NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 3

TRAFFIC-SAFE AND HYDRAULICALLY EFFICIENT DRAINAGE PRACTICE

HIGHWAY RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
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RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS IN COOPERATION WITH THE BUREAU OF PUBLIC ROADS

SUBJECT CLASSIFICATION:
HIGHWAY DESIGN
HIGHWAY DRAINAGE
ROADSIDE DEVELOPMENT
CONSTRUCTION
MAINTENANCE, GENERAL
HIGHWAY SAFETY

HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING 1969

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Bureau of Public Roads, United States Department of Transportation.

The Highway Research Board of the National Academy of Sciences-National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway departments and by committees of AASHO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Highway Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

This report is one of a series of reports issued from a continuing research program conducted under a three-way agreement entered into in June 1962 by and among the National Academy of Sciences-National Research Council, the American Association of State Highway Officials, and the U. S. Bureau of Public Roads. Individual fiscal agreements are executed annually by the Academy-Research Council, the Bureau of Public Roads, and participating state highway departments, members of the American Association of State Highway Officials.

This report was prepared by the contracting research agency. It has been reviewed by the appropriate Advisory Panel for clarity, documentation, and fulfillment of the contract. It has been accepted by the Highway Research Board and published in the interest of an effectual dissemination of findings and their application in the formulation of policies, procedures, and practices in the subject problem area.

NCHRP Project 20-5 FY '68

NAS-NRC Publication 309-01780-7

Library of Congress Catalog Card Number: 73-604308

PREFACE

There exists a vast storehouse of information relating to nearly every subject of concern to highway administrators and engineers. Much of it resulted from research and much from successful application of the engineering ideas of men faced with problems in their day-to-day work. Because there has been a lack of systematic means for bringing such useful information together and making it available to the entire highway fraternity, the American Association of State Highway Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Highway Research Board to undertake a continuing project to search out and synthesize the useful knowledge from all possible sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series attempts to report on the various practices without in fact making specific recommendations as would be found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available concerning those measures found to be the most successful in resolving specific problems. The extent to which they are utilized in this fashion will quite logically be tempered by the breadth of the user's knowledge in the particular problem area.

Included with this document is a return card by which reader reaction is invited. The knowledge gained therefrom will be directed toward improvement of future issues in light of the express needs of the potential users. Further follow-up will be made to determine the usefulness of the syntheses in highway practice and to effect updating as appropriate.

FOREWORD

By Staff

Highway Research Board

Administrators, engineers and researchers are faced continually with many highway problems on which much information already exists either in documented form or in terms of undocumented experience and practice. Unfortunately, this information is often fragmented, scattered, and unevaluated. As a consequence, full information on what has been learned about a problem is frequently not brought to bear on its solution, costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem. In an effort to resolve this situation, a continuing NCHRP project, carried out by the Highway Research Board as the research agency, has the objective of synthesizing and reporting on highway practices—a synthesis being defined as a composition or combination of separate parts or elements so as to form a whole. Reports from this endeavor constitute a new NCHRP series that collects and assembles the various forms of information into single, concise documents pertaining to specific highway problems or sets of closely related problems. This third report of this series documents highway drainage practices currently in use across the nation that are hydraulically efficient yet traffic-safe. This report should be of special interest to highway design engineers, highway drainage specialists, traffic safety engineers, and maintenance engineers.

For the convenience and safety of the traveling public and the structural integrity of the roadway, virtually all highways are provided with extensive drainage structures. At times, these facilities will impose potentially hazardous obstacles for errant vehicles leaving the traveled roadway. The danger exists for all types of highway drainage features, including crossdrains and their appended culvert end structures, median and curb inlets, roadside channels or ditches, as well as many other special drainage structures. Because highway personnel responsible for the design, construction and maintenance of highway drainage facilities have a perpetual need for the best "how-to-do-it" information, the Highway Research Board has attempted in this project to set down those measures that have been found most successful in minimizing the adverse safety features of drainage structures while maintaining the hydraulic efficiency.

To develop this synthesis in a comprehensive manner and to insure inclusion of most significant knowledge, the Board analyzed all information—for example, current practices, plans, specifications, manuals, and research recommendations—assembled from the knowledge of highway departments, toll road agencies, and other agencies responsible for highway and street design, construction and maintenance. Furthermore, a thorough literature search of all pertinent publications was made, interviews were held with knowledgeable highway personnel, and a correspondence survey for pertinent information was conducted. A topic advisory panel of persons knowledgeable in the subject area was established to guide the researchers in organizing and evaluating the collected data, and for reviewing the final synthesis report.

As a follow-up, the Board will evaluate carefully the effectiveness of the synthesis after it has been in the hands of its users for a period of time. Meanwhile, the search for better methods is a continuing activity and should not be diminished. Hopefully, an early updating of this document will be made to reflect improvements that may be discovered through research or practice.

CONTENTS

ACKNOWLEDGMENTS

This synthesis was completed by the Highway Research Board under the supervision of Paul E. Irick, Assistant Director for Special Projects. The Principal Investigator responsible for conduct of the synthesis was Thomas L. Copas, Special Projects Engineer.

Special appreciation is expressed to B. H. Rottinghaus, Partner, Howard, Needles, Tammen & Bergendoff, who, as special consultant to the Advisory Panel, was responsible for the collection of data and the preparation of the report.

Instrumental in the preparation of this synthesis were the members of the Advisory Panel, consisting of Robert A. Norton, Engineer of Bridges and Structures, Connecticut Department of Highways; Raymond S. Pusey, Traffic Engineer, Delaware Department of Highways; and F. W. Thorstenson, Design Standards Engineer, Minnesota Department of Highways. The Advisory Panel was augmented by liaison representatives Lester A. Herr, Chief, Hydraulics Branch, Bridge Division, Office of Engineering and Operations, and Wayne A. McCollam, Acting Chief, Traffic Engineering Division, Office of Traffic Operations, both of the Bureau of Public Roads. Larry F. Spaine, Engineer of Design, Highway Research Board, assisted the Special Projects staff and the Advisory Panel.

This synthesis could not have been completed without the assistance of the many state highway agencies that provided information on the procedures they follow to provide traffic-safe end structures for drainage devices.

TRAFFIC-SAFE AND HYDRAULICALLY EFFICIENT DRAINAGE PRACTICE

SUMMARY

Some highway drainage structures are potentially hazardous and, if located in the path of an errant vehicle, can substantially increase the probability of an accident. With prudent judgment many of these hazards can be minimized or avoided without seriously interfering with the effectiveness of drainage facilities. No set of rules can be prescribed that would cover every situation. The highway engineer needs a safety consciousness, or awareness, about potential hazards, and the resourcefulness to take countermeasures for their elimination.

Four principal objectives for providing safer roadsides (as applied to drainage structures) have been identified. In order of priority, they are:

1. Unnecessary drainage structures should be eliminated.
2. Necessary drainage structures should be located so that they create the least possible hazard.
3. Structures which cannot be eliminated or redesigned should be designed to inflict minimum damage.
4. Where the first three objectives cannot be feasibly accomplished, guardrail should be installed.

Median inlets should be flush with the ground, or should present no obstacle to a vehicle that is out of control. Such median inlets can be designed to be hydraulically efficient.

End structures for cross drains or culverts should be placed outside the designated recovery area wherever possible. If grates are considered necessary to cover culvert inlets, care must be taken to design the grate so that the inlet will not clog during floods. Where curb inlet systems are used, setbacks should be minimal, and grates should be designed for hydraulic efficiency and safe passage of vehicles. Roadside channels should have flat side slopes. Hazardous channels or energy-dissipating devices should be located outside the designated recovery area or adequate guardrail protection should be provided.

The design and location of drainage structures should receive as much attention from a safety standpoint as other roadway features—such as geometrics, lighting, signing, and guardrail.

Excessive use of guardrail to protect traffic from hazardous drainage structures is both a psychological and a physical hazard. Existing structures should be made safer by relocation or modification. Guardrail should be used only as a last resort.

It is necessary to emphasize that liberties should not be taken with the hydraulic design of drainage structures to make them safer unless it is clear that their function and efficiency will not be impaired by the contemplated changes. Engineering judgment should be used every time grate installation is considered. Even minor changes at culvert inlets can seriously disrupt hydraulic performance.

The key criterion for safety is that potentially dangerous openings to drainage structures should be situated away from the roadways, in locations where they are less likely to be traffic hazards.

CHAPTER ONE

INTRODUCTION

There were 55,200 people killed on U.S. highways in 1968. This represents a 45 percent rise over the past eight years. During this same period motor vehicle registrations have increased only 37 percent and traffic mileage has increased only 31 percent (*1*). This indicates some basic flaws in the car-driver-roadway system. In the past it has been too easy to point to the driver as the primary contributor to accidents, but more recently attention has been turned to the automobile and finally the roadway itself.

This synthesis is based on information received from contact with all 50 states, Puerto Rico, and the District of Columbia regarding roadway drainage structures and devices currently in use, or under experimental development. These data were examined with the object of (1) evolving designs and practices that will provide drainage efficiency without creating an undue traffic hazard, and (2) publishing the findings that illustrate current design practice.

This study was concerned exclusively with one type of accident—i.e., the single-vehicle, fixed-object accident that occurs when a vehicle, for any reason, leaves the traveled roadway and strikes a drainage device.

Over 27 percent of all turnpike accidents involved a single vehicle leaving the roadway, with 12.7 percent involving a vehicle colliding with a bridge, curb, median barrier, or other fixed object (*2*). Similar data for completed sections of the Interstate System are given in Tables 1 and 2. The only way this type of accident can be prevented entirely is by elimination of all fixed objects, which is often impractical. However, the report of the Special AASHO Traffic Safety Committee (*3*) discloses that 80 percent of the vehicles involved in "ran-off-the-road" accidents do not travel more than about 30 ft from the traveled roadway. Figure 1 shows the percent of accidents occurring at various distances from the edge of pavement, according to three different studies (*4*).

TABLE 1

FIXED OBJECTS STRUCK FIRST IN SINGLE-VEHICLE, OFF-THE-ROAD FATAL ACCIDENTS ON COMPLETED SECTIONS OF THE INTERSTATE SYSTEM, 1968

First object struck	Number	Percent
Total, all objects	1,208	100.0
Guardrail [1]	364	30.1
Bridge or overpass	217	18.0
Sign	97	8.0
Embankment	86	7.1
Curb	72	6.0
Divider [2]	71	5.9
Pole [3]	63	5.2
Ditch or drain	57	4.7
Culvert	51	4.2
Fence [4]	28	2.3
Tree	26	2.2
Other	76	6.3

[1] Includes cable type.
[2] Includes rail, concrete, and chainlink.
[3] Principally light poles.
[4] Principally right-of-way fences.

Source: *Pub. Roads,* Vol 35, No. 10, p. 223 (Oct. 1969).

Many agencies recognize the need for providing an unobstructed recovery area adjacent to the roadway to help minimize these accidents. The width of this area will vary because of right-of-way and grading problems. This synthesis stresses the desirability of eliminating, minimizing, or modifying fixed-object drainage structures located within this designated recovery area to reduce the hazard. Nevertheless, some serious accidents do occur beyond the normal recovery area. This fact should always be borne in mind and every reasonable effort should be made to eliminate hazardous structures beyond the designated recovery area.

The concept of a traffic-safe, hydraulically efficient drainage structure requires some explanation. To be traffic-safe, a structure or device should not have vertical faces projecting above the ground, or steep-sided depressions below the surface. These configurations may cause an automobile leaving the roadway to come to an abrupt stop or to veer out of control, causing death or injury to the occupants and extensive damage to the vehicle. To be hydraulically efficient, a drainage device must be capable of accepting a quantity of water as inflow and discharging it as outflow, without becoming clogged during floods. In the past, hydraulic efficiency often has been achieved with structures having hazardous geometrical shapes. It is the responsibility of the designer to provide, insofar as possible, both a traffic-safe and an efficient hydraulic design. Fortunately, hydraulically efficient drainage structures and safety are compatible in many cases—for example, wide channels with flat side slopes. Where efficiency and safety conflict, good design may dictate that the inlet or outlet structure be located outside the recovery area. The increased construction costs for traffic-safe design are justified in terms of a reduction in fatalities, injuries, and property damage.

The term "traffic-safe" requires further definition. A traffic-safe structure is one which does not inhibit the driver's ability to regain control of his vehicle—permitting him either to return to the traveled roadway or to stop safely without damage or injury. This is, of necessity, a general definition, but it does indicate an objective for which to strive. The hazard imposed by a device is a function of the speed at which it is struck. Consequently,

TABLE 2

FIRST AND SECOND FIXED OBJECTS STRUCK IN SINGLE-VEHICLE, OFF-THE-ROAD FATAL ACCIDENTS ON COMPLETED SECTIONS OF THE INTERSTATE SYSTEM, 1968

First object struck	Guardrail	Bridge or overpass	Sign	Embankment	Curb	Divider	Pole	Ditch	Culvert	Fence	Tree	Other
Second object struck:												
None	151	181	76	58	16	47	44	46	38	9	21	53
Bridge	102	16	6	2	10	2	4	1	2	1	1	3
Embankment	36	4	2	2	4	1	2	5	2	5		1
Guardrail	18	4	2	1	17	10	3		2			3
Pole	17	3	3	1	11	2	1	1		3		1
Sign	14				4	5	2					6
Ditch	6	4	3		3	1	4	1	1	3	1	1
Culvert	3		1	4	1			2		1		1
Curb	3	1		1	2							
Divider	3	1	1	2		1	1					1
Fence	4	1	1	6	1	2	2		1	2		
Tree	2			5	2			1	3	3	3	4
Other	5	2	2	4	1				2	1		4
Total, all collisions	364	217	97	86	72	71	63	57	51	28	26	76

Source: *Pub. Roads*, Vol. 35, No. 10, p. 223 (Oct. 1969).

a device which is considered safe for use on a low-speed city street may constitute a hazard when used on a high-speed freeway. Therefore, the setback of the hazard from the roadway should be a function of the probable travel speed (Fig. 2).

Although some hazardous roadside features may be relocated, the designer should keep in mind that he has less freedom in the placement of drainage structures. When structures are positioned at an exact location for drainage, relocation as a safety measure may be extremely difficult.

It is common practice to place guardrail barriers between traffic and hazardous drainage structures. The placing of many feet of guardrail between these structures and the roadway is the least desirable solution. The guardrail itself is a hazard extending for a great distance, and is a continuing maintenance problem.

The location of drainage devices with respect to horizontal curves should also be considered (Fig. 3). Locations on the outside of curves may be more hazardous than those on the inside. However, there are sites where more accidents occur on the inside as a result of vehicle speed, surface conditions, and geometric features of the curve. Therefore, both sides of a curve should be considered more hazardous locations for drainage structures than locations beside tangent sections.

When considering the elimination of hazardous drainage structures, the designer should give priority to isolated or unexpected hazards. A higher cost for modification or elimination of these hazards may be justified, because the driver has become accustomed to having available a safe recovery area.

In summary, the guidelines in the BPR *Instructional Memo 21-6-66* (*5*) describe methods of providing traffic-safe drainage structures. They are:

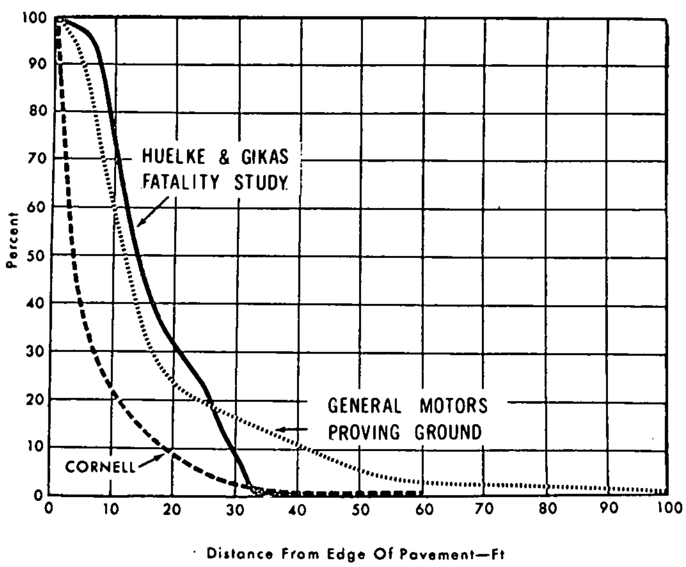


Figure 1. Distribution of impacted roadside obstacles vs distance from edge of roadway (63 cases) (4).

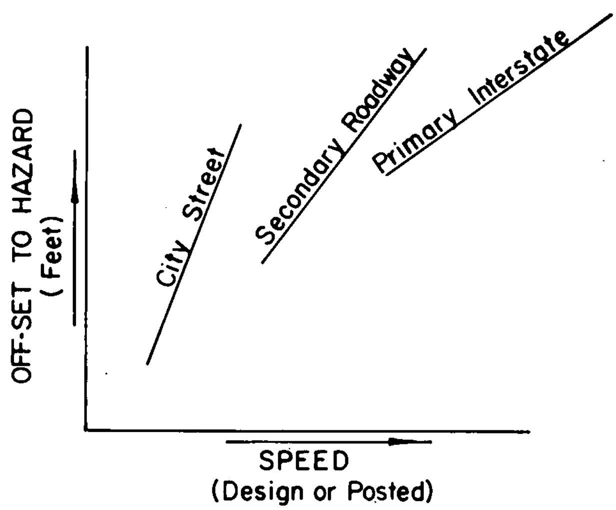


Figure 2. Relationship between speed, type of roadway, and offset to hazard.

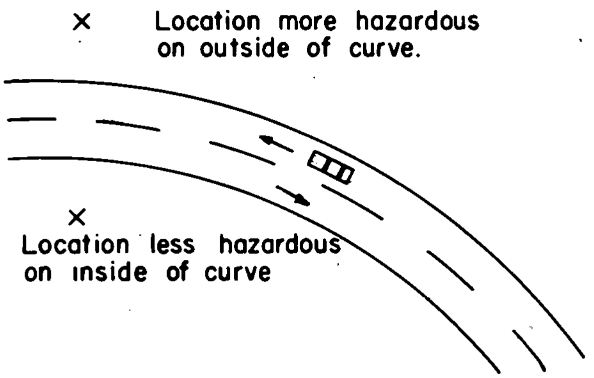


Figure 3. Drainage structures located adjacent to curved sections are greater potential hazards than those along tangents.

1. Unnecessary drainage structures (such as concrete ditches and ditch checks and excessive roadway cross drains) should be eliminated.

2. Necessary drainage structures should be located so as to create the least practical hazard, or existing structures should be relocated to positions outside the designated recovery area, or underground.

3. Drainage structures which cannot be eliminated or relocated should be modified to reduce the hazard, if such modification could be made without adversely affecting hydraulic performance.

4. Where the first three objectives cannot be feasibly accomplished, suitable protective barriers should be installed.

CHAPTER TWO

MEDIAN DRAINAGE STRUCTURES

Median drainage structures are designed to convey storm runoff away from the roadway, maintain subgrade stabilization, and prevent flooding. The drainage area consists of the median and that portion of both roadways sloping toward the median. These drainage structures fall into two basic categories: flush-type, and projecting. Because of their unavoidable proximity to the traveled roadway, they are of extreme concern from the safety viewpoint.

FLUSH TYPE

Median drains that are flush with the ground usually consist of metal grates mounted over concrete catch basins. The most common placement is at the bottom of the median ditch. However, in flat country or locations with shallow fills, inlets are located on the median side slope (Fig. 4).

The flush grate is traffic-safe in that an out-of-control vehicle can pass over it without striking any obstruction. Safety requirements also dictate that the grate have sufficient strength to support the design wheel load, with bars arranged and spaced to prevent penetration by the narrowest vehicle tire using the facility (Fig. 5).

Hydraulic efficiency of the flush-type grated median inlet is satisfactory, inasmuch as debris usually is not a problem. If the inlet is placed in a ditch without a sump, some bypass flow may occur during peak runoff. The bypass flow may be reduced by lengthening or widening the inlet (Fig. 6), or by providing a ditch dike (Fig. 7) to increase interception. Such ditch dikes create an artificial sump; however, it must be recognized that steep slopes on such dikes could create a hazard and impede a driver's efforts to regain control of the vehicle. Therefore, slopes should be as flat as is practicable (Fig. 7).

Orientation of the grate bars may affect the hydraulic efficiency. Bars should be placed parallel to the flow to obtain greater efficiency (Fig. 8).

When the inlet structure is placed in a sump, the bypass problem is usually eliminated. A head may build up over the grate, but, assuming that the inflow area has been properly proportioned for the design discharge, grate configuration should not adversely affect the inlet capacity, unless clogging by debris is a problem (Fig. 9).

A concrete apron around the inlet structure discourages overgrowth, improves inlet efficiency, assists the maintenance effort, and reduces erosion (Fig. 10).

For most median drainage the amount of debris is small, and the penalty for flooding is slight, thus permitting the use of grates.

Another type of inlet structure, the round precast unit, admits water through openings in the four quadrants. Figure 11 shows this precast concrete structure without grate. There are other versions with either a manhole cover or a grate that are used where there is a need for cleaning and performing maintenance (Fig. 12). These structures are traffic-safe if they are constructed flush with the ground and the openings are small enough to prevent a wheel from entering.

