

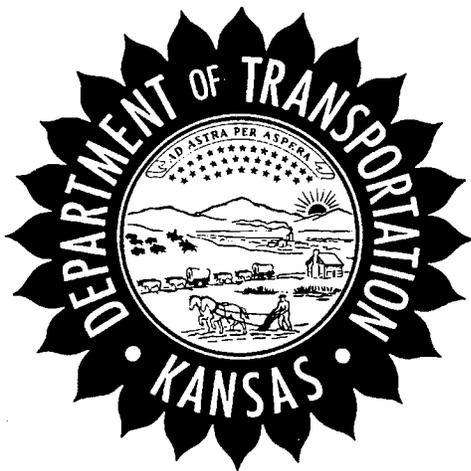


PB99-155558

Report No. K-TRAN: KSU-97-7
Final Report

GUIDELINES FOR REMOVAL OF HANDRAILS ON NARROW CULVERTS AND BRIDGES

Hani G. Melhem
Rafael E. Morice
Eugene R. Russell
Bob L. Smith
Kansas State University
Manhattan, Kansas



April 1999

K-TRAN

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

**A COOPERATIVE TRANSPORTATION RESEARCH PROGRAM BETWEEN:
KANSAS DEPARTMENT OF TRANSPORTATION
THE KANSAS STATE UNIVERSITY
THE UNIVERSITY OF KANSAS**



**GUIDELINES FOR REMOVAL OF HANDRAILS
ON NARROW CULVERTS AND BRIDGES**

Final Report
on Research Sponsored by the
Kansas Department of Transportation (KDOT)
Project K-TRAN:KSU 97-7
and the
Mid-America Transportation Center (MATC)
Project MATC/KSU 97-3

by

Hani G. Melhem
Rafael E. Morice
Eugene R. Russell
Bob L. Smith

Department of Civil Engineering
Kansas State University
Manhattan, KS 66506

April 1999

PROTECTED UNDER INTERNATIONAL COPYRIGHT
ALL RIGHTS RESERVED.
NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE



PREFACE

This research project was funded by the Kansas Department of Transportation K-TRAN research program and the Mid-America Transportation Center (MATC). The Kansas Transportation Research and New-Developments (K-TRAN) Research Program is an ongoing, cooperative and comprehensive research program addressing transportation needs of the State of Kansas utilizing academic and research resources from the Kansas Department of Transportation, Kansas State University and the University of Kansas. The projects included in the research program are jointly developed by transportation professionals in KDOT and the universities.

NOTICE

The authors and the State of Kansas do not endorse products or manufacturers. Trade and manufacturers names appear herein solely because they are considered essential to the object of this report.

This information is available in alternative accessible formats. To obtain an alternative format, contact the Kansas Department of Transportation, Office of Public Information, 7th Floor, Docking State Office Building, Topeka, Kansas, 66612-1568 or phone (785)296-3585 (Voice) (TDD).

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or the policies of the State of Kansas. This report does not constitute a standard, specification or regulation.



ABSTRACT

Old style handrails, parapets, and hub-guards of narrow culverts and bridges on local, low-volume roads (LVR) restrict their use by wide farm equipment and can cause severe damage and personal injury if hit by a vehicle. In many cases, these rigid obstacles can become roadside hazards and may be more of a hazard to the motorist than the streambed or drainage area.

The objective of this study is to develop several guidelines for determining when to remove substandard handrails taking into account safety considerations, structural integrity, and cost effectiveness. Eliminating any rigid object in or near the roadway will allow use of the roadway by wide farm equipment and may make for a safer road environment.

The ROADSIDE software developed and made available by AASHTO was used in this study to compute accident costs for several combinations of vehicle speeds, culvert widths, and ditch depths for both cases where the handrails are present and when the handrails have been removed. It was found that, based on accident cost, it is recommendable to remove the handrails for culverts having a ditch height of 2.1 meters (7 feet) or less. For all other culvert heights judgment should be used when determining whether or not to remove the handrails.

Based on this investigation, site visits, accident data analysis, professional expertise, and engineering judgement, the research team agrees that for bridges or culverts which are 2.4 meters (8 feet) or less in depth, the bridge railing end is probably the greater hazard and for depths greater than about 2.4 meters the bridge rail end may be the lesser hazard.

Adding galvanized steel tapered sleeves, extending the culvert to achieve safer end slopes, and attaching end sections with parallel safety bars (grates) are typical procedures recognized by the Federal Highway Administration. Such products and services exist commercially nationwide and are available in Kansas. It is suggested that such alternatives to guard fences and bridge rails on low-volume roads be investigated in further depth.

Acknowledgment

The guidance and cooperation of Mr. Vernon Everhart, Assistant Chief of Local Projects at KDOT and project monitor for this research study, have been crucial for the progress of the work in this study. The assistance of Mr. Norman Bowers, County Engineer, and Mr. Donald Hovey, Assistant County Engineer, of Johnson County has been appreciated. Also the cooperation of Mr. Dean Chesnut, County Engineer for Republic County, and Mr. Buddy Clark, Highway Director for Miami County, has been very helpful especially during the county visits. The research project Advisory Committee included Mr. Ron Seitz (KDOT Design), Mr. Jerry Priem (KDOT Local Projects), Mr. Gary Rosewicz, County Engineer for Marshall County and Mr. Richard Teaford, County Engineer for Jefferson County.

Thanks are due to Mr. Nick Clough, Civil Engineering undergraduate student at KSU, who helped with the county visits and statewide survey and to Mrs. Linda Harbes for working on this manuscript.

Table of Contents

ABSTRACT.....	i
Acknowledgment	ii
List of Figures	v
List of Tables	vii
1.0 INTRODUCTION	1
2.0 DATA COLLECTION	2
2.1 Statewide Survey	2
2.2 Accident Data.....	5
2.3 County Visits	6
2.3.1 Johnson County.....	6
2.3.2 Republic County	11
2.3.3 Miami County	17
3.0 COST EFFECTIVENESS	19
3.1 ROADSIDE Design Guide Software.....	19
3.2 Input Parameters	20
3.2.1 Geometry.....	20
3.2.2 Design Speeds and Encroachment Angles.....	21
3.2.3 Average Daily Traffic	21
3.2.4 Highway Type.....	21
3.2.5 Project Life and Discount Rate	21
3.2.6 Culvert Location and Size.....	21
3.2.7 Handrail Location and Size.....	21
3.3 ROADSIDE Results.....	22
4.0 CONCLUSIONS.....	27
4.1 Summary of Cost Analysis	27
4.2 Conclusions.....	27
4.3 Handrail Removal	28
4.4 Recommendation for Future Studies	29
REFERENCES	30
APPENDIX A - Statewide Survey	31
APPENDIX B - DOT Form No. 850.....	36

APPENDIX C - ROADSIDE Computer Results.....	39
APPENDIX D - Roadside Safety Clear Zone Concept	75
D.1 Cross Drainage Features	77
D.1.1 Traversable Designs for Cross drainage Structure.....	78
D.1.2 Structure Extension.....	81
D.2 Parallel Drainage Structures.....	82
D.2.1 Eliminating the Structure	82
D.2.2 Relocating the Structure.....	83
D.2.3 Installing Traversable Designs.....	84
D.3 Construction and Maintenance of Drainage Features	86
D.3.1 Construction of Drainage Features.....	86
D.3.2 Maintenance Needs	88
D.3.3 Summary of Drainage Features.....	89
D.4 Traversable and Non-Traversable Ditches and Back Slopes	90
D.5 Roadside Terrain Features.....	96
D.6 Parallel Slope Embankments	97
D.7 Intersecting Embankments (Cross Slopes)	98
D.8 Determining the Desirable Clear Zone for Parallel Slopes.....	100
D.8.1 For Noncritical and High Height Parallel Slope	100
D.8.2 For Critical and High Height Parallel Slope	102
D.9 Horizontal Curve Adjustment	105
D.10 Roadside Obstacles	106
D.11 Example of Roadside Clear Zone Determination for Parallel Slopes.....	107

List of Figures

Figure 1 - Number of Counties and Culvert Problems	4
Figure 2 - 207 th Ridgeview and Woodland in Johnson County	7
Figure 3 - Closeup of 207 th Ridgeview and Goodland in Johnson County	7
Figure 4 - Lackman 207 th and 199 th Street in Johnson County	8
Figure 5 - 199 th Quivera and 191 st Street in Johnson County	9
Figure 6 - 199 th Quivera and 191 st Street in Johnson County	9
Figure 7 - Waverly between 207 th and 191 st Streets in Johnson County	10
Figure 8 - 191 st Street east of Woodland in Johnson County	10
Figure 9 - Sector M-26 in Republic County	11
Figure 10 - Sector M-26 in Republic County	12
Figure 11 - Sector P-8 in Republic County	12
Figure 12 - Sector J-11 in Republic County	13
Figure 13 - Sector J-11 in Republic County	13
Figure 14 - Sector C-10 in Republic County	14
Figure 15 - Sector S-35 in Republic County	15
Figure 16 - Sector S-35 in Republic County	16
Figure 17 - Sector O-11 in Republic County	16
Figure 18 - Somerset Road between 311 th and 319 th Streets in Miami County	17
Figure 19 - Columbia Road between 319 th and 327 th Streets in Miami County	18
Figure 20 - Accident Cost Comparison for a 4.9 m Lane Width Culvert	23
Figure 21 - Accident Cost Comparison for a 5.5 m Lane Width Culvert	24
Figure 22 - Accident Cost Comparison for a 6.1 m Lane Width Culvert	25
Figure 23 - Typical Cross Drainage Inlet Designs.....	78
Figure 24 - Orientation of Safety Pipe Grate for Cross Drainage Structures.....	79
Figure 25 - Design Details of Safety Pipe Installation for Cross Drainage Structures.....	80
Figure 26 - Example of Cross Drainage Safety Slope End	81
Figure 27 - Example of Parallel Drainage Structure.....	82
Figure 28 - Outward Extension of Ditch Line	83
Figure 29 - Example of Inlet/outlet Design for Parallel Drainage Structures.....	84
Figure 30 - Example of Improper Safety Pipe on Parallel Drainage Opening.....	85
Figure 31 - Example of Vehicle Damage Resulting from Impacting a 460 mm Raised Concrete Parapet with a 1:2 Entrance Slope	85
Figure 32 - Example of Parallel Drainage Safety Slope End Section.....	86
Figure 33 - Steps Involved in Installing Safety End Section.....	87
Figure 34 - Abrupt Slope Change Ditch Design.....	91
Figure 35 - Gradual Change Slope Ditches	92
Figure 36 - Preferred Cross Sections for Ditches with Abrupt Slope Changes.....	94
Figure 37 - Preferred Cross Section for Ditches with Gradual Slope Changes	95
Figure 38 - Diagram of Raised Roadway Embankment	96
Figure 39 - Diagram of Depressed Roadway Embankment	96
Figure 40 - Representation of Slope Magnitude	97
Figure 41 - Poor Intersecting Slope Design.....	98
Figure 42 - Preferred Intersecting Slope Design.....	99

Figure 43 - Clear Zone Distance Curves 100
Figure 44 - Guidelines for Embankment Barrier Need Used by the State of Washington 103
Figure 45 - Comparative Risk Warrants for Embankments from the AASHTO Guide 104
Figure 46 - Example of Typical Parallel Embankment Slope Design Problem 107

List of Tables

Table 1 - Summary of Survey Results	3
Table 2 - Accident Data Results	5
Table 3 - Total Accidents	6
Table 4 - Total Average Cost	20
Table 5 - Geometry Assumptions	20
Table 6 - Accident Cost for a 4.9 m Lane Width Road	23
Table 7 - Accident Cost for a 5.5 m Lane Width Road	24
Table 8 - Accident Cost for a 6.1 m Lane Width Road	25
Table 9 - Safety Pipe Sizes for Both Cross and Parallel Drainage Structures	80
Table 10 - Clear Zone Distances.....	101
Table 11 - Horizontal Curve Adjustments Kcz (Curve Correction Factor).....	105
Table 12 - Typical Roadside Terrain and Fixed Object Hazards	106



1.0 INTRODUCTION

Old style handrails, parapets, and hub-guards of narrow culverts and bridges on local low-volume roads (LVR) restrict their use by wide farm equipment and can cause severe damage and personal injury if hit by a vehicle. In many cases, these rigid obstacles can become roadside hazards and may be more of a hazard to the motorist than the streambed or drainage area.

This study investigates when the existing hazard is less dangerous than the hazard of the streambed or the ditch at the structure. Therefore, the objective of this study is to develop guidelines for determining when to remove substandard handrails taking into account safety considerations, structural integrity, and cost effectiveness. Eliminating any rigid object in or near the roadway will allow use of the roadway by wide farm equipment and may make for a safer road environment.

A number of field trips were conducted as part of this study to investigate actual conditions of culvert and small bridges with handrail problems.

As for any research study, the first step was to specify the objectives of the research and the means of researching these objectives. Several meetings were conducted at the Kansas Department of Transportation (KDOT) headquarters in Topeka (November 6, 1996 and May 5, 1997) and in the Johnson County Public Works office in Olathe (July 11, 1997), in which elements of the research team met with KDOT officials and county engineers from representative regions. The outcome of these meetings delineated the research strategy to be followed in this study, including field visits to counties and a statewide survey.

As concluded in the meetings with the sponsor and county engineers, it was necessary to determine the actual conditions concerning culvert handrails in the State of Kansas. For this purpose a survey was conducted over the entire state in which 41 different Kansas counties participated.

With the help of this survey, actual figures were obtained indicating the degree of severity that culvert handrails present in several counties. Thanks to the KDOT Bureau of Transportation Planning, accident records for the past six years were obtained.

The ROADSIDE software developed and made available by AASHTO was used in this study to compute accident costs for several combinations of vehicle speeds, culvert widths, and ditch depths for both cases where the handrails are present and when the handrails have been removed. A cost analysis and cost comparison was made based on these results.

The study also included the investigation of other means of reducing roadside culvert hazards and the feasibility of implementing alternative solutions including adding galvanized steel tapered sleeves, extending the culvert to achieve safer end slopes, and attaching end sections with parallel safety bars (grates).

2.0 DATA COLLECTION

2.1 Statewide Survey

The purpose of the statewide survey was to obtain some general knowledge of the existing culvert handrail conditions (See Appendix A for statewide survey). The major interests in conducting the survey were to obtain the following information:

1. Number of culverts in the county
2. Number of culverts with handrail problems
3. Number of requests for the removal of culvert handrails
4. Number of handrails removed by county officials
5. Reason for the removal
6. Deaths or severe injuries involving culvert handrails.

Forty-one counties responded to the survey. These counties are: Barber, Barton, Butler, Chase, Clark, Clay, Decatur, Douglas, Ellis, Ellsworth, Finney, Ford, Gove, Jefferson, Jewell, Johnson, Kingman, Leavenworth, Lincoln, Linn, Lyon, Marion, Marshall, McPherson, Meade, Montgomery, Morton, Neosho, Ottawa, Pawnee, Pottawatomie, Republic, Riley, Rush, Saline, Scott, Sheridan, Sumner, Thomas, Washington, and Woodson.

The answers obtained from each county are summarized in Table 1. Note that some of the values for the number of culverts with handrail problems are missing. This is due to the fact that those specific counties did not know exactly how many culverts they have.

Table 1 - Summary of Survey Results

County	# Culverts	# Culverts with Problems	Request for Removal	% Culverts Removed	Severe Injuries
Barber	317	175	8	62.5	1
Barton	—	200	30	50	1
Butler	2000	400	5	100	0
Chase	200	150	5	100	0
Clark	300	5	5	100	0
Clay	150	75	15	53	0
Decatur	200	200	40	12.5	0
Douglas	2123	150	5	100	3
Ellis	390	200	8	62.5	0
Ellsworth	500	---	30	50	0
Finney	159	125	5	100	0
Ford	250	180	30	0	0
Gove	125	2	5	100	0
Jefferson	—	—	5	100	1
Jewell	1500	275	5	100	0
Johnson	1625	200	5	160	0
Kingman	700	35	5	100	3
Leavenworth	322	30	5	100	0
Lincoln	—	—	5	100	0
Linn	3000	500	5	100	0
Lyon	3537	450	15	267	0
Marion	—	—	5	100	0
Marshall	1200	400	30	50	1
McPherson	725	71	8	62.5	0
Meade	43	0	5	100	0
Miami	—	—	15	33	1
Morton	100	0	5	100	0
Neosho	2500	600	8	100	1
Ottawa	—	—	5	100	0
Pawnee	444	50	5	160	0
Pottawatomie	983	250	10	100	0
Republic	1400	450	15	53	0
Riley	188	62	15	100	7
Rush	156	15	5	100	0
Saline	977	61	5	100	0
Scott	250	8	5	100	0
Sheridan	138	60	40	75	0
Sumner	150	75	30	100	0
Thomas	—	5	5	100	0
Washington	1950	200	15	53	0
Woodson	550	150	40	75	5

From Table 1, one can conclude that out of the 41 counties responding to the survey, 27 counties (56 percent) have up to 200 culverts with problems. Two counties have between 200 and 400 of their culverts with problems, and six counties have more than 400 of their culverts with problems. This is illustrated in Figure 1.

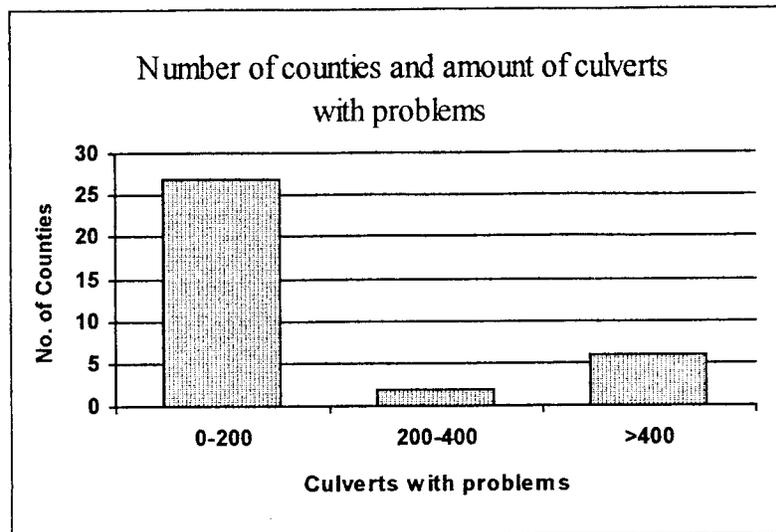


Figure 1 – Number of Counties and Culvert Problems

These data indicate that culvert handrails create problems. Several counties indicated that they received a large number of requests to remove certain handrails, and even though the counties did not take any action to remove them, they were eventually knocked down anyway. This means that the handrails were actually removed without the county's permission or they were unintentionally hit, presumably by large farm equipment.

At the beginning of this research project, the research team from Kansas State University (KSU) met with KDOT officials and representative county engineers to discuss the needs or reasons for handrail removal. The main reason seems to be the width of farm equipment. As technology advances and farming needs become greater, farm machinery tends to increase in size. With this increase in the size of farm machinery, narrow culverts with handrails tend to create bigger problems. Another reason why several counties remove the handrails is to increase the effective roadway width. The problem, therefore, is related to the width of the vehicles that travel the road and road width available.

After the handrails were removed, 95 percent of the counties have not received any complaints and there has been no change in the number of accidents after removal.

If one looks at the severe injuries created by culvert handrails, there have been 23 accidents in 41 counties. No information was provided as to why the accident happened and the time of the accident (season, weather condition, etc).

2.2 Accident Data

With the help of the KDOT Bureau of Transportation Planning, a database containing specific motor vehicle accident information between 1990 and 1996 was obtained. The data corresponds to DOT Form No. 850, "Motor Vehicle Accident Report" (shown in Appendix B). All accidents indicating a vehicle colliding with a culvert (i.e. FIXED OBJECT TYPE = 11) were pulled out and examined.

The fixed-object accident results obtained were examined for the following counties: Atchison, Brown, Clay, Dickinson, Douglas, Geary, Jefferson, Jewell, Johnson, Lyon, Miami, Pottawatomie, Republic, Riley and Washington. The results are shown in Table 2. The data includes the following:

1. Number of vehicles involved in the accident
2. Number of fatalities
3. Number of disabling or severe personal injuries (SPI)
4. Number of non-incapacitating or moderate personal injuries (MPI)
5. Number of possible injuries or slight personal injuries (SLPI)
6. Number of property damage only (PDO).

Table 2 - Accident Data Results

County	# Vehicles	# Fatalities	# SPI	# MPI	# SLPI	# PDO
Atchison	18	0	3	8	6	1
Brown	41	1	4	13	5	18
Clay	12	0	3	4	1	4
Dickinson	34	0	2	16	5	11
Douglas	98	2	18	25	13	40
Geary	24	0	0	5	6	13
Jefferson	38	3	4	7	7	17
Jewell	9	0	0	4	5	0
Johnson	193	2	12	48	130	100
Lyon	70	0	9	37	10	14
Miami	53	0	12	12	10	19
Pottawatomie	39	1	8	17	13	0
Republic	18	0	0	3	1	14
Riley	34	0	7	13	14	0
Washington	22	0	0	10	4	8

From the data in Table 2 one can determine the percentage of accidents and classify them by accident type. This is shown in Table 3.

Table 3 - Total Accidents

Category	Total %
Fatality Accidents	2
Severe Personal Injury	11
Moderate Personal Injury	31
Slight Personal Injury	19
Property Damage Only	37

After gathering all the accident data and surveys, visits were made to a number of counties. During these visits, the culverts that had problems with handrails were studied. The main objective was to observe the condition of the culvert and handrail, and to obtain general culvert data such as the width of roadway before and after the culvert, depth of water stream (if any) and dimensions of wing walls. That could be used in developing a cost-effective analysis for different culverts. The results of these visits are shown in the next section.

2.3 County Visits

In order to obtain first hand information about existing culverts, visits were made to three counties. The counties visited were Johnson, Miami and Republic Counties. Each visit is individually described below.

2.3.1 Johnson County

In July 1997, the researchers visited Johnson County to survey the problems existing with culvert handrails. Several days before the visit, a copy of Johnson County's culvert electronic database was sent to us detailing information of existing culverts. After a study of this database several culverts were selected for further investigation based on their geometry. The criteria for the selection were:

1. culverts with a width less than 6 m (20 feet), and
2. tapered or non-tapered road.

During the meeting that superceded the field visits, it was pointed out that most of the culverts identified had already been replaced and only a few cases had width and guardrail problems. These cases were visited and examined. Several photographs of these culverts were taken and the results are discussed in the following paragraphs.

The first culvert was located between 207th Ridgeview and Woodland (see Figures 2 and 3). The general characteristics of this culvert are: reinforced concrete box with 45 degree wings

in both inlet and outlet end-sections, length is 5.8 m (19 ft), span is 5.5 m (18 ft) and height is 2.4 m (8 ft). This particular culvert has a 914 mm (36-inch) reinforced concrete railing on both sides, and two OM-3 markers, one at each side of the culvert. As it can be seen in Figure 3, one quarter of the railing is actually missing, which suggests that the railing has been hit by a vehicle or farm equipment.

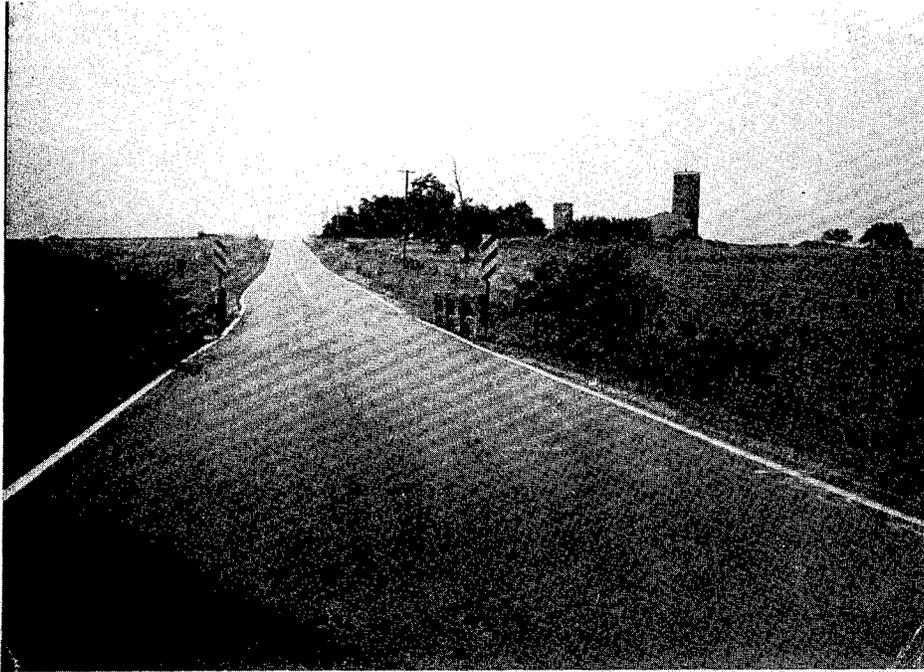


Figure 2 – 207th Ridgeview and Woodland in Johnson County



Figure 3 – Close-up of 207th Ridgeview and Goodland in Johnson County

The second culvert is located between 207th Lackman and 199th Street (see Figure 4). This particular culvert consists of a boxed reinforced concrete structure with 45 degree wings in both inlet and outlet end-sections. The length is 4 m (13 ft), the span is 4.9 m (16 ft) and the height is 914 mm (3 ft). This culvert does not have any type of railing left. However OM-3 markers are staggered to inform approaching motorists.



Figure 4 – Lackman 207th and 199th Street in Johnson County

The third culvert is located between 199th Quivera and 191st Street (See Figures 5 and 6). This culvert consists of a single span reinforced concrete structure with 45 degree wings in both inlet and outlet end-sections. The length is 4.5 m (15 ft), the span is 2 m (7 ft) and the height is 2.4 m (8 ft). There are no railings left on this culvert and two OM-3 markers provide warning for motorists.



Figure 5 - 199th Quivera and 191st Street in Johnson County



Figure 6 - 199th Quivera and 191st Street in Johnson County

The next culvert is located at Waverly between 207th and 199th Streets (see Figure 7). The length of this culvert is 4.9 m (16 ft), the span is 1.8 m (6 ft) and the height is .5 m (1.5 ft). There are OM-3 markers to warn traffic and the actual condition of the structure is very poor.



Figure 7 – Waverly between 207th and 191st Street in Johnson County

The last culvert visited is located on 191st Street East of Woodland (See Figure 8). This culvert is very similar to the one shown in Figure 2. Although railings are provided, their actual condition and probable function are questionable.

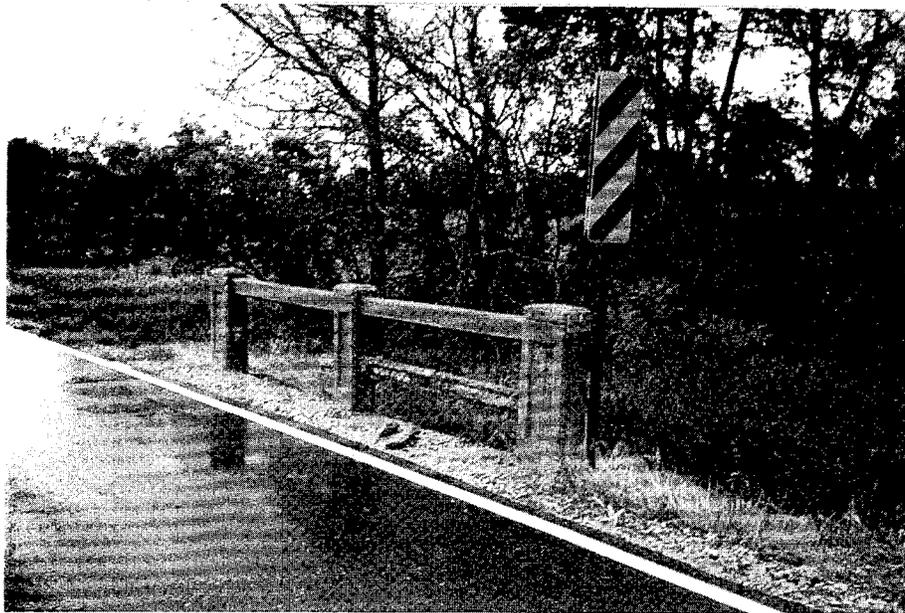


Figure 8 – 191st Street East of Woodland in Johnson County

Due to the availability of funding in Johnson County, almost all of the problematic culverts have been re-designed and reconstructed. This includes widening the actual culvert structure, which provides a wide shoulder and allows a wider clear zone. This was possible because Johnson County is in an urban region, which includes part of the Kansas City metropolitan area. However, this is not the case in more remote areas and suburban counties.

