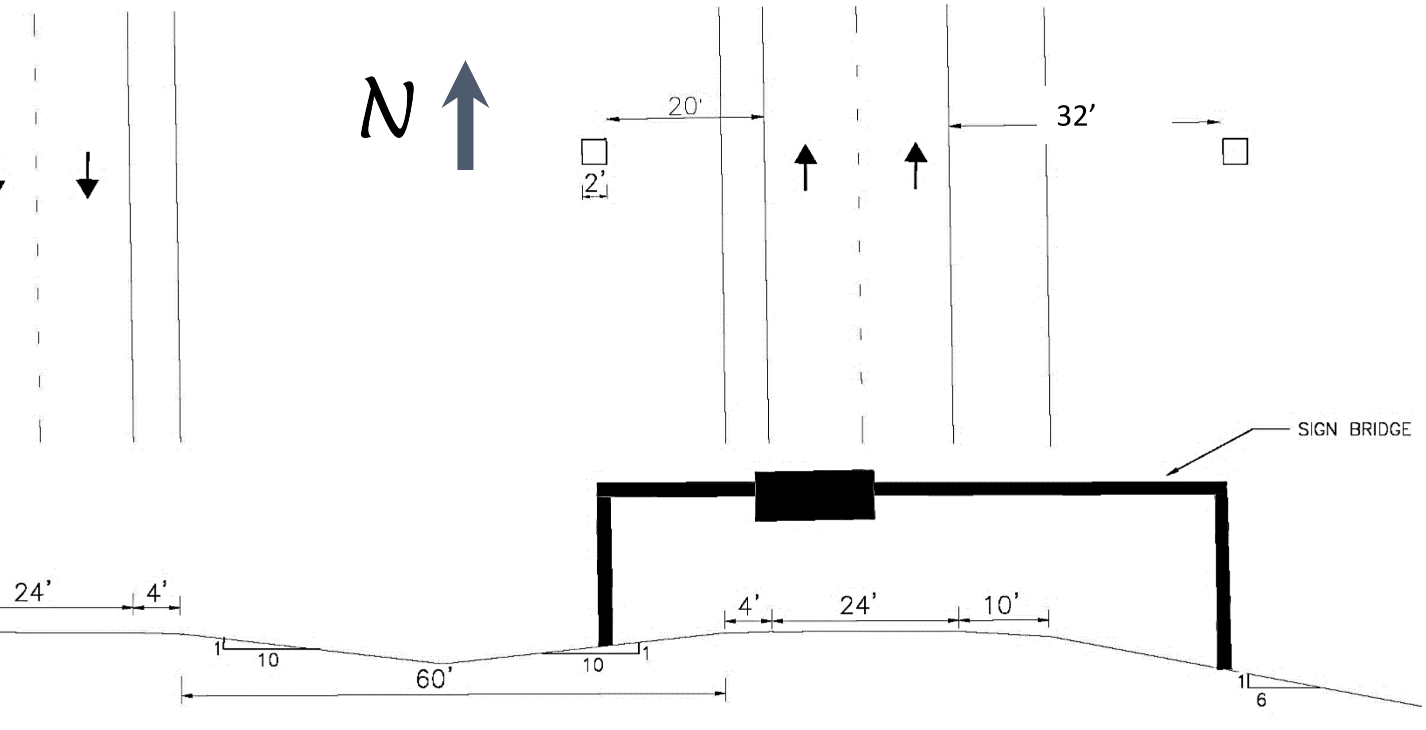



**ELEVATION VIEW**

**TRANSITION FROM OR 1′-11″ TO 2′-1″ W-BEAM GUARDRAIL MOUNTING HEIGHT**

| | | | |
|---|---|---|---|
| 862.02 | SHEET 4 OF 8 | ROADWAY STANDARD DRAWING FOR<br>**GUARDRAIL INSTALLATION** | 1-18<br>STATE OF<br>NORTH CAROLINA<br>DEPT. OF TRANSPORTATION<br>DIVISION OF HIGHWAYS<br>RALEIGH, N.C. |

# Design Workshop #1 - LON




Design speed: 70 mph

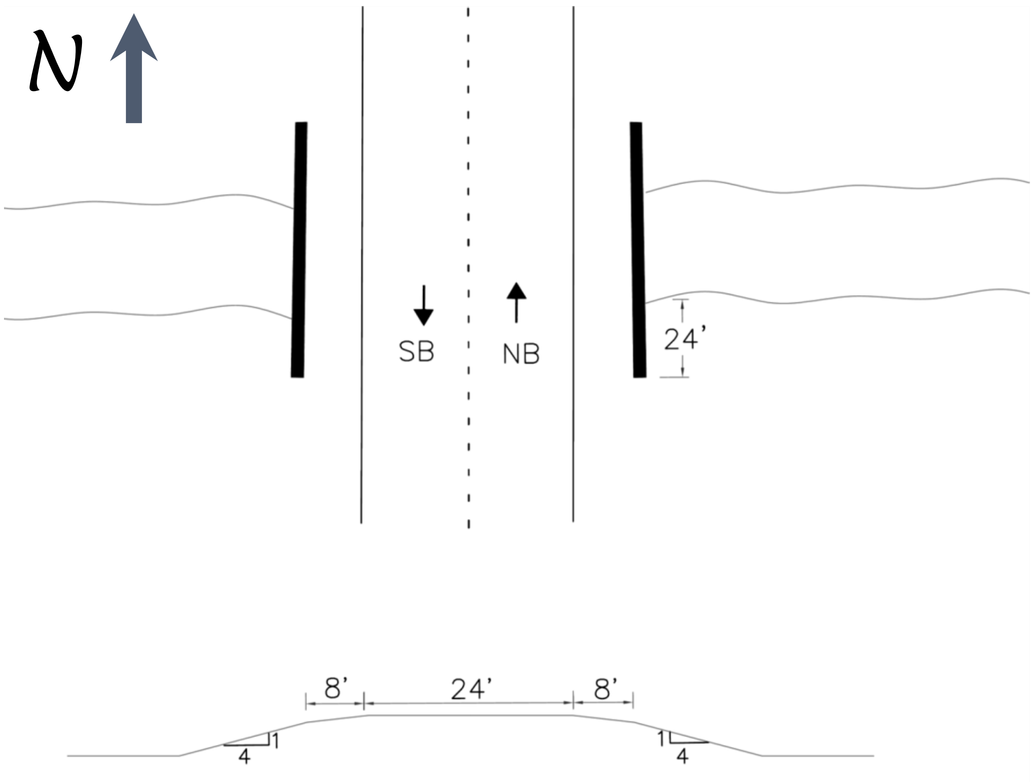
ADT: 53,000

Side slope:

10:1 Left, 6:1 Right

DETERMINE TREATMENTS FOR NB TRAFFIC

# Design Workshop #2: LON for Bridge on Rural Road




Bridge on Rural Road with Two-way Traffic

Design Speed 60 mph

AADT 2,250

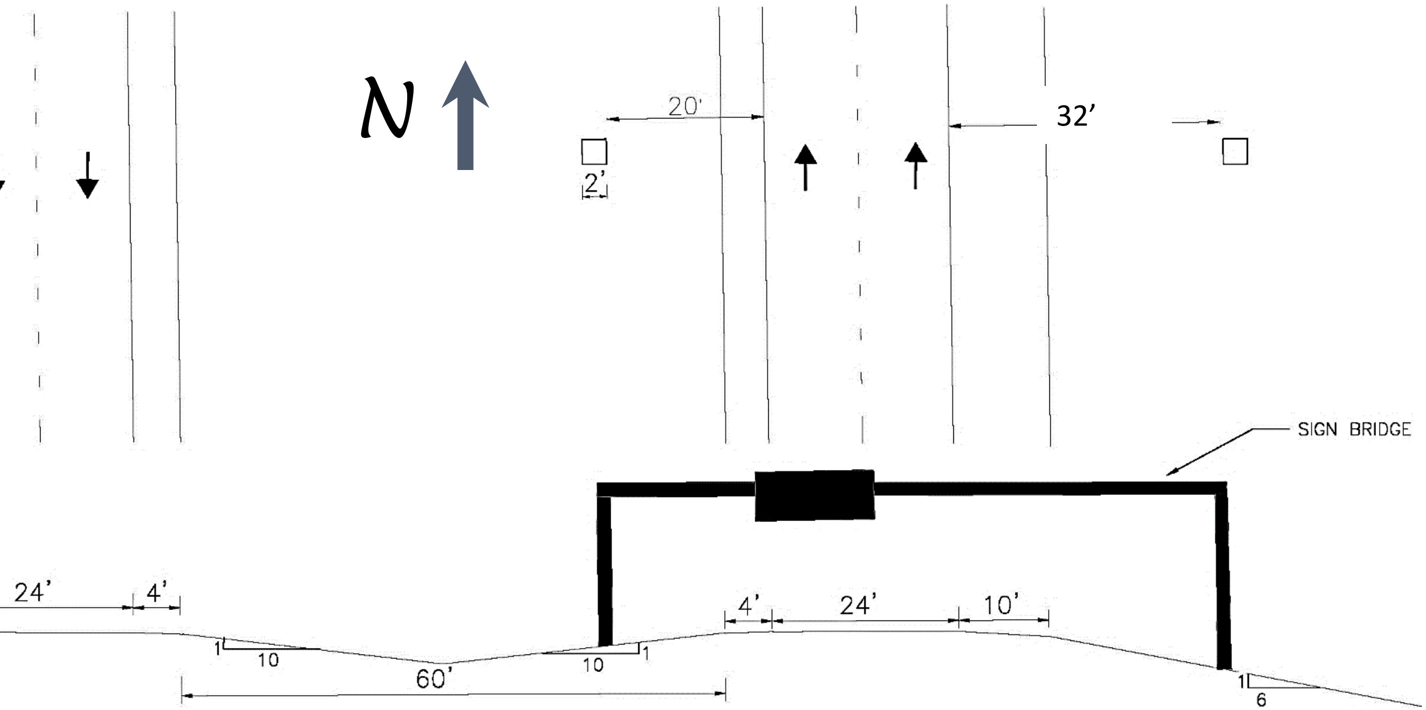
Lane width: 12 ft.

