

CONTENTS

1	SUMMARY
	PART I
2	CHAPTER ONE Introduction
4	CHAPTER TWO Median Drainage Structures Flush Type Projecting Type Conclusions
9	CHAPTER THREE Culvert End Structures Conclusions
17	CHAPTER FOUR Curbside and Curb Opening Inlets Conclusions
20	CHAPTER FIVE Roadside Channels Conclusions
22	CHAPTER SIX Special Drainage Structures Conclusions
24	CHAPTER SEVEN Miscellaneous Considerations
25	REFERENCES
	PART II
26	APPENDIX A Comparison of Culvert Extension Costs with Guardrail Barrier Costs
27	APPENDIX B One Possible Prefabricated End Section for Mod- ifying Culvert
27	APPENDIX C Standard Plan Sheets

TRAFFIC-SAFE AND HYDRAULICALLY EFFICIENT DRAINAGE PRACTICE

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.

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 Ta-

bles 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).

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 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.

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.....	96	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			1
Sign.....	14				4	5	2			3		1
Ditch.....	6	4	3		3	1	4		1			6
Culvert.....	3	1	1	4	1			2	1	3	1	1
Curb.....	3			1	2					1		1
Divider.....	3	1	1	2	1		1					1
Fence.....	4	1	1	6		2			1	3	3	1
Tree.....	2			5	2		2			2		4
Other.....	2	2	2	4	1			1	3	1	3	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 re-located, 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:

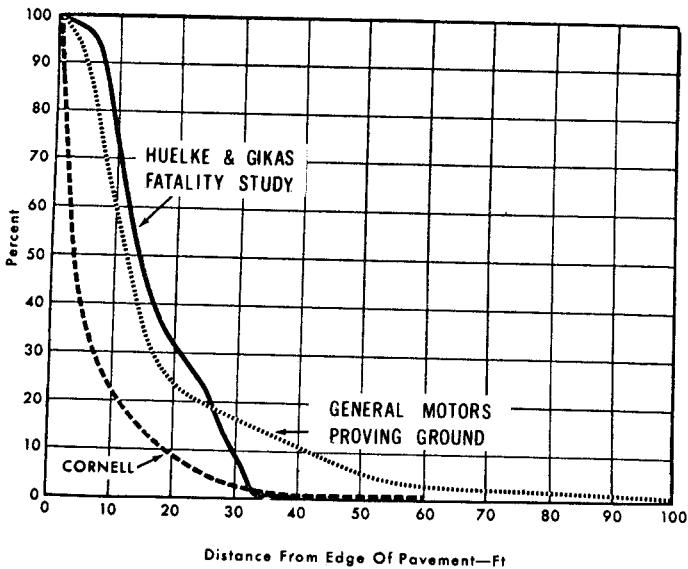


Figure 1. Distribution of impacted roadside obstacles vs distance from edge of roadway (63 cases) (4).

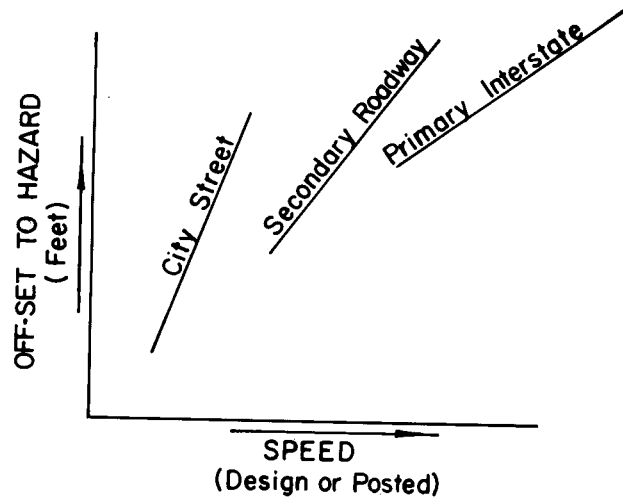


Figure 2. Relationship between speed, type of roadway, and offset to hazard.

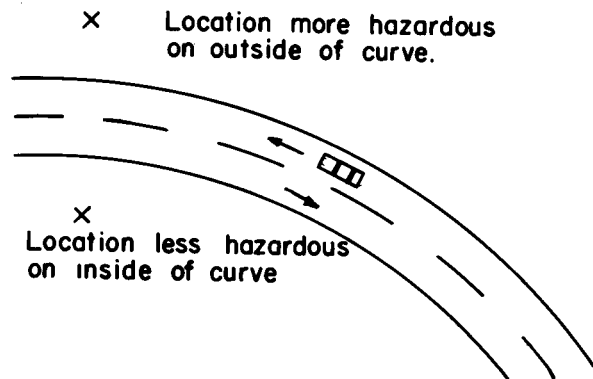


Figure 3. Drainage structures located adjacent to curved sections are greater potential hazards than those along tangents.

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.

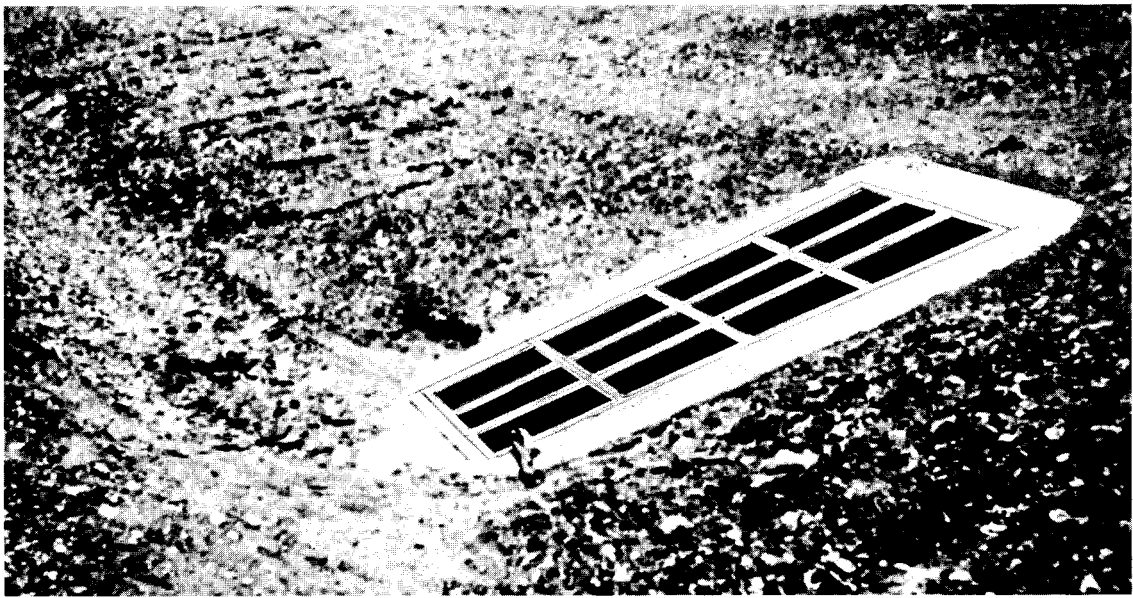


Figure 4. Drain with grate, located on median side slope.

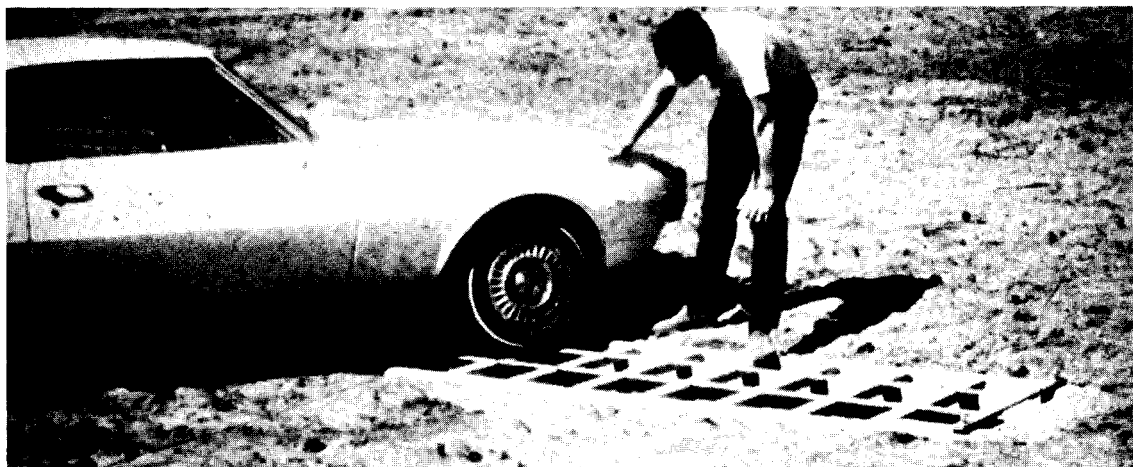
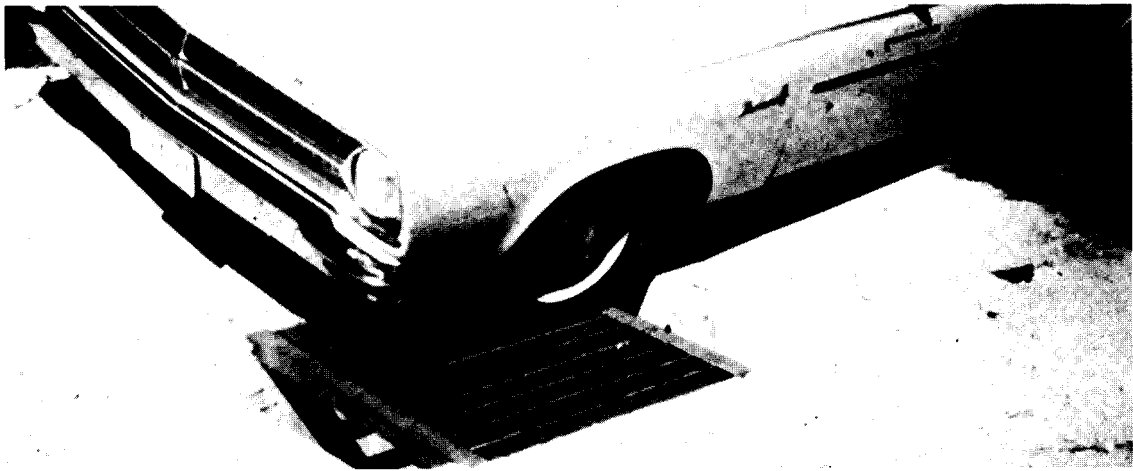


Figure 5. Drop inlet grates designed to support wheel load and prevent tire penetration.

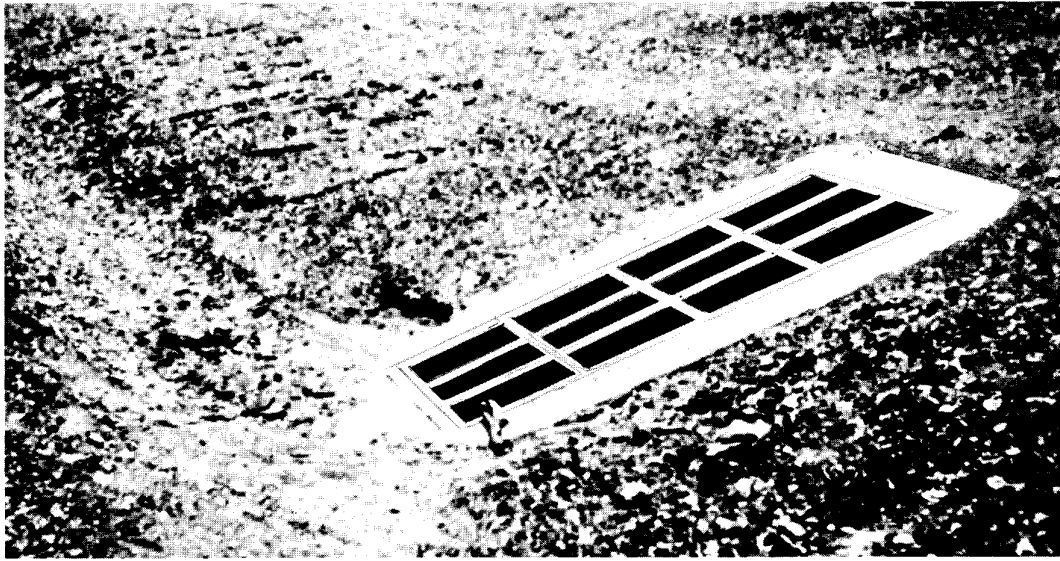


Figure 4. Drain with grate, located on median side slope.

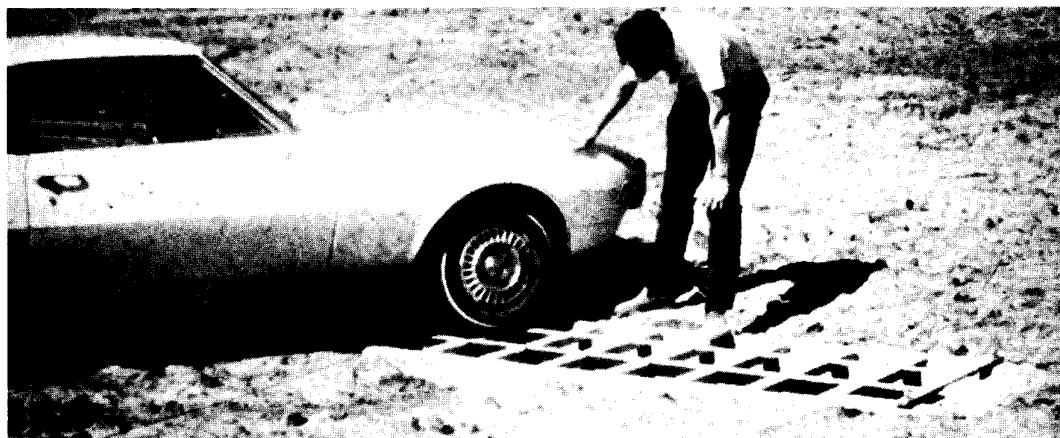
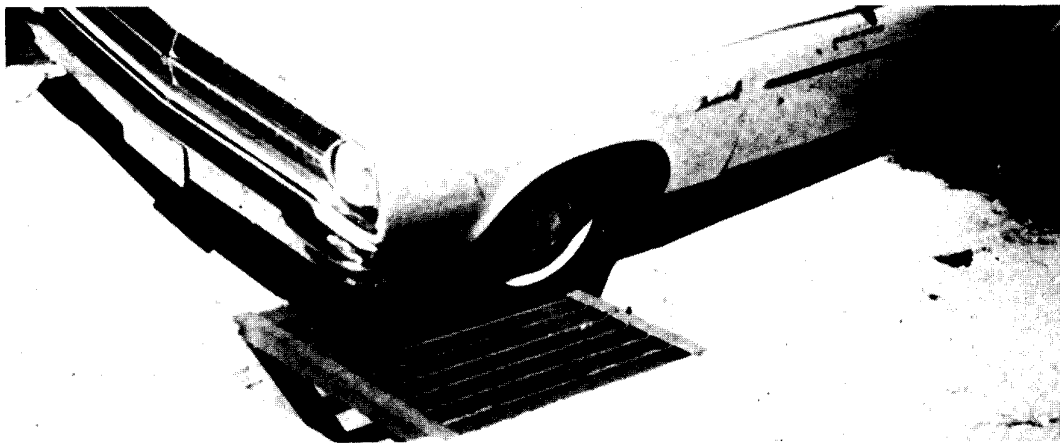


Figure 5. Drop inlet grates designed to support wheel load and prevent tire penetration.