2.3.2 Republic County

During the first days of August 1997 a similar visit was made to Republic County. Republic County does not have a computerized database of existing culverts, as does Johnson County. The culverts visited were selected based on the knowledge of the County Engineer. He stated that they don't have many problems with culvert handrails, but rather with object markers. In most cases wide farm equipment run over the markers and break them.

Concerning handrails, it was stated that in most cases local farmers use the low volume roads and know where the culverts are located. In other words, they are careful when crossing the culverts. On the following pages several photographs are presented summarizing the conditions of existing culverts in Republic County.

In Figures 9 and 10 the actual width of the culvert is sufficient for wide farm equipment to cross. The problem here is the lack of markers to warn motorists of the existing hazard. If one looks at the right side of Figure 9, the existing handrail is not visible because of vegetation. This can be a hazardous situation.

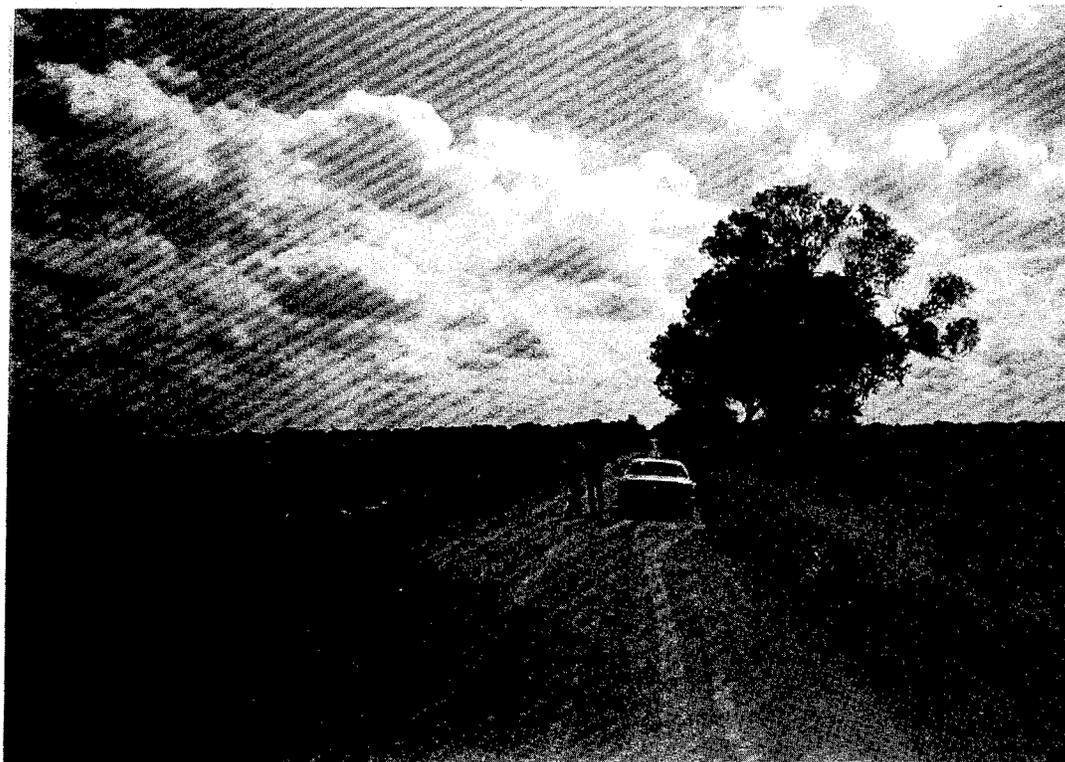


Figure 9 – Sector M-26 in Republic County

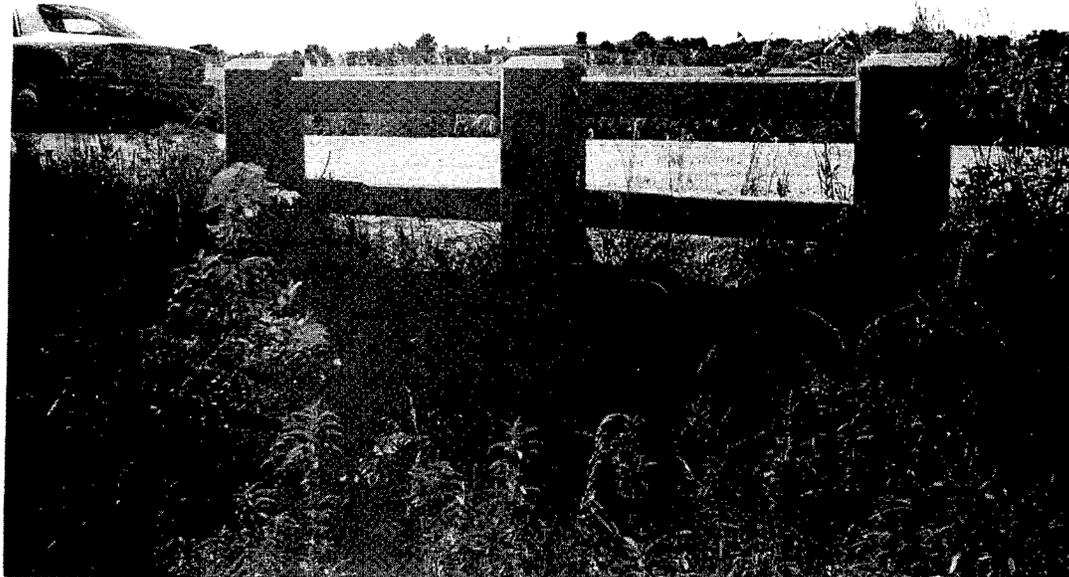


Figure 10 - Sector M-26 in Republic County

Figure 11 shows a culvert in which the handrails were removed. According to the county records no accidents have been reported since the removal.



Figure 11 - Sector P-8 in Republic County

Figures 12 and 13 show a reinforced concrete box culvert. This culvert is the most common type of culvert encountered during the visit.

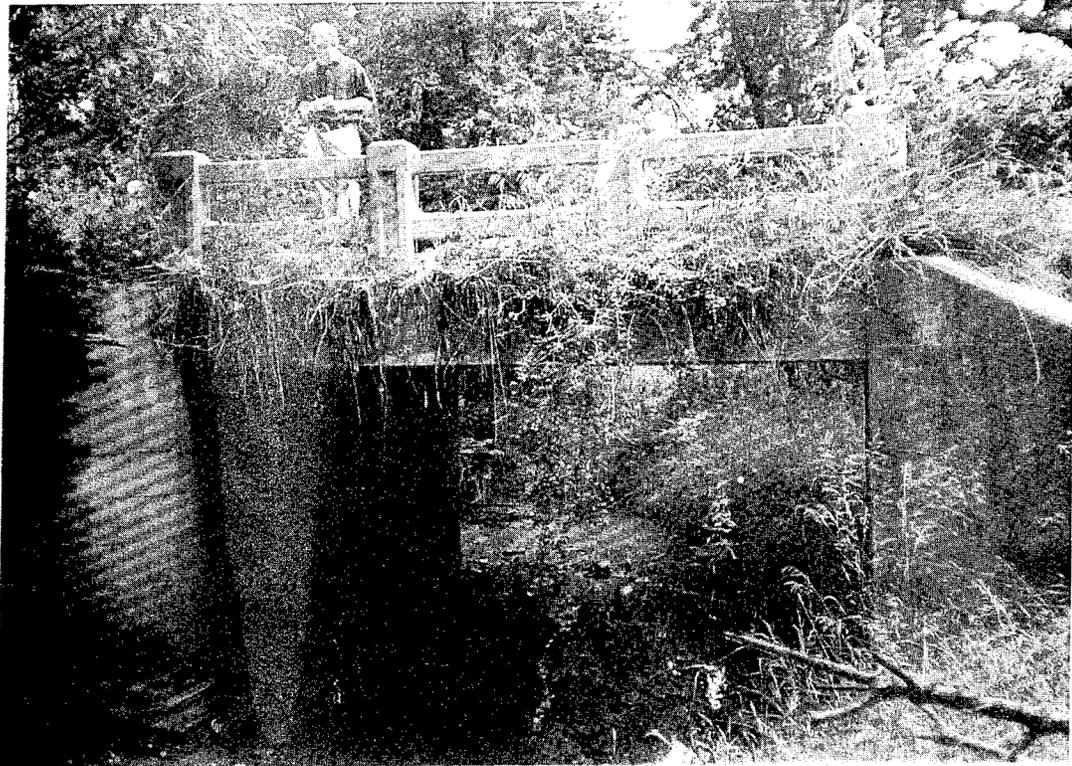


Figure 12 - Sector J-11 in Republic County



Figure 13 - Sector J-11 in Republic County

Figure 14 shows a culvert that has no handrails, where the actual structural condition is also questionable.



Figure 14 - Sector C-10 in Republic County

During the visit to Republic County, several culverts were encountered with only parts of the handrail remaining intact. These partial handrails do not provide much safety to the motorist and can be as hazardous as full handrails. Figures 15, 16, and 17 show different examples of these unusual handrail configurations. In Figure 15 a straight reinforced concrete column sticks up assuming the role of a handrail at the right side of the culvert. The column at the left side of the same culvert (see Figure 16) has been either removed or hit. Figure 17 shows the remaining portion of a small concrete headwall that was probably originally intended to be a handrail.



Figure 15 – Sector S-35 in Republic County



Figure 16 - Sector S-35 in Republic County

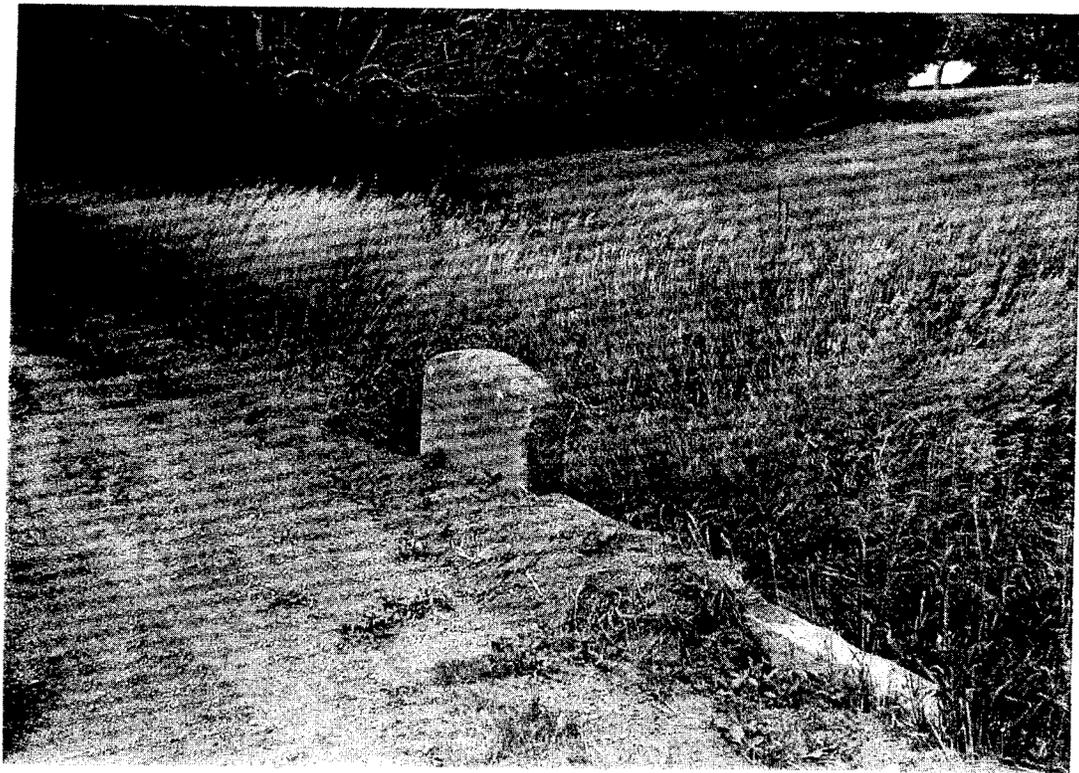


Figure 17 - Sector O-11 in Republic County

2.3.3 Miami County

On August 21st, 1997 Miami County was visited to perform a similar examination of some existing culverts. The County Engineer hosted the visit. The locations of the photograph shown in the next pages include some of the most common types of structures in Miami County.

Figure 18 shows a typical culvert located at Somerset Road between 311th and 319th Streets. This culvert includes object markers and handrails at both ends of the structure. Figure 19 shows a culvert located at Columbia Road between 319th and 327th Streets. For the latter, it looks like the handrail has been hit or removed in order for wide equipment to traverse the culvert. Flexible object markers delineate the culvert for approaching motorists.

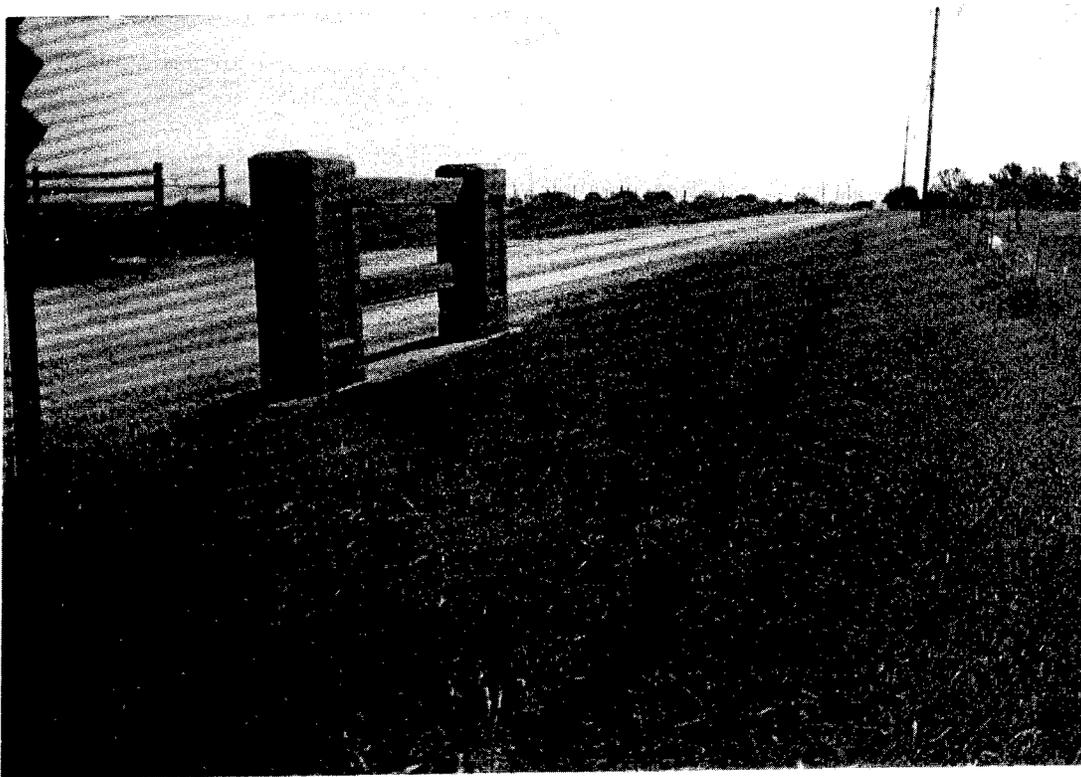


Figure 18 - Somerset Road between 311th and 319th Streets in Miami County



Figure 19 - Columbia Road between 319th and 327th Streets in Miami County

3.0 COST EFFECTIVENESS

It has been suggested that narrow bridge and culvert rails are roadside hazards and, where feasible, they should be removed since it is likely that the end of the rigid rail can be more hazardous to the motorist than the streambed or drainage area (8).

The two strategies considered when determining railing needs are:

1. remove the existing railing, and
2. do not remove the existing railing.

Before considering these strategies, it was necessary to estimate the cost of an accident. The "ROADSIDE" Software (2) was used to obtain accident costs. A quick overview of ROADSIDE and a summary of the parameter used in the program is given below.

3.1 ROADSIDE Design Guide Software

ROADSIDE (Version 5.0) was used to compare the costs of two types of accidents on the same culvert. The first is hitting the guardrail and the other is falling into the ditch if the guardrail has been removed.

ROADSIDE calculates the Total Present Worth (TPW) of accident costs and highway department costs incurred over a specified analysis period (project life), using the following equation:

$$TPW = CA (KC) + CI + ARC + CM (KT) - CS (KJ)$$

where:

- CA* = Accident cost based on initial collision frequency
- KC* = Factor to account for project life, discount rate, and traffic growth rate
- CI* = Installation cost
- ARC* = Present worth of accident repair cost
 $= \sum KC \times (CDi) \times (CFi)$
- CDi* = Average collision damage repair cost for sides, corners, and face
- CFi* = Initial collision frequencies for sides, corners, and face
- CM* = Annual maintenance cost
- KT* = Factor to account for the project life and the discount rate
- CS* = Salvage value of feature being studied
- KJ* = Factor to account for the project life and the discount rate

For further explanation and operation of the software, the reader is encouraged to review Appendix A of the AASHTO Roadside Design Guide (2).

3.2 Input Parameters

The first step in performing this analysis was to estimate the accident costs corresponding to the different accident severity levels. Costs by accident types developed by KDOT and used in a recent K-TRAN study (6) were also used in this analysis. These were based on the Federal Highway Administration's (FHWA) Technical Advisories, dated October 31, 1994 and on the change of Consumer Price Index (C.P.I.) from January 1994 to January 1995. These costs are shown in Table 4.

Table 4 - Total Average Cost

Accident Type	Cost \$
Fatal accident	\$2,672,900
Major personal injury accident	185,050
Moderate personal injury accident	37,000
Minor personal injury accident	19,550
Property damage only accident	2,050

In order to pursue the investigation of handrail removal, several parameters were assigned to the geometry of the structure, encroachment angles, design speeds, average daily traffic (ADT), highway type, project life and discount rate. After these assumptions were made, ROADSIDE was used to obtain costs corresponding to various culvert locations and sizes, vehicle speeds and road widths. The values assigned to the different parameters are described below.

3.2.1 Geometry

As a result of the county visits and examination of existing culverts, the following typical culvert geometry values were used in the analysis.

Table 5 - Geometry Assumptions

Geometry	Value
Material	Reinforced Concrete
Span	4.9 m (16 ft)
Ditch width	4.9 m (16 ft)
Wing type	45 (at each end section)
Type	Box Culvert

3.2.2 Design Speeds and Encroachment Angles

The encroachment angles depend on the speed of the traveling vehicle before the accident or collision. For the purpose of comparison, speeds of 50, 60, and 70 km/h (30, 35, and 45 mph) were considered in this study. These speeds provide encroachment angles of 13, 12.8, and 12.4 degrees, respectively.

3.2.3 Average Daily Traffic

Once again, this study deals with low volume roads. Considering the data obtained for the different counties and with the help of the county engineers, an assumed value of 80 vehicles per day was used.

3.2.4 Highway Type

ROADSIDE is mainly developed for highways. In our case, we primarily deal with low-volume undivided county roads. Lane widths of 4.9, 5.5, and 6.1 meters (16, 18, and 20 ft) were assumed to characterize the different road types. The input to the program is such that the road is only one lane at the culvert (single lane bridge). Therefore the road width is the same as the lane width. This is a more conservative assumption for the analysis.

3.2.5 Project Life and Discount Rate

The project life is usually taken as the expected service life of the structure. A life of 20 years was selected with a 4.0 percent discount rate. According to the Roadside Design guide this value for the discount rate is very reasonable (2).

3.2.6 Culvert Location and Size

Different values were used for culvert heights to compute accident costs. These values ranged from 0.6 m to 2.4 m (2 ft to 8 ft). This was done to establish a correlation between the height of the culvert and the accident cost.

3.2.7 Handrail Location and Size

In order to use ROADSIDE to compute the accident cost induced by colliding with the handrail, a number of other assumptions had to be made. For instance, it was assumed that the handrail is a fixed object with a span length of 4.9 m (16 ft), width of 0.3 m (1 ft) and a height of 0.6 m (2 ft). In this case the height of the culvert ditch was not used. It was also assumed that there was no offset between the handrail and the edge of the roadway. Under these conditions, different severity indices were obtained from Table A.13.9 (p A-80) of the Roadside Design

Guide (2). These are as follows:

Severity Index (SI) for:	<u>50 km/h</u>	<u>60 km/h</u>	<u>70 km/h</u>
Approach Side	3.4	3.8	4.2
Corner	3.4	3.8	4.2
Traffic Face	1.9	2.0	2.2

For the cases where the handrails are removed or non-existent (no handrail), the dimensions of the handrail are not needed. Instead, the height of the ditch becomes the main factor taken into account when calculating accident costs. Severity indices for cases of no handrail are taken from

Table A.13.10 (p A-88) of the Roadside Design Guide (2). As stated in the footnote of that table, *“the ditch beyond the culvert end is also an obstacle and should be accounted for in an economic analysis.”*

3.3 ROADSIDE Results

As mentioned previously, the ROADSIDE software was used in this study to compute accident costs for several combinations of vehicle speeds, culvert widths, and ditch depths for both cases where the handrails are present and when the handrails have been removed. Appendix C shows the ROADSIDE software outputs (with input data) for the computer runs pertaining to the cases of vehicle speed of 50 km/h (30 mph). Different costs were obtained for vehicle speeds of 60 km/h (35 mph) and 70 km/h (45 mph). Results are summarized below.

Table 6 and Figure 20 show the summary of accident costs for a 4.9 m (16ft) wide road. Ditch height varies from 0.6 m to 2.4 m (2 ft to 8 ft) and vehicle speed is 50, 60, or 70 km/h (30, 35, 45 mph). For each combination of ditch height and vehicle speed, two cases are presented. Case 1 is the case of an accident when the handrail is removed or non-existent (no handrail). This accident cost is basically the cost of falling into the ditch. Case 2 is the case of an accident in the presence of a handrail. Case 2 then includes two conditions: (A) hitting the handrail (collision), and (B) falling into the ditch due to vehicle encroachment before and after the rail.

Condition 2B must be taken into account because the handrail prevents a vehicle from falling while over the main span of the bridge or culvert, but does not prevent running off into the ditch from the approach or around the corners of the rail. Condition 2B is designated “falling off handrail” as shown in Appendix C for the different height and speed combinations. It is obtained by running the program as for a case of no handrail with appropriate severity indices for the Approach Sides and Corner Sides, but with a severity of zero for the Traffic Face.

The cost of Case 2 is therefore the sum of the cost of Condition A (hitting handrail) and Condition B (falling off handrail). As shown in the footnote of Table 6 (for a 4.9 m (16 ft) road width), the cost of Condition A is constant for a given vehicle speed regardless of the ditch height.

This procedure is repeated for road widths of 5.5 m (18 ft) and 6.1 m (20 ft). Table 7 and Figure 21 show the corresponding results for the 5.5 m (18 ft) road width, while Table 8 and Figure 22 show those for the 6.1 m (20 ft) road width.

Table 6 - Accident Cost for a 4.9 m (16 ft) Lane Width Road

Ditch height (m)	Vehicle speed (km/h)					
	50 km/h		60 km/h		70 km/h	
	w/o rail	with rail*	w/o rail	with rail*	w/o rail	with rail*
0.6 m	\$198	\$392	\$356	\$685	\$522	\$1,129
1.0 m	\$289	\$454	\$471	\$768	\$781	\$1,327
1.2 m	\$465	\$594	\$710	\$964	\$1,050	\$1,566
1.8 m	\$774	\$822	\$1,102	\$1,285	\$1,556	\$1,998
2.4 m	\$1,152	\$1,128	\$1,604	\$1,694	\$2,332	\$2,637

* These columns include costs of hitting the handrails (independent of ditch height) which are \$235, \$395, and \$693 for vehicle speeds of 50, 60 and 70 km/h, respectively.

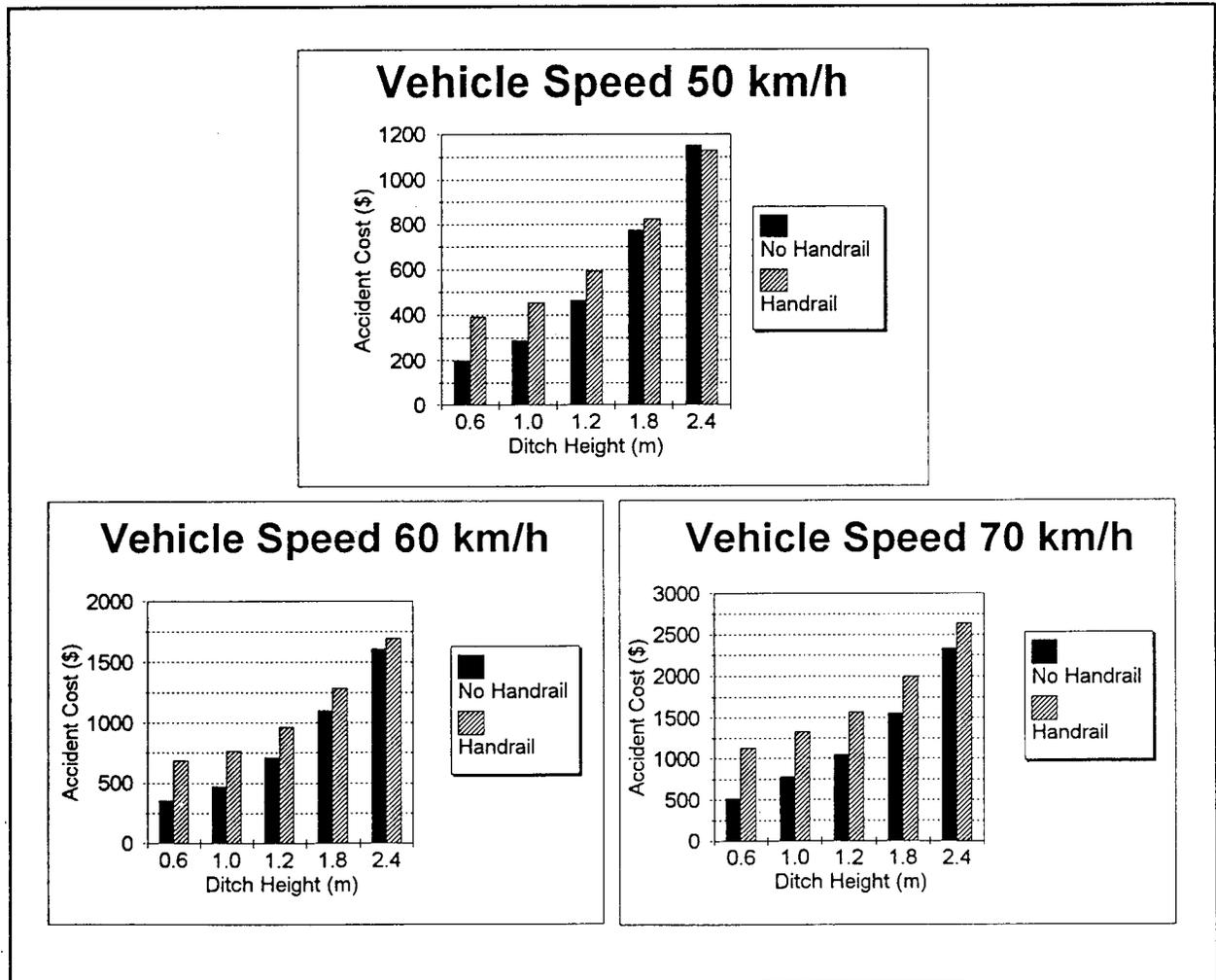


Figure 20 – Accident Cost Comparison for a 4.9 m (16 ft) Lane Width Culvert

Table 7 - Accident Cost for a 5.5 m (18 ft) Lane Width Road

Ditch height (m)	Vehicle speed (km/h)					
	50 km/h		60 km/h		70 km/h	
	w/o rail	with rail*	w/o rail	with rail*	w/o rail	with rail*
0.6 m	\$193	\$382	\$346	\$666	\$506	\$1,095
1.0 m	\$282	\$442	\$457	\$746	\$758	\$1,286
1.2 m	\$454	\$579	\$690	\$936	\$1,019	\$1,518
1.8 m	\$756	\$801	\$1,071	\$1,248	\$1,510	\$1,936
2.4 m	\$1,125	\$1,100	\$1,559	\$1,645	\$2,262	\$2,556

* These columns include costs of hitting the handrails (independent of ditch height) which are \$229, \$384, and \$672 for vehicle speeds of 50, 60 and 70 km/h, respectively.

