North Carolina Department of Transportation
Guidelines for the Use of Positive Protection in Work Zones

INTRODUCTION

Positive protection is defined by Federal Highway Administration (FHWA) as *"devices that contain and/or redirect vehicles and meet the crashworthiness evaluation criteria contained in NCHRP Report 350."* By this definition, positive protection devices should then also prevent intrusion into the work area.

These guidelines address the use of positive protection devices in work zones to supplement the Work Zone Safety and Mobility Policy and comply with the Federal Highway Administration Final Rule Subpart K to CFR Part 630. These guidelines are not intended to be a rigid standard or policy; rather, they are guidance to be used in conjunction with engineering judgment. These guidelines are not a stand-alone document on work zone application of positive protection and must be used in conjunction with other traffic control standards and resources.

EXPOSURE CONTROL MEASURES

Prior to including positive protection in a transportation management plan, careful consideration must be given to alternatives which would avoid or minimize exposure for workers and road user. Alternatives that are often considered include detouring traffic, minimizing exposure time, or maximizing the separation between traffic and workers. A more inclusive list of potential exposure control measures include:

- Removal of the hazard from the clear zone
- Full road closure/ramp closure with traffic detoured
- Road closure with diversion (i.e. onsite detour, median crossover, temporary pavement)
- Performing work during off-peak periods when traffic volumes are lower
- Accelerated construction techniques
- Directional detours or alternate route detours
- Rolling road blocks

WARRANT

A warrant for using positive protection in a work zone is based on the premise that positive protection will reduce the severity of potential crashes. Positive protection in work zones is considered warranted whenever an engineering study indicates any of the following:

- Consequences of striking a fixed object or running off the road are believed to be more serious than striking the positive protection
- Consequences of striking a worker or pedestrian are believed to be more serious than striking the positive protection

TYPICAL APPLICATION

The following provides a list of areas where positive protection has been used in the past. However, this list is intended to provide guidance and should not be used in place of performing an engineering study.

- Objects that are within the clear zone such as:
  - Temporary shoring locations
  - Bridge piers
  - Overhead sign supports including foundations
  - Staged pipe or culvert construction
  - Stored construction material or equipment
  - Pavement edge drop offs
  - Non-transversable slope or steep/rough embankments within the clear zone
- Staged bridge construction
- Worker's or pedestrian safety is at risk due to the proximity of work to travel lanes
- Separation of opposing traffic

ENGINEERING STUDY AND ANALYSIS

An Engineering Study is a process which will integrate data, analysis, judgment, and creativity to determine the best strategy for a given scenario. An Engineering Study does not take the place of good engineering judgment, but should be used in conjunction with engineering judgment to guide the decision making process. It is most important to understand that one individual factor can not independently determine if positive protection is needed. Considering all the factors will provide the fundamental information for the designer to analyze if an individual operation warrants the need for positive protection.

The Engineering Study performed to determine the need for positive protection shall take into consideration clear zone distances, roadway geometry, anticipated construction year traffic volumes, traffic speeds, roadside geometry, workers safety, pedestrian safety, etc. The following describes in more detail how these areas of concern are considered.

1. PRIMARY FACTORS TO CONSIDER

A. Clear Zone Distances

The *2002 Roadside Design Guide* (RDG) defines the principles of clear zone. Objects outside the clear zone will generally not require positive protection. A designer must determine if a fixed object or worker will be within this lateral distance from the travel way. Clear zones can be determined using Figure 3.1b or Chart 3.1 from the *RDG*.

Chapter 9 of the *RDG* provides information specifically for work zones. Table 9.1 provides example work zone clear zones. This table can be considered, using good engineering judgment, when evaluating the need for positive protection.

The <u>lateral distance</u> from the travel way to a drop off or embankment could affect the need for positive protection. The height of a fill section is related to the slope a vehicle would have to travel toward the obstacle. Figure 5.1b of the *RDG* helps to determine if positive protection is needed for a given fill height.

B. Roadside Geometry

The depth and slope of the drop off or an embankment (roadside geometry) is an important factor to consider and will affect the decision to use positive protection.

- *Pavement Edge Drop off*

  "Safety in Construction Zones Where Pavement Edges and Drop-Offs Exist", shown in the appendix as Figure 16, provides guidance on a correlation between the depth of a drop off, the distance the drop off is from the travel lane, and the roadside slope.

