LTAP
KANSAS LOCAL TECHNICAL ASSISTANCE PROGRAM

Guide for Installation and Removal of Handrail and Guardrail on Low-Volume Rural Roads

FIRST EDITION, 2020

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Printing, design and technical assistance for this handbook was provided by the Kansas Local Technical Assistance Program at the University of Kansas Transportation Center.

Cover photo: Norm Bowers

GUIDE FOR INSTALLATION AND REMOVAL OF HANDRAIL AND GUARDRAIL ON LOW-VOLUME RURAL ROADS

Purpose
The purpose of this guide is to provide assistance to local officials and supervisors responsible for maintenance and safety of rural roads. It provides a convenient reference to help address safety concerns commonly encountered in the field related to guardrail and culvert and bridge handrails.

Disclaimer
This guide offers suggestions and guidance for many typical situations that arise on rural roads related to handrail and guardrail. The suggestions and guidance are based on the latest published research on this topic on conditions typical for Kansas rural roads. Specific site conditions may make that guidance inappropriate. The decision to take a particular action should be made on the basis of either an engineering study or the application of engineering judgment. Thus, while this guide provides suggestions and guidance it should not be considered a substitute for engineering judgment and common sense. Many solutions to safety problems are obvious and can be handled in the daily course of business. More difficult problems may need to be referred to a supervisor to make the decision or seek advice from experts. Technical help is available from peers in other local agencies, the Kansas Department of Transportation (KDOT), the Kansas Local Technical Assistance Program (LTAP), the Kansas Association of Counties (KAC), as well as consultants. This guide is not all encompassing and should not be considered as a legal document.

Acknowledgements
The guide is based on research performed at Kansas State University, KDOT, and the University of Nebraska. These studies are listed in the Bibliography. The principal author is Norman L. Bowers, P.S. and P.E., who is the Local Road Engineer at the Kansas Association of Counties. The guide has been reviewed by Clark Rusco, P.E. and Mike Perkins who are both Local Field Liaisons with Kansas LTAP, and also Tod Salfrank, Assistant Bureau Chief of the Kansas Department of Transportation Bureau of Local Projects.

Duty to the motorist
Generally, road agencies have a duty to construct and maintain public roads that are reasonably safe for use by motorists. Kansas state law has also specified three additional specific duties:

- Counties and townships are required to keep their roads in repair and remove or cause to be removed all obstructions (KSA 68-115).
- Cities, counties and townships are required to place and maintain traffic control devices upon roads under their jurisdiction as they may deem necessary to regulate, warn or guide traffic (KSA 8–2005).
- All traffic control devices on public roads must comply with the Manual on Uniform Traffic Control Devices abbreviated as MUTCD (KSA 8-2003).

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GUIDE FOR INSTALLATION AND REMOVAL OF HANDRAIL AND GUARDRAIL ON LOW-VOLUME RURAL ROADS

INTRODUCTION

Roadside Safety Considerations

Road officials try to maintain a reasonably safe road system for the motorists. We know that crashes will occur on our roads for many reasons outside of our control, such as impaired driving. However, we do our part in reducing crashes, and the resulting injuries and property damage, by providing an as safe as possible driving environment within our limited resources.

Most of our local roads have a low traffic count, so multi-vehicle accidents are not as common as they are on state highways. In fact, 77 percent of all crashes on rural local-owned roads are single-vehicle crashes—typically run-off-the road. This is much higher than the 56 percent on state highways. One of the most effective crash reduction strategies is to have a roadside area free of dangerous fixed objects available for safe use by errant vehicles. This area is called the clear zone. Right-of-way limitations or terrain can make it difficult to achieve or maintain a desired clear zone, but we try to make improvements where they are needed within our limited resources.

Traffic safety professionals have studied roadside safety and have developed a priority ranking used to mitigate safety related roadside obstacles. Options for reducing roadside obstacles, in order of preference, are listed below.

1. *Remove* the obstacle
2. *Relocate* the obstacle to a safer place
3. *Redesign* the obstacle
4. *Reduce* impact severity
5. *Shield* with guardrail
6. *Delineate* to guide drivers around it

There are many roadside obstacles in our road right-of-way, some of which we do not have direct control over, such as utility facilities and mailboxes. This guide is concerned about the obstacles that are within local government control: handrails on culverts and bridges, and guardrail for bridges, culverts, and slopes.

Bridge and Culvert Definition

For the purpose of this guide a culvert is a crossroad pipe or a concrete box culvert with a total span of 20 feet or less. A bridge is a box culvert or span structure having a waterway opening measured along the centerline of the roadway greater than 20 feet between undercopings of the abutments or spring lines of arches or extreme ends of openings for multiple boxes and multiple pipes.

STEEL HANDRAILS ON CULVERTS AND BRIDGES

Steel Handrails at Culvert Openings

Old concrete culverts may have steel handrails to mark the end of the culvert. Steel and concrete handrails were a common way of marking cast-in-place culvert ends prior to 1960. In the early 1960's local governments started marking the culvert ends with object markers, and usually omitted the construction of handrails on culverts. Now that culvert ends are marked with object markers in rural areas, steel handrails serve no purpose. The steel handrails are too weak to prevent vehicles from passing over the culvert end, and thus are essentially no safer than omitting the culvert rail completely. In fact, the potential for those rails to damage wide farm equipment and to penetrate the vehicle compartment is likely to make an impact crash more severe than with no handrail. The roadway environment will be made safer if the steel handrail is removed and the culvert end marked with an object marker. Figures 1 thru 4 show typical steel handrails on culverts that if removed will make the roadway environment safer. Pedestrians are not common in rural areas, but if a large culvert is located near a subdivision or park, the handrail may protect pedestrians from falling over the culvert end. In those rare cases consider leaving the handrail in place and modify the rail ends to deter spearing.

Figure 1. Pipe handrail is common in some areas and should be considered for removal.

Source: Norm Bowers

Figure 2. Steel handrail serves no purpose and could be removed.

Source: Norm Bowers

Figure 3. W-beam guardrail serves no purpose and should be considered for removal.