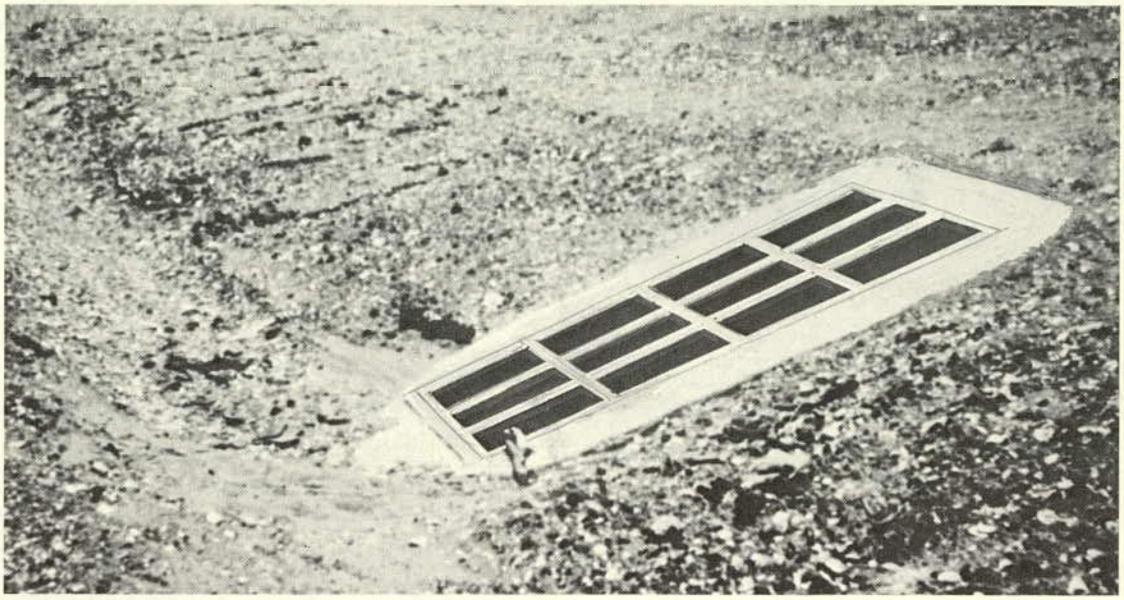


Figure 4. Drain with grate, located on median side slope.

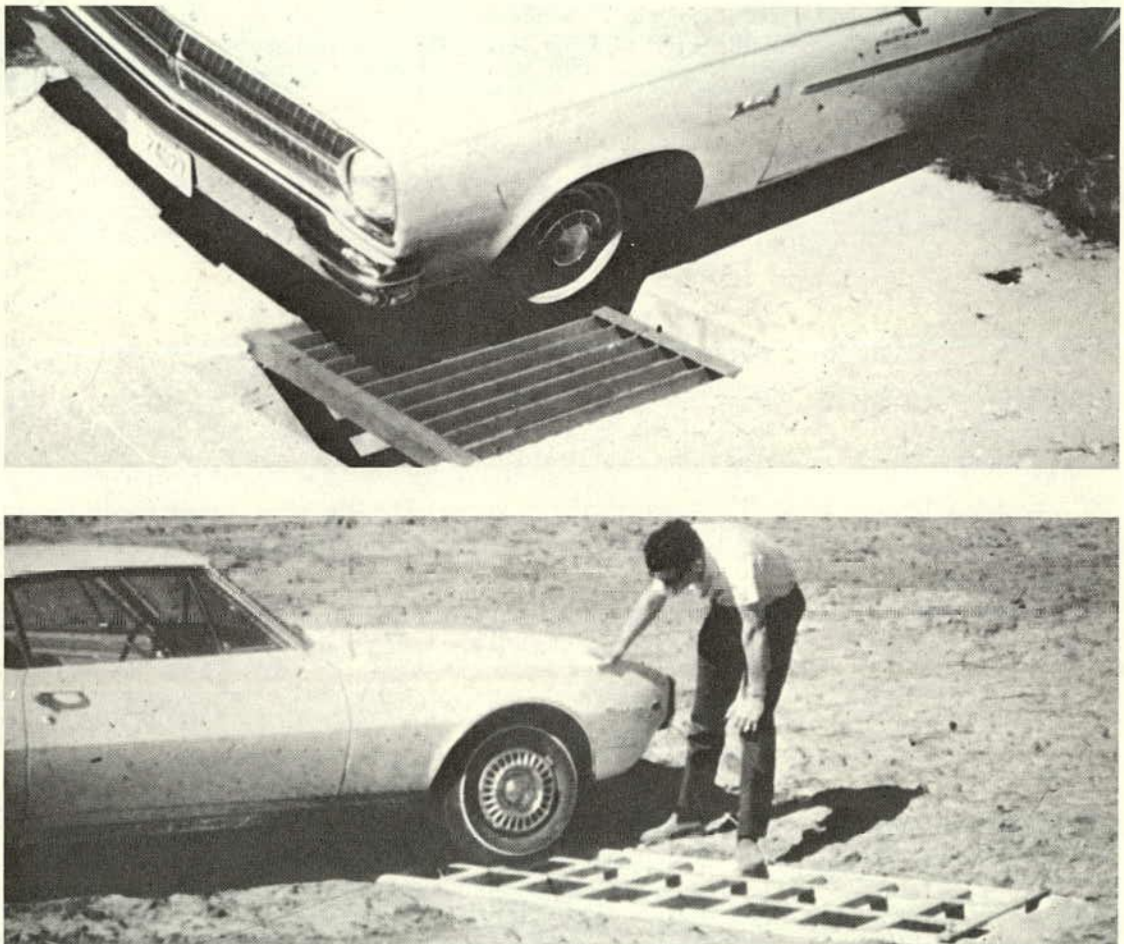


Figure 5. Drop inlet grates designed to support wheel load and prevent tire penetration.

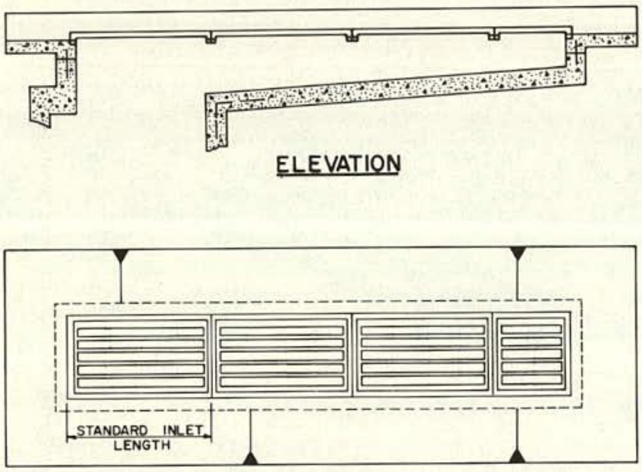


Figure 6. Drop inlet—elongated to increase penetration.

PROJECTING TYPE

Another type of median inlet has some part that projects above the adjacent ground surface. This category includes inlets flush with the ground on three sides, with an exposed vertical face where the flow enters the structure (Fig. 13).

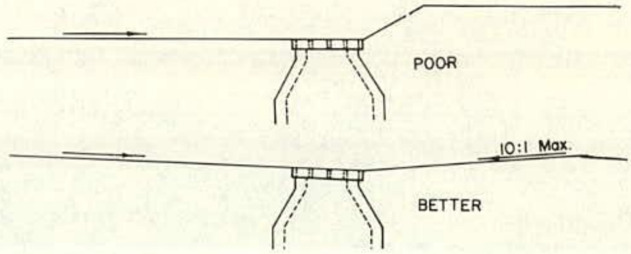


Figure 7. Ditch dikes increase interception, but should be as flat as practicable.

The hydraulic efficiency of this type of inlet is satisfactory, particularly when the structure is located at the bottom of a vertical curve and admits water on both sides. But this type of drainage structure presents serious safety problems. Vehicles striking the projecting surface could be damaged and the occupants subjected to serious injury.

Figure 14 shows a median inlet structure with a concrete cover weighing approximately 750 lb that has been dislodged by a vehicle. Figure 15 shows another cover that has been broken by wheel impact or load. There are records of accidents where the automobile cartwheeled after striking the median drainage structure, throwing the occupants out of the car. Figure 16 shows an accident in which an out-

Figure 8. Median drop inlet with grate bars oriented in the same direction as flow.

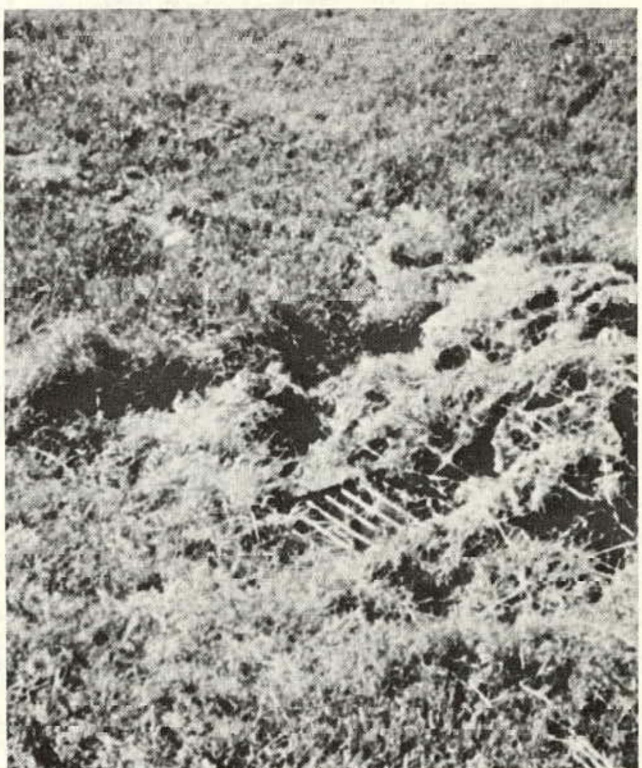


Figure 9. Capacity of drop inlet is threatened by debris and overgrowth.

Figure 10. One type of concrete apron to discourage vegetation overgrowth, prevent erosion, and facilitate maintenance.

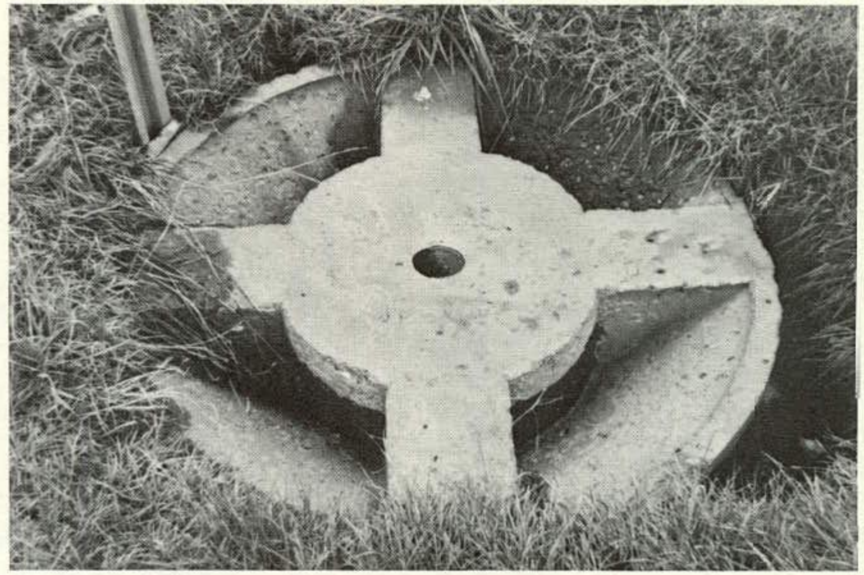


Figure 11. Precast concrete median inlet with non-removable top. Note 4-in. hole for inserting steam line for thawing ice.

Figure 12. Precast concrete drop inlet with removable cover. Slender post aids location under snow.

Figure 13. Drop inlet (in median) with exposed vertical face where flow enters the structure.

Figure 14. A concrete inlet cover weighing more than 750 lb that has been displaced by vehicle impact.

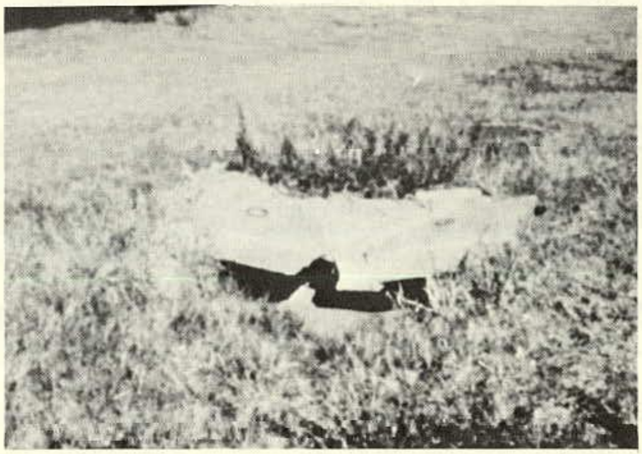


Figure 15. This concrete drop inlet was unable to support vehicle load.

Figure 16. Accident involving an out-of-control vehicle and a median drainage structure.

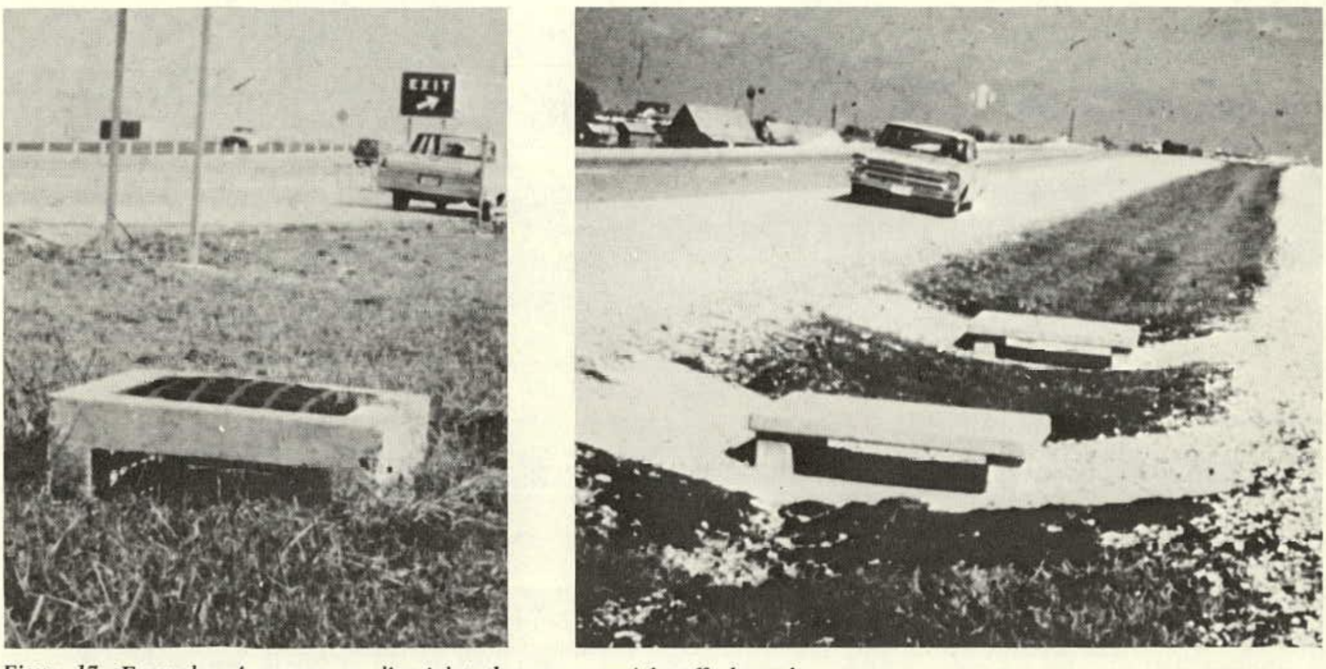
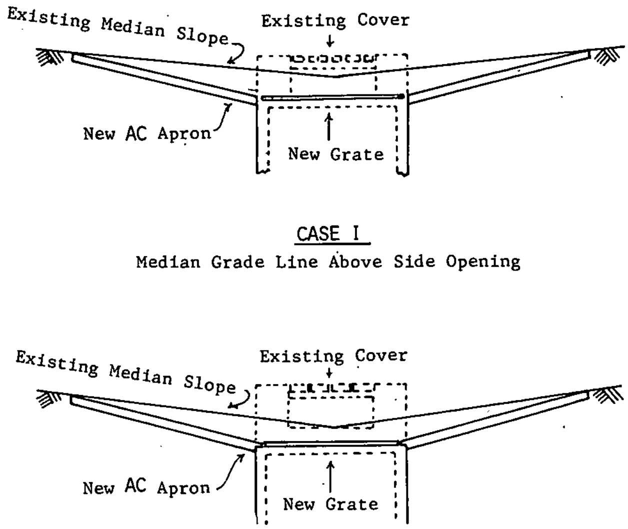


Figure 17. Examples of common median inlets that are potential traffic hazards.

of-control vehicle struck a projecting concrete median inlet. Existing hazardous structures such as those shown in Figure 17 should be modified. A tentative plan for converting two types of projecting inlets to safer flush types is shown in Figure 18.

CONCLUSIONS

1. Median structures should be flush with the ground or side slope.
2. Grates should consist of bars of sufficient strength and spacing to safely support vehicle wheels.
3. Hydraulic capacity of inlets should be increased by elongation, widening of the opening, or by flat-sloped ditch dikes.
4. Deep depressions in medians should be avoided.
5. Small paved aprons should be provided at flush inlets.
6. Vertical projections should not be permitted except where medians are wide and the structure is beyond the recovery area.
7. Existing hazardous structures should be modified to eliminate the features that are traffic hazards.
8. As a final resort, a barrier system may be used to separate traffic from hazardous structures.



CASE I
Median Grade Line Above Side Opening

CASE II
Median Grade Line At Bottom Of Opening

Figure 18. Methods of converting projecting median inlets to safer design.

CHAPTER THREE

CULVERT END STRUCTURES

Culvert end structures consist of precast sections or cast-in-place head and wingwalls. Their purpose is to retain the earth fill and to prevent erosion where the culvert barrel emerges from the embankment. The large openings and heavy concrete walls of these end structures have in the past presented many obstacles to traffic, especially when they are placed within the recovery area (Figs. 19, 20).

Most culverts are constructed to carry streamflow across the highway right-of-way. The size is based on the need to protect the highway and adjacent property from undue damage from floodwaters. The design of traffic-safe culvert openings that are hydraulically efficient during floods is difficult, and construction usually is costly. No one solution is applicable to all situations, and standard designs or general rules should be used with caution.

The low embankment situation is the most troublesome from the safety standpoint, because a culvert constructed to conform to the normal cross-section will have its ends close to the roadway. In these cases several alternatives are available to the designer in reducing the traffic hazards caused by the culvert inlet or outlet. However, care must be taken to assure that the hydraulic efficiency of the culvert is not impaired during floods, or the entire investment may be lost in the interest of safety.

In selecting a satisfactory design it is necessary to consider topography, size of culvert, height of fill, clogging potential, and the cost of the various alternates. Three general solutions have been used:

1. Lengthen the culvert to place the ends beyond the specified recovery area.
2. Modify the culvert end structure to accept a grate that is designed to carry a vehicle.
3. Install a guardrail barrier to protect traffic from dangerous culvert end sections.

Although the first solution could be the most costly and requires warping of the embankment to secure adequate cover and proper aesthetics, it satisfies both hydraulic and safety requirements. Grates, as used in many locations, can collect drift which clogs culverts; this results in a flooded roadway, which is a safety hazard. If such grates are to be used on culverts, the drift potential must be evaluated, and

Figure 19. Projecting headwall located within the recovery area.

Figure 20. U*-type culvert end section is dangerous when located within the recovery area. Post marker warns traffic and maintenance workers.*

debris collection facilities should be installed if warranted (*6*). Although guardrails have been used, they represent an additional hazard and are costly to install and maintain. Appendix A shows that many smaller culverts may be extended to terminate beyond the recovery area at less cost than constructing a guardrail.

Culvert headwalls (Fig. 21) are constructed in medians or between the main lanes and frontage roads. Such structures are safety hazards and can be avoided by continuing the main culvert through these areas, with appropriate connections for local drainage (Fig. 21). Steep ditches which are subject to erosion, often can be avoided by adopting this type of design.

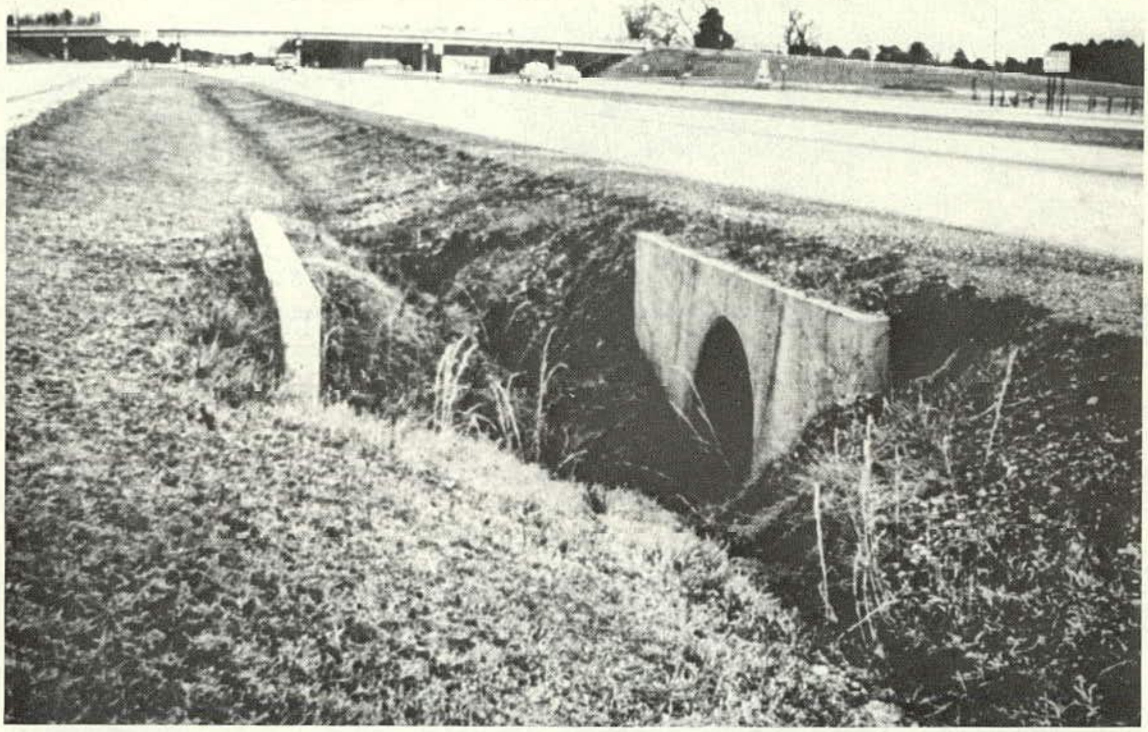
Grates may be fitted to precast end sections. The typical sections shown in Appendix B can be designed to accept standard grates that could be constructed of various structural shapes and materials and could be placed in the slot provided or bolted into place. The use of elliptical pipes having reduced height would result in a shorter end structure and would require less grating.