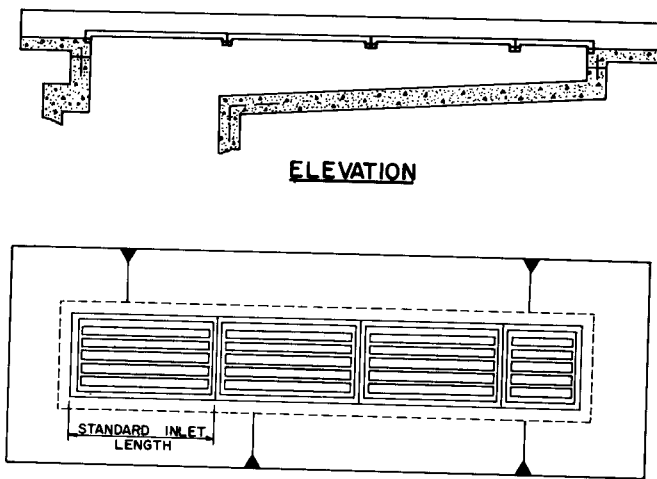


Figure 6. Drop inlet—elongated to increase penetration.

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).

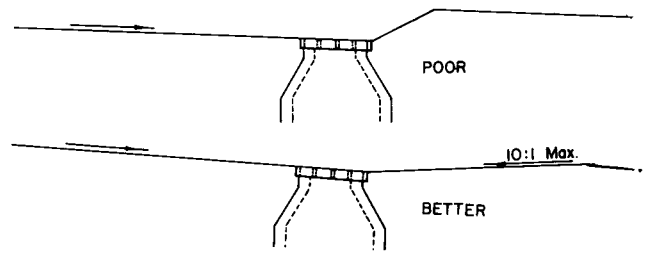


Figure 7. Ditch dikes increase interception, but should be as flat as practicable.

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.

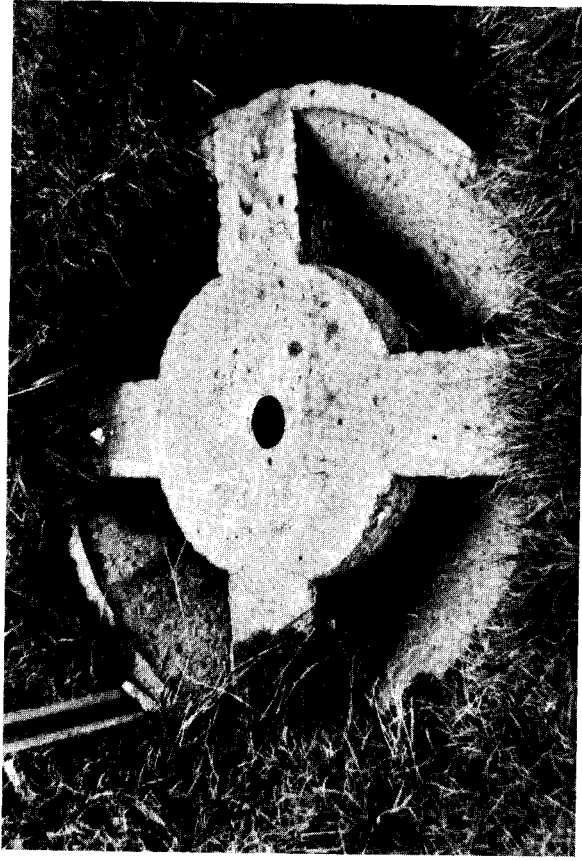


Figure 11. Precast concrete median inlet with non-removable top. Note 4-in. hole for inserting steam line for thawing ice.

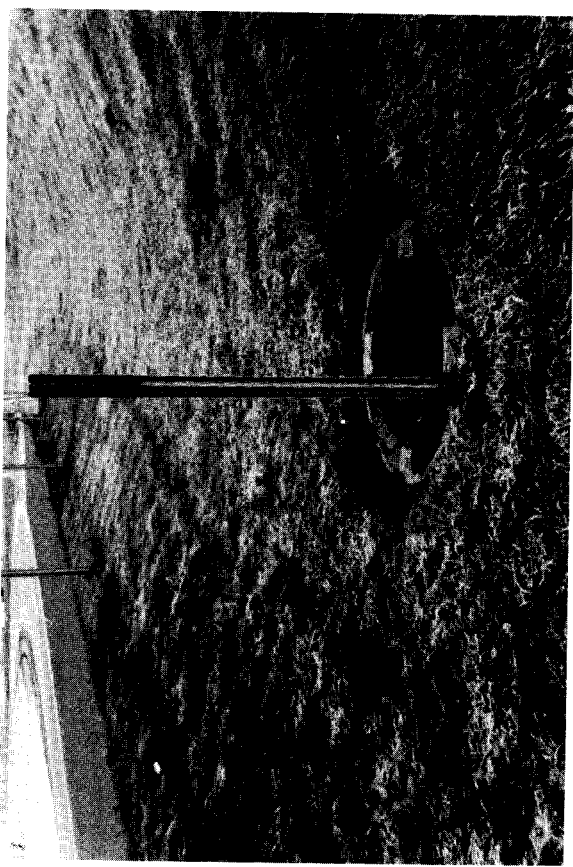


Figure 12. Precast concrete drop inlet with removable cover. Slender post aids location under snow.

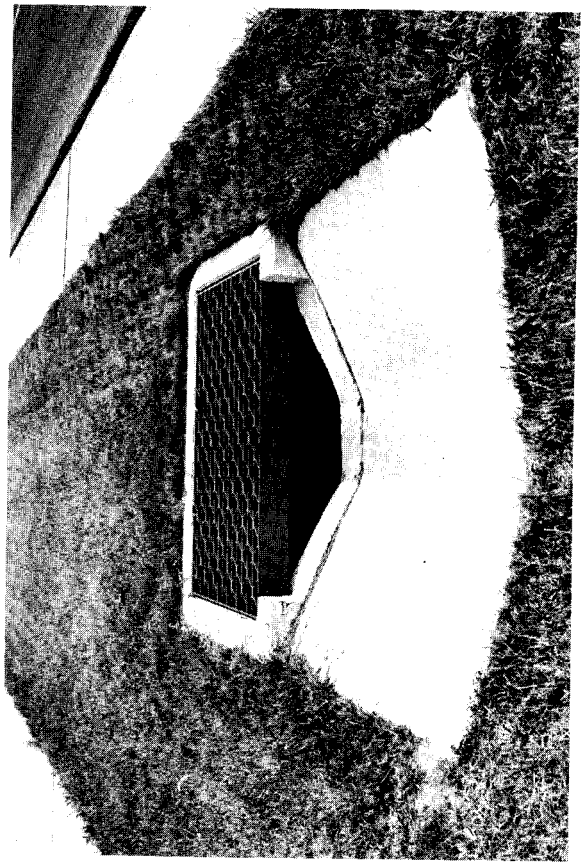


Figure 13. Drop inlet (in median) with exposed vertical face where flow enters the structure.

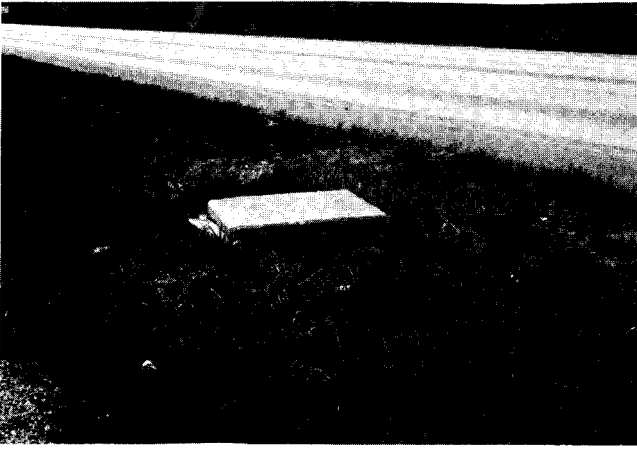


Figure 14. A concrete inlet cover weighing more than 750 lb that has been displaced by vehicle impact.

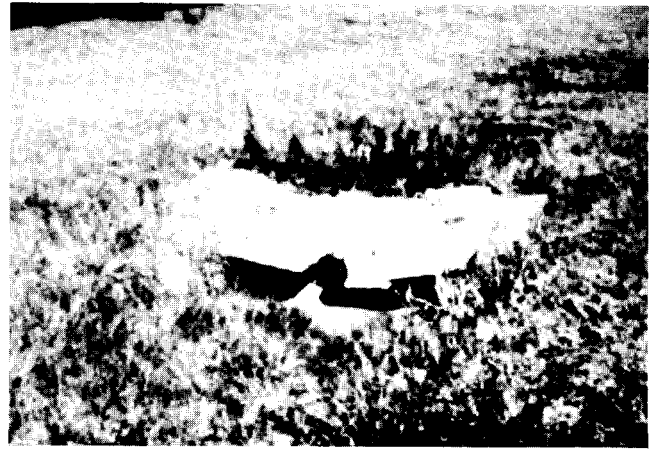


Figure 15. This concrete drop inlet was unable to support vehicle load.



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

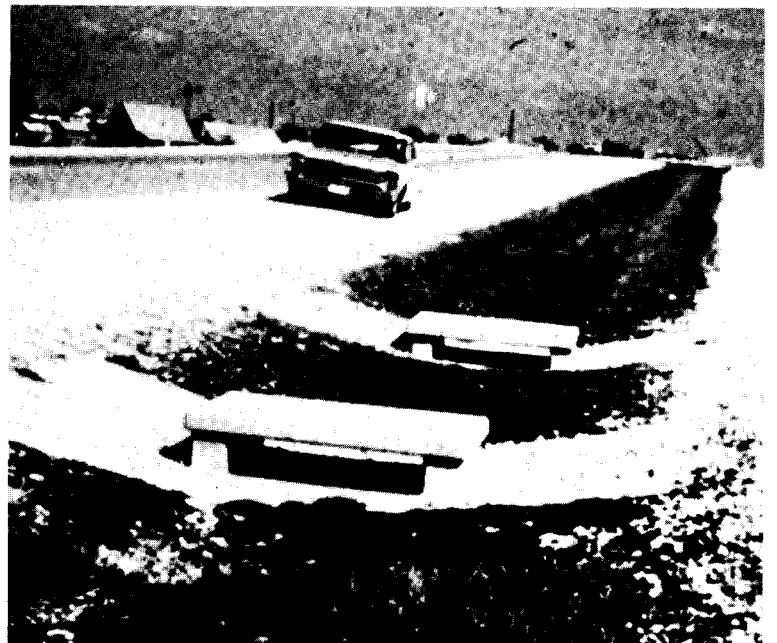
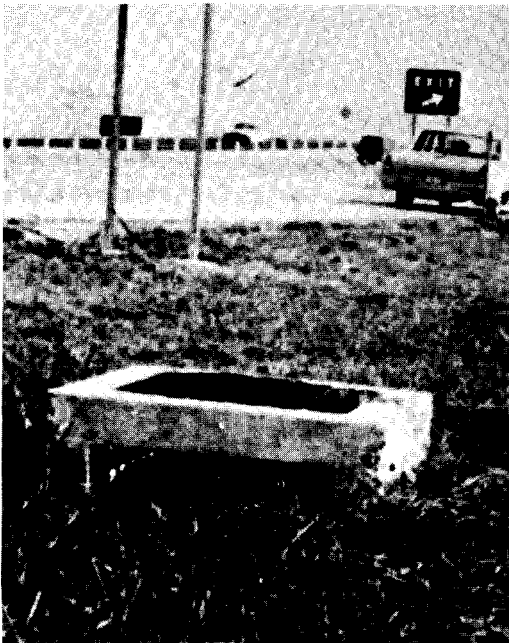


Figure 17. Examples of common median inlets that are potential traffic hazards.

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.

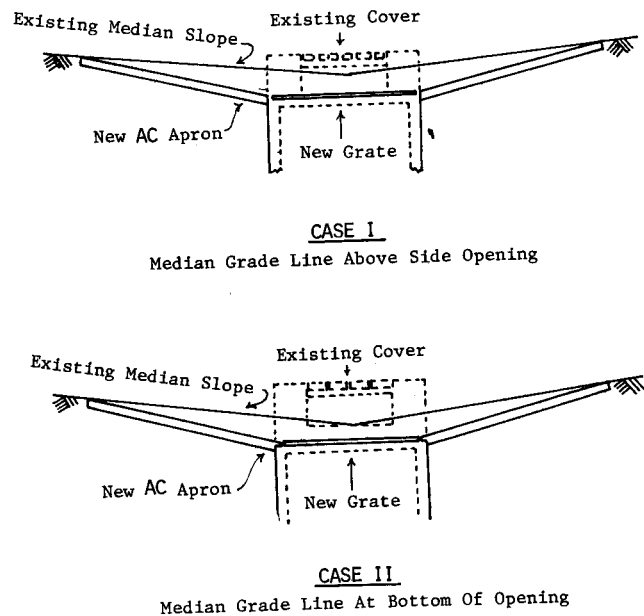


Figure 18. Methods of converting projecting median inlets to safer design.

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.

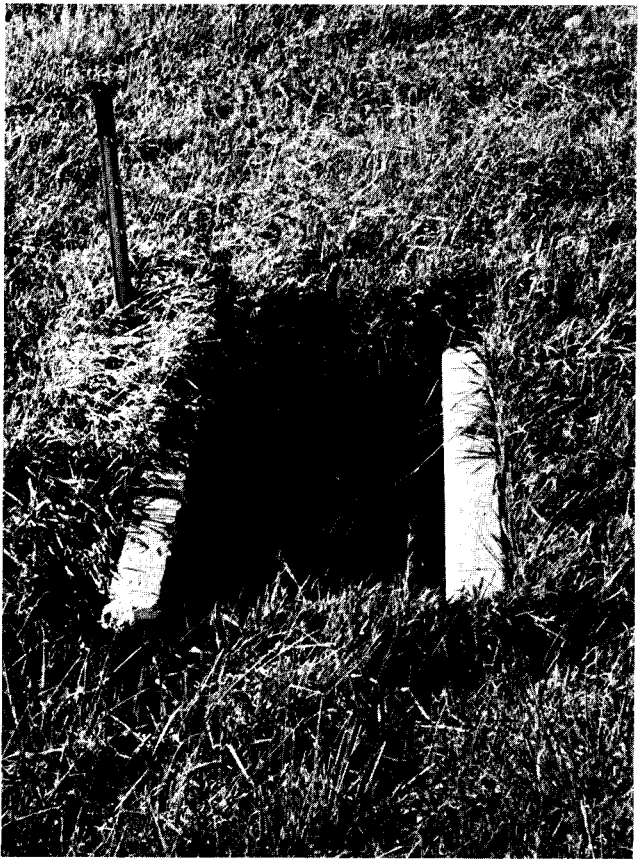


Figure 20. U-type culvert end section is dangerous when located within the recovery area. Post marker warns traffic and maintenance workers.