Source: Norm Bowers

Figure 4. W-beam guardrail on a newer culvert that could be removed to enhance safety.

Source: Norm Bowers

Steel Handrail Ends on Bridges

While we typically remove steel handrails on culvert-sized structures, that is not the case on bridges. Steel handrail on bridges may not deflect a standard vehicle at road speed but they may corral a slower speed vehicle or one that hits the rail at a glancing blow. The steel rail also provides a visual delineation of the bridge edge and provides protection for pedestrians. There are two major types of steel bridge rails: 1) standard W-beam guardrail as shown in Figure 5, and 2) some type of structural steel as shown in Figure 6.

Figure 5. W-beam guardrail used for bridge handrail.

Source: Norm Bowers

Figure 6. Structural steel used as handrail above a concrete curb.

Source: Darryl Lutz

As previously stated, a bridge rail is needed to delineate the bridge edge, protect pedestrians, and to provide some degree of deflection for errant vehicles. Exposed guardrail ends can spear into the vehicle, and it is appropriate to mitigate the possibility of spearing by modifying the exposed end. For W-beam guardrail the simplest upgrade is replacing the standard end shoe (fish tail) shown in Figure 5 with a curved end shoe such as the buffer end shoe (boxing glove) shown in Figure 7. The buffer end shoe has not been crash tested but still appears to be a better option than the standard end shoe. If striped sheeting is applied the buffer end shoe also functions as an OM-3.

Figure 7. A buffer end shoe is an alternate to a standard end shoe shown in Figure 5.

Source: Internet

The exposed end of a structural steel handrail can spear a vehicle if struck by the vehicle. To prevent or retard spearing there are a number of options to make it safer. The rail end could be heated and curved outward so the blunt end is not exposed to traffic. The end of the rail could be angled into the ground as shown in Figure 8. If a concrete curb is present, a concrete end post can be poured on top of the curb, and rebar would need to be drilled and grouted into the curb. While these solutions make the end safer, they have not been crash tested and are for the purpose of retarding spearing and are not an upgrade to a tested solution.

Figure 8. Bridge rail bent down to retard spearing.

Source: Darryl Lutz

GUARDRAIL

Guardrail in General

As mentioned before, 77 percent of all crashes on rural locally-owned roads in Kansas are single-vehicle crashes—typically run-off-the road. A good way to reduce deaths, injuries and property damage due to run-off-road crashes is to provide a roadside area free of fixed objects and other hazards, sometimes called a clear zone. Narrow right-of-way widths on low-volume roads limit our ability to provide a wide clear zone. Options for reducing roadside obstacles were included in the Introduction, and in order of preference, are listed again below.

1. *Remove* the obstacle
2. *Relocate* the obstacle to a safer place
3. *Redesign* the obstacle
4. *Reduce* impact severity
5. *Shield* with guardrail
6. *Delineate* to guide drivers around it

Earlier in this guide, removal was recommended for steel handrail on culverts and redesign for exposed ends of bridge rail. At locations where removal or redesign is not practical, shielding with guardrail may be an option. Always remember that guardrail itself is a hazard and is only used when the result of a vehicle striking the guardrail is less severe than colliding with the object the guardrail is designed to shield.

The installation of guardrail on low-volume roads can add costs and other safety and maintenance problems that may outweigh the proposed benefits. Guardrail itself is a fixed object nearer the roadway and longer than the object it shields, potentially resulting in more crashes. Guardrail is also known to increase snow drifting during the winter months, providing an additional maintenance and safety concern. Additionally, grass and weeds that grow near the guardrail cannot be cut by traditional roadside mowers thus requiring workers to use labor-intensive weed cutting devices or chemicals around guardrail posts close to the roadway.

The Federal Highway Administration (FWHA) has standards for guardrail on the National Highway System (NHS), but states and local jurisdictions are given discretion to develop their own policies or guidelines for non-NHS roadways, such as county roads or secondary state highways. It is important to determine the appropriate criteria for placement of guardrail on non-NHS roadways. This guide provides recommendations for removing existing guardrail that has been damaged or has reached its useful life, and for the need for guardrail at typical conditions commonly encountered on low-volume roads. These recommendations are based on common sense and the most recent applicable studies. When uncomfortable with the recommendations, and in non-standard locations, it is appropriate to consult an experienced engineer.

Determining Age of Guardrail Design

The guardrail end terminal is a key indicator of the age and functionality of the guardrail. When guardrail came into use, the original end was the blunt end. Over time, safer end terminals were developed and implemented to reduce the severity of impacts with the guardrail.

Blunt Ends (Pre 1960's)

Blunt ends with no flare were the standard on guardrail prior to 1960. Note in Figure 9 no bracing between the first two posts, and no noticeable flare away from the road. Later versions had a horizontal brace between the first two posts but retained the straight alignment and standard blunt end shoe. When this type of end is impacted, the rail may penetrate the grill, wheel well, or side door of an automobile and then pass through the passenger compartment.

Figure 9. Blunt end.

Source: KDOT

Flared and Anchored Ends (1960's)

Flared and anchored ends were an improvement to blunt ends, and came into common use in the early 1960's. This treatment lessened the severity of vehicle crashes into the end section but serious crashes showed a need for further design improvements. Flared and anchored end treatments still used the blunt end terminal guardrail shoe.

Figure 10. Flared and anchored ends.

Source: KDOT

Turned Down Ends (1970's)

The turned down end treatment was developed in the late 1960's to prevent spearing. The rail was bent down and twisted 90 degrees and anchored flat on the ground. Although these turned-down end treatments were successful at preventing vehicular impalements, several years of field experience and crash testing showed their tendency to not only vault and roll vehicles but also to channel vehicles into an impact with objects that the guardrail was intended to shield. The turned down end treatment is rare on local roads, but if present indicates a 1970's era guardrail.

Figure 11. Turned down end.