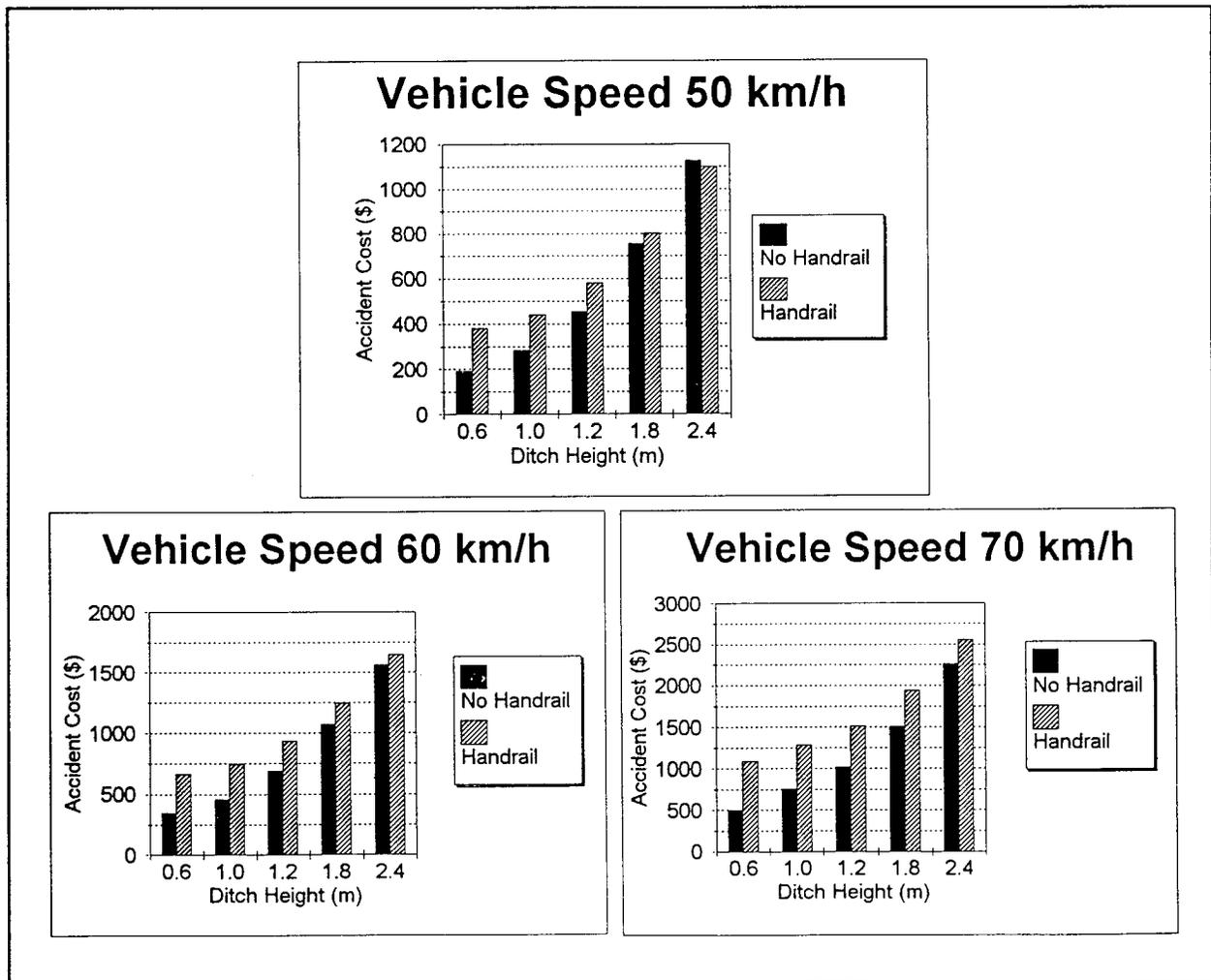


Figure 21. Accident Cost Comparison for a 5.5 m (18 ft) Lane Width Culvert

Table 8 - Accident Cost for a 6.1 m (20 ft) Lane Width Road

Ditch height (m)	Vehicle speed (km/h)					
	50 km/h		60 km/h		70 km/h	
	w/o rail	with rail*	w/o rail	with rail*	w/o rail	with rail*
0.6 m	\$189	\$375	\$338	\$500	\$493	\$1,066
1.0 m	\$276	\$434	\$446	\$578	\$738	\$1,253
1.2 m	\$445	\$568	\$673	\$764	\$992	\$1,478
1.8 m	\$741	\$785	\$1,045	\$1,068	\$1,470	\$1,885
2.4 m	\$1,102	\$1,077	\$1,522	\$1,455	\$2,203	\$2,488

* These columns include costs of hitting the handrails (independent of ditch height) which are \$225, \$375, and \$655 or vehicle speeds of 50, 60 and 70 km/h, respectively.

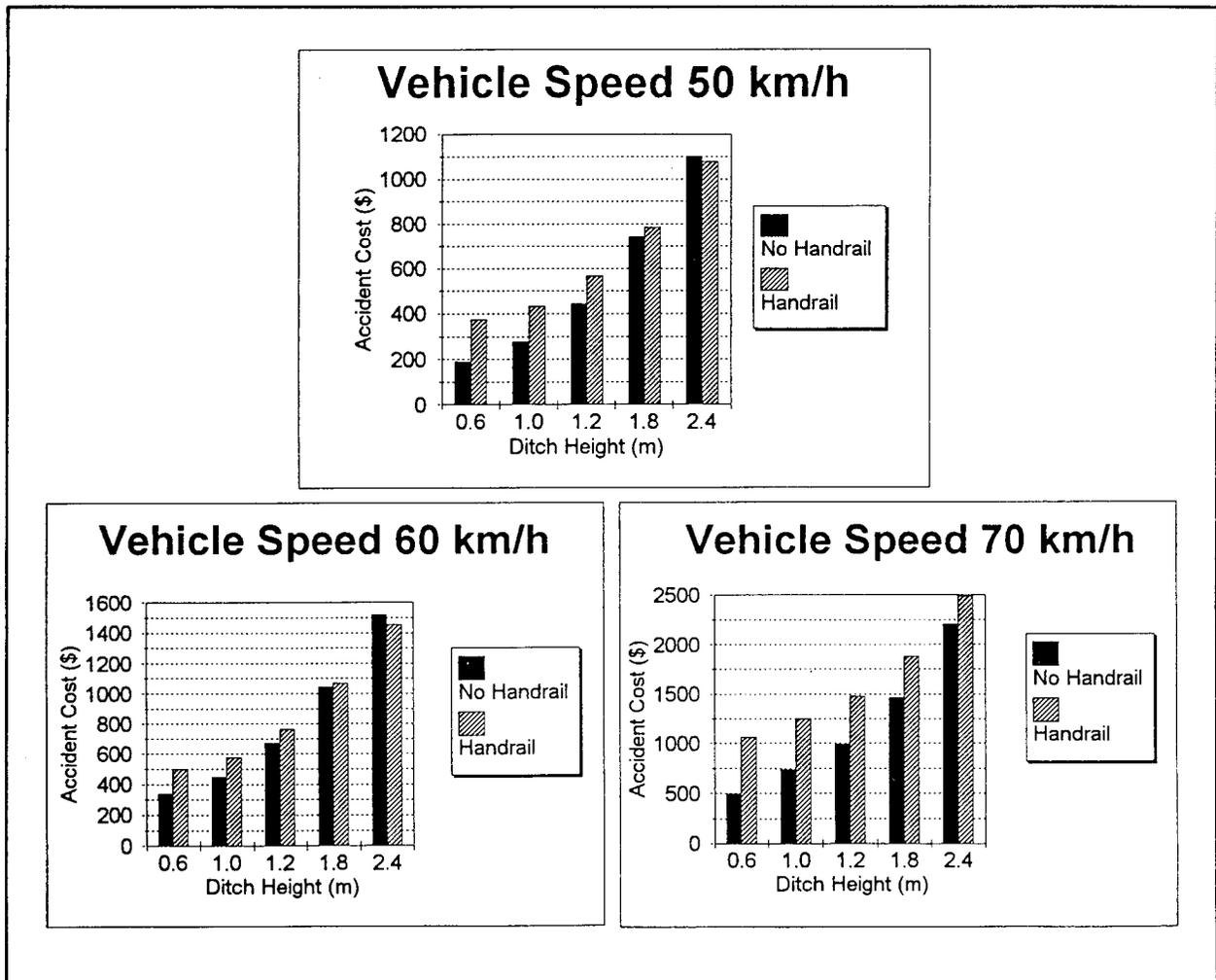


Figure 22 – Accident Cost Comparison for a 6.1 m (20 ft) Lane Width Culvert

By examining Figure 20, it is clear that for a 4.9 m (16 ft) road width, the accident costs in the existence of the handrail are usually higher than those without handrails. The only exception is the case of a 2.4 m (8 ft) deep ditch and 50 km/h (30 mph) vehicle speed. Even for this case, removing the rail increases the accident cost only by about 2%. The same can be observed from Figure 21 for a 5.5 m (18 ft) wide road. Figure 22 is slightly different such that for a wider road, 6.1 m (20 ft), two cases rather than one give a higher accident cost when the handrail is removed: These are for a 2.4 m (8 ft) deep ditch with both 50 km/h (30 mph) and 60 km/h (35 mph) vehicle speeds. However, the cost increase is very small: 2.3 % in the first case and 4.6 % in the second.

The computer results obtained from the economic analysis are consistent and logical. Accident costs increase as the vehicle speed increases and as the height of the bridge or culvert increases. Costs decrease when the road is wider because the situation is less hazardous and consequently severity indices are smaller. It is important to notice that the handrail prevents a vehicle from falling into the ditch when it is over the main part of the structures, but does not prevent it from running off the road and into the ditch when on the approaches by the wingwalls and before (or after) the structure. Also, in addition to the costs of accidents due to encroachment (despite the presence of the handrail), costs of hitting the handrail are higher as the vehicle speed is higher and the road is narrower.

In general, from the cases considered in this cost analysis, it can be concluded that the accident costs are always reduced when the handrail is removed and the depth of the ditch is up 1.8 m (6 ft). For ditch depth of 2.4 m (8 ft), four cases out of nine gave higher costs when the handrails are removed but the cost increase is less than 5%. By simple interpolation, it can be concluded that up to 2.1 m (7 ft) depth, accident costs will always be less when the handrails are removed.

The previous analysis is based only on accident costs. If one takes into account the cost to the farmers to move the farm equipment through some other location, money savings when the handrails are removed will be even bigger. Apparent cost increase due to removing the handrails for the four cases corresponding to ditch depth of 2.4 m (8 ft) will also disappear.

Therefore, it can be concluded that if an accident occurs at a culvert or narrow bridge that has a ditch height of 2.1 m (7 ft) or less, it will generally cost less to fall into the ditch when handrails are removed than to hit the handrail or run-off the road and hit the wingwalls or bottom of the ditch. Considering transportation costs for moving the farm equipment, it will generally be more economical to remove handrails on narrow bridges and culvert when the depth of the ditch is less than 2.4 m (8 ft).

4.0 CONCLUSIONS

4.1 Summary of Cost Analysis

The ROADSIDE software developed and made available by AASHTO was used in this study to compute accident costs for several combinations of vehicle speeds, culvert widths and ditch depths for both cases where the handrails are present and when the handrails have been removed. A cost analysis and cost comparison was made based on these results. The summary of the cost analysis is as follows:

1. Low accident costs are obtained using the Roadside Design Software. This was expected since the software was designed to be used on high traffic, high intensity roads. In the cases under consideration, the ADT is very low, therefore the number of accidents in a year are also very low.
2. If one looks at the results obtained for culverts with and without handrails one can see that as the road width decreases, accident costs tend to increase. As also expected, accident cost tends to increase as the height of the culvert ditch and the vehicle speed increase.
3. When comparing the values obtained between leaving the handrail in place and removing the handrail, one can see that the accident cost associated with a culvert having a height less or equal to 2.1 meters (7 ft) and no handrail is less than the cost of an accident in the presence of the handrail. If one takes into account the cost to the farmer having to move the farm equipment via another route, this difference in costs becomes more significant. In this case it is more economical to remove handrails from culverts and narrow bridges when the height is less or equal to 2.4 meters (8 ft).
4. It can therefore be recommendable to remove the handrails for culverts having a ditch height of 2.4 meters (8 ft) or less. For all other culvert heights judgment should be used when determining whether or not to remove the handrails. The cost of removing a handrail in 1982 was approximately \$50 - \$100 (8). If a 4% inflation rate is used, today it will cost about \$370 to \$740 to remove a handrail.

4.2 Conclusions

When possible, the best option for reducing problems with farm equipment is to replace the existing culvert structure and allow sufficient clear zone. Almost all of the existing narrow culverts were designed 50 years ago when the need for wide structures was limited.

Based on this investigation, site visits, accident data analysis, professional expertise, and engineering judgement, the research team agrees that for bridges or culverts which are 2.4 meters (8 feet) or less in depth, the bridge railing end is probably the greater hazard and for depths greater than about 2.7 m (9 ft) the bridge rail end may be the lesser hazard. The above

considerations are most appropriate, safety-wise, for Type A and B roads. The removal of rails on Type C roads is not as important, due to lower operating speeds.

Handrail removal depends on whether the handrail is a structural or non-structural element of the bridge or culvert. Structural handrails are those designed to carry, distribute, or transfer part of the loads on the structure. To determine if a handrail is structural, one can do one or more of the following:

1. Check the road or bridge plans for the structure in question, if available,
2. Ask engineers in the Bureau of Local Projects of KDOT who can generally provide assistance in this matter,
3. Check with other county engineers, or
4. Seek services of a consulting engineer.

Structural handrails are usually cast-in-place with the culvert itself. In all the cases visited during this study, all handrails encountered on narrow bridges and culverts were non-structural elements.

If handrails are found to be a structural element of the bridge or culvert, rails should not be removed. In the case where they are found to be non-structural (added to the culvert bridge structure) they can be removed as follows:

1. Use a jackhammer for the reinforced concrete and a cutting torch for the reinforcing steel.
2. Use a concrete saw for the reinforced concrete and a cutting torch or appropriate saw for the reinforcing steel.

It seems logical that for cross road structures or culverts with openings less than 2.3 square meters (25 square feet), the solid objects projecting from the structure should be removed. The existing structure should be extended with corrugated steel pipes to allow for safer end slopes and to gain additional road width required for safe travel and farm equipment passage. In general and whenever possible, by making adjacent end slopes 6:1 or flatter, the hazard would be eliminated.

Adding galvanized steel tapered sleeves, extending the culvert to achieve safer end slopes, and attaching end sections with parallel safety bars (grates), are typical procedures recognized by FHWA. Such products and services exist commercially nationwide and are available in Kansas.

4.3 Handrail Removal

If it is decided that certain handrails can be removed, the following points must be carefully considered.

1. The most important aspect of handrail removal is how deep to cut the handrail. For

purposes of safety, handrails should be removed flush with the roadway surface, and the removal will be more effective if they do not extend higher than 100 mm (4 inches) above the roadway surface. Remains of handrails extending more than 100 mm (4 inches) above the road surface can be more of a hazard than the handrail itself because they may not be as visible as a full handrail. Hitting them will result in a serious collision.

2. Some handrails may have been hit by vehicles or farm equipment and have only the lower part of the handrail remaining. If the existing parts of handrails are more than 100 mm (4 inches) above the road surface, they need to be cut down flush with the road level. Alternatively, the road level can be elevated a few inches so that the clear height extending above the final surface of the roadway will be within the 100 mm (4 in). Raising the road surface level can be accomplished by adding gravel or asphalt concrete to the surface. This alternative should not be used if the structural condition of the culvert or bridge is questionable such that the addition of the deadweight of the gravel or pavement layer may endanger the structure.
3. Another important factor to take into account when considering culvert handrails removal is the type of road on which they are located. Most of the culverts are located in rural settings where low operating speeds are expected and motor vehicle drivers (automobiles, pickup trucks, vans, etc) should normally anticipate encountering narrow structures. In many cases when the height of the culvert or depth of the ditch/water stream is less than 1.0 m (3.3 ft), handrail removal will be the most viable way of reducing damage due to hitting the vertical obstacle. As for farm equipment, removing the handrail will allow farmers to move such equipment over the culverts and narrow bridges without hitting an obstacle. If handrails are removed to a height of 100 mm (4 inches) above the surface of the roadway, this effectively widens the road by 0.6 to 0.9 m or 2 to 3 ft (8).
4. A very important aspect when removing handrails is to use adequate signing to inform approaching drivers. The best way to perform this task is by placing staggered OM-3 object markers. Typical roadway signing procedures are discussed in the Low Volume Rural Roads Handbook (5).

4.4 Recommendation for Future Studies

This study also included the investigation of other means of reducing roadside culvert hazards and the feasibility of implementing alternative solutions. As discussed in Appendix D, the clear zone concept and reduced end slopes are important factors that will reduce roadside culvert hazards, and consequently reduce personal injury, property damage, and possible litigation.

It is suggested that alternatives to guard fences and bridge rails on low-volume roads be investigated with further depth. Additional research is recommended to study the cost and suitability of installing grates and transverse bars not only on pipe culverts, but also on the sides of reinforced concrete boxes and small-span bridges.

REFERENCES

1. American Association of State Highway and Transportation Officials, Guide Specifications for Bridge Railings, Washington, D.C., 1989.
2. American Association of State Highway and Transportation Officials, Roadside Design Guide, Washington, D.C., 1995.
3. American Association of State Highway and Transportation Officials, A Guide for Selecting, Locating, and Designing Traffic Barriers, Washington, D.C., 1977.
4. Ross, Jr., H.E., Sicking, D.L, Zimmer, R.A., and Michie, J.D., "Recommended Procedures for the Safety Performance Evaluation of Highway Features," NCHRP Report 350, TRB, Washington, D.C., 1993.
5. Kansas Department of Transportation, Handbook of Traffic Control Practices for Low Volume Rural Roads, Topeka, KS, 1991.
6. Rys, M.J. and Russell, E.R., "Use of Guardrail on Low-Volume Roads According to Safety and Cost Effectiveness," Final Report for K-TRAN Project No. KSU-96-6, KDOT, Topeka, KS, May 1997.
7. Miaou, Shaw-Ping, "Estimating Vehicle Roadside Encroachment Frequencies Using Accident Prediction Models," Paper No. 970967, Transportation Research Board 76th Annual Meeting, TRB, Washington, D.C., January 1997.
8. Smith, B.L., "Guidelines for Removing Bridge and Culvert Rails on Low Volume Roads," Transportation Research Board Record 875, Washington D.C., 1983.
9. Stephens L.B, "Guardrail Warrants for Low Volume Roads," In: Issues Surrounding Highway and Roadside Safety Management, Transportation Circular No. 416, Transportation Research Board, National Research Council, Washington D.C., 1993.
10. Design Construction and Maintenance of Highway Safety Features and Appurtenances, Users Handbook, Publication No. FHWA-HI-97-026, National Highway Institute, FHWA, June 1997.
11. Russell, E.R., Smith, B.L., and Brondell, W., "Traffic Safety Assessment Guide," Report for Contract No. DTFH61-94-C-00123, Kansas State University, Manhattan, KS (574 pages).
12. J & J Drainage Products Co., "Safety Slope End Section - Sales Literature", P.O. Box 829, Hutchinson, KS 67504, Tel: 1-800-331-7465.

APPENDIX A
Statewide Survey

STATE OF KANSAS



KANSAS DEPARTMENT OF TRANSPORTATION

E. Dean Carlson
Secretary of Transportation

Docking State Office Building
Topeka 66612-1568
(913) 296-3566
TTY (913) 296-3585
FAX (913) 296-1095

Bill Graves
Governor of Kansas

BUREAU OF LOCAL PROJECTS

October 20, 1997

MEMORANDUM TO: County Engineers, Road Supervisors and
County Highway Administrators

SUBJECT: KTRAN Project KSU 97-7

The Kansas Department of Transportation has an on-going research project with Kansas State University to develop guidelines for removal of handrails on narrow culverts and bridges on low volume roads.

The objective is to develop guidelines for determining when to remove substandard handrails taking into account safety consideration, structural integrity, and cost effectiveness.

To aid in the research, the Bureau of Local Projects is requesting your assistance in completing the attached survey form. Please return your completed survey form to Dr. Hani Melhem at the address noted on the form.

Thank you for cooperation.

Larry W. Emig, P.E.
Chief of Local Projects

By: *Vernon L. Everhart*
Vernon L. Everhart, P.E.
Assistant Chief of Local Projects

NAME: _____

DATE: _____

COUNTY: _____

1- Total number of culverts (including short bridges span <20ft) in your county

Number: _____

2- Estimate the number of culverts with width/headwall problems in your county

Number: _____

3- How many requests to remove bridge rails/headwalls on narrow culverts and bridges have you received in the past three years ?

0 - 5

20 - 40

5 - 10

over 40

10 - 20

4- How many bridge rails/headwalls have been removed in the past three years ?

0 - 5

20 - 40

5 - 10

over 40

10 - 20

5- Have there been any accidents or complaints after removal?

Yes , how many _____

No

6- Has there been any changes in the number of accidents after removal?

INCREASE: Significant Moderate Slight

DECREASE: Significant Moderate Slight

No Change

7- What are some of the reasons for the removal of bridge rail/headwall ?

- ◇ Height of opening / ditch depth
 - ◇ Width of road
 - ◇ Number of complaints
 - ◇ Increase clear zone
 - ◇ Width of farm equipment
 - ◇ Other:
-
-

8- After removal of bridge rail/headwall do you use any special roadway signs to warn motorists?

- ◇ Yes : ◇ OM2 ◇ OM3
- ◇ No
- ◇ Other, specify _____

9- What is the most common height of the headwalls ?

- ◇ 0" - 6" ◇ 12" - 24"
- ◇ 6" - 12" ◇ over 24"

10- What features do most of the water drainage structures have?

- ◇ Headwall
- ◇ Wingwall
- ◇ No walls
- ◇ Other : _____

11- Do you keep accident records involving culvert bridge rails/headwalls ?

- ◇ DOT Forms No. 850, 851
- ◇ Others: _____
- ◇ Keep no records

12- For how long are these records (if any) kept in your office?

- ◇ Since _____
- ◇ For the last _____ years

13- Can the research team at Kansas State University have access to such files?

- ◇ Yes
- ◇ No

14- Do you know of any death or severe injury accidents involving culvert bridge rails/headwalls ?

- ◇ Yes, how many _____
- ◇ No

ADDITIONAL COMMENTS / REMARKS:

Please mail or fax response by **October 31, 1997** to:

Dr. Hani Melhem
Department of Civil Engineering
Kansas State University
Seaton Hall
Manhattan, KS 66506
fax: (785) 532-7717

APPENDIX B
DOT Form No. 850

SPECIAL DATA (State Use Only)				USE CODE "99" FOR UNKNOWN														
Dr/Pd #	Violation Charged	Citation No.	Dr/Pd #	Violation Charged	Citation No.	Dr/Pd #	Violation Charged	Citation No.										
OFFICER'S OPINIONS OF APPARENT CONTRIBUTING CIRCUMSTANCES (Factor Type-Unit Number/Specific Factor) Enter in order all codes that apply.																		
LIGHT 01 Daylight 02 Dawn 03 Dusk 04 Dark street lights on 05 Dark no street lights		TRAFFIC CONTROLS O/A (On/At Road) Type Present OK/NF (OK/Non-functional) <table border="1"> <tr><td>1</td><td>1</td></tr> <tr><td>2</td><td>2</td></tr> <tr><td>3</td><td>3</td></tr> <tr><td>4</td><td>4</td></tr> <tr><td>5</td><td>5</td></tr> </table> 00 None 01 Officer, flagger 02 Traffic signal 03 Stop sign 04 Flasher 05 Yield sign 06 RR gates or signal 07 RR crossing signs 08 No passing zone 09 Center/edge lines 88 Other		1	1	2	2	3	3	4	4	5	5	ACCIDENT CLASS 00 Other non-collision 01 Overtumed COLLISION WITH: 02 Pedestrian 03 Other motor vehicle* 04 Parked motor vehicle 05 Railway train 06 Pedalcycle 07 Animal(specify) 08 Fixed object** 09 Other object		* COLLISION WITH OTHER MOTOR VEH. 01 Head on 02 Rear end 03 Angle 04 Sideswipe-opposing 05 Sideswipe-overtaking 06 Backed into 88 Other		
1	1																	
2	2																	
3	3																	
4	4																	
5	5																	
WEATHER 00 No adverse conditions 01 Rain 08 Freezing rain 02 Sleet 14 Rain & fog 03 Snow 16 Rain & wind 04 Fog 24 Sleet & fog 05 Smoke 36 Snow & winds 06 Strong winds 07 Blowing dust, sand, etc. 88 Other		ROAD CHARACTER 01 Straight and level 02 Straight on grade 03 Straight at hillcrest 04 Curved and level 05 Curved on grade 06 Curved at hillcrest 88 Other		ACCIDENT LOCATION ON ROADWAY: 11 Non-intersection 12 Intersection 13 Intersection-related 14 Parking lot or driveway access 15 Interchange area 16 On crossover OFF ROADWAY: 21 Roadside (including shoulder) 22 Median 23 Parking lot, rest area trafficway 88 Other		** FIXED OBJECT TYPE 01 Bridge structure 02 Bridge rail 03 Crash cushion (barrels) 04 Divider, median barrier 05 Overhead sign support 06 Utility pole, devices 07 Other post or pole 08 Building 16 Mailbox 09 Guardrail 17 Ditch 10 Sign post 18 Embankment 11 Culvert 19 Wall 12 Curb 20 Tree 13 Fence 21 RR crossing fixtures 14 Hydrant 88 Other												
SURFACE TYPE 01 Concrete 02 Blacktop 03 Gravel 04 Dirt 05 Brick 88 Other		CONST./MAINT. ZONE 00 None apply 01 Construction zone 02 Maintenance zone 03 Utility zone		ROAD SPECIAL FEATURES Enter any visible identifier, refer by code Identify up to three 00 None 04 Railroad crossing 01 Bridge 05 Interchange 02 Bridge overhead 06 Ramp 03 Railroad bridge 88 Other		ROAD SPECIAL FEATURES Enter any visible identifier, refer by code Identify up to three 00 None 04 Railroad crossing 01 Bridge 05 Interchange 02 Bridge overhead 06 Ramp 03 Railroad bridge 88 Other												
VEHICLE MANEUVER BEFORE CRASH 01 Straight/following road 02 Left turn 03 Right turn 04 U turn 05 Overtaking (passing) 06 Changing lanes 07 Avoiding maneuver 08 Merging 09 Parking 10 Backing 11 Stopped awaiting turn 12 Stopped in traffic 13 Illegally parked 14 Disabled in roadway 15 Slowing or stopping 88 Other		DAMAGE LOCATION AREA--Vehicle 1 F R O N T 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Trailer? <input type="checkbox"/> Present <input type="checkbox"/> Damaged		VEHICLE BODY TYPE 01 Automobile 02 Motorcycle 03 Motorscooter or Moped 04 Van 05 Pickup truck 06 Single truck 4-tires 07 Camper or RV 08 Farm equipment 09 All terrain vehicle(ATV)		PEDESTRIAN LOCATION BEFORE IMPACT-- IN INTERSECTION: 01 In crosswalk or bikeway 02 Not in crosswalk or bikeway 03 In intersection without crosswalk or bikeway NOT IN INTERSECTION 11 In available crosswalk or bikeway 12 Not in available crosswalk or bikeway 13 In area without crosswalk or bikeway 25 NOT IN ROADWAY												
VEHICLE DAMAGE 00 None/None known 01 Damage (minor) 02 Functional 03 Disabling 04 Destroyed 88 Other		DAMAGE LOCATION AREA--Vehicle 2 F R O N T 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Trailer? <input type="checkbox"/> Present <input type="checkbox"/> Damaged		PEDESTRIAN ACTION 01 Entering or crossing road 02 Walking or riding on road 03 Approaching, leaving, or working on vehicle 04 Working (not on vehicle) 05 Playing or standing 06 Approaching or leaving bus 07 In parked vehicle 88 Other		PED OBEDIENCE TO TRAF SIG 00 No pedestrian signal 01 Obeyed pedestrian signal 02 Disobeyed ped signal 03 Ped signal malfunction 04 Not applicable												
DR. LIC. COMPLY (Code each driver) 00 Not licensed 01 Valid license 02 Invalid license		RESTRICT. COMPLY (Code each driver) 00 No restrictions 01 Complied with 02 Did not comply		SUBSTANCE USE AP - Alcohol Present AC - Alcohol Contributed DP - Illegal Drug Present DC - Illegal Drug Contributed MP - Medication Present MC - Medication Contributed		DRIVER/PED IMPAIRMENT TEST TR Alcohol or drug Test Refused PT Positive preliminary Test RP Test given, Results Pending B.A.C. 0.												