  The Center for Transportation Research and Education (CTRE) in Iowa summarized the other state's drop-off criteria shown in the appendix from "Traffic Control Strategies in Work Zones with Edge Drop-Offs"

- *Embankment*

  Figure 5.2b of the *Roadside Design Guide*, shown in the appendix indicates the relationship between the roadside slope, the height of an embankment and the traffic volume.

C. Anticipated Traffic Volumes

For best analysis, the construction year traffic volumes would provide a more realistic "anticipated" traffic volume than the current or the design year volumes. When analyzing the traffic volumes, the traffic mix should be considered. This includes the percent of truck traffic as well as motorists unfamiliar with area including seasonal tourists or for special events.

With higher traffic volumes, night work is often used as an exposure control measure. Night work may present unique challenges that must be taken into account such as, increased speeds, glare from portable lighting, driver's impaired visibility, and possible increase of inattentive drivers. Nightly installation and removal of positive protection devices will increase time and traffic exposure and may offset any advantage associated with the use of positive protection, except in cases where it can be installed and left in place for extended periods. These items need to be considered prior to requiring night work.

Higher volumes increase the risk to road users and roadway workers. Therefore, positive protection will more likely be used in locations with higher volumes.

D. Traffic speeds

For best analysis, the prevailing speed provides a more realistic speed than the speed limit or design speed for the roadway. If a speed study is available, use the 85th percentile speed. The higher the speed the more likely positive protection will be needed.

E. Roadway Geometry

The geometry of the roadway may affect the site distance for motorists, especially at entrance ramps. If the construction operation is on the outside curve of a road, the clear zone distance may be affected. Table 3.2 of the *RDG* provides adjustment factor for the clear zone. This data considers ADT, speed, and the roadway geometry. The tighter the curve, the more clear zone distance needed.

F. Duration

Duration is the length of time the hazard potentially requiring positive protection will be present. A designer must consider the exposure time associated with completing the operation versus the risk of installing the positive protection. In addition, the percent increase in duration must be considered when the installation of the barrier is included in the operation. If the duration to install the positive protection is longer than the construction operation itself, then positive protection may not be justified.

"Safety in Construction Zones Where Pavement Edges and Drop-Offs Exist" provides a figure to determine when temporary barrier may be justified to shield a drop-off as it relates to the ADT and duration/ exposure time of the drop off condition. This is shown in the appendix as Figure 16.

2. SPECIAL FACTORS TO CONSIDER

A. Worker's Safety

Where worker's exposure to traffic cannot be adequately managed through the application of an exposure control measure, positive protection should be considered. Consider positive protection in situations that place workers at increased risk from motorized traffic. Consideration must be given to an increase in worker's exposure during the installation and anchorage of positive protection.

B. Pedestrian Safety

Positive protection should be considered if there is a high potential for vehicle intrusion into pedestrian paths.

C. Separating Opposing Traffic

Positive separation should be considered in situations where multilane divided facilities are temporarily shifted to a 2 lane 2 way traffic pattern for periods lasting longer than three days. Conditions that may influence the decision to use positive protection would be high speed facilities, narrowed lanes, and high traffic volumes.

3. SECONDARY FACTORS TO CONSIDER

While the primary factors to consider are the driving force in the decision to use positive protection, secondary factors should not be dismissed especially in situations where a clear decision is not evident. The following are a list of secondary factors that may influence the decision to use positive protection:

- Crash History. Crash history of the area prior to construction lessons learned from the crash history of previous work zone projects may be helpful in determining the need for positive protection. The Traffic Safety Unit is a good resource to help identify any potential areas of concern.
- Impacts on Project Cost and Duration. Positive protection will have an impact on the overall project duration and cost.
- Impacts on available lane widths. Restricted lane widths due to the use of positive protection may affect mobility for road users and the contractor. Consideration must be given to wide loads and equipment requirements to complete the work.
- Roadway Classification. The roadway classification is indicative of the characteristics of the road. Characteristics that may have an affect on the decision to use positive protection may include, speed, access, rural vs. urban, etc.
- Work Area Restrictions. Access to and from the work area for the delivery of materials and equipment should be considered. In addition, consideration should be given to the area needed for storage of equipment and materials and the area needed for equipment operation.
- Bridge Construction**.** Positive protection could affect the weight posting of the bridge for overweight vehicles. In addition, the ability to anchor positive protection to an existing bridge may be limited.

