

HIGHWAY
EXTENSION
AND
RESearch
PROJECT
IFOR
COUNTIES

**Principles of
Highway Drainage
and
Erosion Control**

PURDUE UNIVERSITY—ENGINEERING EXPERIMENT STATION

in cooperation with

THE COUNTY COMMISSIONERS OF INDIANA

COUNTY HIGHWAY SERIES—No. 4

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HIGHWAY EXTENSION AND RESEARCH AT PURDUE

The Highway Extension and Research Project for Indiana Counties was organized in July 1959 to carry on extension and research programs specifically for County Highway Departments throughout the state of Indiana. The Project was organized as a result of legislation designating Purdue University through its Engineering Experiment Station and School of Civil Engineering as the agency to perform this service. The intent of the legislation was that the University through the School of Civil Engineering should extend its existing highway research and extension program at the county level to assist and guide county highway officials in their problems of planning, design, operation, and management of the county departments throughout the state.

The Highway Extension and Research Project for Indiana Counties (HERPIC) operates as a cooperative effort between the county commissioners of Indiana and Purdue University. As a relatively new organization the HERPIC program is still being developed. However, initial effort is directed toward providing guide manuals that set forth recommended procedures on important topics. In addition regional workshop conferences are held in various parts of the state, and at these conferences typical county road problems of the specific area are reviewed.

An older and more widely known highway research and extension organization is the Joint Highway Research Project which has operated since 1936 as a cooperative effort between the Indiana State Highway Department and Purdue University. Since its inception the Joint Highway Research Project has made many significant contributions toward the improvement of highway design and operational procedures at both state and local levels. In addition the Joint Highway Research Project sponsors the Annual Purdue Road School, an activity that brings together people from all segments of the highway industry and provides an opportunity to develop better relationships through discussion of mutual problems.

COUNTY HIGHWAY SERIES

**principles of highway
drainage
and erosion control**

compiled by

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HIGHWAY DRAINAGE AND EROSION CONTROL

PURPOSE AND IMPORTANCE

Excess water is Highway Enemy No. 1. Uncontrolled water is the primary cause of broken or soft surfaces, mudholes, rutting, washed out shoulders, and even loss of complete sections of roadway or structures. Prevention of such failures makes roads safer for motorists and pedestrians, reduces maintenance costs, and adds immeasurably to the pleasure and satisfaction in use of the roads for business and recreation.

The cost of controlling water is a significant part of total highway expense, which indicates the importance of the subject to highway personnel. Approximately a quarter of the cost of new construction is for drainage or erosion control. The proportion of maintenance costs directly related to control of water is probably much greater. Erosion is a particularly expensive factor because it costs money in two ways—soil lost must be replaced and soil deposited in drainage structures must be cleaned out. It is important, therefore, to plan and develop, carefully, adequate facilities for drainage, and measures for controlling erosion.

Control of nearly 80 per cent of the road mileage in Indiana is in the hands of local highway personnel. The extent to which they apply sound principles of highway drainage and erosion control determines in part the condition and cost of Indiana roads. What are these principles?

A cardinal rule would be to **interfere with nature's drainage as little as possible**. Ideally, this might be done by putting all roads along ridges or drainage divides. For most roads, however, location is already determined and minimum interference with nature will mean to stabilize earth surfaces with some kind of cover, to provide a place for water to run freely over the surface in ditches or underground in culverts and subdrains, to conduct the collected water safely to a natural watercourse, and to encourage landowners to use the soil in accordance with good agricultural and conservation practice.

This manual is an attempt to describe the important principles involved in these measures, and to describe some specific applications of those principles.

SLOPE PROTECTION

Sound slope protection is based on six fundamental principles:

1. Keep slopes flat and edges well rounded to reduce erosion potential to a minimum.
2. Establish a healthy, continuous vegetal cover as quickly as possible.
3. Intercept water from higher ground before it reaches slopes susceptible to erosion.
4. Provide safe outlets for water collected in intercepting ditches and gutters.
5. Protect slopes from freely flowing underground water.
6. Take special precautions around structures which protrude above slope surfaces.

Steepness of Slope

Highway slopes should be stable so as to remain uniform with a minimum of maintenance. The first step in accomplishing this is to construct cuts and fills as flat as is economically feasible. In flat or gently rolling country many slopes can be 3:1 or 4:1. (A slope of 3:1 means 3 ft of horizontal distance per foot of vertical distance.) In hilly country and around structures, high costs and



Fig. 1. A flatter cut slope would improve sight distance and establishment of vegetal cover.

limited right-of-way will require slopes as steep as 2:1. Though most soils will stand at slopes of $1\frac{1}{2}$:1, such steep slopes are difficult to maintain and are generally undesirable for earth cuts and fills. Rock cuts, of course, can be much steeper—up to $\frac{1}{2}$:1 or $\frac{1}{4}$:1 in sound rock.

Flat slopes have advantages of ease of construction and seeding, fewer washouts during early stages of cover growth and permitting use of machinery for maintenance. Tractor operated equipment tends to dig up turf on slopes steeper than 3:1 and generally cannot be operated at all on slopes steeper than 2:1. Water flows gently, in sheets, over flat slopes, but rapidly, in erosive streams, on steep slopes. The “streamlined” shape of relatively flat slopes presents little interference to the wind, therefore reduces snow drifting and encourages the sweeping action of the wind on the roadway, helping to keep costs of snow removal down. In addition, flat

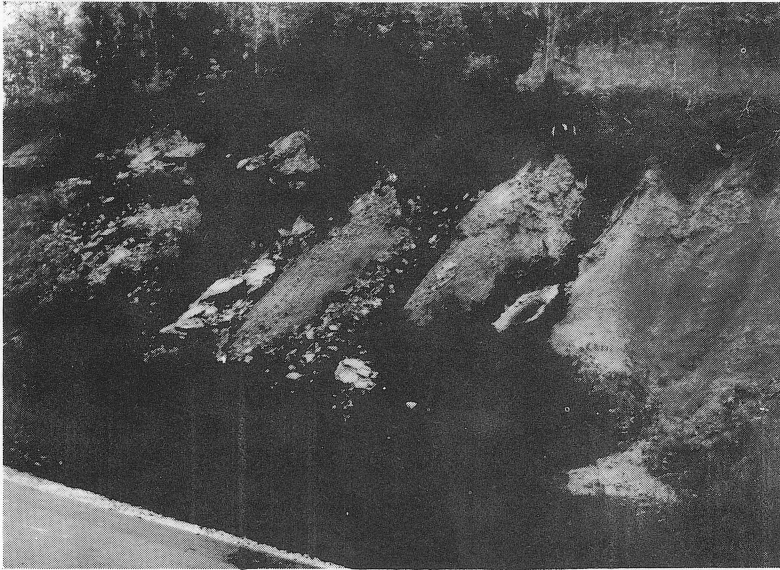


Fig. 2. A vigorous turf cover is needed to stabilize this slope. Stopping erosion would improve drainage and eliminate the clean up problem.

slopes (4:1 or less) are safer because a vehicle can move onto these slopes in an emergency with little danger of serious accident. Flat cut slopes on curves also provide greater sight distance.

Even though flat slopes require larger volumes of cut and fill than steep slopes, their benefits in increased safety and reduced maintenance justify their use. For these reasons cut and fill slopes

of 4:1 or flatter are preferred whenever practical. In rugged, hilly country, as is typical in the southern counties of Indiana, slopes as steep as 3:1, and 2:1, will be necessary in most cases. Even in relatively flat areas, when fills higher than 5' to 10 ft are necessary, right-of-way limitations will require the steeper slopes. In any case, 2:1 should be considered a maximum acceptable slope except in extremely difficult conditions of steep land and insufficient right-of-way.

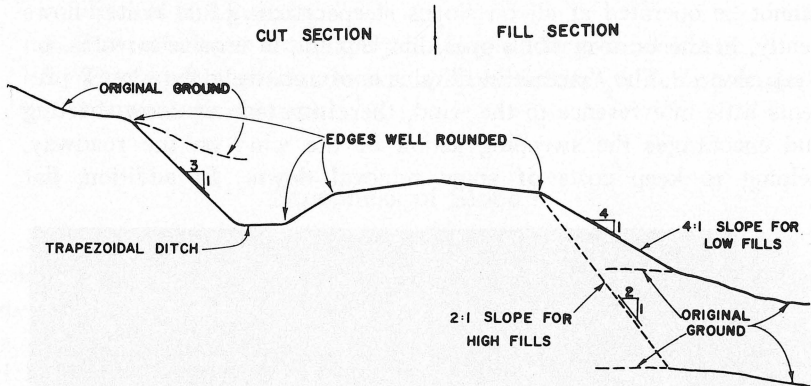


Fig. 3. Cross section properties which are especially important in maintaining stable roadways include flat slopes with well rounded edges and adequate ditches. Slopes preferably should be 4:1 or flatter. Vegetal protection is essential.

Edges of slopes where cut or fill surfaces meet the natural ground surface should be well rounded. Sharp edges encourage water and wind erosion, and are difficult places to get vegetation started. At sharp intersections of surfaces water forms gullies which get progressively worse. Also, wind eddies are created at sharp edges, picking up soil and blowing it away. This is greatly reduced by blending surfaces in freely rounded intersections.

For Maximum Stability and Safety Strive for Slopes of 4:1 or Flatter and Round the Intersections of Slopes with Natural Ground.

Vegetal Cover

Flat slopes are desirable for stability, but no exposed slope will remain uniform unless protected from rain and wind by a healthy stand of some vegetation, usually grass, legumes, or shrubs.

Choice of Species

If soil and moisture conditions are suitable, grass is usually the most economical cover for protecting slopes from erosion. In Indiana an excellent turf is formed by a 4 to 1 mixture of tall fescue and bluegrass. The fescue (either Alta or Kentucky 31) is quick starting and will provide early protection. Bluegrass fills out the turf forming a firm uniform sod which, with proper maintenance, will provide a satisfactory permanent cover.

Where conditions are unfavorable for grasses, such as low fertility and free draining soil, where the soil is particularly erosive, or where slopes are too steep to operate mowing equipment, Penn-gift Crown Vetch will provide a strong, dense cover. The Vetch is slow to develop, therefore slopes must also be seeded to fescue and bluegrass to get early temporary protection. The advantages appear after two or three growing seasons, when the Crown Vetch is well established, because it practically eliminates maintenance. Weeds are choked out; spraying and mowing are unnecessary; fertilizing is reduced to a minimum; and dense root systems, stems and foliage so thoroughly protect the soil that very little is washed away to be deposited in ditches or culverts. A desirable by-product of protecting slopes with Crown Vetch is the attractive appearance when the plant is in bloom for several weeks each summer.



Fig. 4. The excellent protection provided by Crown Vetch is illustrated on this steep embankment slope. (Courtesy W. H. Daniels)

When the road runs through wooded areas extensive slopes of mowed grass may look out of place. In such cases a basic grass mixture may be sown for quick protection of an exposed slope, but natural growth encouraged to take over. Once the grass is there to hold soil in place only that area necessary for sight distance and for clear, open ditches is mowed. In the remainder of the slopes natural woody growth may be allowed to come in to provide a ground cover which blends into the surroundings pleasantly and at the same time eliminates a great deal of mowing and fertilizing.



Fig. 5. A well protected slope where native woody growth has been allowed to take over.

Another use for woody plants is to keep costs down in an area where shrubs are readily available near the road. Such ground hugging plants as juniper, lowbush blueberry and sweet fern will serve very satisfactorily where erosive conditions are not too severe, and if they can be acquired freely adjacent to the work they may prove an economical solution to the problem of stabilizing a slope face.

Soil Preparation

Proper soil preparation is essential to insure rapid establishment of cover. The soil surface should be loosened by scarifying, harrowing, or raking. How much fertilizer and lime should be used?

One hundred pounds per acre each of nitrogen, phosphorus, and potassium is a good standard application for seedbeds. This can be provided by 20 lb per 1000 sq ft or 870 lb per acre of 12-12-12 or equal. It is still better to get a soil test and follow the recommendation of the testing agency. A soil test should always be obtained before applying lime to the seedbed as many Indiana soils will not require any lime. With this treatment most Indiana soils will support a satisfactory turf. In cases of exceptionally clean and well drained gravels it is desirable to spread 3 to 4 in. of topsoil as a seedbed. For best results fertilizer, and lime when needed, should be well mixed into the soil before seeding.

Seeding and Planting

Small areas are usually seeded by hand. After the soil is loosened and fertilized, seed is spread either by broadcasting handfuls in a broad, sweeping action or with a small mechanical spreader of the lawn seeding variety. A standard mixture of 80 per cent fescue and 20 per cent bluegrass sown at the rate of 40 to 80 lb per acre or 1 to 2 lb per 1000 sq ft is generally satisfactory. For Crown Vetch, 5 to 10 lb per acre, or $\frac{1}{4}$ lb per 1000 sq ft is recommended.

A more satisfactory method of starting Crown Vetch is to plant crowns at about 3-ft intervals in staggered rows about 3 ft apart beginning at the top of the slope. This is more expensive than seeding but it will give the Vetch a much earlier foothold on the slope.