APPENDIX C

ROADSIDE Computer Results

Summary/Contents of Appendix C

Output files shown are for case of 50 km/h (30 mph) vehicle speed only. Similar output files were obtained for 60 km/h (35 mph) and 70 km/h (45 mph). Results are summarized in Tables 6, 7 and 8.

Global Parameters	41
Problem 4.9m50h: 4.9 m wide, hitting handrail	42
Problem 4.9m50a: 4.9 m wide, 0.6 m deep, no handrail	43
Problem 4.9m50af: 4.9 m wide, 0.6 m deep, falling off handrail	44
Problem 4.9m50b: 4.9 m wide, 1.0 m deep, no handrail	45
Problem 4.9m50bf: 4.9 m wide, 1.0 m deep, falling off handrail	46
Problem 4.9m50c: 4.9 m wide, 1.2 m deep, no handrail	47
Problem 4.9m50cf: 4.9 m wide, 1.2 m deep, falling off handrail	48
Problem 4.9m50d: 4.9 m wide, 1.8 m deep, no handrail	49
Problem 4.9m50df: 4.9 m wide, 1.8 m deep, falling off handrail	50
Problem 4.9m50e: 4.9 m wide, 2.4 m deep, no handrail	51
Problem 4.9m50ef: 4.9 m wide, 2.4 m deep, falling off handrail	52
Problem 5.5m50h: 5.5 m wide, hitting handrail	53
Problem 5.5m50a: 5.5 m wide, 0.6 m deep, no handrail	54
Problem 5.5m50af: 5.5 m wide, 0.6 m deep, falling off handrail	55
Problem 5.5m50b: 5.5 m wide, 1.0 m deep, no handrail	56
Problem 5.5m50bf: 5.5 m wide, 1.0 m deep, falling off handrail	57
Problem 5.5m50c: 5.5 m wide, 1.2 m deep, no handrail	58
Problem 5.5m50cf: 5.5 m wide, 1.2 m deep, falling off handrail	59
Problem 5.5m50d: 5.5 m wide, 1.8 m deep, no handrail	60
Problem 5.5m50df: 5.5 m wide, 1.8 m deep, falling off handrail	61
Problem 5.5m50e: 5.5 m wide, 2.4 m deep, no handrail	62
Problem 5.5m50ef: 5.5 m wide, 2.4 m deep, falling off handrail	63
Problem 6.1m50h: 6.1 m wide, hitting handrail	64
Problem 6.1m50a: 6.1 m wide, 0.6 m deep, no handrail	65
Problem 6.1m50af: 6.1 m wide, 0.6 m deep, falling off handrail	66
Problem 6.1m50b: 6.1 m wide, 1.0 m deep, no handrail	67
Problem 6.1m50bf: 6.1 m wide, 1.0 m deep, falling off handrail	68
Problem 6.1m50c: 6.1 m wide, 1.2 m deep, no handrail	69
Problem 6.1m50cf: 6.1 m wide, 1.2 m deep, falling off handrail	70
Problem 6.1m50d: 6.1 m wide, 1.8 m deep, no handrail	71
Problem 6.1m50df: 6.1 m wide, 1.8 m deep, falling off handrail	72
Problem 6.1m50e: 6.1 m wide, 2.4 m deep, no handrail	73
Problem 6.1m50ef: 6.1 m wide, 2.4 m deep, falling off handrail	74

GLOBAL PARAMETER VALUES FOR STUDY TITLED:

1. FATAL ACCIDENT COST = \$ 2,672,900
2. SEVERE INJURY ACCIDENT COST = \$ 185,050
3. MODERATE INJURY ACCIDENT COST = \$ 37,000
4. SLIGHT INJURY ACCIDENT COST = \$ 19,550
5. PDO LEVEL 2 ACCIDENT COST = \$ 2,050
6. PDO LEVEL 1 ACCIDENT COST = \$ 650
7. ENCROACHMENT RATE = 0.0003000 ENCROACHMENTS/km/YR/VPD
8. 50 km/h DES SPEED ENC ANGLE = 13.0 DEG AND TRAF VOL CAP = 24000 VPD/LANE
9. 60 km/h DES SPEED ENC ANGLE = 12.8 DEG AND TRAF VOL CAP = 23900 VPD/LANE
10. 70 km/h DES SPEED ENC ANGLE = 12.4 DEG AND TRAF VOL CAP = 23700 VPD/LANE
11. 80 km/h DES SPEED ENC ANGLE = 12.0 DEG AND TRAF VOL CAP = 23300 VPD/LANE
12. 90 km/h DES SPEED ENC ANGLE = 11.6 DEG AND TRAF VOL CAP = 22800 VPD/LANE
13. 100 km/h DES SPEED ENC ANGLE = 11.1 DEG AND TRAF VOL CAP = 22000 VPD/LANE
14. 110 km/h DES SPEED ENC ANGLE = 10.7 DEG AND TRAF VOL CAP = 21000 VPD/LANE
15. 120 km/h DES SPEED ENC ANGLE = 10.3 DEG AND TRAF VOL CAP = 20000 VPD/LANE
16. SWATH WIDTH = 3.600 m

SEVERITY INDEX	COST
0.0	\$ 0
0.5	\$ 650
1.0	\$ 3,198
2.0	\$ 8,347
3.0	\$ 43,878
4.0	\$ 107,760
5.0	\$ 253,596
6.0	\$ 535,834
7.0	\$ 869,741
8.0	\$ 1,394,226
9.0	\$ 2,040,574
10.0	\$ 2,672,900

1. TITLE: 4.9 m wide, 50 km/h, hitting handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 4.90 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 0.30 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0000	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0000	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00032 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.008
9. SEVERITY INDEX SU = 3.40 SD = 3.40 CU = 3.40 CD = 3.40 FACE= 1.90
 ACCIDENT COST \$ 69,431 \$ 69,431 \$ 69,431 \$ 69,431 \$ 7,832
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 11
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 2
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 1
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 14
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 235 ANNUALIZED \$ 17

ACCIDENT COST	= \$	235	ANNUALIZED \$	17
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 4.9m wide, 0.6 m deep, 50km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 4.90 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00037 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 2.60 SD = 2.60 CU = 3.00 CD = 3.00 FACE= 2.30

ACCIDENT COST	\$ 29,665	\$ 29,665	\$ 43,878	\$ 43,878	\$ 19,006
INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE				OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE				OF FEATURE = \$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER				OF FEATURE = \$	7
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER				OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH FACE				OF FEATURE = \$	2
TOTAL INITIAL ANNUAL ACCIDENT COST = \$					12
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 198 ANNUALIZED \$ 15

ACCIDENT COST	= \$	198	ANNUALIZED \$	15
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 4.9 m wide, 0.6 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 4.90 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (TVeff) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00037 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 2.60 SD = 2.60 CU = 3.00 CD = 3.00 FACE= 0.00
 ACCIDENT COST \$ 29,665 \$ 29,665 \$ 43,878 \$ 43,878 \$ 0

INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE	OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE	OF FEATURE = \$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER	OF FEATURE = \$	7
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER	OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH FACE	OF FEATURE = \$	0
TOTAL INITIAL ANNUAL ACCIDENT COST = \$		10
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 157 ANNUALIZED \$ 12

ACCIDENT COST	= \$	157	ANNUALIZED \$	12
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 4.9m wide, 1.0m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 4.90 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00037 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSO = 0.0000 CFCO = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 2.70 SD = 2.70 CU = 3.30 CD = 3.30 FACE = 2.70
 ACCIDENT COST \$ 33,219 \$ 33,219 \$ 63,042 \$ 63,042 \$ 33,219
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 10
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 4
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 18
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 289 ANNUALIZED \$ 21

ACCIDENT COST	= \$ 289	ANNUALIZED \$ 21
HIGHWAY DEPARTMENT COST	= \$ 0	ANNUALIZED \$ 0
INSTALLATION COST	= \$ 0	ANNUALIZED \$ 0
REPAIR COST	= \$ 0	ANNUALIZED \$ 0
MAINTENANCE COST	= \$ 0	ANNUALIZED \$ 0
SALVAGE VALUE	= \$ 0	ANNUALIZED \$ 0

1. TITLE: 4.9 m wide, 1.0 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 4.90 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00037 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 2.70 SD = 2.70 CU = 3.30 CD = 3.30 FACE = 0.00

ACCIDENT COST	\$ 33,219	\$ 33,219	\$ 63,042	\$ 63,042	\$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE					\$	1
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE					\$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER					\$	10
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER					\$	1
INITIAL COST/YEAR IMPACTS WITH FACE					\$	0
TOTAL INITIAL ANNUAL ACCIDENT COST = \$						13
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 219 ANNUALIZED \$ 16

ACCIDENT COST	= \$ 219	ANNUALIZED \$	16
HIGHWAY DEPARTMENT COST	= \$ 0	ANNUALIZED \$	0
INSTALLATION COST	= \$ 0	ANNUALIZED \$	0
REPAIR COST	= \$ 0	ANNUALIZED \$	0
MAINTENANCE COST	= \$ 0	ANNUALIZED \$	0
SALVAGE VALUE	= \$ 0	ANNUALIZED \$	0

1. TITLE: 4.9 m wide, 1.2 m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 4.90 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (Tveff) ENC/km/YR

	EFFECTIVE	BASELINE	CURVATURE	GRADE	USER	TOTAL
	TRAFFIC VPD	ENC/km/YR	FACTOR	FACTOR	FACTOR	ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00037 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSO = 0.0000 CFCO = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 3.30 SD = 3.30 CU = 3.90 CD = 3.90 FACE= 3.10
 ACCIDENT COST \$ 63,042 \$ 63,042 \$ 101,371 \$ 101,371 \$ 50,266
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 3
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 17
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 2
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 7
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 29
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 465 ANNUALIZED \$ 34

ACCIDENT COST	= \$	465	ANNUALIZED \$	34
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 4.9 m wide, 1.2 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 4.90 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR

	EFFECTIVE	BASELINE	CURVATURE	GRADE	USER	TOTAL
	TRAFFIC VPD	ENC/km/YR	FACTOR	FACTOR	FACTOR	ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00037 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 3.30 SD = 3.30 CU = 3.90 CD = 3.90 FACE= 0.00

ACCIDENT COST	\$ 63,042	\$ 63,042	\$ 101,371	\$ 101,371	\$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE					OF FEATURE = \$	3
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE					OF FEATURE = \$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER					OF FEATURE = \$	17
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER					OF FEATURE = \$	2
INITIAL COST/YEAR IMPACTS WITH FACE					OF FEATURE = \$	0
TOTAL INITIAL ANNUAL ACCIDENT COST = \$						22
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 359 ANNUALIZED \$ 26

ACCIDENT COST	= \$	359	ANNUALIZED \$	26
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 4.9 m wide, 1.8 m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 4.90 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	ENCROACHMENTS/YEAR
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00037 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 3.90 SD = 3.90 CU = 4.40 CD = 4.40 FACE= 3.70
 ACCIDENT COST \$ 101,371 \$ 101,371 \$ 166,094 \$ 166,094 \$ 88,595
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 4
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 27
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 4
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 12
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 48
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 774 ANNUALIZED \$ 57

ACCIDENT COST	= \$	774	ANNUALIZED \$	57
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 4.9 m wide, 1.8 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 4.90 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR

	EFFECTIVE	BASELINE	CURVATURE	GRADE	USER	TOTAL
	TRAFFIC VPD	ENC/km/YR	FACTOR	FACTOR	FACTOR	ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00037 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 3.90 SD = 3.90 CU = 4.40 CD = 4.40 FACE= 0.00
 ACCIDENT COST \$ 101,371 \$ 101,371 \$ 166,094 \$ 166,094 \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 4
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 27
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 4
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 0
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 36
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 587 ANNUALIZED \$ 43

ACCIDENT COST	= \$	587	ANNUALIZED \$	43
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 4.9 m wide, 2.4 m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 4.90 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (Tveff) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASILINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	ENCROACHMENTS/YEAR
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00037 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 4.30 SD = 4.30 CU = 5.00 CD = 5.00 FACE= 4.10
 ACCIDENT COST \$ 151,510 \$ 151,510 \$ 253,596 \$ 253,596 \$ 122,343
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 6
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 42
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 6
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 16
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 71
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 1,152 ANNUALIZED \$ 85

ACCIDENT COST	= \$ 1,152	ANNUALIZED \$ 85
HIGHWAY DEPARTMENT COST	= \$ 0	ANNUALIZED \$ 0
INSTALLATION COST	= \$ 0	ANNUALIZED \$ 0
REPAIR COST	= \$ 0	ANNUALIZED \$ 0
MAINTENANCE COST	= \$ 0	ANNUALIZED \$ 0
SALVAGE VALUE	= \$ 0	ANNUALIZED \$ 0

1. TITLE: 4.9 m wide, 2.4 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 4.90 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00037 IMPACTS PER YEAR

ADJACENT	CFTA = 0.0003	CFSU = 0.0000	CFCU = 0.0002	CFFA = 0.0001
OPPOSING	CFTO = 0.0000	CFTD = 0.0000	CFTD = 0.0000	CFTO = 0.0000

EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 4.30 SD = 4.30 CU = 5.00 CD = 5.00 FACE = 0.00

ACCIDENT COST	\$ 151,510	\$ 151,510	\$ 253,596	\$ 253,596	\$ 0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE				OF FEATURE = \$	6
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE				OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER				OF FEATURE = \$	42
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER				OF FEATURE = \$	6
INITIAL COST/YEAR IMPACTS WITH FACE				OF FEATURE = \$	0
TOTAL INITIAL ANNUAL ACCIDENT COST = \$					55
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 893 ANNUALIZED \$ 66

ACCIDENT COST	= \$ 893	ANNUALIZED \$	66
HIGHWAY DEPARTMENT COST	= \$ 0	ANNUALIZED \$	0
INSTALLATION COST	= \$ 0	ANNUALIZED \$	0
REPAIR COST	= \$ 0	ANNUALIZED \$	0
MAINTENANCE COST	= \$ 0	ANNUALIZED \$	0
SALVAGE VALUE	= \$ 0	ANNUALIZED \$	0

1. TITLE: 5.5 m wide, 50 km/h, hitting handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 5.50 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR

	EFFECTIVE	BASELINE	CURVATURE	GRADE	USER	TOTAL
	TRAFFIC VPD	ENC/km/YR	FACTOR	FACTOR	FACTOR	ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 0.30 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0000	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0000	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00032 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSO = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.008
9. SEVERITY INDEX SU = 3.40 SD = 3.40 CU = 3.40 CD = 3.40 FACE = 1.90
 ACCIDENT COST \$ 69,431 \$ 69,431 \$ 69,431 \$ 69,431 \$ 7,832
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 11
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 1
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 14
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 229 ANNUALIZED \$ 17

ACCIDENT COST	= \$	229	ANNUALIZED \$	17
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 5.5 m wide, 0.6 m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 5.50 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (Tveff) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00036 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 2.60 SD = 2.60 CU = 3.00 CD = 3.00 FACE = 2.30
 ACCIDENT COST \$ 29,665 \$ 29,665 \$ 43,878 \$ 43,878 \$ 19,006
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 7
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 2
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 12
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 193 ANNUALIZED \$ 14

ACCIDENT COST	= \$ 193	ANNUALIZED \$ 14
HIGHWAY DEPARTMENT COST	= \$ 0	ANNUALIZED \$ 0
INSTALLATION COST	= \$ 0	ANNUALIZED \$ 0
REPAIR COST	= \$ 0	ANNUALIZED \$ 0
MAINTENANCE COST	= \$ 0	ANNUALIZED \$ 0
SALVAGE VALUE	= \$ 0	ANNUALIZED \$ 0

1. TITLE: 5.5 m wide, 0.6 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 5.50 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (TV_{eff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	ENCROACHMENTS/YEAR
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00036 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 2.60 SD = 2.60 CU = 3.00 CD = 3.00 FACE = 0.00
 ACCIDENT COST \$ 29,665 \$ 29,665 \$ 43,878 \$ 43,878 \$

INITIAL COST/YEAR IMPACTS WITH	OF FEATURE = \$
INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE	1
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER	7
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER	1
INITIAL COST/YEAR IMPACTS WITH FACE	0
TOTAL INITIAL ANNUAL ACCIDENT COST = \$	9
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 153 ANNUALIZED \$ 11

	= \$	ANNUALIZED \$
ACCIDENT COST	153	11
HIGHWAY DEPARTMENT COST	0	0
INSTALLATION COST	0	0
REPAIR COST	0	0
MAINTENANCE COST	0	0
SALVAGE VALUE	0	0

1. TITLE: 5.5 m wide, 1.0 m deep, 50km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 5.50 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (Tveff) ENC/km/YR

	EFFECTIVE	BASELINE	CURVATURE	GRADE	USER	TOTAL
	TRAFFIC VPD	ENC/km/YR	FACTOR	FACTOR	FACTOR	ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00036 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 2.70 SD = 2.70 CU = 3.30 CD = 3.30 FACE= 2.70
 ACCIDENT COST \$ 33,219 \$ 33,219 \$ 63,042 \$ 63,042 \$ 33,219

INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE	OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE	OF FEATURE = \$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER	OF FEATURE = \$	10
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER	OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH FACE	OF FEATURE = \$	4
TOTAL INITIAL ANNUAL ACCIDENT COST = \$		17
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 282 ANNUALIZED \$ 21

ACCIDENT COST	= \$ 282	ANNUALIZED \$ 21
HIGHWAY DEPARTMENT COST	= \$ 0	ANNUALIZED \$ 0
INSTALLATION COST	= \$ 0	ANNUALIZED \$ 0
REPAIR COST	= \$ 0	ANNUALIZED \$ 0
MAINTENANCE COST	= \$ 0	ANNUALIZED \$ 0
SALVAGE VALUE	= \$ 0	ANNUALIZED \$ 0

1. TITLE: 5.5 m wide, 1.0 m deep, 50km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 5.50 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (Tveff) ENC/km/YR

	EFFECTIVE	BASELINE	CURVATURE	GRADE	USER	TOTAL
	TRAFFIC VPD	ENC/km/YR	FACTOR	FACTOR	FACTOR	ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00036 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 2.70 SD = 2.70 CU = 3.30 CD = 3.30 FACE= 0.00
 ACCIDENT COST \$ 33,219 \$ 33,219 \$ 63,042 \$ 63,042 \$

INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE	OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE	OF FEATURE = \$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER	OF FEATURE = \$	10
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER	OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH FACE	OF FEATURE = \$	0
TOTAL INITIAL ANNUAL ACCIDENT COST = \$		13
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 213 ANNUALIZED \$ 16

ACCIDENT COST	= \$	213	ANNUALIZED \$	16
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 5.5 m wide, 1.2 m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 5.50 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (TVeff) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00036 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 3.30 SD = 3.30 CU = 3.90 CD = 3.90 FACE = 3.10
 ACCIDENT COST \$ 63,042 \$ 63,042 \$ 101,371 \$ 101,371 \$ 50,266
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 3
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 17
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 2
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 6
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 28
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 454 ANNUALIZED \$ 33

ACCIDENT COST	= \$ 454	ANNUALIZED \$ 33
HIGHWAY DEPARTMENT COST	= \$ 0	ANNUALIZED \$ 0
INSTALLATION COST	= \$ 0	ANNUALIZED \$ 0
REPAIR COST	= \$ 0	ANNUALIZED \$ 0
MAINTENANCE COST	= \$ 0	ANNUALIZED \$ 0
SALVAGE VALUE	= \$ 0	ANNUALIZED \$ 0

1. TITLE: 5.5 m wide, 1.2 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 5.50 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (Tveff) ENC/km/YR

	EFFECTIVE	BASELINE	CURVATURE	GRADE	USER	TOTAL
	TRAFFIC VPD	ENC/km/YR	FACTOR	FACTOR	FACTOR	ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00036 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 3.30 SD = 3.30 CU = 3.90 CD = 3.90 FACE= 0.00

ACCIDENT COST	\$ 63,042	\$ 63,042	\$ 101,371	\$ 101,371	\$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE					OF FEATURE = \$	3
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE					OF FEATURE = \$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER					OF FEATURE = \$	17
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER					OF FEATURE = \$	2
INITIAL COST/YEAR IMPACTS WITH FACE					OF FEATURE = \$	0
TOTAL INITIAL ANNUAL ACCIDENT COST = \$						22
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 350 ANNUALIZED \$ 26

ACCIDENT COST	= \$	350	ANNUALIZED \$	26
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 5.5 m wide, 1.8 m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 5.50 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (TVeff) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00036 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 3.90 SD = 3.90 CU = 4.40 CD = 4.40 FACE = 3.70
 ACCIDENT COST \$ 101,371 \$ 101,371 \$ 166,094 \$ 166,094 \$ 88,595
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 4
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 27
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 3
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 11
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 47
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 756 ANNUALIZED \$ 56

		ANNUALIZED \$
ACCIDENT COST	= \$ 756	56
HIGHWAY DEPARTMENT COST	= \$ 0	0
INSTALLATION COST	= \$ 0	0
REPAIR COST	= \$ 0	0
MAINTENANCE COST	= \$ 0	0
SALVAGE VALUE	= \$ 0	0

1. TITLE: 5.5 m wide, 1.8 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 5.50 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (TV_{eff}) ENC/km/YR

	EFFECTIVE	BASELINE	CURVATURE	GRADE	USER	TOTAL
	TRAFFIC VPD	ENC/km/YR	FACTOR	FACTOR	FACTOR	ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00036 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 3.90 SD = 3.90 CU = 4.40 CD = 4.40 FACE= 0.00
 ACCIDENT COST \$ 101,371 \$ 101,371 \$ 166,094 \$ 166,094 \$ 0

INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE	OF FEATURE = \$	4
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE	OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER	OF FEATURE = \$	27
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER	OF FEATURE = \$	3
INITIAL COST/YEAR IMPACTS WITH FACE	OF FEATURE = \$	0
TOTAL INITIAL ANNUAL ACCIDENT COST = \$		35
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 572 ANNUALIZED \$ 42

ACCIDENT COST	= \$	572	ANNUALIZED \$	42
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 5.5 m wide, 2.4 m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 5.50 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (TVeff) ENC/km/YR

	EFFECTIVE	BASELINE	CURVATURE	GRADE	USER	TOTAL
	TRAFFIC VPD	ENC/km/YR	FACTOR	FACTOR	FACTOR	ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00036 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 4.30 SD = 4.30 CU = 5.00 CD = 5.00 FACE= 4.10
 ACCIDENT COST \$ 151,510 \$ 151,510 \$ 253,596 \$ 253,596 \$ 122,343
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 6
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 42
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 5
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 16
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 69
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 1,125 ANNUALIZED \$ 83

ACCIDENT COST	= \$	1,125	ANNUALIZED \$	83
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 5.5 m wide, 2.4 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 5.50 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	ENCROACHMENTS/YEAR
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00036 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 4.30 SD = 4.30 CU = 5.00 CD = 5.00 FACE= 0.00

ACCIDENT COST	\$	151,510	\$	151,510	\$	253,596	\$	253,596	\$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE										6
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE										1
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER										42
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER										5
INITIAL COST/YEAR IMPACTS WITH FACE										0
TOTAL INITIAL ANNUAL ACCIDENT COST										\$ 54
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 871 ANNUALIZED \$ 64

ACCIDENT COST	= \$	871	ANNUALIZED \$	64
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 6.1 m wide, 50 km/h, hitting handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 6.10 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (TVeff) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 0.30 m

	ZONE 1	ZONE 2	ZONE 3	ENCROACHMENTS/YEAR
ADJACENT	0.0000	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0000	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00031 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.008
9. SEVERITY INDEX SU = 3.40 SD = 3.40 CU = 3.40 CD = 3.40 FACE = 1.90
 ACCIDENT COST \$ 69,431 \$ 69,431 \$ 69,431 \$ 69,431 \$ 7,832
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 11
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 1
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 14
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 225 ANNUALIZED \$ 17

	PRESENT WORTH \$	ANNUALIZED \$
ACCIDENT COST	225	17
HIGHWAY DEPARTMENT COST	0	0
INSTALLATION COST	0	0
REPAIR COST	0	0
MAINTENANCE COST	0	0
SALVAGE VALUE	0	0

1. TITLE: 6.1 m wide, 0.6 m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 6.10 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR
- | | EFFECTIVE
TRAFFIC VPD | BASELINE
ENC/km/YR | CURVATURE
FACTOR | GRADE
FACTOR | USER
FACTOR | TOTAL
ENC/km/YR |
|----------|--------------------------|-----------------------|---------------------|-----------------|----------------|--------------------|
| ADJACENT | 40 | 0.0120 | 2.00 | 1.00 | 1.00 | 0.0240 |
| OPPOSING | 40 | 0.0120 | 2.00 | 1.00 | 1.00 | 0.0240 |
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m
- | | ZONE 1 | ZONE 2 | ZONE 3 | ENCROACHMENTS/YEAR |
|----------|--------|--------|--------|--------------------|
| ADJACENT | 0.0005 | 0.0004 | 0.0001 | ENCROACHMENTS/YEAR |
| OPPOSING | 0.0005 | 0.0004 | 0.0001 | ENCROACHMENTS/YEAR |
8. INITIAL COLLISION FREQUENCY = 0.00035 IMPACTS PER YEAR
- | | | | | |
|--|---------------|---------------|---------------|---------------|
| ADJACENT | CFTA = 0.0003 | CFSU = 0.0000 | CFCU = 0.0002 | CFFA = 0.0001 |
| OPPOSING | CFTO = 0.0000 | CFSD = 0.0000 | CFCD = 0.0000 | CFFO = 0.0000 |
| EXPECTED IMPACTS OVER PROJECT LIFE = 0.009 | | | | |
9. SEVERITY INDEX SU = 2.60 SD = 2.60 CU = 3.00 CD = 3.00 FACE = 2.30
- | | | | | | |
|--|-----------|-----------|-----------|-----------|-------------------|
| ACCIDENT COST | \$ 29,665 | \$ 29,665 | \$ 43,878 | \$ 43,878 | \$ 19,006 |
| INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE | | | | | OF FEATURE = \$ 1 |
| INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE | | | | | OF FEATURE = \$ 0 |
| INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER | | | | | OF FEATURE = \$ 7 |
| INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER | | | | | OF FEATURE = \$ 1 |
| INITIAL COST/YEAR IMPACTS WITH FACE | | | | | OF FEATURE = \$ 2 |
| TOTAL INITIAL ANNUAL ACCIDENT COST = \$ | | | | | 12 |
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 189 ANNUALIZED \$ 14
- | | | | |
|-------------------------|----------|---------------|----|
| ACCIDENT COST | = \$ 189 | ANNUALIZED \$ | 14 |
| HIGHWAY DEPARTMENT COST | = \$ 0 | ANNUALIZED \$ | 0 |
| INSTALLATION COST | = \$ 0 | ANNUALIZED \$ | 0 |
| REPAIR COST | = \$ 0 | ANNUALIZED \$ | 0 |
| MAINTENANCE COST | = \$ 0 | ANNUALIZED \$ | 0 |
| SALVAGE VALUE | = \$ 0 | ANNUALIZED \$ | 0 |

