GUARDRAIL REPLACEMENT
HIGHWAY SAFETY PROGRAM

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Introduction:

During 1977 there were 3,698 fatalities on Texas highways, of which 1,318 or 35.6% could be associated with the roadside environment. Collision with a fixed object accounted for 871 deaths, and overturned and/or ran-off-the-road was the cause for 405 fatalities. Other non-collision accidents resulted in 42 fatalities.

As early as 1963 an intensive effort was begun by highway engineers to make highways more forgiving. This effort mainly included the use of breakaway design for roadside sign supports and luminaires, the installation of vehicle impact attenuators, and the expanded use of guardrail as a fixed object treatment. Roadway alignment, slope design, and curb and drainage structure safety design was limited to new roadway projects and special safety projects. The 1977 accident statistics indicate that there is still much to be done in the implementation of roadside safety design and in new safety design concepts.

Much of our existing highway system has objectionable features built in and until we can correct these, guardrail will have to be used to protect the motorist. The lower type class of highway is usually in worse condition as far as guardrail practices are concerned, but the higher grade interstate system also has some deficiencies. On new construction the use of guardrail can be reduced considerably due to safety design concepts. In many roadside situations; however, there are fixed objects that cannot be relocated the preferred 30 feet from the roadway (Proving Ground, Hutchinson, and Cornell "hazard" curves), there are steep side slopes which cannot be economically changed, and there are hazardous approaches to bridges which need protection. In these cases guardrail is usually in place, but the installation is not always up to current safety standards as far as the manner in which it was maintenance costs. Minimum thickness is 10 guage (0.1382 inches, Class A) or 12 guage (0.1084 inches, Class B) for steel guardrail. The guardrail is mounted on either 7 inch diameter treated Southern Yellow Pine timber posts or 6 inch x 4 inch x WF8.5 lb/ft. steel posts so that the top of the guardrail is 27 inches above the roadway surface. This should be a maximum height, otherwise sight distance may be restricted or a vehicle may run under the guardrail and pocket on a post. The guardrail is specified in either 12½ foot or 25 foot sections, and post spacing is normally at 6 feet, 3 inches with a minimum of 8 posts adjacent to structures spaced at 3 feet, 1½ inches. Both ends of the guardrail must be anchored securely so that the tensile strength of the guardrail can be used effectively. Present standards call for the guardrail ends to be twisted 90° and fastened to a heavy anchor post to develop full strength of the guardrail. The anchor post is the strongest part of the guardrail system, as eight bolts are used to connect the guardrail to the terminal connector, which is in turn fastened with four bolts to a concrete footing or wooden post. The W-section does not have much strength unless it is supported at frequent intervals and at the ends. If it is securely anchored where hit, it can tolerate high tensile loads and acts much like a cable, as it flattens upon impact.

Current standards call for a post spacing of 6 feet, 3 inches in lieu of the old 12 feet, 6 inch spacing. By reducing the spacing and anchoring both ends of the railing, the chances of a vehicle pocketing between the posts is greatly reduced and the possibility of redirection is greatly increased. To get the cable effect out of the guardrail, it has been found that at least 150 feet or guardrail should be used, because even with closer post spacing, shorter sections of guardrail do not perform well.

An exception to the 6 foot, 3 inches post spacing is made on the approach turndown guardrail section. By placing the first post at 25 feet and the next two posts at 12 feet, 6 inch spacing before going to the 6 feet, 3 inch post spacing, the turndown section is made weaker than the remainder of the guardrail. This allows the guardrail to lay down when struck headon by a vehicle. A vehicle hitting this turndown section usually pushes the guardrail to the ground by breaking it loose from the posts one by one. This usually does heavy damage to the underside of the vehicle; however, the passenger compartment usually remains undamaged. Otherwise, a vehicle hitting the approach end at high speeds could be launched over the rail or could roll over.

Due to a problem of stiff behavior of the turndown section when impacted by lightweight vehicles, a new terminal section design was developed and will possibly become the new standard. The "nested" backup plate terminal design is a new experimental system which calls for short, W-section backup plates bolted to the first five guardrail posts with the guardrail nested over the backup plates and fastened with a weak clip. The post spacing would be the same as mentioned above, but the approach turndown will become less rigid. The guardrail will give way when a vehicle hits the turndown end and brings the vehicle to a stop with damage generally confined to the underside.