CONCLUSION

In conclusion, there are great benefits to using positive protection in appropriate situations. Positive protection techniques, when properly implemented, can help improve safety for workers and the motoring public. However, careful evaluation needs to be exercised before installing positive protection. The decision to use positive protection should be based on the best overall management of safety, mobility, constructability, cost, and overall project duration. These guidelines are meant to be coupled with engineering judgment in determining the use of positive protection.

APPENDIX A
Graphs and Charts

Figure 3.1b Clear-zone distance curves
Roadside Design Guide p. 3-4

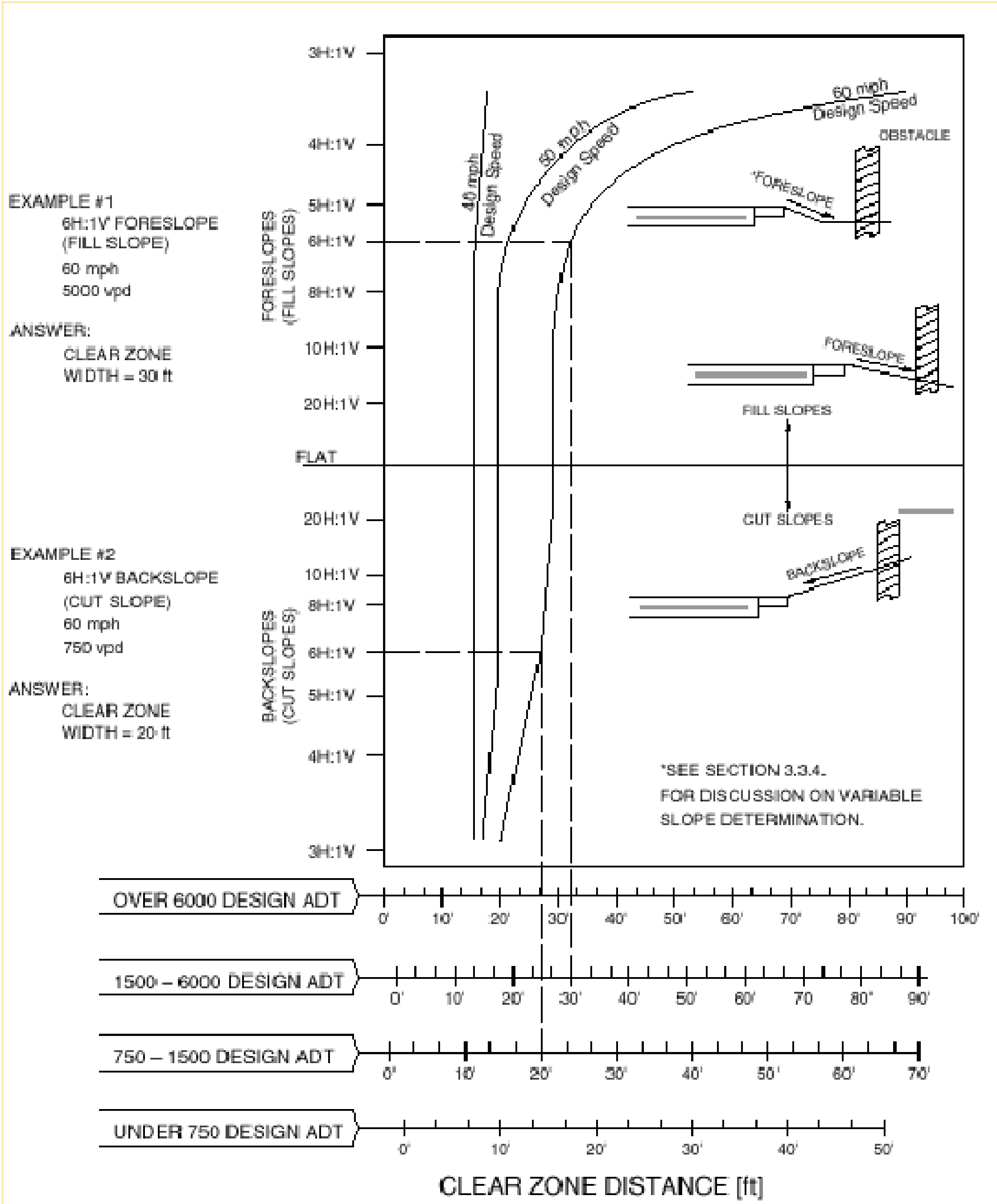


Table 3.1 Clear-zone distance in feet from edge of through traveled way

Roadside Design Guide p. 3-6

[U.S. Customary Units]

