# 7 DESIGN CRITERIA

## 7.1 Design Space Requirements

The Nebraska Department of Roads (NDOR) provided examples of intersections where an approved guardrail end terminal and Approach Guardrail Transition (AGT) could not be used to shield the bridge rail end adjacent to an intersecting roadway due to lack of space, as shown in Figure 11. From discussions with the Technical Advisory Committee (TAC), some specific site constraints were determined.

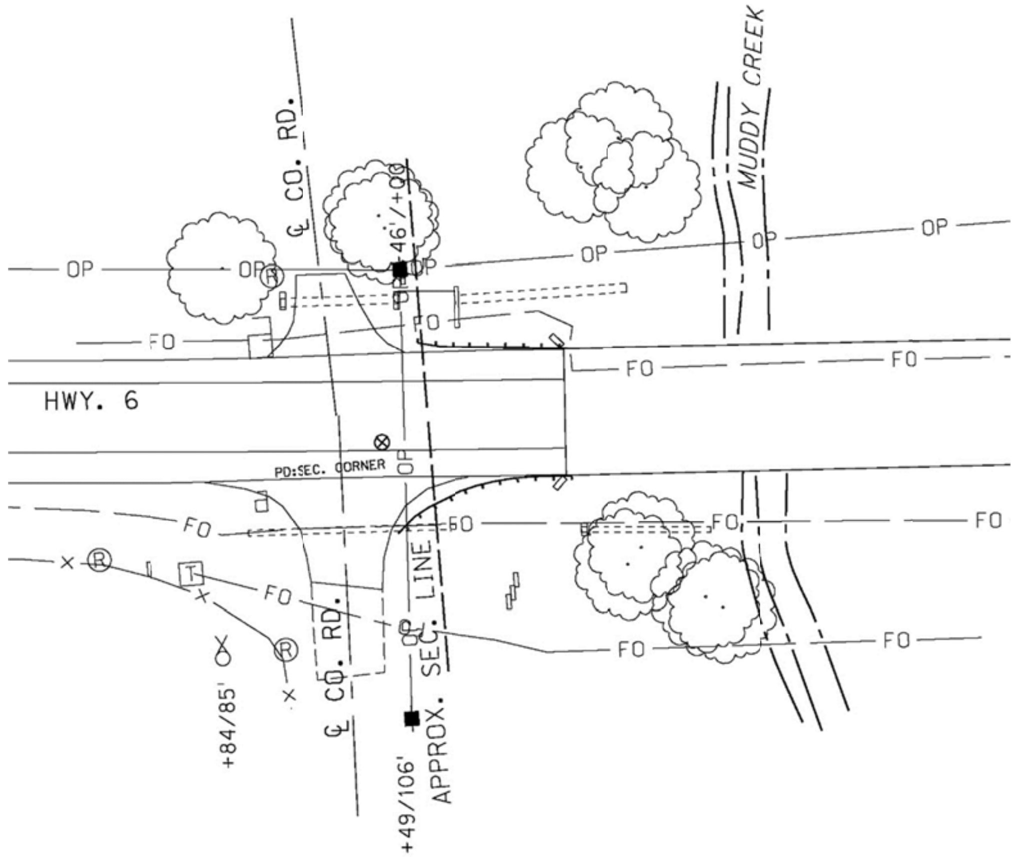



Figure 11. Example Intersection [44]

Typical intersection radii for these locations often range between 25 ft (7.6 m) and 50 ft (15.2 m). The bridge railing end is often located within 25 ft (7.6 m) from the intersection with many locations having steep slopes beginning downstream of the bridge rail end. The bridge rail was assumed to be laterally offset 4 ft (1.2 m) away from the roadway edge. Also, the sponsor suggested that a clear-zone distance of 30 ft (9.1 m) should be assumed for all locations. These design details are shown in Figure 12.