This system has been tested with wood posts, which shear off when hit, but steel posts have not yet been tested. Judgment will have to be used when installing this type of end treatment, because it should not be used on approaches to bridges as a vehicle may ride the guardrail down and hit the bridge abutment. In other words, it should only be used when 150 feet or more of guardrail is installed.

An opposite situation is desirable on an approach to a bridge. In this case the post spacing is reduced to transition the guardrail stiffness to be more consistent with that of the bridge railing. Other methods of accomplishing this would be to increase the post size, or reinforce the guardrail by doubling it or using the thrie beam design. Bridge railing is a rigid type barrier and the semi-rigid guardrail must be smoothly transitioned to insure that a vehicle will not pocket on the end of the bridge instead of being redirected. There should be no gap between the guardrail and the bridge rail, which may cause a vehicle to snag. The guardrail must be attached with enough bolts to secure the guardrail and in a manner such that the bridge rail or bridge wingwall will remain intact upon collision. Many of our older bridges have curbs and/or sidewalks, which in many cases also become a hazard. This situation is handled by blocking out the guardrail or turning it down flush with the face of the curb. If there is a curb on the bridge which is less than 12 inches wide, the guardrail should be blocked out so that it is flush with the face of the curb. If there is a curb or sidewalk 12 inches or more wide, then the guardrail should be twisted 90° and attached with a terminal connector to the curb or sidewalk so that it is also flush with the face of the curb. This type of approach treatment will often prevent a vehicle from pocketing or ramping if it happens to hit the guardrail at or near the bridge railing. The transition from the approach end to the bridge should be smooth, so that there is no place for a vehicle to pocket or snag and so that the vehicle is not redirected across the roadway into opposing traffic or into the opposite side of the bridge.

The anchorage of the guardrail to the curb and/or sidewalk should be at least 15 or 20 feet onto the bridge. The terminal connector should be carefully installed so that the splice connection to the W-section is made with the bolts at the extreme end of the 3 inch expansion slots. If this is not done, there may be lateral deflection in the guardrail causing the vehicle to pocket. If 10 guage material is used for the terminal connector, then four 7/8 inch bolts (A 307) are needed for anchoring the connector, and if 12 guage material is used, then six 3/4 inch bolts are required.

There are several types of expansion bolts available to use for attaching the terminal connector to the bridge curb. The Kwik-bolt or the Taper-bolt should be adequate and require a drilled hole only as large as the bolt (not available in 7/8 inch size). An equally strong anchorage could be achieved by setting a head bolt in a 4½ inch deep hole, which is ¼ inch greater in diameter than the bolt. The hole can be filled with DHT Type B 102 epoxy binder mixed with sand. This anchorage hole should not be placed closer than 2 inches from the edge of the curb; otherwise, the concrete may fail when the guardrail is hit.

In the case of a curb 12 inches or less in width, blockouts should be used. Blockouts may be of any material that will not severely crush on impact. Sections of round or rectangular wood could be used, with the guardrail mounting bolt extending through the block into the existing bridge rail. The mounting bolts and blockouts should be spaced at 6 foot, 3 inch centers (same as normal guardrail) regardless of the post spacing on the bridge.

The transition problem is compounded by the existence of a large number of different types of bridge rail. Many of our older bridges with curbs have bridge rail that is weak, and in these cases a continuous concrete parapet wall or a strong rail (T101) should be built onto the curb. Highway engineers will often have to be innovative in designing and installing transition sections in some locations, but the general principles already discussed should be followed.

Approximately 20% of the fixed object fatal accidents involve bridge rail systems. Hazards include vehicle penetration of the bridge rail and collisions with the bridge abutment or approach guardrail. The latter condition may be improved by proper approach guardrail installation and attachment to the bridge rail as discussed earlier. The first two hazards will have to be handled by either replacing the bridge rail with a stronger railing or by continuing the approach guardrail across the entire structure.

There are many bridges, mostly in cities, that have decorate bridge railing between concrete posts. These provide no redirection and will snag a vehicle or allow a vehicle to penetrate. It would be desirable to retrofit this type bridge rail on our highway system with a rail system that will provide a smooth and continous barrier across the entire structure.