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	12 – 14	16 – 20	**	10 – 12	12 – 14	14 – 16
	1500 – 6000	16 – 18	20 – 26	**	12 – 14	14 – 16	16 – 18
	OVER 6000	18 – 20	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

* Where a site specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear-zone distances greater than the clear-zone shown in Table 3.1. Clear zones may be limited to 30 ft for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

** Since recovery is less likely on the unshielded, traversable 1V:3H slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope. While the application may be limited by several factors, the foreslope parameters which may enter into determining a maximum desirable recovery area are illustrated in Figure 3.2.

Table 3.2 Horizontal Curve Adjustments
Roadside Design Guide p. 3-7

K_{cz} (Curve Correction Factor) [U.S. Customary Units]

RADIUS [ft]	DESIGN SPEED [mph]						
	40	45	50	55	60	65	70
2860	1.1	1.1	1.1	1.2	1.2	1.2	1.3
2290	1.1	1.1	1.2	1.2	1.2	1.3	1.3
1910	1.1	1.2	1.2	1.2	1.3	1.3	1.4
1640	1.1	1.2	1.2	1.3	1.3	1.4	1.5
1430	1.2	1.2	1.3	1.3	1.4	1.4	—
1270	1.2	1.2	1.3	1.3	1.4	1.5	—
1150	1.2	1.2	1.3	1.4	1.5	—	—
950	1.2	1.3	1.4	1.5	1.5	—	—
820	1.3	1.3	1.4	1.5	—	—	—
720	1.3	1.4	1.5	—	—	—	—
640	1.3	1.4	1.5	—	—	—	—
570	1.4	1.5	—	—	—	—	—
380	1.5	—	—	—	—	—	—

$CZ_C = (L_C)(K_{CZ})$

Where:

CZ_C = clear zone on outside of curvature, meters [feet]

L_C = clear-zone distance, meters [feet] (Figure 3.1 or Table 3.1)

K_{CZ} = curve correction factor

Note: The clear-zone correction factor is applied to the outside of curves only. Curves flatter than 900 m [2860 ft] do not require an adjusted clear zone.

Table 9.1 Example of clear-zone widths for work zones
Roadside Design Guide p. 9-2

Speed (km/h)	Widths (m)	Speed [mph]	Widths [ft]
100 – 110	9	[60 – 70]	[30]
90	7	[55]	[23]
70 – 80	5	[45 – 50]	[16]
50 – 60	4	[30 – 40]	[13]

Figure 5.1b Comparative risk warrants for embankments
Roadside Design Guide p. 5-4