When shrubs are used they should be delivered in such a manner as to avoid damage by drying out. If plants must be held more than a few hours before planting they should be placed in a shady area, the roots covered with earth if not balled and burlaped, and kept watered. Holes should be dug twice as large as the transplanted root system and the roots spread out naturally with no bending or crowding. Fill is placed carefully to avoid breaking roots when it is firmed in place. Care should be taken to avoid placing fertilizer directly on roots or under plants. It is best to mix fertilizer with the backfill before placing, or to apply it to the surface, with mulch, after planting.

Protection During Establishment

Seeding and/or planting should be followed immediately by a mulch which serves to protect the slope until seedlings are established and helps to provide conditions of temperature and moisture favorable to germination. The usual mulch is straw or hay spread

evenly by hand, or blown over the surface with a mechanical spreader. About $1\frac{1}{2}$ tons per acre or 70 lb per 1000 sq ft, giving 1 to 2 in. of cover over the soil, is most effective.

On very steep slopes or windy exposures the mulch needs to be tied down. This may be accomplished with binder twine criss-crossed and pegged, by running over the surface with a disc harrow set straight, by placing soil or asphalt strips over the mulch, or by spraying with "mud-slurry" or a light asphalt spray.

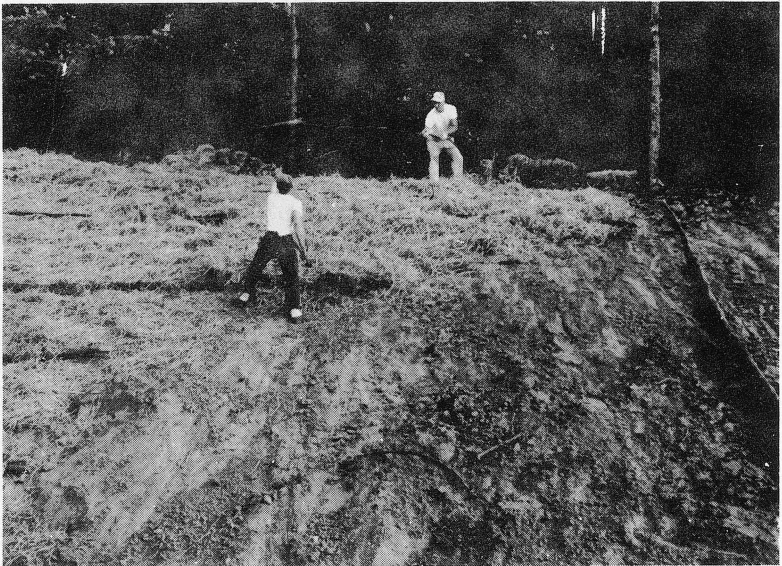


Fig. 6. Mulch is being applied to this slope immediately after seeding to give temporary protection until cover is established and to assist in establishment of grass. If the slope were flatter, mulching would be easier and cheaper.

Other materials that have been used for mulching are sawdust, commercially processed wood fibre, asphalt emulsions, chemical sprays, and paper or jute netting. The particular advantage of the commercially produced mulches (wood fibre, asphalt, and chemicals) lies in their use with hydraulic seeding methods.

Hydraulic seeding is an alternate method of seeding roadsides which is especially useful for large areas. In this process, fertilizer and seed are mixed together in a water slurry and sprayed over the prepared soil surface in a single operation. Some of the commercially produced mulches can be added to the fertilizer and seed slurry, and thus mulching is accomplished in the same operation.



Fig. 7. Application of the principles of slope protection is well illustrated on this county road. Note the flat slopes with well rounded edges, and the turf cover over the entire slope.

The equipment required is relatively expensive, so this method is usually employed only when large amounts of seeding are to be done, or for small areas, when done on a contract basis.

Whatever the species or method, the important principle is—*Fertilize and Seed for a Turf Cover Immediately After Grading, and Mulch to Provide Immediate Protection.*

Intercepting Ditches and Gutters

Cut faces are frequently subject to large amounts of water running down from higher ground. To prevent this water doing serious damage it should be collected in an intercepting ditch in the form of a small berm or trench a few feet above the slope face. A berm may be formed by placing a ridge of earth about 6 to 12 in. high and 1 to 2 ft wide along the surface and then seeding for vegetal cover just as in the slope face. If possible the berm should be placed where the up-slope side of the ditch will be quite flat and where there is established natural vegetation to slow the water as it enters the ditch section.

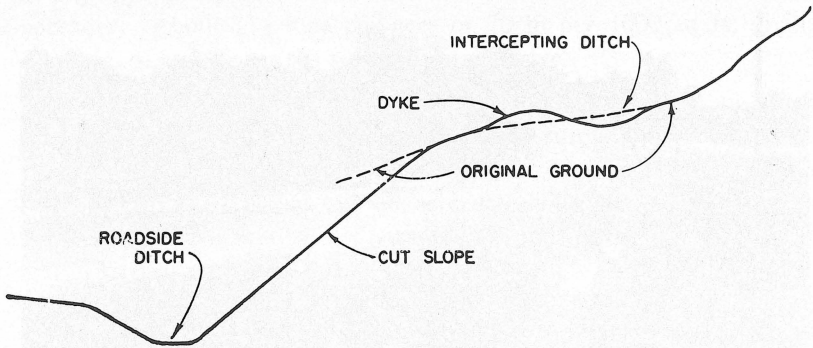


Fig. 8. Cut slopes may be protected from surface water from above by constructing intercepting ditches as shown here. The ditch must run full length of the slope and have a safe outlet.

On a long grade the roadway itself may collect erosive quantities of water. This can be collected in a gutter formed by an asphalt dyke 4 to 8 in. high and released at intervals into prepared waterways. In this situation it is desirable to have the gutter as far away from traffic as possible to minimize splash and ice problems in the roadway and to encourage traffic to use the full width of the road. This may be done by surface treating the shoulder and forming the gutter at the outer edge of the shoulder.

Water collected in gutters and intercepting ditches should be released down slopes at controlled outlets—the ends of cut slopes and the low point of the roadway profile, and at intermediate points if the ditch or gutter is very long. This is an extremely important consideration in using intercepting ditches, because unless properly outletted, concentrated flow in such ditches can do more damage than the same water flowing over the slope face.

On many miles of unpaved county roads a berm has been inadvertently formed along the edge of the traveled surface by continual grading and scraping of the road and neglect of the shoulders. In some places these berms may be useful in serving as a gutter. However, water collected by these berms and ponded at low points in the road are a traffic hazard, and tend to saturate the base of the road, leading to serious rutting. Where these berms do not serve as necessary protection for shoulders or fill slopes, they should be removed to permit water to drain directly to the side ditches. When



Fig. 9. This berm has no outlet. The water collected saturates and softens the roadway so that traffic creates ruts.

the berms are retained it is important to cut openings through them and form channels to drain the collected water away from the roadway.

A third principle—*Intercept Erosive Surface Water Before it Reaches Long, Steep Slope Faces.*

Down Drains

Outlets from intercepting ditches and gutters may be shallow, depressed sections in the slope face or may be paved troughs or pipe sections. The main difficulty with these channels is getting protection established because the concentrated water at each rainfall tends to wash away seed and mulch. Sodding is one way to overcome this problem. A depression is formed in the slope and the soil loosened and fertilized. Sod strips are then placed snugly in the trench and rolled or tamped. The sod should be watered frequently as weather demands during the first few weeks after planting. Using shallow cut sod—about $\frac{3}{4}$ in. deep—will keep cost of transportation and placing to a minimum, and sod should be mowed short before cutting, as excess foliage hastens drying out of the sod.



Fig. 10. This curb contains water from the long grade, so it will not destroy the side slope. Outlets both at the end of the curb and midway up the hill carry water safely to the foot of the slope.

Another approach which has proved successful is to seed the channel depression as usual then cover it with an open mesh burlap, or jute matting. This net, with openings about 1 in. square, when tied down with wire staples 8 to 12 in. long at about 6-ft intervals, will hold the soil and seed in place until the turf is established. The mat need not be removed since it ultimately rots away and serves as humus.

Where water must be carried down steep slopes, or quantities are especially large, turf linings, even if they can be established, may not give adequate protection against severe scour. In this situation it is necessary to protect the sluice with a paved lining or a half section of pipe.

The turf on the adjacent slope should be well established right up to the edges of whatever lining is used. If necessary, sod strips may be placed along the edge of the lining.

Whatever kind of channel is formed, it is essential to flare the ends to avoid scour at entrance and exit. The water should enter in a broad sheet from the ditch or gutter and converge in the sluice. At the bottom the channel should level out and widen again, to spread the water out into a relatively slow moving sheet at the bottom

of the slope. The area at the bottom of a sluice may be protected by a layer of coarse gravel or crushed stone, or may even be paved if the discharge tends to undercut the cut slope or erode the roadway fill.

Provide Safe Outlets for all Water Collected in Channels.

Subdrains

Veins of free running water intersecting a cut face will wash away the slope regardless of surface treatment. This type of erosion can be prevented by intercepting the water before it reaches the surface. A subdrain installed in a trench back of the slope will serve this function as will a perforated pipe driven or drilled horizontally into the cut face. The trench is cut to a depth 3 to 6 in. below the water bearing material, and drain tile placed in the bottom. Backfill must be a pervious material tamped firmly in place. The top foot of fill should be a relatively impervious silty or clayey material to keep surface water out of the drain. This subdrain must be extended the full width of the cut and outletted safely, as ditches and



Fig. 11. No amount of grass will hold this slope which is softened by subsurface water. Subdrains must intercept the water in back of the slope to keep the soil dry.

gutters are, either to the roadside ditch or to natural drainage. In cases where the pervious material is very deep, it may be more economical to drive or drill a pipe horizontally from the slope face into the pervious layer, or to place riprap over the slope face to the height of the seepage layer.

Protection from Underground Water Depends on Intercepting and Diverting Subsurface Streams or Providing a Safe Outlet at the Slope Face.

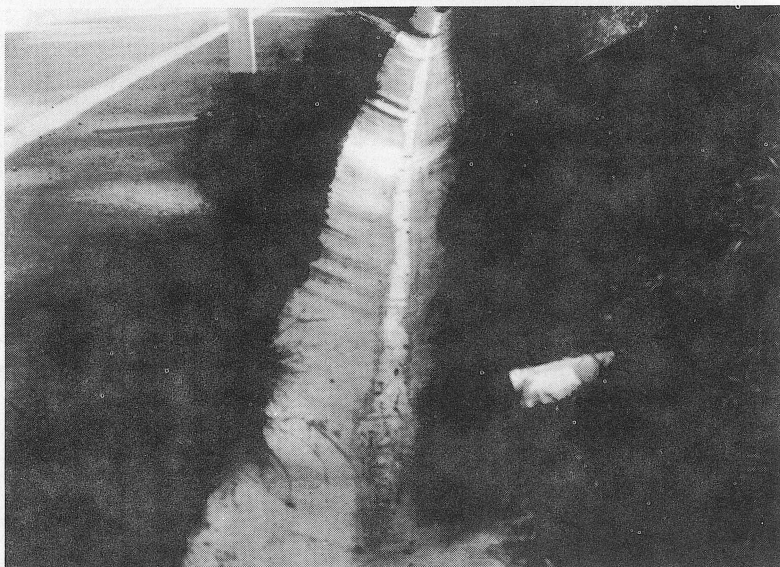


Fig. 12. Subdrains in the slope on the right keep the soil dry and stable. Notice the water in the ditch from the subdrains even during dry weather.

Special Problems

Special attention is demanded wherever surface water tends to collect and run along a structure. As it collects, the quantity of water is built up and speed increases. Because the erosive power of water is primarily a function of depth and velocity of flow, the conditions at such points of concentration are especially critical. To avoid this problem, surface water should be diverted to the ditch or natural stream before it reaches bridge abutments or culvert headwalls. Water collecting on a structure should be dropped through scuppers or contained by curb or gutter sections until it

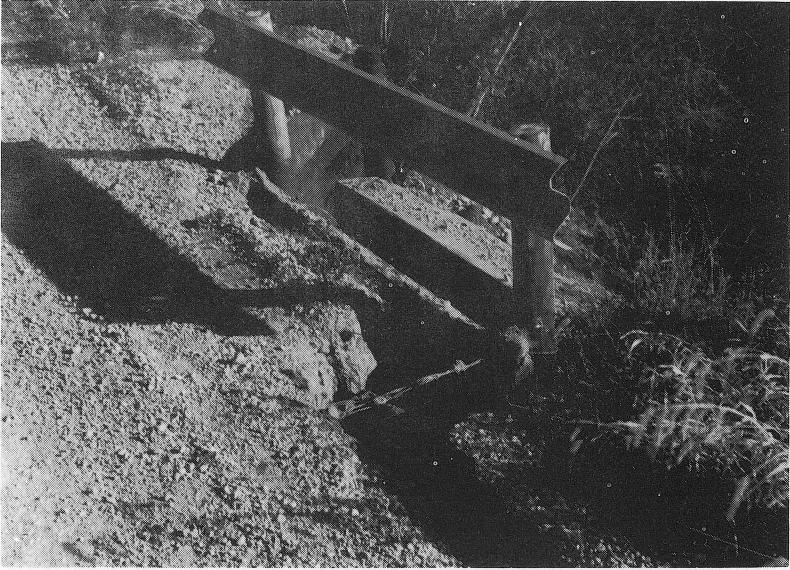


Fig. 13. Water has washed out both the original headwall here and the timber replacement. The correction of this problem is diverting the water down the side slope before it reaches the structure.

can be released well away from critical points around the structure. Some water, however, is bound to reach protruding objects. When erosion starts, such points should be sodded, or seeded and protected with jute matting, to insure rapid establishment of a strong turf.