Guardrail Location:

Guardrail can be used to protect drivers from steep slopes, fixed objects, at bridges, and at medians.

Many design situations dictate the use of a flat side slope next to the roadway and then a steeper slope at 10 to 12 feet from the pavement edge. Sometimes rounding of this slope in design can eliminate the need for guardrail. Slopes should be rounded at the shoulder and at the toe of the slope to reduce the chance of a vehicle becoming airborne. In most cases guardrail is used along embankments with a slope of 3:1 or greater for embankment heights greater than 5 feet. The "Guide For Use of Guard Fence For Embankment Heights And Slopes" curve in the appendix should be used as a guide to determine the situations in which guardrail should be used. It is evident from this curve that flatter embankment slopes may need guardrail for higher enbankments; however, guardrail is not usually needed for slopes of less than 4:1, when there are no other hazards present. It must be kept in mind that a vehicle leaving the roadway and traversing a slope will usually travel to the bottom of the slope, thus the required clear zone for fixed objects may be greater than the 30 foot distance suggested for more or less level terrain.

As already discussed, the guardrail should normally be 150 feet in length for it to perform adequately. Gaps of less than 200 feet between guardrail installations should be avoided, unless roadside geometry will permit desirable terminal layouts. As a general rule guardrail should be placed as far from the roadway as conditions permit to minimize the probability of impact. A chart, shown in the appendix, has been developed to aid in the placement of guardrail with respect to the area of concern. By knowing the distance of the object or area from the roadway, the length of guardrail may be determined.

The use of guardrail at bridges is generally based on the 30 foot clear zone from the edge of the roadway. For bridges with two-way traffic, if the roadway is 60 feet or less wide, then guardrail is required on all four ends of the bridge. If the roadway is greater than 60 feet wide, then guardrail is only installed on two approaches. For one-way traffic guardrail is installed on both sides of the approach. Current practice is to build separate bridge structures on divided highways, which leaves a hazardous opening between the bridges. There are many such situations across the state which should be closed with guardrail. Another hazard is introduced when the median is narrowed by design at the bridge openings as a means of closing the opening, unless median barrier is installed. For narrow medians guardrail is sometimes installed on the approaches to the bridges where the posts and back of the rail is exposed to an errant vehicle traveling between the bridges. In these cases guardrail could be placed on the back of the posts.

Warrants for median barriers are usually based on median width and traffic volumes. The curve shown in the appendix should be used to determine if median barrier is needed at a particular location. For median barriers, the use of the concrete median barrier is encouraged due to its longer design life and low maintenance requirements, and consideration should also be given to using the concrete barrier for a bridge rail. A median barrier should normally be installed for medians of 30 feet and less in width on higher volume highways.

Emergency openings through the median barrier should be avoided because they create another roadside hazard.

Guardrail Replacement Program:

As mentioned before, there are many different types of guardrail and there is still considerable variation in installation and location of guardrail across Texas. In order to bring the guardrail up to current standards in Texas, the following annual work programs have been submitted to and approved by the Federal Highway Administration:

1.	Interstate Safety - Guardrail and Concrete Median Barrier	$ 10,000,000.
2.	Interstate Safety - Upgrading Nonstandard Damaged Guardrail To Current Standards	$ 500,000.
3.	Non-Interstate - Upgrading Existing Nonstandard Guardrail to Current Standards	$ 1,050,000.
4.	Non-Interstate - Upgrading Nonstandard Damaged Guardrail to Current Standards	$ 500,000.
	TOTAL	$ 12,050,000.

The program is broken down into Interstate and Non-Interstate guardrail replacement; however, it is anticipated that a maintenance program will be developed to allow each District to repair or replace damaged guardrail with State Forces to the current standards when immediate repair is needed. If in the opinion of the engineer, the damaged guardrail is not necessary based on current guardrail standards, the guardrail should be removed as part of this program. The Districts will charge this work to a statewide Project Designator (P.D.) number. Each District will keep a record of the work done, which will be periodically verified by Federal Highway Administration field personnel. Records will consist of work orders showing the type and amount of work done.