Shoulder width: 8 ft.

Side slope: 4:1

Design for both sides of road, NB

# Design Workshop #1 - LON




Design speed: 70 mph

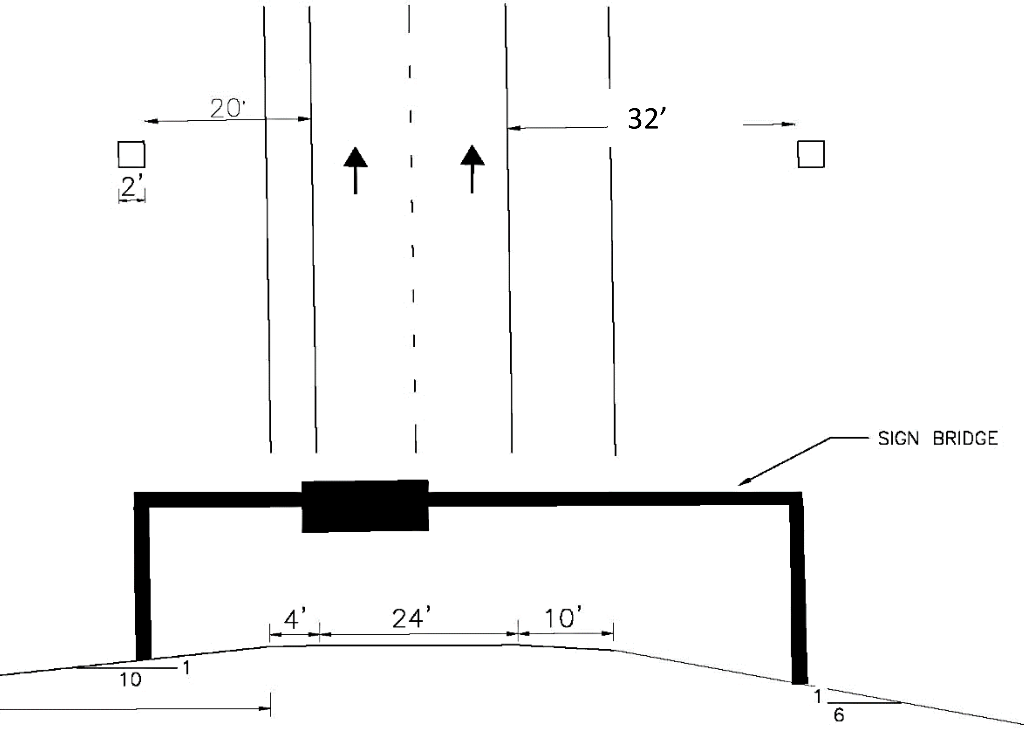
ADT: 53,000

Side slope:

10:1 Left, 6:1 Right

DETERMINE TREATMENTS FOR NB TRAFFIC

# Design Workshop #1 - LON




## Determine Design Clear Zone

The Clear Zone is a look up value from NCDOT Design Manual

Design speed: 70 mph

ADT: 53,000

Side slope: 10:1 or 6:1

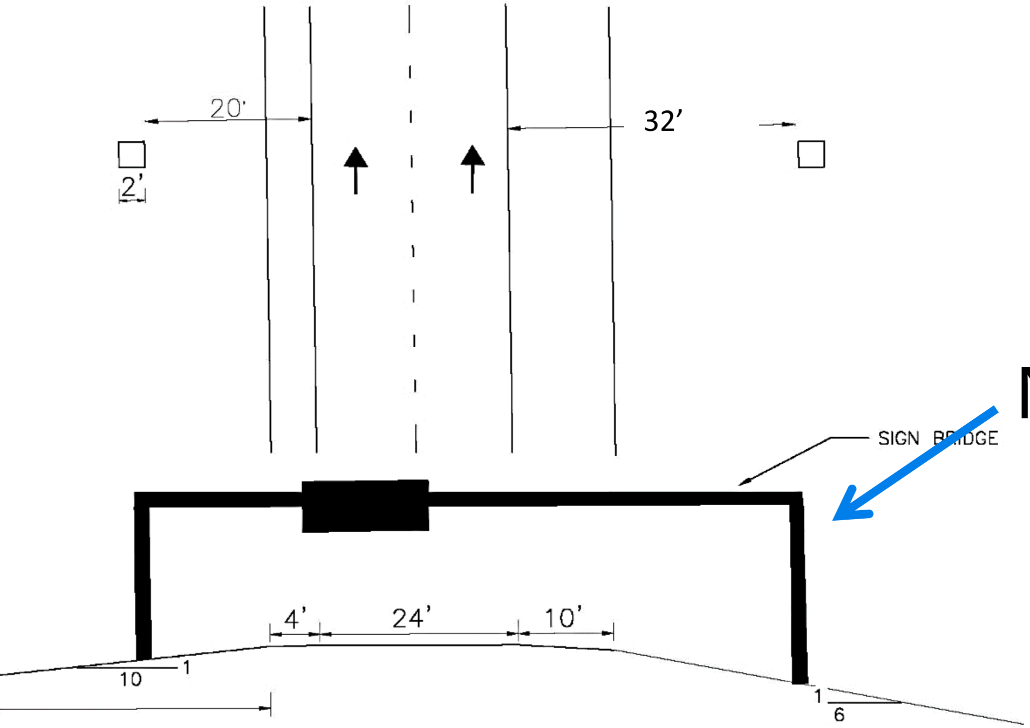
# Design Clear Zone Distance – Fill

| Design Speed (mph) | Design ADT | Foreslopes | | |
|---|---|---|---|---|
| | | 1V:6H or flatter | 1V:5H to 1V:4H | 1V:3H |
| 40 mph | UNDER 750 | 7-10 | 7-10 | b |
| | 750-1500 | 10-12 | 12-14 | b |
| | 1500-6000 | 12-14 | 14-16 | b |
| | OVER 6000 | 14-16 | 16-18 | b |
| 45-50 mph | UNDER 750 | 10-12 | 12-14 | b |
| | 750-1500 | 14-16 | 16-20 | b |
| | 1500-6000 | 16-18 | 20-26 | b |
| | OVER 6000 | 20-22 | 24-28 | b |
| 55 mph | UNDER 750 | 12-14 | 14-18 | b |
| | 750-1500 | 16-18 | 20-24 | b |
| | 1500-6000 | 20-22 | 24-30 | b |
| | OVER 6000 | 22-24 | 26-32[a] | b |
| 60 mph | UNDER 750 | 16-18 | 20-24 | b |
| | 750-1500 | 20-24 | 26-32[a] | b |
| | 1500-6000 | 26-30 | 32-40[a] | b |
| | OVER 6000 | 30-32[a] | 36-44[a] | b |
| 65-70 mph | UNDER 750 | 18-20 | 20-26 | b |
| | 750-1500 | 24-26 | 28-36[a] | b |
| | 1500-6000 | [illegible] | 34-42[a] | b |
| | OVER 6000 | 30-34[a] | 38-46[a] | b |