One type of grate or rack that has been used to improve the safety of existing structures consists of lengths of hollow rectangular structural steel sections welded together (Fig. 22). These sections have a high section modulus compared to other light structural shapes. This type of grate may be placed so that it covers the hazardous pipe end, with the surrounding ground bearing the load (Fig 23).

Culvert end structures for pipes placed parallel to the roadway under median crossovers, entrances, and driveways present hazards as great as, or greater than culvert openings (Fig. 24). To be safely mountable, these end structures should have grates that are flush with the surface. However, it is desirable to place the grate above the ditch bottom. Inasmuch as these two requirements are irreconcilable, one or the other must be compromised at the discretion of the designer. If the grate is on the upstream side and the grade permits, a solution may be to drop the ditch bottom immediately before the grate (Fig. 25). The grate shown in Figure 23 could be used also for end treatment of ramp drainage structures.

The possible use of hinged grates on the outfall end structure to prevent blockage at times of peak runoff deserves consideration, as does the feasibility of a system of constructing end structures by using precast sections as shown in Appendix B.

In many cases hazardous structures have been constructed where a safer design might have been used. Figure 26 shows an existing culvert end structure, and possible remedial measures. Figure 27 shows an ineffective guardrail installation that was used where the cross culvert was discontinued at the median. A practical improvement is shown with 10:1 slopes. Another unsafe condition, where a culvert passes beneath a median crossing, is shown in Figure 28. It was decided to close the crossing by installing guardrail, an additional hazard, rather than removing the culvert itself, as shown. Guardrail should be used only as a last resort to protect traffic from drainage structures (Fig. 29).



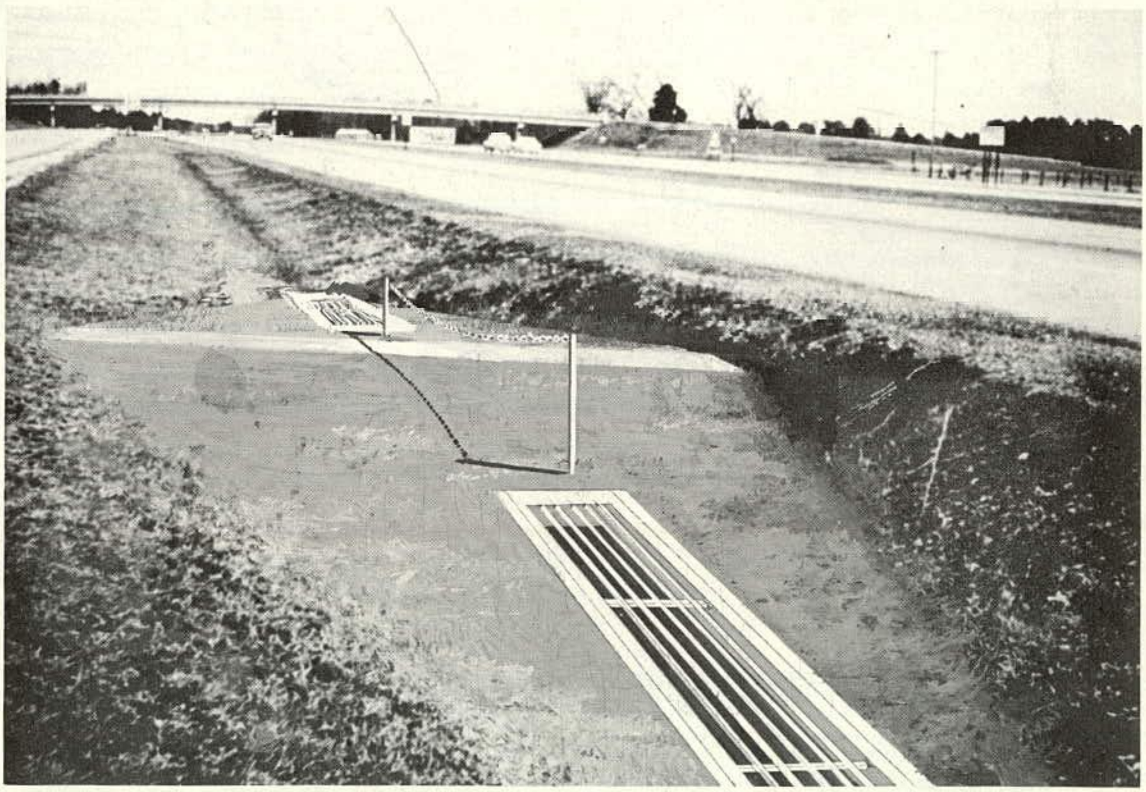


Figure 21. Two headwalls representing a double hazard (top). A possible solution is to install median inlets on a 10:1 slope, with connections into the extended cross drain (bottom).

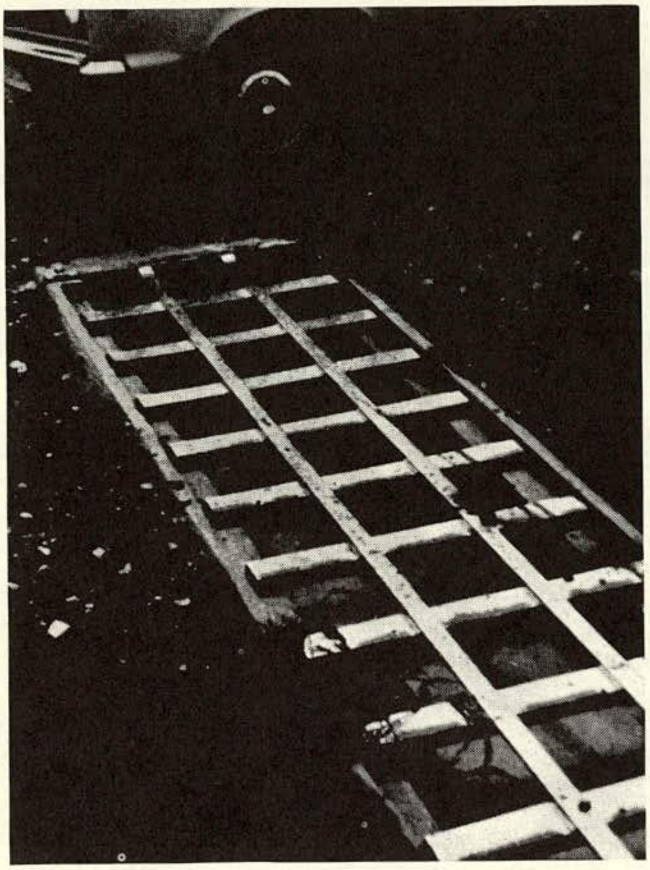


Figure 22. Culvert end structure with special grate.

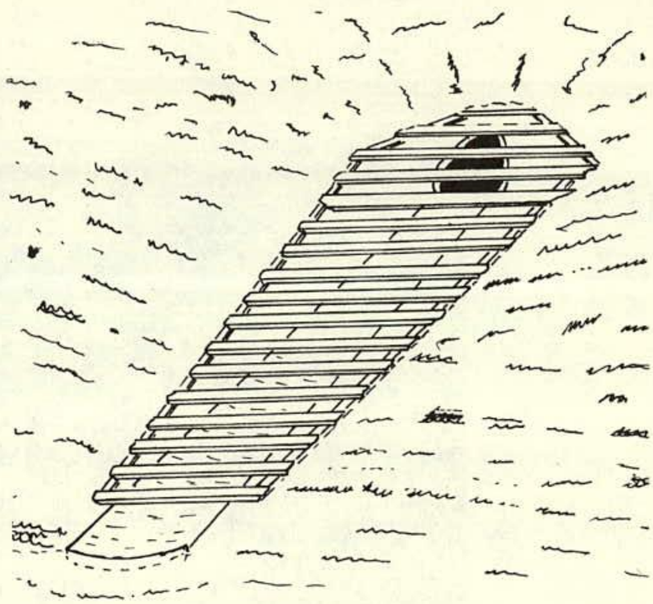


Figure 23. One possible modification for ends of median, ramp, or cross-drain structures. This unit may be made up of rectangular steel sections and placed with very little preparation. Side and end slopes should be 10:1 or flatter.

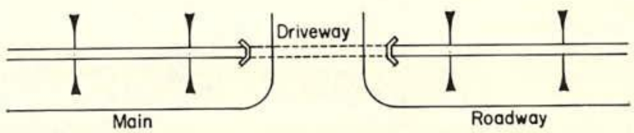


Figure 24. Typical culvert layout with unsafe headwalls that often has been used at driveways and intersections.

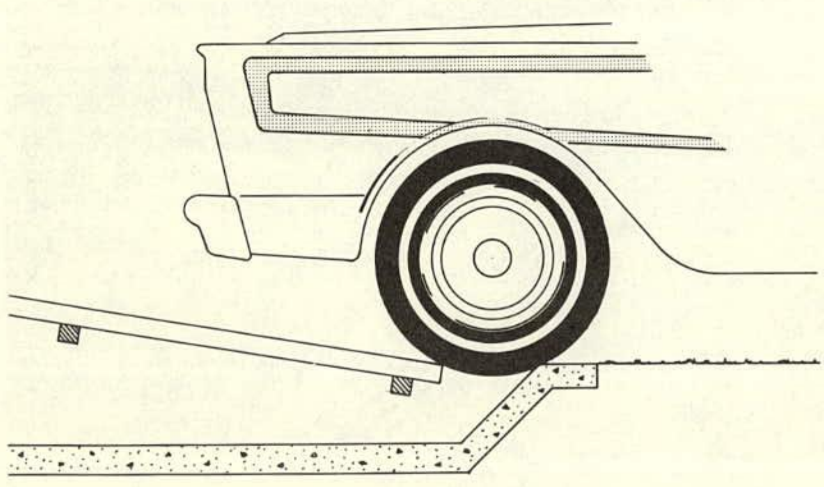
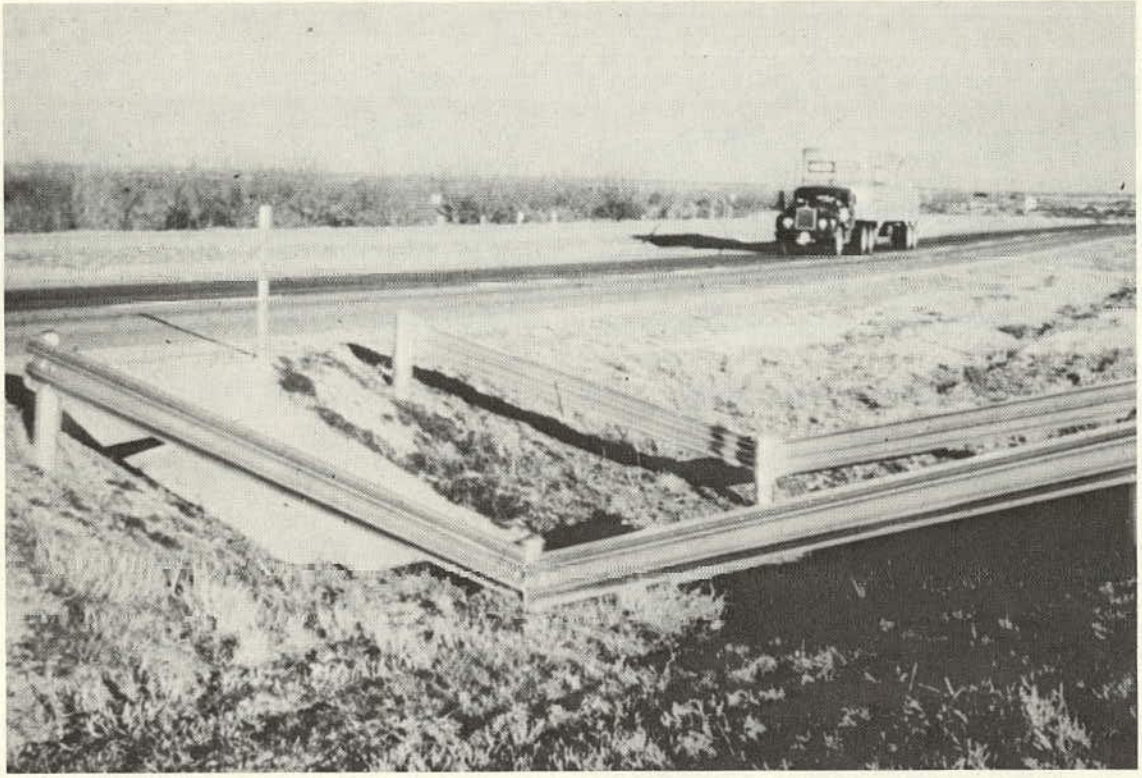


Figure 25. Special culvert entrance designed to permit passage of debris by dropping ditch grade to minimize hazard.

Figure 26. Hazardous drainage practice between two roadways (top). Possible modification with drop inlet and flat slopes (bottom).



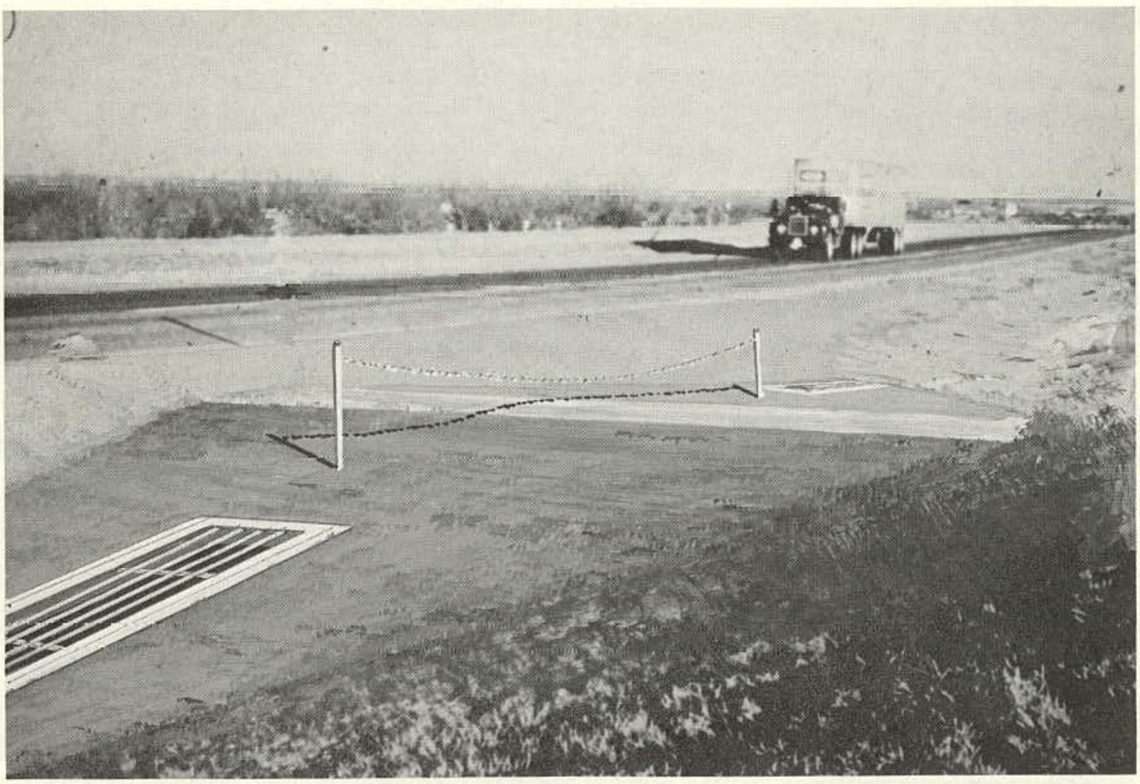


Figure 27. Guardrail has been placed to prevent vehicles from hitting culvert inlets (top). The solution sketched in Figure 21 could be used (bottom).

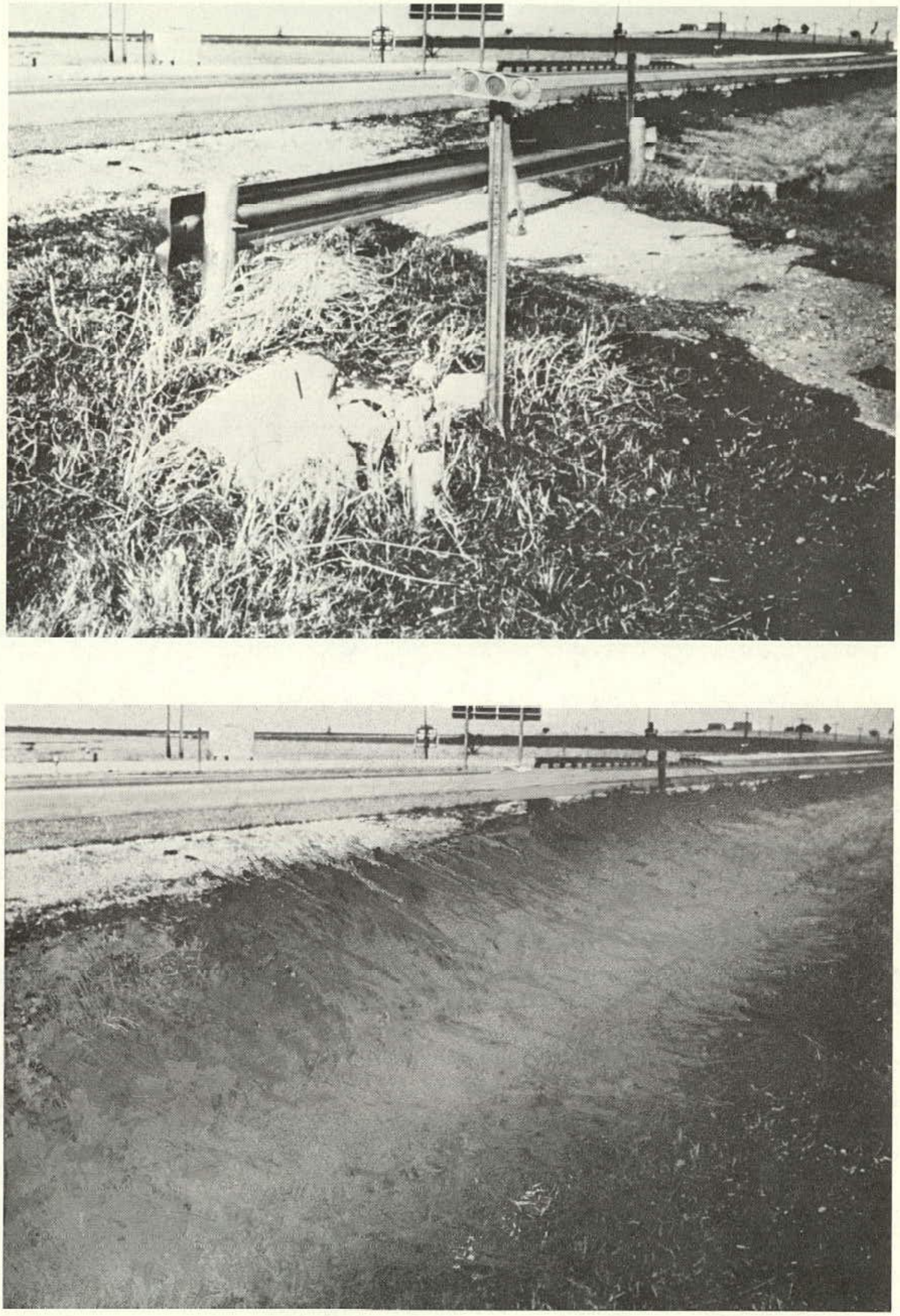
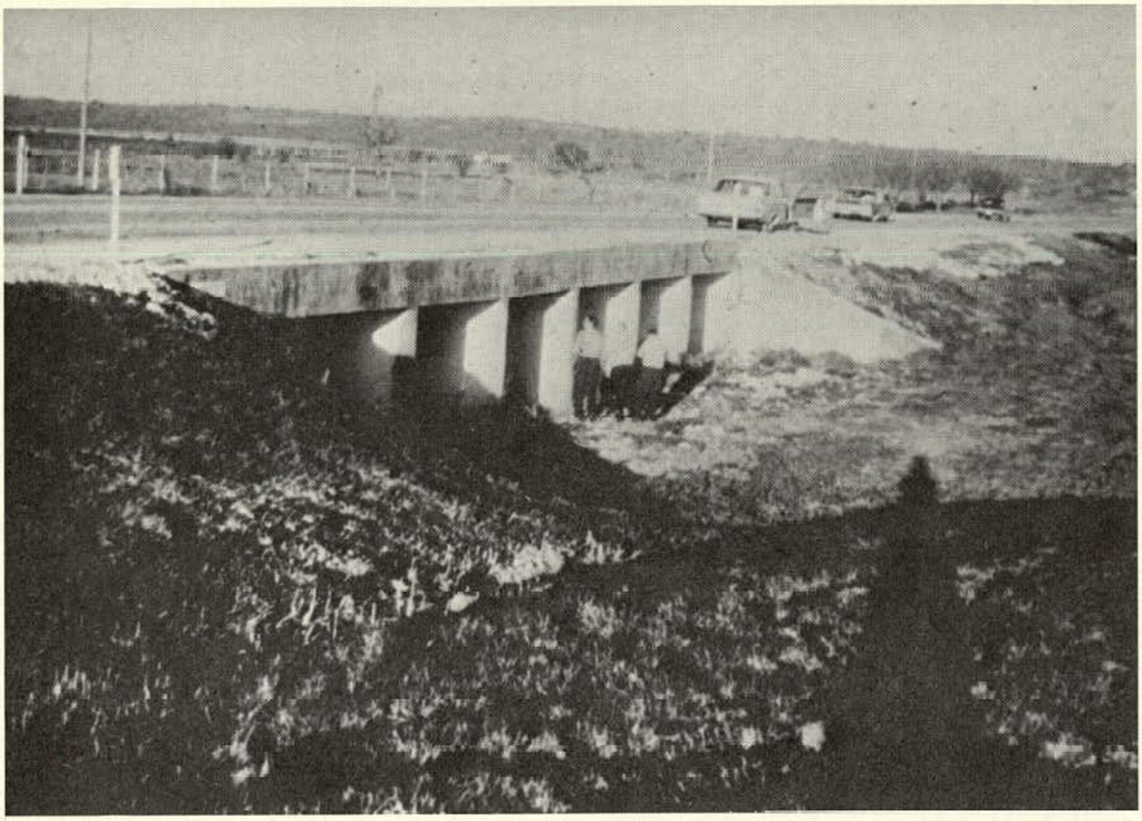


Figure 28. Closing of median crossover or drive entrance with guardrail barrier compounds hazards (top). Preferred solution would be to remove both the drainage structure and the guardrail and regrade the slope (bottom).