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).

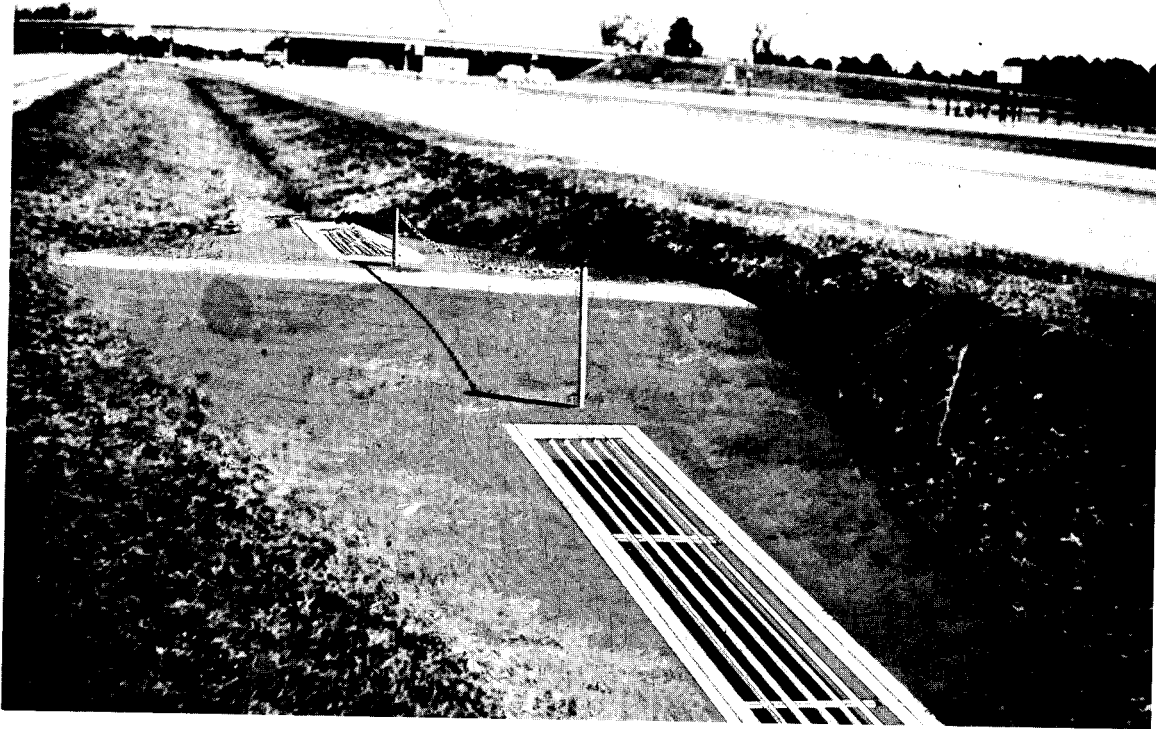
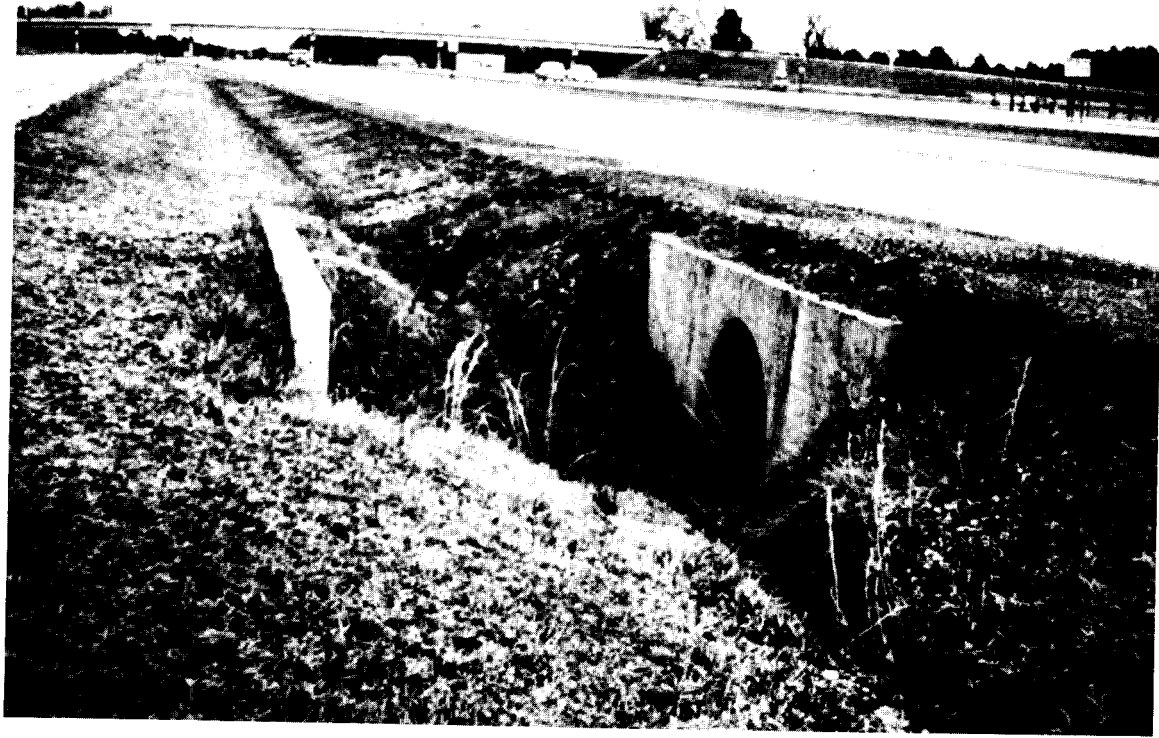


Figure 21. Two headwalls representing a double hazard (top). A possible solution is to install median inlets on a 10:1 slope, with connections into the extended cross drain (bottom).

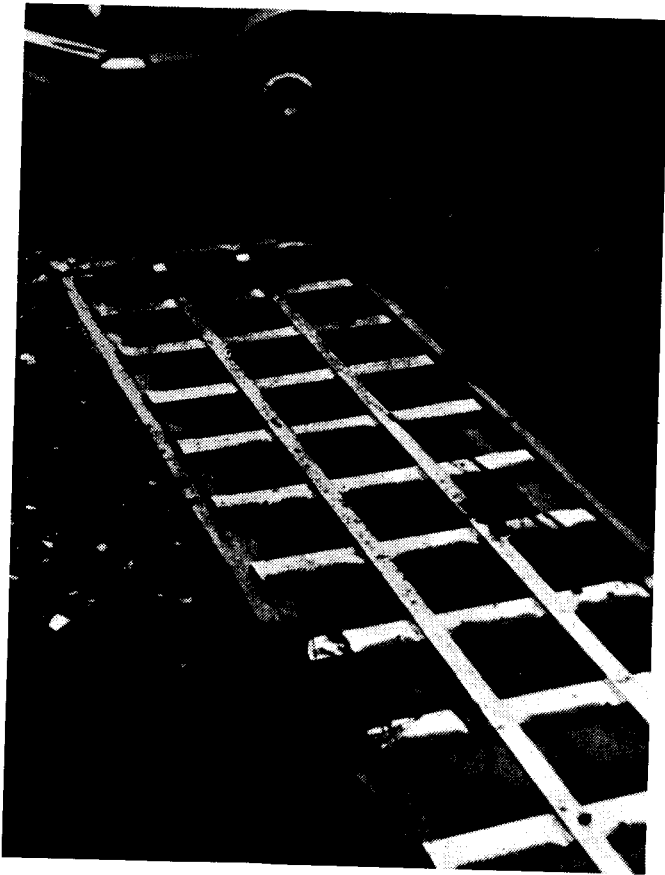


Figure 22. Culvert end structure with special grate.

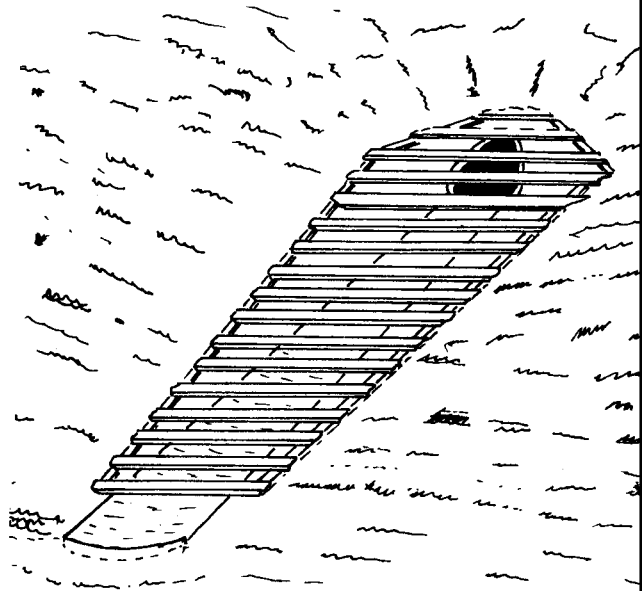


Figure 23. One possible modification for ends of median, ramp or cross-drain structures. This unit may be made up of rectangular steel sections and placed with very little preparation. Side and end slopes should be 10:1 or flatter.

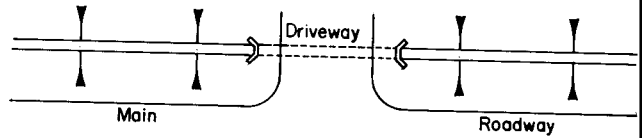


Figure 24. Typical culvert layout with unsafe headwalls that often has been used at driveways and intersections.

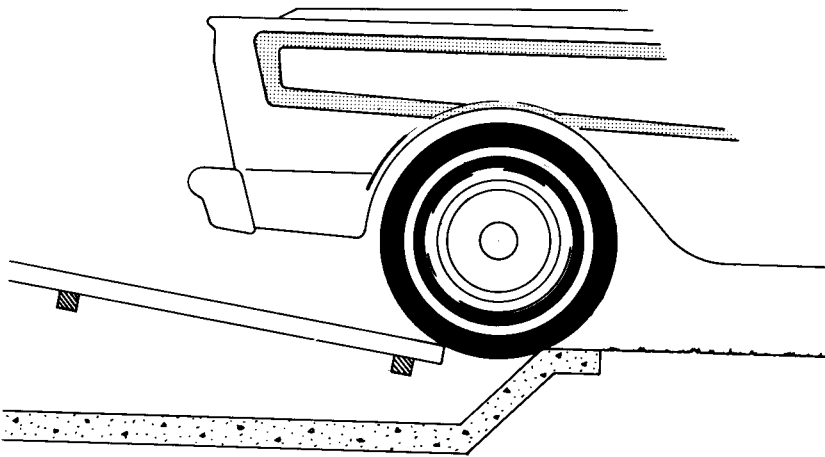


Figure 25. Special culvert entrance designed to permit passage of debris by dropping ditch grade to minimize hazard.

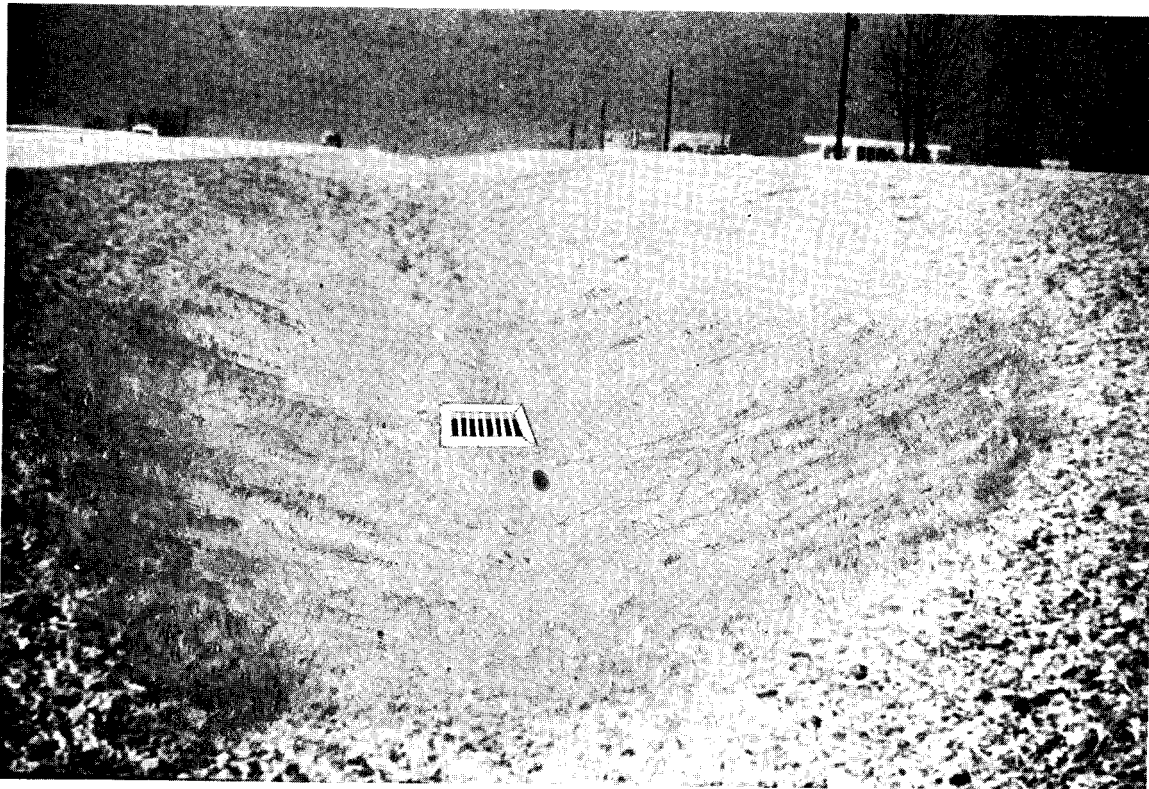


Figure 26. Hazardous drainage practice between two roadways (top). Possible modification with drop inlet and flat slopes (bottom).