Design Speed 70 mph
AADT = 53,000

**LC = 32 ft.**

# Example – LON

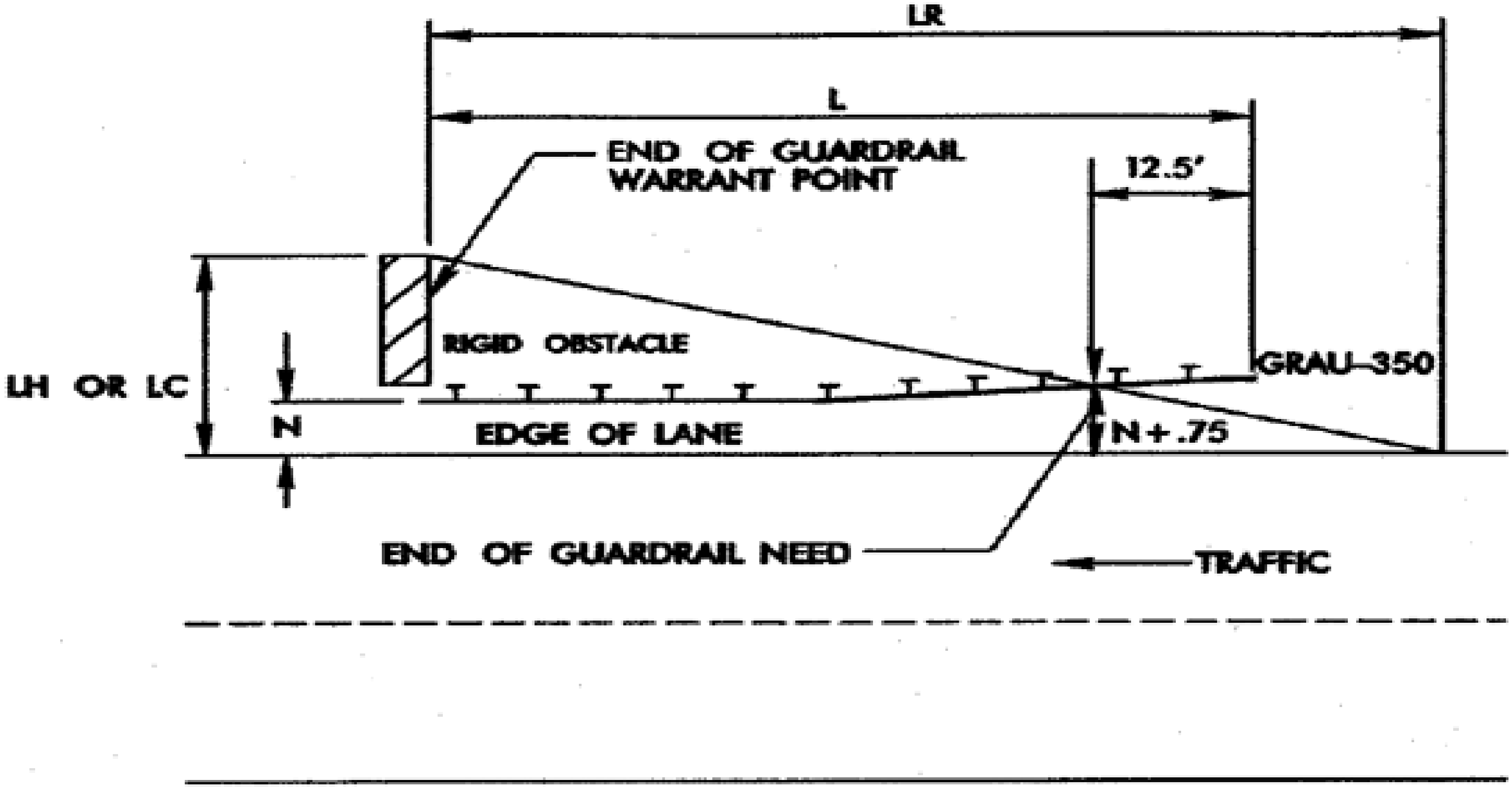



Identify ALL the hazards

NOT SHIELDED

Sign supports – both sides

# Calculating the Length of Need (L)

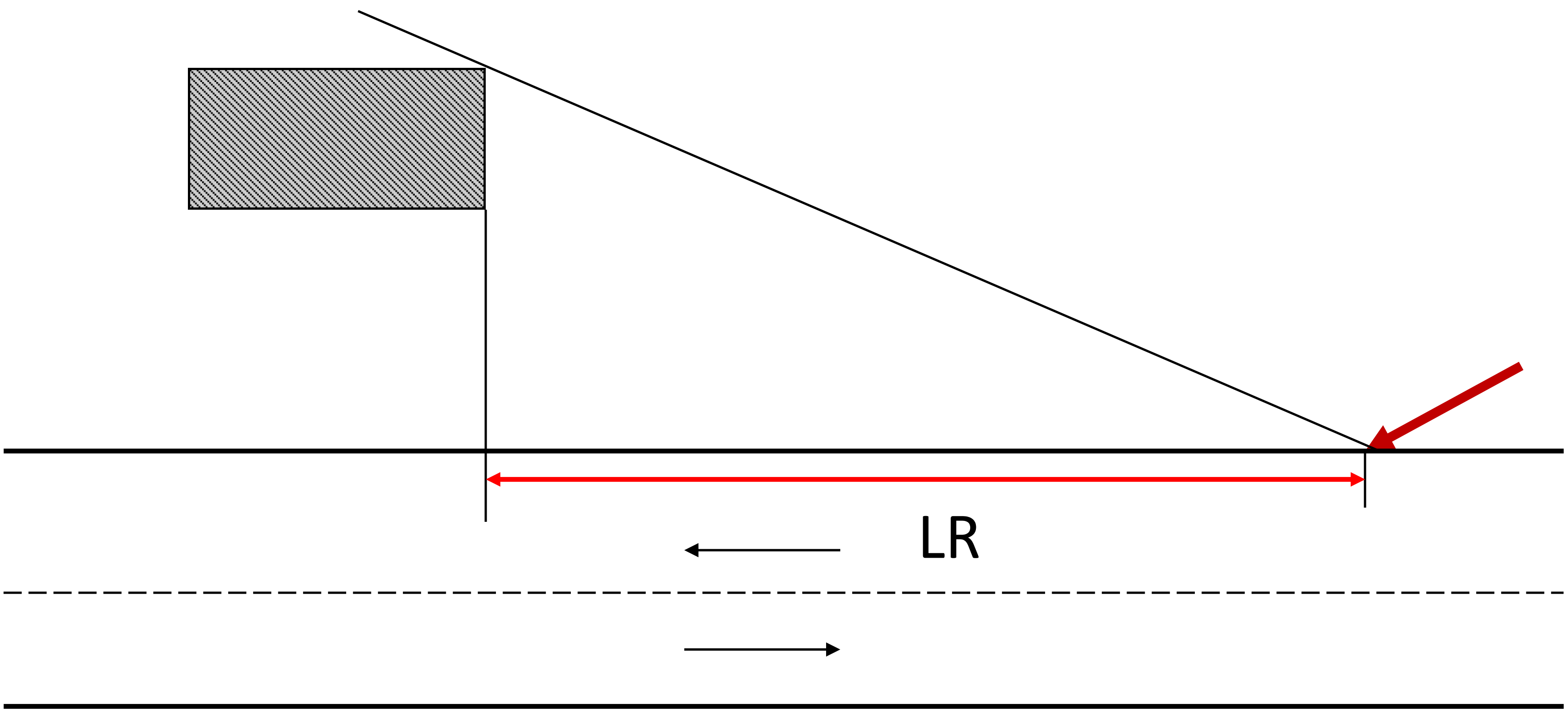


# Length of Need – NCDOT

- Calculating the length of need (L) for straight or nearly straight sections of roadway for parallel installation:

$$L = \frac{LH - N}{LH/LR}$$

# Step 2: Define the Point of Departure



# Look up LR:

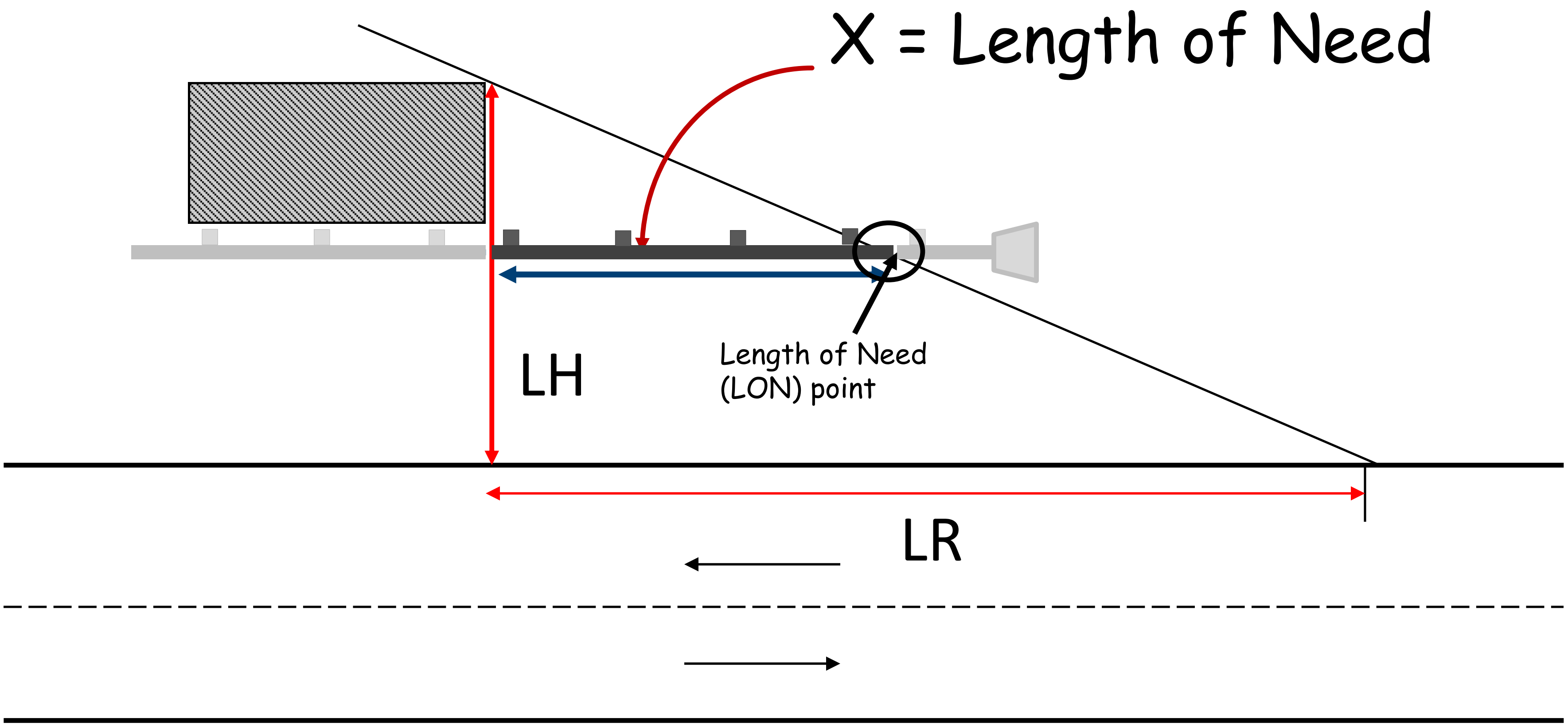
Design Speed 70 mph
AADT = 53,000

| Design Speed (mph) | Runout Length ($L_R$) Given Traffic Volume (ADT) (ft) | | | |
|---|---|---|---|---|
| | Over 10,000 | 5,000 to 10,000 | 1,000 to 5,000 | Under 1,000 |
| 80 | 470 | 430 | 380 | 330 |
| 70 | 360 | 330 | 290 | 250 |
| 60 | 300 | 250 | 210 | 200 |
| 50 | 230 | 190 | 160 | 150 |
| 40 | 160 | | 110 | 100 |
| 30 | 110 | 90 | 80 | 70 |