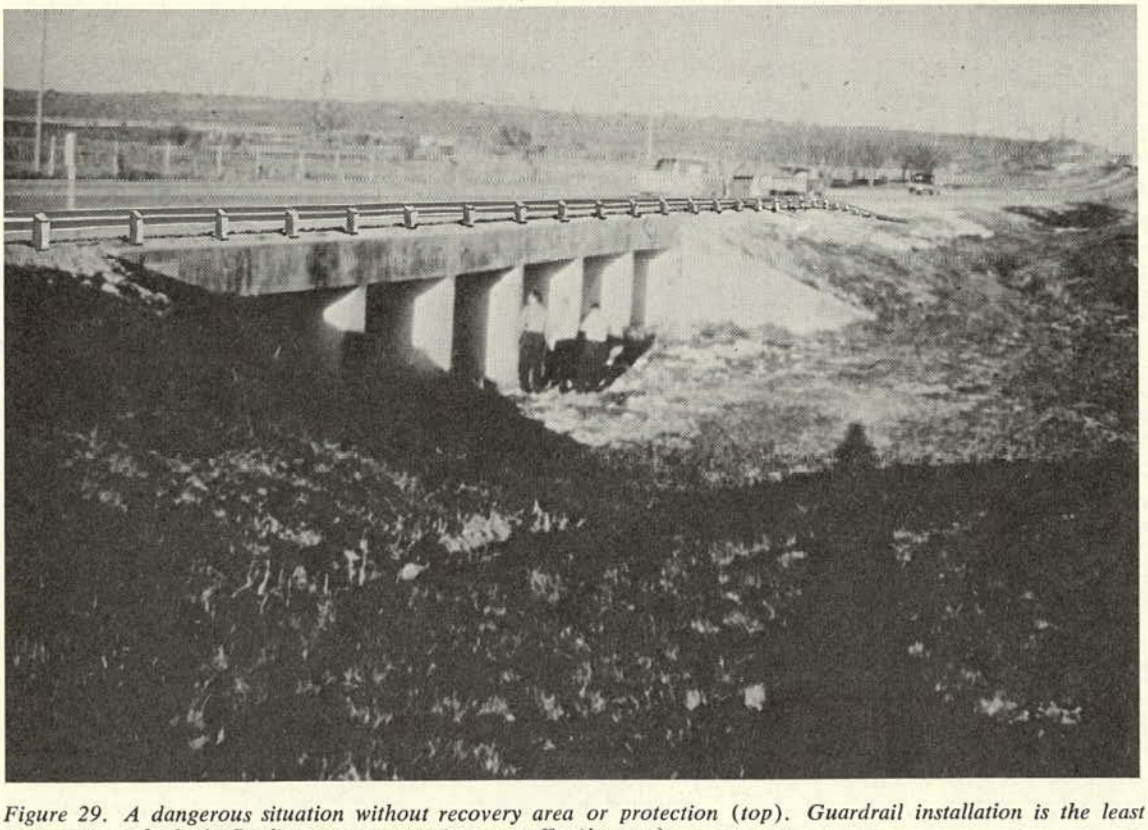


Figure 29. A dangerous situation without recovery area or protection (top). Guardrail installation is the least expensive method of affording some protection to traffic (bottom).

CONCLUSIONS

1. On facilities where there is sufficient right-of-way, the culvert end structure should be located outside the designated recovery area.

2. On installations within the recovery area, and beyond if warranted, a vehicle should be protected from falling into the structure by grates capable of supporting the design wheel load, unless such a grate would interfere with the hydraulic function of the culvert and cause flood damage.

3. Any projection of the end structure above the ground surface should be minimal.

4. Where these recommendations cannot be met, the vehicle occupants should be protected from the hazard by a sufficient length of properly installed guardrail.

5. Guardrail should not be installed if it would be a greater hazard than the drainage structure itself.

6. Where conditions allow, consideration should be given to orienting culvert end structures away from the direction of traffic.

CHAPTER FOUR

CURBSIDE AND CURB OPENING INLETS

The curbside inlet intercepts water flowing in the gutter along the edge of the roadway surface or shoulder and the curb face. It may consist of a catch basin with grate placed in the gutter along the curb, flush with the surface or slightly depressed, or an opening in the curb face itself (Fig. 30).

Many catch basin designs employ both a grate and a curb opening. In itself, the curbside inlet presents no hazard to traffic; the hazard is the curb. An out-of-control vehicle striking the curb may deflect onto the roadway, thereby endangering other traffic, or bounce over the curb, with the driver less prepared to regain control. Contact with the curb usually will be oblique, and the flatter the angle the less the shock of impact. Therefore, in situations where the catch basin has been set back behind the curb line and the curb curved back to form a "pocket" (Fig. 31), the angle at which the vehicle may strike the curb is increased. This practice is hazardous and should be avoided.

Mountable or sloped curbs minimize the hazard from impact without sacrificing the gutter capacity, provided the overall curb height is not reduced.

Hazardous conditions are created, however, when inlet structures are set back from the normal curb line. Such

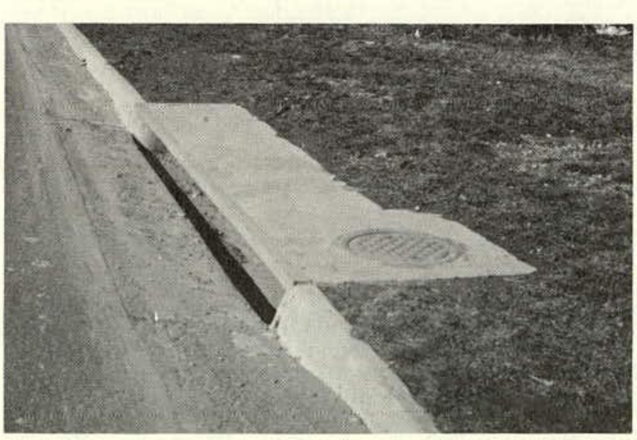


Figure 30. Typical curb-opening inlet often used in urban areas.

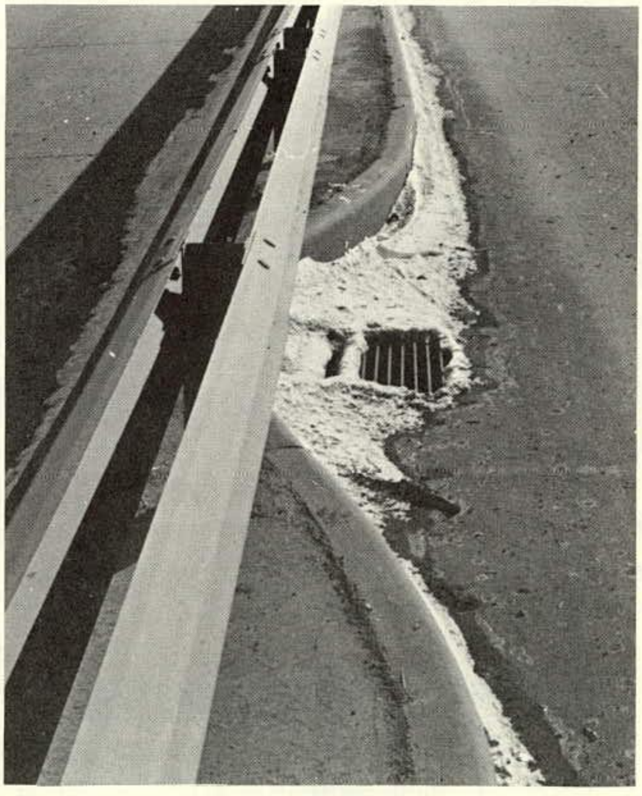


Figure 31. Curb has been curved to direct water to the drop inlet, creating a potential hazard to traffic.

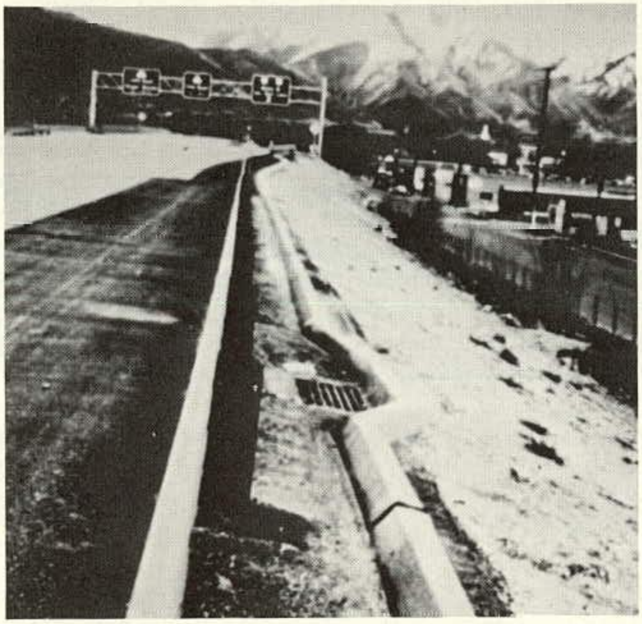


Figure 32. Curb and inlet placed behind guardrail.

Figure 33. Drainage inlet designed for use with low mountable curb. Bars are oriented in the direction of flow.

practice should be avoided. Where existing structures are set back, the danger may be minimized by placing guardrail along the projected curb line.

In some locations, where steep embankments have required guardrail installation, the curbing has been placed behind the guardrail (Fig. 32).

The grates selected for curbside inlets may affect the amount of bypass flow. Grates with bars oriented in the direction of flow intercept a higher percentage of water than those with bars oriented normal to the flow (Fig. 33). Orienting grate bars in the direction of flow presents a hazard only to bicycles or other narrow-tired vehicles. If bicycle traffic is a consideration, some compromise such as diagonal bars or closer bar spacing is recommended (Fig. 34). Circular castings are sometimes carelessly placed in random positions that could have an adverse effect on inlet efficiency—turbulence is increased and self-cleaning properties are reduced (Fig. 35). This suggests that circular grates should be keyed to prevent rotation and to maintain capacity.

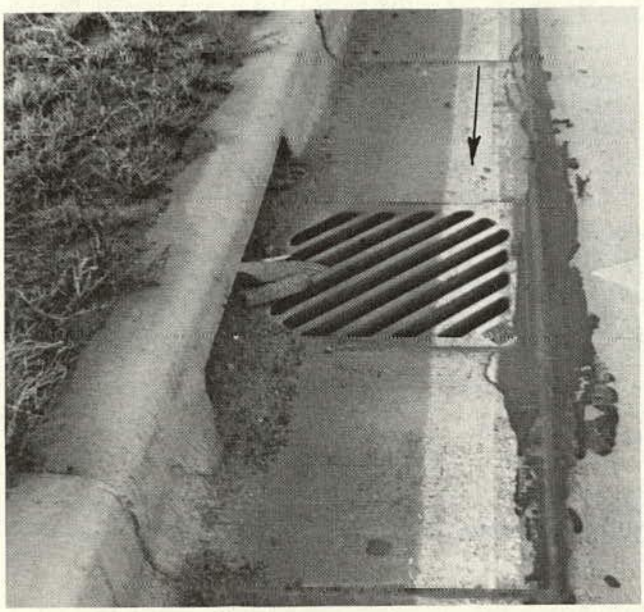


Figure 34. Drop inlet grate with bars positioned diagonally to deflect flow into curb inlet and to lessen hazard to narrow-tired vehicles.

The "New Jersey" type of barrier is being used on some narrow medians. Drainage features associated with this device are still largely experimental. The entire roadway could be sloped away from the median, thereby eliminating the problem, except on curves. One state is experimenting with an 18-in.-diameter galvanized steel pipe inside the structure. Access from the gutter is by direct openings in the side of the barrier and pipe (Fig. 36). Another state is using a pipe below the median, with inlets situated as shown in Figure 37. These drainage devices may be more attractive to southern states, where icing is not a problem.

Storm drain collection systems using curb inlets are usually less effective than open ditch collection systems. Grated inlets can become clogged with snow, ice, or debris, causing roadways to become flooded, with adverse effects on traffic. Likewise, storms which overtax the design capacity of curb inlets can produce roadway flooding. Wher-

Figure 35. Improper grate orientation, reducing inlet capacity.

ever the designer has a choice, open ditch drainage is usually more efficient and less hazardous when flat side slopes are used. Urban conditions, however, often require curb inlets and subsurface collection systems, which should be designed in accord with good safety practices.

CONCLUSIONS

1. Catch basin grates are not normally hazardous for automobile traffic.

2. Grates with close bar spacing or crossbars on the underside should be used for bicycle traffic.

3. Grate configurations should be selected for hydraulic efficiency and proven intake capacity.

4. Grates with bars transverse to flow are much less efficient than those with longitudinally oriented bars.

5. Self-cleaning characteristics of grates should be considered.

6. Grates should key into castings to assure proper orientation.

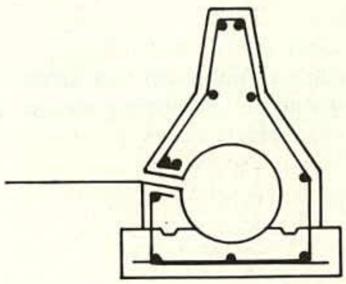


Figure 36. "New Jersey" type of barrier with pipe inside the structure.

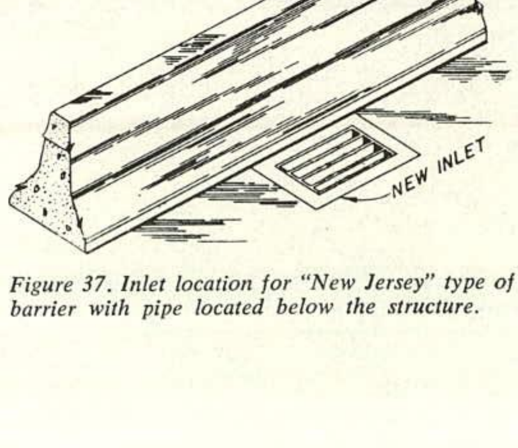


Figure 37. Inlet location for "New Jersey" type of barrier with pipe located below the structure.

CHAPTER FIVE

ROADSIDE CHANNELS

Roadside channels include all open drainage ways used to convey surface water. They range from the shallowest ditch to large concrete channels (Fig. 38). The hazard to traffic is a function of the distance from the roadway, channel orientation, and side slopes.

In situations where large rectangular concrete channels are required, every effort should be made to locate the channel outside the designated recovery area. Ditches with flat side slopes are much less hazardous. However, vehicles that are forced to traverse even shallow ditches are more difficult to bring under control. The side slopes of such ditches should have approximately the same transverse slope as the embankment. This would mean a 6:1 or flatter slope for ditches located within the designated recovery area

The final report for NCHRP Project 15-2 states: "Safety considerations require that the side slopes of highway embankments be relatively flat and wide enough so that vehicles leaving the roadway can recover and return to the driving lanes or be stopped without serious danger to the occupants." That report suggests a means of erosion protection that is safely traversable and prevents the occurrence of dangerous roadside erosion.

Open channels or flumes are sometimes used to convey runoff from the roadway to the bottom of an embankment section, especially at the ends of bridges. In such cases, the curb is transitioned from the roadway to the head of the flume. This may constitute a traffic hazard unless a suitable barrier is provided to deflect vehicles away from the curb (Fig. 39). If the curb is very much in front of the protective guardrail, there is a possibility that a vehicle striking the curb would vault over the barrier. Good safety practice requires continuity of alignment; there should be no horizontal deviation for curbs approaching bridges or for guardrail connecting to the bridge rail.

Erosion can change the depth, shape, and location of a ditch, making it differ from the original design. This may affect the hydraulic efficiency and usually increases the hazard to traffic. The designer should determine flow velocities and require an appropriate ditch lining if it seems likely that erosion may occur. The remedial measures shown in Figure 40 are not satisfactory solutions. *NCHRP Research Results Digest 1* (*7*) provides a design procedure for stabilizing earth channels with gravel or crushed stone conforming to AASHO standard gradations. This reduces the need for ditch checks and results in a more traffic-safe roadside channel. Grass-lined ditches are preferred if the ditches are in a region that will support this type of growth.

Figure 38. This paved channel is a traffic hazard when located near the roadway.

CONCLUSIONS

1. Where traffic operates at high speed, channels within the designated recovery area should have sides sloping at the same rate as the adjacent embankment—preferably 6:1 or flatter.

2. When channels pass under driveways, headwall safety practices should comply with those referred to in Chapter Three.

3. Rectangular concrete channels should either be located outside of the designated recovery area or covered.

4. Consideration should be given to the purchase of additional right-of-way for drainage purposes, where necessary.

5. Ditches subject to erosion should be protected by an appropriate lining.

6. Riprap lining may be used effectively where the size of stone would not adversely affect an out-of-control vehicle.

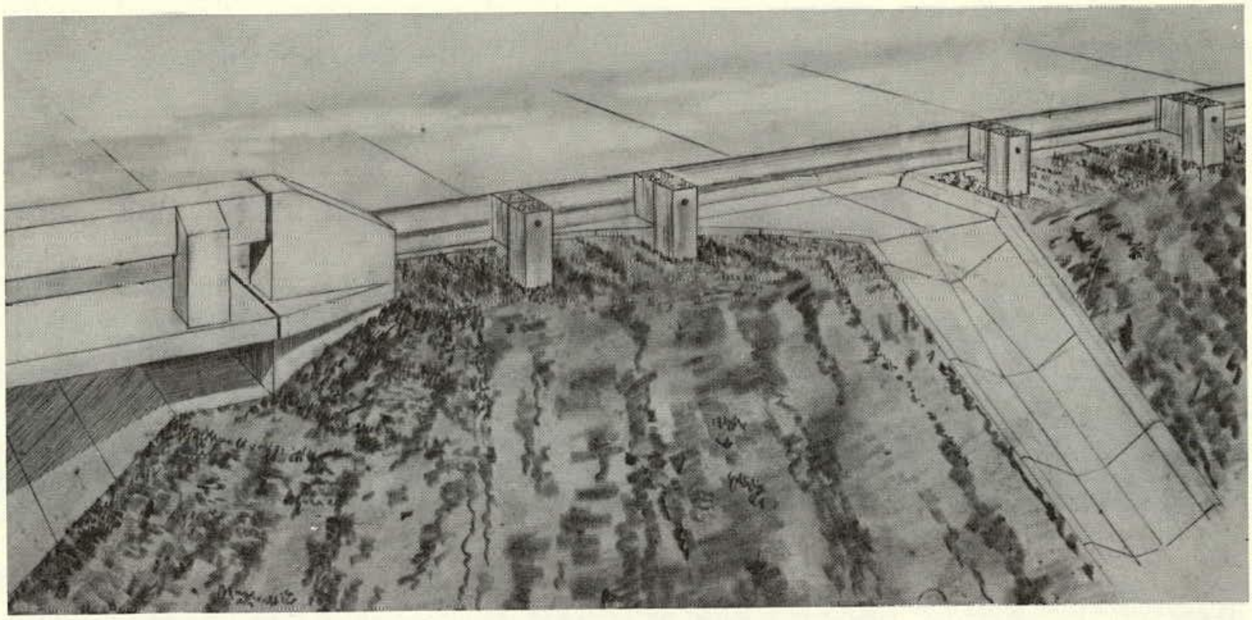


Figure 39. Continuation of the guardrail across the head of the flume minimizes a potential hazard.

Figure 40. A double hazard: (1) the ditch and (2) the checks that have been placed to stop further erosion.

CHAPTER SIX

SPECIAL DRAINAGE STRUCTURES

Special drainage structures are usually designed to perform a specific function at a particular location. Included in this category are deflecting walls, baffles, stilling basins, and drop structures that are designed to control or dissipate the kinetic energy of swift-flowing water. Many of these structures have been located near the roadway and are considered a potential traffic hazard.

It is common practice to use vertical deflecting walls or baffles to direct water from steep paved ditches into the roadside ditch (Fig. 41). Special boxes are also used to dissipate energy at the outlet end of steep pipes that transport surface water down cut slopes (Fig. 42). Various types of stilling basins are used to prevent erosion at culvert outlets (Fig. 43). Another common erosion-control device is the ditch check. It may be a designed concrete structure (Fig. 44) or may consist of dumped stone placed by the maintenance force.

All of these structures should be relocated outside of the recovery area, unless they can be made safe by lowering or covering with grates. Protective guardrail should be used as a last resort as it may be a greater hazard than the drainage device—especially where several panels of guardrail must be installed to develop the strength that is considered necessary to prevent penetration.