The major parts of this program will consist of upgrading non-standard guardrail or removing guardrail that is not needed on sections of highway on a project basis. These projects may either be performed by contract or State Forces and will be submitted by the Districts, reviewed in the Austin office, and then submitted to the Federal Highway Administration for approval.

Conclusion:

There is much to do on Texas highways to bring existing guardrail up to current standards, especially on some of the lower class roadways. The guidelines for use and placement discussed should be used, but sound engineering judgement should not be omitted. I see this as a continuing process, because new and better guardrail concepts will continue to be developed. In the future look for stronger bridge rail to be produced and installed that will be capable of containing trucks and buses as a result of some spectacular accidents in Houston. The nested backup plate terminal design may become the new required standard set by the Federal Highway Administration; however, there is still room for the development of a better terminal design. For the present we are faced with the challenge of upgrading our existing guardrail and barrier systems to current standards to provide a safer driving environment for people using Texas highways. It is certain that our efforts will be worthwhile and beneficial for all.

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APPENDIX

GUARDRAIL WARRANTS FOR FIXED OBJECTS AND NONTRANSVERSABLE HAZARDS

1. Sign, traffic signal, and luminaire supports with:

    a) Breakaway or yielding design greater than 1,100 lb.-sec.

    b) Concrete base extending 6 inches or more above the ground

2. Fixed sign bridge supports

3. Bridge piers and abutments at underpasses

4. Retaining walls and culverts

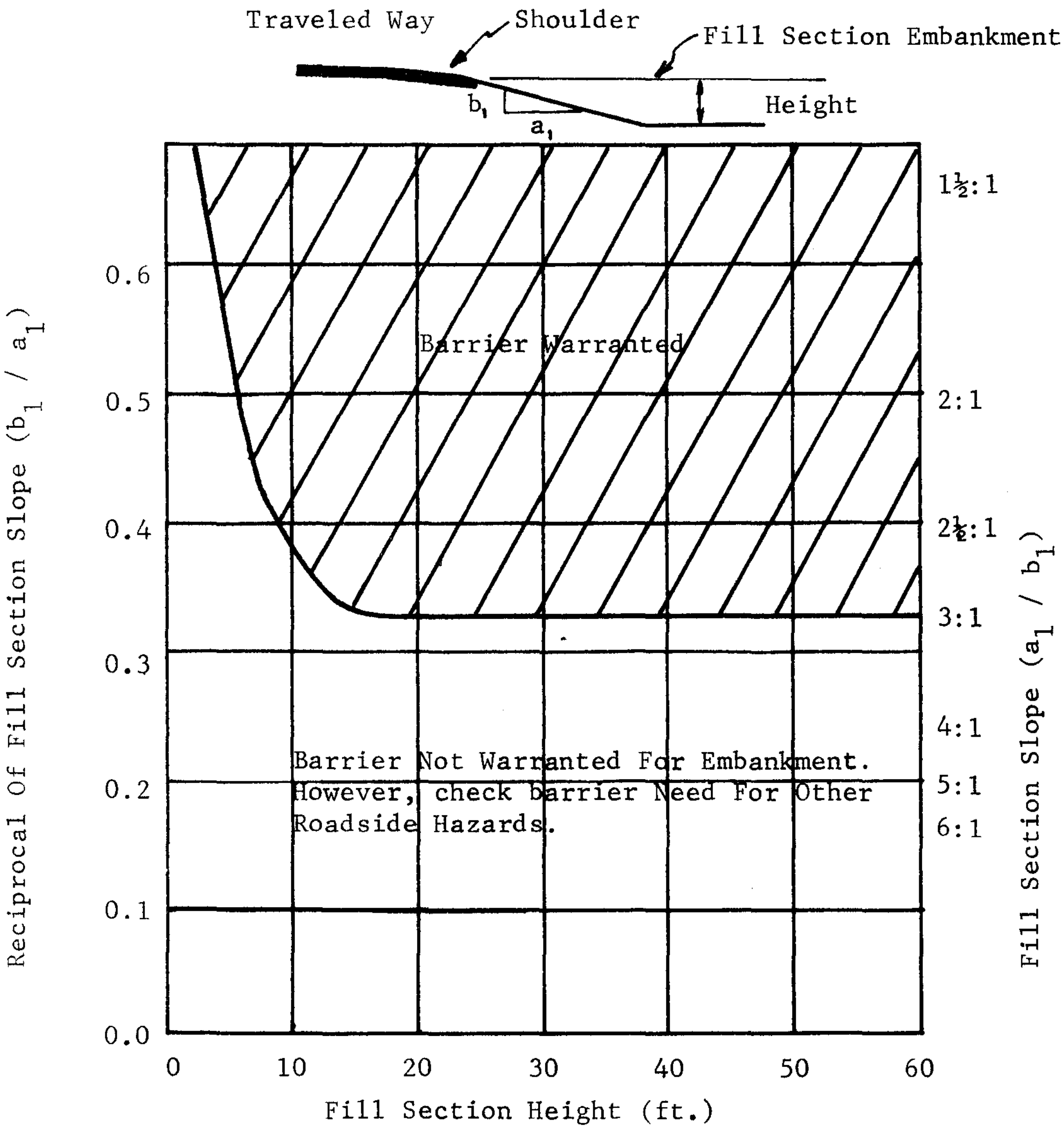
5. Trees with diameter greater than 6 inches