Source: John C. Glennon

Breakaway Cable Terminals (1972 to late 1990's)

In the early 1970's, the breakaway cable terminal (BCT) was developed as an alternative to minimize both the spearing and rollover tendencies of earlier end treatments. On end-impacts, the first two posts were designed to break away allowing the rail to bend away from an impacting vehicle. A cable, which anchored the rail to the ground, allowed the beam to function in tension when a side impact occurred near the end. The BCT was the most widely used end treatment for about 20 years. The BCT was modified slightly to improve performance in its "ELT" and "MELT" variations, but eventually was replaced by energy-absorbing and controlled buckling end treatments.

Figure 12. BCT, ELT, and MELT have this general appearance, but vary in details.

Source: Norm Bowers

Current End Terminals (late 1990's to present)

There are two broad categories of end terminals currently in use: non-flared energy absorbing and the flared non-energy absorbing. Both categories are crashworthy but function differently in head-on impacts.

Energy-absorbing end treatments not only prevent vehicle impalements but also allow impacting passenger vehicles to decelerate at a rate tolerable for vehicle occupants. The non-flared rail usually has a blunt end as shown in Figure 13 and Figure 14. Energy absorbing end-terminal systems were available as early as 1990 but were not usually deployed on local roads until the late 1990's.

Figure 13. ET Plus System by Trinity Highway.

Source: Trinity Highway

Figure 14. Energy absorbing terminal by Trinity Products.

Source: Trinity Products

Non-energy absorbing end terminals are flared with a controlled buckling system that retards vehicle spearing.The most common flared end controlled buckling system is the SRT as shown in Figure 15. The flared end is less likely to have a head-on impact and will only dissipate a minimal amount of energy and allow the vehicle to pass through the system.

Figure 15. SRT end terminal by Trinity Products.

Source: Trinity Products

strong enough to function as intended. The W-beam may not be attached to the bridge end. The rail may be low tension cables or another non-traditional rail.

Figure 16. Old style guardrail with blunt ends and no spacers at posts.

Source: FHWA

Evaluating Existing Guardrail

An agency's attention is usually called to a section of existing guardrail due to collision damage. The agency then needs to decide if the guardrail damage should be just repaired in kind, the entire run replaced in kind, entire run upgraded to current standards, or the guardrail removed. The existing guardrail run needs to be physically examined and evaluated. The major factors in existing guardrail include:

- Type of end treatment
- Wood post condition
- Functionality

End treatment: Usually on low-volume roads, breakaway cable terminals (BCT) and newer terminals are acceptable and can be replaced in kind. Older end terminals are outdated and may be more of a hazard than the object being shielded.

Wood posts: Wood guardrail posts have a useful live of about 25 years; maybe longer in drier areas of Kansas. The posts may look good but be rotten at or below the ground line. If there are any broken posts, they can easily be checked for rot. If there are no broken posts it may be necessary to drive a spike into the post below the ground line to determine if the wood is solid. Usually all the posts are in the same condition, so if one post is rotten all the posts are probably rotten.

Functionality: Due to pavement overlays or other changes to the roadway over the years, the guardrail may be at the wrong height. Old guardrail may not have blocks between the post and rail. Old round wood posts are not usually

Repair, Replace or Remove

After evaluating the guardrail run, a decision can be made on the proper course of action.

Repair: If the damage is minor, such as a few damaged posts and some bent rail, or perhaps a damaged end section treatment, the decision will likely be to repair in kind. The insurance company of the driver who caused the damage is usually billed for the repair. If the end treatment, posts and functionality are compromised, the options are obviously replacement or removal.

Removal: Before traffic counts were considered a factor in installing guardrail, there was a tendency to place more guardrail on low-volume roads than is now justified by a benefit-cost analysis. Depending on the situation, check the benefit vs. cost results for the site conditions listed in the next section of this guide. If the cost does not justify the benefits, consider removing the guardrail.

Replacement-in-kind: On low-volume rural roads replacement in kind is usually adequate for guardrail with BCT and newer terminals. This work may involve just installing new posts and damaged rail and hardware.

Replace to current standards: For older style guardrail the alternatives are upgrade to current standards or removal. The older style guardrail includes low tension cable, W-beam guardrail without spacers between the rail and post, and end sections with turned down ends and blunt ends including flared and anchored ends. This older guardrail does not function properly and is not usually replaced in kind. There are many factors to consider when upgrading to current standards—to name just a few: alignment, needed length, fill support behind the posts, grading for approach to the end section, transition to bridge end, and clearance from the shielded object. Services of an engineer and detailed plans are almost always required on guardrail upgrades.

Removal of Inappropriate Guardrail

Guardrail itself is a hazard if struck. The purpose of guardrail is to keep vehicles from striking a more serious hazard. If the guardrail is more of a hazard than the hazard it shields, the guardrail should be removed. Over the years occasionally guardrail has been installed at a location that may be contrary to improving safety. When checking a site, the first question should always be: "What is the bigger hazard here?" If it is obvious that the guardrail should never have been installed, it is not necessary to do a cost-benefit analysis. Figures 16, 17 & 18 illustrate situations where the guardrail is the greater hazard and should be removed.

Figure 17. Guardrail that protects a gentle slope is more of a hazard than the slope.

Source: FHWA

Figure 18. Guardrail is protecting the trees, not vehicles, and should be removed.

Source: Norm Bowers

LOW-VOLUME ROAD SAFETY IMPROVEMENTS BENEFITS VS COSTS

Benefit vs Cost Analysis

Because funding is limited for roadside safety treatments, especially in rural areas on low traffic count roads, prioritization of limited resources is essential. It makes the most sense to concentrate on items that are cost effective; that is, where the cost of the improvement is offset in benefits (which are largely reduction in crashes and resulting accident costs). Before computers were widely in use the cost effectiveness of various safety improvements could not be easily calculated, and typically guardrail and other safety treatments were installed based on physical conditions at the site based on standards. Standards were usually developed by the state highway department based on factors related to state highways and were not often relevant to conditions on low volume rural roads with low traffic counts, slower speeds, shorter trips, and more driver familiarity.