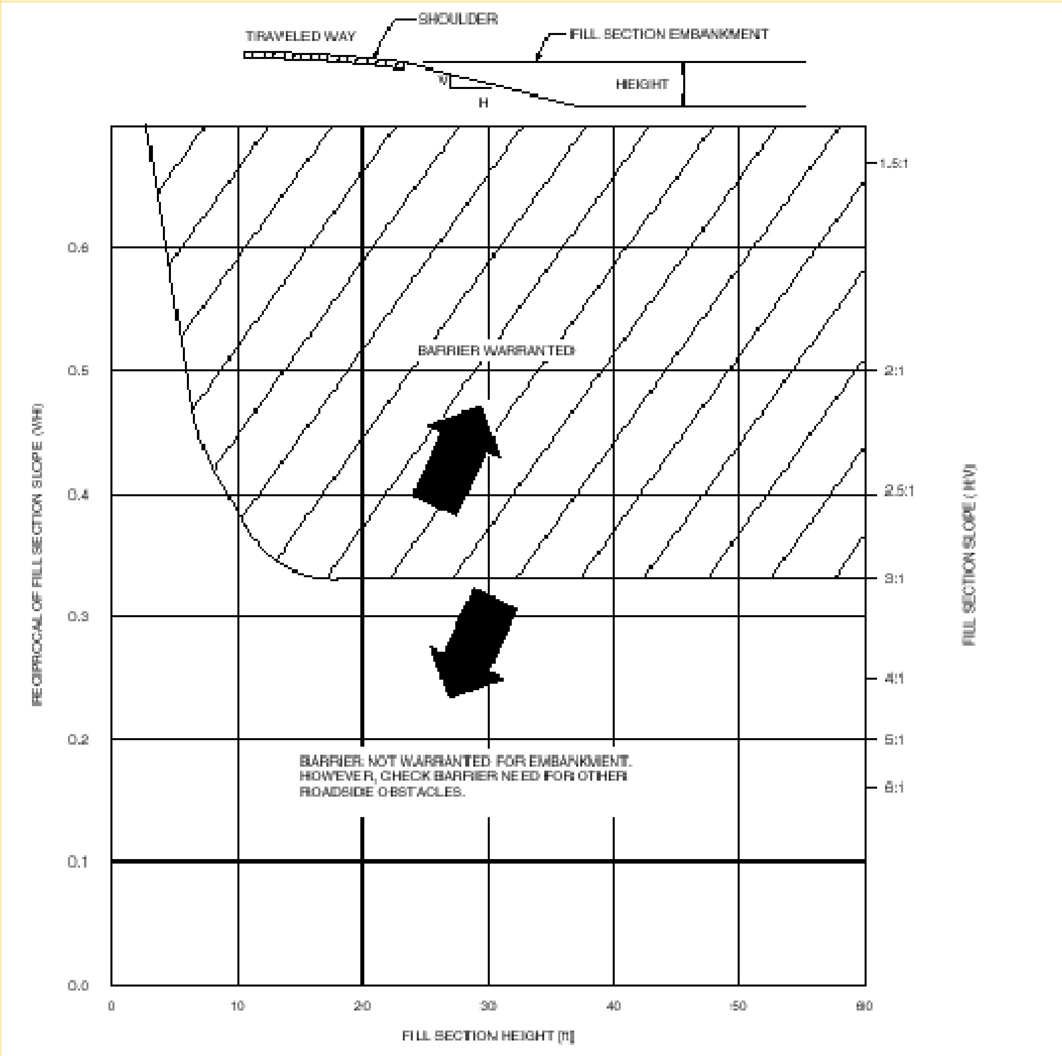


Figure 5.2b Example design chart for embankment warrants based on fill height, slope, and traffic volume
Roadside Design Guide p. 5-6