6. Wood poles or posts with area greater than 50 $in.^2$

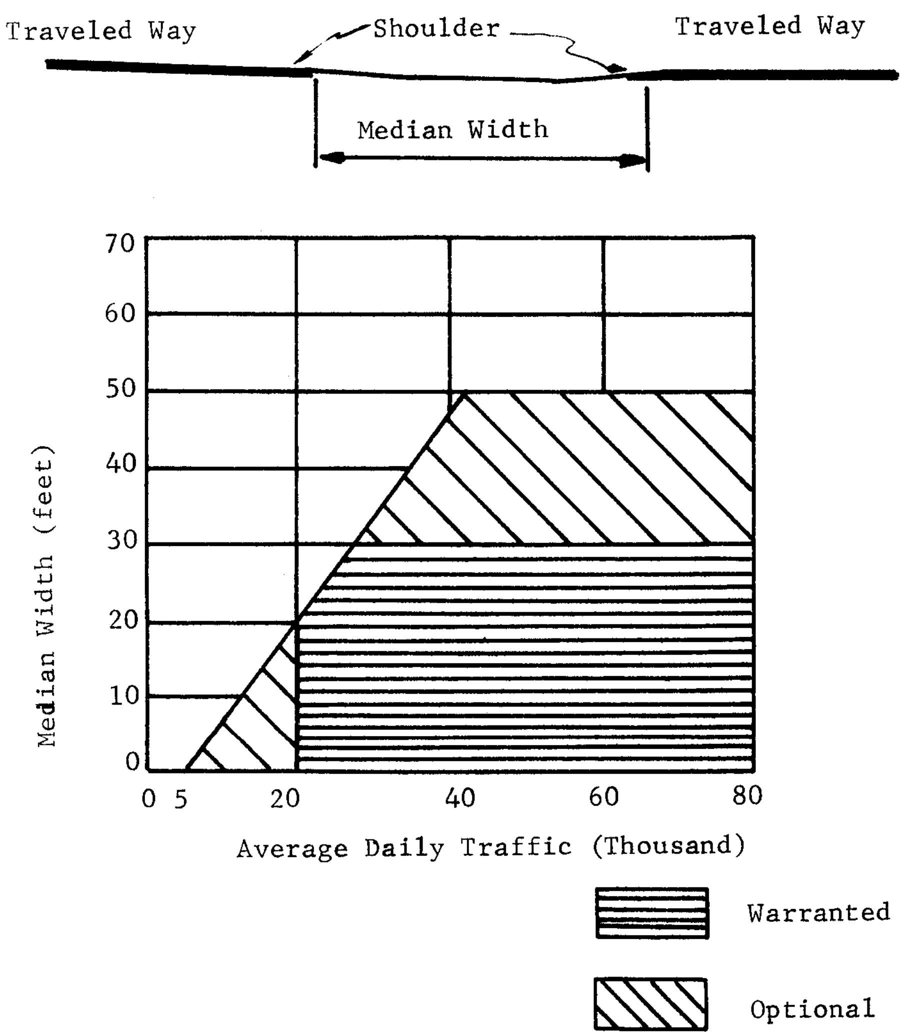
7. Rock cuts or large boulders

8. Streams or permanent bodies