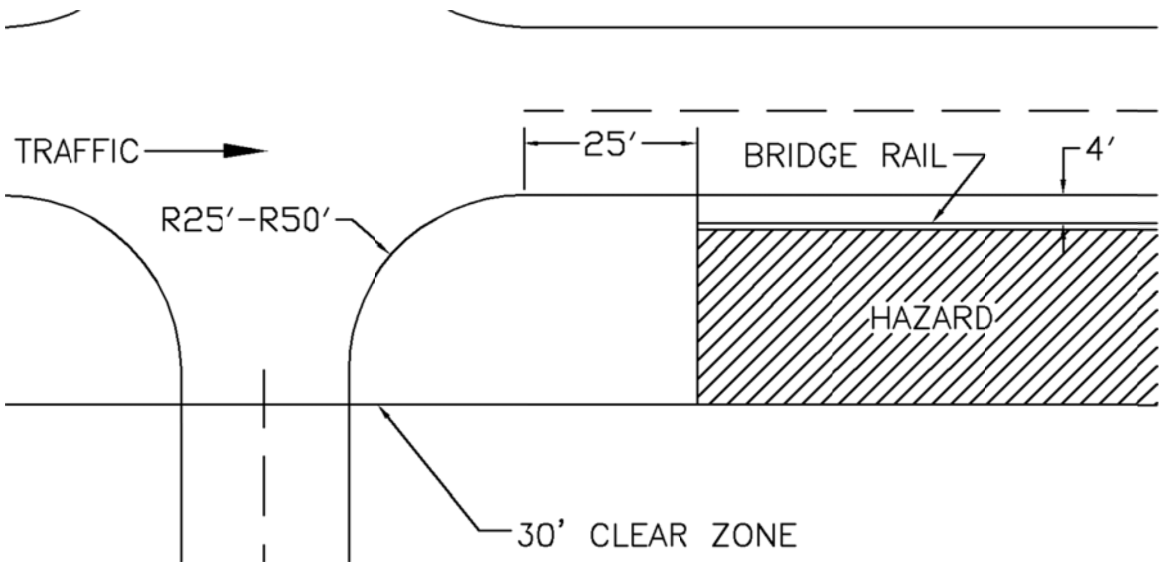


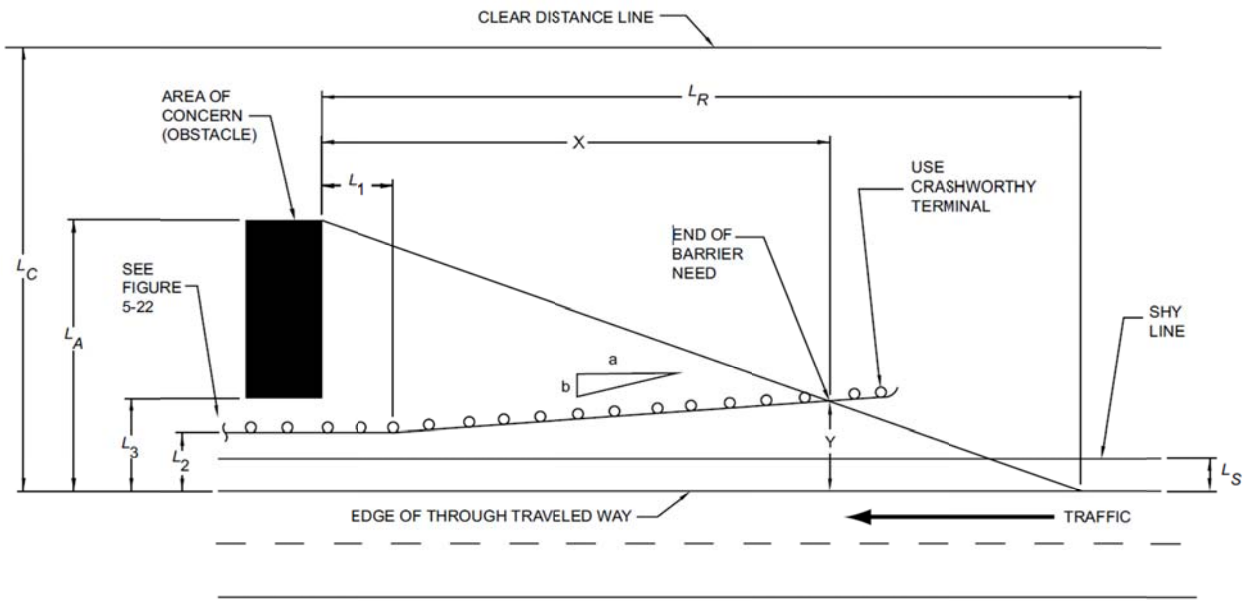

Figure 12. Site Constraints for New Impact Attenuation System

## 7.2 Impact Conditions Determined By Length of Need

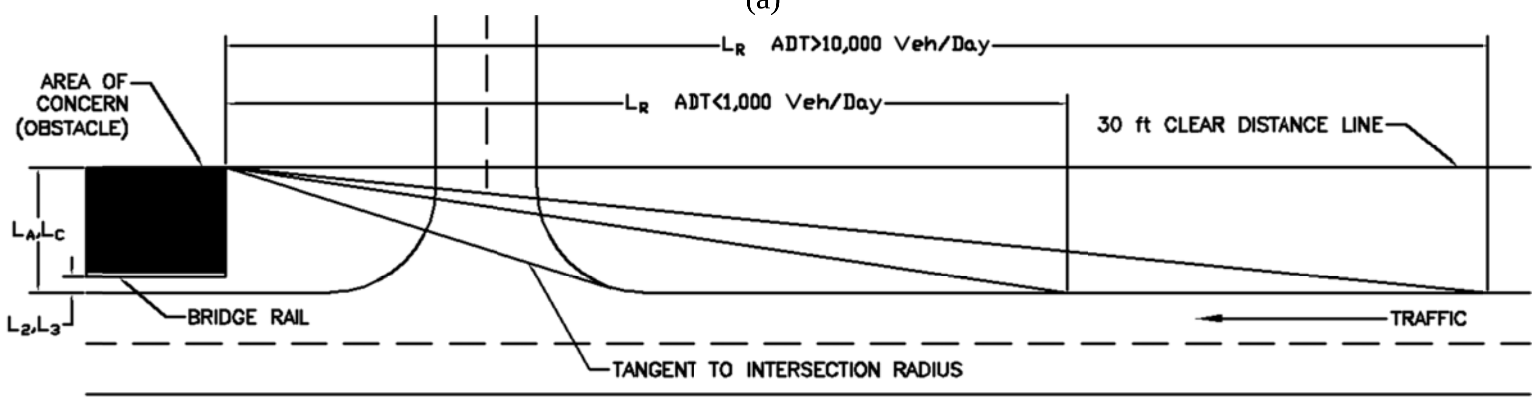
When developing new ideas to treat these situations, it became apparent that different evaluation criteria were needed to compare the new concepts. Previous testing performed on short-radius guardrail systems was based on AASHTO bridge protection guidelines or modified crash cushion test matrices. The test matrix was adapted to the geometry of the guardrail systems, but it did not address all of the potential impacts possible near intersecting roadways.

The discrepancy between previous testing of short-radius guardrail systems and the actual impact conditions relative to bridges adjacent to intersecting roadways was discussed with NDOR sponsors. This discussion led to the determination to treat the intersection condition in a similar manner as used for general hazards found within the clear zone distance, as shown in Figure 13. The hazard would extend perpendicular from the end of the bridge railing to the maximum clear zone distance, also shown in Figure 13. The area shielded would be determined with the runout length and LON from the RDG [1]. The upstream end of the bridge railing was used to define the beginning of the hazard as steep slopes often begin at the end of the bridge railing. The length of need was determined using runout lengths suggested in the RDG ($4^{th}$ Ed.) for 60 mph (100 km/h) design speeds, as shown in Table 18. The resultant runout length for the system was 300 ft (91.4 m), assuming the ADT for the primary road would be 10,000 vehicles per day or greater, as shown in Figure 13. For 1,000 ADT and less, the runout length for the system would be only 200 ft (61.0 m), but for the purpose of this project, a higher ADT was assumed and deemed more conservative.