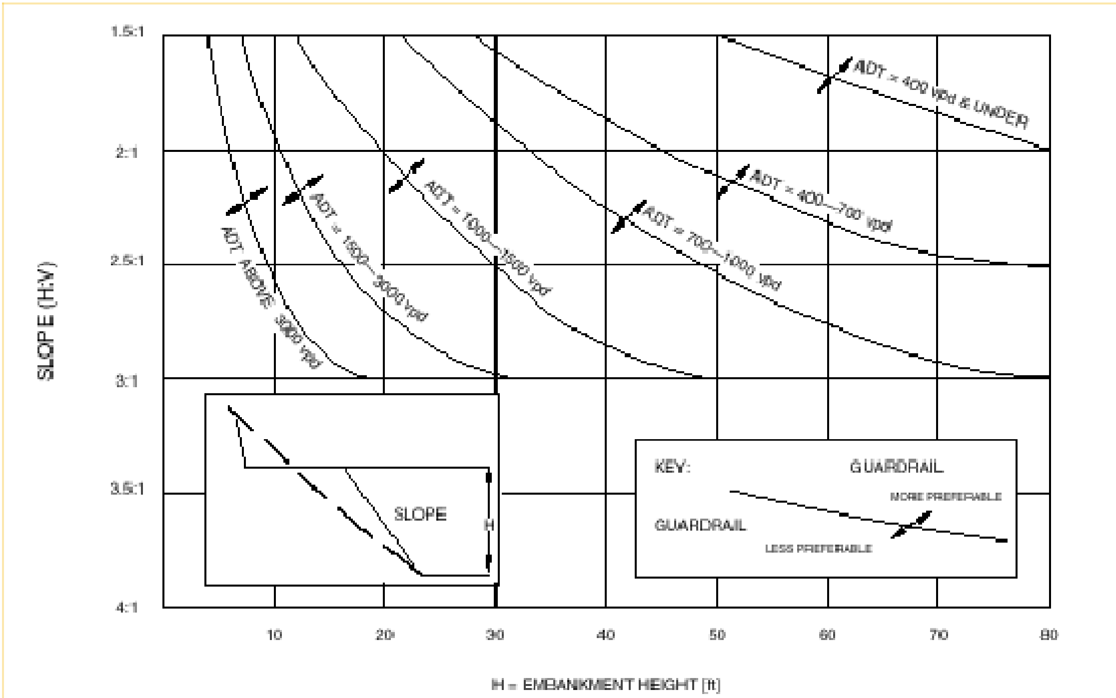
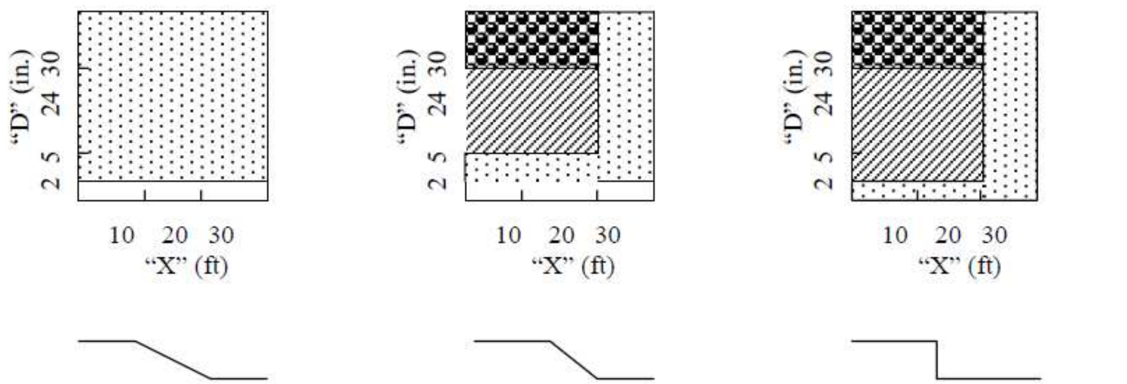


Figure 16 Definition of Treatment Zones and Treatment Selection Guidelines for Various Edge Conditions

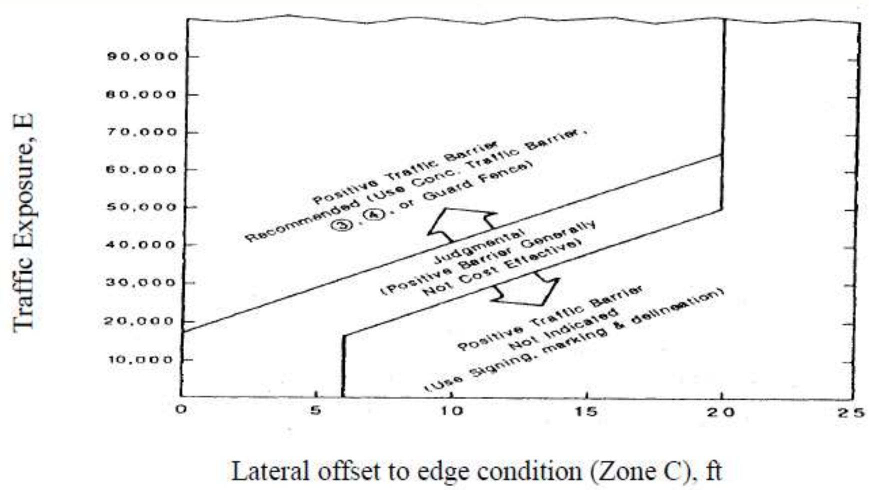
Traffic Control Strategies in Work Zones with Edge Drop-offs p. 38



Edge Condition I: 3:1 or flatter Edge Condition II: 2.99:1 to 1:1 Edge Condition III: 0.84:1 to 0:1

Zone	Usual Treatment
A	SHOULDER DROP-OFF or UNEVEN LANES signs plus vertical panels.
B	SHOULDER DROP-OFF or UNEVEN LANES signs plus drums with steady burn lights. Where restricted space precludes the use of drums, use vertical panels. An edge fill may be provided to change the edge slope to that of the preferable Edge Condition I.
C	Check indications for positive barrier. Where positive barrier is not indicated, the treatment shown above for zone B may be used after consideration of all other applicable factors.