Divert Surface Water Before it Reaches Protruding Structures.



Fig. 14. Asphalt curbs contain water in this roadway, carrying it away from the structure and steep slopes.

Maintenance

Maintenance of slopes is primarily good management, just as it is for any cultivated area. It is important, however, that where drainage or erosion problems occur a minimum of work be done on the symptoms and the major efforts be directed at eliminating the causes of the difficulty.

Grasses must be mowed regularly and fertilized occasionally if they are to remain healthy and continue to protect the slopes. Every grassed area should be mowed at least once a year and preferably three to four times. Equipment should not be operated on turf areas when the ground is very wet, however. Nitrogen fertilization is most important for grasses because this element is readily leached away and is most depleted by plant usage. Therefore, maintenance fertilizer should be high in nitrogen, such as 18-6-6. An established dense cover may not need annual fertilization. However, it is desirable to provide for grassed slopes to be fertilized on a rotational basis, so that some areas are covered each year—at least those areas where cover is thin. An amount of fertilizer providing 40 lb of nitrogen per acre, or 1 lb per 1000 sq ft, is satisfactory for one application. For best results fertilizer should be spread in the spring and in the fall. For slopes with Crown Vetch or other legumes nitrogen should not be included as these plants contribute usable nitrogen to the soil. If cover is thin, an application of 50 to 100 lb each of phosphorus and potassium per acre, or 1 to 2 lb each per 1000 sq ft will hasten growth, but this need not be a regular practice. This coverage would be provided by 200 to 400 lb per acre of 0-25-25, or equivalent.

Where shrubs or natural woody growth is used, occasional thinning will help to keep the cover vigorous. An adequate herbicide program to keep noxious weeds and rank growth from taking over the slopes is part of good maintenance. Stands of Crown Vetch should *not* be sprayed, however, since this plant is susceptible to weed killing sprays. Weeds and brush will not be a problem because the Crown Vetch chokes out all other growth.

Whenever damage to turf occurs it should be repaired promptly because any break in the vegetal cover is a point where erosion will proceed rapidly. It is far less expensive maintenance to repair damaged spots at once than it is to repair extensive scarred slopes and clean out ditches and culverts where the eroded material was deposited.

Except where entire slopes are being reworked it is best not to use road graders or other heavy equipment on maintenance opera-

tions because they tend to tear up established vegetation, creating new points for erosion to occur.

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ROADSIDE DITCHES

Establishing cover on earth slopes must be accompanied by providing stable waterways for the collection of surface water if erosion control is to be adequate. The water concentrated by roadway surfaces and cut slopes can quickly reach erosive quantities and velocities, and unless the roadside is protected from this flow serious damage to slopes and roadway will occur. A secondary function of roadside ditches is to drain the base of the roadway to prevent saturation and loss of support for traffic.

In order to serve these purposes roadside ditches should be built and maintained in accordance with these principles:

1. **Provide enough area to accommodate storm flow and depth enough to drain the base course.**
2. **Protect the surface of ditches from erosion with turf cover or other suitable lining.**
3. **Keep velocities low enough to prevent erosion but great enough to prevent deposition or silting.**
4. **Maintain a continuous and unobstructed waterway.**
5. **Provide stable outlets to natural channels or drainage ditches.**

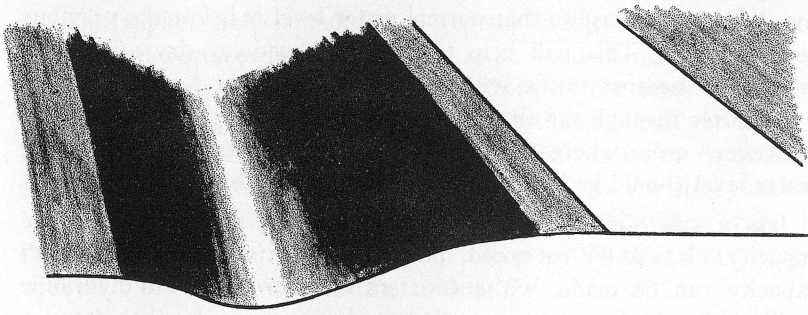
Cross Section

Roadside ditches are constructed with parabolic, trapezoidal and triangular, or "V" shaped, cross sections. The parabolic section is hydraulically the best and the most erosion resistant. The trapezoidal section is easier to construct and makes an adequate and stable ditch for most locations. It is used far more generally than the parabolic section. The "V" ditch is easily blocked with debris and is highly susceptible to erosion, and, therefore, is generally not recommended.

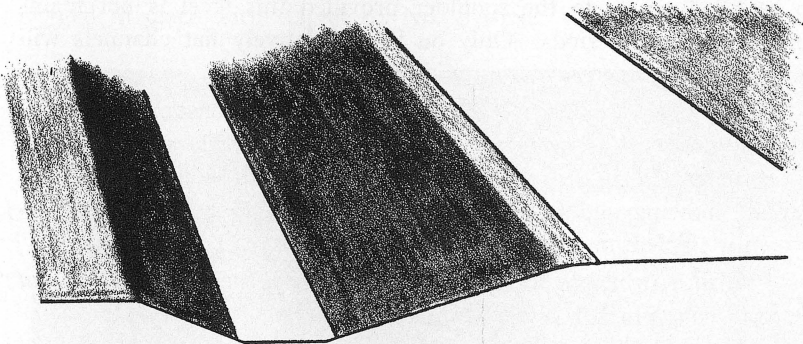
Ditch side slopes, as earth slopes generally, should be flat—4:1 to 2:1— and their intersections freely rounded. The liberal rounding of corners or edges is important because it makes establishment of grass easier and encourages a continuous turf.

The bottom of the ditch may be 1 to 4 ft wide, depending on the quantity of water, the length of the ditch and the grade. Generally the grade is parallel to the roadway grade, but in flat land the ditch may be steeper than the road and in rugged country the ditch grade may have to be flatter than the road grade.

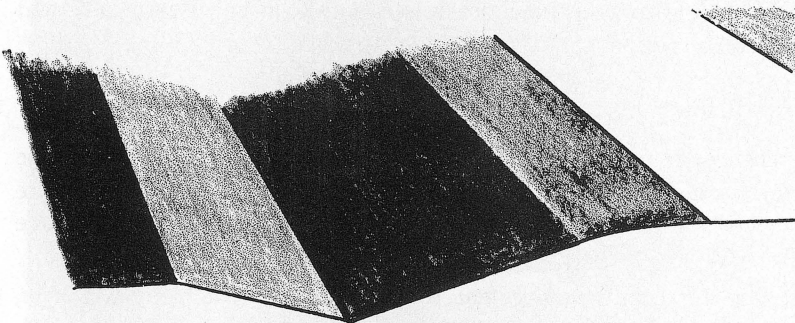
The secondary function of the ditch (draining the base course) is accomplished by cutting the ditch bottom to a depth 1 to 2 ft below



a. A parabolic ditch is the most efficient ditch section, and the least subject to erosion.



b. A compromise between hydraulic efficiency and ease of construction is achieved with this trapezoidal ditch. If the corners are well rounded, erosion is not severe. It is also much safer for traffic than triangular ditches.



c. The triangular ditch section, illustrated here, is the easiest ditch to construct. However, it is hydraulically inefficient and subject to erosion.

Fig. 15. Typical Ditch Cross Sections

the shoulder, at least so that normal water level is below the pervious base material. This will help to keep the roadway dry and stable enough to support traffic without rutting. It is best to extend the base course through the shoulder so it can drain freely into the ditch. However, even where cost precludes this construction, the free water level should be kept below the bottom of the base.

As a rule ditches satisfying these criteria will have adequate capacity. It should be noted, however, that further judgment of capacity can be made, without extensive hydrologic and hydraulic studies, simply by observing ditches during and shortly after an intense rain. The occasion of a spring rain accompanying a thaw is an excellent time to determine which ditches are serving adequately and which need improving. It may be perfectly safe for a ditch to be filled nearly to the shoulder provided this level is not maintained for long periods. Only on long, relatively flat channels will it ordinarily be necessary to provide extra capacity.

The shape and size of the ditch need not be constant. Capacity may be increased as necessary on a long channel without making the entire length to the extra size. A minimum width which will accommodate mowing and fertilizing equipment may be established, however, for efficient maintenance.

The first principle then—*Provide Capacity for Peak Flows and Depth Enough to Drain the Base Course.*

Surface Lining

Bare earth surfaces will stand only a limited amount of flow without serious erosion. Therefore, ditches should be given a protective lining to keep them serviceable and to prevent expensive and dangerous erosion.

Grass Lining

The most practical lining in most situations is grass. It is more economical than other linings to establish and will provide adequate protection indefinitely if a small amount of maintenance is done faithfully.

The important requirement for the grass is that it form a firm, dense turf. Bluegrass serves this function well in Indiana, with some tall fescue to give quick protection. The 4:1 mixture of fescue and bluegrass seed suggested for slopes can also be used in ditches. Reed canary grass also serves well as a ditch lining, giving good protection and requiring little care.

The rapid establishment of a vegetal lining in ditches is not difficult but requires attention to the same fundamentals as starting cover on slopes. The sides and the bottom of the ditch should be even and the edges smoothly rounded. Fertilizer should be applied at a rate of about 20 lb of 12-12-12 per 1000 sq ft, or equivalent, and worked into the soil. If lime is required, as shown by a soil test, it may be applied at the same time as the fertilizer. Seed is then broadcast at the rate of $1\frac{1}{2}$ lb to 3 lb per 1000 sq ft and covered with 70 lb to 80 lb of straw or hay mulch.

In areas and seasons subject to considerable rainfall there may be difficulty in holding seed and mulch in the ditch. To overcome this problem an open mesh matting of paper or jute may be used instead of straw or hay mulch. The matting is laid down after seeding and pegged in place with staples of No. 8 wire. Where more than one

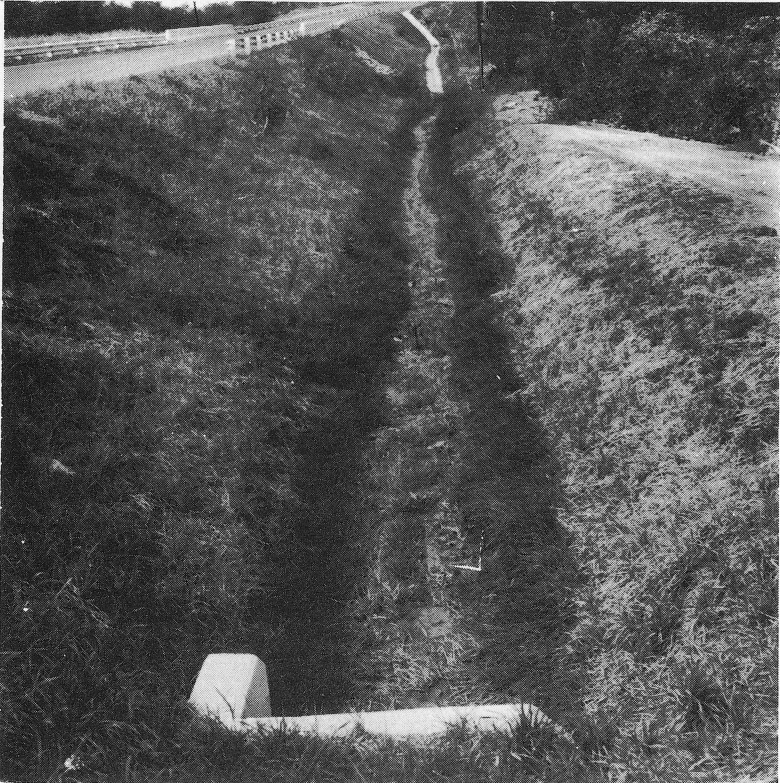


Fig. 16. A ditch and slope both protected with a healthy turf. The slopes were seeded and mulched. The thick, darker growth in the ditch illustrates the advantage of sod in providing immediate protection and more rapid development.

width of matting is required, as is usually the case, the adjacent strips should be overlapped 2 to 3 in. and stapled at 6 to 8 ft intervals. Care must be taken that the matting is everywhere in contact with the soil, for if water gets under the matting the seed and soil will wash away. The effectiveness of this installation depends on making the water flow over the net. When properly used this matting effectively prevents erosion until vegetation is established, even when subjected to substantial flows.

Another alternative is lining the ditch with sod, freshly cut, to a depth of about $\frac{3}{4}$ in., from a well established, dense turf. Sod strips should be placed across the ditch rather than lengthwise. Joints should be staggered and strips pressed firmly against one another. After sod is in place it is tamped or rolled to produce a smooth continuous surface. To keep the sod alive and insure a permanent lining it should be watered, as conditions require to prevent drying out, for several weeks after placing. This must, of course, be considered in estimating the cost of sod as a lining for ditches. However, a healthy bluegrass turf placed in this manner will withstand a considerable flow of water immediately after placing.

Paved Linings

There are two extreme situations where grass may be an unsatisfactory lining for roadside ditches—very flat grades and very steep grades.