CONCLUSIONS

1. Special drainage structures that are considered hazardous should be located outside of the designated recovery area.

2. Any structure that must remain in the recovery area should be reconstructed or covered to reduce the hazard.

3. Guardrail barrier should be used as a final resort.

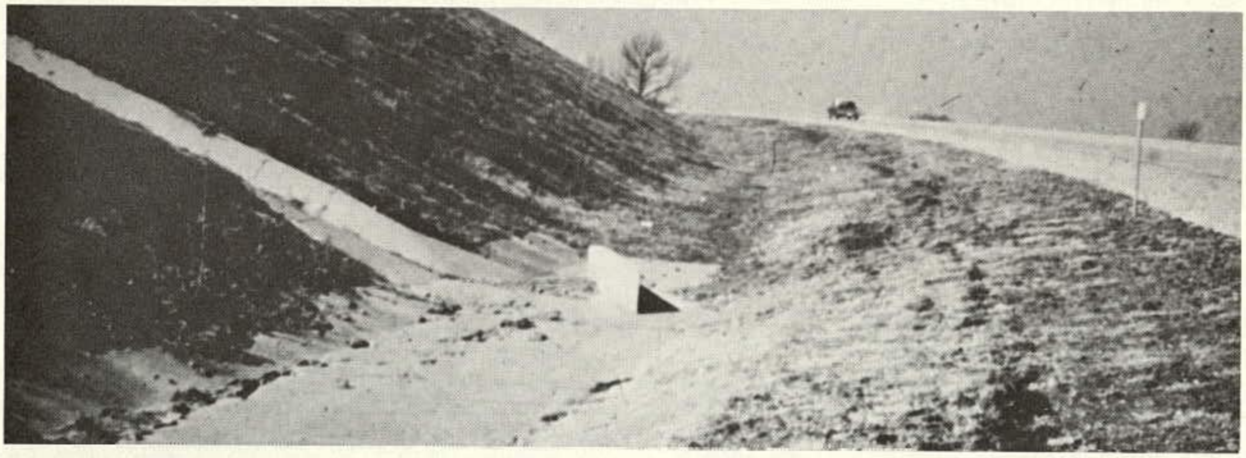


Figure 41. A vertical baffle used to deflect flow from the top of the cut into the ditch.

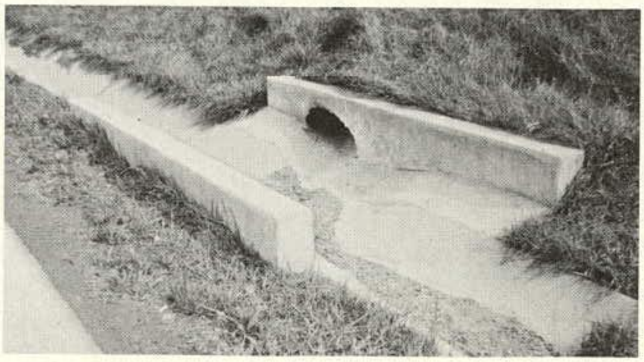


Figure 42. Energy-dissipation devices used to control piped flow from the top of a roadway cut. Both are located near the roadway and are hazards to traffic.

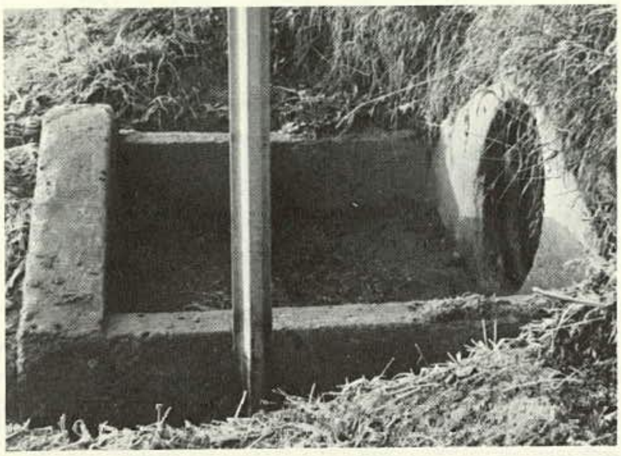
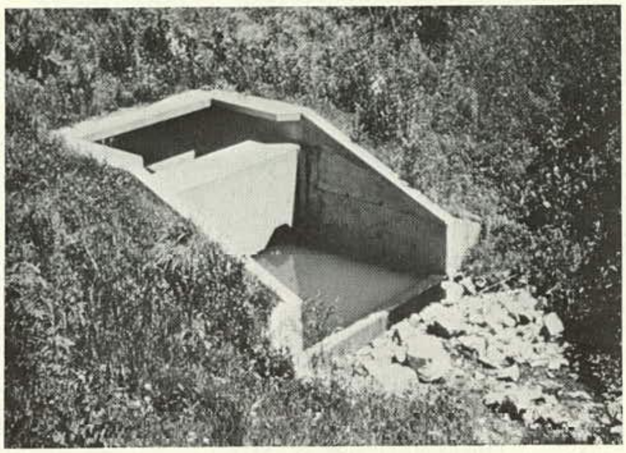
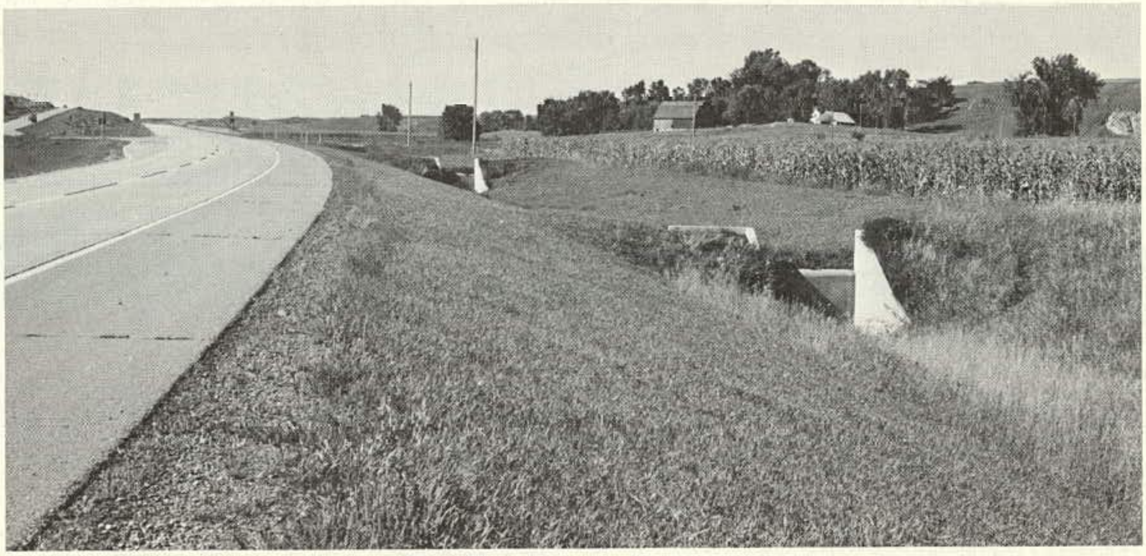



Figure 43. Stilling basins used at culvert outlets to reduce erosion.



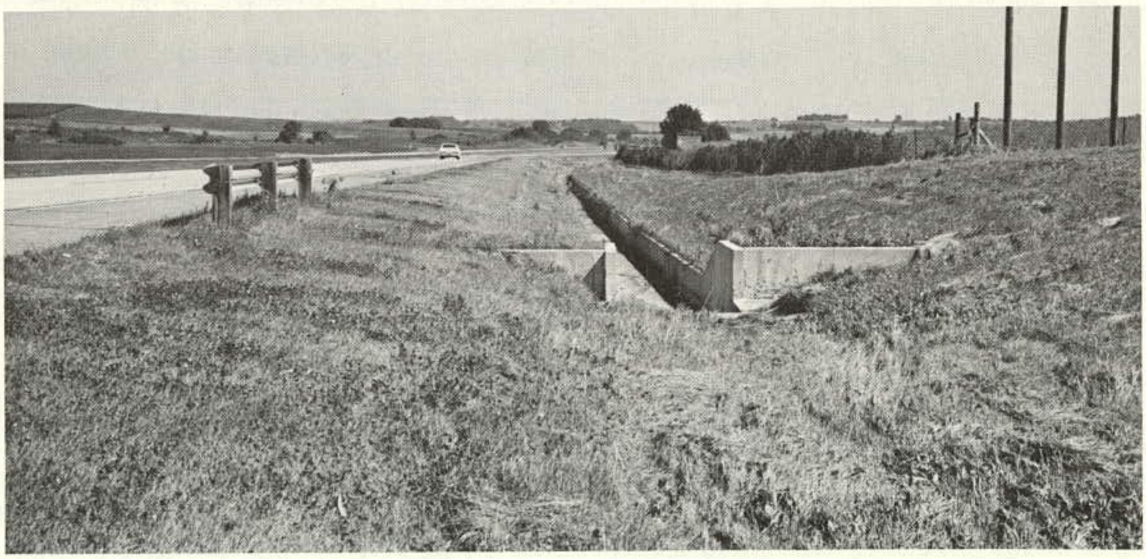


Figure 44. Hydraulic drop structures designed to control flow velocities in open channels.

CHAPTER SEVEN

MISCELLANEOUS CONSIDERATIONS

Some other aspects of drainage features and safety deserve brief mention. These are minor items that can adversely affect driver behavior or prove dangerous for highway employees or pedestrians and for children playing in the vicinity of the highway or street.

One area requiring some safety sensitivity is the adjustment of manholes and catch basin castings to conform to grades for resurfacing projects. When these structures are not adjusted by using collars, telescoping fittings, or other satisfactory means, depressions or "bumps" are created; these may not of themselves constitute substantial hazards but may cause drivers to take evasive actions that could result in accidents.

Conversely, settlement around inlets and manholes causes them to protrude. This settlement also reduces drainage effectiveness and causes ponding or icing that could be potentially dangerous. These hazards could be avoided by more careful construction or by subsequent maintenance.

Another area of concern is the safety of employees or other individuals who may be on foot within the median or along the roadside and who could sustain injury by inadvertently slipping or falling into drainage structures not designed to preclude such accidents. Also, storm sewer outlets—particularly those with large pipes—seem to arouse the explorer instinct in children. Storm sewers can become a dangerous playground unless preventive measures are taken by road authorities. Areas frequented by children, such as parks and playgrounds, should have drainage structures designed, fenced, or grated to discourage trespassing and prevent any possibility of small children being pulled into the device by unsuspected suction where ponding occurs.

Several states have design review teams whose job is to inspect new highway sections and, among other things, make a critique from the safety viewpoint. Their reports bring to the attention of the engineering staff any deficiencies that should be programmed for correction.

Other research projects directed specifically at providing traffic-safe and hydraulically efficient roadside drainage have not been undertaken. Nevertheless, this area is one of interest and concern to highway departments. Numerous studies are under way that are investigating all hazards that are adjacent to the roadways, including sign mounting, guardrail installation, structure supports, and hazardous drainage installations (Table 3).

TABLE 3

SUMMARY OF KNOWN RESEARCH ACTIVITIES RELATED TO DRAINAGE PRACTICE [a]

RESEARCH PROJECT TITLE	RESEARCH AGENCY	HRIP [b] NO.
Widths and Cross Sections for Medians of Divided Highways	University of Illinois	22 001637
Roadside Features Related to Safety	New York State Department of Transportation, Bu. Phys. Res.	22 083287
Hollowing out of Gulleys	Swiss Federal Institute of Technology; City, Reg. & Nat. Planning Institute (Switzerland)	23 062122

[a] As of August 1969. [b] Acquisition number assigned by the Highway Research Information Service of the Highway Research Board; HRIP = publication entitled *Highway Research in Progress* (current issue).

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5. "Safety Provisions for Roadside Features and Appurtenances." *Instructional Memo 21-6-66,* BPR, 5 pp. (Aug. 1, 1966).
6. "Debris-Control Structures." *Hydraulic Eng. Circular No. 9,* BPR, 26 pp. (Feb. 1964).
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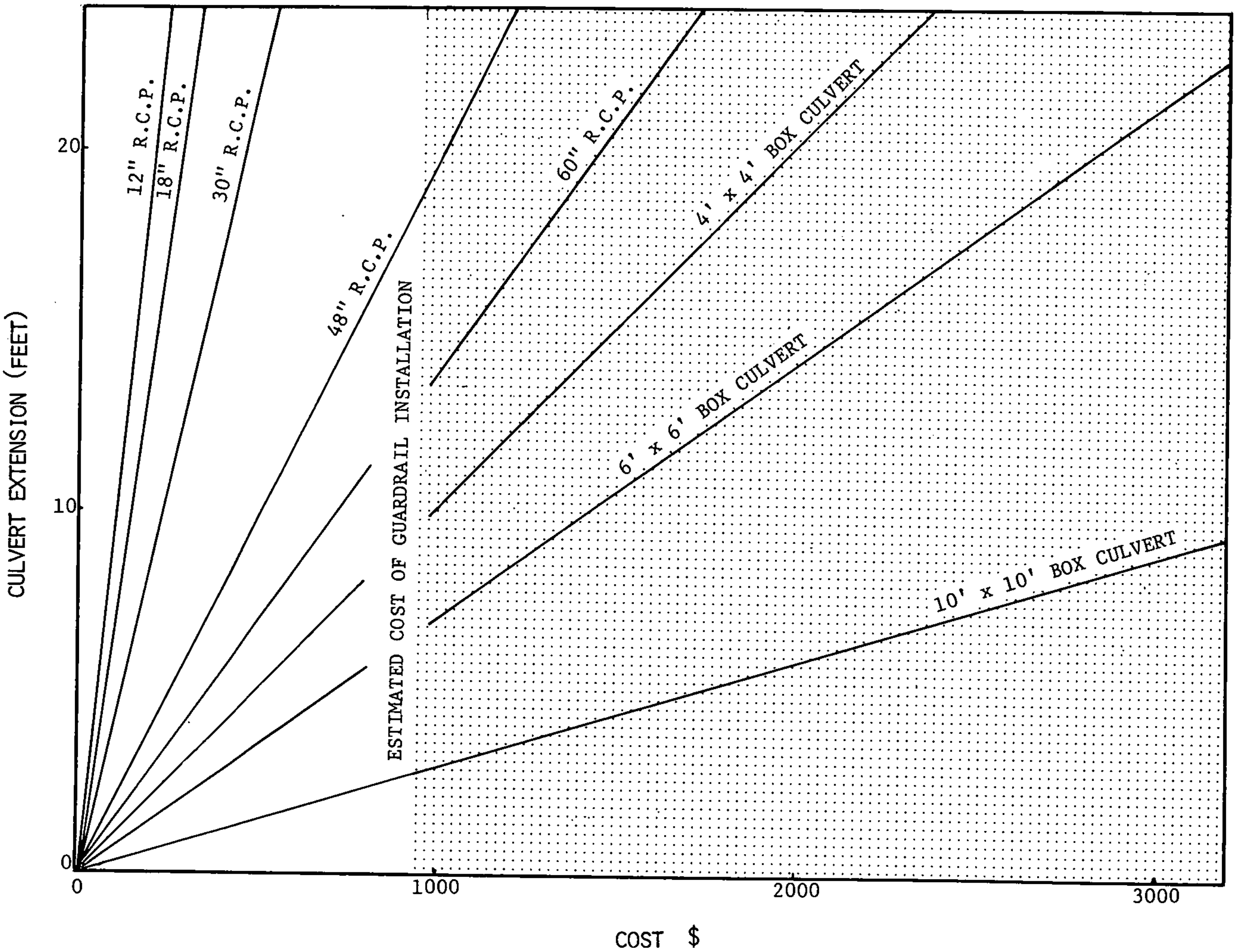
14. "Safety Criteria—Drainage Structures." *Instructional & Information Memo. No. LD-68(R)-50,* Virginia Dept. of Hwys., 1 p. (May 1, 1968).

APPENDIX A

COMPARISON OF CULVERT EXTENSION COSTS WITH GUARDRAIL BARRIER COSTS

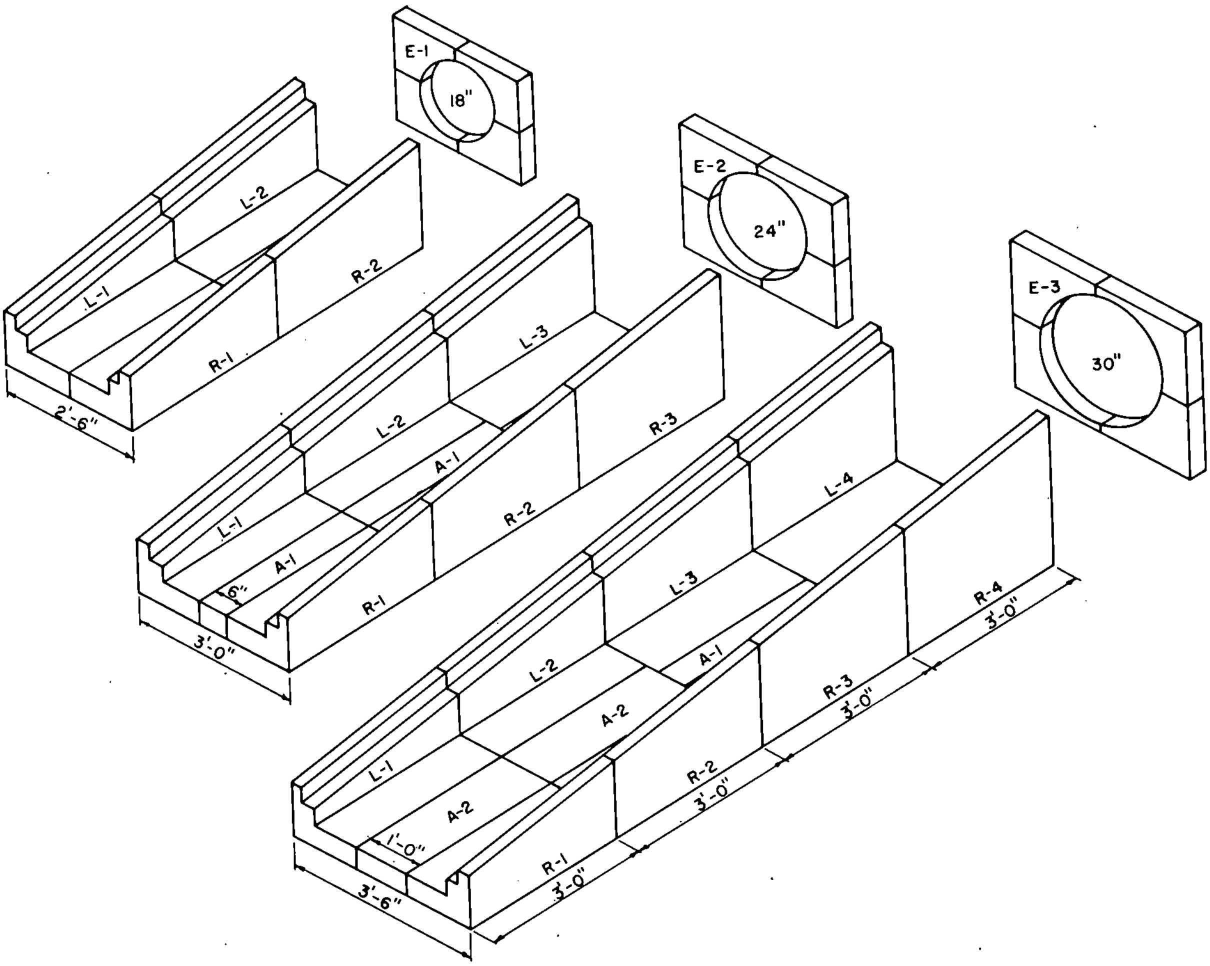


THIS CHART IS BASED ON THE FOLLOWING ASSUMPTIONS:

- THERE WILL BE NO REQUIREMENT FOR ADDITIONAL RIGHT-OF-WAY.
- COMMON END SECTIONS WILL BE UTILIZED FOR BOTH ALTERNATES.
- MINIMAL GRADING TO PROVIDE CULVERT COVER AND SAFE SLOPES.
- AVERAGE UNIT PRICES WERE USED TO COMPUTE INSTALLED COSTS.
- ESTIMATED 100 FEET OF GUARDRAIL WITH TWO END ASSEMBLIES.