1. TITLE: 6.1 m wide, 0.6 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 6.10 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (TV_{eff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00035 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 2.60 SD = 2.60 CU = 3.00 CD = 3.00 FACE = 0.00
 ACCIDENT COST \$ 29,665 \$ 29,665 \$ 43,878 \$ 43,878 \$
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 7
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 0
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 9
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 150 ANNUALIZED \$ 11

ACCIDENT COST	= \$	150	ANNUALIZED \$	11
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 6.1 m wide, 1.0 m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 6.10 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (Tveff) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	ENCROACHMENTS/YEAR
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00035 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 2.70 SD = 2.70 CU = 3.30 CD = 3.30 FACE = 2.70
 ACCIDENT COST \$ 33,219 \$ 33,219 \$ 63,042 \$ 63,042 \$ 33,219
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 10
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 4
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 17
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 276 ANNUALIZED \$ 20

ACCIDENT COST	= \$	276	ANNUALIZED \$	20
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 6.1 m wide, 1.0 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 6.10 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (TVeff) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00035 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSO = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 2.70 SD = 2.70 CU = 3.30 CD = 3.30 FACE= 0.00

ACCIDENT COST	\$	33,219	\$	33,219	\$	63,042	\$	63,042	\$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE					OF FEATURE = \$					1
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE					OF FEATURE = \$					0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER					OF FEATURE = \$					10
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER					OF FEATURE = \$					1
INITIAL COST/YEAR IMPACTS WITH FACE					OF FEATURE = \$					0
TOTAL INITIAL ANNUAL ACCIDENT COST = \$										13
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 209 ANNUALIZED \$ 15

ACCIDENT COST	= \$	209	ANNUALIZED \$	15
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 6.1 m wide, 1.2 m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 6.10 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_{veff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00035 IMPACTS PER YEAR

ADJACENT	CFTA = 0.0003	CFSU = 0.0000	CFCU = 0.0002	CFFA = 0.0001
OPPOSING	CFTO = 0.0000	CFSO = 0.0000	CFTD = 0.0000	CFFO = 0.0000
EXPECTED IMPACTS OVER PROJECT LIFE = 0.009				
9. SEVERITY INDEX SU = 3.30 SD = 3.30 CU = 3.90 CD = 3.90 FACE = 3.10

ACCIDENT COST	\$ 63,042	\$ 63,042	\$ 101,371	\$ 101,371	\$ 50,266
INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE					OF FEATURE = \$ 3
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE					OF FEATURE = \$ 0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER					OF FEATURE = \$ 17
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER					OF FEATURE = \$ 1
INITIAL COST/YEAR IMPACTS WITH FACE					OF FEATURE = \$ 6
TOTAL INITIAL ANNUAL ACCIDENT COST = \$					27
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 445 ANNUALIZED \$ 33

ACCIDENT COST	= \$ 445	ANNUALIZED \$ 33
HIGHWAY DEPARTMENT COST	= \$ 0	ANNUALIZED \$ 0
INSTALLATION COST	= \$ 0	ANNUALIZED \$ 0
REPAIR COST	= \$ 0	ANNUALIZED \$ 0
MAINTENANCE COST	= \$ 0	ANNUALIZED \$ 0
SALVAGE VALUE	= \$ 0	ANNUALIZED \$ 0

1. TITLE: 6.1 m wide, 1.2 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 6.10 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (TV_{eff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00035 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 3.30 SD = 3.30 CU = 3.90 CD = 3.90 FACE= 0.00
 ACCIDENT COST \$ 63,042 \$ 63,042 \$ 101,371 \$ 101,371 \$

INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE	OF FEATURE = \$	3
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE	OF FEATURE = \$	0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER	OF FEATURE = \$	17
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER	OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH FACE	OF FEATURE = \$	0
TOTAL INITIAL ANNUAL ACCIDENT COST = \$		21
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 343 ANNUALIZED \$ 25

ACCIDENT COST	= \$	343	ANNUALIZED \$	25
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 6.1m wide, 1.8m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 6.10 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (Tveff) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00035 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 3.90 SD = 3.90 CU = 4.40 CD = 4.40 FACE = 3.70
 ACCIDENT COST \$ 101,371 \$ 101,371 \$ 166,094 \$ 166,094 \$ 88,595
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 4
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 27
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 2
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 11
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 46
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 741 ANNUALIZED \$ 55

		ANNUALIZED \$
ACCIDENT COST	\$ 741	55
HIGHWAY DEPARTMENT COST	\$ 0	0
INSTALLATION COST	\$ 0	0
REPAIR COST	\$ 0	0
MAINTENANCE COST	\$ 0	0
SALVAGE VALUE	\$ 0	0

1. TITLE: 6.1m wide, 1.8m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 6.10 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (TV_{eff}) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00035 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSO = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 3.90 SD = 3.90 CU = 4.40 CD = 4.40 FACE = 0.00
 ACCIDENT COST \$ 101,371 \$ 101,371 \$ 166,094 \$ 166,094 \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 4
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 0
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 27
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 2
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 0
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 34
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 560 ANNUALIZED \$ 41

ACCIDENT COST	= \$	560	ANNUALIZED \$	41
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 6.1 m wide, 2.4 m deep, 50 km/h, no handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 6.10 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_veff) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00035 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSO = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 4.30 SD = 4.30 CU = 5.00 CD = 5.00 FACE= 4.10
 ACCIDENT COST \$ 151,510 \$ 151,510 \$ 253,596 \$ 253,596 \$ 122,343
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF FEATURE = \$ 6
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF FEATURE = \$ 1
 INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF FEATURE = \$ 42
 INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF FEATURE = \$ 4
 INITIAL COST/YEAR IMPACTS WITH FACE OF FEATURE = \$ 15
 TOTAL INITIAL ANNUAL ACCIDENT COST = \$ 68
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 1,102 ANNUALIZED \$ 81

ACCIDENT COST	= \$	1,102	ANNUALIZED \$	81
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

1. TITLE: 6.1 m wide, 2.4 m deep, 50 km/h, falling off handrail
2. INITIAL TRAFFIC VOLUME = 80 VEHICLES PER DAY
 TRAFFIC GROWTH RATE = 2.000 %/YEAR UNCAPPED DES YR ADT = 119 VPD
 TRAFFIC VOLUME CAP = 24,000 VPD/LANE AT 323.0 YR RND TO 323 YR
3. UNDIVIDED HIGHWAY TOTAL LANE(S) = 1 LANE WIDTH = 6.10 m
4. CURVATURE (RADIUS IN METERS) = 0 GRADE (PERCENT) = 0.0
5. INITIAL ENCROACHMENT FREQUENCY = 0.0003000 * (T_veff) ENC/km/YR

	EFFECTIVE TRAFFIC VPD	BASELINE ENC/km/YR	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC/km/YR
ADJACENT	40	0.0120	2.00	1.00	1.00	0.0240
OPPOSING	40	0.0120	2.00	1.00	1.00	0.0240
6. DESIGN SPEED = 50 km/h ENC ANGLE = 13.0 DEG SWATH WIDTH = 3.60 m
7. LATERAL OFFSET (A) = 0.00 m
 LONGITUDINAL LENGTH (L) = 4.90 m
 WIDTH OF OBSTACLE (W) = 4.90 m

	ZONE 1	ZONE 2	ZONE 3	ENCROACHMENTS/YEAR
ADJACENT	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
OPPOSING	0.0005	0.0004	0.0001	ENCROACHMENTS/YEAR
8. INITIAL COLLISION FREQUENCY = 0.00035 IMPACTS PER YEAR
 ADJACENT CFTA = 0.0003 CFSU = 0.0000 CFCU = 0.0002 CFFA = 0.0001
 OPPOSING CFTO = 0.0000 CFSD = 0.0000 CFCD = 0.0000 CFFO = 0.0000
 EXPECTED IMPACTS OVER PROJECT LIFE = 0.009
9. SEVERITY INDEX SU = 4.30 SD = 4.30 CU = 5.00 CD = 5.00 FACE= 0.00
 ACCIDENT COST \$ 151,510 \$ 151,510 \$ 253,596 \$ 253,596 \$ 0

INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE	OF FEATURE = \$	6
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE	OF FEATURE = \$	1
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER	OF FEATURE = \$	42
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER	OF FEATURE = \$	4
INITIAL COST/YEAR IMPACTS WITH FACE	OF FEATURE = \$	0
TOTAL INITIAL ANNUAL ACCIDENT COST = \$		52
10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 4.000 %/YR
 CRF = 0.07358 KC = 16.25177 KT = 13.59033 KJ = 0.45639
11. INSTALLATION COST = \$ 0 SALVAGE VALUE = \$ 0
12. REPAIR COST/ACC \$ SU= 0 SD= 0 CU= 0 CD= 0 F= 0
13. MAINTENANCE COST PER YEAR = \$ 0.
14. TOTAL PRESENT WORTH = \$ 852 ANNUALIZED \$ 63

ACCIDENT COST	= \$	852	ANNUALIZED \$	63
HIGHWAY DEPARTMENT COST	= \$	0	ANNUALIZED \$	0
INSTALLATION COST	= \$	0	ANNUALIZED \$	0
REPAIR COST	= \$	0	ANNUALIZED \$	0
MAINTENANCE COST	= \$	0	ANNUALIZED \$	0
SALVAGE VALUE	= \$	0	ANNUALIZED \$	0

APPENDIX D

Roadside Safety Clear Zone Concept

ROADSIDE SAFETY CLEAR ZONE CONCEPT

Before making the final decision to remove the cross-drainage bridge or culvert rails near the edge of the road, one needs to consider the following: Culverts or bridges that are designed to carry water underneath and perpendicular to the roadway are called cross drainage structures. Parallel drainage structures are those culverts which contain the flow of parallel ditches (parallel to the roadway) under driveways and intersecting roadways. Safety issues for parallel drainage structures are discussed in a following section.

The current reference source for guidance on safer roadside design is the AASHTO Roadside Design Guide. This publication is intended as a guide to practices that may be adopted by agencies having responsibility for roadside design, construction and maintenance. It is intended only as a guide and does not establish either standards or policy.

The purpose of the Roadside Design Guide is to provide information that enables highway professionals to reduce the number and severity of off-road accidents. The Roadside Design Guide provides guidelines on the amount of roadside border area that should be available for safe use by a vehicle that has left the traveled way. This area, referred to as the desirable clear zone, starts at the edge of the traveled way and includes the shoulder and auxiliary lanes in addition to the roadside features. The extent of the desirable clear zone is dependent on the design speed and the probability of a vehicle leaving the roadway. There is, therefore, no definite answer to the amount of clear zone required. Engineering judgement must be used to provide as much clear zone as can reasonably be obtained consistent with the class of road, design speed, traffic volume, horizontal curves, prevalent roadside characteristics, accident experience and available resources.

Run-off-the-road accidents are typically high severity crashes that involve vehicles impacting fixed objects and/or rolling over. The ideal solution is to provide a level roadside that is free of all fixed objects, at least within and preferably beyond the desirable clear zone area. As a practical concern, this is rarely a practical option; roadways are often constructed at a higher or lower elevation than the surrounding terrain. The result is roadside slopes that may be positive, negative or variable with drainage ditches often existing near the traveled way. The direction and severity of roadside slopes complicates the determination of the desirable clear zone width.

The term "clear zone" refers to the desirable unobstructed area available for the recovery of vehicles that have left the traveled way. When possible, there should be no physical obstructions within the clear zone area. If the obstructions cannot be removed, then engineering judgement must be used to determine if a longitudinal barrier or a crash cushion should shield the obstruction. *A barrier should only be installed, however, if it is clear that an impact resulting from a vehicle striking the barrier will be less severe than the accident resulting from striking the unshielded object.*

Obstructions and non-traversable hazards within the clear zone should be, in order of preference:

1. Removed or redesigned so that they can be safely traversed.
2. Relocated outside of the clear zone to a point where they are less likely to be hit.
3. Made breakaway to reduce impact severity. - Not feasible for Low Volume Roads
4. Shielded with a traffic barrier or impact attenuator. - Not usually feasible for Low Volume Roads.
5. Delineated if the above treatments are not practical.

Barriers should only be installed if they can be expected to reduce the severity of potential accidents. Since the severity of potential accidents is not directly related to the probability or frequency of run-off-the-road accidents, it is often difficult to determine when a barrier should be installed. Some agencies determine barrier need by comparing the costs associated with the barrier (installation cost, maintenance cost and accident cost) to those associated with the unshielded hazard. The cost analysis should be performed to evaluate three options: 1) remove the hazard, 2) install an appropriate barrier and 3) leave the hazard unshielded. The third option is usually cost effective only on low speed, low volume roadways where engineering studies indicate a low probability of accidents.

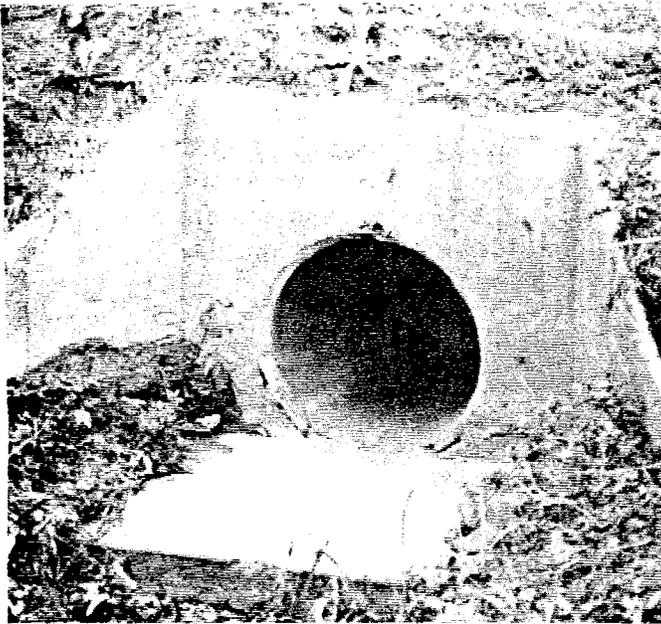
Note that the objective should be to provide a “clear zone” as wide as is practical. The clear zone concept means having a traversable and non-obstructed roadside zone measured from the edge of the traveled way, that is adequate to permit a high percentage of vehicles to recover safely after they have left the roadway. Much of the material in this chapter came from Reference 10*.

It has been suggested that on LVR (≤ 400 ADT) where operating speeds are expected to be 80 km/h (50 mph) or greater, that a minimum 3.0-meter (10-foot) wide clear zone should be provided (11). If a minimum clear zone cannot be provided, or where fill slopes are high, then guardrail installation should be considered. Guidelines for guardrails are covered in Reference 11* (pp. 230-245).

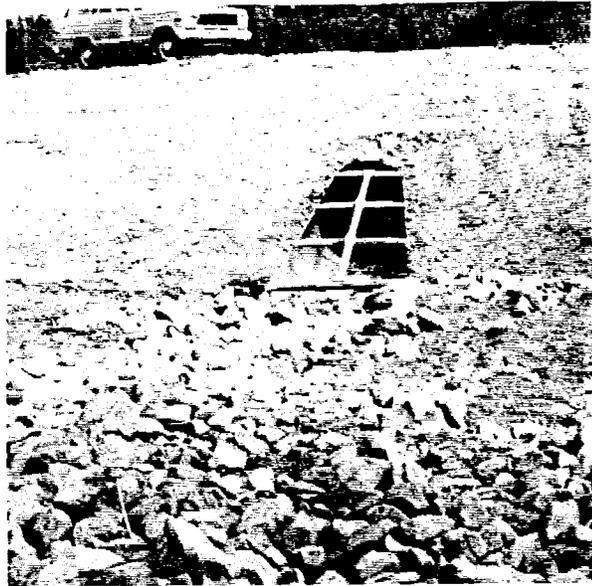
D.1 Cross Drainage Features

Cross drainage structures are designed to carry water underneath and perpendicular to the roadway. They can vary in size from 460 mm (18 in) concrete or corrugated metal pipes to large shapes 3 meters (10 ft) or more in diameter. To reduce erosion problems the inlets and outlets consist of concrete headwalls and wingwalls for the larger sections and beveled end sections for the smaller pipes as presented in Figure 23.

*List of references is given on page 30 of this report.



a) headwall and wingwall inlet design



b) beveled inlet design

Figure 23 – Typical Cross Drainage Inlet Designs

Cross drainage structures can pose a hazard to errant motorists due to the design of the headwall or wingwall and due to the drainage opening itself. Headwalls and wingwalls often result in concrete extending above surface level. Errant vehicles can become snagged on the exposed concrete or drop into the opening causing an abrupt stop. The alternatives that can be taken to minimize these hazards include:

- Eliminating the structure - it may no longer be functional or needed.
- Installing a traversable design.
- Moving the drainage structure away from the traveled way - see the section on clear zones in Reference 11 (pp.208-230).
- Shielding the structure - usually not practical for low volume roads.

D.1.1 Traversable Designs for Cross Drainage Structure

The inlets and outlets of cross drainage structures can generally be located on the foreslope or bottom of parallel ditches. If the foreslope is 1:3 or flatter, it is preferable to extend, or shorten the cross drainage structure to match the face of the embankment slope. Matching the structure to the slope results in a traversable design, reduces hazard area, reduces erosion problems and simplifies mowing operations. Matching the faces of the drainage structure with

the embankment could also be accomplished by warping the embankment in or out to match the drainage opening. This latter method is not recommended, however, since it will cause discontinuities in the slope resulting in possible vehicle control problems and increased erosion.

Matching the drainage structure to the slope of the embankment is all that is required when the slope is 1:3, or flatter, and the culvert has a single round pipe of 915 mm (36 in) or less. Pipes with a clear opening width of 1000 mm (39 in) and greater can be made traversable for passenger vehicles by using grates or pipes to reduce the clear opening width. Crash tests indicate that automobiles can cross culvert end sections on slopes as steep as 1:3 at speeds as low as 30 km/h (19 mph) and as high as 100 km/h (62 mph) when steel safety pipes are placed on 750 mm (29.5 in) centers for cross drainage structures. This spacing does not provide a smooth ride over the culvert, but will prevent wheel entrapment and not decrease the hydraulic capacity of the culvert. The flow capacity can be adversely affected, however, if debris accumulates and causes partial clogging of the inlet. It is important that proper maintenance be performed to keep the inlets free of debris.

The safety pipes for cross drainage structures should run from top to bottom of the drainage structure. This will orientate the safety pipes so that an errant vehicle, traveling parallel to the roadway, will have its wheel travel from pipe to pipe and not fall between adjacent safety pipes. Figure 24 presents the proper orientation for a cross drainage structure pipe grate. The recommended pipe sizes, at a 750 mm (29.5 in) spacing, to support a full size automobile are presented in Table 9 and the design details as Figure 25. Stainless steel or galvanized 16 mm (.6 in) “Molly” parabolts, or other approved fastening device, should be used if the safety pipes are directly connected to the concrete of the paved slope headwall. This will allow for removal of the safety pipes if the drainage structure should get plugged with debris.

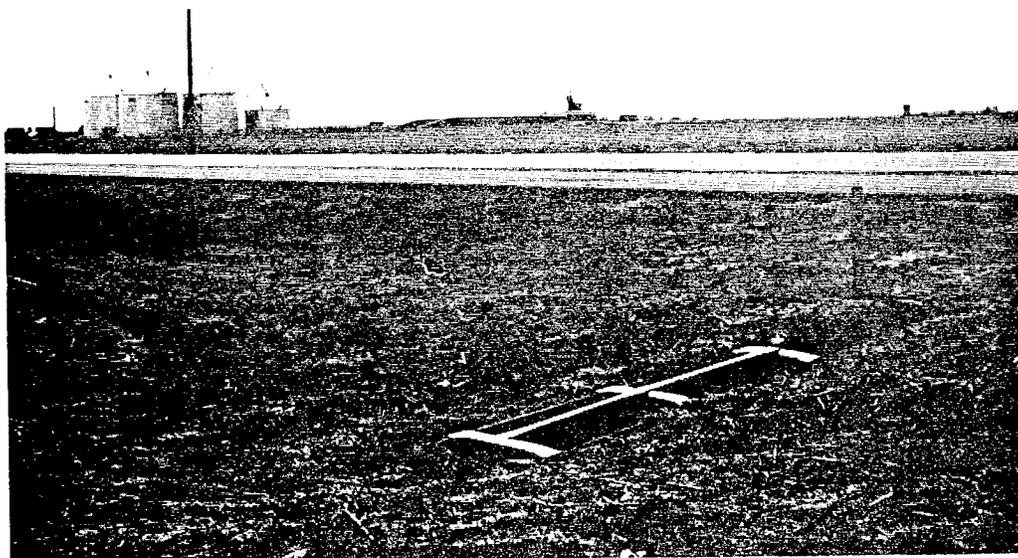


Figure 24 – Orientation of Safety Pipe Grate for Cross Drainage Structures

Table 9 - Safety Pipe Sizes for Both Cross and Parallel Drainage Structures

Span length (m)	Safety pipe (Schedule 40) Inside diameter (mm)
up to 3.7	75
3.7 to 4.9	90
4.9 through 6.1	100
6.1 or less with center support	75

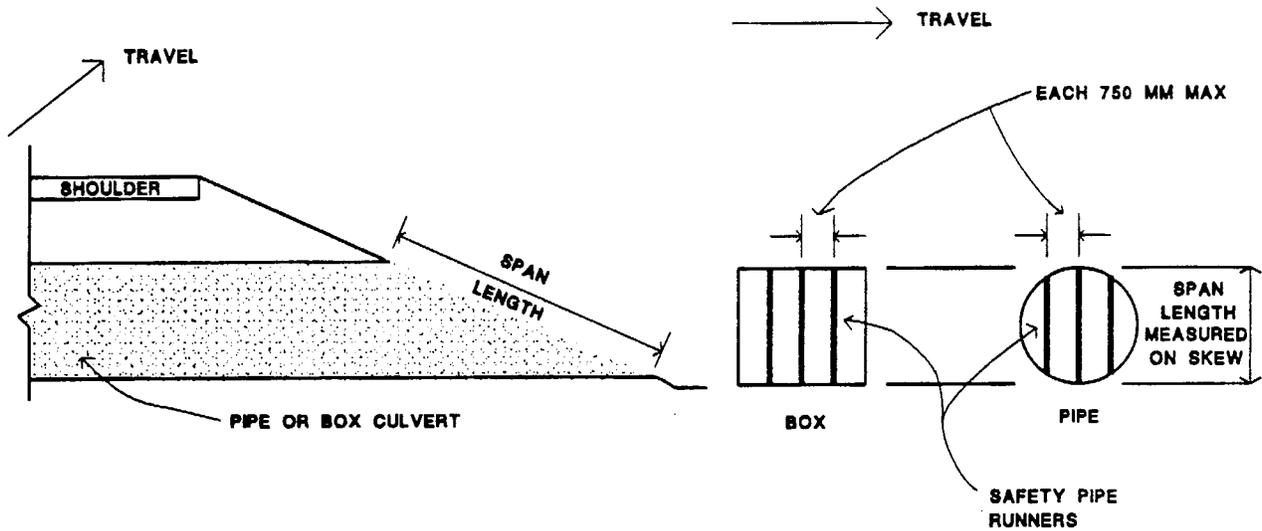


Figure 25 - Design Details of Safety Pipe Installation for Cross Drainage Structures

Commercially available devices are also available (see Figure 26) to provide a sloped end treatment and safety bars for cross drainage structures. This is an example of a commercially available device manufactured by J & J Drainage Products Company (12). Such devices are discussed more fully in Section 4.2 on parallel structure design. This cross drainage safety slope end section may be attached directly to a culvert end or to an extension of a culvert.

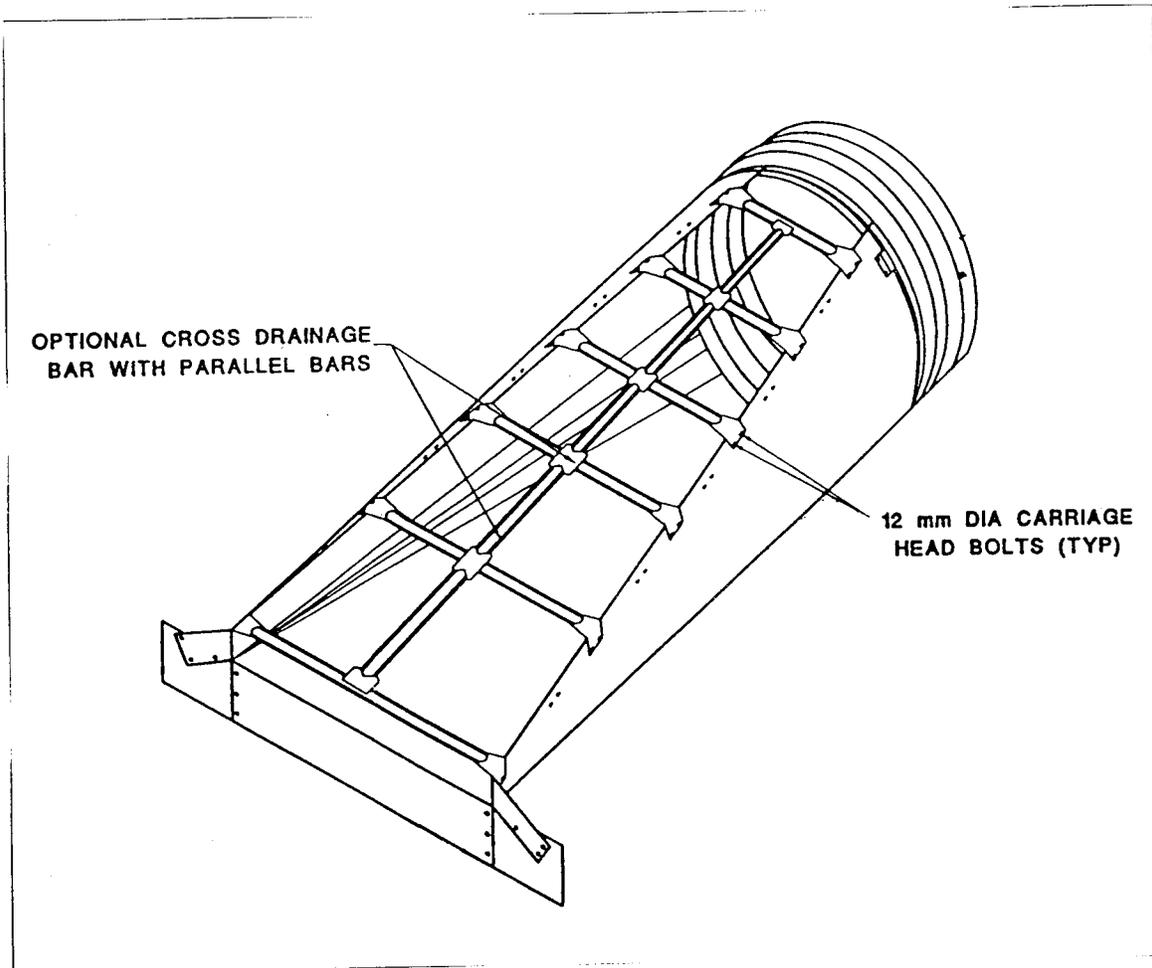


Figure 26 – Example of Cross Drainage Safety Slope End Section

For the grated culvert opening to have a significant safety benefit, the ditch bottom should be a preferred design as described in Section D.4, Traversable and Non-traversable Ditches and Backslopes.

D.1.2 Structure Extension

Extending a cross drainage structure whose inlets and outlets cannot be made traversable, beyond the clear zone, reduces the possibility of the pipe end being impacted, but it does not eliminate the possibility. The desirable clear zone is not an exact distance and engineering judgment is required. Redesigning the inlet/outlet so that it is traversable and no longer an obstacle is the preferred treatment.