In the 1990's software called ROADSIDE was developed by the American Association of State Highway Transportation Officials (AASHTO). ROADSIDE computed accident costs for combinations of vehicle speeds and site conditions that allowed calculation of benefits for proposed modifications to the road environment. ROADSIDE continued to evolve, and its successor, RSAP (Roadside Safety Analysis Program), has been distributed with the AASHTO *Roadside Design Guide* since the 2002 edition. RSAP is an encroachment-based computer software tool for cost-effectiveness evaluation of roadside safety improvements. The analytical model behind the encroachment-based approach uses a series of conditionally independent probabilities representing vehicle roadside encroachment events, the conditional probability of a crash given a roadside encroachment has occurred, the probable severity of crashes that are likely to occur and the expected benefit vs. cost ratios (B/C) of various roadside design alternatives. The generally accepted threshold for deciding to make a road or bridge improvement based on B/C analysis is between 2.0 and 4.0. KDOT typically uses a B/C of 2.0 as a minimum to support that decision. This guide also uses a minimum B/C of 2.0 to support decisions.

Since the availability of ROADSIDE and RSAP there have been a number of research projects evaluating the B/C of various roadside safety alternatives on low-volume roads. Costs for guardrail projects are almost as high on low-volume roads as on major roads such as state highways. Benefits are reduction in accident costs due to the safety improvement. As might be expected, the probability of a crash occurring at any particular location is directly related to traffic count. This then results in a low annual accident-cost on low-volume roads. Research studies have generally found that many of the types of safety projects that are economically justified on state highways may not be justified on low-volume roads.

This guide summarizes the findings of the research projects for typical situations where guardrail is commonly considered. For non-typical situations or for a range of conditions outside of the studies, an individual analysis by an engineer experienced with using the software will be required. The studies quoted in this guide are:

1. **KSU-2020:** *Guardrail Evaluation for Hazards on Low-Volume Rural Roadways in Kansas Using RSAP*, by Wang & Fitzsimmons. KTRAN KSU 19-4, Kansas State University 2020.
2. **Nebraska-2012:** *Cost-Effective Safety Treatments for Low-Volume Roads*, by Schrum, Sicking, and other., MwRSF Research Report No. TRP-03-222-12, University of Nebraska 2012.
3. **KDOT-2014:** *Guardrail and Bridge Rail Recommendations for Very Low-Volume Local Roads in Kansas*, by Seitz & Salfrank. Report No. KS-14-16 KDOT 2014.
4. **KDOT-2017:** *Guardrail and Bridge Rail Recommendations for Very Low-Volume Local Roads in Kansas Addendum*, by Seitz & Salfrank. Report No. KS-17-03 KDOT 2017.
5. **KSU-1998:** *Guidelines For Removal of Handrails on Narrow Culverts and Bridges*, by Melhem, Russell and others. KTRAN KSU 97-3, Kansas State University 1998.

All of these studies involve typical situations in Kansas, and evaluation of accident histories in addition to calculating B/C. Complete information is included in the Bibliography section of this guide.

Ornamental Concrete Handrails on Culverts

Between 1920 and the late 1950's the standard box culvert in Kansas included a concrete post-and-beam handrail as shown in Figure 19. There were also many other kinds of concrete handrails constructed since concrete construction became common in the late 1800's.

Figure 19. Standard post and beam concrete handrail could be removed to make a safer roadside.

Source: Norm Bowers

Figure 20. One example of many non-standard handrails constructed in Kansas pre 1950's.

Source: Norm Bowers

Many types of concrete rails on old culverts are not crash-worthy and will result in a sudden stop if struck by an errant vehicle. In many cases these handrails may be more of a hazard to the motorist than the ditch or streambed that would be impacted if the handrail was not present. A study performed by Kansas State University (KSU-1998) compared crash costs at culverts with and without the concrete handrail in place using ROADSIDE software. The study found that when the depth from the road shoulder to the streambed was 8 ft or less the accident cost was less when the concrete handrail was not present. Based on these results it is a safety improvement to remove the handrail if the depth is 8 ft or less from shoulder to stream; if more than 8 ft, the handrail should remain in place. A 2012 study at the University of Nebraska (Nebraska-2012) studied various scenarios up to 500 ADT (average daily traffic). The study found that for slopes flatter than 2:1, removal of handrail was cost justified (B/C=2) in all cases where traffic count was less than 249 ADT. For steeper slopes and higher traffic counts refer to the full study.

Summary: In summary, considering both studies under normal conditions it is a safety improvement to remove concrete handrail at locations where the depth to the streambed is 8 ft or less and the traffic count is less than 249 ADT. For traffic counts exceeding 249 ADT refer to the Nebraska-2012 study results for the specific site conditions. Both studies assumed normal conditions on the slopes and did not anticipate deep water. Larger culverts may span water from a lake or pond, and if normal water level is more than a few feet deep consider leaving the handrail in place. Handrails protect pedestrians from falling over the culvert end, but there are few pedestrians in a rural area. For large culverts, consider leaving the handrail in place where pedestrians are expected, such as near a fishing area or rural subdivision.

Guardrail on Crossroad Culverts

Crossroad culverts are placed in streams to carry water under the road. As mentioned earlier, culverts are smaller than bridges and include pipes and box culverts with a clear span of 20 feet or less. The culvert opening upstream and downstream is a hazard if struck by an errant vehicle. Often guardrail is installed across the road fill near the shoulder as shown in Figure 21. However, on low-volume roads the cost of the guardrail may not be offset by the reduction in crash costs if the guardrail were not present. Typical Kansas culvert situations were the subject of two studies mentioned above: KSU-2020 and Nebraska-2012.

Figure 21. Guardrail protecting a culvert opening.

Source: FHWA

The KSU-2020 study focused on two-track gravel roads as shown in Figure 22, and three-track gravel roads or paved roads as shown in Figure 21. A two-track gravel road is typical of a township road or local county road. A three- or four-track gravel or paved road is typical of a major county through-road, which is wider and carries more traffic than the two-track gravel road.

Figure 22. Two-track gravel road.