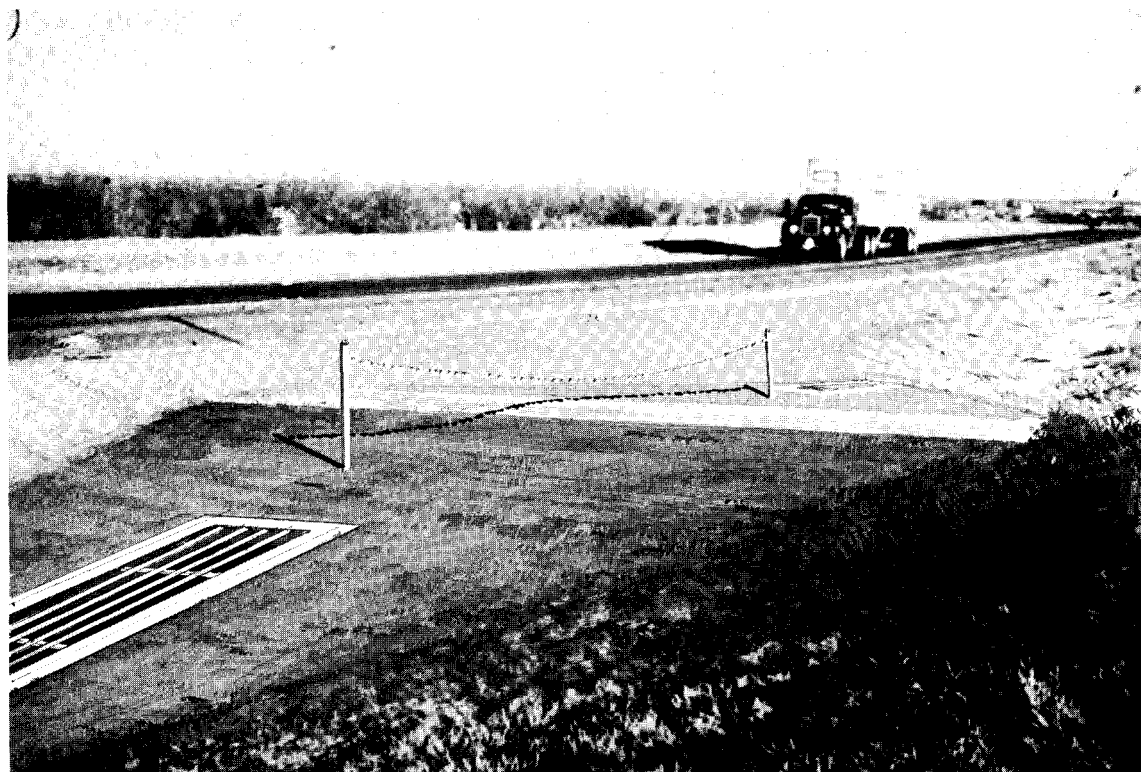
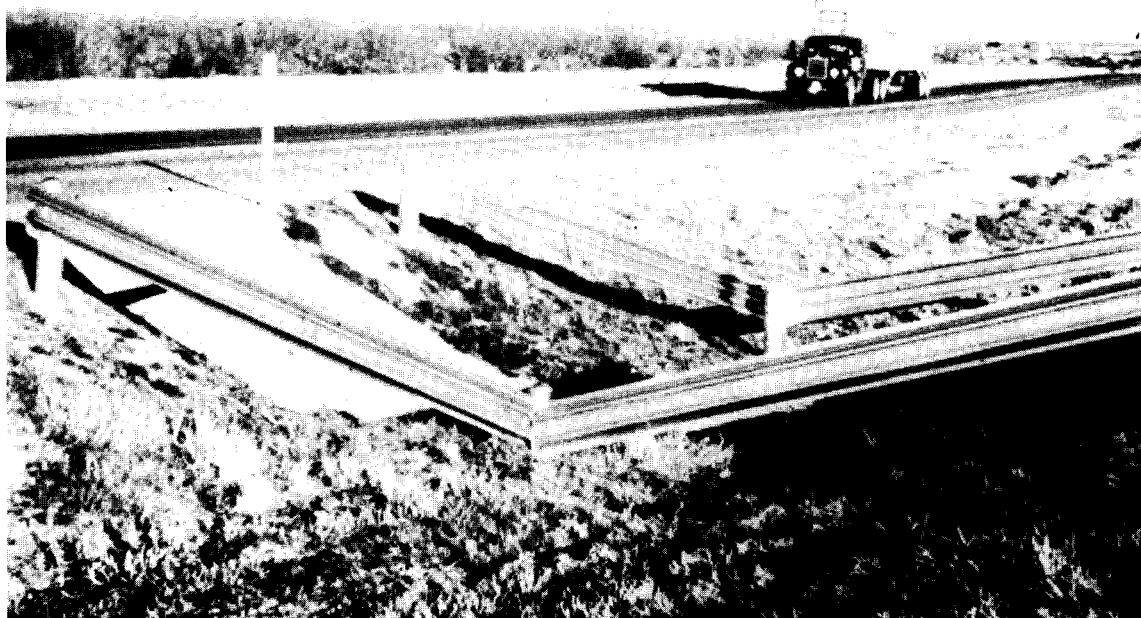


Figure 27. Guardrail has been placed to prevent vehicles from hitting culvert inlets (top). The solution sketched in Figure 21 could be used (bottom).



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

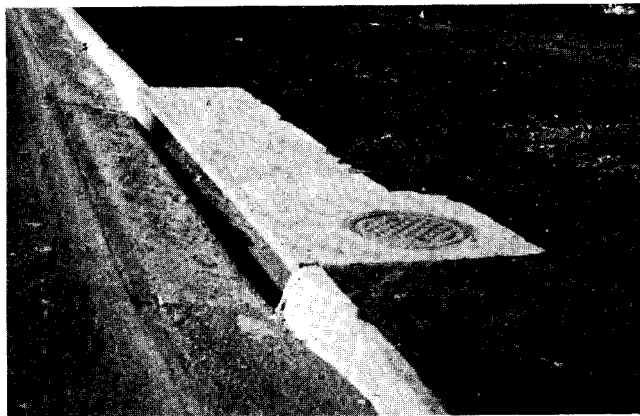


Figure 30. Typical curb-opening inlet often used in urban areas.



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



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

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.

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. Where-

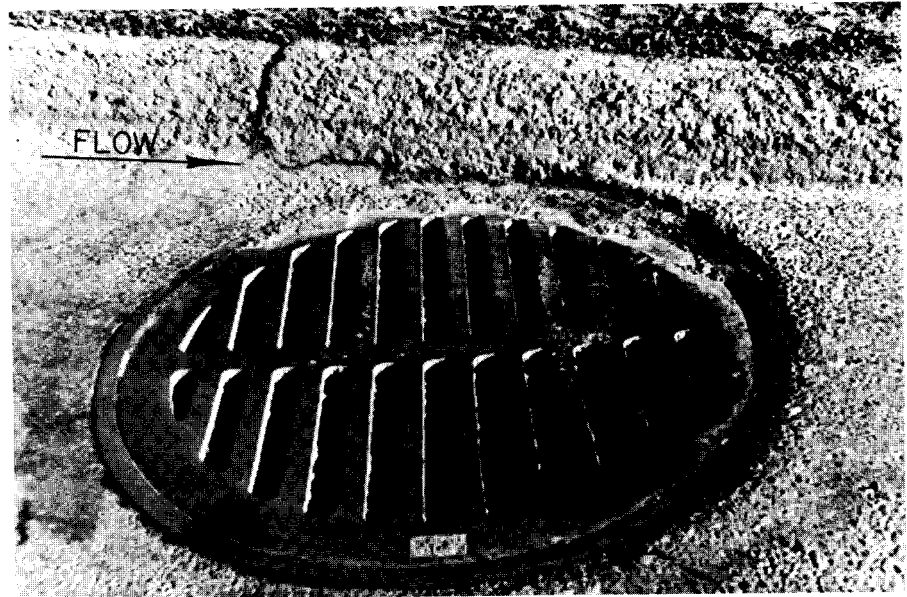


Figure 35. Improper grate orientation, reducing inlet capacity.

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.

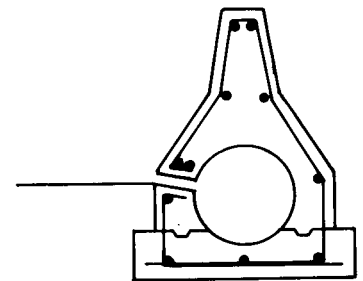


Figure 36. "New Jersey" type of barrier with pipe inside the structure.

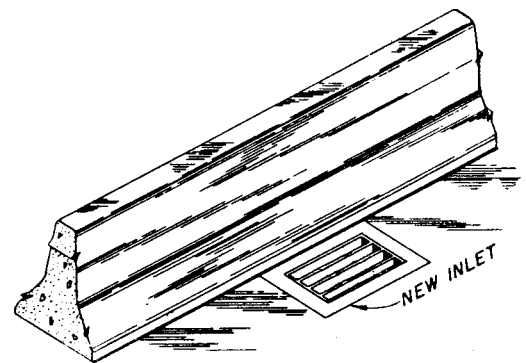


Figure 37. Inlet location for "New Jersey" type of barrier with pipe located below the structure.

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 AASHTO 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 lo-

cated 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.

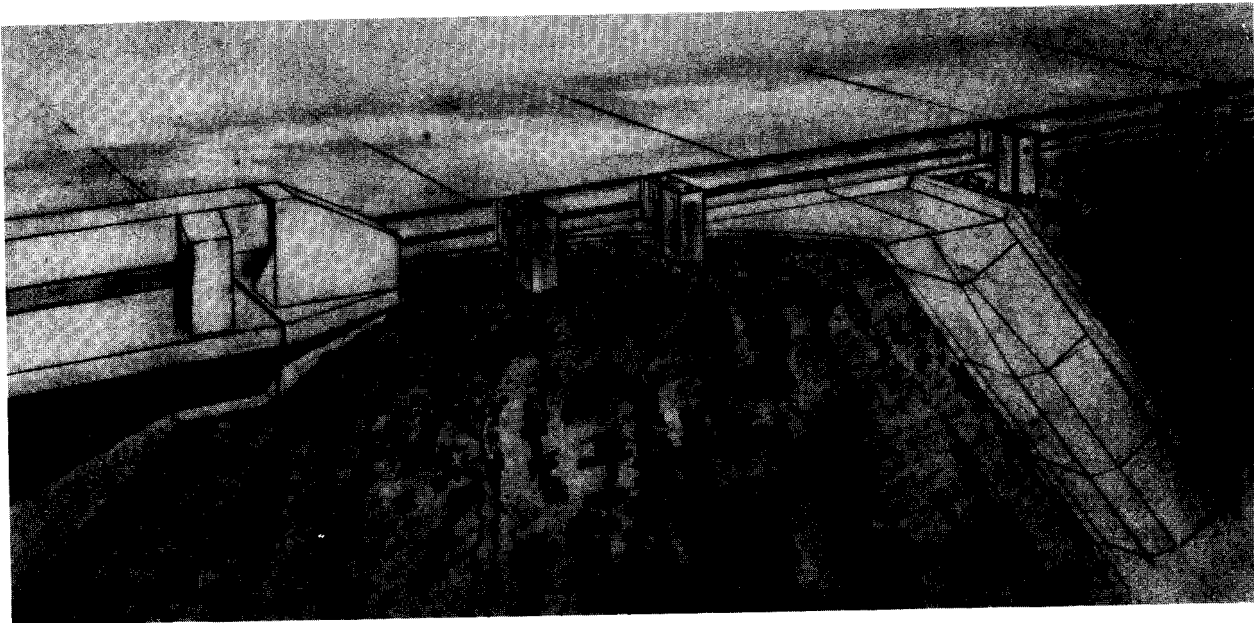


Figure 39. Continuation of the guardrail across the head of the flume minimizes a potential hazard.



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

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.

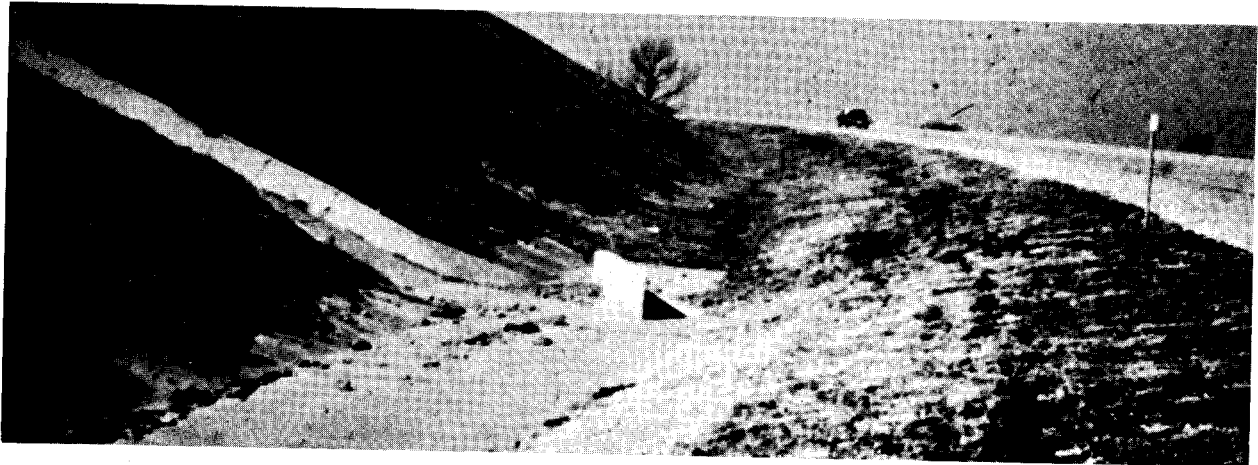


Figure 41. A vertical baffle used to deflect flow from the top of the cut into the ditch.



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.