D.2 Parallel Drainage Structures

Parallel drainage culverts, such as Figure 27, are those which continue the flow of parallel ditches under driveways, intersecting roadways and median crossovers. Parallel drainage features present a significant safety hazard because vehicles can strike them head on.

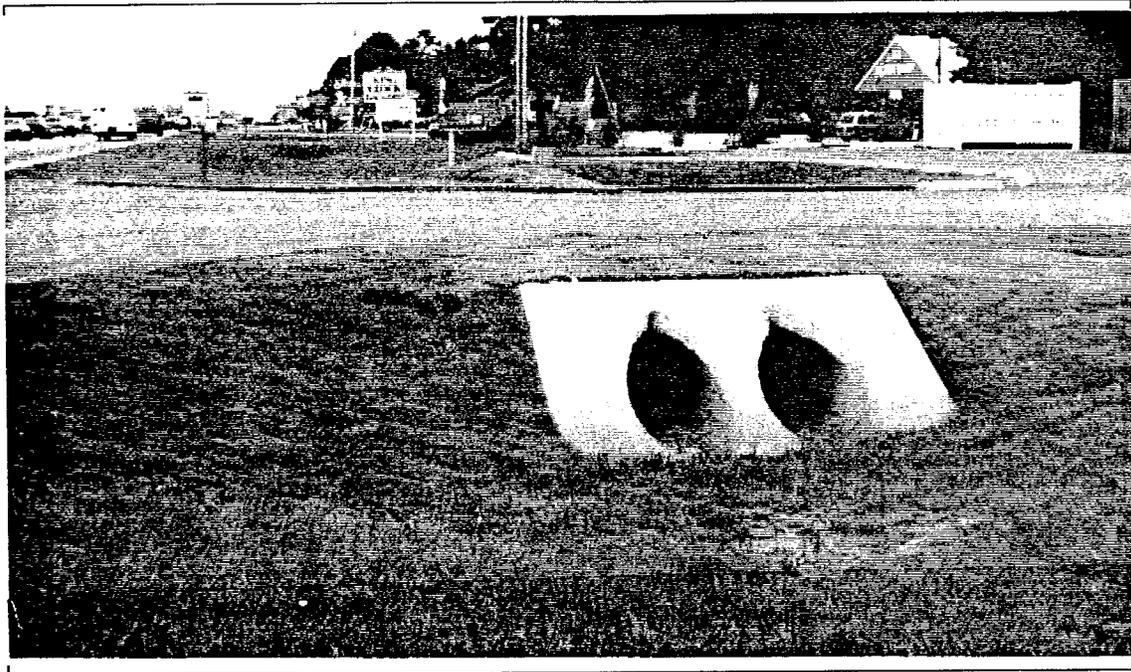


Figure 27 – Example of Parallel Drainage Structure
(This structure is too steep)

Effective treatments for improving the safety of parallel drainage features, in order of preference, include:

- Eliminating the structure,
- Relocating (moving) the structure away from the traveled way,
- Installing a traversable design,
- Shielding the structure (usually not practical on Low Volume Roads).

D.2.1 Eliminating the Structure

Eliminating parallel drainage structures is the preferred choice for increasing roadside safety. This can be accomplished by developing an overflow section and by converting an open ditch to a storm drain. The overflow section is an alternative that should be exercised with care. It consists of eliminating the parallel pipes by allowing the water from the parallel ditch to flow over the surface of intersecting minor roads, field entrances and driveways. The treatment is only

appropriate at low volume locations and requires lowering the intersecting roadway surface. One major problem with overflow designs is that they can reduce the sight distance available to drivers entering the major road at the same time that the resultant minor road upgrade causes increased vehicle passage time. Water freezing on the roadway surface and erosion are also potential problems. The erosion problem can be reduced by paving the overflow section, on gravel roads, and by adding upstream and downstream aprons at locations where water velocities and soil conditions make erosion likely.

Connecting an open ditch to a submerged storm drain is the ideal, but expensive, solution. The expense of a submerged storm drain can, however, be cost effective at proper locations. Rural roadways with closely spaced residential driveways are good candidates for converting an open ditch to a storm drain. Similarly, locations along the outside of curves or where a history of run-off-the-road accidents have occurred are good locations to convert the open ditch into a storm drain and backfilling the areas between adjacent driveways. This treatment eliminates the embankments and ditch bottom as well as the pipe inlets and outlets.

D.2.2 Relocating the Structure

Where sufficient right-of-way exists at intersections, the parallel drainage structure can be moved further from the main roadway edge. This also enables the design engineer to provide a flatter embankment slope within the desirable clear zone of the main roadway. Although the structure is further removed from the main roadway, it is still recommended that the inlet and outlet match the embankment slope.

At access roads, an outward extension of the ditch line will eliminate a severe hazard near the roadway of the main road. This is illustrated in Figure 28.

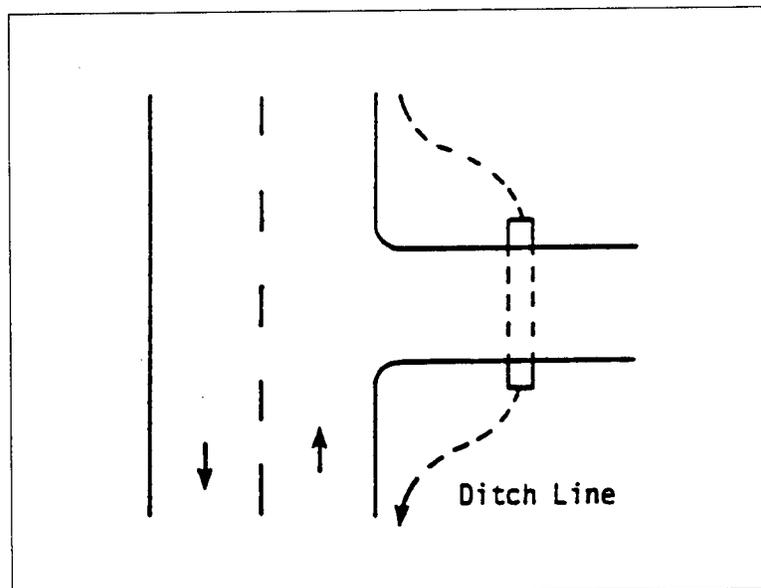


Figure 28. Outward Extension of Ditch Line
(Source: Federal Highway Administration, undated).

D.2.3 Installing Traversable Designs

The discussion in Reference 10 (Section 2.1.3) states that designers should try to provide the flattest feasible cross slopes. This is especially true in locations with a high probability of head-on accidents with drainage structures. Cross slopes of 1:10 or flatter are suggested, with slopes of 1:20 desirable when possible. The pipe inlet and outlet structures should match the selected cross slope.

Research on parallel drainage structures has shown that grates consisting of pipes or bars set on 600 mm (24 in) centers, and installed perpendicular to traffic, can reduce wheel snagging in the drainage opening. As a general rule for parallel structures, single drainage pipes of 600 mm (24 in) or less in diameter do not require a grate. However, when multiple drainage pipes are involved, the installation of a grate for the smaller drainage pipes should be considered. The center of the bottom safety pipe should be set at 100 mm to 200 mm (4 in to 8 in) above the culvert inlet. The 100 mm to 200 mm (4 in to 8 in) range applies to back inlet and outlet on two way roadways and only to the side facing traffic on divided roadways. Figure 29 presents a sample grate for parallel drainage structures.

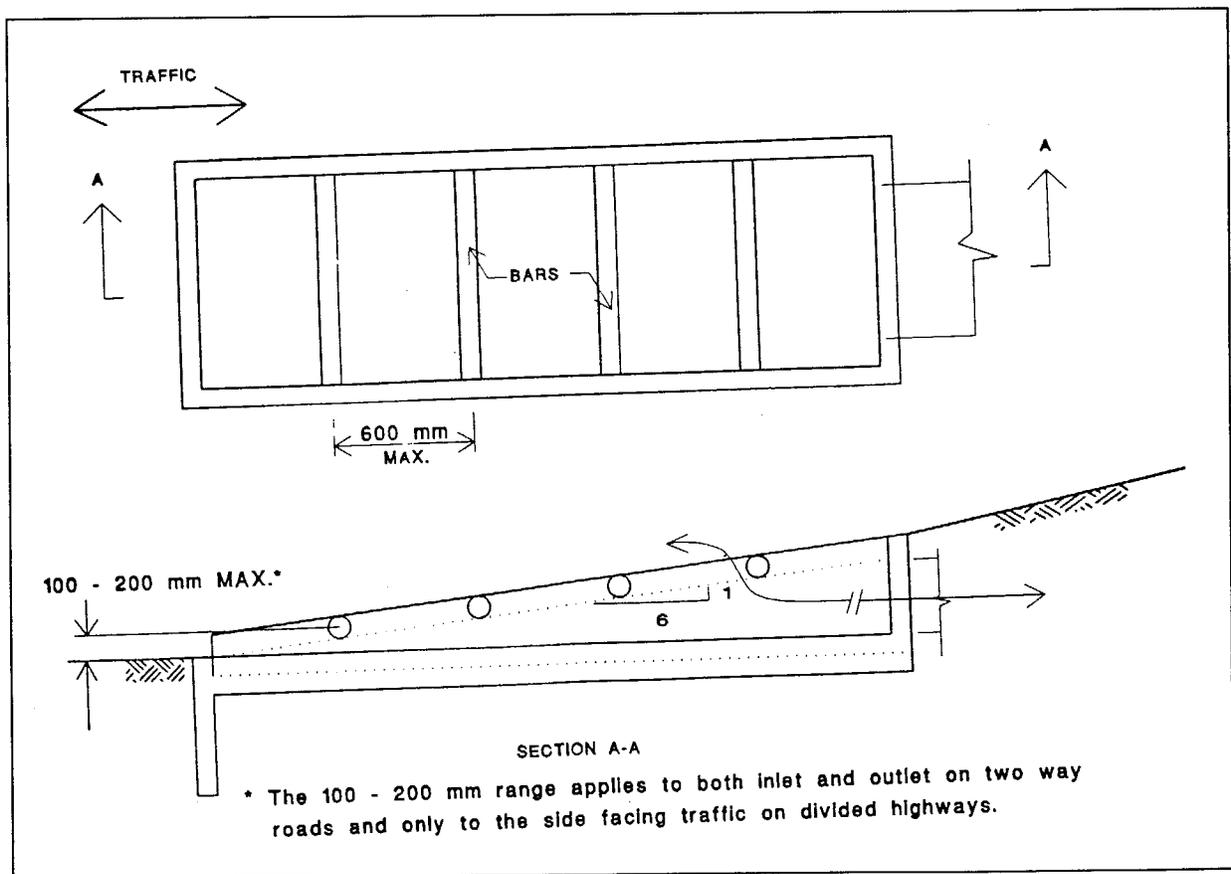


Figure 29 – Example of Inlet/Outlet Design for Parallel Drainage Structures

An example of an attempt to provide a traversable design is presented as Figure 30. Notice that while the slope is acceptable, the pipes do not extend over the whole opening. This design can still result in significant vehicle damage such as that of Figure 31.

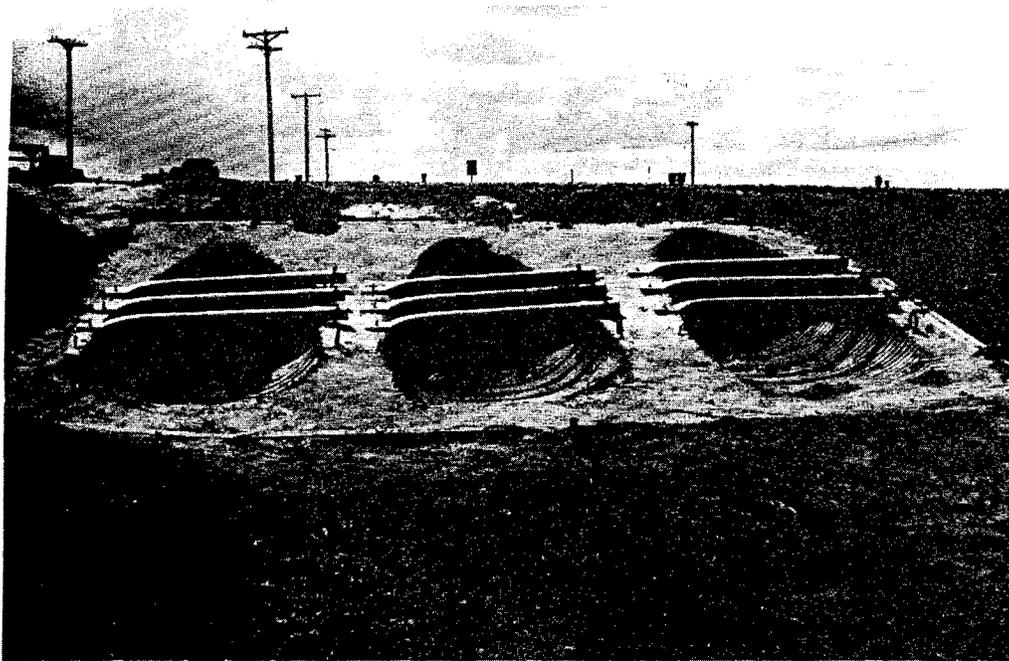


Figure 30 - Example of Improper Safety Pipe on Parallel Drainage Opening

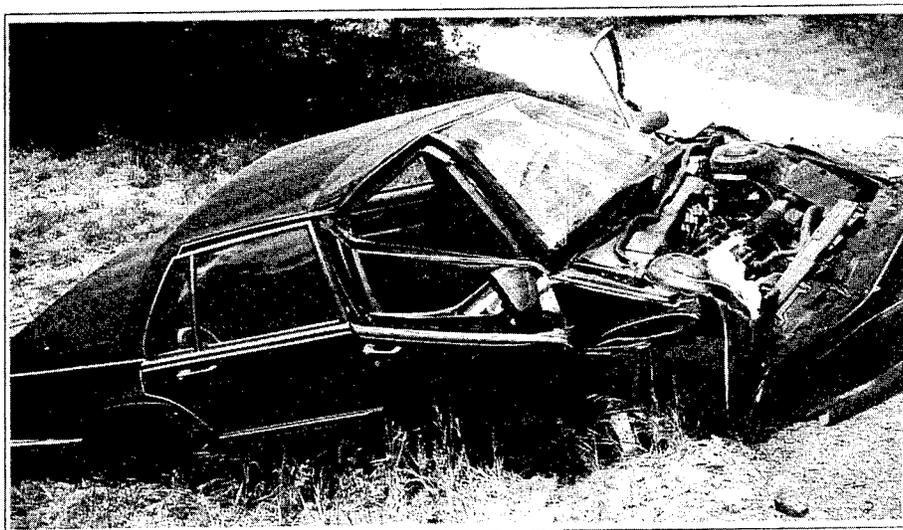


Figure 31 - Example of Vehicle Damage Resulting from Impacting a 460 mm Raised Concrete Parapet with a 1:2 Entrance Slope

Safety slope end sections are available from commercial manufacturers. Figure 32 and Figure 26 present parallel and cross drainage structures available from J & J Drainage Products Co. (12). These metal end sections attach to the existing pipe and extend the culvert to achieve a 1:6 slope.



Figure 32 – Example of Parallel Drainage Safety Slope End Section

D.3 Construction and Maintenance of Drainage Features

Effective drainage is one of the most critical elements in roadway design. Proper drainage prevents roadway flooding, vehicle hydroplaning and controls erosion. However, drainage features must be constructed and maintained properly to ensure proper hydraulic efficiency and roadside safety.

D.3.1 Construction of Drainage Features

There are a large number of drainage features with specific designs that vary between States. It is important that the design details provided in the State standard drawings be followed. Some important items to remember while constructing the drainage features include the following:

- Inlets and outlets of drainage structures should be removed from the clear zone, made traversable or shielded.
- Inlets and outlets can be made traversable by matching the slope of the structure to the embankment, when the slope is 1:3 or flatter, and the culvert has a single round pipe of 915 mm (36 in) or less.
- Pipes greater than 915 mm (36 in) can be made traversable for passenger vehicles by using safety grates or pipes to reduce the clear opening width. State specifications should be followed on the spacing of the safety pipes. The safety pipes should be installed so that a vehicle tire will roll from safety pipe to safety

pipe. This means that the safety pipes will be installed from top to bottom on drainage pipes going under the roadway and from side to side for drainage pipes at roadside ditches.

If State specifications on the safety pipes are not available, then they should be spaced on 760 mm (30 in) centers when running from top to bottom of the drainage pipe. Parallel drainage pipes should have the safety pipes at 610 mm (24 in) and run from side to side.

No part of the drainage feature should extend more than 100 mm (4 in) above the surrounding terrain.

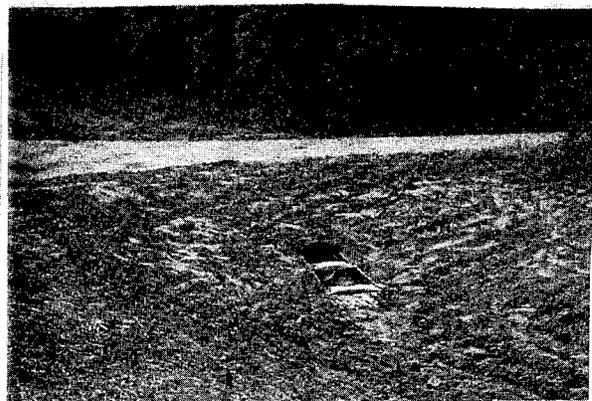
Safety slope end sections are available from commercial manufacturers. Pictures of installation steps for attaching the J & J Safety Slope end section are available from commercial manufacturers. Pictures of installation steps for attaching the J & J Drainage Products Co. Safety Slope end section to existing pipe are presented in Figure 33.



a. Add galvanized steel tapered sleeve



b. Extend culvert to achieve 1:6 slope



c. Back fill

Figure 33 – Steps Involved in Installing Safety End Section

D.3.2 Maintenance Needs

Many factors that adversely affect the safety and water removal performance of drainage structures can be identified during routine maintenance. Some of these can be readily corrected and others may require extensive redesign. Listed below are factors that should be addressed during routine maintenance.

Drainage Structure

1. Bent or broken safety pipes from prior impacts can severely affect performance during the next impact. Bent or broken safety pipes should be repaired or replaced.
2. Check to ensure that the safety pipes are installed in the proper direction. Safety pipes on culverts passing beneath the main road should be placed on 760 mm (30 in) centers and run from top to bottom of the culvert. Parallel culverts should have the safety pipes on 610 mm (24 in) centers and run from side to side.
3. Check that the safety pipes are the proper size for the culvert opening as specified in Table 9. Also, check that the bolts are 16 mm (.6 in) and fastened securely.
4. Check that grate assemblies are correctly fastened and do not extend more than 100 mm (4 in) above the surrounding terrain.
5. Check if the headwall is flush with embankment slope. Is redesign or barrier installation necessary?
6. Clean drainage pipe with water jet or other appropriate method.
7. Look for cracks, disintegration of concrete and broken wing walls. Report deterioration to the Maintenance Engineer.
8. Culverts under high fills, especially in the first few years after construction, should be checked for settlement that may cause cracks or cause construction joints to open.

Pipe Apron:

9. Check the apron guard to determine if it requires cleaning. If there is debris on the guard, it should be cleaned.
10. Look for damage on the pipe apron. If the pipe apron is damaged, repair to a like-new condition. If replacement of the pipe apron is required, contact the resident maintenance engineer to determine what pipe apron should be used.
11. Look for damage on the apron guard. If the apron guard is damaged, repair to a like-new condition. Replace the apron guard if damage is too extensive to repair.
12. Check to see if there is erosion at the outlet. If so, place broken concrete or stone at the outlet to prevent erosion problems. The stone placed shall not project up more than 100 mm (4 in) above the ground to avoid snagging vehicles.

Ditches:

The primary function of a roadside ditch is to collect and convey surface water along the highway right-of-way until it can be drained away from the roadbed. Ditches vary in width depending on the amount of water that they need to carry.

The locations where the slope changes are called the break points. These points occur between the shoulder and foreslopes, at the toe of the foreslope (one side of the ditch) and at the toe of the backslope (the other side of the ditch). Break points make a clear zone less traversable because of the abrupt change of grade. The break points at the transition between the shoulder and the foreslope and the toes of the slopes should be rounded so that they are more traversable.

1. Determine if the ditch requires cleaning. Remove silt from ditch when it interferes with normal functioning. The silt needs to be removed when water ponds in the ditch, water is diverted onto private property or when water is diverted onto the shoulder or surface.
2. Has the ditch deteriorated due to erosion? Repair the ditches when it appears that the roadway, structures or adjoining property may be damaged by continued erosion.
3. Has the ditch deteriorated due to cave-ins? Repair the ditch when it appears that the roadway, structures or adjoining property may be damaged by continued cave-ins.
4. Does the ditch meet the original standards that it was built to? If not, work should be scheduled to regrade the ditch.

Shielding Concerns

1. Is a barrier needed?
2. Does an existing barrier adequately shield the drainage structure?
3. Is the barrier installed correctly with approved terminals?
4. If the barrier has been impacted, is it still serviceable or is maintenance required?
5. Are appropriate hazard markers and delineators in place?

D.3.3 Summary of Drainage Features

1. The flatter the embankment slopes the safer the roadside. Parallel embankments should be as flat as possible, but not steeper than 1:3. Cross slopes should be preferably 1:10, but generally not less than 1:6.

Cross slopes in urban areas and on low speed (less than 65 km/h or 40 mph) may be steeper than 1:6.

2. Headwalls of the drainage structure should match the slope of the embankment.
3. Culverts passing beneath the main roadway (i.e., cross drainage structures), should not be installed on slopes steeper than 1:3. Cross drainage structures consisting of a clear span of 1000 mm (39 in) pipe or multiple round pipes of 750 mm (30 in) or less do not need grates or safety pipes.
4. Cross drainage structures larger than above should have grates or safety pipes installed. Safety pipes should be installed on 750 mm (39 in) centers and run from top to bottom of the culvert. The safety pipe should be sized to the culvert opening, as presented in Table 9.
5. A culvert for passing water parallel to the main roadway should generally not be installed on slopes steeper than 1:6. Generally parallel structures consisting of a single pipe 600 mm (24 in) or less in diameter do not require a grate.
6. Parallel structures consisting of multiple pipes or a single pipe greater than 600 mm (24 in) require a grate or safety pipes. Safety pipes for parallel grates should be placed on 600 mm (24 in) centers and run from side to side. The safety pipe should be sized to the culvert opening as presented in Table 9.
7. Preferred ditch sections must be used with parallel grates. (See Section D.4).
8. The best solution is to eliminate parallel drainage structures by installing a drainage sewer and covering to achieve a flat roadside. This option should be considered for medians, roadways with closely spaced driveways and locations with high accident potential.
9. Consideration should be given to moving cross drainage structures further away from the main roadway.
10. Drainage structures should not extend more than 100 mm (4 in) above the surrounding terrain. This includes headwalls, wingwalls, grates and the end of the culvert pipe.
11. Commercial products are available to extend the existing drainage pipe and achieve a safety slope end section.
12. If everything to provide a safe and hydraulically efficient drainage structure fails, then shielding should be considered.

D.4 Traversable and Non-Traversable Ditches and Back Slopes

Ditches are present on the majority of rural roadsides. Their primary function is to collect and distribute the roadway surface water away from the roadbed. Ditches are designed to accommodate runoff from heavy rainstorms with minimal highway flooding or damage. Deep ditches constructed close to the roadway are the most efficient in removing and retaining the water from the roadway surface. Deep ditches close to the roadway are, however, a hazard to errant vehicles. Proper ditch design requires considerations of roadside safety as well as hydraulic efficiency.

Typical ditches can be classified by whether they are designed with abrupt or gradual

slope changes. Abrupt slope change designs include vee ditches, rounded ditches with a bottom width less than 2.4 m (8 ft) and trapezoidal ditches with bottom widths less than 1.2 m (4 ft). Diagrams of abrupt change slope ditches are presented as Figure 34. Gradual slope change ditches, presented as Figure 35, include rounded ditches with bottom widths of 2.4 m (8 ft) or more and trapezoidal ditches with bottom widths equal to or greater than 1.2 m (4 ft).

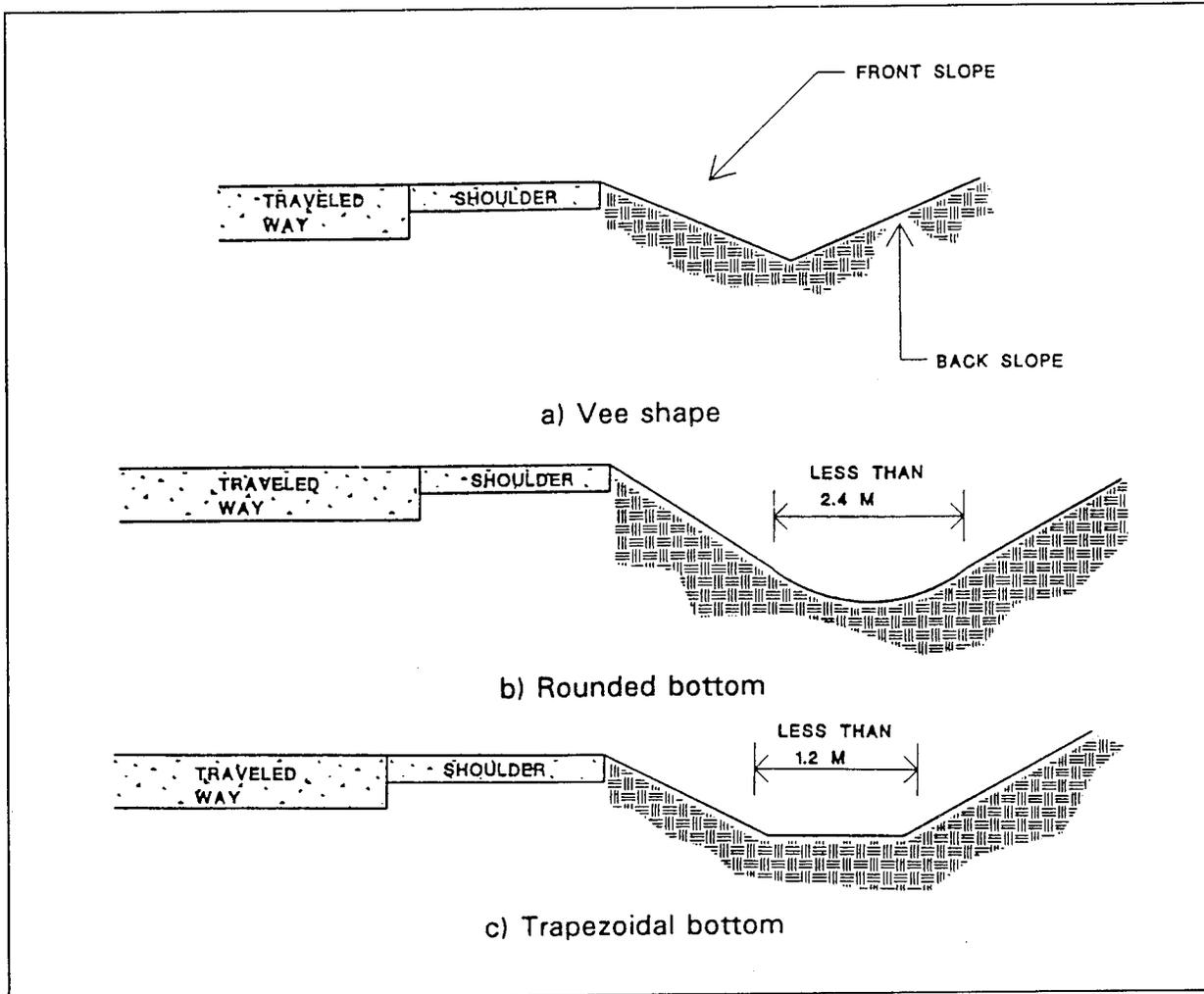


Figure 34 – Abrupt Slope Change Ditch Design

Vehicles leaving the roadway and encroaching on a ditch face three hazard areas:

- Ditch front slope. If the front slope is 1:4 or steeper, the majority of vehicles entering the ditch will be unable to stop and can be expected to reach the bottom.
- Ditch bottom. Abrupt slope changes can result in errant vehicles impacting the ditch bottom.
- Ditch back slope. Vehicles traveling through the ditch bottom or becoming airborne from the front slope can impact the backslope.