An alternative method was considered for determining the protected area, which assumed that vehicles could not traverse the area upstream from the secondary roadway. For this method, a line was drawn tangent to the radius opposite of the safety treatment and through a point to the back of the hazard. This approach may be applicable if a guardrail system was installed on the road upstream from the intersection. This third option decreased the coverage area required for new impact-attenuation systems, especially systems with very short intersection radii. Ultimately, the AASHTO RDG LON option was used to determine the protected or shielded area as it better represented the worst-case scenario and would be largely consistent with State DOT design practice for treating roadside hazards. This conservative LON method does create a larger protected area, which is more difficult to shield. In the end, the sponsor decided that shielding that larger area was justified, given the treatment of other hazards.




(a)




(b)

Figure 13. (a) Approach Guardrail with Variables [1], (b) Intersection Near Bridge with Variables

Table 18. Suggested Runout Length ($L_R$) for Barrier Design Given Traffic Volume (ADT) [1]

| Design Speed | Runout Length, $L_R$ | | | |
|---|---|---|---|---|
| | Over 10,000 veh/day | 5,000 to 10,000 veh/day | 1,000 to 5,000 veh/day | Under 1,000 veh/day |
| mph (km/h) | ft (m) | ft (m) | ft (m) | ft (m) |
| 80 (130) | 470 (143) | 430 (131) | 380 (116) | 330 (101) |
| 70 (110) | 360 (110) | 330 (101) | 290 (88) | 250 (76) |
| 60 (100) | 300 (91) | 250 (76) | 210 (64) | 200 (61) |
| 50 (80) | 230 (70) | 190 (58) | 160 (49) | 150 (46) |
| 40 (60) | 160 (49) | 130 (40) | 110 (34) | 100 (30) |
| 30 (50) | 110 (34) | 90 (27) | 80 (24) | 70 (21) |

### 7.3 Line of Sight Considerations

Intersections are designed so that their geometry and nearby obstacles or features do not create navigational problems for motorists that could result in traffic collisions. The sight distance, as defined in *Intersection Safety: A Manual for Local Rural Road Owners*, is the distance a motorist can see an approaching vehicle before their line of sight is blocked by an obstruction near the intersection [45]. The driver of a vehicle approaching or leaving an intersection requires an unobstructed view of the intersection with sufficient lengths along the intersecting roadway to anticipate and avoid potential collisions.