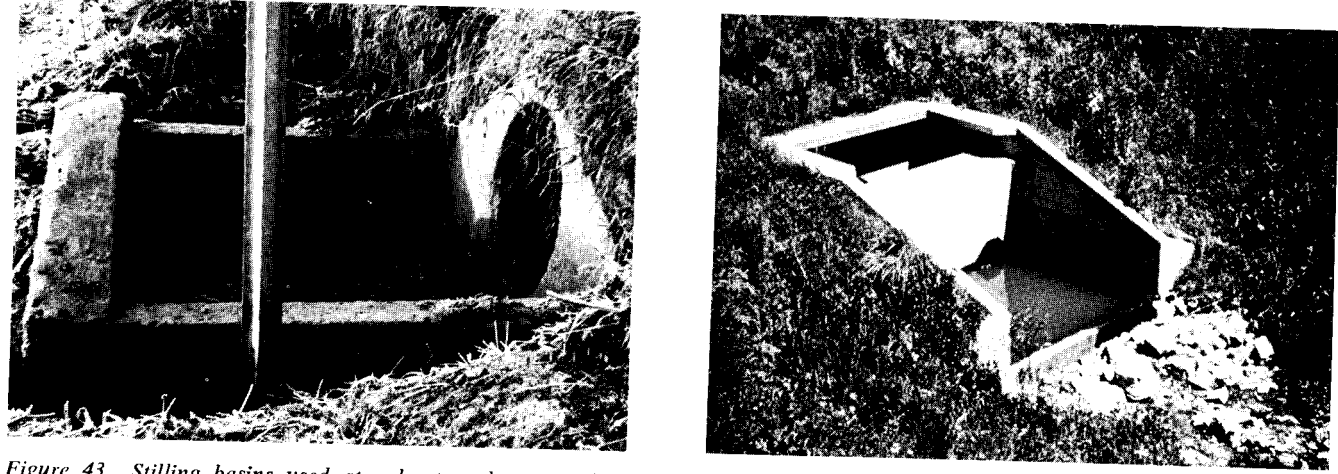


Figure 43. Stilling basins used at culvert outlets to reduce erosion.

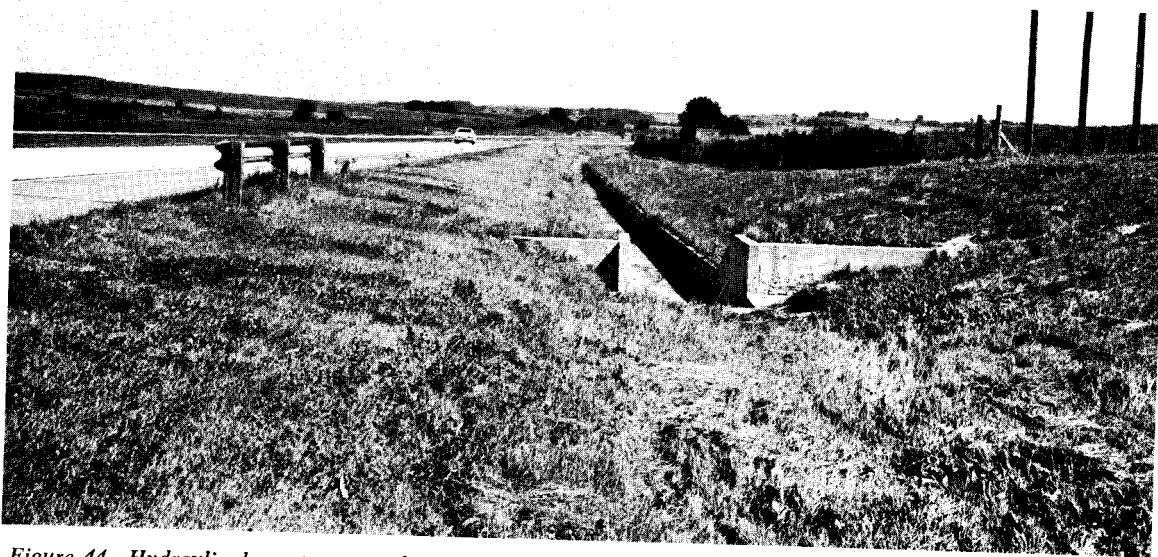


Figure 44. Hydraulic drop structures designed to control flow velocities in open channels.

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 out-

lets—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).

REFERENCES

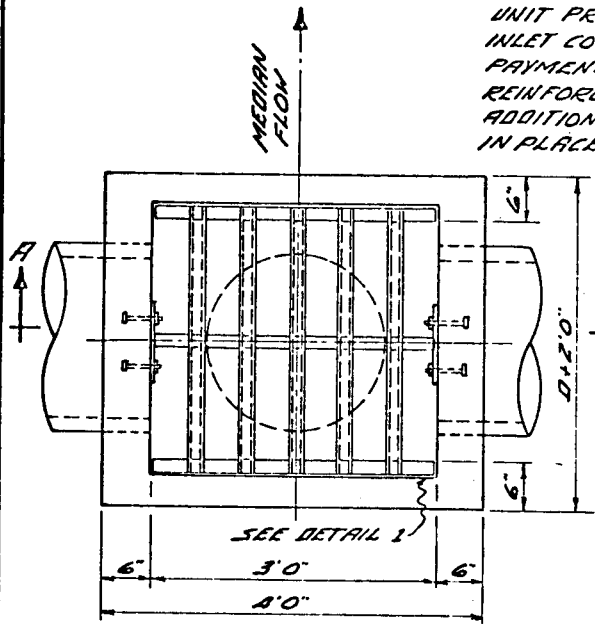
1. "Accident Facts—1969." National Safety Council, 96 pp. (1969).
2. "Accident Facts—1968." National Safety Council, 96 pp. (1968).
3. *Highway Design and Operational Practices Related to Highway Safety*. Part III, "Roadside Design and Appurtenances." AASHO, pp. 19-21 (Feb. 1967).
4. HUELKE, DONALD F., and GIKAS, PAUL W., "Non-Intersectional Automobile Fatalities—A Problem in Roadway Design." *Hwy. Res. Record No. 152* (1967) pp. 103-119.
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).
7. ANDERSON, A. G., PAINTAL, A. S., and DAVENPORT, J. T., "Tentative Design Procedure for Riprap-Lined Channels." *NCHRP Research Results Digest 1* (Dec. 1968); a digest of the results contained in a forthcoming *NCHRP Report* on Project 15-2.
8. "Dangerous Headwalls Removed." *Eng. News-Rec.*, Vol. 127, No. 3, p. 79 (July 17, 1941).
9. "Drainage," *Handbook of Highway Safety Design and Operating Practices*. U.S. Dept. of Transportation, pp. 29-32 (May 1968).
10. GREENE, WILLIAM C., "Vehicle Collisions with Roadside Objects." *HRB Roadside Develop. Rept. 1962* (1962) pp. 48-55.
11. HUTCHINSON, J. W., and KENNEDY, T. W., "Medians of Divided Highways—Frequency and Nature of Vehicle Encroachments." *Bull. No. 487*, Univ. of Ill. Eng. Exp. Station, 35 pp. (1966).
12. JORSTAD, JOHN R., "Safety Grate for Concrete Flared End Sections." *Special Report on Use of Equipment and Methods of Construction*, BPR, 2 pp. (July 1968).
13. O'HARRA, W. G., "Treatment of Culvert Ends and Associated Obstructions in Arizona." Paper presented at Region IV AASHO Design Committee Meeting, Santa Fe, 5 pp. (1968).
14. "Safety Criteria—Drainage Structures." *Instructional & Information Memo. No. LD-68(R)-50*, Virginia Dept. of Hwys., 1 p. (May 1, 1968).

State Highway Commission
 Helena, Montana

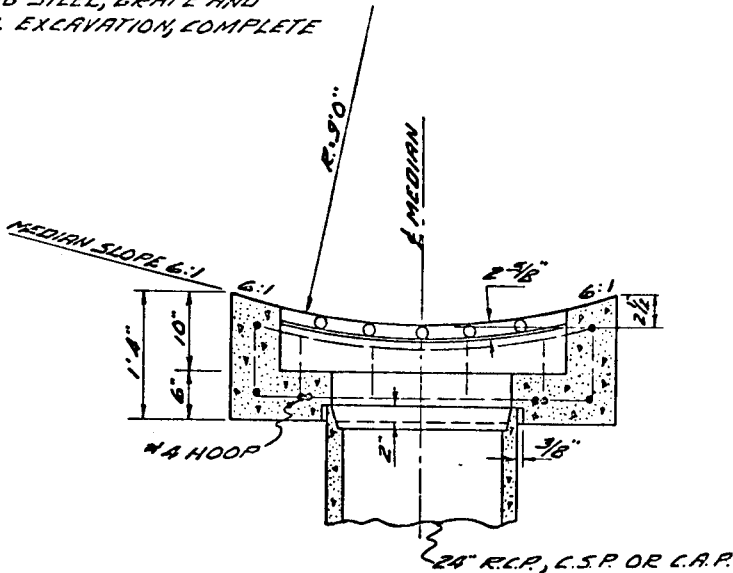
MEDIAN INLET COVER

Approved
[Signature]
 State Highway Engineer

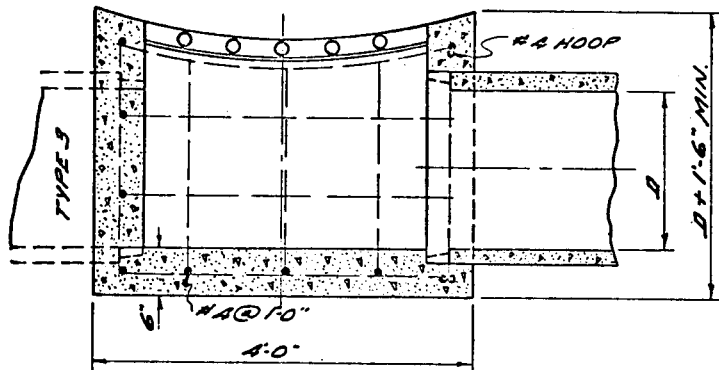
UNIT PRICE BID FOR MEDIAN INLET COVER SHALL INCLUDE PAYMENT FOR THE CONCRETE, REINFORCING STEEL, GRATE AND ADDITIONAL EXCAVATION, COMPLETE IN PLACE



PLAN VIEW
 TYPICAL FOR TYPES 1, 2, & 3

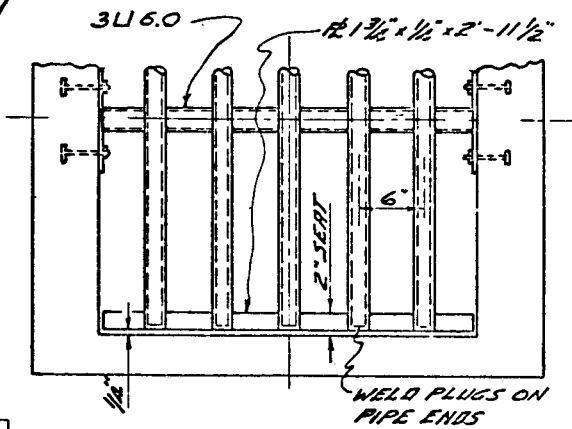
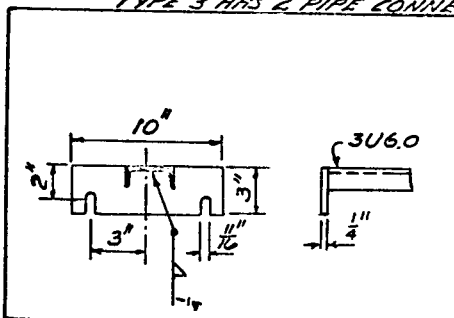
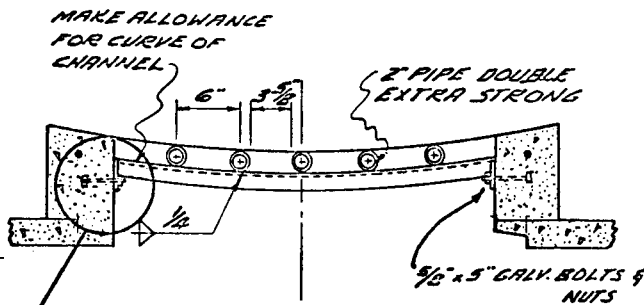


SECTION A-A
 TYPE 1



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. "00" CONCRETE

TYPE	24"	30"	36"
1	.5 YD ³	-	-
2	.9 YD ³	1.1 YD ³	1.3 YD ³
3	.9 YD ³	1.0 YD ³	1.1 YD ³

* 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

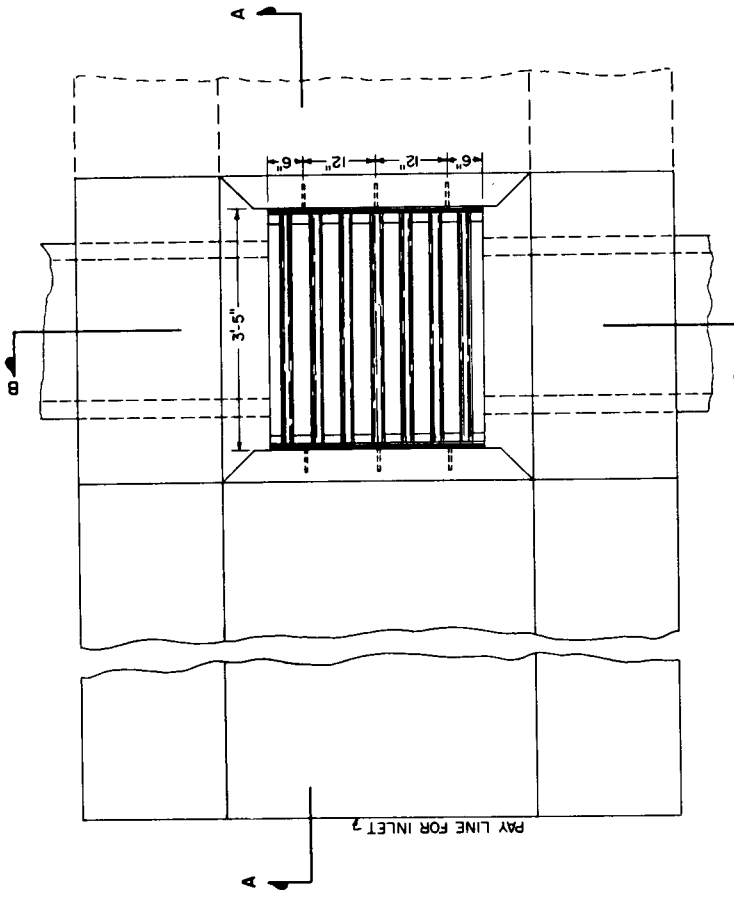
DI-7A-7B

GENERAL NOTES

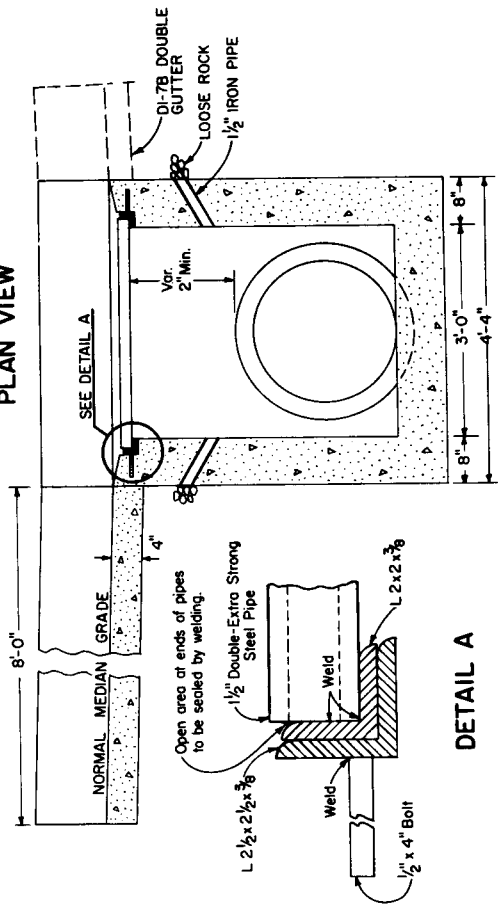
- DI-7A single gutter when inlet is on a grade.
- DI-7B double gutter when drop inlet is in a sag between two grades.
- Class A3 concrete to be used.
- All concrete quantities are figured for two concrete pipes of the sizes tabulated.
- Median ditch to be warped to tie smoothly into inlet gutter.
- Paved 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'-11 1/4".
- 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