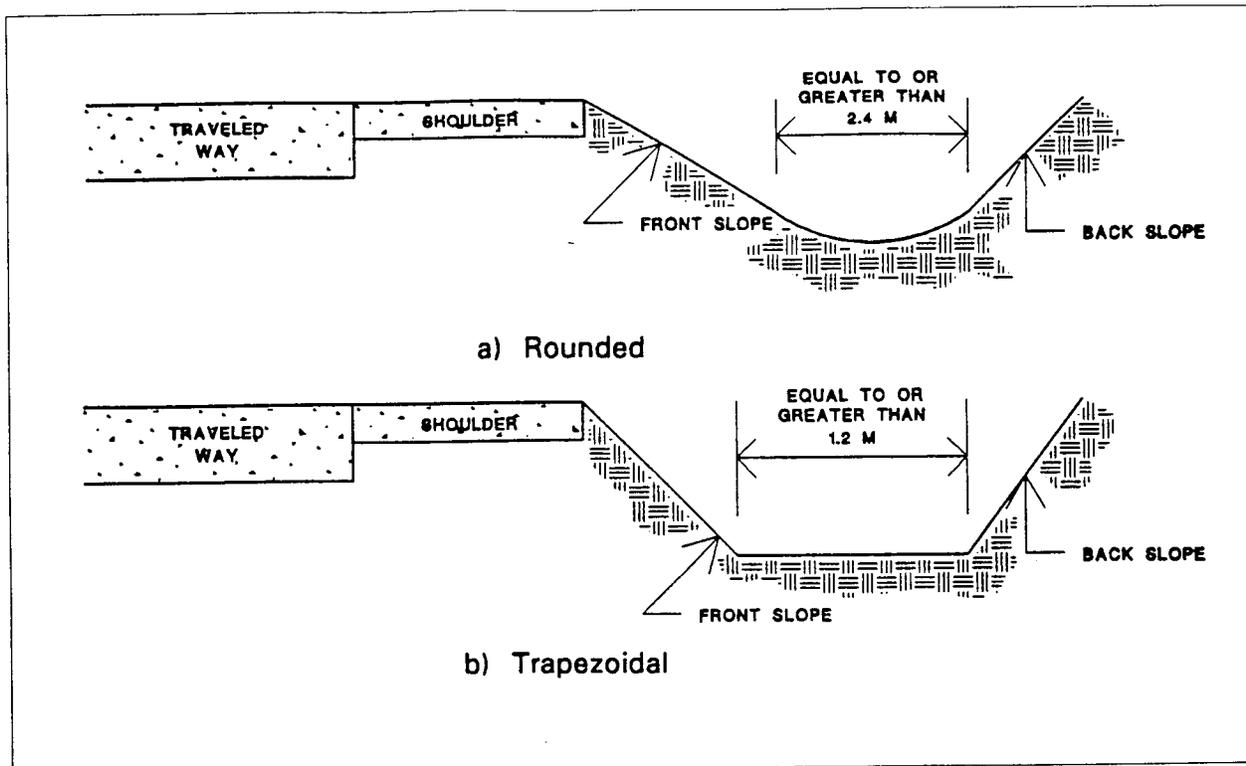


Figure 35 – Gradual Slope Ditches

Figures 36 and 37 present preferred design for abrupt and gradual change slopes, respectively. Ditch cross sections, which fall within the shaded region of each of these figures, are considered as traversable. These preferable ditch designs are not considered hazardous and need not be constructed at or beyond the clear zone distance for a specific roadway.

Ditch sections, which fall outside the shaded area of Figures 36 and 37, are considered non-traversable. As a general rule, they should either be located beyond the clear zone, reshaped, converted to a closed system (culvert or pipe), or in some cases shielded with a traffic barrier.

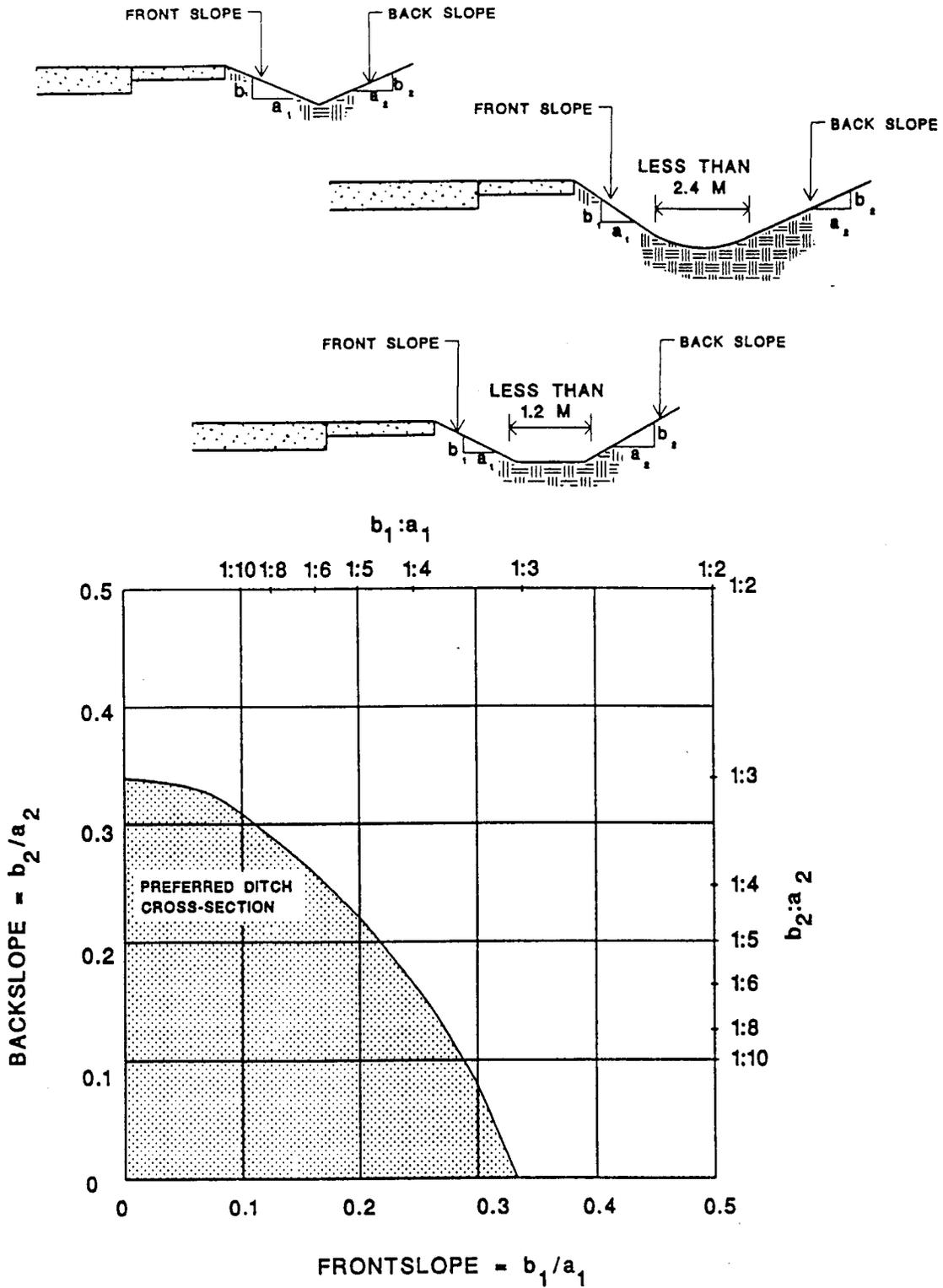
As noted earlier, for grated cross drainage openings (or ungrated ones with the culvert openings flush with the foreslope) to have the greatest safety benefit, the cross drainage ditches should have cross-sections similar to those recommended for ditches paralleling the roadway, i.e., the ditch should have the “preferred” cross section as shown in Figures 36 or 37. Where this is impractical, the front or foreslope (i.e. the slope the errant vehicle will first reach) and backslope (the slope the errant vehicle will strike after crossing the ditch bottom), should be made as flat as is feasible.

In other words, the newly graded ditch front (fore) slopes and backslopes should be made as close to the preferred ditch cross section as is practical. These cross slopes are to be measured on a path that a leave-the-road (errant) vehicle will probably travel.

Cross-drainage ditch cross section changes can often be combined with debris removal operations. If the ditch bottom and slopes are free of any fixed objects, then non-preferred ditch sections may be acceptable for projects having restrictive right-of-way, rugged terrain, for

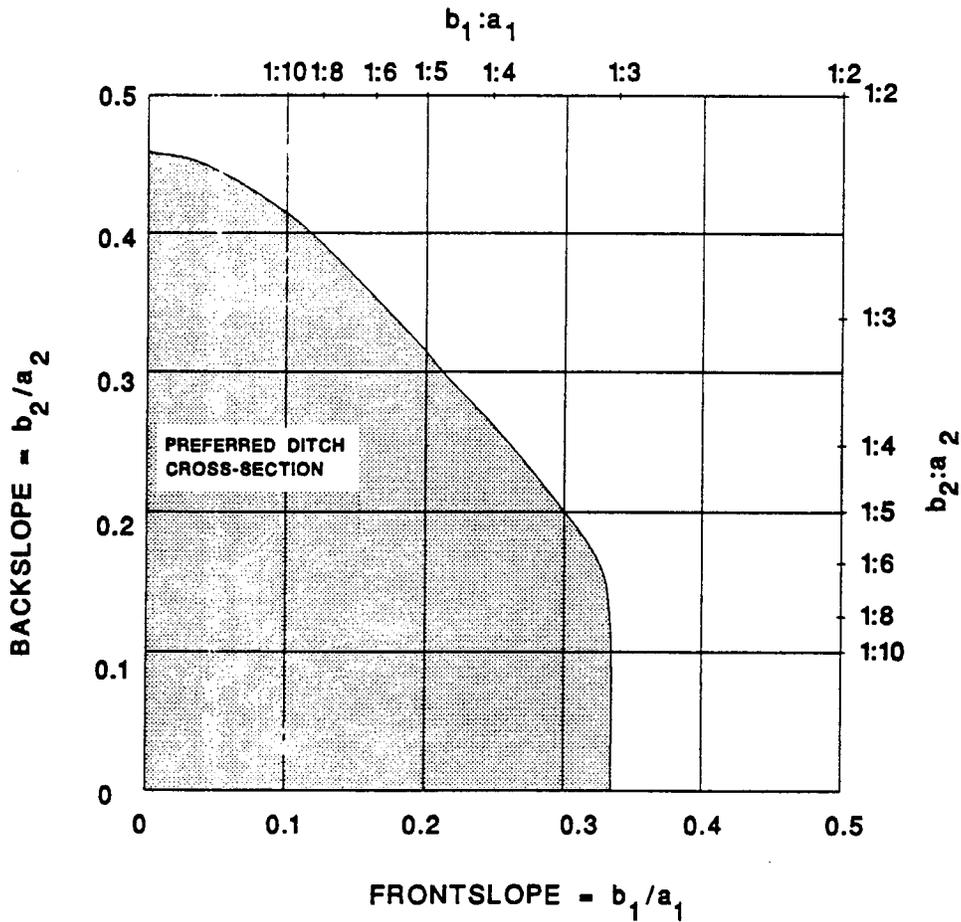
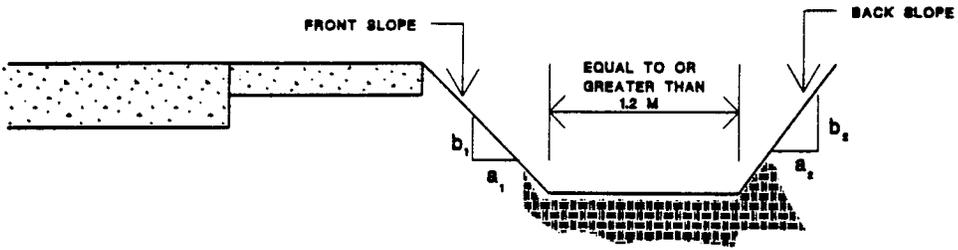
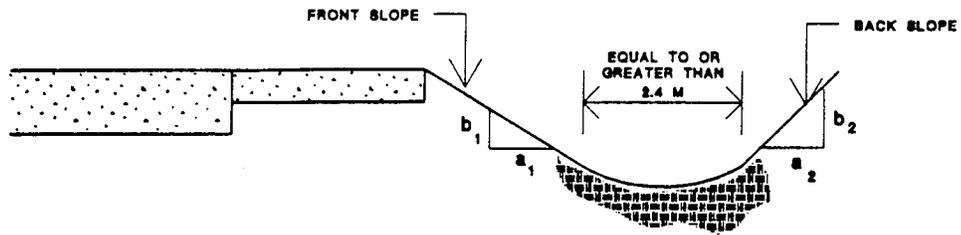
resurfacing, restoration or rehabilitation (RRR) projects, or on low volume, low speed roadways. Ditches, both abrupt and gradual slope designs, can funnel a vehicle along the ditch bottom. This increases the probability of impact with any fixed objects present on the slopes or ditch bottom.

In studies of vehicles traversing ditches, it was found that traversing the vee ditch generally produced acceleration rates or G-forces that were less severe than those caused by traversing the round or trapezoidal ditches having widths of 2.4 meters (8 feet) or less, or the rounded trapezoidal ditch in the 1.2 to 2.4 meter (4 to 8 foot) range.



PREFERRED CROSS SECTIONS FOR DITCHES WITH ABRUPT SLOPE CHANGES. THIS CHART IS APPLICABLE TO ALL VEE DITCHES, ROUNDED DITCHES WITH BOTTOM WIDTHS LESS THAN 2.4 M, AND TRAPEZOIDAL DITCHES WITH BOTTOM WIDTHS LESS THAN 1.2 M.

Figure 36 - Preferred Cross Sections for Ditches with Abrupt Slope Changes



PREFERRED CROSS SECTIONS FOR DITCHES WITH GRADUAL SLOPE CHANGES. THIS CHART IS APPLICABLE TO ROUNDED DITCHES WITH BOTTOM WIDTHS OF 2.2 M OR MORE, AND TO TRAPEZOIDAL DITCHES WITH BOTTOM WIDTHS EQUAL TO OR GREATER THAN 1.2 M.

Figure 37 - Preferred cross section for ditches with gradual slope changes

D.5 Roadside Terrain Features

The characteristics of the roadside terrain have direct impact on a driver's ability to maintain control of a vehicle after it leaves the roadway. Roadside terrain features that are not level are referred to as "embankments." These embankments can be parallel or perpendicular to the traveled way. Since the type and rate of slope of embankments affects vehicle control and occupant safety, an understanding of embankments is necessary to apply the clear zone concepts.

If the roadway was constructed by building up or filling the roadway bed to a higher elevation than the roadside terrain, the resulting embankment is termed a foreslope, fill slope, or negative slope. All three terms indicate that the embankment slopes away from an elevated roadway as presented in Figure 38.

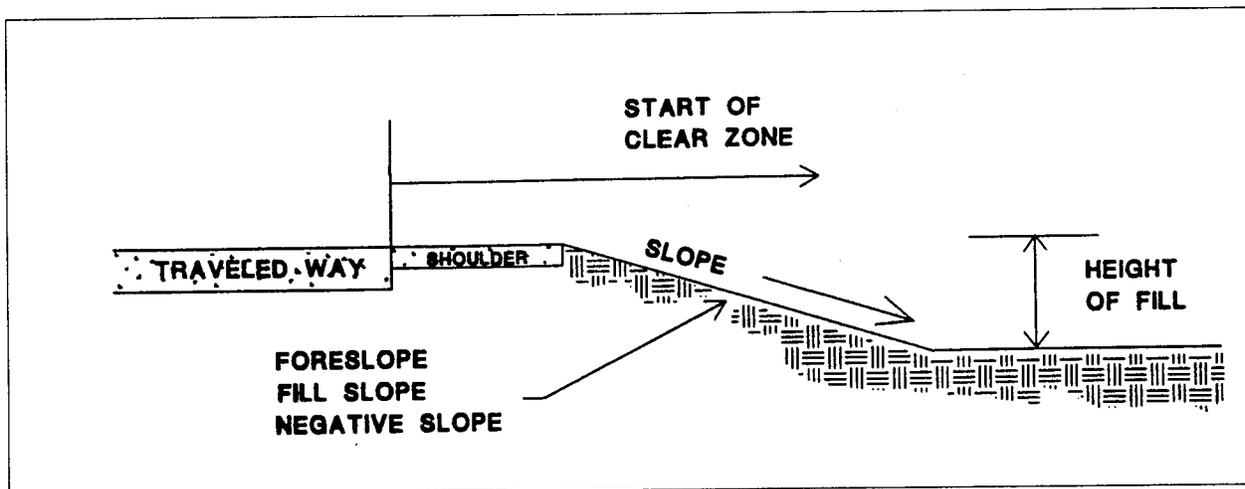


Figure 38 - Diagram of Raised Roadway Embankment

When the roadway is constructed by removing material or cutting, so that the roadway is lower than the surrounding terrain, the resulting embankment is termed a backslope, cut slope, or positive slope. All three terms indicate that the embankment slopes toward a depressed roadway as presented in Figure 39.

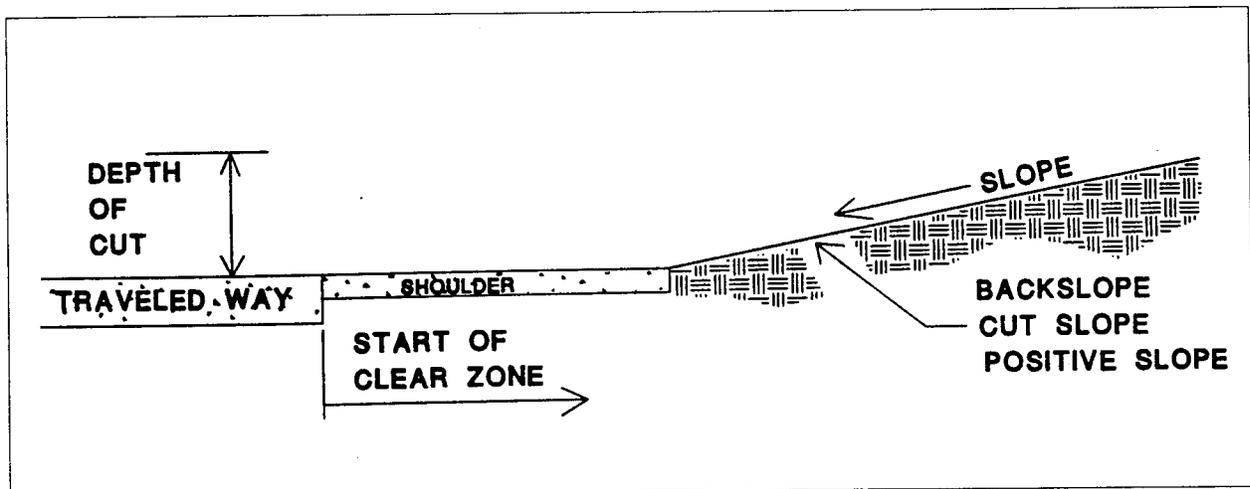


Figure 39 - Diagram of Depressed Roadway Embankment

Embankment slopes have a pronounced effect on both the outcome of vehicle excursions onto the slope, and on the effectiveness of barriers placed on the embankment. Slope is a method of presenting the vertical rise and horizontal run of an embankment. A slope of 1:6 indicates that there exists a rise of one unit for every six units of horizontal distance. The closer the run unit is to one, the more severe the slope.

A 1:6 slope is flatter, and hence less severe by half, than a 1:3 slope, as presented in Figure 40. Foreslopes are often called front slopes, whereas, 1:6 slopes are usually called 6:1 and 1:3 slopes are called 3:1, and so forth.

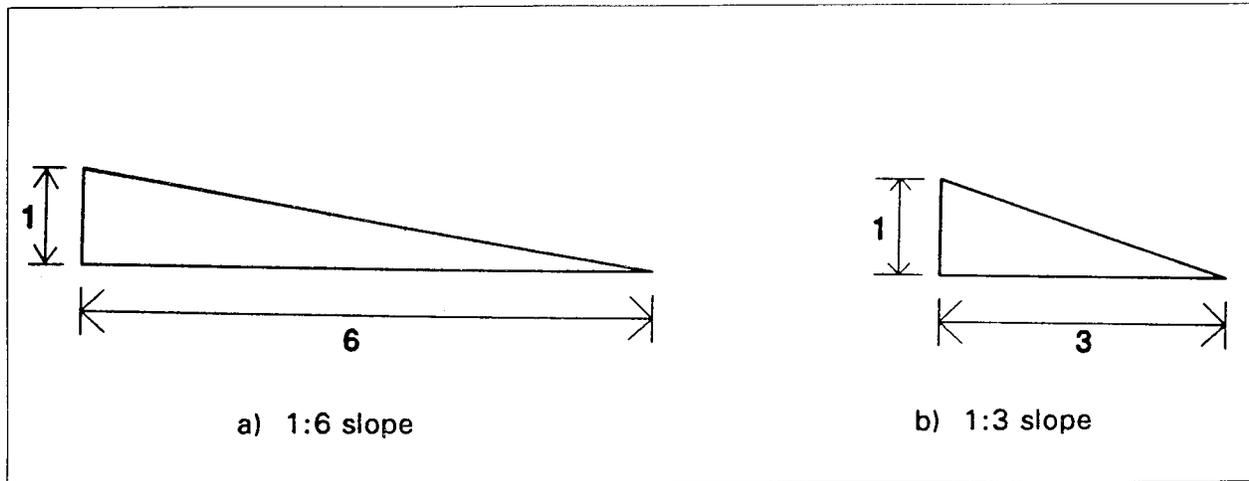


Figure 40 – Representation of Slope Magnitude

Measurement of the desirable clear zone starts at the edge of the traveled way. Shoulder width and auxiliary lanes are included as part of the clear zone distance. The total area for a vehicle to make a safe maneuver is called the recovery area. The recovery area will be the sum of the clear zone distance and any additional distance available for safe use by an errant vehicle. It should be noted that the clear zone concept is usually applied only to uncurbed roadways.

D.6 Parallel Slope Embankments

Embankments that are parallel to the traveled way are classified as recoverable, non-recoverable, or critical. This classification is based on the rate of slope. Parallel slopes as steep as 1:4 are generally considered as recoverable slopes, because errant vehicles can either return to the roadway or stop. Parallel slopes steeper than 1:3 are likely to result in vehicle overturn, and are generally not acceptable within the desired roadside recovery width. Slopes between these two values will generally not result in overturning, but the vehicle cannot recover before proceeding to the bottom of such slopes.

Recoverable Parallel Slope. Slopes 1:4 and flatter are generally considered recoverable. A recoverable slope enables a motorist to retain or regain control of a vehicle. Motorists who enter a recoverable slope can generally stop their vehicles or slow them enough to return to the roadway.

Non-recoverable Parallel Slope. Embankment slopes between 1:4 and 1:3 generally fall into this category. Motorists who enter a non-recoverable slope are generally able to slow and stop safely, but are unable to return to the roadway easily. Vehicles on non-recoverable fill slopes can typically be expected to reach the bottom. Since a high percentage of encroaching vehicles can be expected to reach the bottom, a clear run out area at the base is desirable.

Critical Parallel Slope. Slopes steeper than 1:3 are considered as critical. Vehicles entering a critical slope are likely to overturn. If a critical slope begins closer to the traveled way than the clear zone, then a barrier should be considered based on a cost effective analysis if the slope cannot be flattened.

D.7 Intersecting Embankments (Cross Slopes)

Intersecting embankments are slopes created by median crossovers, intersecting roadways or driveways. As presented in Figure 41, intersecting embankments, or cross slopes, are typically struck head-on by run-off-the-road vehicles. Cross slope embankments of 1:20 are desirable for that section of the embankment immediately adjacent to traffic for freeways. In many cases providing this flat cross slope for intersecting roadways or driveways is not practical due to width restrictions and maintenance problems associated with the long tapered ends of pipes or culverts.

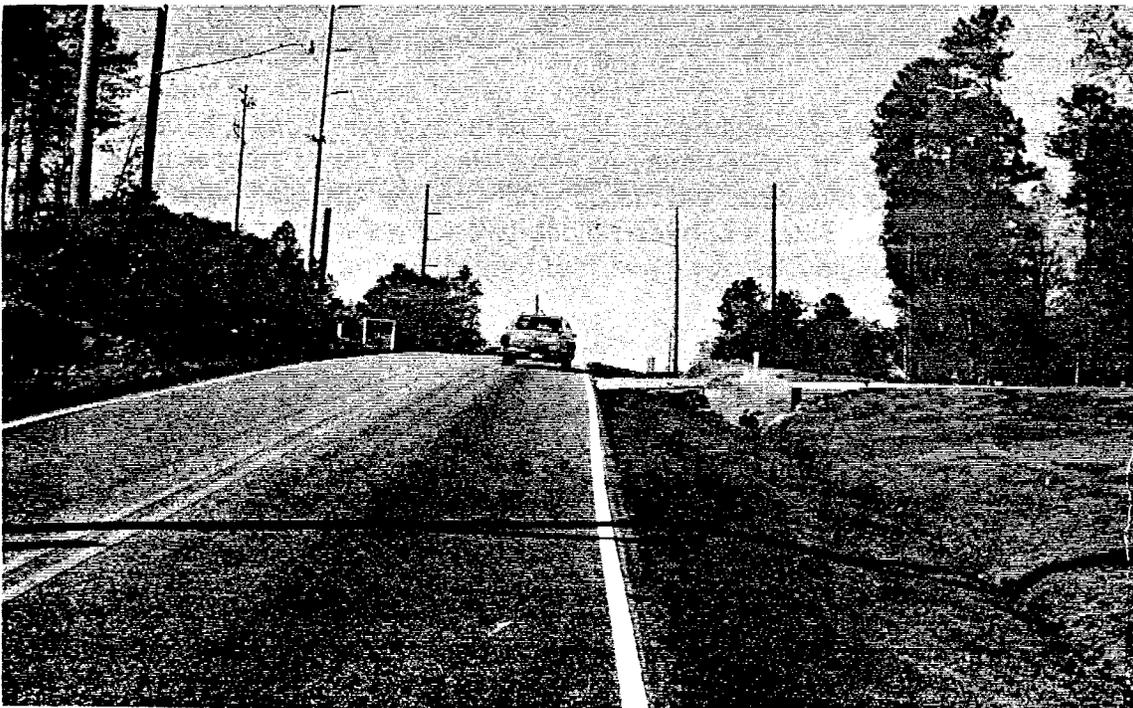


Figure 41 – Poor Intersecting Slope Design

A maximum intersecting slope of 1:10 is suggested for high speed, high volume roadways. Embankment intersecting slopes steeper than 1:10 may be considered for urban areas or for low speed facilities. Figure 42 presents a preferred intersecting slope design where slopes in the vicinity of intersection have been flattened and the drainage pipe removed as far from the main roadway as practical. Further discussion of the proper design of drainage features is presented in Reference 10 (Section 2.10).