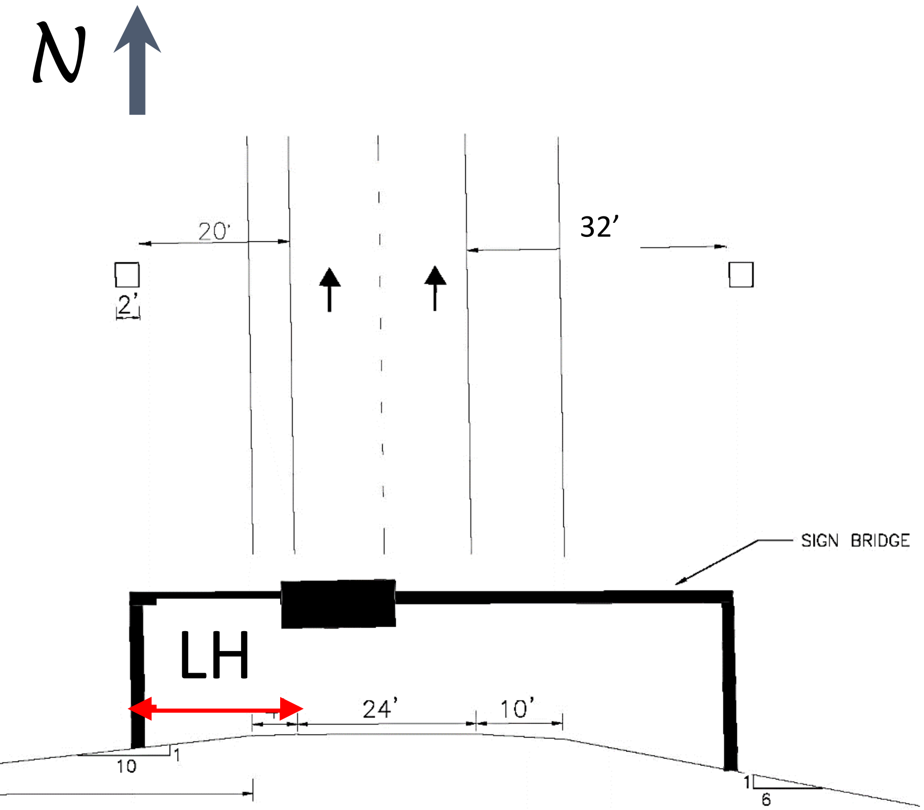
**LR = 360 ft.**

AASHTO Runout Lengths – LR

# Step 3: Intersect the Hypotenuse



# Example – LON

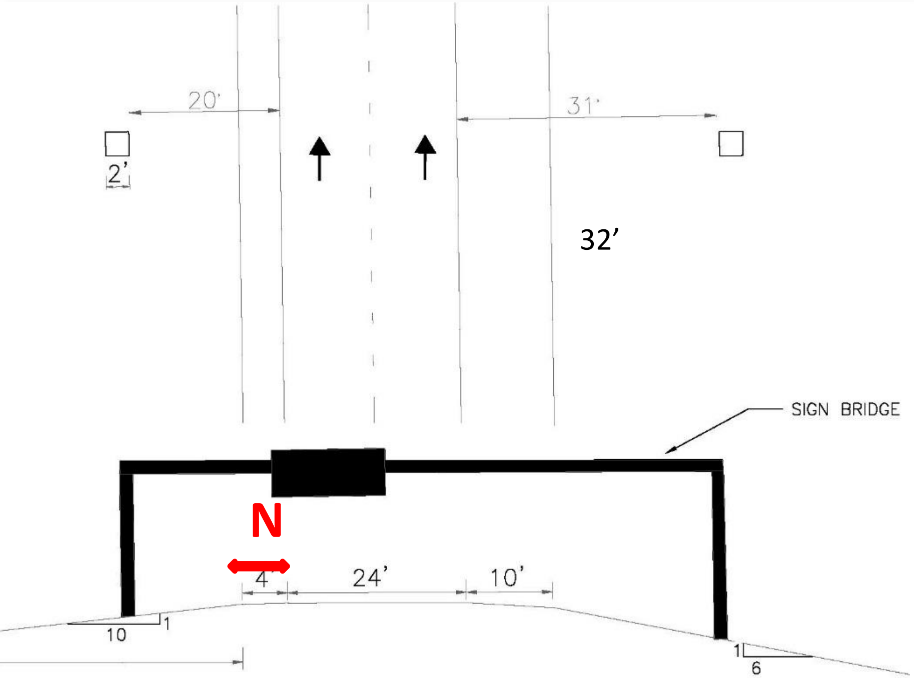



Determine LH – distance to the backside of hazard

For the back of the sign support:

LH = 20 + 2 = 22'

# Find N

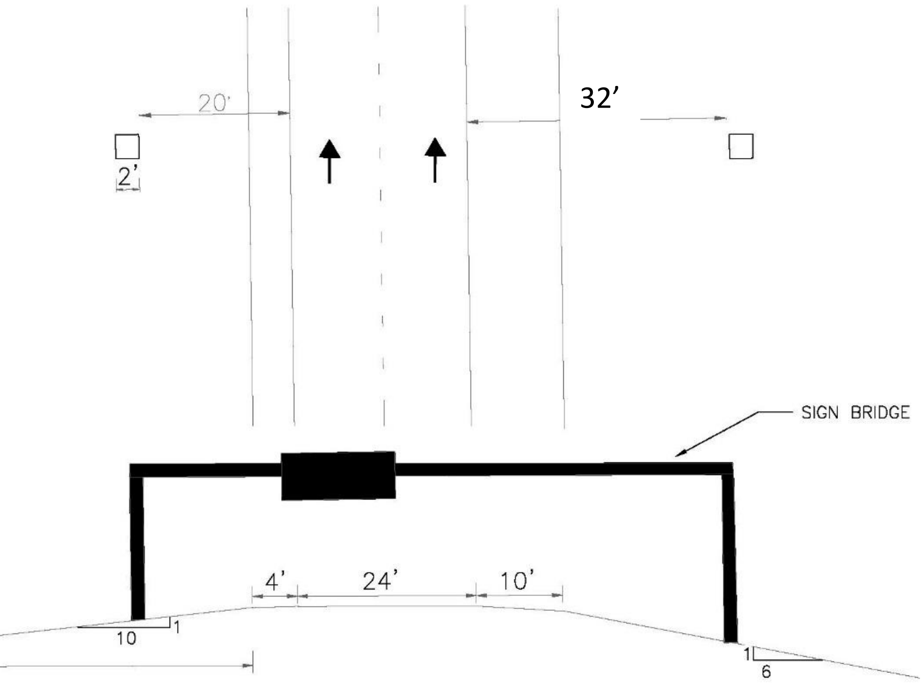



N – Guardrail offset from edge of travel lane.

N = 6 ft.

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

# Calculate LON – Determine Bid Item




LH = 22 ft N = 6 ft LR = 360

Using the formula L =

$$L = \frac{LH - N}{LH/LR}$$

$$= \frac{22 - 6}{22/360}$$

$$= 262 \text{ ft.}$$

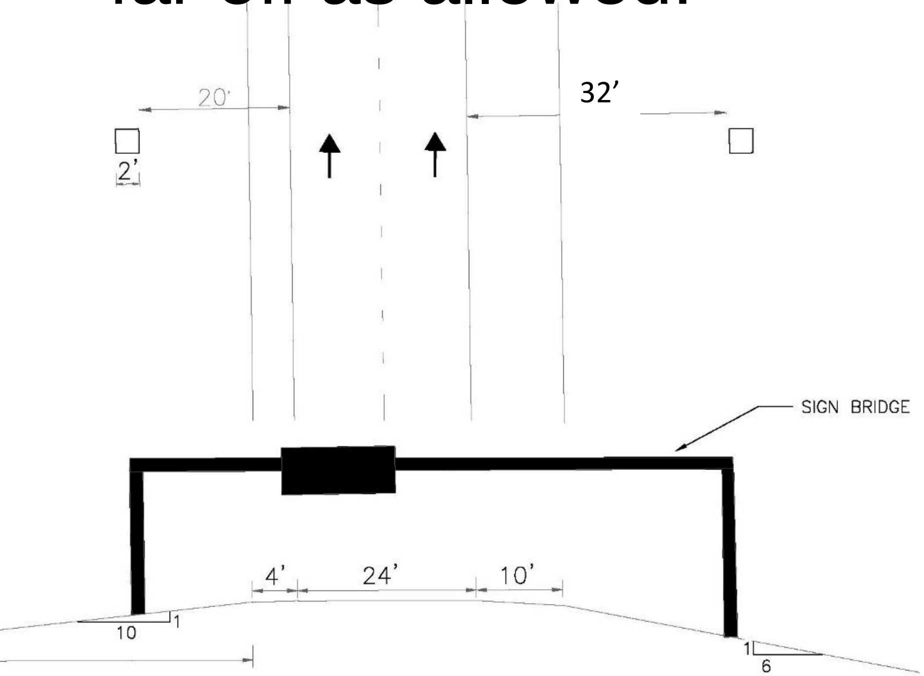
Does **NOT** include Terminal: GREU (50±')

Add 2' for length of hazard; add 25' for CAT-1 effectiveness; convert to panel lengths by dividing by 12.5, rounding up to whole number, and multiplying by 12.5

A CAT-1 must be added

# Calculate LON – Additional Offset

If guardrail is placed as far off as allowed:




LH = 22 ft N = (20'-5.5') =14.5' LR = 360'

Using the formula L =

$$L = \frac{LH - N}{LH/LR}$$

$$= \frac{22 - 14.5}{22/360}$$

$$= 123 \text{ ft.}$$

A CAT-1 must be added

BIG savings by offsetting the barrier: 123' VS 262'

# Example – LON

## TALKING POINTS

What if the situation were a dual bridge? Normal design sets $L_A$ to $L_C$, in this case 32'; but if the designer chose to shield the ENTIRE opening, $L_A$ would be 64'(to the opposite bridge rail).