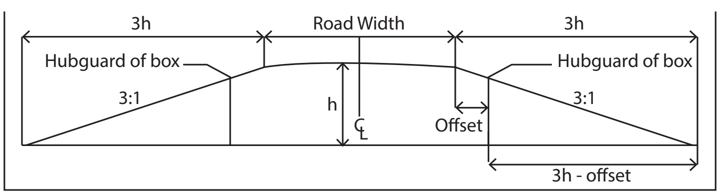
Source: Norm Bowers

Roadway widths of two-wheel-track roads in the KSU-2020 study were 18 ft, 20 ft, 22 ft, and 24 ft, with the 10 ft width wheel track in the center of the road defining the lane width. Any extra space on the roadway besides the 10 ft lane width was considered the shoulder width. The AADT (annual average daily traffic) used in the study was 100 and 200 vehicles per day.

Three- or four-wheel-track gravel or paved roads in the KSU-2020 study consisted of two 12 ft lanes. Roadway widths were 24 ft, 26 ft, and 28 ft with the extra over 24 ft considered shoulder. After deducting the two-lane width from the road, shoulder widths were 0 ft, 1 ft, and 2 ft The AADT for three- or four-wheel-track gravel or paved roads in this study were 100, 400, and 1,000 vehicles per day.

Speeds in the KSU-2020 study were 45 MPH and 55 MPH. Depth from road to flow line of the culvert was 10 ft and 14 ft Span of the box culvert was 20 ft—the maximum for a culvert. The foreslope was 3:1. The hub guard offset from the road shoulder was 0 ft, 2 ft and 4 ft See the cross section in Figure 23.

Figure 23. Cross section of culvert simulation.



Source: Kansas-2020 study

Two Wheel Track Gravel Road

Table 1 shows the various parameters in the KSU-2020 study for a two-wheel track gravel road.

Table 1. Parameters on two wheel track gravel roads in the KSU-2020 study.

Road Width	Vehicles per day (ADT)	Shoulder w/10 ft lane	Hub guard offsets from shoulder	Speeds	Culvert Height (h) or (drop)
18 ft.	100 & 200	4 ft.	0, 2, & 4 ft.	45 & 55 MPH	10 & 14 ft.
20 ft.	100 & 200	5 ft.	0, 2, & 4 ft.	45 & 55 MPH	10 & 14 ft.
22 ft.	100 & 200	6 ft.	0, 2, & 4 ft.	45 & 55 MPH	10 & 14 ft.
24 ft.	100 & 200	7 ft.	0, 2, & 4 ft.	45 & 55 MPH	10 & 14 ft.

KSU-2020 study conclusion for a two-track road: The results of the analysis on all scenarios was a B/C ratio of less than 0.1. A B/C of 2 or greater is used by most agencies to justify safety improvements. The conclusions of the study were that guardrail to protect culvert openings is not cost justified. Study limitations were 200 vehicles per day, minimum of 18 ft between hub guards, 20 ft span culvert, maximum height of 14 feet, 3:1 or flatter foreslope, and straight alignment.

Nebraska-2012 study conclusion for a two-track road: The Nebraska study evaluated various foreslopes at the culvert, and traffic counts to 500 ADT. The study assumed two travel lanes 12 ft wide with the hub guard 1 ft from the edge of the road. With a 2:1 foreslope or flatter, and a Benefit/Cost of 2 or greater, guardrail was never found justified below 250 ADT. See Table 14 in the Appendix for the recommendations based on height, span, and foreslope.

Combined conclusions for a two-track road: On two-track gravel roads, guardrail across culvert openings are not cost justified with traffic counts less than 200 ADT and foreslopes flatter than 2:1. Consider removing rather than replacing guardrail that is no longer functional if within study parameters. The road should be on a straight alignment, the foreslope should be free of obstructions such as trees, free of deep water in the channel, such as backwater from a pond or lake, and the site should be properly signed. Guardrail is not justified on new projects within study parameters if the foreslope is 3:1 or flatter and hub guards do not narrow the road.

Figure 24. One of many variations of culvert openings.

Source: MwRSF Report No. TRP-03-222-12

Three- or Four-Wheel-Track Gravel or Paved Road

Table 2 shows the various parameters in the KSU-2020 study for three- or four-wheel-track gravel or paved roads.

Table 2. Parameters on three- or four-wheel-track gravel or paved roads in the KSU-2020 study.

Road Width	Vehicles per day (ADT)	Shoulder w/2 12 ft lanes	Hub guard offsets from shoulder	Speeds	Culvert Height (h) or (drop)
24 ft.	100, 400 & 1000	0 ft.	0, 2, & 4 ft.	45 & 55 MPH	10 & 14 ft.
26 ft.	100, 400 & 1000	1 ft.	0, 2, & 4 ft.	45 & 55 MPH	10 & 14 ft.
28 ft.	100, 400 & 1000	2 ft.	0, 2, & 4 ft.	45 & 55 MPH	10 & 14 ft.

Kansas-2020 study conclusion for three- or four-wheel-track gravel or paved roads: The results of the analysis on all scenarios was a B/C of less than 0.23. A B/C of 2 or greater is used by most agencies to justify safety improvements. The conclusions of the study were that guardrail to protect culvert openings is not cost justified. Study limitations were 1000 vehicles per day, minimum of 24 ft between hub guards, 20 ft span culvert, maximum height of 14 feet, 3:1 or flatter foreslope, and straight alignment.

Nebraska-2012 study conclusion for three- or four-wheel-track gravel or paved roads: The Nebraska study evaluated various foreslopes at the culvert and traffic counts to 500 ADT. This study evaluated existing culvert situations and assumed the culvert hub guard was 1 ft from the edge of the road. The study assumed two travel lanes 12 ft wide. With a 3:1 foreslope or flatter and a Benefit/Cost of 2 or greater guardrail was never found justified below 250 ADT. See Table 14 in the Appendix for the recommendations based on height, span, and foreslope.

Combined conclusion for three- or four-wheel-track gravel or paved roads:

Traffic count less than 250 ADT & 3:1 or flatter foreslopes: Both the KSU-2020 and Nebraska-2012 studies found that guardrail is not cost justified with 3:1 foreslopes or flatter and less than 250 ADT.