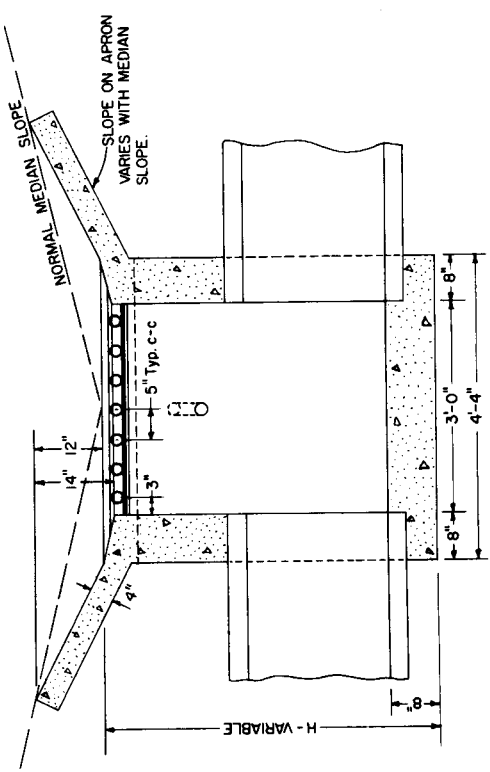


PLAN VIEW



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)

NO. 13 GRATING & FRAMES

Approx. Weight 840 Lb

FEDERAL ROAD DISTRICT NO.	DIVISION	PROJECT NO.	SHEET NO.
			TOTAL SHEETS

QUANTITIES

H	TYPE 3 INLET		TYPE 3 DOUBLE INLET	
	NO. OF CLASS A REINFORCING STEEL	CU. YD. CONCRETE	NO. OF CLASS A REINFORCING STEEL	CU. YD. CONCRETE
3'-0"	3	1.30	4	1.47
3'-6"	4	1.47	5	1.64
4'-0"	5	1.64	6	1.81
4'-6"	6	1.81	7	1.98
5'-0"	7	1.98	8	2.15
5'-6"	8	2.15	9	2.32
6'-0"	9	2.32	10	2.49
6'-6"	10	2.49	11	2.66
7'-0"	11	2.66	12	2.83
7'-6"	12	2.83	13	2.99
8'-0"	13	2.99	14	3.17
8'-6"	14	3.17	15	3.34
9'-0"	15	3.34	16	3.51
9'-6"	16	3.51	17	3.68
10'-0"	17	3.68	18	3.85
10'-6"	18	3.85	19	4.02
11'-0"	19	4.02	20	4.19
11'-6"	20	4.19	21	4.37
12'-0"	21	4.37	22	4.54
12'-6"	22	4.54	23	4.71
13'-0"	23	4.71	24	4.88
13'-6"	24	4.88	25	5.05
14'-0"	25	5.05	26	5.22
14'-6"	26	5.22	27	5.39
15'-0"	27	5.39	28	5.56
15'-6"	28	5.56	29	5.73
16'-0"	29	5.73	30	5.90
16'-6"	30	5.90	31	6.07
17'-0"	31	6.07	32	6.24
17'-6"	32	6.24	33	6.41
18'-0"	33	6.41	34	6.58
18'-6"	34	6.58	35	6.75
19'-0"	35	6.75	36	6.92
19'-6"	36	6.92	37	7.09
20'-0"	37	7.09	38	7.26
20'-6"	38	7.26	39	7.43
21'-0"	39	7.43	40	7.60
21'-6"	40	7.60	41	7.77
22'-0"	41	7.77	42	7.94
22'-6"	42	7.94	43	8.11
23'-0"	43	8.11	44	8.28
23'-6"	44	8.28	45	8.45
24'-0"	45	8.45	46	8.62
24'-6"	46	8.62	47	8.79
25'-0"	47	8.79	48	8.96
25'-6"	48	8.96	49	9.13
26'-0"	49	9.13	50	9.30
26'-6"	50	9.30	51	9.47
27'-0"	51	9.47	52	9.64
27'-6"	52	9.64	53	9.81
28'-0"	53	9.81	54	9.98
28'-6"	54	9.98	55	10.15
29'-0"	55	10.15	56	10.32
29'-6"	56	10.32	57	10.49
30'-0"	57	10.49	58	10.66
30'-6"	58	10.66	59	10.83
31'-0"	59	10.83	60	11.00
31'-6"	60	11.00	61	11.17
32'-0"	61	11.17	62	11.34
32'-6"	62	11.34	63	11.51
33'-0"	63	11.51	64	11.68
33'-6"	64	11.68	65	11.85
34'-0"	65	11.85	66	12.02
34'-6"	66	12.02	67	12.19
35'-0"	67	12.19	68	12.36
35'-6"	68	12.36	69	12.53
36'-0"	69	12.53	70	12.70
36'-6"	70	12.70	71	12.87
37'-0"	71	12.87	72	13.04
37'-6"	72	13.04	73	13.21
38'-0"	73	13.21	74	13.38
38'-6"	74	13.38	75	13.55
39'-0"	75	13.55	76	13.72
39'-6"	76	13.72	77	13.89
40'-0"	77	13.89	78	14.06
40'-6"	78	14.06	79	14.23
41'-0"	79	14.23	80	14.40
41'-6"	80	14.40	81	14.57
42'-0"	81	14.57	82	14.74
42'-6"	82	14.74	83	14.91
43'-0"	83	14.91	84	15.08
43'-6"	84	15.08	85	15.25
44'-0"	85	15.25	86	15.42
44'-6"	86	15.42	87	15.59
45'-0"	87	15.59	88	15.76
45'-6"	88	15.76	89	15.93
46'-0"	89	15.93	90	16.10
46'-6"	90	16.10	91	16.27
47'-0"	91	16.27	92	16.44
47'-6"	92	16.44	93	16.61
48'-0"	93	16.61	94	16.78
48'-6"	94	16.78	95	16.95
49'-0"	95	16.95	96	17.12
49'-6"	96	17.12	97	17.29
50'-0"	97	17.29	98	17.46
50'-6"	98	17.46	99	17.63
51'-0"	99	17.63	100	17.80
51'-6"	100	17.80	101	17.97
52'-0"	101	17.97	102	18.14
52'-6"	102	18.14	103	18.31
53'-0"	103	18.31	104	18.48
53'-6"	104	18.48	105	18.65
54'-0"	105	18.65	106	18.82
54'-6"	106	18.82	107	18.99
55'-0"	107	18.99	108	19.16
55'-6"	108	19.16	109	19.33
56'-0"	109	19.33	110	19.50
56'-6"	110	19.50	111	19.67
57'-0"	111	19.67	112	19.84
57'-6"	112	19.84	113	20.01
58'-0"	113	20.01	114	20.18
58'-6"	114	20.18	115	20.35
59'-0"	115	20.35	116	20.52
59'-6"	116	20.52	117	20.69
60'-0"	117	20.69	118	20.86
60'-6"	118	20.86	119	21.03
61'-0"	119	21.03	120	21.20
61'-6"	120	21.20	121	21.37
62'-0"	121	21.37	122	21.54
62'-6"	122	21.54	123	21.71
63'-0"	123	21.71	124	21.88
63'-6"	124	21.88	125	22.05
64'-0"	125	22.05	126	22.22
64'-6"	126	22.22	127	22.39
65'-0"	127	22.39	128	22.56
65'-6"	128	22.56	129	22.73
66'-0"	129	22.73	130	22.90
66'-6"	130	22.90	131	23.07
67'-0"	131	23.07	132	23.24
67'-6"	132	23.24	133	23.41
68'-0"	133	23.41	134	23.58
68'-6"	134	23.58	135	23.75
69'-0"	135	23.75	136	23.92
69'-6"	136	23.92	137	24.09
70'-0"	137	24.09	138	24.26
70'-6"	138	24.26	139	24.43
71'-0"	139	24.43	140	24.60
71'-6"	140	24.60	141	24.77
72'-0"	141	24.77	142	24.94
72'-6"	142	24.94	143	25.11
73'-0"	143	25.11	144	25.28
73'-6"	144	25.28	145	25.45
74'-0"	145	25.45	146	25.62
74'-6"	146	25.62	147	25.79
75'-0"	147	25.79	148	25.96
75'-6"	148	25.96	149	26.13
76'-0"	149	26.13	150	26.30
76'-6"	150	26.30	151	26.47
77'-0"	151	26.47	152	26.64
77'-6"	152	26.64	153	26.81
78'-0"	153	26.81	154	26.98
78'-6"	154	26.98	155	27.15
79'-0"	155	27.15	156	27.32
79'-6"	156	27.32	157	27.49
80'-0"	157	27.49	158	27.66
80'-6"	158	27.66	159	27.83
81'-0"	159	27.83	160	28.00
81'-6"	160	28.00	161	28.17
82'-0"	161	28.17	162	28.34
82'-6"	162	28.34	163	28.51
83'-0"	163	28.51	164	28.68
83'-6"	164	28.68	165	28.85
84'-0"	165	28.85	166	29.02
84'-6"	166	29.02	167	29.19
85'-0"	167	29.19	168	29.36
85'-6"	168	29.36	169	29.53
86'-0"	169	29.53	170	29.70
86'-6"	170	29.70	171	29.87
87'-0"	171	29.87	172	30.04
87'-6"	172	30.04	173	30.21
88'-0"	173	30.21	174	30.38
88'-6"	174	30.38	175	30.55
89'-0"	175	30.55	176	30.72
89'-6"	176	30.72	177	30.89
90'-0"	177	30.89	178	31.06
90'-6"	178	31.06	179	31.23
91'-0"	179	31.23	180	31.40
91'-6"	180	31.40	181	31.57
92'-0"	181	31.57	182	31.74
92'-6"	182	31.74	183	31.91
93'-0"	183	31.91	184	32.08
93'-6"	184	32.08	185	32.25
94'-0"	185	32.25	186	32.42
94'-6"	186	32.42	187	32.59
95'-0"	187	32.59	188	32.76
95'-6"	188	32.76	189	32.93
96'-0"	189	32.93	190	33.10
96'-6"	190	33.10	191	33.27
97'-0"	191	33.27	192	33.44
97'-6"	192	33.44	193	33.61
98'-0"	193	33.61	194	33.78
98'-6"	194	33.78	195	33.95
99'-0"	195	33.95	196	34.12
99'-6"	196	34.12	197	34.29
100'-0"	197	34.29	198	34.46
100'-6"	198	34.46	199	34.63
101'-0"	199	34.63	200	34.80
101'-6"	200	34.80	201	34.97
102'-0"	201	34.97	202	35.14
102'-6"	202	35.14	203	35.31
103'-0"	203	35.31	204	35.48
103'-6"	204	35.48	205	35.65
104'-0"	205	35.65	206	35.82
104'-6"	206	35.82	207	35.99
105'-0"	207	35.99	208	36.16
105'-6"	208	36.16	209	36.33
106'-0"	209	36.33	210	36.50
106'-6"	210	36.50	211	36.67
107'-0"	211	36.67	212	36.84
107'-6"	212	36.84	213	37.01
108'-0"	213	37.01	214	37.18
108'-6"	214	37.18	215	37.35
109'-0"	215	37.35	216	37.52
109'-6"	216	37.52	217	37.69
110'-0"	217	37.69	218	37.86
110'-6"	218	37.86	219	38.03
111'-0"	219	38.03	220	38.20
111'-6"	220	38.20	221	38.37
112'-0"	221	38.37	222	38.54
112'-6"	222	38.54	223	38.71
113'-0"	223	38.71	224	38.88
113'-6"	224	38.88	225	39.05
114'-0"	225	39.05	226	39.22
114'-6"	226	39.22	227	39.39
115'-0"	227	39.39	228	39.56
115'-6"	228	39.56	229	39.73
116'-0"	229	39.73	230	39.90
116'-6"	230	39.90	231	40.07
117'-0"	231	40.07	232	40.24
117'-6"	232	40.24	233	40.41
118'-0"	233	40.41	234	40.58
118'-6"	234	40.58	235	40.75
119'-0"	235	40.75	236	40.92
119'-6"	236	40.92	237	41.09
120'-0"	237	41.09	238	41.26
120'-6"	238	41.26	239	41.43
121'-0"	239	41.43	240	41.60
121'-6"	240	41.60	241	41.77
122'-0"	241	41.77	242	41.94
122'-6"	242	41.94	243	42.11
123'-0"	243	42.11	244	42.28
123'-6"	244	42.28	245	42.45

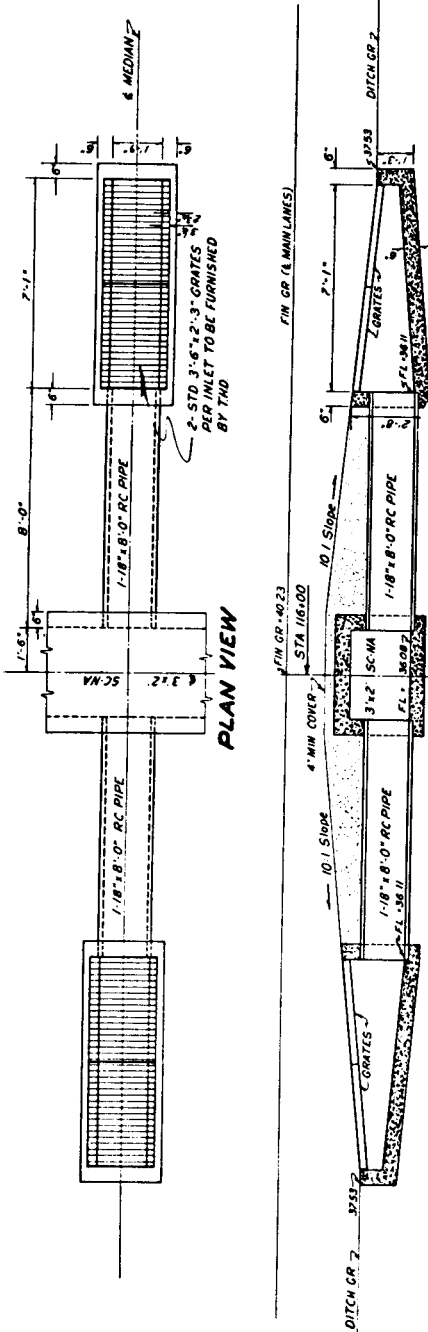
TEXAS

QUANTITIES FOR TWO DROP INLETS

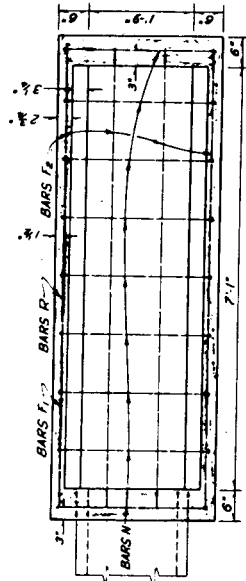
BARS	NO	SIZE	SPAC	LENGTH	WEIGHT
F	8	#4	7"	7'-9"	41
L	8	#4	10"	7'-9"	41
N	18	#4	11"	5'-7 1/2"	67
R	4	#4	—	11'-0"	29
REINF STEEL				1.8	178
CL A CONC				0.9	170
RC PIPE (CL III) (8 IN)				2.7	76

GENERAL NOTES:

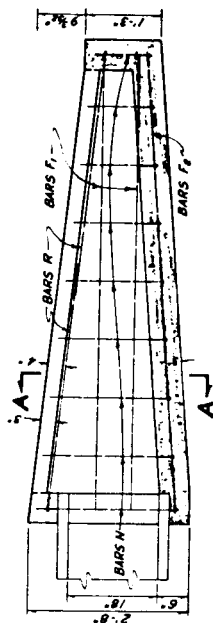
- ALL CONCRETE SHALL BE CLASS A. CHAMFER EXPOSED CORNERS 3/4"
- ALL DIMENSIONS RELATING TO REINFORCING STEEL ARE TO CENTERS OF BARS
- REINFORCING STEEL IN WALLS OF SC-MA BOX SHALL BE MODIFIED BY BENDING OR CUTTING AS DIRECTED BY THE ENGINEER TO GIVE THE RC PIPE 2" CLEARANCE.