On grades less than 0.5 per cent flow over a grass lining is likely to be too slow. (The per cent grade expresses the slope of the ditch bed in feet of rise or fall per 100 ft of horizontal distance—0.5 per cent is $\frac{1}{2}$ ft fall per 100 ft; 2 per cent slope is 2 ft of fall per 100 ft.) When flow is too slow, silting or deposition occurs, creating a clean-up problem. Also, water remains in the ditch for long periods, killing the grass and providing a breeding place for mosquitoes.

Extremely steep grades, on the other hand, tend to create erosive velocities, scouring the turf and ultimately destroying such a lining completely if it were possible to obtain at all. On slopes between 5 per cent and 10 per cent the primary problem is establishing the turf. If it can be started, and is kept healthy by good maintenance, a grass lining will probably be satisfactory. On steeper grades it is difficult or impossible to establish and maintain a turf lining.

Alternative linings for these conditions can be constructed of asphaltic materials, portland cement concrete, or rubble masonry. These are all relatively expensive solutions, however, and are not recommended except where essential.

Bituminous Lining

Where a paved lining is clearly justified an asphalt concrete surface may be constructed. For this purpose a well-graded, dense, rich mix is desirable, using a paving grade asphalt of penetration between 60 and 100. Aggregate should be clean, sound and well graded with a maximum size of $\frac{3}{8}$ in. to $\frac{1}{2}$ in. Final thickness of the lining should be 1 in. to $1\frac{1}{2}$ in. Compaction is an important part of this construction. After the mix is spread over the surface it should be thoroughly rolled or tamped to produce a dense lining with a smooth surface.

In areas where weeds and brush are common it is well worth while to apply a soil sterilant to the ditch before a bituminous lining is placed because vegetation is one of the major causes of deterioration of such linings. Monuron, diuron, simazine, or comparable chemicals recommended for highway use may be used for this purpose.

Concrete Lining

Perhaps the most practical concrete lining construction for county highway operations is the prefabricated type. In this construction, panels are cast in standard forms at a convenient central location and hauled to the ditch site.

The ditch section is first shaped to line and grade, and the surfaces smoothed. The slabs are then placed in the ditch with joints

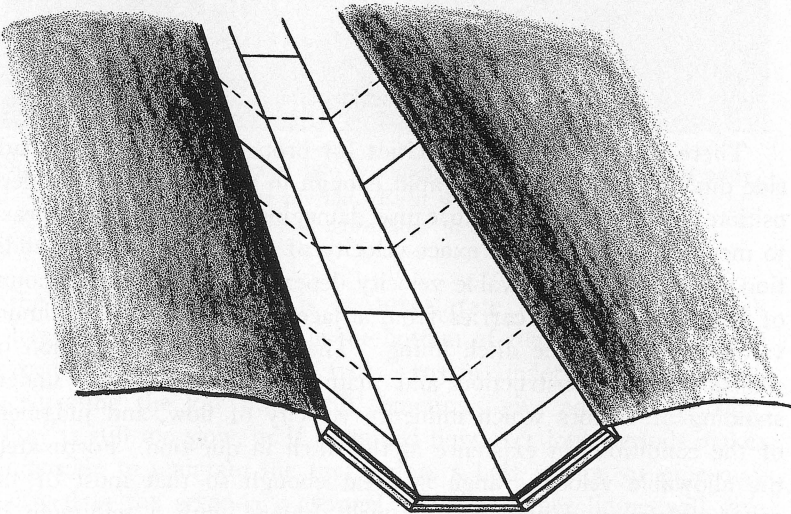


Fig. 17. Precast concrete slabs provide a convenient means of lining steep sections of ditches where turf does not give adequate protection. Slabs are cast at a central location and assembled in the ditch.

staggered. Galvanized No. 8 wire is run through holes in the panels and fastened with a loop, or "pigtail," on each end to lace the units into a continuous mat. The concrete should extend up the sides at least 6 in. higher than normal flow. The banks above the concrete are then sodded, or seeded and mulched, to establish a turf right up to the edge of the lining.

Prefabricated panels for this purpose can be constructed easily either out of doors on smooth bare ground, or inside on a hard floor. A panel 1 ft by 3 ft by 2 in. thick weighs about 75 lb and is a practical size for handling, although narrower units may be cast for the bottom of small ditch sections.

Concrete for precast slabs should be of a medium consistency, using a $\frac{3}{4}$ in. maximum size aggregate and not more than 5 gal of water per sack of cement. The slabs should be kept wet continuously for at least three days, and preferably seven days, after placing in order to get full strength in the concrete.

Only rarely will it be necessary to use a paved lining. Generally, turf, with proper attention to ditch capacity and water velocity, will serve well and be most economical. Regardless of choice of material, however, the fundamental principle is—*Establish an Erosion Resistant Lining to Protect Ditches from Scour.*

Velocity

There are two limiting velocities for proper functioning of roadside ditches. Flow must be rapid enough to prevent silting, or deposition, yet not so fast as to cause damaging scour. It is not easy to measure or predict the exact velocity of flow in a ditch. In addition, the minimum allowable velocity depends in part on the amount of material the water carries from adjacent land, and the maximum value depends on the ditch lining. Therefore, a major portion of roadside ditch construction and maintenance is based on understanding of factors which influence velocity of flow, and judgment of the conditions in existence at the ditch in question. Fortunately the allowable velocity range is great enough so that most of the county highway system can be well drained with a minimum of maintenance by using a basic ditch section, roughly parallel to the road, and lined with turf. A few situations will require attention to the limiting velocities.

Low Velocity

In flat terrain the problem may be to get the water to flow.

Grasslined ditches should have a slope of at least 0.5 per cent. When the roadway grade is less than 0.5 per cent the ditch must have a steeper grade than the roadway. This means that the ditch will get deeper as it moves down grade, and, if one is to keep the side slopes flat, the ditch will move farther away from the centerline of the road. The grade of a ditch should always be smooth, with no sudden changes of direction. It is especially important in the case of flat ditches that the grade be checked with a survey instrument because a flattening of the grade at any point may reduce velocity enough to cause serious silting. One approach



Fig. 18. This ditch illustrates two weaknesses—the outlet is plugged with debris, and the slope is too flat. Even when the outlet is cleaned out, this ditch will need more slope to drain all the water.

to the problem of silting is to concentrate low flow in a small V-shaped secondary channel in the bottom of the ditch. This should be seeded also to protect it from erosion under storm flow, but concentrating the low flows will sometimes give adequate velocity. If flow is still too slow, or if sustained flow over long periods makes it impossible to maintain the turf lining, a half section of pipe may be placed in the secondary channel. The smoother lining will give greater velocity and still protect the soil from substantial flow. The turf in the main channel must be well established right up to the pipe to prevent scour or undercutting at that point.

High Velocity

Steep, hilly country, in contrast to the plains, is likely to present the problem of preventing excessive velocities. A good strong turf lining will withstand velocities up to 6 to 8 ft per second—that is, about 4 to 5½ miles per hour. One way to get a rough idea of velocity of flow is to throw a wood chip into the ditch during an intense storm. If a man can keep up with the chip at a moderate walk the velocity is safely below the maximum. If he must walk as fast as possible to keep up with the chip the velocity is at, or above, the safe maximum. That is, a turf lining would not withstand more than short periods of such a flow, and is likely to require excessive maintenance if it is to give adequate protection.

Excessive velocities are likely to occur where grades are more than 6 per cent. Therefore it is desirable to keep ditch grades less than that. If the roadway grade is not much steeper than 6 per cent it is sometimes possible to keep the ditch grade flat enough by making the ditch deeper at the upper end than at the lower end. In this case the location is fixed by the lower end, and, if possible, the ditch centerline moves away from the roadway as it moves uphill to keep the side slopes flat.

On steep grades a series of checks can be installed in the ditch so that the ditch grade is considerably flatter than the roadway, and the excess fall is taken up at the drops. Such checks may be constructed of sod, rubble or timber planking. If rubble or plank is used, it should be set well into the ditch banks and bottom to protect against undercutting. Checks may be 6 to 24 in. high and must have an apron of rubble or pavement for 3 to 4 ft on the downstream side. The top should be perfectly level to distribute the flow evenly.

An alternative solution to the problem of high velocities is to pave the ditch with rubble, bituminous concrete or portland cement concrete. It is important to remember, however, that paved linings result in still greater velocities representing erosive energy which must be controlled at lower levels. If the water cannot be emptied directly into a stream that is deep enough to absorb the flow without scouring it may be necessary to build a drop structure or stilling basin to absorb the excessive energy. Therefore it is recommended that paved linings not be used unless a turf lining is clearly inadequate or impossible to establish.

The guiding principle with respect to velocity is—*Keep Flow Fast Enough to Prevent Deposition Yet Slow Enough to Prevent Scour.*

Continuity

One often neglected principle of a satisfactory drainage system is to have a continuous waterway, unobstructed by cross roads, driveways, turnouts and the like. It is evident that if a ditch is so obstructed that the water is ponded, drainage is less than satisfactory. Stagnant pools tend to saturate the road bed, destroying its stability, and they also are breeding places for mosquitoes.

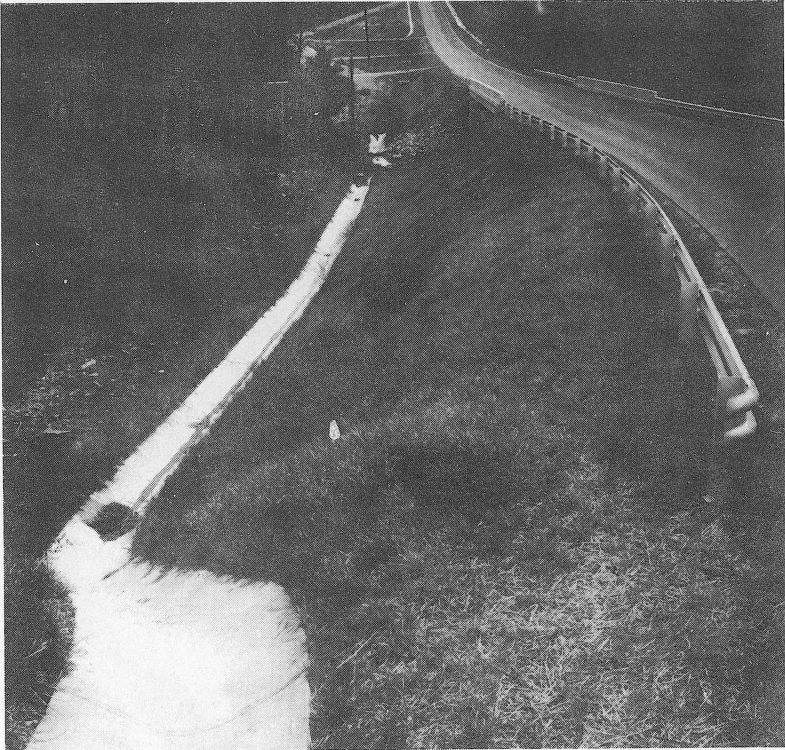
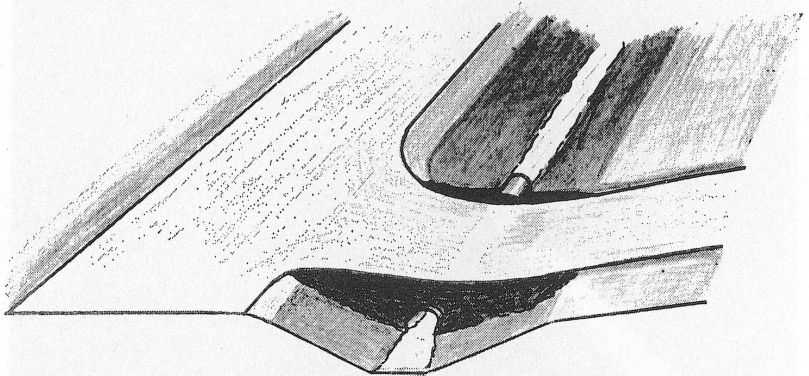


Fig. 19. An excellent example of a continuous ditch is shown here. Note culverts (top center) under each driveway, paved lining on steep sections, and the outlet to the stream.

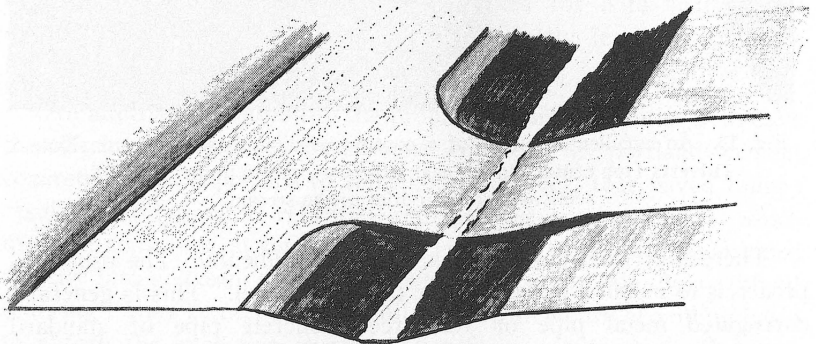
There are two ways to get around this difficulty. The usual approach is to install a culvert under the obstruction. This is generally corrugated metal pipe or reinforced concrete pipe of standard strength. The pipe should be large enough to carry the storm flow in the ditch, and at least 8 to 12 in. in diameter. Smaller pipes are easily clogged by leaves and sticks and are difficult to clean. If the fill is subject to heavy loads, such as an entrance to a gravel pit, the specifications of the manufacturer should be checked

to see that the pipe will carry these loads with the amount of cover which is proposed. The invert of the pipe should be placed in line with, and at the same grade as, the ditch bottom. Also the culvert should be long enough so that an easy turn can be made by traffic moving off or onto the road. It is desirable to depress driveways where they cross the ditch line to avoid shedding surface water from higher ground onto the roadway.