APPENDIX B

ONE POSSIBLE PREFABRICATED END SECTION FOR MODIFYING CULVERT



APPENDIX C

STANDARD PLAN SHEETS

(Pages 28 through 38)

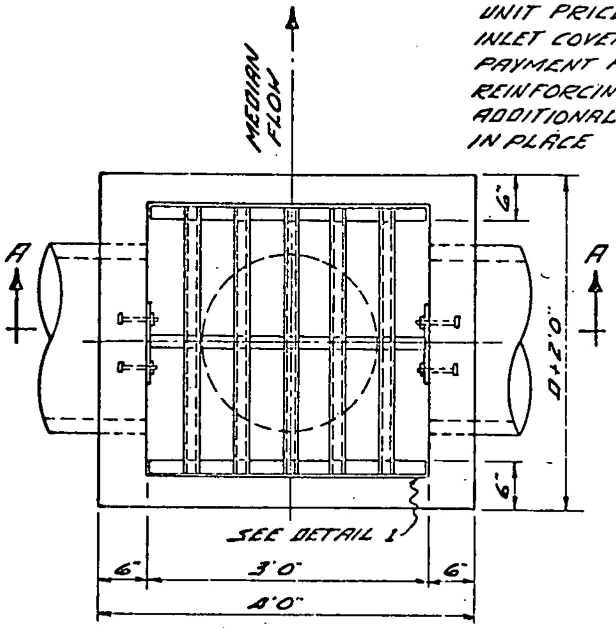
Drawn 4-22-58	Revised	9-1-59	5-1-63	7-1-63	3-6-67	11-24-67	STANDARD DRAWING NO. 75-03
Effective 4-22-58	Effective	9-1-59	5-1-63	7-1-63	5-1-67	12-1-67	

State Highway Commission
Helena, Montana

MEDIAN INLET COVER

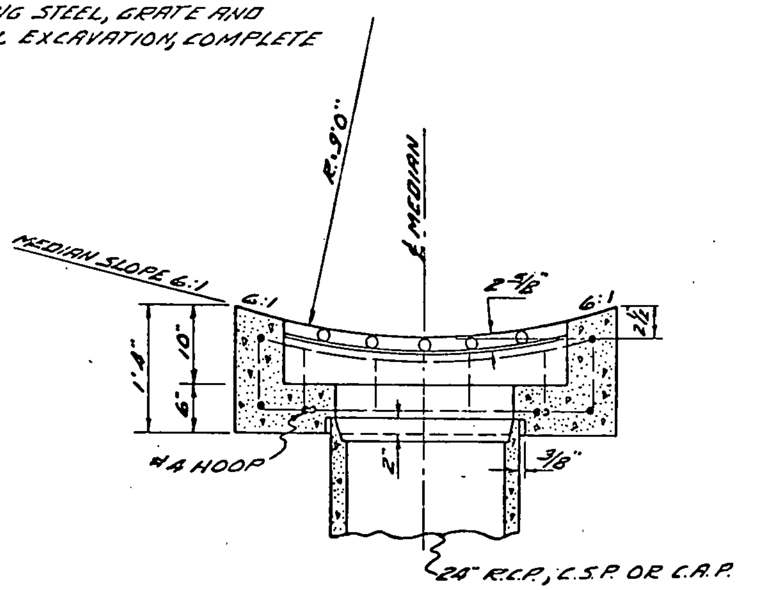
Approved
State Highway Engineer

UNIT PRICE BID FOR MEDIAN INLET COVER SHALL INCLUDE PAYMENT FOR THE CONCRETE, REINFORCING STEEL, GRATE AND ADDITIONAL EXCAVATION, COMPLETE IN PLACE



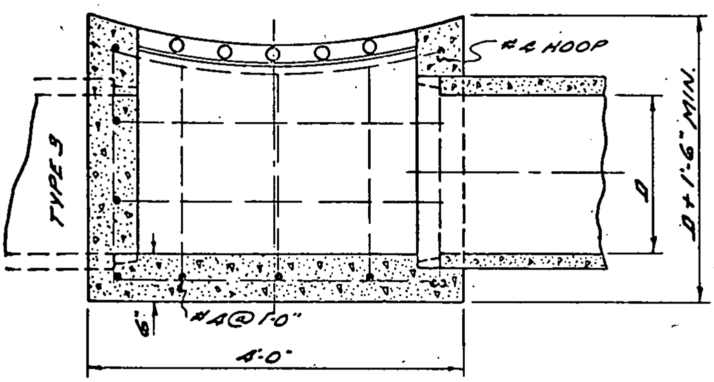
PLAN VIEW

TYPICAL FOR TYPES 1, 2, & 3



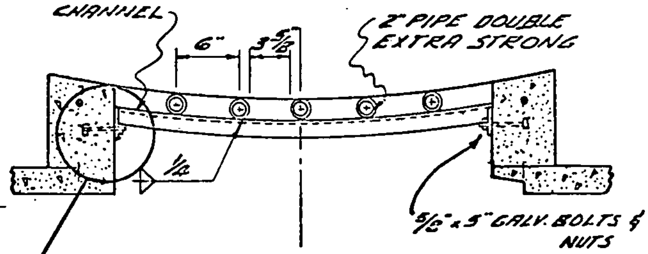
SECTION A-A

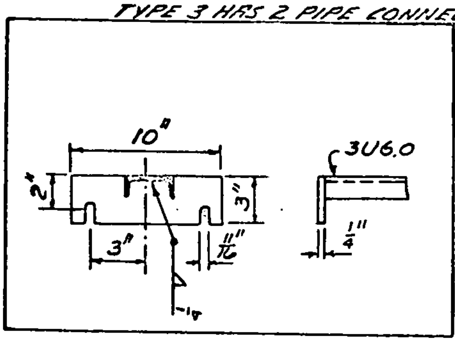
TYPE 1

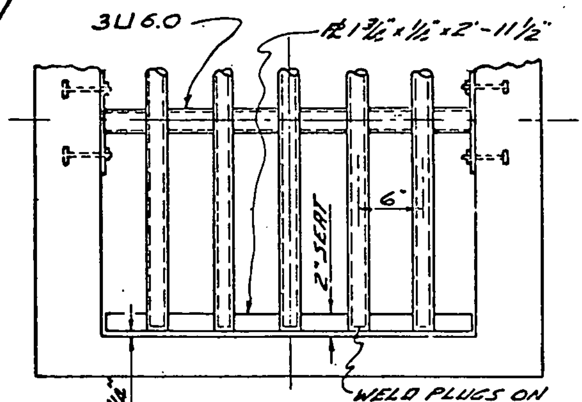


SECTION A-A

TYPE 2 & 3 – R.C.P., C.S.P. OR C.A.P.
TYPE 2 HAS 1 PIPE CONNECTION
TYPE 3 HAS 2 PIPE CONNECTIONS







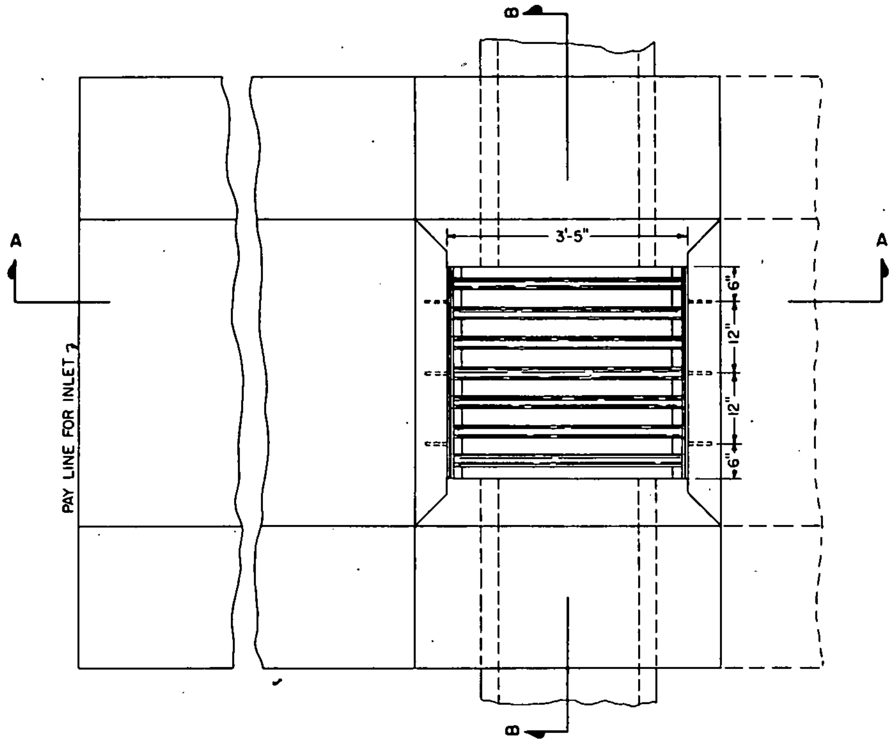
DETAIL 1

*CL. "DD" CONCRETE			
TYPE	24"	30"	36"
1	.5 YD³	–	–
2	.9 YD³	1.1 YD³	1.3 YD³
3	.9 YD³	1.0 YD³	1.1 YD³

*GRATE & REINF. STEEL			
	24"	30"	36"
TYPE 1	50 LBS.	–	–
TYPE 2	85 LBS.	95 LBS.	105
TYPE 3	*85 LBS.	*95 LBS.	*105
GRATE	165 LBS.	185 LBS.	210 LBS.

* QUANTITIES ARE FOR ESTIMATING PURPOSES ONLY. TYPE 3 WILL BE A SPECIAL CASE TO BE FIGURED FOR THE PARTICULAR INSTALLATION

NOTE: ALL EXPOSED METAL PARTS TO BE PAINTED WITH ONE COAT OF RED LEAD AND TWO COATS OF ALUMINUM PAINT



PLAN VIEW

GENERAL NOTES

DI-7A single gutter when inlet is on a grade.

DI-7B double gutter when drop inlet is in a sag between two grades.

Class A3 concrete to be used.

All concrete quantities are figured for two concrete pipes of the sizes tabulated.

Median ditch to be warped to tie smoothly into inlet gutter.

Paved median ditches are to be transitioned to meet inlet gutter as shown in Std. PG-1.

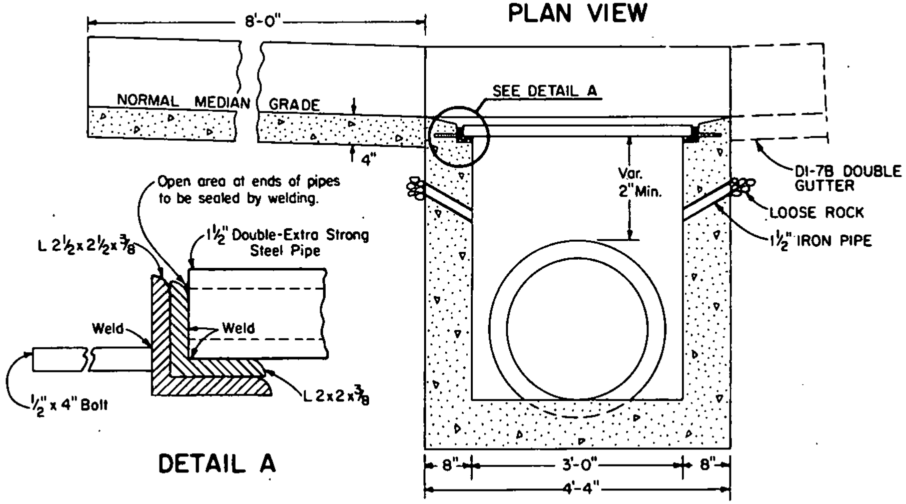
The cost of furnishing and assembling all components for the inlet grate as detailed hereon is to be included in the price bid for the drop inlet complete.

Outside dimensions of grate to be 3'-4" x 2'-11¾".
Maximum Depth (H) to be 12'-8".

PIPE SIZE	12"	15"	18"	24"	30"	36"
MINIMUM DEPTH H	2'-8"	2'-11"	3'-2"	3'-8"	4'-2"	4'-8"
CU. YDS.* CONC.	1.326	1.383	1.434	1.515	1.570	1.598

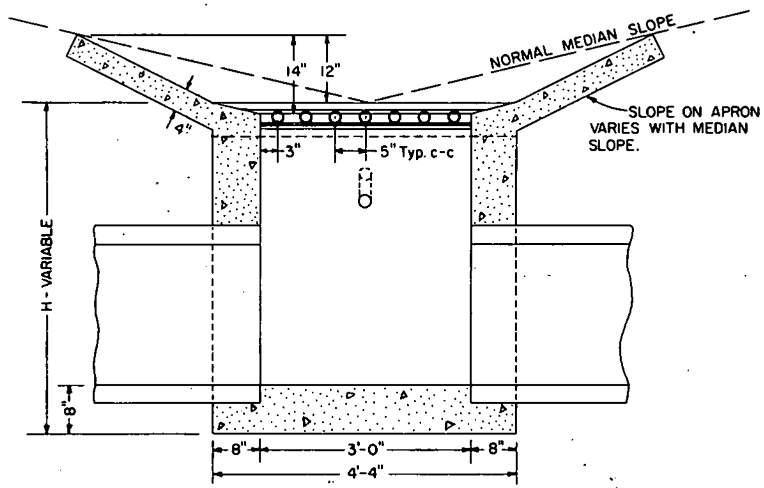
*Increment per foot of additional depth (H) = 0.362 cu. yds.

CU. YDS. CONC. FOR GUTTER: DI-7A = 0.903, DI-7B = 1.805



DETAIL A

SECTION A-A



SECTION B-B

STANDARD MEDIAN DROP INLET

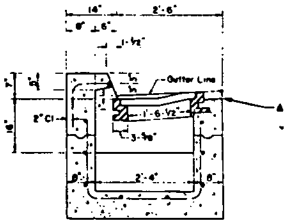
FOR USE IN DEPRESSED MEDIAN STRIPS WITH 12"-36" PIPES

VIRGINIA
DEPARTMENT OF HIGHWAYS

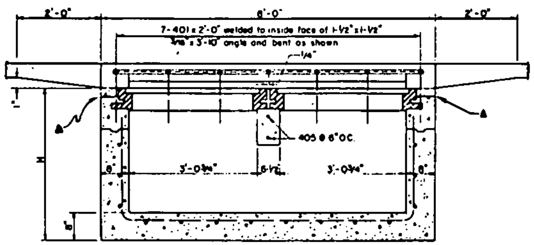
STANDARD M-604-AA

(APRIL 21, 1967)

FEDERAL ROAD REGION NO.	DIVISION	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLORADO			

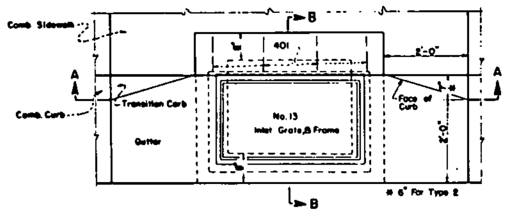


SECTION B-B

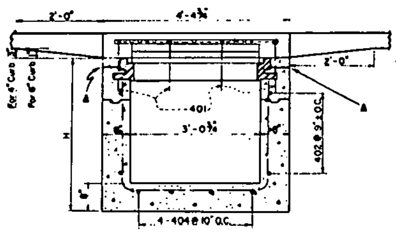


SECTION A-A

DOUBLE INLET
TYPE 3



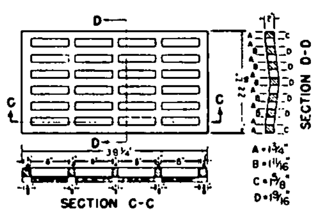
PLAN - (For Comb. Curb, Gutter & Sidewalk or Type 2 Curb & Gutter)



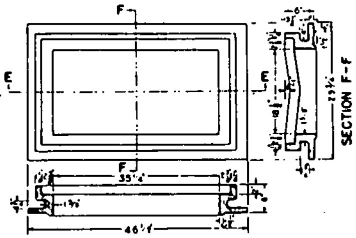
SECTON A-A (For Comb Curb, Gutter, & Sidewalk or Type 2 Curb & Gutter)

NO. 13 GRATING & FRAMES

Approx. Weight 680 lbs

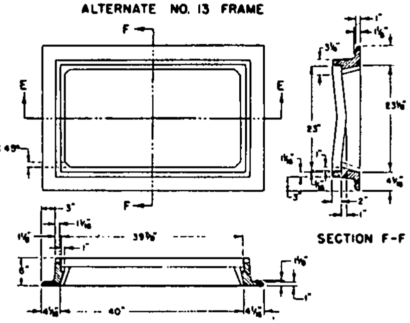


SECTION C-C



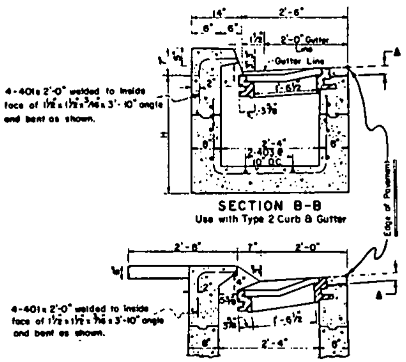
SECTION E-E

ALTERNATE NO. 13 FRAME



SECTION F-F

SECTION E-E



SECTION B-B

Use with Type 2 Curb & Gutter

SECTION B-B

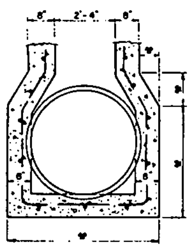
Use with Comb. Curb, Gutter, & Sidewalk

INLET TYPE 3

No. 13 Grate and Frame to be used with Type 3 Inlet.

DETAILS OF INLET ALTERATION

For Larger Size or Skewed Pipes



NOTE:
Vary steel shape and quantity as required.

* Variable - to suit pipe size or skew angle.

▲ — When bituminous material is to extend to the edge of the grating frame, concrete may be depressed.

NOTE: Use steps for all inlets with H = 3'-6" or more Start 2'-0" below gutter line and space equally at Minimum of 18".

Details of Steps on Standard M-604-D.

QUANTITIES

H	NO. OF 402 BARS REQ'D	TYPE 3 INLET CLASS A CONCRETE CU. YD.	TYPE 3 INLET REINFORCING STEEL ϴ LB.	TYPE 3 DOUBLE INLET CLASS A CONCRETE CU. YD.	TYPE 3 DOUBLE INLET REINFORCING STEEL ϴ LB.
3'-0"	3	1.30	64.29	2.20	110.77
3'-6"	4	1.47	78.35	2.51	132.47
4'-0"	4	1.64	82.40	2.82	139.22
4'-6"	5	1.81	96.46	3.13	160.92
5'-0"	6	1.98	110.51	3.44	182.63
5'-6"	6	2.15	114.56	3.75	189.38
6'-0"	7	2.32	128.62	4.06	211.08
6'-6"	8	2.49	142.68	4.37	232.78
7'-0"	8	2.66	146.73	4.68	239.53
7'-6"	9	2.83	160.79	4.99	261.24
8'-0"	10	3.00	174.85	5.30	282.94
8'-6"	10	3.17	178.90	5.61	289.69
9'-0"	11	3.34	192.96	5.92	311.39
9'-6"	12	3.51	207.02	6.23	333.10
10'-0"	12	3.68	211.07	6.54	339.84

ϴ Includes 1% for overrun.

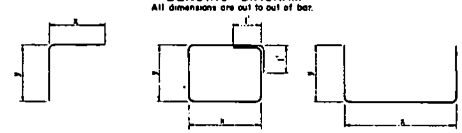
BAR LIST FOR H = 3'-0"

MARK	TYPE	TYPE 3 INLET NO. REQ'D	TYPE 3 INLET DIMENSIONS x	TYPE 3 INLET DIMENSIONS y	TYPE 3 INLET LENGTH	TYPE 3 DOUBLE INLET NO. REQ'D	TYPE 3 DOUBLE INLET DIMENSIONS x	TYPE 3 DOUBLE INLET DIMENSIONS y	TYPE 3 DOUBLE INLET LENGTH
401	I	4	1'-0"	1'-0"	2'-0"	7	1'-0"	1'-0"	2'-0"
402	II	3	3'-7 1/4"	2'-10 1/2"	14'-11 1/2"	3	7'-2 1/2"	2'-10 1/2"	22'-2"
403	III	2	3'-5 3/4"	* 2'-0 1/2"	7'-6 3/4"	2	7'-1"	* 2'-0 1/2"	11'-2"
404	III	4	2'-9"	* 2'-1"	6'-11"	8	2'-9"	* 2'-1"	6'-11"
405	STR.					2			3'-0"

* Add 6" to this dimension for each 6" increase in "H" above 3'-0".

BENDING DIAGRAM

All dimensions are out to out of bar.



REVISIONS		
(R-1) 7-19-68	Dept. Name	M.R.H.

GENERAL NOTES

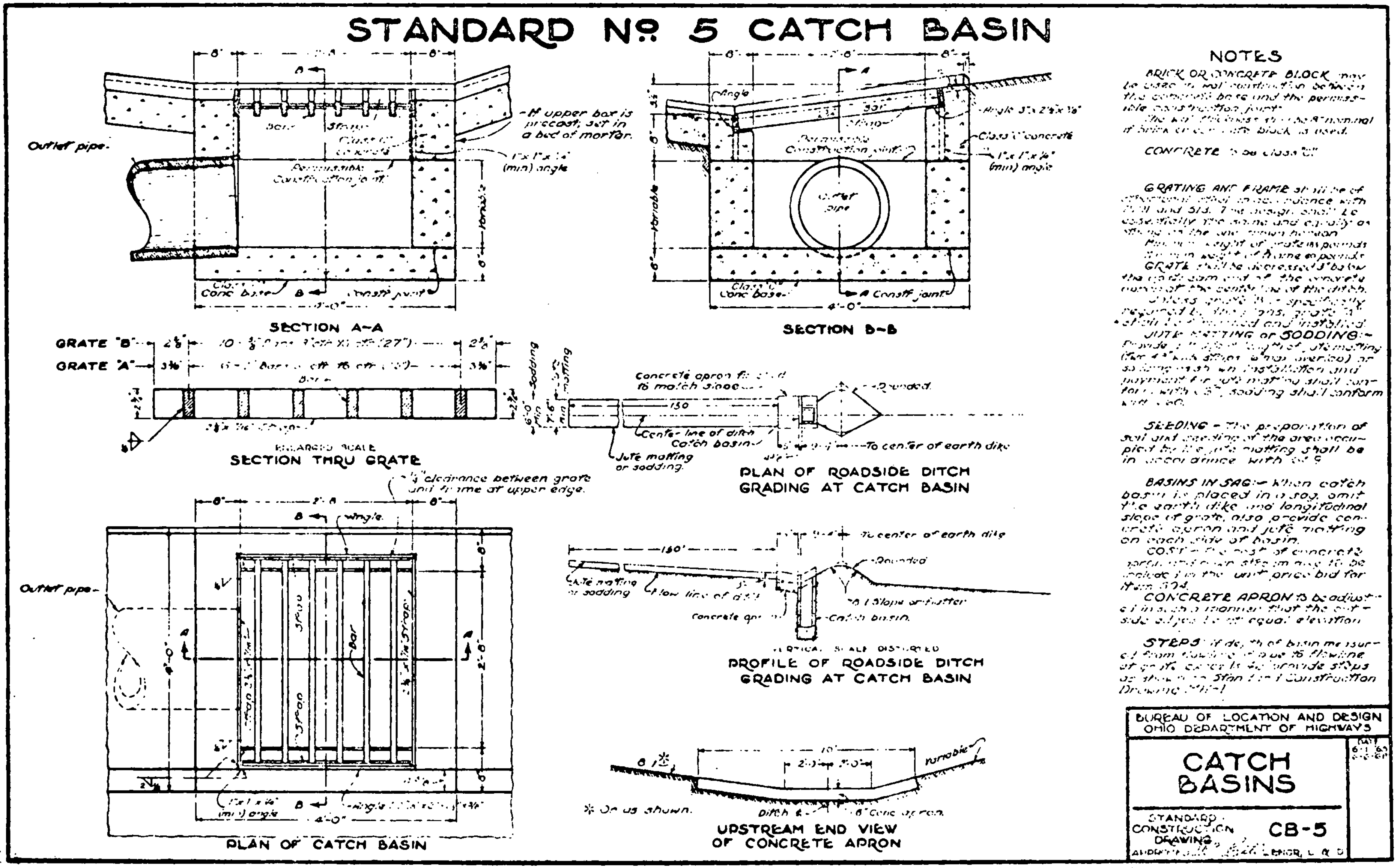
All work shall be done in accordance with the Standard Specifications applicable to the project.