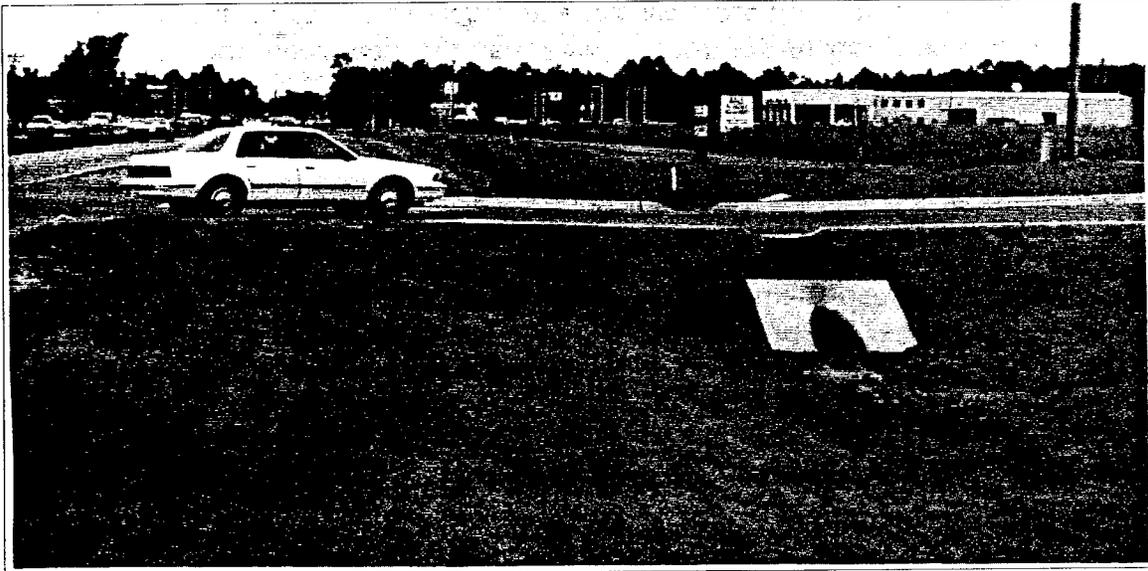


Figure 42 - Preferred Intersecting Slope Design

D.8 Determining the Desirable Clear Zone for Parallel Slopes

D.8.1 For non-Critical and High Height Parallel Slope

Desirable clear zone distances for parallel slopes not steeper than 1:3 may be obtained from Figure 43 or Table 10.

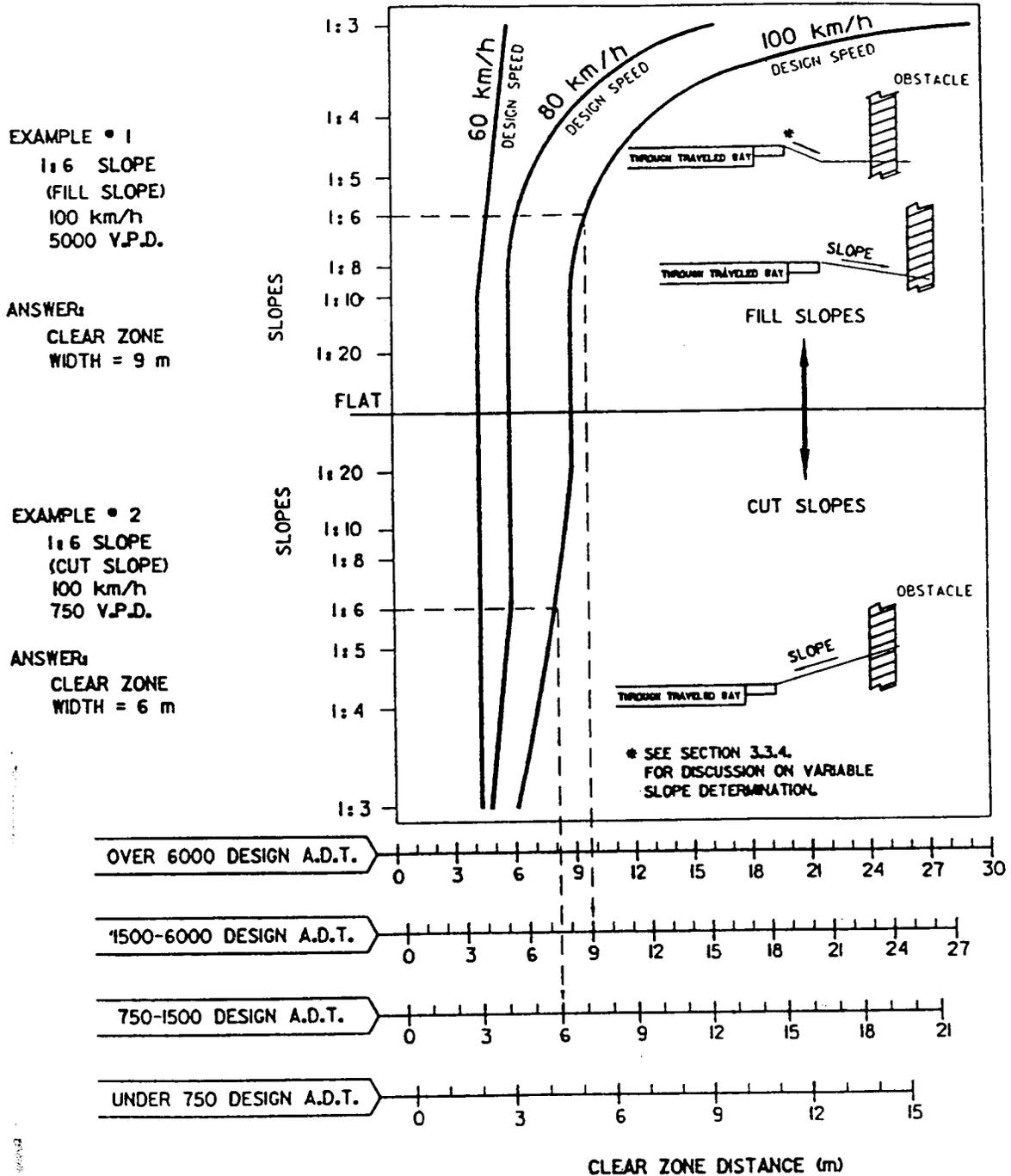


Figure 43 - Clear Zone Distance Curves

Table 10 - Clear Zone Distances (in meters from edge of driving lane)

Design Speed	Design ADT	Fill Slopes			Cut Slopes		
		1:6 OR flatter	1:5 to 1:4	1:3	1:3	1:4 to 1:5	1:6 or flatter
60 km/h or less	UNDER 750	2.0-3.0	2.0-3.0	* *	2.0-3.0	2.0-3.0	2.0-3.0
	750-1500	3.0-3.5	3.5-4.5	* *	3.0-3.5	3.0-3.5	3.0-3.5
	1500-6000	3.5-4.5	4.5-5.0	* *	3.5-4.5	3.5-4.5	3.5-4.5
	OVER 6000	4.5-5.0	5.0-5.5	* *	4.5-5.0	4.5-5.0	4.5-5.0
70-80 km/h	UNDER 750	3.0-3.5	3.5-4.5	* *	2.5-3.0	2.5-3.0	3.0-3.5
	750-1500	4.5-5.0	5.0-6.0	* *	3.0-3.5	3.0-4.5	4.5-5.0
	1500-6000	5.0-5.5	6.0-8.0	* *	3.5-4.5	4.5-5.0	5.0-5.5
	OVER 6000	6.0-6.5	7.5-8.5	* *	4.5-5.0	5.5-6.0	6.0-6.5
90 km/h	UNDER 750	3.5-4.5	4.5-5.5	* *	2.5-3.0	3.0-3.5	3.0-3.5
	750-1500	5.0-5.5	6.0-7.5	* *	3.0-3.5	4.5-5.0	5.0-5.5
	1500-6000	6.0-6.5	7.5-9.0	* *	4.5-5.0	5.0-5.5	6.0-6.5
	OVER 6000	6.5-7.5	8.0-10.0	* *	5.0-5.5	6.0-6.5	6.5-7.5
100 km/h	UNDER 750	5.0-6.0	6.0-7.5	* *	3.0-3.5	4.5-5.0	4.5-4.9
	750-1500	6.0-8.0	8.0-10.0*	* *	3.5-5.0	5.5-6.0	6.0-6.5
	1500-6000	8.6-9.0	10.0-12.0*	* *	5.0-6.0	6.5-7.5	8.0-8.5
	OVER 6000	9.0-10.0*	11.-13.5*	* *	6.5-7.5	8.0-9.0	8.5-9.0
110 km/h	UNDER 750	5.5-6.0	6.0-8.0	* *	3.0-3.5	4.5-5.0	4.5-4.9
	750-1500	7.5-8.0	8.5-11.0*	* *	3.5-5.0	5.5-6.0	6.0-6.5
	1500-6000	8.5-10.0*	10.5-13.0*	* *	5.0-6.0	6.5-7.5	8.0-8.5
	OVER 6000	9.0-10.5*	11.5-14.0*	* *	6.5-7.5	8.0-9.0	8.5-9.0

*Where a site specific investigation indicates a high probability of continuing accidents, or such occurrences are indicated by accident history, the designer may provide clear zone distances greater than 9 m (30 ft) as indicated. Clear zones may be limited to 9 m (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 1:3 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 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 accident histories. Also, the distance between the edge of the travel lane and the beginning of the 1:3 slope should influence the recovery area provided at the toe of slope.

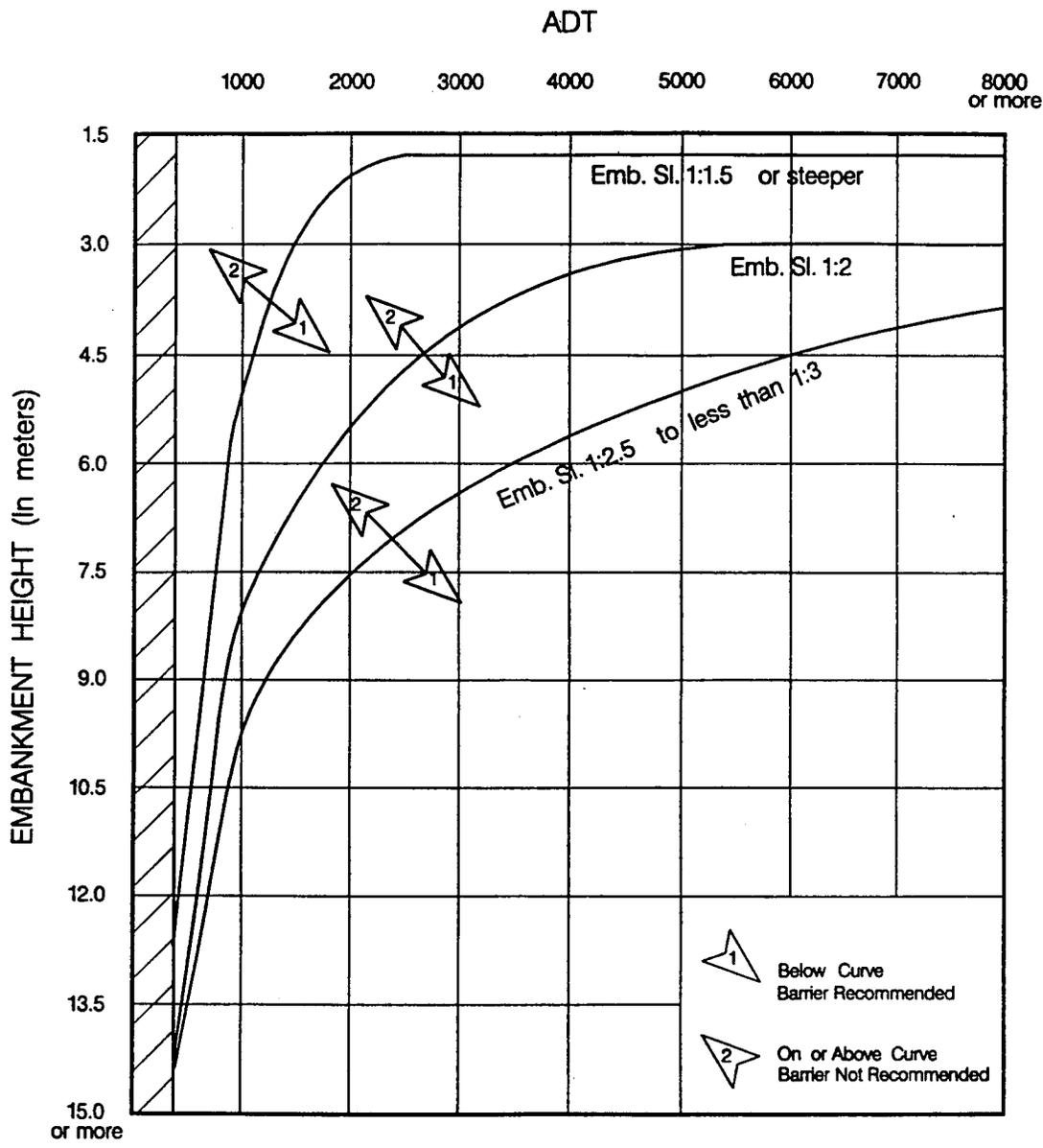
Table 10 consists of ranges of average daily traffic (ADT) side slopes, and clear zone distances. The designer should understand the ADT ranges and not always use the minimum value for a location falling within the ADT and slope range. Instead, the designer should interpolate between the slopes and ADT, and select a distance from within the clear zone range. It should be pointed out that the smallest value in the clear zone range refers to the smallest ADT

and flatter slope. The largest value refers to the highest ADT and the steeper slope. It is preferred that the largest clear zone be used whenever practical.

Parallel embankment slopes between 1:4 and 1:3 can be safely traversed by an errant vehicle if they are free of fixed object hazards. The severity of the slope, however, increases the probability that vehicles will continue down to the bottom. It is desirable, therefore, to provide a clear run-out area beyond the bottom of non-recoverable slopes. The width of the run out area can be the remainder of the desirable clear zone distance that is not part of a recoverable slope. This procedure is demonstrated by the example in section D11.

D.8.2 For Critical and High Height Parallel Slope

Critical slopes, slopes steeper than 1:3, and slopes of high height can cause severe crashes. Embankment height and side slope are the basic factors considered in determining the need for barriers at critical and high height parallel slope locations. The relative accident severity of a vehicle going down the embankment versus impacting a barrier should be determined. Many States have made this determination and developed barrier warrant charts, such as Figure 44, used by the State of Washington. Figure 45 presents the comparative risk warrant for barrier placement at embankments contained in the Roadside Design Guide. Figure 45 does not adequately estimate the probability of a vehicle entering the embankment (i.e., no consideration of ADT) nor the relative costs of installing a barrier versus leaving the slope unshielded. Highway agencies should develop their own warrant criteria based on their cost-effectiveness evaluations.



NOTE: Routes with ADTs under 400 may be evaluated on a case by case basis.

Figure 44 - Guidelines for Embankment Barrier Need Used by the State of Washington

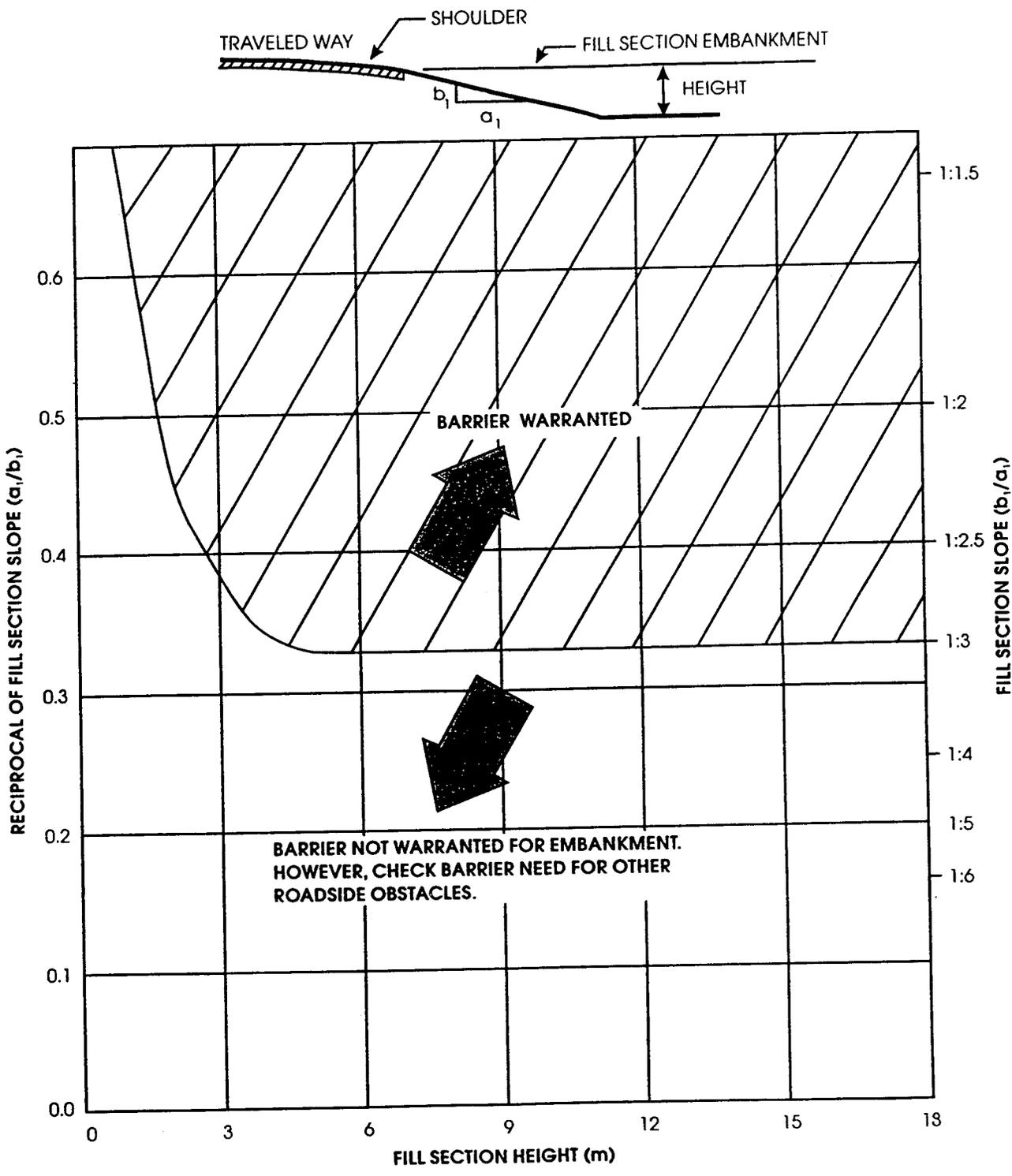


Figure 45 - Comparative Risk Warrants for Embankments from the AASHTO Guide [2]

D.9 Horizontal Curve Adjustment

The clear zone distance can be increased on the outside of horizontal curves. This modification is normally only necessary where there is supporting accident history or site inspection indicates that accident potential could be reduced by increasing the clear zone width. Determining the need to increase the desirable clear zone width can be assisted by an economic analysis. Table 11 contains adjustment factors that can be used to adjust the desirable clear zone distance on the outside of horizontal curves.

Table 11 - Horizontal curve adjustments Kcz (curve correction factor)

Radius (m)	Design Speed (km/h)					
	60	70	80	90	100	110
900	1.1	1.1	1.1	1.2	1.2	1.2
700	1.1	1.1	1.2	1.2	1.2	1.3
600	1.1	1.2	1.2	1.2	1.3	1.4
500	1.1	1.2	1.2	1.3	1.3	1.4
450	1.2	1.2	1.3	1.3	1.4	1.5
400	1.2	1.2	1.3	1.3	1.4	
350	1.2	1.2	1.3	1.4	1.5	
300	1.2	1.3	1.4	1.5	1.5	
250	1.3	1.3	1.4	1.5		
200	1.3	1.4	1.5			
150	1.4	1.5				
100	1.5					

Increasing the superelevation at horizontal curves is a viable countermeasure for reducing the occurrence of run-off-the-road accidents. Horizontal curve design should be checked to ensure that the superelevation is adequate to increase safety and provide a more comfortable ride.

D.10 Roadside Obstacles

Terrain features and fixed objects which can pose a hazard when within the clear zone can be either manmade or natural. Table 12 contains a list of obstacles which should be considered to be removed, relocated, modified (to be less hazardous) or shielded when located within the clear zone. Most manmade objects, such as traffic signs, can be designed to eliminate or minimize the hazard to roadway users, thus, eliminating the need for shielding.

Table 12 - Typical Roadside Terrain and Fixed Object Hazards^{1,2}

Obstacles	Mitigating Measure
bridge piers, abutments and railing ends	shielding generally required
Boulders	a judgement decision based on nature of hazard and likelihood of impact
culverts, pipes, headwalls	a judgement decision based on size, shape and location of hazard (see section 2.9)
cut slopes (smooth)	shielding not generally required
cut slopes (rough)	a judgement decision based on likelihood of impact
ditches (parallel)	refer to section 2.2
Ditches (perpendicular)	shielding generally required if likelihood of head-on impact is high
Embankment	a judgement decision based on fill height and slope (see sections 2.1.2 and 2.1.3)
Retaining walls	a judgement decision based on relative smoothness of wall and anticipated maximum angle of impact
sign/luminaire supports ³	shielding generally required for non-breakaway supports
traffic signal supports ⁴	isolated traffic signals within a clear zone on high-speed rural facilities may warrant shielding
Trees	a judgement decision based on site specific circumstances (see example 2.1.2)
utility poles	shielding may be warranted on a case-by-case basis
permanent bodies of water	a judgement decision based on location and depth of water and likelihood of encroachment.
<p>¹Shielding a non-traversable or fixed object hazard is usually warranted only when the hazard is within the clear zone and cannot practically or economically be removed, relocated or made breakaway, and it is determined that the barrier is a lesser hazard than the unshielded condition.</p> <p>²Marginal situations, with respect to placement or omission of a barrier, will usually be decided by accident experience, either at the site or at a comparable site.</p> <p>³Where feasible, all sign and luminaire supports should be a breakaway design regardless of their distance from the roadway if there is reasonable likelihood of their being hit by an errant motorist.</p> <p>⁴In practice, relatively few traffic signal supports, including flashing light signals and gates used at railroad crossing, are shielded. If shielding is deemed necessary, however, crash cushions are sometimes used in lieu of a longitudinal barrier installation.</p>	

D.11 Example of Roadside Clear Zone Determination for Parallel Slopes

A Typical Parallel Embankment Slope Design

Figure 46 presents a variable sloped roadside design that is often used as a compromise between roadside safety and economics. The relatively flat recoverable slope immediately adjacent to the traveled way increases the probability that drivers will be able to retain vehicle control and return to the roadway. Motorists extending beyond the recoverable slope and onto the non-recoverable slope will still be able to slow and possibly stop their vehicles but will have limited steering capability. For this reason the distance occupied by non-recoverable slopes are not included in determining the available clear zone. The desirable clear zone not provided by a recoverable slope may be provided beyond the non-recoverable slope if practical. This distance is represented as the clear run out area in Figure 46.

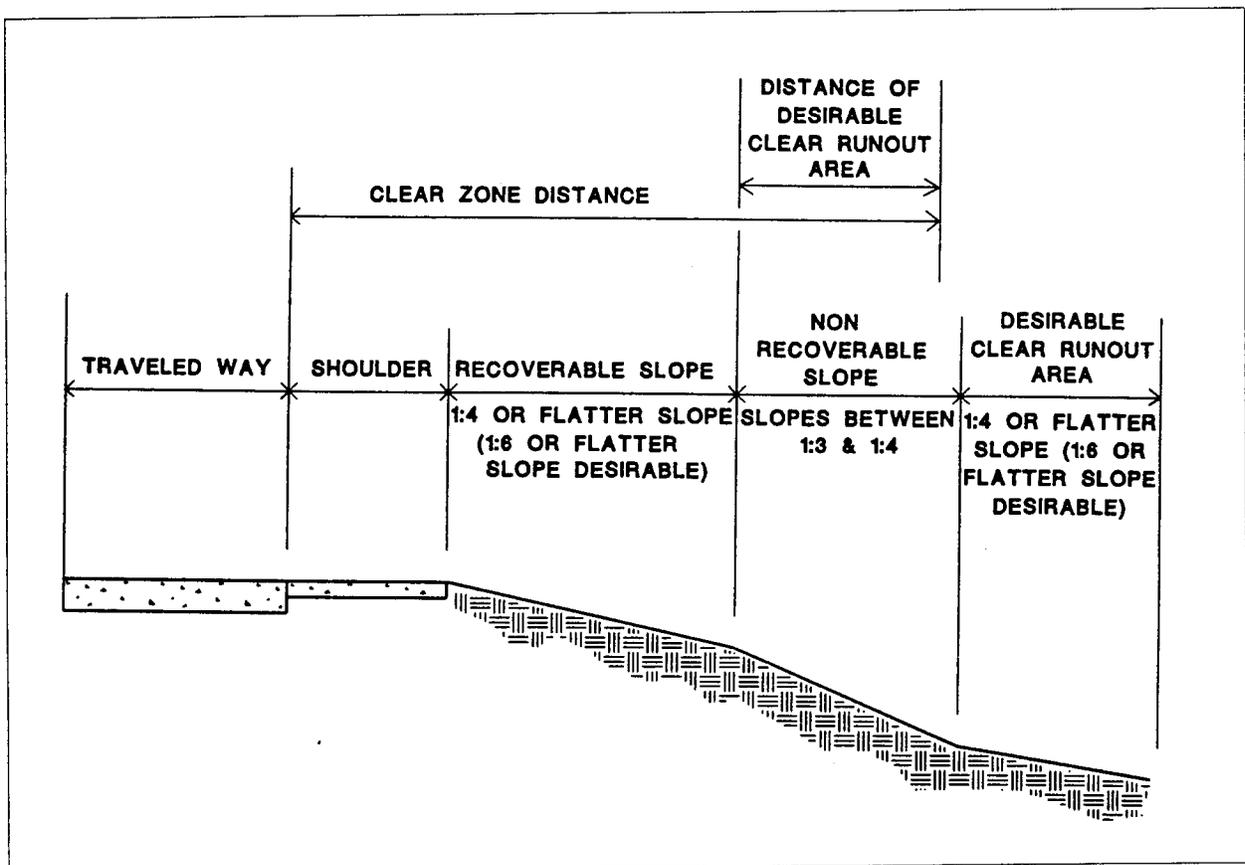


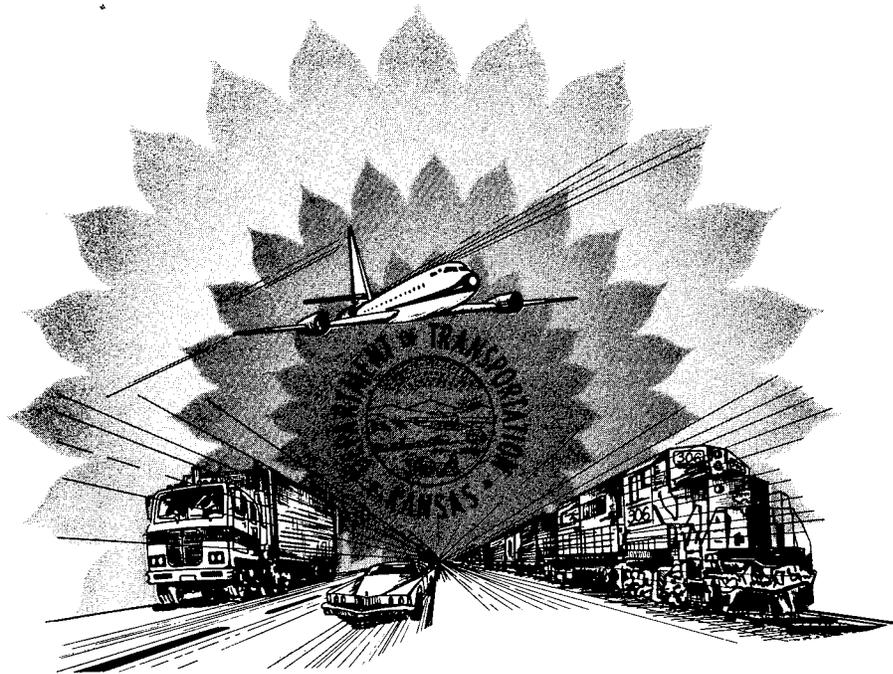
Figure 46 - Example of Typical Parallel Embankment Slope Design Problem





K - TRAN

KANSAS TRANSPORTATION RESEARCH
AND
NEW - DEVELOPMENTS PROGRAM



A COOPERATIVE TRANSPORTATION RESEARCH PROGRAM BETWEEN:

KANSAS DEPARTMENT OF TRANSPORTATION



THE KANSAS STATE UNIVERSITY



THE UNIVERSITY OF KANSAS