A barrier's height is an important consideration when considering new concepts. A system that is too tall reduces the sight distance for drivers on the secondary road turning onto the primary roadway. The AASHTO *Policy on Geometric Design of Highways and Streets* advises that roadside features should be less than 3.0 ft (0.91 m) above the road [46]. This criterion could be violated if the structure, such as a net, could be seen through. The area needed for this unobstructed view is called the Clear Sight Triangle, as shown in Figure 14. The Intersection Sight Distance (ISD) is measured along the major road beginning at a point that coincides with the location of the minor road vehicle. The ISD is based on the following assumptions [45]:

- Stop control of the minor road approaches;
- Using driver eye and object heights associated with passenger cars;
- Both minor and major roads are considered at level grade;
- Considers a left-turn from the minor road as the worst-case scenario (i.e., requiring the most sight distance); and
- The major road is an undivided, two-way, two-lane roadway with no turn lanes.

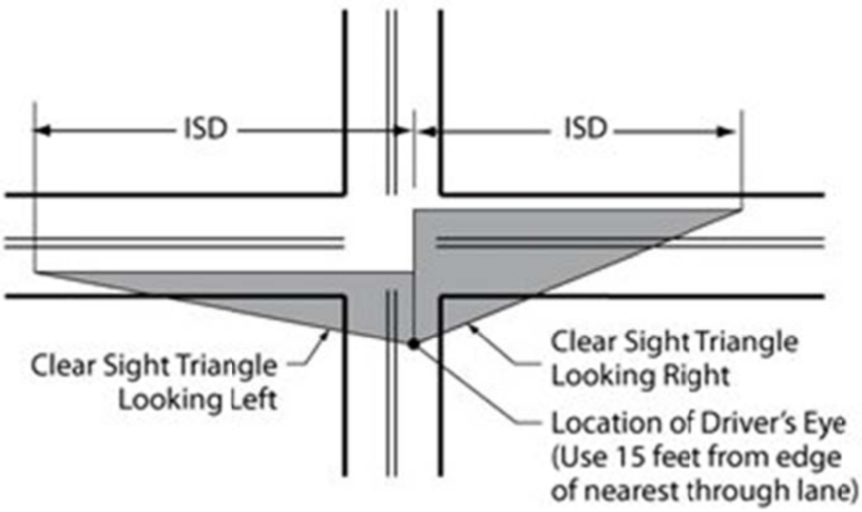



Figure 14. Clear Sight Distance Triangles for 4-Leg Stop-controlled Intersections [45]

The Stopping Sight Distance (SSD) refers to the distance required for drivers to avoid potential collisions. Sight distances that exceed the recommended SSD, as shown in Table 19, are desirable.

Table 19. Sight Distance at Intersections [45]

| Speed<br>mph (km/h) | Stopping Sight<br>Distance<br>ft (m) | Design<br>Intersection Sight<br>Distance<br>ft (m) |
|---|---|---|
| 25 (40) | 155 (47.2) | 280 (85.3) |
| 30 (48) | 200 (61) | 335 (102.1) |
| 35 (56) | 250 (76.2) | 390 (118.9) |
| 40 (64) | 305 (93) | 445 (135.6) |
| 45 (72) | 360 (109.7) | 500 (152.4) |
| 50 (80) | 425 (129.5) | 555 (169.2) |
| 55 (89) | 495 (150.9) | 610 (185.9) |
| 60 (97) | 570 (173.7) | 665 (202.7) |
| 65 (105) | 645 (196.6) | 720 (219.5) |

### 7.4 Preference for Existing Technologies

Preference was given to design concepts that utilized existing technologies in order to limit new hardware development for this project. An important consideration for this project was how well designs could be implemented into new concepts without interfering with the operation of another technology.

### 7.5 Other Considerations

Many locations that require a short-radius guardrail system have moderate to steep slopes inside the intersection radius. Though there are no specific criteria, it is desirable for new concepts to accommodate moderate slopes. These locations are often found in wetland areas. Thus, there are environments that limit the use of chemicals to control weeds and brush in that area. As such, that the protected area should allow access for mowers and other equipment to be used in the protected area. NDOR also indicated that it would be preferable if a guardrail system was not required along the secondary road.