All concrete shall be class "A".
All concrete walls shall be formed on both sides (R-1)
All exposed concrete corners shall be beveled to a 1" face
All reinforcing bars shall be deformed, of intermediate grade, and tagged with bar designation and station number.
All dimensions not shown as clear are to ℄ of bar.
All gratings, rings and covers shall be cast iron.

DEPARTMENT OF HIGHWAYS
STATE OF COLORADO
DIVISION OF HIGHWAYS

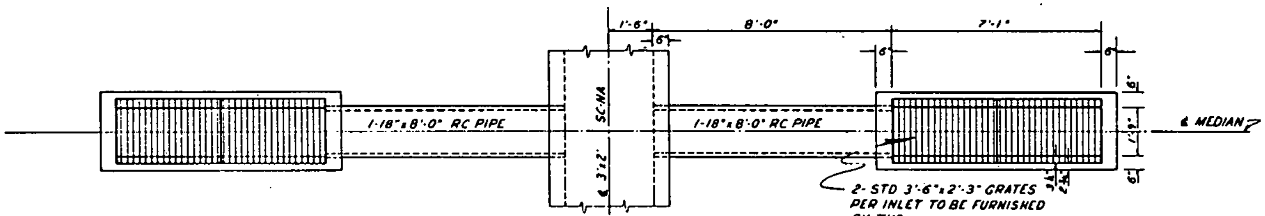
CONCRETE INLETS
TYPES 3 & 3 DOUBLE

Designed by: W.I.F. | Approved by:
Made by: J.R.B. | Staff Design Eng'r.
Checked by: M.R.H. | Date: APRIL 21, 1967

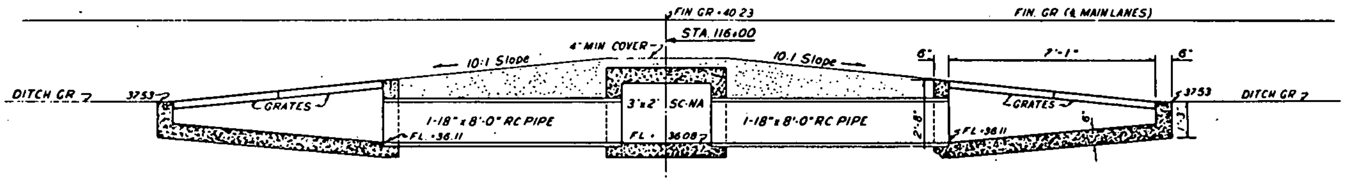


STANDARD Nº 5 CATCH BASIN
NOTES
Outlet pipe
If upper box is precast, set in a bed of mortar.
SECTION A-A
SECTION B-B
GRATE "B"
GRATE "A"
SECTION THRU GRATE
Concrete apron
Center line of ditch
Catch basin
To center of earth dike
Jute matting or sodding
PLAN OF ROADSIDE DITCH GRADING AT CATCH BASIN
Rounded
Catch basin
PROFILE OF ROADSIDE DITCH GRADING AT CATCH BASIN
Outlet pipe
PLAN OF CATCH BASIN
UPSTREAM END VIEW OF CONCRETE APRON
BUREAU OF LOCATION AND DESIGN OHIO DEPARTMENT OF HIGHWAYS
CATCH BASINS
STANDARD CONSTRUCTION DRAWING
CB-5

TEXAS



PLAN VIEW



PROFILE VIEW

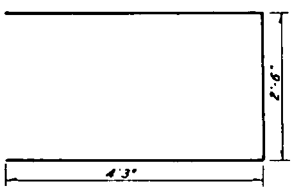
BARS	NO	SIZE	SPAC	LENGTH	WEIGHT
QUANTITIES FOR TWO DROP INLETS					
F_1	8	#4	7"	7'-9"	41
F_2	8	#4	10"±	7'-9"	41
N	18	#4	11"±	5'-7" Avg	67
R	4	#4	—	11'-0"	29
REINF STEEL				LB.	178
CL A CONC.				C.Y.	170
RC PIPE (CL III) (18 IN)				LF	16

GENERAL NOTES:

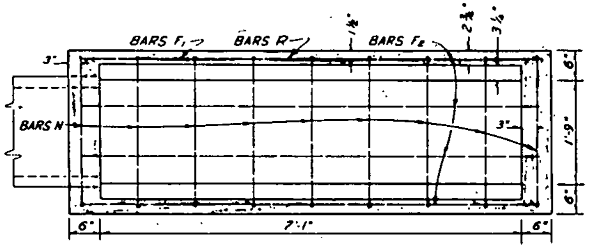
ALL CONCRETE SHALL BE CLASS A. CHAMFER EXPOSED CORNERS ¾".

ALL DIMENSIONS RELATING TO REINFORCING STEEL ARE TO CENTERS OF BARS.

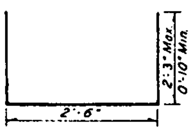
REINFORCING STEEL IN WALLS OF SC-NA BOX SHALL BE MODIFIED BY BENDING OR CUTTING AS DIRECTED BY THE ENGINEER TO GIVE THE RC PIPE 2" CLEARANCE.



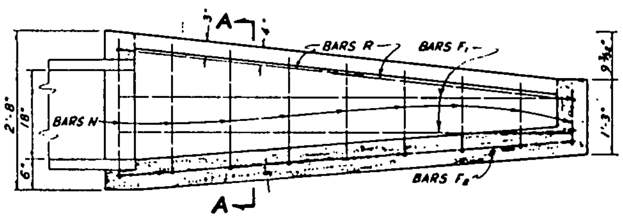
BARS R



REINF. STEEL
PLAN VIEW

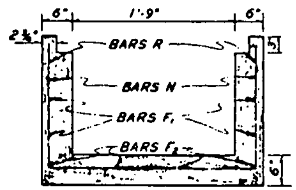


BARS N



PROFILE VIEW

INLET BOX DETAIL



SECTION A-A

DROP INLET DETAILS

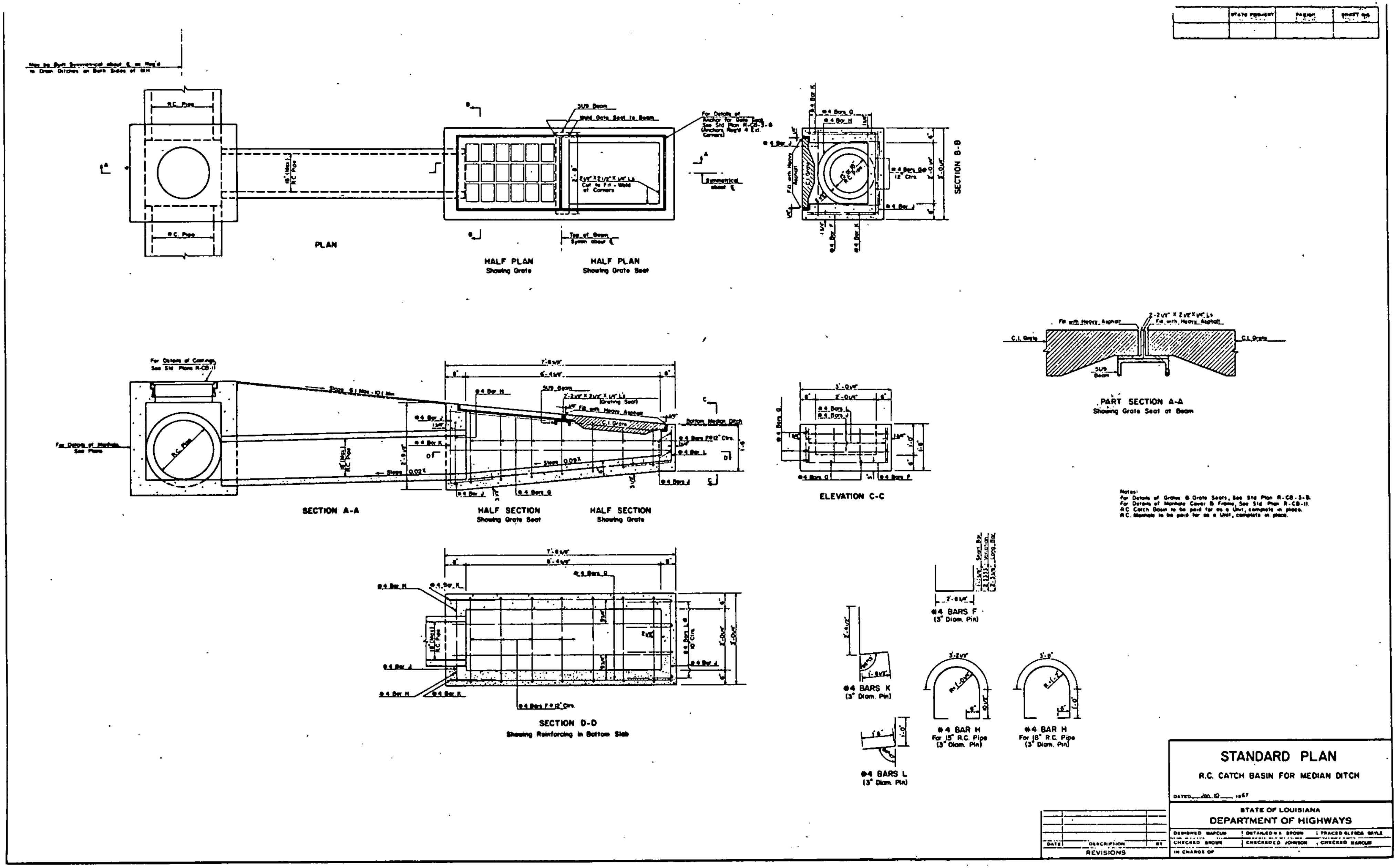
STA. 116+00

FIELD CHANGE NO. 1

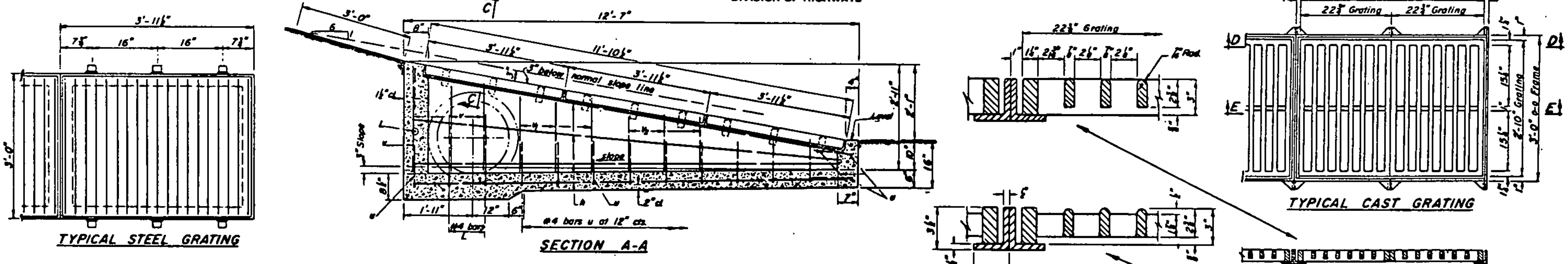
TEXAS

36-A

6 | MIDLAND | 5 | 15 | 6 | 1-20


PLAN
HALF PLAN
Showing Grate
HALF PLAN
Showing Grate Seat
SECTION B-B
PART SECTION A-A
Showing Grate Seat at Beam
SECTION A-A
HALF SECTION
Showing Grate Seat
HALF SECTION
Showing Grate
ELEVATION C-C
SECTION D-D
Showing Reinforcing in Bottom Slab
#4 BARS F
(3" Diam. Pin)
#4 BARS K
(3" Diam. Pin)
#4 BAR H
For 15" R.C. Pipe
(3" Diam. Pin)
#4 BAR H
For 18" R.C. Pipe
(3" Diam. Pin)
#4 BARS L
(3" Diam. Pin)
Notes:
For Details of Grates & Grate Seats, See Std Plan R-CB-3-B.
For Details of Manhole Cover & Frame, See Std. Plan R-CB-11.
R.C. Catch Basin to be paid for as a Unit, complete in place.
R.C. Manhole to be paid for as a Unit, complete in place.
STANDARD PLAN
R.C. CATCH BASIN FOR MEDIAN DITCH
DATED Jan. 10 1967
STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
DATE
DESCRIPTION
BY
REVISIONS
DESIGNED MARCUM
CHECKED BROWN
IN CHARGE OF

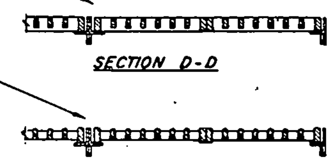
STATE OF ILLINOIS
DEPARTMENT OF PUBLIC WORKS & BUILDINGS
DIVISION OF HIGHWAYS



TYPICAL STEEL GRATING

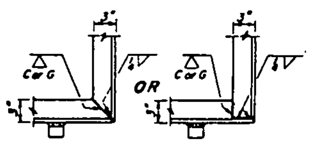
SECTION A-A

TYPICAL CAST GRATING

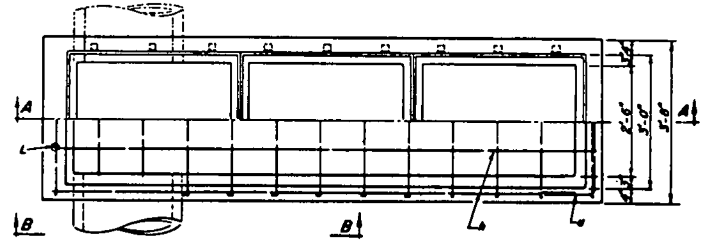


SECTION D-D

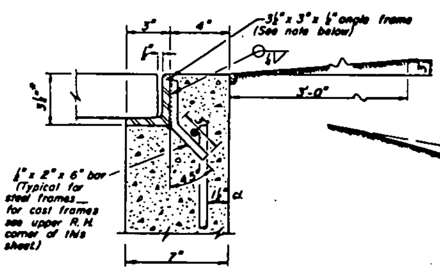
SECTION E-E



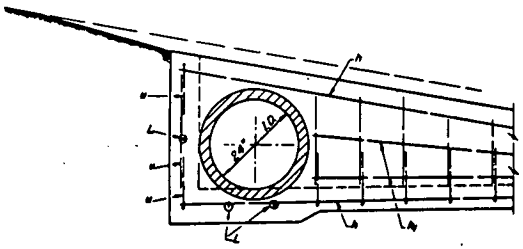
TYPICAL CORNER of STEEL GRATING FRAME



PLAN



SECTION C-C



SECTION B-B

GENERAL NOTES

Class X concrete for headwalls shall be used throughout.

Exposed edges shall be beveled ¾".

The steel grating shall have the main bearing bars running perpendicular to the centerline of the inlet box. The main bearing bars shall have a minimum section modulus of 2.47 inches cube per foot width of grating. The grating shall seat firmly in the frame but shall not be secured to the frame. The length and width of grating shall be such as to leave no more than ⅛" clearance on either side when in place in the frame. The grating shall be cut in such manner that all riveted or welded connections are left in tact. Grating shall be approved by the Engineer.

Steel grating and frames shall conform to ASTM designation A-36 and galvanized to ASTM designation A-123 after fabrication. (ASTM A-7 steel may be used for reticuline bars in riveted grating.)

The cast grating shall conform to Specifications for Ductile Iron Castings — ASTM designation A-339-55, Grade 60-45-10

The cast frames shall conform to Specifications for Gray Iron Castings — ASTM designation A-48, Class 30.

The cast gratings and frames shall not be galvanized.

For backfilling and embankment, see Standard Specifications.

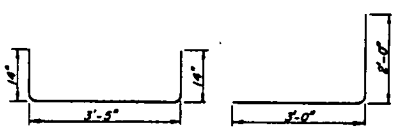
All bars shall be lapped 20 diameters unless otherwise specified.

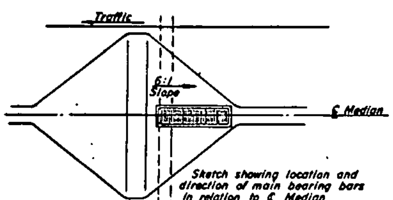
BILL of MATERIAL

Bar	No.	Size	Length
h	8	#4	12'-0"
h₁	2	#4	9'-0"
L	5	#4	5'-0"
u	14	#4	5'-9"
v	6	#4	2'-6"
v₁	6	#4	2'-0"
v₂	6	#4	1'-6"
Cl. X Concrete Headwalls		Cu. Yds.	2.0
Reinf. Bars		Lbs.	170
Grating		Sq. Ft.	33.9

*NOTE:

The dimensions of the angle iron frames shall be as shown except that the 3½" leg dimension may vary according to type of grating used. In all cases, the surface shall be flush with the top of edge of frame, sidewalls and headwall. All frames shall be galvanized and anchored in concrete. They shall be factory assembled and all joints shall be welded per detail.

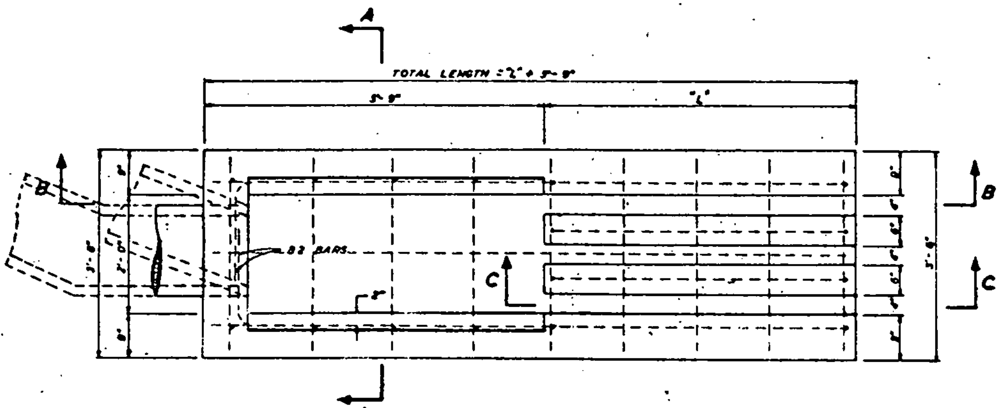




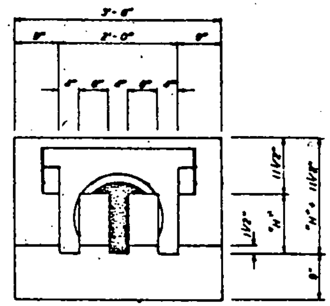
STATE OF ILLINOIS DEPARTMENT OF PUBLIC WORKS & BUILDINGS DIVISION OF HIGHWAYS	ISSUED 5-26-67	
PASSED April 15 1968	REVISIONS	
Engineer of Bridge and Traffic Structures		8-7-67
APPROVED April 15 1968		4-15-68
Engineer of Design		

INLET BOX for MEDIAN DITCH CHECK (6:1 Slope) with 24" I. D. CULVERT

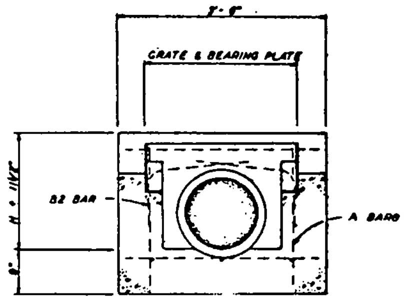
STANDARD 2243-2
(Full Size)



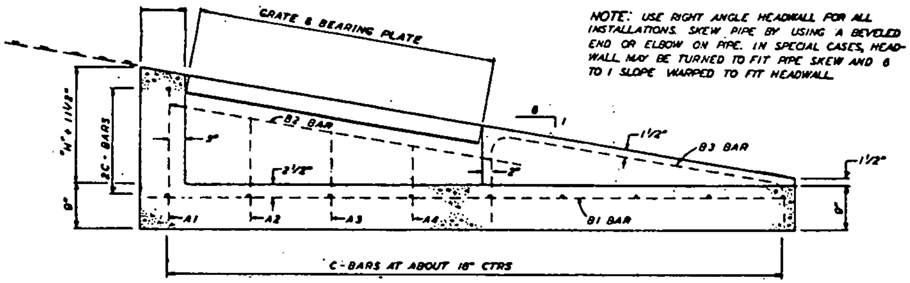
PLAN VIEW



END ELEVATION

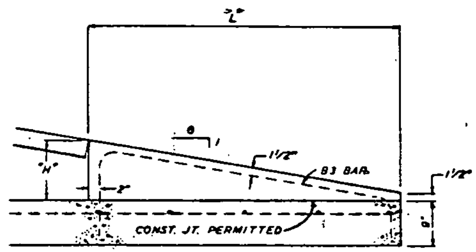


SECTION A-A



SECTION B-B

NOTE: USE RIGHT ANGLE HEADWALL FOR ALL INSTALLATIONS. SKEW PIPE BY USING A BEVELED END OR ELBOW ON PIPE. IN SPECIAL CASES, HEADWALL MAY BE TURNED TO FIT PIPE SKEW AND 6 TO 1 SLOPE WARPED TO FIT HEADWALL.