Figure 17 Conditions Indicating Use of Positive Protection
Traffic Control Strategies in Work Zones with Edge Drop-offs p. 39



Notes:

1) E = ADT * T, Where ADT is that portion of the average daily traffic volume traveling within 20 feet (generally two adjacent lanes) of the edge dropoff condition and, T is the duration time in years of the dropoff condition.
2) Primarily applicable to high speed conditions only.
3) Barrel Mounted Guard Fence may be used in lieu of CTB where speeds of 45 mph or less and impacting angles of 15 degrees or less are anticipated.
4) An approved end treatment should be provided for any positive barrier end located within a lateral offset of 20' from the edge of the travel lane.

Table 17 Typical Criteria for Consideration for Temporary Traffic Positive Protection

Traffic Control Strategies in Work Zones with Edge Drop-offs p. 76

State	Criteria
Iowa	Drop-off depth > 10 inches, located within 10 feet of travel way (informal)
Arkansas	Drop-off depth > 5 feet
California	Drop-off depth > 6 inches, located within 8 feet of travel way; special engineering consideration for all drop-offs > 2.5 feet
Florida	Drop-off depth > 3 inches, located within 12 feet, project duration > 1 day
Minnesota	Optional for drop-off depth > 4 inches, if no wedge, located adjacent to travel way, speed > 30 mph, project duration > 3 days, length < 50 feet; if 12 inches, recommended
Missouri	Alternative for use with lane closures when drop-off depth > 2 inches
Montana	Drop-off located within 30 feet of travel way, if no wedge provided, exposures exceeding 48 hours, spacing factor < 20 feet by formula)
New York	Drop-off depth > 2 feet, speed limit > 45 mph, AADT ≥ 7500, project duration ≥ 60 days
North Dakota	Drop-off depth > 5 inches located between travel lanes, drop-offs depth > 12 inches, located adjacent to travel way, speed limit> 30 mph, project duration > 7 days, project length > 50 feet.
Ohio	Drop-off depth > 5 inches located between travel lanes, drop-off depth > 2 feet located within 30 feet of travel way, overnight exposure
Texas	Drop-off depth > 2 feet, speed limit > 40 mph
West Virginia	Drop-off depth > 3 inches, project duration > 48 hours, speed limit > 45 mph, located within 30 feet of travel way on multilane highways, located within 20 feet of travel way on undivided highways

DEFINITIONS

Clear Zone is defined as the total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope, and/or a clear run-out area. The desired minimum width is dependent upon traffic volumes and speeds and on the roadside geometry. Simply stated, it is an unobstructed, relatively flat area beyond the edge of the traveled way that allows a driver to stop safely or regain control of a vehicle that leaves the traveled way.

Travel Way is the portion of the roadway for the movement of vehicles, exclusive of shoulders.

Transverable Slope is a slope from which a motorist will be unlikely to steer back to the roadway but may be able to slow and stop safely. Slopes between 1V:3H and 1V:4H generally fall into this category**.**

Recoverable Slope is a slope on which a motorist may, to a greater or lesser extent, retain or regain control of a vehicle by slowing or stopping. Slopes flatter than 1V:4H are generally considered recoverable.

Non-Recoverable Slope is a slope which is considered traversable but on which an errant vehicle will continue to the bottom. Embankment slopes between 1V:3H and 1V:4H may be considered traversable but non-recoverable if they are smooth and free of fixed objects.

REFERENCES/RESOURCES

American Association of State Highway and Transportation Officials (2002). Roadside Design Guide.

Ivey, Don L., King K. Mak, Harold D. Cooner, and Mark A. Marek. “Safety in Construction Zones Where Pavement Edges and Drop-Offs Exist.” Transportation Research Record 1163, 1988, pp. 43-62.

Center for Transportation Research and Education, Department of Civil and Construction Engineering, Iowa State University, “Traffic Control Strategies in Work Zones with Edge Drop-Offs”, August 2002 p. 76.

Federal Highway Administration (2000). Manual on Uniform Traffic Control Devices (MUTCD). U.S. Department of Transportation, Washington, D.C.

Bryden, James and Mace, Douglas (2002). Guidelines for Design and Operation of Nightime Traffic *Control for Highway Maintenance and Construction*, National Cooperative Highway Research Program Report NCHRP-476, Transportation Research Board of the National Academies, Washington, D.C.