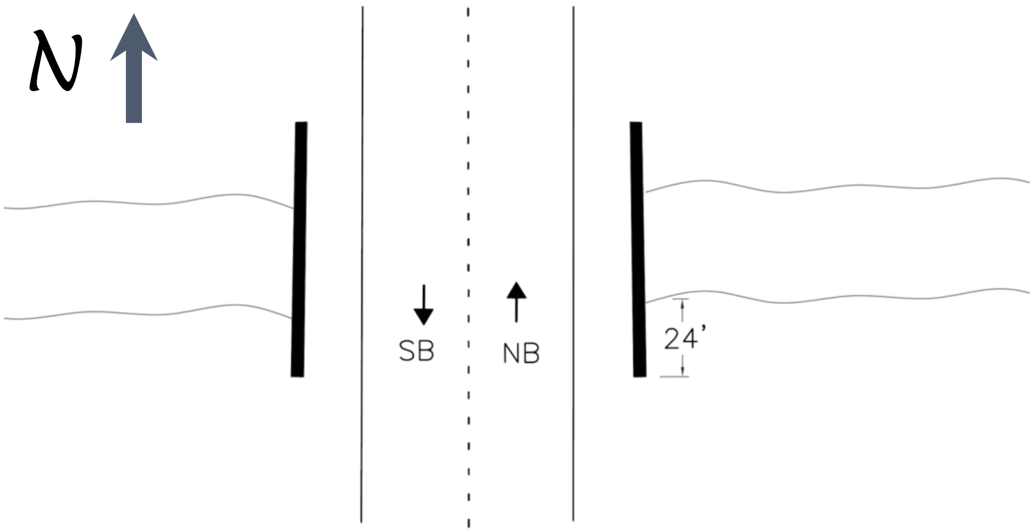
How much more barrier would that require?

Placing the barrier at the 6' offset and parallel, the two lengths are:

For $L_A$ = 32' (and $L_2$ = 6'), L = 293'

For $L_A$ = 64' (and $L_2$ = 6'), L = 326'

# Design Workshop #2: LON for Bridge on Rural Road




Bridge on Rural Road with Two-way Traffic

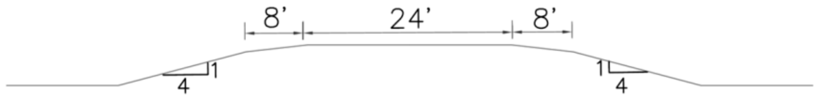
Design Speed 60 mph

AADT 2,250

Lane width: 12 ft.

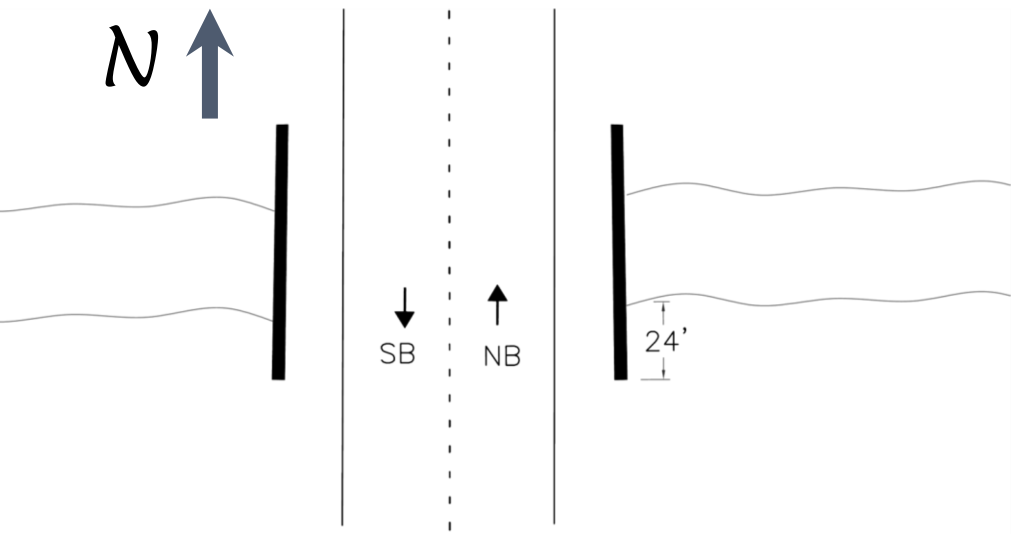
Shoulder width: 8 ft.

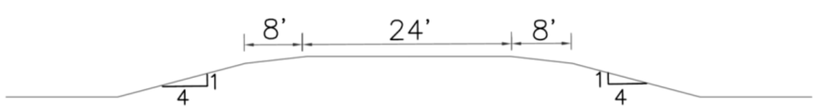
Side slope: 4:1




Design for both sides of road, NB

# Design Workshop #2: LON for Bridge on Rural Road




## Determine Design Clear Zone

The Clear Zone is a look up value from NCDOT Design Manual

Design speed: 60 mph

AADT: 1250

Side slope: 4:1

# Design Clear Zone Distance – Fill

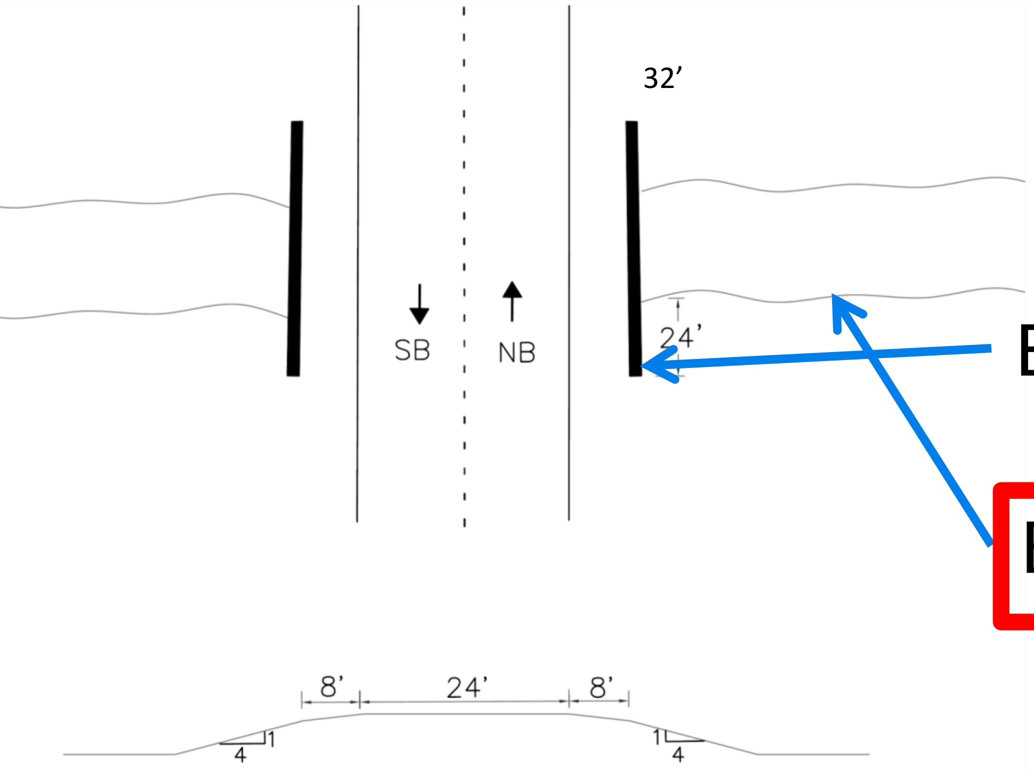
| Design Speed (mph) | Design ADT | Foreslopes | | |
|---|---|---|---|---|
| | | 1V:6H or flatter | 1V:5H to 1V:4H | 1V:3H |
| 40 mph | UNDER 750 | 7-10 | 7-10 | b |
| | 750-1500 | 10-12 | 12-14 | b |
| | 1500-6000 | 12-14 | 14-16 | b |
| | OVER 6000 | 14-16 | 16-18 | b |
| 45-50 mph | UNDER 750 | 10-12 | 12-14 | b |
| | 750-1500 | 14-16 | 16-20 | b |
| | 1500-6000 | 16-18 | 20-26 | b |
| | OVER 6000 | 20-22 | 24-28 | b |
| 55 mph | UNDER 750 | 12-14 | 14-18 | b |
| | 750-1500 | 16-18 | 20-24 | b |
| | 1500-6000 | 20-22 | 24-30 | b |
| | OVER 6000 | 22-24 | 26-32[a] | b |
| 60 mph | UNDER 750 | 16-18 | 20-24 | b |
| | 750-1500 | 20-24 | 26-32 | b |
| | 1500-6000 | 26-30 | 32-40[a] | b |
| | OVER 6000 | 30-32[a] | [illegible] | b |
| 65-70 mph | UNDER 750 | 18-20 | 20-26 | b |
| | 750-1500 | 24-26 | 28-36[a] | b |
| | 1500-6000 | 28-32[a] | 34-42[a] | b |
| | OVER 6000 | 30-34[a] | 38-46[a] | b |