of water more than 2 feet deep

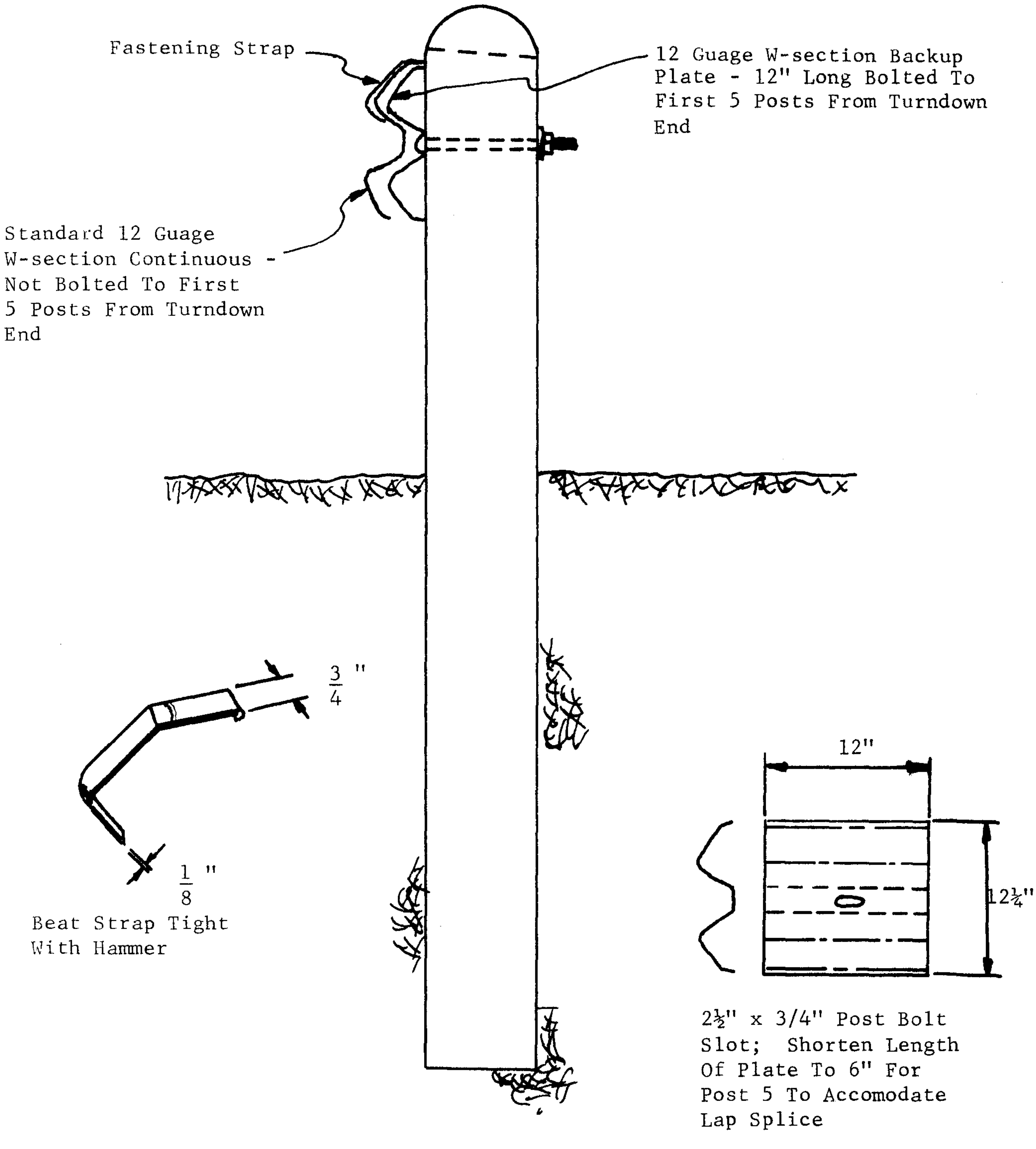
9. Shoulder drop-off with slope steeper than 1:1 and height greater than 2 feet