The other approach, where topography permits, is to put a dip in the profile of the fill or driveway. The dip must be to the depth of the bottom of the ditch, and the ditch sides graded to meet the



- a. A culvert is provided under a driveway to provide a *continuous* waterway so that collected water is not ponded above the obstruction. Note the low point in the driveway to shed water from the drive into the ditch, rather than onto the roadway.



- b. Where topography permits, the driveway may dip into the ditch instead of using a culvert. Full depth of the ditch must be maintained and the edges of the driveway graded naturally into the ditch sides.

Fig. 20. Typical Driveway Profiles.

profile of the driveway. This construction will not be acceptable for traffic of any substantial speed, however, and should be used with care.

A great deal of good work in ditches is wasted if this principle is neglected—*Make Roadside Ditches Continuous, Unobstructed Waterways to Natural Watercourses.*

Outlets

A large portion of ditch erosion occurs at points of outlet to natural waterways or drainage channels. When outlets are not made safe from erosion serious damage frequently occurs to the road as well as to bridges and culverts. Therefore it is essential to provide a well protected sluice or chute to carry water from the ditch level to the stream level, or to build an outlet structure.

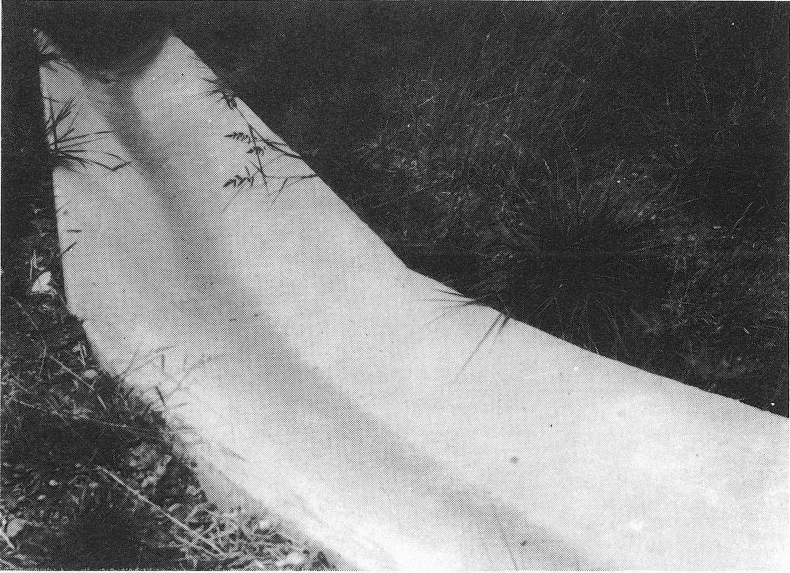


Fig. 21. A paved sluice, such as this, is a stable outlet for a ditch. The lining protects the slope from erosion.

In most situations a sluice can be made to serve safely and is less expensive to construct than a structure. The grade should be as flat as possible—preferably less than 10 per cent. Since there usually is a considerable drop from ditch to collecting channel it is necessary to divert the sluice well away from the road as it drops to the stream in order to meet the grade requirement. Turf is the most

economical lining where it can be used. Frequently however, the problems of establishing it will require some of the special measures for starting grass linings. The most common approach is to sod the channel as described for ditch lining. Because of the concentrated flow that may occur at the outlet it is wise to peg the sod strips down with wooden stakes driven flush to the surface. Also, the lining should be extended far enough up the sides of the sluice to insure that the water will not rise above it, for that could cause the entire lining to be washed away.



Fig. 22. Two pipes overhanging the stream provide outlets to the ditch from both sides of this stream.

If the grade is not too steep or the quantities great, the method of seeding and covering with jute or paper matting may be used. It is especially important here that the matting be in contact with the ground at all points because it protects the soil only by making the water run over the mesh. If water gets under the matting the seed bed may be completely destroyed. The staples should be closely spaced. The matting along the sides of the sluice should be above the highest water and turned under the soil at the top edges.

Where conditions are too severe to permit establishing a turf lining, or if right-of-way is too limited to permit flaring the sluice, a paved surface may be used instead, or an outlet structure may be installed. Frequently such a structure may consist simply of a

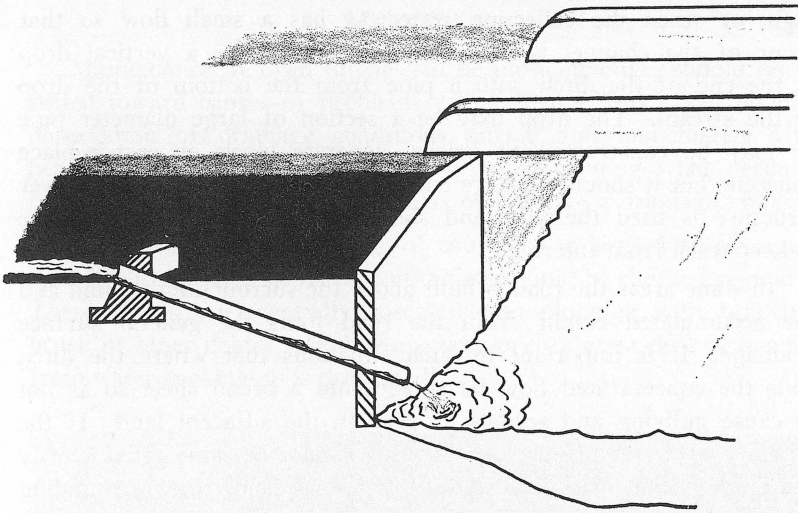


Fig. 23. A straight pipe may be used to outlet a ditch where the drop is too steep to maintain a sluice without erosion.

pipe running from the end of the ditch to the stream. The outlet end should be at least 1 ft above the water level in the stream and, preferably, should extend out from the stream bank far enough so the flow does not fall on the bank. If this is impossible, the bank may be protected with rubble or paving. When the drop is very

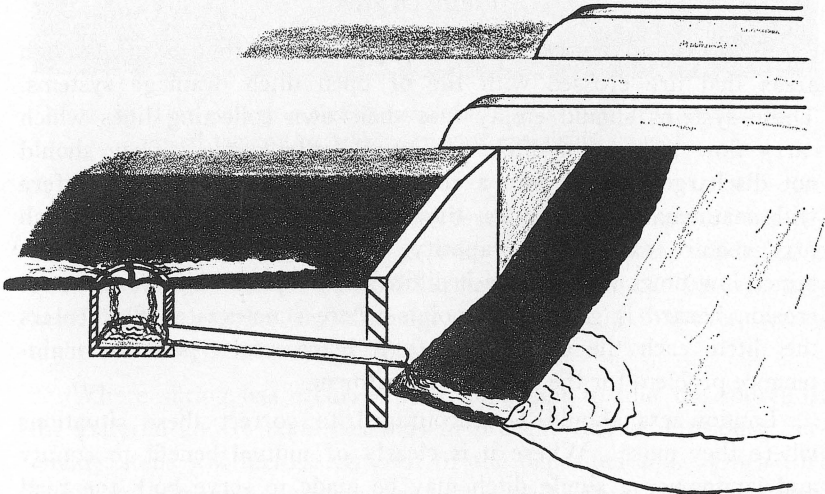


Fig. 24. For high drops into shallow waterways, a drop inlet may be used to reduce the grade of the outlet pipe. Here the excess energy is dissipated in the drop inlet, so erosion does not occur in the stream.

high, or when the collecting waterway has a small flow so that scour of the channel is likely, the outlet may be a vertical drop at the end of the ditch with a pipe from the bottom of the drop to the stream. The drop may be a section of large diameter pipe or may be constructed of bricks, concrete block or cast-in-place concrete, but it should be large enough to permit cleaning. Whatever structure is used the inlet end should be protected with a device to keep trash from entering.

In some areas the road is built above the surrounding ground and the accumulated runoff from the road joins the general surface drainage. It is important in such situations that where the ditch ends the concentrated flow be spread into a broad sheet so as not to cause gulying and serious erosion on the adjacent land. If the quantity of water is so great that this cannot be done satisfactorily the ditch section may be continued at a level below the surrounding ground to carry the accumulated flow to a stream or drainage channel.

Concrete or metal pipe crossovers may be installed to drain water from one side of the road, where there is no natural outlet, to the other side, if the flow can be carried away in a ditch or over the surface.

An important principle for all ditches—*Provide Safe Outlets to Natural or Artificial Watercourses.*

Field Drains

In areas of agricultural drainage roads often pass through areas that are crossed with tile or open ditch drainage systems. These systems should empty into their own collecting lines which carry flow to a main ditch or natural watercourse. They should not discharge directly into a roadside ditch because they interfere with maintenance operations, they contribute additional flow which may require extra ditch capacity, and they may contribute sustained low flows which make it difficult to keep turf alive. Also, the erosion hazard is greatest at points where concentrated flow enters the ditch, each tile outlet, therefore, represents a potential maintenance problem for the highway department.

Landowners should be encouraged to correct these situations where they exist. Where it is clearly of mutual benefit to county and landowner a single ditch may be made to serve both the road and the adjacent land rather than building two parallel ditches. However, the maintenance, as well as the benefits, of the ditch then should be shared by the county and the affected landowners.

Maintenance

Maintenance of open ditches, to be most effective, should be directed toward causes of problems rather than effects. To this end, observation of drainage conditions during and immediately after heavy storms is particularly helpful in determining what needs to be done to correct existing problems or improve a drainage system.

A first requisite for ditches, of course, is to keep them clean and free of obstructions. Culverts and outlets should be checked regularly. These points are especially susceptible to plugging with branches, brush or other debris. If they are kept open a great deal of damage from water backing up is prevented.



Fig. 25. This culvert is almost completely useless until it is cleaned out and the erosion which produced the silt is stopped.

Regular mowing and occasional fertilizing will keep turf healthy and reduce problems of weeds and brush. Where undesirable growth does get started a sound herbicide program can be especially helpful in improving the drainage. Dead brush, branches, leaves and trash should be removed from the ditch.

Where silting has occurred it is important to find the source of the material and to take measures to prevent further erosion. Secondary steps will include removal of the deposited soil. On a turf lined ditch cleaning operations are best done by hand. Blade graders have been used for ditch cleaning, but unless blading is part of a general reshaping and seeding, or sodding, project it should be avoided wherever possible. The blade tends to dig into established

turf, exposing the earth and creating points where erosion will proceed much more rapidly. Material removed from ditches should be hauled away rather than spread on the shoulders to be washed back into the ditch.

Wherever the protective lining is damaged it should be repaired immediately to forestall further erosion. Points to be watched especially for this are outlets from ditches and places where concentrated flow enters. Efforts, such as these, directed toward prevention of erosion and maintaining well drained roads will help to stretch the highway dollar over the most miles.

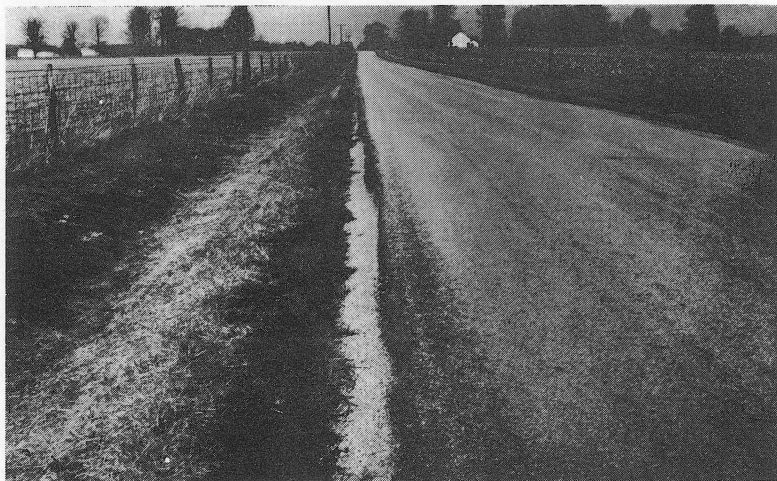


Fig. 26. Two extremes—above, a well constructed and maintained ditch; below, a ditch completely overgrown with weeds and brush.

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CULVERTS

Culverts may serve county highway drainage in almost every location where roads intersect or a driveway enters a highway, in locations where water in a roadside ditch must cross the highway to reach natural drainage, and at many stream crossings. In any of these situations, a culvert separates the water and traffic streams to permit continuous flow of both.

Though culverts are constructed in several different forms and of various materials, the selection and installation of culverts for all locations are based on the same fundamental principles. In the case of large structures for stream crossings, waterway area and strength may be the controlling factors, while for a pipe under a driveway, ease of cleaning and limited headroom may be more important considerations. However, in all cases these are the guiding principles:

1. Choose a culvert type and material to suit conditions at the particular location.
2. Provide enough area to take care of flood flows and strength enough for the loads to be applied.
3. Establish a grade and alignment which will give smooth, steady flow.
4. Provide a firm foundation and compact backfill for complete support around the structure.
5. Protect entrances and exits from scour, and flare entrances for maximum capacity.