Design Speed 60 mph
AADT = 2250

**LC = 32 ft.**

For Both Sides

# Example #2: LON for Bridge on Rural Road Near Side

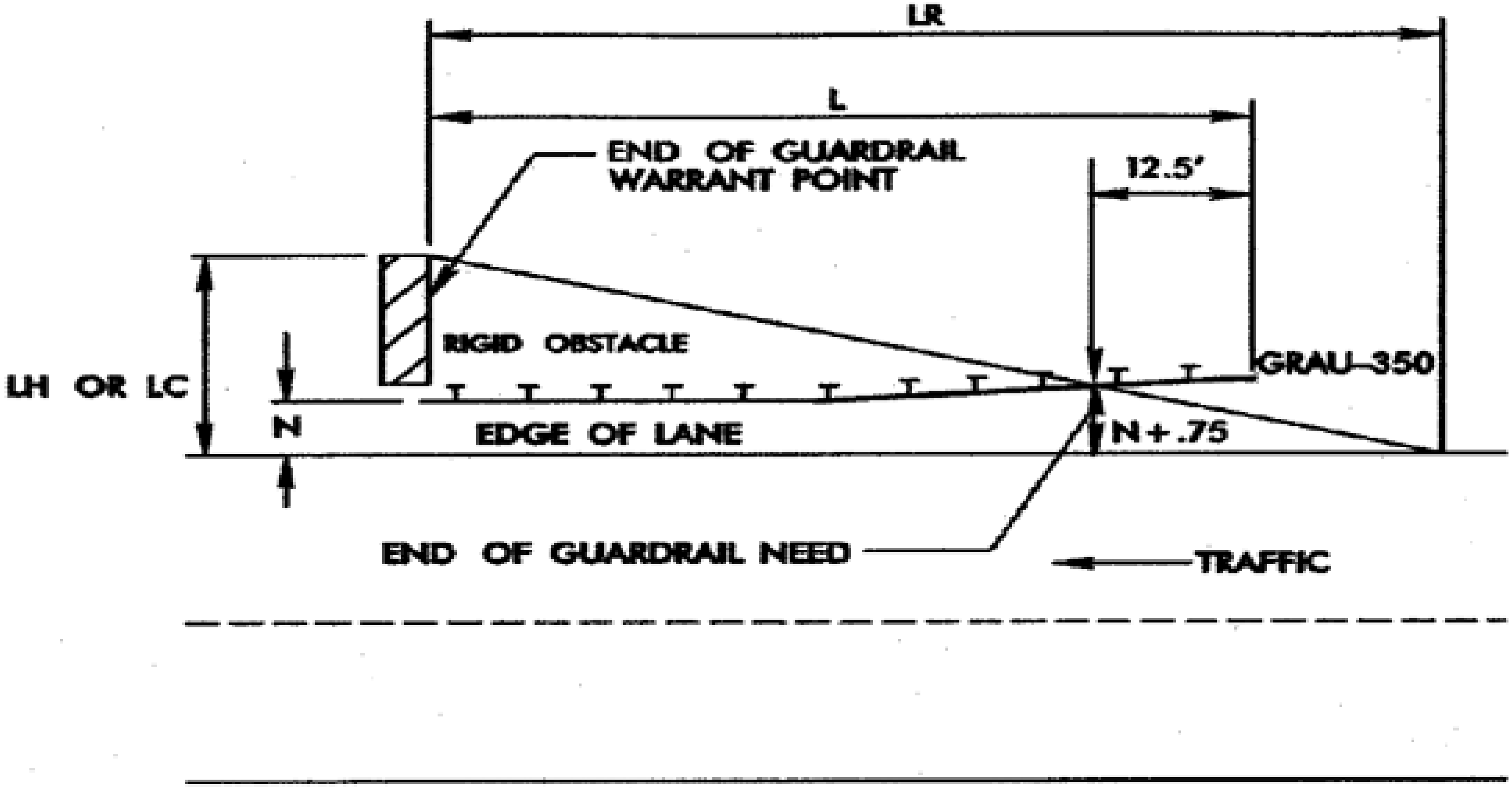



Identify ALL the hazards

End of the Bridge Parapet

Bank of the River

# Calculating the Length of Need (L)

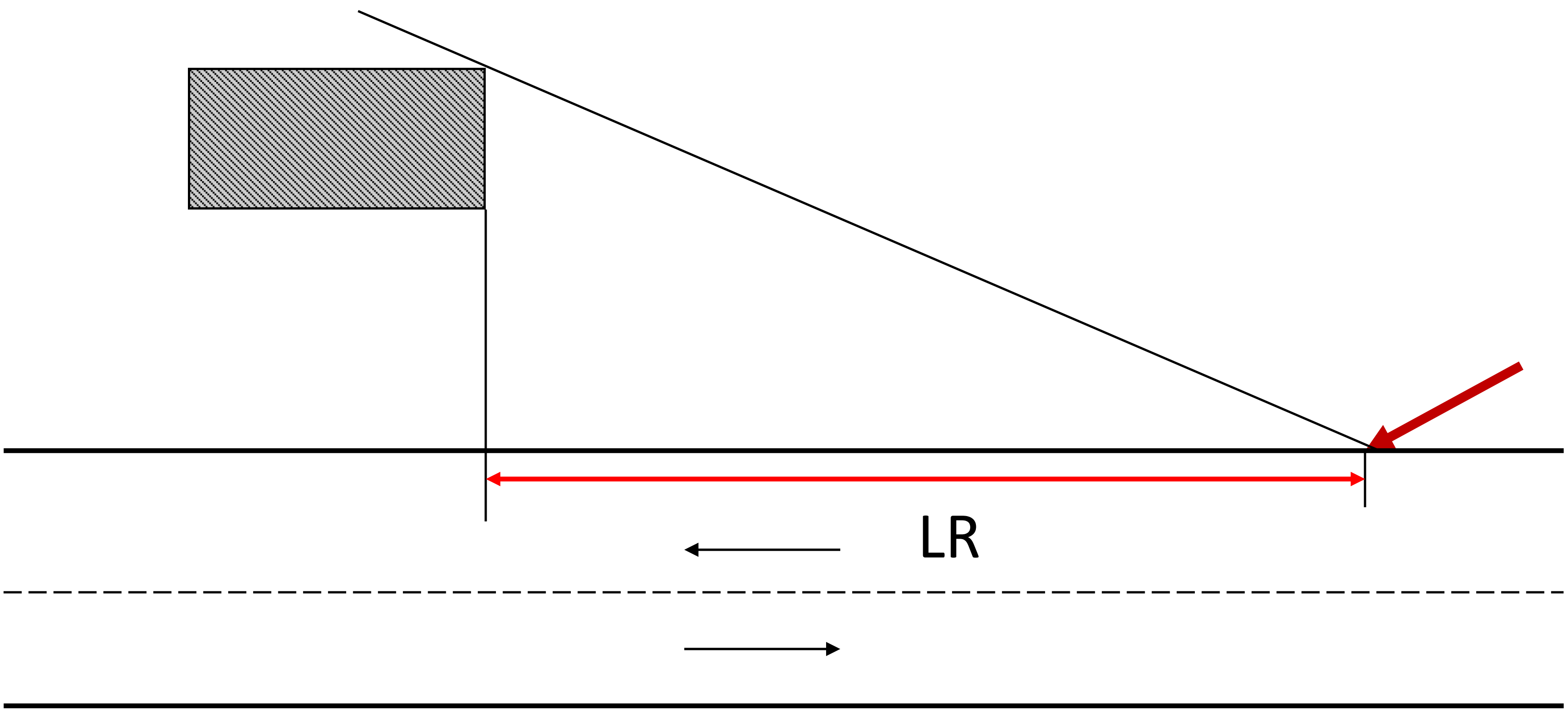


# Length of Need – NCDOT

- Calculating the length of need (L) for straight or nearly straight sections of roadway for parallel installation:

$$L = \frac{LH - N}{LH/LR}$$

# Step 2: Define the Point of Departure



# Look up $L_R$:

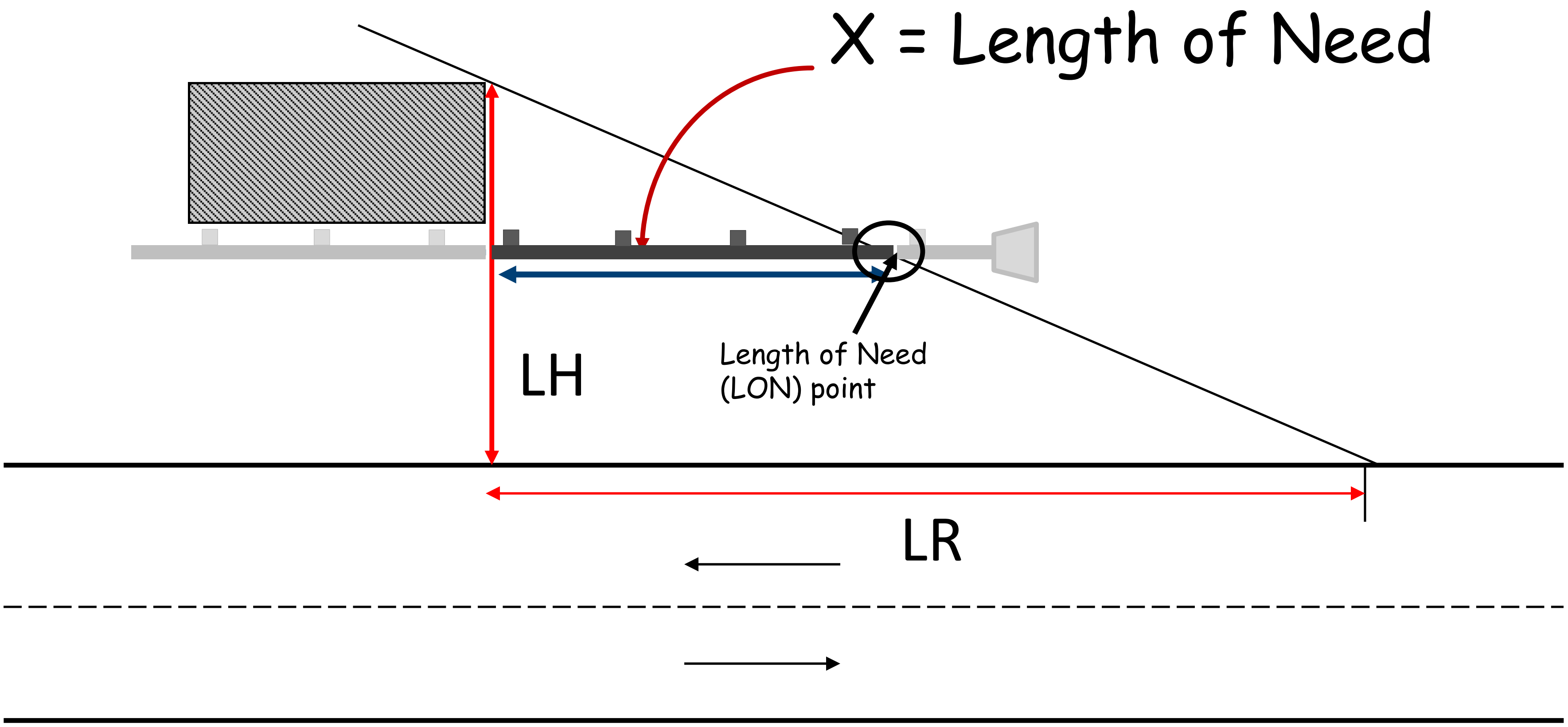
Design Speed 70 mph
AADT = 53,000

| Design Speed (mph) | Runout Length ($L_R$) Given Traffic Volume (ADT) (ft) | | | |
|---|---|---|---|---|
| | Over 10,000 | 5,000 to 10,000 | 1,000 to 5,000 | Under 1,000 |
| 80 | 470 | 430 | 380 | 330 |
| 70 | 360 | 330 | 290 | 250 |
| 60 | 300 | 250 | 210 | 200 |
| 50 | 230 | 190 | 160 | 150 |
| 40 | 160 | | 110 | 100 |
| 30 | 110 | 90 | 80 | 70 |

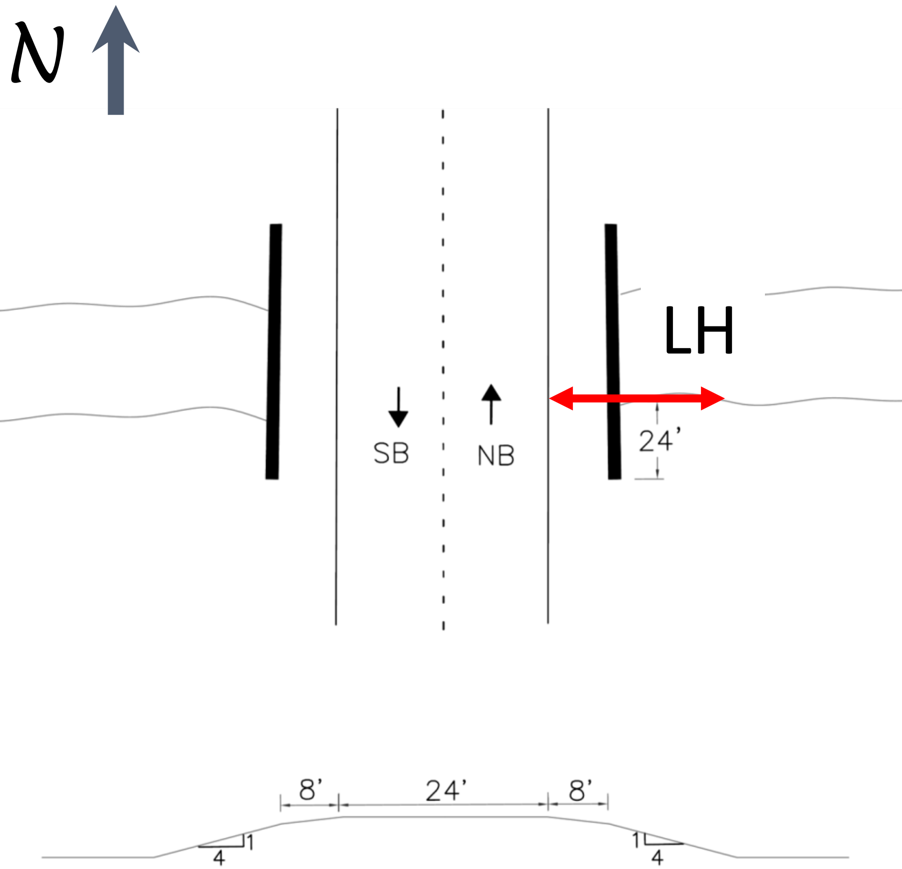
**LR = 210 ft.**

AASHTO Runout Lengths – $L_R$

# Step 3: Intersect the Hypotenuse



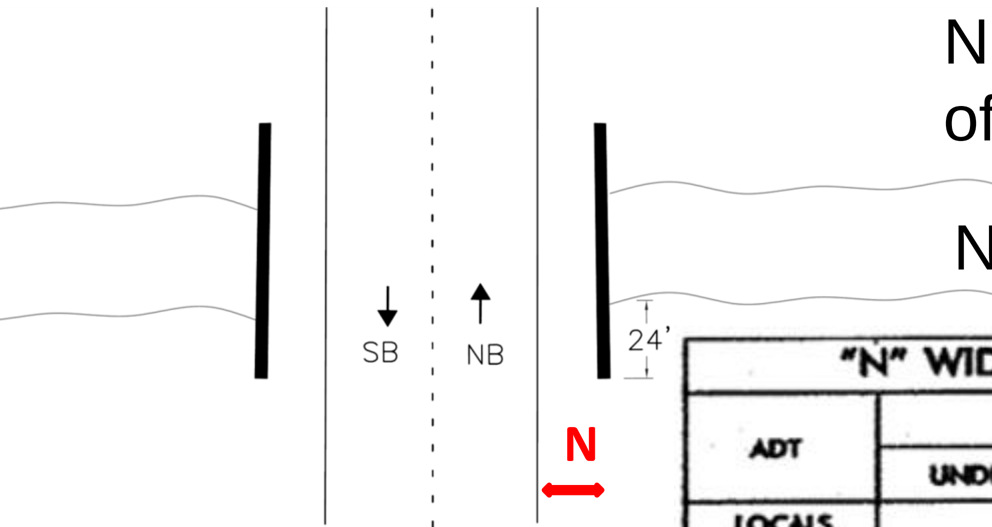
# Example #2: LON for Bridge on Rural Road Near Side




Determine LH – distance to the backside of hazard

For controlling hazard (the bank), LH = LC = 32'

# Find N




N – Guardrail offset from edge of travel lane.

N = 8 ft.

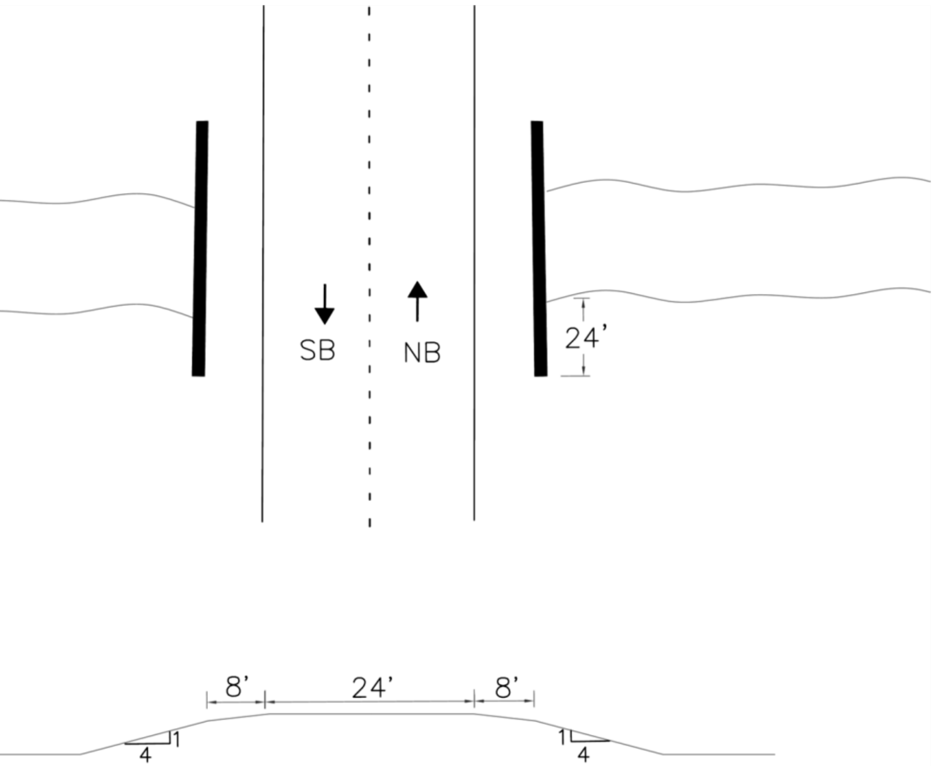
| "N" WIDTH FOR LOCALS AND COLLECTORS | | | | |
|---|---|---|---|---|
| ADT | DESIGN YEAR | | | |
| | UNDER 400 | 400-1500 | 1501-2000 | OVER 2000 |
| LOCALS AND COLLECTORS | 2' | 5' | 6' | 8' |

N = The distance from the edge of the travel lane to the face of the guardrail.