PROFILE VIEW

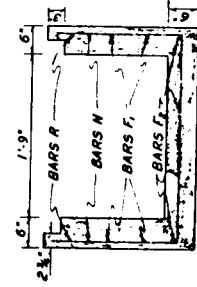


REINF STEEL PLAN VIEW



PROFILE VIEW

INLET BOX DETAIL



SECTION A-A

DROP INLET DETAILS

STA 116+00

FIELD CHANGE NO 1

TEXAS

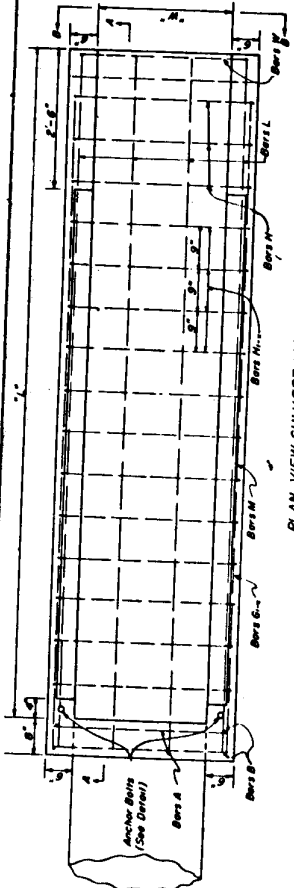
NO.	DATE	BY	CHKD
1	5-15-16	1-20	
2			
3			
4			
5			
6			

Table of Dimensions and Quantities for One Headwall

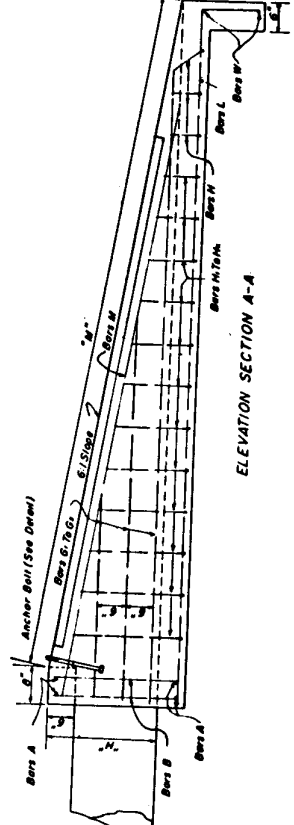
Table of Dimensions		Bill of Materials		Bill of Materials		Bill of Materials		Bill of Materials	
Span	Depth	No. Bars	Length	No. Bars	Length	No. Bars	Length	No. Bars	Length
3	29	4	15'-0"	4	15'-0"	4	15'-0"	4	15'-0"
4	36	4	18'-0"	4	18'-0"	4	18'-0"	4	18'-0"
5	43	4	21'-0"	4	21'-0"	4	21'-0"	4	21'-0"

Quantities for One Headwall (Cont.)

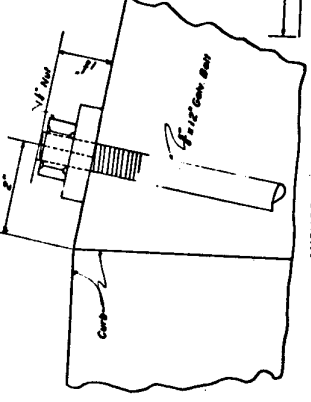
Total Quantities		Steel		Concrete	
Span	Depth	Lbs	Cu Yds	Lbs	Cu Yds
3	29	157	1.38	1.65	2.49
4	36	185	1.65	1.96	2.92
5	43	248	2.49	4.3	6.4



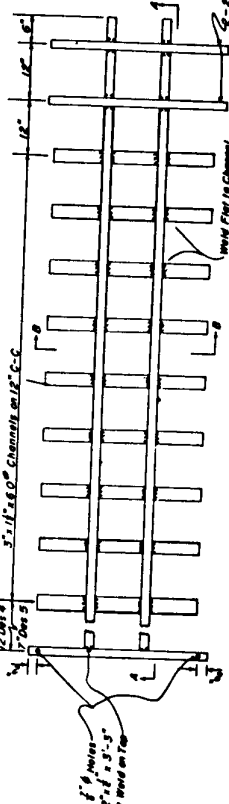
PLAN VIEW CULVERT WINGWALL



ELEVATION SECTION A-A



ANCHOR BOLT DETAIL

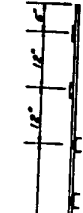


PLAN GRATE DETAIL TYPE C FOR DESIGN 3, 4, 5 CON PIPE

Bill of Steel for One Grate (Type C)

Bar No.	Design 3		Design 4		Design 5	
	Flt	Chan	Flt	Chan	Flt	Chan
1	3	3	3	3	3	3
2	3	3	3	3	3	3
3	3	3	3	3	3	3
4	3	3	3	3	3	3
5	3	3	3	3	3	3
6	3	3	3	3	3	3
7	3	3	3	3	3	3
8	3	3	3	3	3	3
9	3	3	3	3	3	3
10	3	3	3	3	3	3
11	3	3	3	3	3	3
12	3	3	3	3	3	3
13	3	3	3	3	3	3
14	3	3	3	3	3	3
15	3	3	3	3	3	3
16	3	3	3	3	3	3
17	3	3	3	3	3	3
18	3	3	3	3	3	3
19	3	3	3	3	3	3
20	3	3	3	3	3	3
21	3	3	3	3	3	3
22	3	3	3	3	3	3
23	3	3	3	3	3	3
24	3	3	3	3	3	3
25	3	3	3	3	3	3
26	3	3	3	3	3	3
27	3	3	3	3	3	3
28	3	3	3	3	3	3
29	3	3	3	3	3	3
30	3	3	3	3	3	3
31	3	3	3	3	3	3
32	3	3	3	3	3	3
33	3	3	3	3	3	3
34	3	3	3	3	3	3
35	3	3	3	3	3	3
36	3	3	3	3	3	3
37	3	3	3	3	3	3
38	3	3	3	3	3	3
39	3	3	3	3	3	3
40	3	3	3	3	3	3
41	3	3	3	3	3	3
42	3	3	3	3	3	3
43	3	3	3	3	3	3
44	3	3	3	3	3	3
45	3	3	3	3	3	3
46	3	3	3	3	3	3
47	3	3	3	3	3	3
48	3	3	3	3	3	3
49	3	3	3	3	3	3
50	3	3	3	3	3	3
51	3	3	3	3	3	3
52	3	3	3	3	3	3
53	3	3	3	3	3	3
54	3	3	3	3	3	3
55	3	3	3	3	3	3
56	3	3	3	3	3	3
57	3	3	3	3	3	3
58	3	3	3	3	3	3
59	3	3	3	3	3	3
60	3	3	3	3	3	3
61	3	3	3	3	3	3
62	3	3	3	3	3	3
63	3	3	3	3	3	3
64	3	3	3	3	3	3
65	3	3	3	3	3	3
66	3	3	3	3	3	3
67	3	3	3	3	3	3
68	3	3	3	3	3	3
69	3	3	3	3	3	3
70	3	3	3	3	3	3
71	3	3	3	3	3	3
72	3	3	3	3	3	3
73	3	3	3	3	3	3
74	3	3	3	3	3	3
75	3	3	3	3	3	3
76	3	3	3	3	3	3
77	3	3	3	3	3	3
78	3	3	3	3	3	3
79	3	3	3	3	3	3
80	3	3	3	3	3	3
81	3	3	3	3	3	3
82	3	3	3	3	3	3
83	3	3	3	3	3	3
84	3	3	3	3	3	3
85	3	3	3	3	3	3
86	3	3	3	3	3	3
87	3	3	3	3	3	3
88	3	3	3	3	3	3
89	3	3	3	3	3	3
90	3	3	3	3	3	3
91	3	3	3	3	3	3
92	3	3	3	3	3	3
93	3	3	3	3	3	3
94	3	3	3	3	3	3
95	3	3	3	3	3	3
96	3	3	3	3	3	3
97	3	3	3	3	3	3
98	3	3	3	3	3	3
99	3	3	3	3	3	3
100	3	3	3	3	3	3

SECTION B-B GRATE DETAIL



SECTION A-A GRATE DETAIL



General Notes
 All Concrete Shall Be Class A
 All Exposed Corners Shall Be Chamfered
 Reinforcing Steel Shall Be Placed With The Centers
 Of The Bars 2" From The Surface Of The Concrete

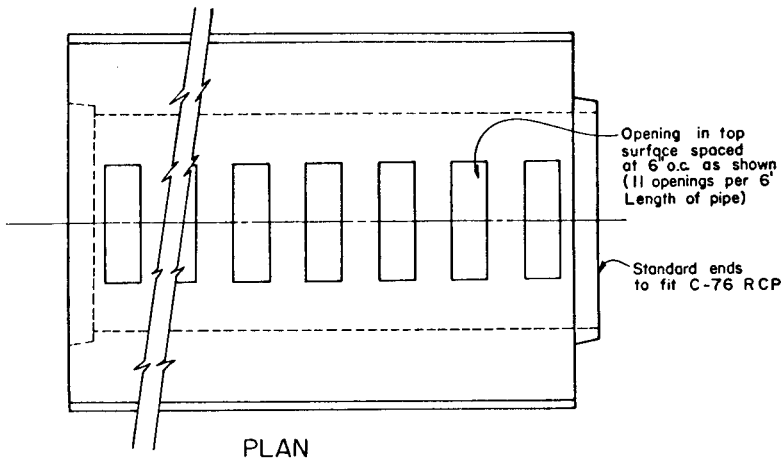
TEXAS HIGHWAY DEPARTMENT
 SPECIAL MEDIAN PIPE CULVERT
 HEADWALLS
 WITH TYPE C INLET GRATES

NO.	DATE	REVISION
1	1-10-57	1066
2	1-10-57	1066
3	1-10-57	1066
4	1-10-57	1066
5	1-10-57	1066

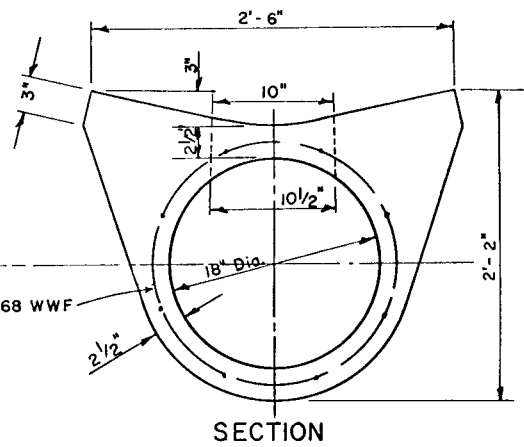
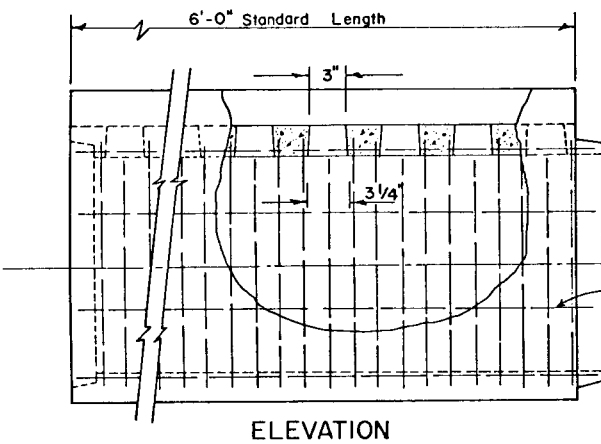
2-127

2-127

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



Weight = 324 #/L.F.