Culvert Type

Pipes

A large number of small culverts are constructed of standard pipe sections of concrete, corrugated metal, vitrified clay or other material. Pipe culverts are an economical solution to a great many drainage problems because they are readily available, easy to handle and install, and can be placed in almost any location.

What kind of pipe should be used? This is primarily a question of economics. The most frequently used materials are concrete and corrugated metal. Because of its smooth surface concrete pipe will have slightly greater capacity than a corrugated metal pipe of equal size. Concrete pipe has good resistance to abrasion and is not likely to produce silting during low flows, therefore it is often desirable for streams carrying large amounts of silt and sand or other debris.

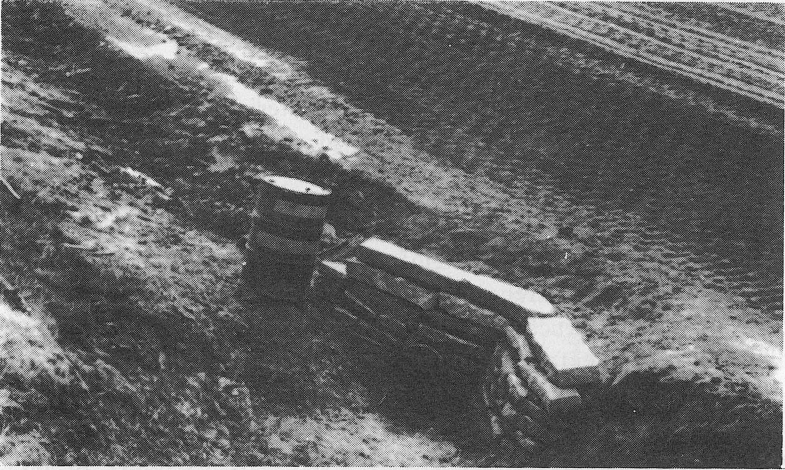


Fig. 27. The majority of county highway drainage structures are simply pipe culverts such as those shown here. (Courtesy Armco Drainage and Metal Products, Inc.)

Corrugated metal pipe has an advantage in its flexibility for use on soft foundation materials or where there is danger of settlements or slides. Corrugated metal helps to minimize erosive power of streams, especially if the pipe is long.

Vitrified clay pipe is quite durable in areas where soil or water are contaminated with corrosive substances. Before choosing a pipe for a location near a coal mining operation, or in the vicinity of peat or muck deposits it is best to have soil and water samples tested by a laboratory. Highly acid or alkaline soils and water

(pH less than 5 or greater than 8) are especially corrosive to metal and concrete pipe. Soils contaminated with sodium or magnesium sulphates are also damaging to these materials. In locations so contaminated, vitrified clay is the best material. If it is necessary to use metal pipe it should be protected with a bituminous coating.

Box and Multiplate Culverts

Capacities greater than that provided by standard pipe sections are sometimes required. Reinforced concrete box culverts and multiplate pipe or arches are sometimes used to get the extra capacity. Such structures may also be used where unusually high fills will create extreme loads on the culvert, or where the span length required would involve a bank of several pipe culverts. With structures of this size, however, economic solutions cannot be achieved by rule of thumb procedures. It is necessary in these cases to make use of careful design both for hydraulic and structural conditions.

The first principle of culvert practice—*Select a Culvert Type and Material Suited to the Conditions of the Particular Location.*

Size

Area of Culvert Opening

Culvert size depends on many factors, including drainage area, soil and vegetation, slope of ground and of culvert, rainfall, and entrance and outlet conditions of the pipe. Figure 28 can be used as a guide to choosing the required size of pipe for watersheds up to 10,000 acres. Two factors are needed to use this chart—the area drained, in acres, and a coefficient, or number, which represents the character of the watershed.

Watershed area is outlined most easily on county drainage maps, but aerial photographs or topographic maps, such as the United States Geologic Survey quadrangles, may be used. Starting from the culvert location a line is drawn completely around the area from which water flows into the culvert. (It should be noted that this line does not cross any streams.) The area may be determined by dividing it into a number of strips. The area of each strip is found by multiplying length times width, measured in inches, and total area by adding all the strips. This figure, which gives area in square inches, is multiplied by the map scale (number of feet per inch) twice and divided by 43560 to give area in acres. The result is the watershed area to be used in the chart. (On the county drainage maps produced by the Joint Highway Research Project at Purdue University the scale is given in miles. For the small

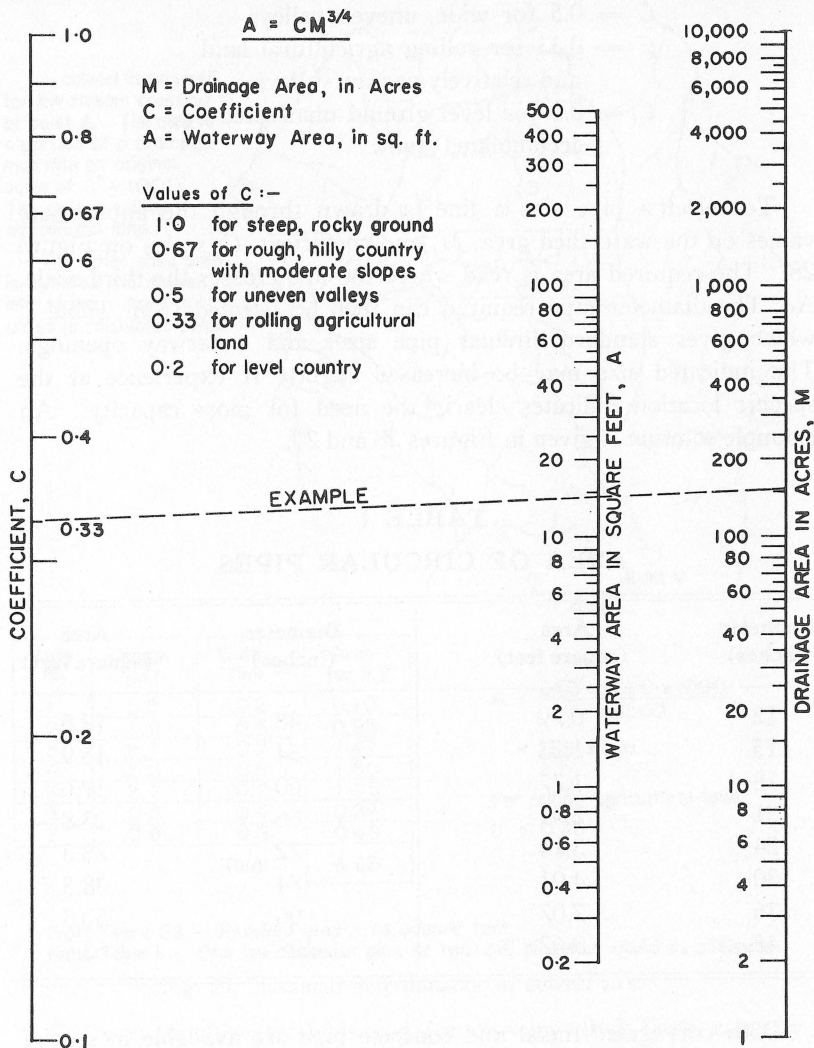


Fig. 28. Nomograph for solution of Talbot's formula, $A = CM^{3/4}$

maps, where 1 in. equals 2 mi, multiply area in square inches by 2560 to get acres. On the large maps, where 1 in. equals 1 mi, multiply square inches by 640 to get acres).

The character of the watershed area is represented by a coefficient ranging from 0.2 to 1. This value is estimated on the following basis—

- C = 1 for steep, rocky ground
- C = 0.67 for rough, hilly country with moderate slopes

- $C = 0.5$ for wide, uneven valleys
- $C = 0.33$ for rolling agricultural land
and relatively narrow valleys
- $C = 0.2$ for level ground unaffected by
accumulated snow

To select a pipe size a line is drawn through the appropriate values on the watershed area, M , and coefficient, C , scales on Figure 28. The required area is read where the line crosses the third scale, A. The diameter pipe required can then be selected from Table I, which gives standard circular pipe sizes and waterway openings. The indicated size may be increased slightly if experience at the specific location indicates clearly the need for more capacity. An example solution is given in Figures 28 and 29.

TABLE I
AREA OF CIRCULAR PIPES

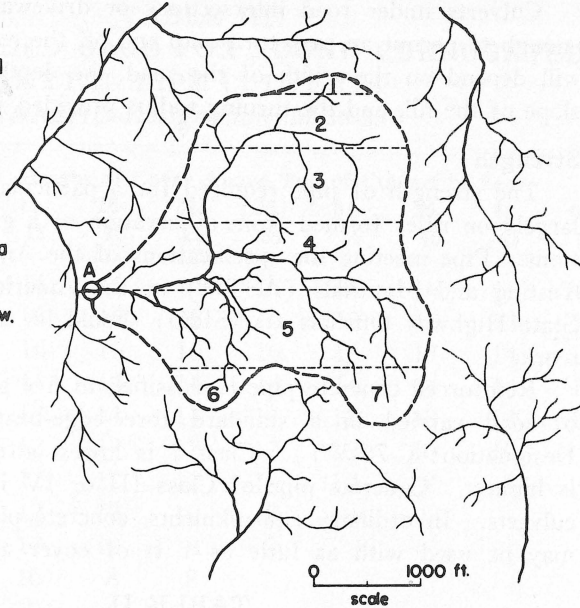
Diameter (inches)	Area (square feet)	Diameter (inches)	Area (square feet)
12	0.79	48	12.6
15	1.23	54	15.9
18	1.77	60	19.6
21	2.41	66	23.8
24	3.14	72	28.3
30	4.91	84	38.5
36	7.07	96	50.3
42	9.62	108	63.6

Both corrugated metal and concrete pipe are available in special shapes for special conditions. Oval-shaped pipe is often used where there is not enough room between stream bed and roadway surface to permit circular pipe of adequate size. The manufacturers' catalogs may be consulted to select an oval pipe of the desired size.

Another way to get extra waterway area is to use two or more pipes side by side. This is frequently done in relatively flat areas where there is width enough to place the pipes in the stream. A disadvantage, however, is that debris plugs up a multiple installation much faster than a single larger pipe. This factor must be considered carefully, especially in hilly, wooded country, before deciding on a multiple installation.

A culvert is required for the stream crossing at point A. The map is a portion of a drainage map with an original scale of 1" = 1000'. The area is rolling agricultural land.

The water shed area is outlined and divided into strips. Area in acres is calculated below.



Strip no.	Length (in.)	Width (in.)	Area (sq. in.)
1	0.5	0.2	0.10
2	1.9	0.5	0.95
3	2.1	0.7	1.47
4	2.5	0.6	1.50
5	2.7	0.7	1.89
6	0.6	0.4	0.24
7	0.8	0.6	0.48
Total			6.63

$$M = \frac{6.63 \times 1000 \times 1000}{43560}$$

$$= 152 \text{ Acres}$$

For rolling agricultural land,
 $C = 0.33$

From Figure 28 - Required area = 14 square feet.
 From Table I - One 54" diameter pipe or two 36" diameter would be adequate.

Fig. 29. Example determination of culvert size.

For very small watersheds and for crossing ditch lines, capacity is usually not the factor which controls size. Pipes smaller than 8 to 12 in. are undesirable because they are easily clogged and are difficult to clean.

Length

Normally, culverts are made long enough to clear the roadway fill at both ends. Where right-of-way is insufficient a headwall and endwall may be built to retain the fill and protect it from scour, but this is usually more expensive construction than the longer pipe. Also, retaining walls protruding above the fill, especially near the traveled surface, are a distinct traffic hazard and should be avoided whenever possible.

Culverts under road intersections or driveways should be long enough to permit an easy turn onto and off the road. Actual length will depend on the width of the road, the depth of the ditch and slope of the fill, and the turning radius provided.

Strength

The strength of pipe required for a particular location is based largely on rules formed from observation of a great many installations. Pipe meeting the specifications of the American Society for Testing and Materials (ASTM) or the American Association of State Highway Officials (AASHO) should be used in all highway work.

Reinforced concrete pipe is classified in five groups on the basis of load carried in a standard three-edge-bearing test (ASTM Designation: C-76-57T). Class I is lowest strength and Class V is highest. Concrete pipe of Class III or IV is usually used for culverts. In ordinary embankments, concrete pipe of these classes may be used with as little as 1 ft of cover and at depths of 9

TABLE II
RECOMMENDED MAXIMUM DEPTH OF TRENCH
FOR REINFORCED CONCRETE PIPE
ASTM Designation: C-76-57T
(Ordinary Bedding)

Inside Diameter in Inches	Depth in Feet	
	Class III	Class IV
12	9.3	20.6
15	10.6	19.1
18	11.7	20.7
21	12.8	21.3
24	13.5	23.0
27	14.3	23.8
30	14.8	24.7
33	15.2	25.2
36	13.7	20.4
42	14.7	21.5
48	15.7	22.6
54	16.5	23.6
60	17.2	24.4
66	18.0	25.1
72	18.7	26.1

From Concrete Pipe Handbook.