APPENDIX B
Examples

R-5678
June 15, 2008
Note to File

Engineering Study to determine if Positive Protection is warranted

Problem:
Culvert extension to one side of a 2L2W. Shoring is required to hold back existing fill slope once existing wings and headwall removed. Shoring location is approximately 15' right of the travelway. Several drives are within the possible length of need.

Exposure Control Measures investigated:
1. No available detour routes.
2. Using temporary pavement or on-site detour not practical due to stream/environmental impacts on the opposite side of the road.

Clear Zone:
Per Roadside Design Guide, the clear zone is 20 - 24' based on 60 mph speed and ADT of 6000. Since this is a work zone, assume the low end of this range.

The hazard is inside this range.

Traffic Speeds:
Posted speed is 55 mph but 85% is probably around 60 as this is a rural route; not heavily congested.

Roadway Geometry:
Favorable; relatively flat and straight.

Duration:
Expect traffic to be exposed to the hazard for 1 month or less based on input from the Resident. (See FDFI minutes)

Impacts on project cost:
Significant. If PCB is used here, as many as 4 crash cushions would be necessary due to breaks in the PCB for the driveways.

Conclusion:
The hazard is within the clear zone for a final design, however it is fairly close to the limit. It should be expected that motorist would have a heightened since of awareness due to advance warning signage and delineation. With this said, whether or not the hazard is within the clear zone in a work zone application is debatable.

It could be argued that the severity of crash would be worse striking PCB here and then redirected into the path of oncoming traffic.

Multiple crash cushions due to the drives significantly raises costs and the breaks in the PCB over a short length would lessen the effectiveness of PCB.

Based on this, in combination with the relatively short duration, I recommend not using positive protection at this site. I do recommend increasing the level of delineation at the site by using waterfilled barrier, not as positive protection, but has a superior delineator to drums or cones. This would also add a minor degree of positive protection that is much more forgiving than PCB.

Other Traffic Control Measures:
Will ask the Division to support an ICT to complete the work requiring barrier within an appropriate amount of time to minimize motorist's exposure.

A temporary speed reduction ordinance was investigated but the criteria were not met. It was determined, however, that an advisory speed panel of 55mph placed on stationary advance warning signs would be appropriate.

R-1234
June 15, 2008
Note to File

Engineering Study to determine if positive protection is warranted

Problem:
End Bent #2 shall be constructed during a full road closure under a 60 day ICT (see Phase I, Steps 3 thru 5). Upon completion, the road is reopened to traffic on the existing alignment with the exposed EB about 10 ft from the SB travel lane.

Exposure Control Measures investigated:

1. There is an available detour. However, three schools are located within 1 mile of the project and the Division as well as the School Board will only support an offsite detour during the summer months. This period will be used to construct the end bent. Attempt to persuade them to extend this period were unsuccessful.
2. Using temporary pavement or an on-site detour is impossible due to the proximity of the existing structure, environmental impacts to the existing stream, and possible impacts to a historic property within the project limits.

Clear Zone:
Per the RDG, Chart 3.1, the clear zone is 16 to 20 ft. based on a posted speed of 50 mph and a construction year ADT of 1300vpd. Since this is a work zone and there are 30 mph design exceptions in the roadway plan, I'm going with the low end of this range.

The hazard is 10 ft from the travel way; clearly within the clear zone even if a 30 mph speed is used for clear zone analysis.

Roadside Geometry
I'd describe geometry as quite adverse based on horizontal curvature of 15 degrees and a slope of 8%.

Duration:
I expect traffic to be exposed to the hazard for 1 to 3 months. Hazards associated with installation of PCB are a non issue because the PCB can be installed while the detour is in place.

Conclusion:
Positive Protection is warranted due to the long term presence of a rigid object clearly within the clear zone. Roadside geometrics are also clearly adverse. I believe it is reasonable to assume a higher than normal percentage of drivers using this facility is inexperienced due to the proximity of a high school. Offsite and onsite detours were investigated as a means to lessen the exposure of motorist. Neither were determined to be practical or feasible.

Other Traffic Control Measures:
Due to adverse geometry and narrow lanes, recommend adding crystal rpm's at 20 ft. spacing along the white edge line adjacent to the PCB. Also, will ask the Resident to request some additional patrolling of the work zone during the first couple of weeks of the school year as they deem appropriate to enforce speed limit.