N = Minimum shoulder width for locals and collectors.

N = Usable shoulder width plus 2' for arterials, interstates and freeways.

# Calculate LON – Determine Bid Item
## Near Side




LH = 32 ft    N = 8 ft    LR = 210

Using the formula L =

$$L = \frac{LH - N}{LH/LR}$$

$$= \frac{32 - 8}{32/210}$$

$$= 158 \text{ ft.}$$

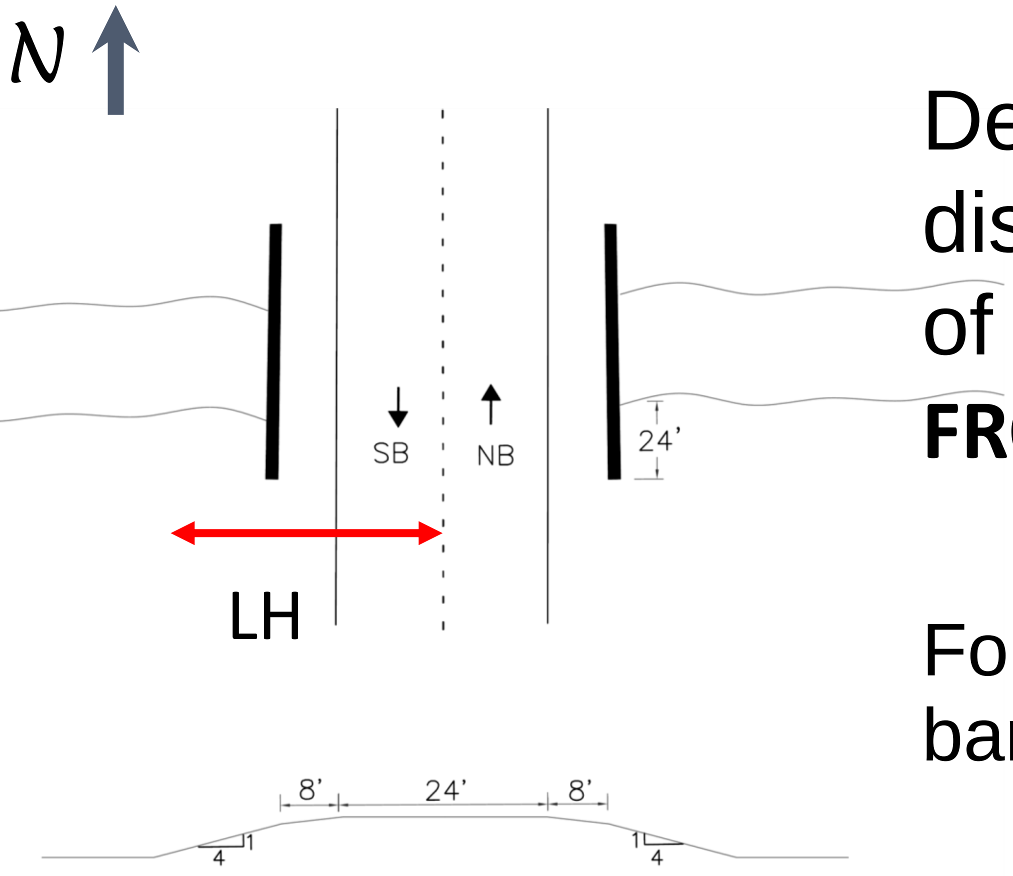
Does **NOT** include Terminal: GREU (50±')

Need a Structure Anchor Unit: 18.75'

24' of Bridge Parapet is Effective Barrier

Therefore 158-19-24 = 115 LF of standard barrier is required; convert to panel lengths by dividing by 12.5, rounding up to whole number, and multiplying by 12.5

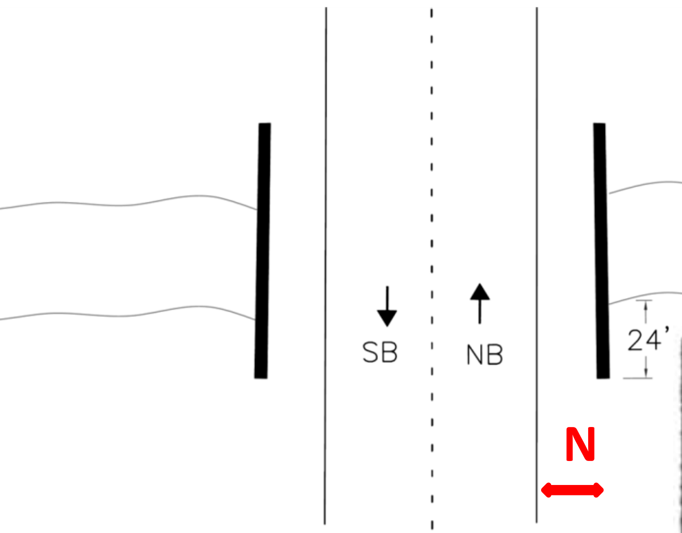
# Example #2: LON for Bridge on Rural Road **Far** Side




Determine LH – distance to the backside of hazard
**FROM CENTERLINE**

For controlling hazard (the bank), LH = LC = 32'

# Find N




N – Guardrail offset from edge of travel lane.

N = ~~8 ft.~~ = 12 + 8 = 20 ft.

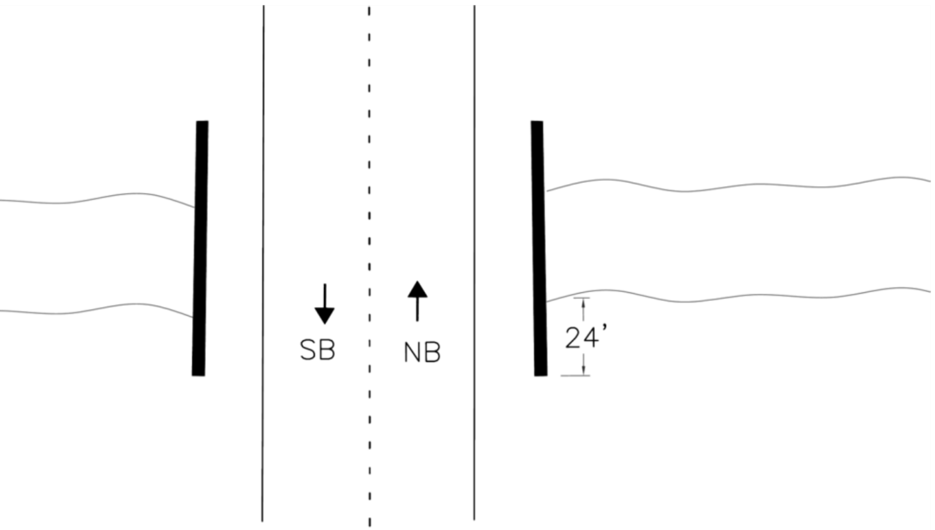
| "N" WIDTH FOR LOCALS AND COLLECTORS | | | | |
|---|---|---|---|---|
| ADT | DESIGN YEAR | | | |
| | UNDER 400 | 400-1500 | 1501-2000 | OVER 2000 |
| LOCALS AND COLLECTORS | 2' | 5' | 6' | 8' |

N = The distance from the edge of the travel lane to the face of the guardrail.

N = Minimum shoulder width for locals and collectors.

N = Usable shoulder width plus 2' for arterials, interstates and freeways.

# Calculate LON – Determine Bid Item
## **Far** Side




LH = 32 ft N = 20 ft LR = 210

Using the formula L =

$$L = \frac{LH - N}{LH/LR}$$

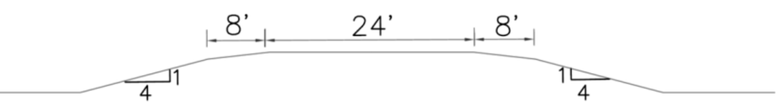
$$= \frac{32 - 20}{32/210}$$

$$= 79 \text{ ft.}$$

Does NOT include Terminal: GREU (50±')

Need a Structure Anchor Unit: 18.75'

24' of Bridge Parapet is Effective Barrier




Therefore 79-24-19 = 36 LF of standard barrier is required (If L had been less than 43', one panel would be needed between the GREU and the structural Anchor Unit.)

# Review Learning Outcomes

- Define the Length of Need and apply the design principles for an optimal installation
- Modify guardrail for special situations