TABLE III
RECOMMENDED GAGE FOR ROUND CORRUGATED
METAL PIPE CULVERTS
AASHO Designation: M-36-53

Diameter in Inches	Height of Cover Above Top of Culvert in Feet								
	1- 10	11- 15	16- 20	21- 25	26- 30	31- 35	36- 40	41- 45	46- 50
15	16	16	16	16	16	16	16	16	16
18	16	16	16	16	16	16	16	14	14
21	16	16	16	16	16	16	14	14	14
24	14	14	14	14	14	14	14	14	12
30	14	14	14	14	14	12	12	12	10
36	12	12	12	12	12	10	10	10	8
42	12	12	12	12	10	10	8	8	8
48	12	12	12	10	8	8			
54	12	12	10	8	8				
60	10	10	8	8					
66	10	10	8						
72	10	8							

From **Handbook of Drainage and Construction Products and Highway Engineering Handbook.**

to 40 ft. The maximum depth depends on the bedding provided and on the diameter of the pipe. Recommended depth for Class III and Class IV pipe with ordinary bedding are shown in Table II. The minimum cover may be reduced to 1 or 2 in. in locations such as driveways not subject to heavy loads. Complete recommendations for all classes of pipe may be found in the *Concrete Pipe Handbook*.

Corrugated metal pipe (AASHO Designation: M36-53) is available in various gages, or thickness of metal, to provide adequate strength for each particular case. The gage required depends on the pipe diameter and the depth of cover. Table III shows recommendations for gage to be used in ordinary situations. Minimum cover for corrugated metal pipe is one-fifth the diameter of the pipe, but not less than 9 in.

For locations subject to frequent applications of unusually heavy loads, or under deep embankments, the recommendations of the manufacturer should be consulted.

For safe and trouble free culverts—*Provide Area Enough for Storm Flows and the Proper Strength for the Size and Load Condition.*

Grade and Alignment

In general, the best location for a culvert is in the natural channel or at the center of the ditch, following the alignment and average grade of the bed. This is especially important in rolling and rough country where water velocities are relatively high.

In flat land, where velocities are low, alignment may be varied from the natural channel to permit placing the culvert in the dry or to make a square, rather than a skew, crossing. Generally the grade should be straight with the inlet and outlet conforming to the existing channel bed.

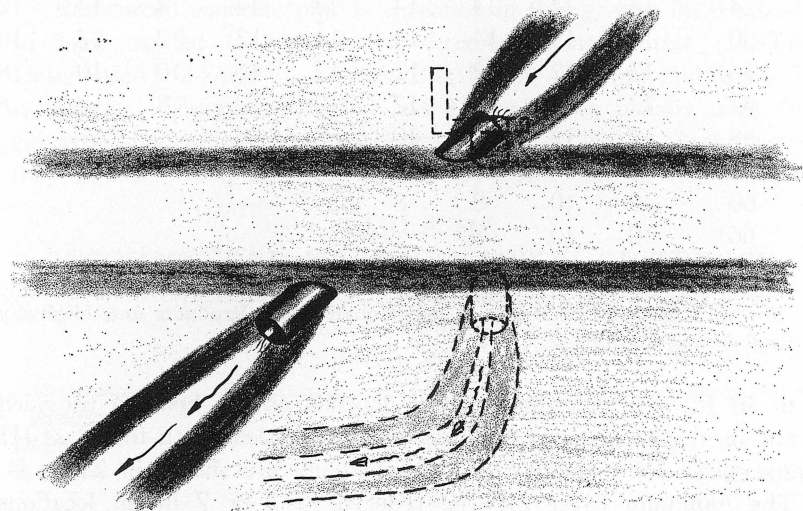
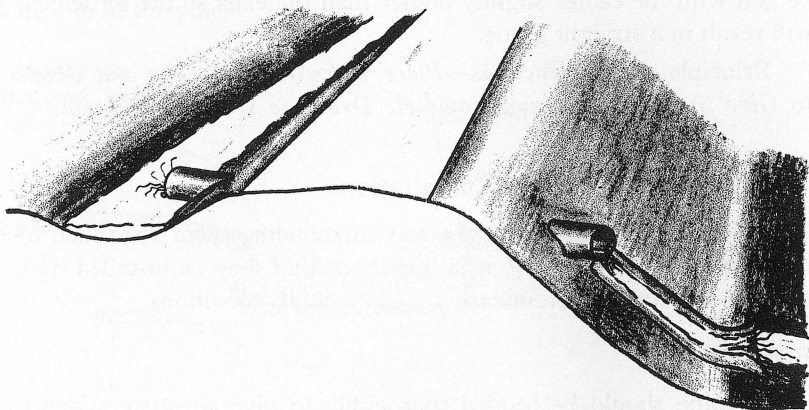


Fig. 30. Usually the extra length of pipe required by a skew crossing pays for itself in better drainage conditions, with no erosion or deposition problems. The alternate location indicated often results in a continuous maintenance problem.

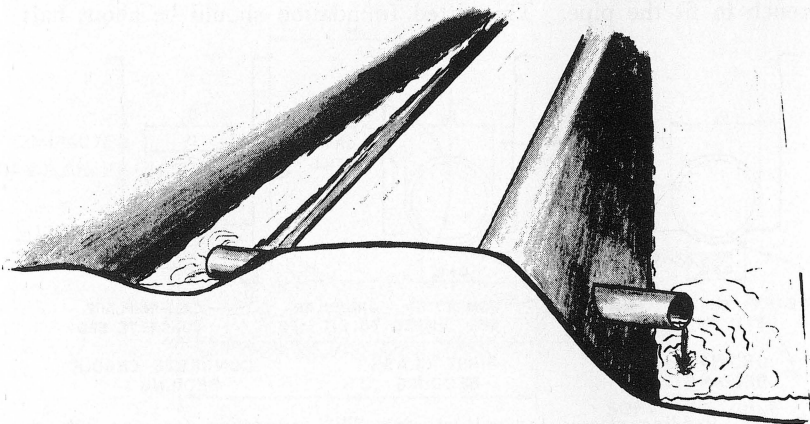
In steep areas with high water velocity it is best to maintain the direction of the channel, even where it requires a skew crossing. A sudden change in direction of fast moving water results in a highly erosive condition on one side of the channel and, frequently, silting on the other side. Where it is essential to change the alignment, the inlet end should be placed in the natural channel and the adjustment made at the outlet end as necessary. Stream velocity may sometimes be reduced by placing the first few feet of pipe on a steep grade and placing the remainder on a flat slope. If the stream bed is in rock or coarse gravel so that erosion is not a problem, the grade line of the culvert may follow the natural ground rather than making rock cuts to get a straight grade or flat slope.

Culvert locations above the natural channel should be avoided where possible because such locations create ponding on the upstream side of the road and may endanger the embankment.

Deposition is usually not a problem in culverts with a straight alignment and direct inlet and outlet because flow is faster in the culvert than in the channel. In roadside ditches at culvert entrances and crossovers control of silting is primarily a question of controlling erosion, as discussed in previous section. Culverts can create erosive conditions, however, by increasing velocity. In such locations corrugated pipe can have an advantage over smooth pipe, especially if the culvert is long, by helping to keep velocity low. Sharp bends at entrances should be avoided. If the channel has



(a)



(b)

Fig. 31. Culvert grades can be reduced by either of these techniques. Protection from erosion at the outlet is essential. Less pipe is required in (a) but maintenance of a sluice is eliminated in (b).

a steep grade, the pipe may be placed at a flatter grade than the channel with a free fall at the outlet end. The outlet end of the pipe should be extended out from the fill far enough so that the flow will not fall on the toe of the slope. A basin may be formed below the exit to absorb the energy of the falling water without erosion. An alternate possibility is to pave the earth slope below the pipe or protect it with riprap. This approach should not be used, however, for a stream which carries a large amount of silt and debris, because the reduced grade of the pipe will reduce water velocity which will result in deposition.

Culverts placed under high fills tend to settle more in the center than at the ends. In order to prevent a sag occurring, the pipe may be laid with the center slightly higher than the ends so the settlement will result in a straight grade.

Principle number three is—*Place Culverts on a Line and Grade to Give Smooth Flow and Complete Drainage Without Erosion.*

Installation

Pipe culverts depend on the soil surrounding them for much of their strength. Therefore, it is important that they be installed with careful attention to foundation and backfill conditions.

Bedding

All pipe should be bedded thoroughly to give adequate support. In firm earth this is accomplished by shaping the bottom of the trench to fit the pipe. This fitted foundation should be about half

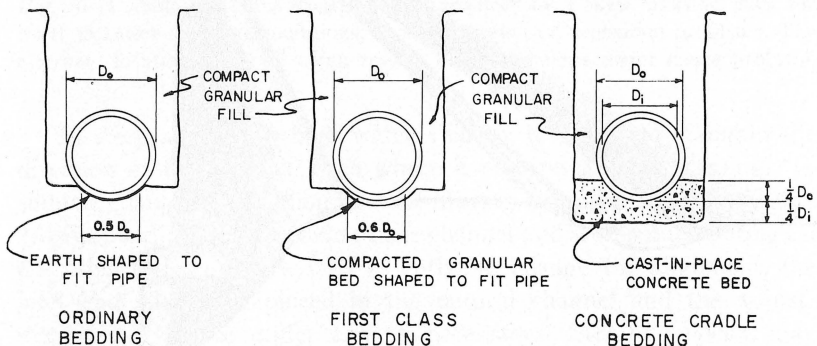


Fig. 32. Bedding classes for culvert pipe. The foundation for pipe culverts should *always* be shaped to fit the pipe. Most culverts are placed with ordinary bedding. Extra strength is provided by first class and concrete cradle bedding. (Concrete cradle should not be used with flexible pipe such as corrugated metal).

as wide as the pipe diameter. When bell-end pipe is used extra depth must be provided for the bells in order to get continuous support through the straight portion of pipe.

Shaping the earth to fit the pipe is satisfactory for most installations and is called ordinary bedding. First class bedding will give greater strength needed for heavy loads or high fills. Rigid pipe may be placed in a concrete cradle for extremely heavy loads. These bedding classes are illustrated in Figure 41. No pipe, of any material, should be placed directly on rock or extremely hard earth. Rock foundations require an over-excavation 8 to 12 in. below the bottom of the pipe and about as wide as the pipe diameter. The excavation is then backfilled with compacted granular fill and shaped to fit the pipe.

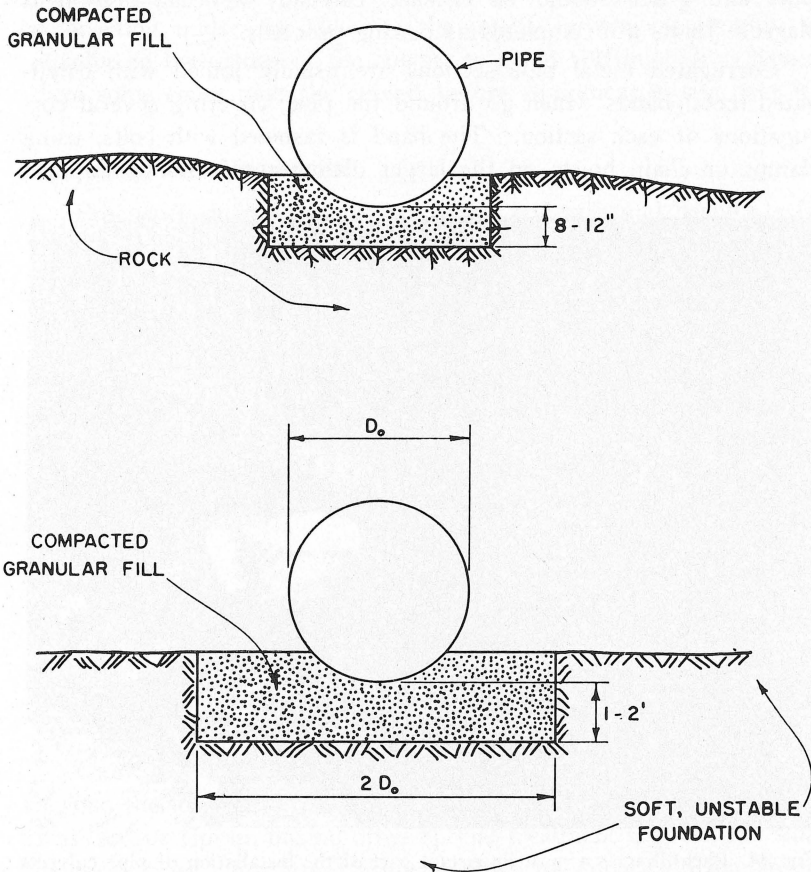


Fig. 33. Foundations in hard and soft materials. Gravel mats should be provided as bedding for pipes both in very hard and very soft material.

Soft, unstable foundations also require special treatment. A gravel mat may be used to support the pipe, as in rock foundation, but a larger layer of fill is generally required. A trench is excavated in the undesirable material about twice as wide as the pipe diameter and 1 to 2 ft deep, as necessary. The trench is then backfilled with compacted gravel and shaped to receive the pipe. In swamp and muck areas a timber or brush mat may be placed on the foundation material and covered with an earth cushion before installing the pipe. Concrete pipe may be placed directly on timber supports.

Placing

As soon as the foundation is prepared, laying of the pipe can begin. Work should begin at the downstream end and progress upstream. Bell or groove ends, if used, should be placed upstream. Line and grade should be checked carefully as each section is placed. Joints are completed as placing proceeds.