Traffic counts above 250 ADT & 3:1 or flatter foreslopes: The KSU-2020 study found that guardrail was not cost justified at 3:1 or flatter foreslopes up to 1000 ADT. But the Nebraksa-2012 study differed from the KSU-2020 study and found justification for guardrail in some situations at 3:1 or flatter foreslopes and traffic counts above 250 ADT. The Nebraska-2012 study assumed a 1 ft hub guard offset. At 3:1 or flatter foreslopes and above 250 ADT, it would be conservative to use the Nebraska-2012 results listed in Table 14 when hub guard offsets are 3 feet or less. Use the KSU-2020 finding of no guardrail justified if the hub guard offset is more than 3 feet.

Foreslopes steeper than 3:1: Use findings of the Nebraska-2012 study listed in Table 14 when the foreslope is steeper than 3:1. Consider removing rather than replacing guardrail that is no longer functional if within study parameters and above conclusions. The road should be on a straight alignment, foreslope should be free of obstructions such as trees and deep water in the channel, such as backwater from a pond or lake, and site properly signed. On new projects guardrail is not cost justified within study parameters if the foreslope is 3:1 or flatter and the hub guard offset is more than 3 ft from road shoulder.

Guardrail Along Embankments

Occasionally low-volume roads are raised above the natural ground and built on fill material. The foreslope from the shoulder to the natural ground can be a hazard for errant vehicles. Often guardrail is installed along the shoulder to prevent a vehicle from travelling down the foreslope. However, on low-volume roads the cost of the guardrail may not be offset by the reduction in crash costs if the guardrail was not present. Typical Kansas fill situations were the subject of two studies: Kansas-2020 and Nebraska-2012.

Two-Track Gravel Roads Along Embankments

KSU-2020 study conclusion for two-track gravel roads: The embankment simulation included one alternative with a bare embankment and another alternative with a guardrail to shield the embankment. The embankment simulations were almost identical to the culvert simulations, except that the embankments had 2:1, 3:1, and 4:1 slopes, and the height of fill was 6, 12, and 18 feet. Table 3 shows the various parameters in the study for two-track gravel roads.

Table 3. Parameters on two wheel track gravel roads with embankments in the Kansas-2020 study.

Road Width	Vehicles per day (ADT)	Shoulder w/10 ft lane	Slope	Speeds	Fill Height (h) or (drop)
18 ft.	100 & 200	4 ft.	2:1, 3:1 & 4:1	45 & 55 MPH	6, 12, & 18 ft.
20 ft.	100 & 200	5 ft.	2:1, 3:1 & 4:1	45 & 55 MPH	6, 12, & 18 ft.
22 ft.	100 & 200	6 ft.	2:1, 3:1 & 4:1	45 & 55 MPH	6, 12, & 18 ft.
24 ft.	100 & 200	7 ft.	2:1, 3:1 & 4:1	45 & 55 MPH	6, 12, & 18 ft.

Conclusion for two-track roads with embankment: The results of the analysis on all scenarios was a benefit/cost negative or near zero. The possibility of minor crashes associated with the new guardrail outweighed the crashes travelling down the slope. A benefit/cost of 2 or greater is used by most agencies to justify safety improvements. The conclusions of the study were that guardrail to protect fills is not cost justified. Study limitations were 200 vehicles per day, minimum road width of 18 ft, maximum fill height of 18 feet, 2:1 or flatter foreslope, and straight alignment. Consider removing rather than replacing guardrail that is no longer functional if within study parameters and considering the above conclusions. The road should be on a straight alignment, foreslope should be free of obstructions such as trees and deep water in the channel, such as backwater from a pond or lake, and site properly signed. On new projects guardrail is not cost justified within study parameters if foreslope is 3:1 or flatter.

Three- or Four-Wheel-Track Gravel or Paved Roads Along Embankments

KSU-2020 study conclusion for three- or four-wheel-track gravel or paved roads:

The embankment simulation, which included one alternative with a bare embankment and another alternative with a guardrail to shield the embankment. The embankment simulations were almost identical to the culvert simulations, except that the embankments had 2:1, 3:1, and 4:1 slopes, and the height of fill was 6, 12, and 18 feet. Table 3 shows the various parameters in the study for three- or four-wheel-track gravel or paved road.

Table 4. Parameters on three- or four-wheel-track gravel or paved roads in the KSU-2020 study.

Road Width	Vehicles per day (ADT)	Shoulder w/2 12 ft lanes	Slope	Speeds	Fill Height (h) or (drop)
24 ft.	100, 400 & 1000	0 ft.	2:1, 3:1 & 4:1	45 & 55 MPH	6, 12, & 18 ft.
26 ft.	100, 400 & 1000	1 ft.	2:1, 3:1 & 4:1	45 & 55 MPH	6, 12, & 18 ft.
28 ft.	100, 400 & 1000	2 ft.	2:1, 3:1 & 4:1	45 & 55 MPH	6, 12, & 18 ft.

KSU-2020 study conclusion for three- or four-wheel-track gravel or paved roads with embankment: The results of the analysis on all scenarios was a negative benefit/cost, meaning that guardrail implementation to shield embankments is not justified in terms of benefit-cost analysis. The minor crashes associated with the new guardrail overweighed the crashes travelling down the slope. A benefit/cost of 2 or greater is used by most agencies to justify safety improvements. The conclusions of the study were that guardrail to protect fills is not cost justified. Study limitations were 100 vehicles per day, minimum road width of 24 ft, maximum fill height of 18 feet, 2:1 or flatter foreslope, and straight alignment.

Nebraska-2012 study conclusion for three- or four-wheel-track gravel or paved roads with embankment: The Nebraska study analyzed embankments at 1.5:1, 2:1, and 3:1 with traffic counts up to 500 ADT. For 3:1 foreslopes at Benefit/Cost =2, guardrail was not justified, which agrees with the Kansas-2020 study. At 2:1 foreslope, guardrail was sometimes justified with fill greater than 7 feet and traffic count exceeding 250 ADT.