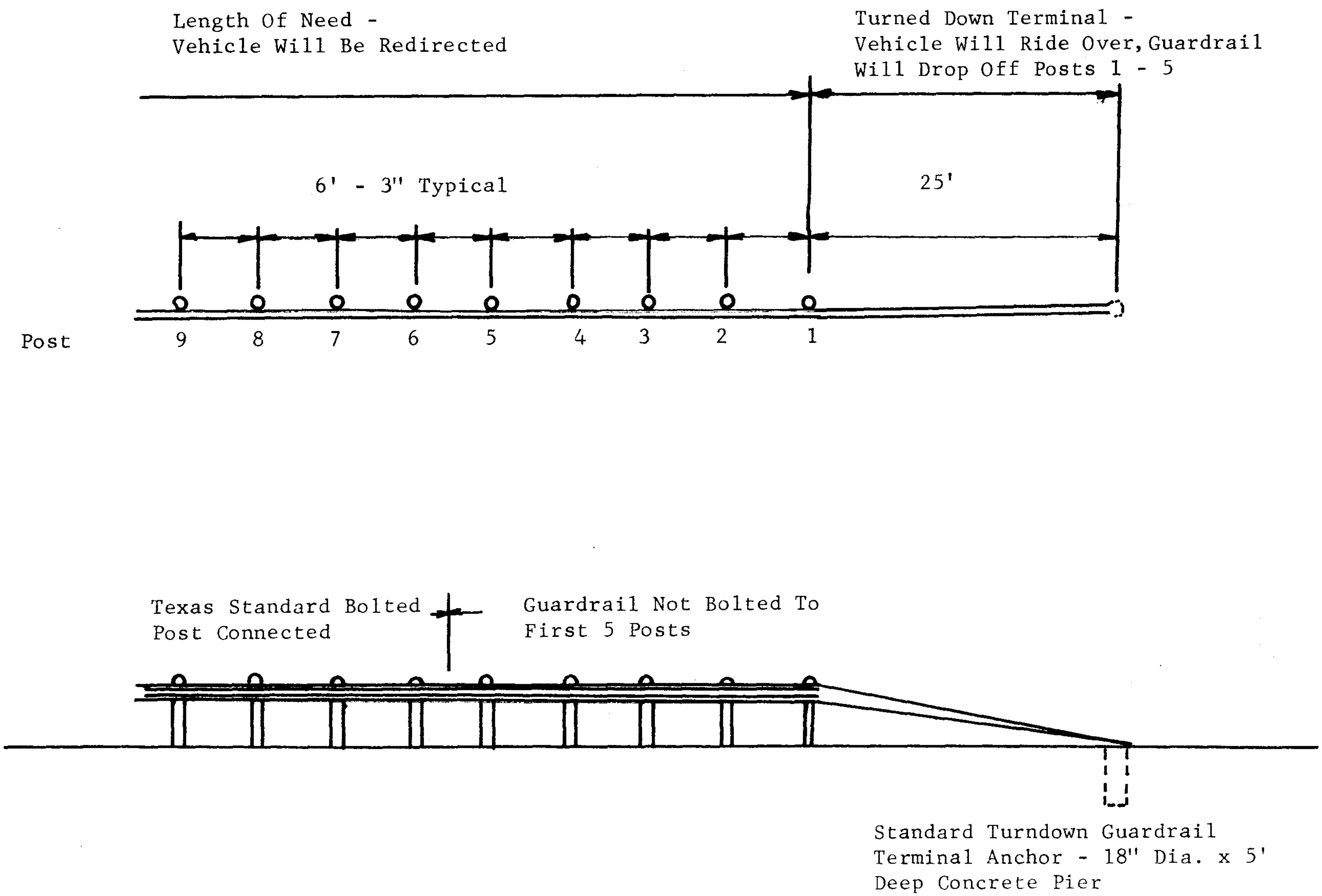
Guide For Use Of Guardrail For Embankment Heights And Slopes



MEDIAN BARRIER WARRANTS



"NESTED" BACKUP PLATE TERMINAL DESIGN



"NESTED" BACKUP PLATE TERMINAL DESIGN