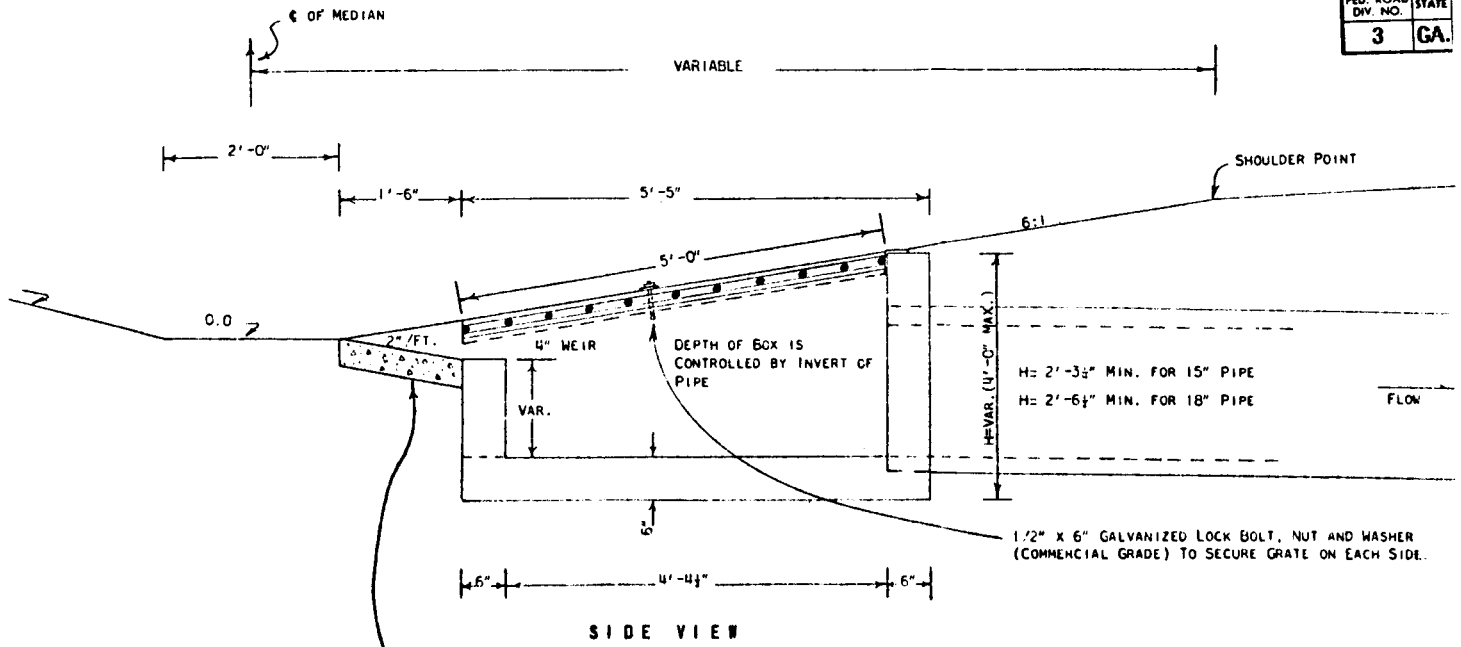


NOTE:

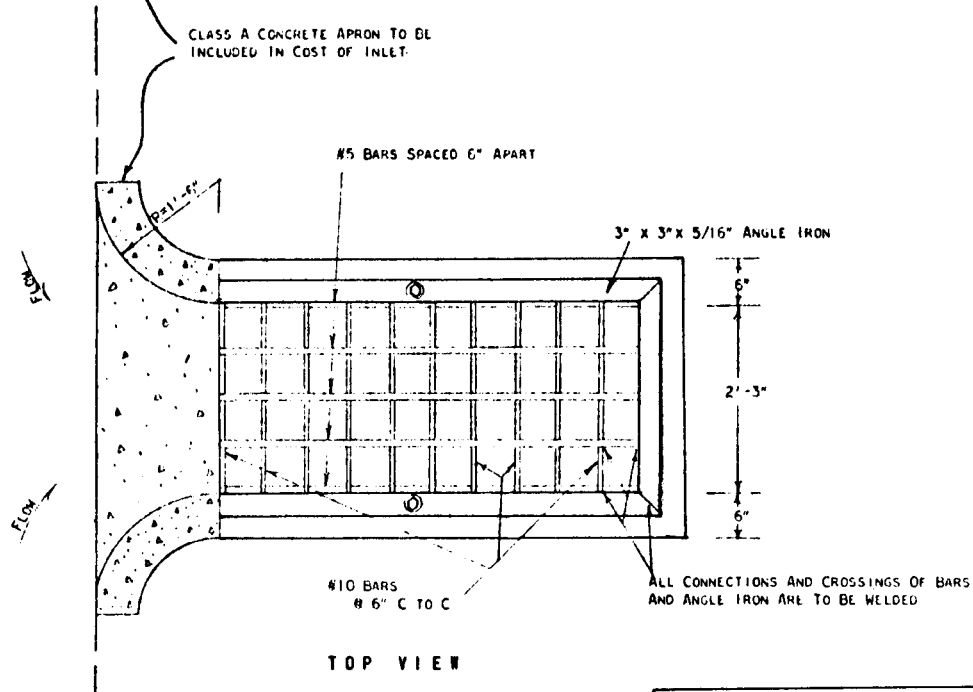
A 2 3/4" thick by 18" diameter end plug, reinforced with 28-68 WWF shall be furnished at locations called for. No separate measurement or payment will be made for end plugs, all costs for same being included in the price for "Slotted Reinforced Concrete Pipe."

SOUTH DAKOTA DEPARTMENT OF HIGHWAYS DETAILS OF SLOTTED REINFORCED CONCRETE PIPE FOR EROSION CONTROL Prepared in Plans Section	STANDARD PLATE No. 127
---	---------------------------------

FED. ROAD DIV. NO.	STATE
3	GA.



SIDE VIEW



TOP VIEW

**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

<i>Rep. No.</i>	<i>Title</i>	<i>Rep. No.</i>	<i>Title</i>
—*	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	18	Community Consequences of Highway Improvement (Proj. 2-2), 37 p., \$2.80
1	Evaluation of Methods of Replacement of Deteriorated Concrete in Structures (Proj. 6-8), 56 p., \$2.80	19	Economical and Effective Deicing Agents for Use on Highway Structures (Proj. 6-1), 19 p., \$1.20
2	An Introduction to Guidelines for Satellite Studies of Pavement Performance (Proj. 1-1), 19 p., \$1.80	20	Economic Study of Roadway Lighting (Proj. 5-4), 77 p., \$3.20
2A	Guidelines for Satellite Studies of Pavement Performance, 85 p.+9 figs., 26 tables, 4 app., \$3.00	21	Detecting Variations in Load-Carrying Capacity of Flexible Pavements (Proj. 1-5), 30 p., \$1.40
3	Improved Criteria for Traffic Signals at Individual Intersections—Interim Report (Proj. 3-5), 36 p., \$1.60	22	Factors Influencing Flexible Pavement Performance (Proj. 1-3(2)), 69 p., \$2.60
4	Non-Chemical Methods of Snow and Ice Control on Highway Structures (Proj. 6-2), 74 p., \$3.20	23	Methods for Reducing Corrosion of Reinforcing Steel (Proj. 6-4), 22 p., \$1.40
5	Effects of Different Methods of Stockpiling Aggregates—Interim Report (Proj. 10-3), 48 p., \$2.00	24	Urban Travel Patterns for Airports, Shopping Centers, and Industrial Plants (Proj. 7-1), 116 p., \$5.20
6	Means of Locating and Communicating with Disabled Vehicles—Interim Report (Proj. 3-4), 56 p., \$3.20	25	Potential Uses of Sonic and Ultrasonic Devices in Highway Construction (Proj. 10-7), 48 p., \$2.00
7	Comparison of Different Methods of Measuring Pavement Condition—Interim Report (Proj. 1-2), 29 p., \$1.80	26	Development of Uniform Procedures for Establishing Construction Equipment Rental Rates (Proj. 13-1), 33 p., \$1.60
8	Synthetic Aggregates for Highway Construction (Proj. 4-4), 13 p., \$1.00	27	Physical Factors Influencing Resistance of Concrete to Deicing Agents (Proj. 6-5), 41 p., \$2.00
9	Traffic Surveillance and Means of Communicating with Drivers—Interim Report (Proj. 3-2), 28 p., \$1.60	28	Surveillance Methods and Ways and Means of Communicating with Drivers (Proj. 3-2), 66 p., \$2.60
10	Theoretical Analysis of Structural Behavior of Road Test Flexible Pavements (Proj. 1-4), 31 p., \$2.80	29	Digital-Computer-Controlled Traffic Signal System for a Small City (Proj. 3-2), 82 p., \$4.00
11	Effect of Control Devices on Traffic Operations—Interim Report (Proj. 3-6), 107 p., \$5.80	30	Extension of AASHO Road Test Performance Concepts (Proj. 1-4(2)), 33 p., \$1.60
12	Identification of Aggregates Causing Poor Concrete Performance When Frozen—Interim Report (Proj. 4-3(1)), 47 p., \$3.00	31	A Review of Transportation Aspects of Land-Use Control (Proj. 8-5), 41 p., \$2.00
13	Running Cost of Motor Vehicles as Affected by Highway Design—Interim Report (Proj. 2-5), 43 p., \$2.80	32	Improved Criteria for Traffic Signals at Individual Intersections (Proj. 3-5), 134 p., \$5.00
14	Density and Moisture Content Measurements by Nuclear Methods—Interim Report (Proj. 10-5), 32 p., \$3.00	33	Values of Time Savings of Commercial Vehicles (Proj. 2-4), 74 p., \$3.60
15	Identification of Concrete Aggregates Exhibiting Frost Susceptibility—Interim Report (Proj. 4-3(2)), 66 p., \$4.00	34	Evaluation of Construction Control Procedures—Interim Report (Proj. 10-2), 117 p., \$5.00
16	Protective Coatings to Prevent Deterioration of Concrete by Deicing Chemicals (Proj. 6-3), 21 p., \$1.60	35	Prediction of Flexible Pavement Deflections from Laboratory Repeated-Load Tests (Proj. 1-3(3)), 117 p., \$5.00
17	Development of Guidelines for Practical and Realistic Construction Specifications (Proj. 10-1), 109 p., \$6.00	36	Highway Guardrails—A Review of Current Practice (Proj. 15-1), 33 p., \$1.60
		37	Tentative Skid-Resistance Requirements for Main Rural Highways (Proj. 1-7), 80 p., \$3.60
		38	Evaluation of Pavement Joint and Crack Sealing Materials and Practices (Proj. 9-3), 40 p., \$2.00
		39	Factors Involved in the Design of Asphaltic Pavement Surfaces (Proj. 1-8), 112 p., \$5.00
		40	Means of Locating Disabled or Stopped Vehicles (Proj. 3-4(1)), 40 p., \$2.00
		41	Effect of Control Devices on Traffic Operations (Proj. 3-6), 83 p., \$3.60

* Highway Research Board Special Report 80.

<i>Rep. No.</i>	<i>Title</i>		
42	Interstate Highway Maintenance Requirements and Unit Maintenance Expenditure Index (Proj. 14-1),	144 p.,	\$5.60
43	Density and Moisture Content Measurements by Nuclear Methods (Proj. 10-5),	38 p.,	\$2.00
44	Traffic Attraction of Rural Outdoor Recreational Areas (Proj. 7-2),	28 p.,	\$1.40
45	Development of Improved Pavement Marking Materials—Laboratory Phase (Proj. 5-5),	24 p.,	\$1.40
46	Effects of Different Methods of Stockpiling and Handling Aggregates (Proj. 10-3),	102 p.,	\$4.60
47	Accident Rates as Related to Design Elements of Rural Highways (Proj. 2-3),	173 p.,	\$6.40
48	Factors and Trends in Trip Length (Proj. 7-4),	70 p.,	\$3.20
49	National Survey of Transportation Attitudes and Behavior—Phase I Summary Report (Proj. 20-4),	71 p.,	\$3.20
50	Factors Influencing Safety at Highway-Rail Grade Crossing (Proj. 3-8),	113 p.,	\$5.20
51	Sensing and Communication Between Vehicles (Proj. 3-3),	105 p.,	\$5.00
52	Measurement of Pavement Thickness by Rapid and Nondestructive Methods (Proj. 10-6),	82 p.,	\$3.80
53	Multiple Use of Lands Within Highway Rights-of-Way (Proj. 7-6),	68 p.,	\$3.20
54	Location, Selection, and Maintenance of Highway Guardrail and Median Barriers (Proj. 15-1(2)),	63 p.,	\$2.60
55	Research Needs in Highway Transportation (Proj. 20-2),	66 p.,	\$2.80
56	Scenic Easements—Legal, Administrative, and Valuation Problems and Procedures (Proj. 11-3),	174 p.,	\$6.40
57	Factors Influencing Modal Trip Assignment (Proj. 8-2),	78 p.,	\$3.20
58	Comparative Analysis of Traffic Assignment Techniques with Actual Highway Use (Proj. 7-5),	85 p.,	\$3.60
59	Standard Measurements for Satellite Road Test Program (Proj. 1-6),	78 p.,	\$3.20
60	Effects of Illumination on Operating Characteristics of Freeways (Proj. 5-2)	148 p.,	\$6.00
61	Evaluation of Studded Tires—Performance Data and Pavement Wear Measurement (Proj. 1-9),	66 p.,	\$3.00
62	Urban Travel Patterns for Hospitals, Universities, Office Buildings and Capitols (Proj. 7-1),	144 p.,	\$5.60
63	Motorists' Needs and Services on Interstate Highways (Proj. 7-7),	88 p.,	\$3.60

<i>Rep. No.</i>	<i>Title</i>		
64	One-Cycle Slow-Freeze Test for Evaluating Aggregate Performance in Frozen Concrete (Proj. 4-3(1)),	21 p.,	\$1.40
65	Identification of Frost-Susceptible Particles in Concrete Aggregates (Proj. 4-3(2)),	62 p.,	\$2.80
66	Relation of Asphalt Rheological Properties to Pavement Durability (Proj. 9-1),	45 p.,	\$2.20
67	Relation of Asphalt Rheological Properties to Pavement Durability (Proj. 9-1),	45 p.,	\$2.20
68	Application of Vehicle Operating Characteristics to Geometric Design and Traffic Operations (Proj. 3-10),	38 p.,	\$2.00
69	Evaluation of Construction Control Procedures—Aggregate Gradation Variations and Effects (Proj. 10-2A),	58 p.,	\$2.80
70	Social and Economic Factors Affecting Intercity Travel (Proj. 8-1),	68 p.,	\$3.00
71	Analytical Study of Weighing Methods for Highway Vehicles in Motion (Proj. 7-3),	63 p.,	\$2.80
72	Theory and Practice in Inverse Condemnation for Five Representative States (Proj. 11-2),	44 p.,	\$2.20
73	Improved Criteria for Traffic Signal Systems on Urban Arterials (Proj. 3-5/1),	55 p.,	\$2.80
74	Protective Coatings for Highway Structural Steel (Proj. 4-6),	64 p.,	\$2.80
75	Effect of Highway Landscape Development on Nearby Property (Proj. 2-9),	82 p.,	\$3.60
76	Detecting Seasonal Changes in Load-Carrying Capabilities of Flexible Pavements (Proj. 1-5(2)),	38 p.,	\$2.00
77	Development of Design Criteria for Safer Luminaire Supports (Proj. 15-6),	82 p.,	\$3.80
78	Highway Noise—Measurement, Simulation, and Mixed Reactions (Proj. 3-7),	78 p.,	\$3.20

Synthesis of Highway Practice

- 1 Traffic Control for Freeway Maintenance (Proj. 20-5, Topic 1), 47 p., \$2.20
- 2 Bridge Approach Design and Construction Practices (Proj. 20-5, Topic 2), 30 p., \$2.00
- 3 Traffic-Safe and Hydraulically Efficient Drainage Practice (Proj. 20-5, Topic 4), 38 p., \$2.20