Combined conclusion three- or four-wheel-track gravel or paved roads with embankment: Considering both the Kansas 2020 and Nebraska-2012 study it is apparent that guardrail is not cost justified with 3:1 foreslope or flatter. For fills exceeding 7 feet and steeper than 3:1 with traffic counts exceeding 250 ADT, the Nebraska-2012 study may recommend guardrail. Refer to the Nebraska-2012 study for recommendations based on specific site conditions. Consider removing rather than replacing guardrail that is no longer functional if within study parameters and above conclusions. The road should be on a straight alignment, foreslope should be free of obstructions such as trees and deep water in the channel, such as backwater from a pond or lake, and the site properly signed. On new projects guardrail is not cost justified within study parameters if foreslope is 3:1 or flatter.

Bridge Rail and Approach Guardrail

Bridge approach guardrail and crash tested bridge rail are a major expense on a bridge project. Historically in Kansas federally-funded bridge projects were required to use KDOT standards for bridge rail and approach guardrail. These items are expensive which may outweigh the expected safety benefits on many low-volume applications. Local agencies on local-funded bridge replacements seldom use KDOT standards on low-volume roads, and typically use a W-beam rail with steel posts for a bridge rail and may omit the approach guardrail. A typical local bridge with W-beam rail and no approach guardrail is shown in Figure 25.

Figure 25. Typical local-funded bridge on a low-volume road.

Source: KDOT

Table 5. Parameters on two wheel track gravel roads in the KSU-2020 study.

Road Width	Vehicles per day (ADT)	Bridge Width	Speeds	Bridget Height (h) or (drop)
18 ft.	100 & 200	20 & 24 ft.	45 & 55 MPH	12 ft.
20 ft.	100 & 200	20 & 24 ft.	45 & 55 MPH	12 ft.
22 ft.	100 & 200	20 & 24 ft.	45 & 55 MPH	12 ft.
24 ft.	100 & 200	20 & 24 ft.	45 & 55 MPH	12 ft.

The concern with using KDOT standards on low-volume roads is basically cost, and if the benefits justify the cost. The concern with using W-beam bridge rail and no approach guardrail is whether the cost savings are outweighed by potential increase in accident costs.

Bridge Rail and Approach Guardrail on Two-Track Gravel Roads

Two KDOT studies: The KDOT-2014 study examined bridges with maximum of 50 ft length and 50 ADT. This study included an RSAP analyses as well as examining 5 years of statewide crash data. The RSAP analysis assumed a two wheel track road with the vehicle lane in the center 10 feet. The conclusion was that the risk of fatal or serious injury crashes occurring at shorter low-volume bridges is very low. In addition, on a system-wide basis, the costs of including a crash-tested bridge rail and approach guardrail cannot be justified because they exceed the anticipated reductions in crash costs. The KDOT-2017 study was an addendum to the KDOT-2014 study and reached the same conclusions for bridges with maximum of 100 ft length and 100 ADT. These two reports were submitted to FHWA and W-beam bridge rail without approach guardrail is allowed on federally funded bridge replacement projects meeting requirements listed in the studies, one of which was a minimum 24 ft wide bridge.

KSU-2020 study conclusion for bridges on two-wheel track roads: The KSU-2020 study expanded the analysis of the above KDOT studies to 200 ADT, 120 ft bridge, and various bridge widths. Parameters were similar to the culvert and embankment analysis, and are shown in Table 5.

The results of the analysis on all scenarios was a B/C ratio of less than 0.1. A B/C of 2 or greater is used by most agencies to justify safety improvements. The conclusions of the study were that W-beam bridge rail with no approach guardrail is justified within study limitations. Study limitations were 200 vehicles per day, minimum of 20 ft bridge width, and maximum length of 120 feet.

Nebraska-2012 study conclusion for bridges on two-wheel track roads: The Nebraska-2012 study did not treat any bridges as one lane in the center of the bridge. The study included a drop to 20 feet and bridge length to 150 feet. Using their listed offsets from the traffic lane and B/C of 2 the study justified W-beam bridge rail with no approach guardrail for all situations with traffic count below 200 ADT.

Combined study conclusions for bridges on two wheel track roads: Combining the results of these four studies, B/C would indicate a W-beam bridge rail without approach guardrail is justified for a 20 ft wide or wider bridge if the traffic count is less than 200 ADT. Consider removing rather than replacing approach guardrail that is no longer functional if within study parameters. On new projects consider just a W-beam bridge rail if within study parameters. Because these guidelines were based solely on B/C analyses, the engineer is encouraged to use these guidelines as foundational. Other factors to consider include accident history at the location or similar locations in the area, depth of water, bridge narrower than approach roadway, alignment and sight distance. Some locations may require more robust treatment options.

Bridge Rail and Approach Guardrail on Three- or Four-Wheel-Track Gravel or Paved Roads

KSU-2020 study conclusion for bridges on three- or four-wheel-track gravel or paved roads: The KSU-2020 study studied the B/C of W-beam bridge rail with blunt ends in lieu of crash tested TL-2 bridge rail with approach guardrail on three- or four-wheel-track gravel or paved roads. Parameters were similar to the culvert and embankment analyses and are shown in Table 6.

Table 6. Parameters on three- or four-wheel-track gravel or paved roads road in the KSU-2020 study.

Road Width	Vehicles per day (ADT)	Bridge Width	Speeds	Culvert Height (h) or (drop)
24 ft.	100, 400 & 1000	20, 22, 24, & 28 ft.	45 & 55 MPH	12 ft.
26 ft.	100, 400 & 1000	20, 22, 24, & 28 ft.	45 & 55 MPH	12 ft.
28 ft.	100, 400 & 1000	20, 22, 24, & 28 ft.	45 & 55 MPH	12 ft.

The results of the analysis on all scenarios was a B/C ratio of less than 1. A B/C of 2 or greater is used by most agencies to justify safety improvements. The conclusions of the study were that the use of W-beam bridge rail with no approach guardrail is justified within study limitations. Study limitations were 1000 vehicles per day, minimum of 20 ft bridge width, and maximum length of 120 feet.