SECTION C-C

GENERAL NOTES:

ALL CONCRETE SHALL BE CLASS "B".

THIS DRAWING AND THE CONCRETE QUANTITIES SHOWN ARE BASED ON THE USING OF CONCRETE PIPE. QUANTITIES OF CONCRETE SHOWN WILL BE USED FOR PAYMENT REGARDLESS OF ANY QUANTITY CHANGES NECESSARY DUE TO THE USE OF ANY OTHER TYPE PIPE SPECIFIED OR PERMITTED.

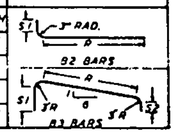
FLOW LINE OF HEADWALL IS TO BE PLACED HORIZONTALLY.

A JOINT, CONSISTING OF 2 LAYERS OF 65# SMOOTH ROLL ROOFING, SHALL BE CONSTRUCTED AROUND THAT PORTION OF THE PIPE EXTENDING INTO THE WALL OF THE STRUCTURE.

SEE STANDARD DRAWING 89.00 FOR GRATE & BEARING PLATE DETAILS.

PIPE SIZE	DIMENSIONS			QUANTITIES		REINFORCING																					
	"H"	"L"	TOTAL LENGTH	CONC.	STEEL	#4 A1 BARS		#4 A2 BARS		#4 A3 BARS		#4 A4 BARS		#4 B1 BARS		#4 B2 BARS				#4 B3 BARS					#4 C BARS	
				C.Y.	LBS.	NO	LENGTH	NO.	LENGTH	NO.	LENGTH	NO	LENGTH	NO.	LENGTH	NO.	"S1"	"R"	LENGTH	NO.	"S1"	"S2"	"R"	LENGTH	NO	LENGTH
12"	9"	3'-9"	9'-6"	1.5	70	2	2'-0"	2	1'-6"	2	1'-3"	2	1'-0"	3	9'-3"	2	1'-5"	5'-8"	7'-6"	4	11"	5"	2'-11"	5'-0"	8	3'-3"
15"	1'-0"	5'-3"	11'-0"	1.8	80	2	2'-3"	2	1'-9"	2	1'-6"	2	1'-3"	3	10'-9"	2	1'-5"	5'-8"	7'-6"	4	1'-2"	5"	4'-5"	6'-9"	9	3'-3"
18"	1'-3"	6'-9"	12'-6"	2.2	90	2	2'-6"	2	2'-0"	2	1'-9"	2	1'-6"	3	12'-3"	2	1'-5"	5'-8"	7'-6"	4	1'-5"	5"	5'-11"	8'-6"	10	3'-3"
24"	1'-9"	9'-9"	15'-6"	3.0	110	2	3'-0"	2	2'-6"	2	2'-3"	2	2'-0"	3	15'-3"	2	1'-5"	5'-8"	7'-6"	4	1'-11"	5"	8'-11"	12'-0"	12	3'-3"

BENDING DETAILS



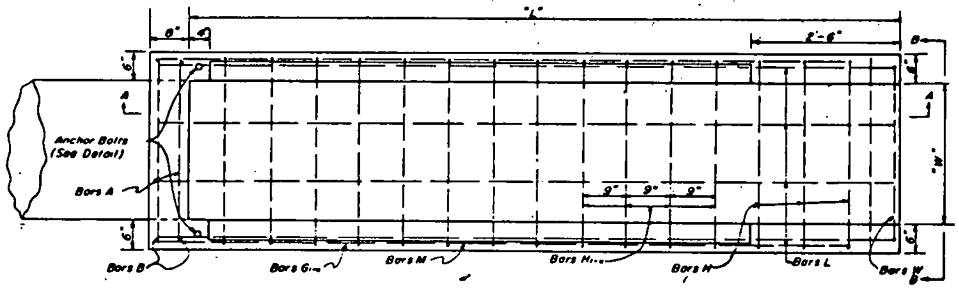
MISSOURI STATE HIGHWAY COMMISSION

PIPE CULVERT HEADWALLS
TYPE S
12" TO 24" DIAMETERS
6:1 SLOPES

SUBMITTED [signature] ENGR. SURVEYS & PLANS APPROVED M. J. Snider CHIEF ENGINEER

NEW
12-1-67

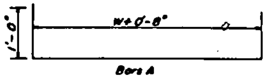
21.96



PLAN VIEW CULVERT WINGWALL

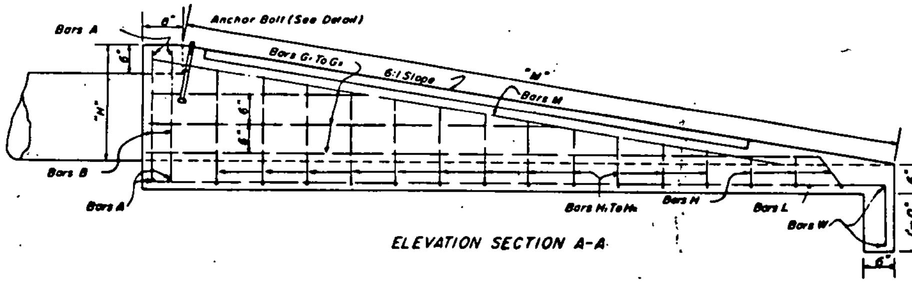
Table of Dimensions and Quantities for One Headwall

Design	Size of Pipe Arch		Table of Dimensions				Bill of Re-inforcing Steel																				
							No 4 Bars A			No 4 Bars B			No 4 Bars G1			No 4 Bars G2			No 4 Bars G3			No 4 Bars H			No 4 Bars H1 to H4		
	Span	Rise	H	L	W	M	No	Lgth	Wt	No	Lgth	Wt	No	Lgth	Wt	No	Lgth	Wt	No	Lgth	Wt	No	Lgth	Wt	No	Av Lgth	Wt
3	29"	18"	2'-0"	12'-0"	2'-5"	12'-2"	4	5'-1"	14"	4	2'-4"	6"	2	[illegible]'-3"	15"	2	7'-3"	10"	2	4'-3"	6"	3	4'-5"	9"	12	5'-5"	45"
4	36"	22"	2'-4"	14'-0"	3'-0"	14'-2½"	4	5'-8"	15"	4	2'-8"	7"	2	11'-3"	18"	2	9'-3"	12"	2	6'-3"	8"	7	4'-10"	10"	15	6'-4"	65"
5	43"	27"	2'-9"	16'-6"	3'-7"	16'-8½"	4	6'-3"	17"	4	3'-1"	8"	2	15'-10"	21"	2	11'-10"	16"	2	8'-10"	12"	3	5'-5"	11"	18	7'-5"	89"

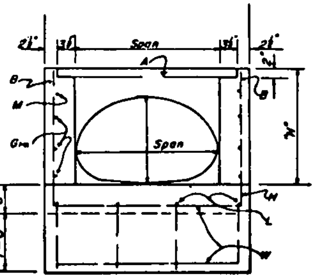


Quantities for One Headwall (Cont.)

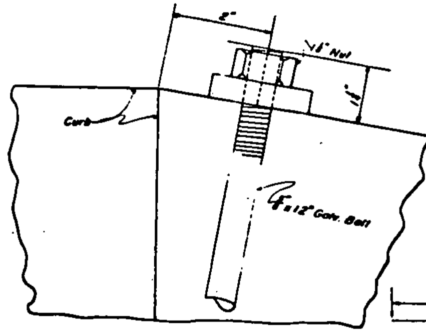
Bill of Reinforcing Steel (Cont.)									Total Quantities		Size of Pipe Arch		Design
No 4 Bars L			No 4 Bars M			No 4 Bars W			Steel Lbs	Concrete Cu Yds	Span	Rise	
No	Lgth	Wt	No	Lgth	Wt	No	Lgth	Wt					
4	13'-6"	36"	2	10'-9"	14"	2	3'-1"	4"	157	1.38	29"	18"	3
4	15'-6"	41"	2	12'-9"	17"	2	3'-8"	5"	196	1.85	36"	22"	4
4	18'-0"	48"	2	15'-3"	20"	2	4'-3"	6"	248	2.49	43"	27"	5



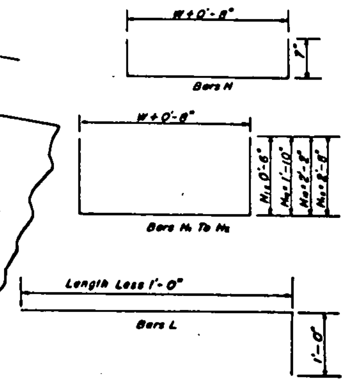
ELEVATION SECTION A-A

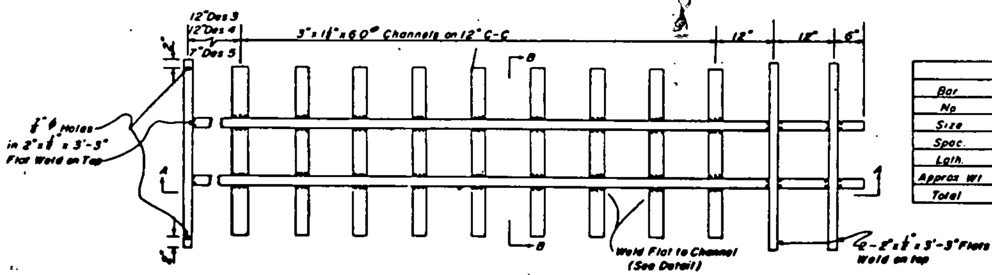


SECTION B-B



ANCHOR BOLT DETAIL





PLAN GRATE DETAIL TYPE C
FOR DESIGN 3, 4, & 5 CGM PIPE

Bill of Steel for One Grate (Type C)

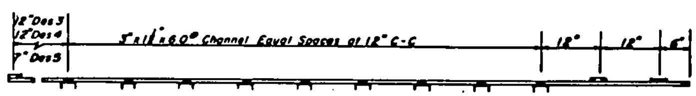
Bar	Design 3			Design 4			Design 5		
	Flat	Chan	Flat	Flat	Chan	Flat	Flat	Chan	Flat
No	3	9	2	3	11	3	3	14	3
Size	2"x¼"	3"x1½"x6.0	2"x¼"	2"x¼"	3"x1½"x6.0	2"x¼"	2"x¼"	3"x1½"x6.0	2"x¼"
Spac.	Shown	12"	12"	Shown	12"	12"	Shown	12"	12"
Lgth.	3'-3"	2'-11"	11'-8"	3'-10"	3'-6"	13'-8"	4'-5"	4'-1"	16'-3"
Approx Wt	33#	158#	79#	39#	231#	139#	45#	343#	166#
Total	Design 3 = 270#			Design 4 = 409#			Design 5 = 554#		

General Notes

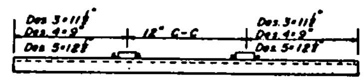
All Concrete Shall Be Class A.

All Exposed Corners Shall Be Chamfered ¾".

Reinforcing Steel Shall Be Placed With The Centers Of The Bars 2" From The Surface Of The Concrete.



SECTION A-A GRATE DETAIL



SECTION B-B GRATE DETAIL

Welding Detail

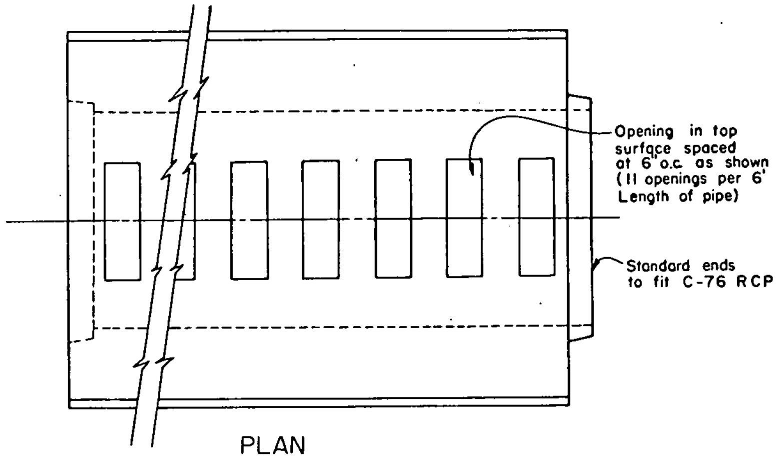
TEXAS HIGHWAY DEPARTMENT

SPECIAL MEDIAN PIPE CULVERT HEADWALLS

WITH TYPE C INLET GRATES

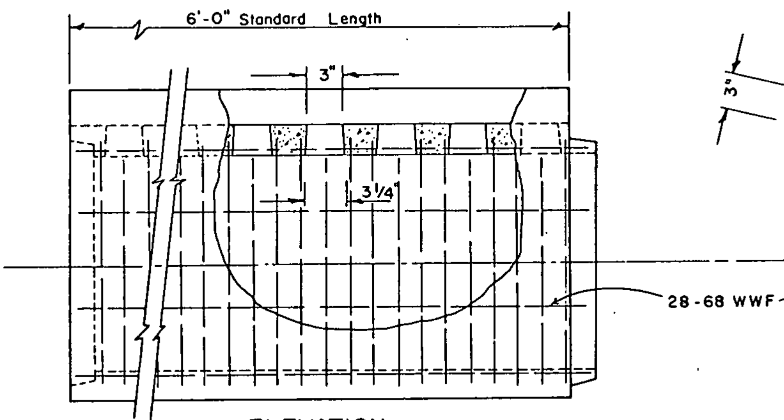
6	TEXAS	I 40-2 (9) 166				190
25	WHEELER	275	13	24	JH 40	

FED. ROAD DIST. NO.	STATE OF	PROJECT	SHEET NO.	TOTAL SHEETS
5	S.D.			

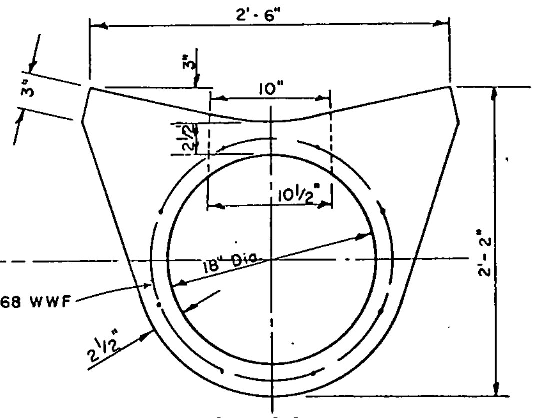


PLAN

Weight = 324 #/L.F.



ELEVATION



SECTION

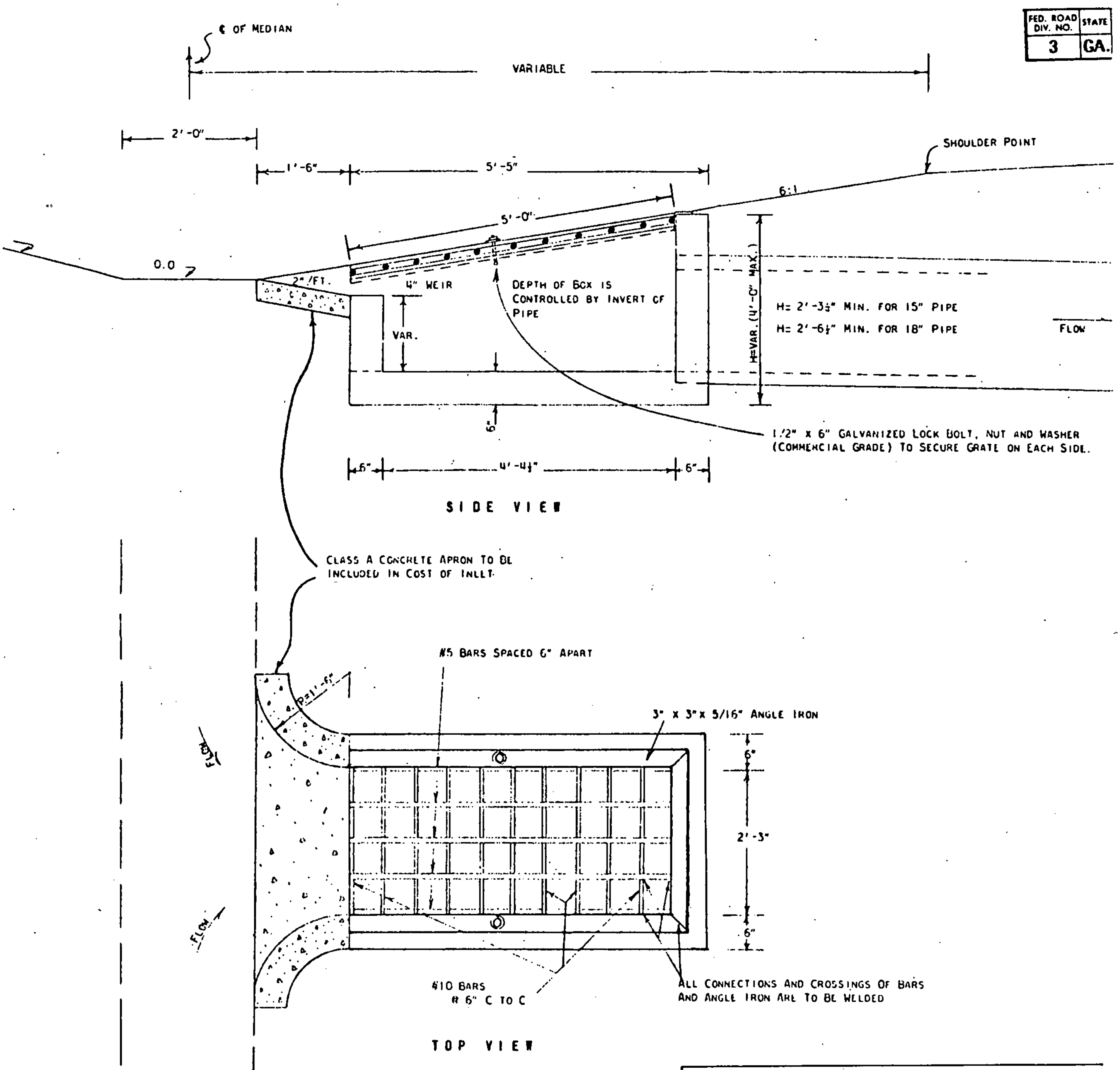
NOTE:
A 2 3/4" thick by 18" diameter end plug, reinforced with 28-68WWF shall be furnished at locations called for. No separate measurement or payment will be made for end plugs, all costs for same being included in the price for "Slotted Reinforced Concrete Pipe."

SOUTH DAKOTA DEPARTMENT OF HIGHWAYS

DETAILS OF SLOTTED REINFORCED CONCRETE PIPE FOR EROSION CONTROL

Prepared In Plans Section

STANDARD PLATE No. 127



DETAILS FOR MEDIAN DROP
SPECIAL DESIGN

(FOR USE AT LOW POINT IN MEDIAN WHERE OUTFALL IS NOT NORMAL DROP INLET)

SCALE: 1"=1'-0"

7-28-67
REVISED: 12-28-67; 6-17-68

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Highway Research Board
National Academy of Sciences
2101 Constitution Avenue
Washington, D.C. 20418

Rep. No.	*Title*
—*	A Critical Review of Literature Treating Methods of Identifying Aggregates Subject to Destructive Volume Change When Frozen in Concrete and a Proposed Program of Research—Intermediate Report (Proj. 4-3(2)), 81 p., $1.80
1	Evaluation of Methods of Replacement of Deteriorated Concrete in Structures (Proj. 6-8), 56 p., $2.80
2	An Introduction to Guidelines for Satellite Studies of Pavement Performance (Proj. 1-1), 19 p., $1.80
2A	Guidelines for Satellite Studies of Pavement Performance, 85 p.+9 figs., 26 tables, 4 app., $3.00
3	Improved Criteria for Traffic Signals at Individual Intersections—Interim Report (Proj. 3-5), 36 p., $1.60
4	Non-Chemical Methods of Snow and Ice Control on Highway Structures (Proj. 6-2), 74 p., $3.20
5	Effects of Different Methods of Stockpiling Aggregates—Interim Report (Proj. 10-3), 48 p., $2.00
6	Means of Locating and Communicating with Disabled Vehicles—Interim Report (Proj. 3-4), 56 p. $3.20
7	Comparison of Different Methods of Measuring Pavement Condition—Interim Report (Proj. 1-2), 29 p., $1.80
8	Synthetic Aggregates for Highway Construction (Proj. 4-4), 13 p., $1.00
9	Traffic Surveillance and Means of Communicating with Drivers—Interim Report (Proj. 3-2), 28 p., $1.60
10	Theoretical Analysis of Structural Behavior of Road Test Flexible Pavements (Proj. 1-4), 31 p., $2.80
11	Effect of Control Devices on Traffic Operations—Interim Report (Proj. 3-6), 107 p., $5.80
12	Identification of Aggregates Causing Poor Concrete Performance When Frozen—Interim Report (Proj. 4-3(1)), 47 p., $3.00
13	Running Cost of Motor Vehicles as Affected by Highway Design—Interim Report (Proj. 2-5), 43 p., $2.80
14	Density and Moisture Content Measurements by Nuclear Methods—Interim Report (Proj. 10-5), 32 p., $3.00
15	Identification of Concrete Aggregates Exhibiting Frost Susceptibility—Interim Report (Proj. 4-3(2)), 66 p., $4.00
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25	Potential Uses of Sonic and Ultrasonic Devices in Highway Construction (Proj. 10-7), 48 p., $2.00
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* Highway Research Board Special Report 80.

Rep. No.	Title
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HIGHWAY RESEARCH BOARD
NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL
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