Nebraska-2012 study conclusion for bridges on three- or four-wheel-track gravel or paved roads: The Nebraska-2012 study related to bridges was similar to the above analysis using two 12 ft lanes. The bridge height varied to a maximum of 20 feet, and a bridge narrower than the two 12 ft lanes was not considered. Results of Nebraska study using a B/C of 2 or greater indicated on a 50 ft x 24 ft wide bridge a crashworthy bridge rail and approach guardrail is justified at 400 ADT with a 20 ft drop, and 450 ADT with a 13 ft drop.

Combined conclusion for bridges on three- or four-wheel-track gravel or paved roads: Combining the results of these two studies B/C would indicate a W-beam bridge rail without approach guardrail is justified for a 24 ft wide or wider bridge if the traffic count is less than 400 ADT. Consider removing rather than replacing approach guardrail that is no longer functional if within study parameters and above conclusions. On new projects consider just a W-beam bridge rail if within study parameters and combined conclusions. Because these guidelines were based solely on B/C analyses the engineer is encouraged to use these guidelines as foundational. Other factors to consider include crash history at the location or similar locations in the area, depth of water, bridge narrower than approach roadway, alignment, and sight distance. Some locations may require more robust treatment options.

OVERALL SUMMARY

This guide offers suggestions and guidance based on the latest research for many typical situations that arise on low-volume rural roads related to handrail and guardrail. Specific site conditions may make that guidance inappropriate. This guide provides suggestions and guidance but it should not be considered a substitute for engineering judgment and common sense. Many solutions to safety problems are obvious and can be handled in the daily course of business. Unusual situations should be referred to a supervisor to make the decision or seek advice from experts.

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Table 14. Culvert Recommendations by ADT, Road Width < 30 ft, Foreslope Cross-Section B/C=2.

Drop Height H	Culvert Length L	Slope Rate SR	Do Nothing	Remove Posts	Install Guardrail	Culvert Grate if wingwalls, else Remove Posts	Culvert Grate if wingwalls, else Install Guardrail	Culvert Grate
< 2 ft	< 5 ft	1.5:1	0-99		100-500			
		2:1	0-49	50-249	250-500			
		≥ 3:1		0-500				
	5 - 10.9 ft	1.5:1	0-49	50-99	100-500			
		2:1		0-299	300-500			
		≥ 3:1		0-500				
	≥ 11 ft	1.5:1	0-49	50-99	100-500			
		2:1	0-49	50-299	300-500			
		≥ 3:1		0-500				
2 - 3.9 ft	< 5 ft	1.5:1	0-49	50-99	100-500			
		2:1		0-249	250-500			
		3:1		0-449	450-500			
		4:1		0-349		350-449		450-500
		≥ 6:1		0-500				
	5 - 6.9 ft	1.5:1	0-49	50-99	100-500			
		2:1		0-299	300-500			
		3:1		0-449	450-500			
		4:1		0-399		400-500		
		≥ 6:1		0-500				
	7 - 8.9 ft	1.5:1	0-149		150-500			
		2:1		0-299	300-500			
		3:1		0-449	450-500			
		4:1		0-449		450-500		
		≥ 6:1		0-449				
	≥ 9 ft	1.5:1	0-49	50-99	100-500			
		2:1		0-249	250-500			
		3:1		0-399	400-500			
		≥ 4:1		0-500				
4 - 7.9 ft	< 5 ft	1.5:1	0-49	50-99	100-500			
		2:1	0-49	50-249	250-500			
		3:1		0-299	300-500			
		4:1		0-299		300-399	400-449	450-500
		6:1		0-449			450-500	
		≥ 8:1		0-500				
	5 - 6.9 ft	1.5:1	0-49	50-99	100-500			
		2:1	0-49	50-249	250-500			
		3:1		0-299	300-500			
		4:1		0-399			400-500	
		6:1		0-449	450-500			

Source: MwRSF Research Report No. TRP-03-222-12

Drop Height H	Culvert Length L	Slope Rate SR	Do Nothing	Remove Posts	Install Guardrail	Culvert Grate if wingwalls, else Remove Posts	Culvert Grate if wingwalls, else Install Guardrail	Culvert Grate
4 - 7.9 ft	5 - 6.9 ft	≥ 8:1		0-500				
	7 - 10.9 ft	1.5:1	0-49	50-99	100-500			
		2:1	0-49	50-249	250-500			
		3:1		0-299	300-500			
		4:1		0-399	400-500			
		6:1		0-449	450-500			
		≥ 8:1		0-500				
	≥ 11 ft	1.5:1	0-49	50-99	100-500			
		2:1		0-249	250-500			
		3:1		0-399	400-500			
		≥ 4:1		0-500				
≥ 8 ft	< 5 ft	1.5:1	0-49	50-99	100-500			
		2:1	0-49	50-249	250-500			
		3:1	0-49	50-199		200-249	250-349	350-500
		4:1	0-49	50-199	200-299			300-500
		6:1	0-49	50-449	450-500			
		≥ 8:1	0-49	50-500				
	5 - 6.9 ft	1.5:1	0-49	50-249	250-500			
		2:1	0-49	50-249	250-500			
		3:1	0-49	50-249	250-349		350-500	
		4:1	0-49	50-299		300-349	350-399	400-500
		6:1	0-49	50-299		300-349	350-399	400-500
		8:1	0-49	50-299		300-349	350-399	400-500
		Flat	0-49	50-500				
	7 - 10.9 ft	1.5:1	0-99		100-500			
		2:1	0-49	50-249	250-500			
		3:1		0-249	250-500			
		4:1		0-299	300-399		400-500	
		6:1		0-449	450-500			
		8:1		0-449	450-500			
		Flat		0-500				
	≥ 11 ft	1.5:1	0-99		100-500			
		2:1	0-49	50-249	250-500			
		3:1		0-249	250-500			
		4:1		0-299	300-500			
		6:1		0-399	400-500			
		8:1		0-449	450-500			
		Flat		0-500				

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