Corrugated metal pipe sections are usually joined with corrugated metal bands which go around the pipe, covering several corrugations of each section. The band is fastened with bolts, using clamps or chain hoists on the larger diameter culverts to help get

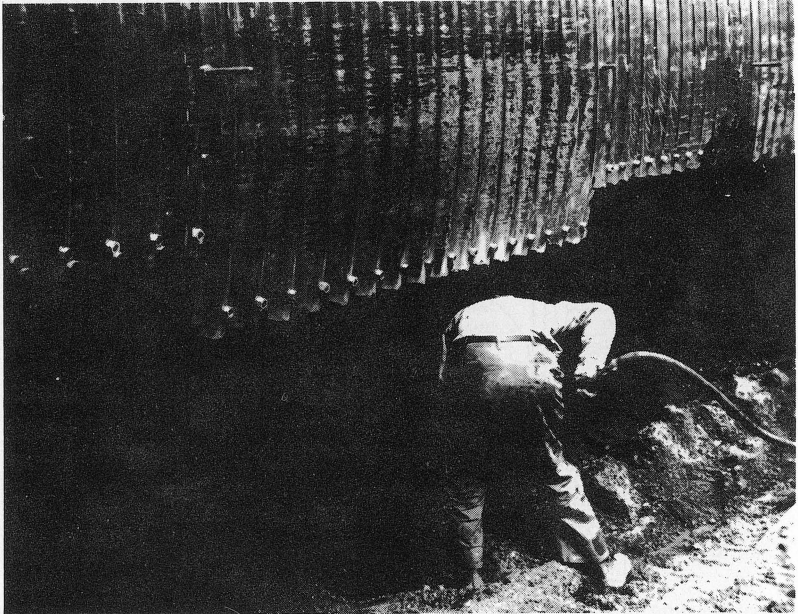


Fig. 34. Backfilling is a most important part of the installation of pipe culverts of all sizes. Note the clean, granular fill and the thorough tamping under the sides of the pipe. (Courtesy Armco Drainage and Metal Products, Inc.)

the band tight. Concrete or clap pipe may be easily joined with rubber gaskets which fit between the tongue and groove ends. Otherwise, joints may be made with portland cement mortar or grout. After the joint is complete, the inside should be finished smooth and even with the surface. For pipe larger than 30 in. in diameter this finishing is usually done after the backfill has been placed. Backfilling can proceed immediately following the jointing, care being taken to prevent displacing the pipe.

Backfill

Backfilling, as pointed out, is a most important phase of culvert installation. The material should be free of stones and debris. Soil should be placed in 6 to 8 in. layers and thoroughly compacted with mechanical or hand tampers. Special care must be taken to insure compaction under the sides of the pipe. Layers are brought up equally on both sides of the culvert to avoid shifting. It is best to have some cover over the culvert before equipment is run over it.

Endwalls and Headwalls

Frequently it is not necessary to use endwalls and headwalls for pipe culverts. When they are used, as where right-of-way is limited, they should be constructed on a firm foundation to prevent settlement or tipping. Footings should be placed well below stream bed to prevent undermining. Shifting of an endwall can pull apart sections of culvert pipe, ultimately causing complete failure. Therefore, they should be constructed so as to prevent movement.

A most important principle for all culverts is—*Provide a Continuous Firm Foundation and a Uniform Well Compacted Backfill for Adequate Support.*

End Treatment

Ends of pipe culverts require special attention to assure effective flow conditions and prevent scour. The length of a culvert, too, may be affected by the type of end treatment.

One common practice is to make the pipe long enough to project beyond the toe of the roadway fill at both ends. The fill is protected with sod or riprap, but no other special treatment is given for small diameter pipes. For larger diameter pipes, the ends are often beveled to conform to the fill slope both to improve appearance and to make a more effective entrance for water on the upstream end.



Fig. 35. Two end treatments are illustrated here. Note the smaller pipe extended straight beyond the toe of the embankment, and the larger pipe beveled to fit the slope. A concrete sill at the invert of the large pipe prevents undermining. (Courtesy Armco Drainage and Metal Products, Inc.)

Culvert length may be shortened considerably where necessary, especially if fill slopes are flat, by installing a headwall and endwall to retain the fill above the pipe. Such a structure may also be used to help prevent scour in a fast moving stream. Total cost, however, is likely to be more than a longer pipe with no end structures.

With the exception of long culverts on flat grades, the entrance conditions are important in determining the capacity of pipe culverts. Straight, sharp entrances; or headwalls with square corners cause water to back up on the upstream side of the fill. This ponding can be reduced by rounding the edges at the entrance or by flaring the entrance to make a gradual transition for the stream. The bell or groove end of concrete and clay pipe provides a reasonably good entrance. Standard flared metal ends are available for the ends of corrugated metal pipe. Where headwalls are used, the corners at the pipe entrance should be well rounded. Wing walls projecting at an angle to the headwall also will provide a flared effect to help converge the flow. Also, as noted, beveling the ends of large diameter pipes to fit the fill slopes improves the entrance condition.



Fig. 36. A typical standard flared end section will improve entrance conditions and protect streambed and embankment from erosion. (Courtesy Armco Drainage and Metal Products, Inc.)

Where the stream bed is erosible, or velocities are high, a paved apron may be constructed, extending 3 to 4 ft from the pipe entrance and exit to prevent gullies from forming. At the end away from the pipe, a sill, or cut-off wall, should extend 1 to 2 ft below stream bed to prevent undercutting.

A major problem with cross drains is to turn the water from the ditch into the culvert. If the cross drain occurs at the end of a ditch this may be accomplished by installing an L-shaped headwall, the projecting leg of the headwall turning the water into the pipe. A better practice, where possible, is to place the culvert deeper under the road with a drop inlet or vertical pipe section at the ditch line. The opening should be protected with a grate.

A fifth principle—*Protect Ends of Culverts From Scour and Flare Entrances for Maximum Capacity.*

Maintenance

The first requirement of culvert maintenance is regular inspection. A major cause of failures is the accumulation of debris at the culvert entrance or on a fence line just above the entrance. The ponds resulting from such barriers saturate the road bed and back up ditches

preventing proper drainage. A fence piled high with brush may give way sending a sudden surge of water which washes out the culvert completely. These maintenance problems are best cured before they occur. Regular inspections will show where cleaning is required and simplify the job of keeping the entire highway drainage system operating properly. Culvert locations should be marked with a stake or iron post near the entrance. On paved roads an arrow and a distance to the upstream end may be painted on the surface.

When inspection shows damaged or separated pipe sections, repair or replacement should be made promptly. If storm flows occur through damaged culverts, the surrounding fill becomes saturated and much of the supporting fill may be washed away.

Scour at inlet or outlet should be controlled by sod, riprap or paving before undermining can endanger the structure.

Silt and sand deposited at culvert entrances may not be a serious problem normally. Where this does accumulate, it is important to recognize that excessive erosion is occurring upstream. Location and correction of the erosion is generally more important than the clean-up operation at the culvert. When silt accumulation reaches serious proportions it should be removed. Sometimes silt can be flushed out with a pump and high pressure stream. Frequently, a hand shovel is a more effective tool. Silt accumulation removed from culverts should, of course, be hauled away from the site rather than be dumped on the shoulder to wash into the ditch again in the next rain.

Winter maintenance should include checking all culverts after snow plowing operations. Snow piled at culvert entrances and exits can effectively block drainage, creating serious ice problems.

Culverts carefully planned with regard to size and location, properly installed, and maintained regularly will go far toward an effective highway drainage system.

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SUBDRAINS

As has been noted, many highway problems are related to excess water. Unfortunately, an excess of water cannot always be prevented by providing only proper surface drainage. Sometimes eroding slopes and soft pavements are the result of water moving through pervious layers of soil, or of a high water table. In order to correct these problems it is necessary to install drains below ground which will intercept and carry the ground water to a stream or open drainage system.

Below are listed a few fundamental principles and guides to successful use of subdrains:

1. **Make subdrains deep enough, long enough, and so located as to drain excess water from critical locations.**
2. **Provide a protected outlet to a stream or open ditch.**
3. **Select a clean, pervious backfill material to serve as a filter.**
4. **Install subdrains on a firm foundation with a well compacted backfill.**

Application

Cut Slopes

Cut slopes which continually slough away at a point where free draining water reaches the face can be stabilized by installing a subdrain back of the cut face. Figure 37 shows such a drain installed to a depth slightly below the pervious material and backfilled with clean sand. The underground water is carried away in the drain to an outlet at a stream, removing the cause of sloughing. Then a normal grass cover will prevent ordinary slope erosion from surface water. This, in some situations, however, may not be possible due

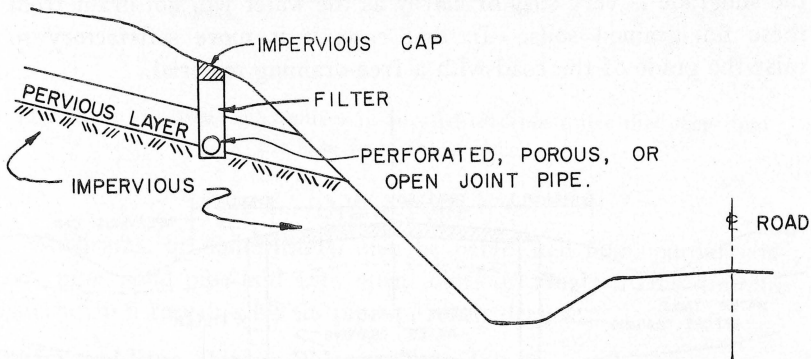


Fig. 37. This shows a subdrain intercepting free water in a slope before it reaches the face where it would cause sloughing or sliding.

to excessive depth of ditching. In cases such as this consideration may be given to installing drilled or driven horizontal drains. An accurate detailed survey must be made by competent persons before such a treatment is attempted.

Subgrade Drainage

Another application of subdrains is shown in Figure 38. Here, the underground water flows in a layer near the road surface. This water can weaken the road and create soft spots and rutting. The drain is installed in the pervious layer, beside the road, to intercept the water before it reaches the roadway.

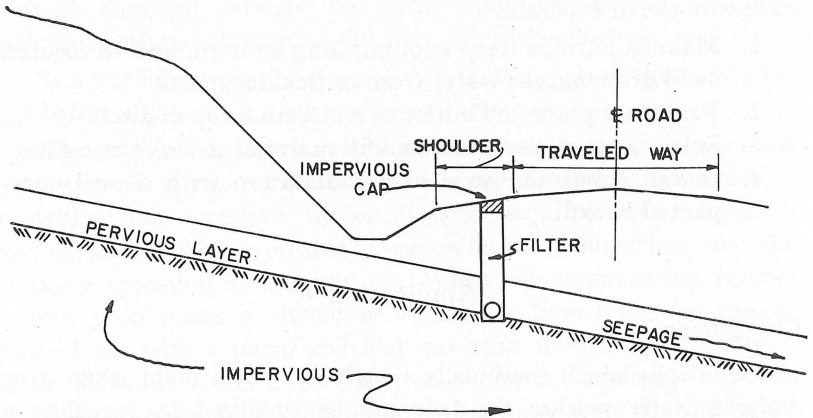


Fig. 38. This subdrain intercepts water flowing under a road to keep the base dry and stable.

A similar installation can be used when the natural ground water level is near the surface. Drains placed along each side of the road will lower the water level under the road to make the base stronger. It should be noted, however, that this system will not be effective if the subgrade is very silty or clayey as the water will not drain from these fine-grained soils. In that case, it is more satisfactory to raise the grade of the road with a free-draining material.

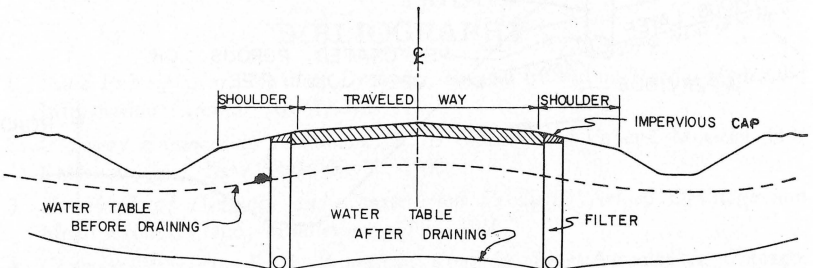


Fig. 39. Subdrains may be used to lower a free water table to strengthen the road and reduce effects of frost.

Another, but less frequently used, application of subdrains is to eliminate deep ditches with steep sides near the traveled surface. This may occur in deep cut sections or on extremely narrow rights-of-way.

Where such ditches are a distinct hazard a subdrain may be placed where the ditch would normally be, and backfilled with sand to a level only slightly lower than the road surface. The shoulder should still slope away from the road at about 1 in. per ft to insure proper surface drainage. Surface water can be conducted into the drain by placing drop inlets or blind drains at intervals along the roadside, connected to the subdrain.

Base Drainage

Subdrains are also used to drain the base course in cut areas where it is not practical to carry the base through the shoulder. These drains do not serve to lower the water table, but carry off water which permeates through the surface rather than running off into ditches. Where subgrade drains are used, they can serve to drain the base course as well. However, where dense graded aggregates are used in the base course, subdrains should not be installed because these materials do not drain freely.

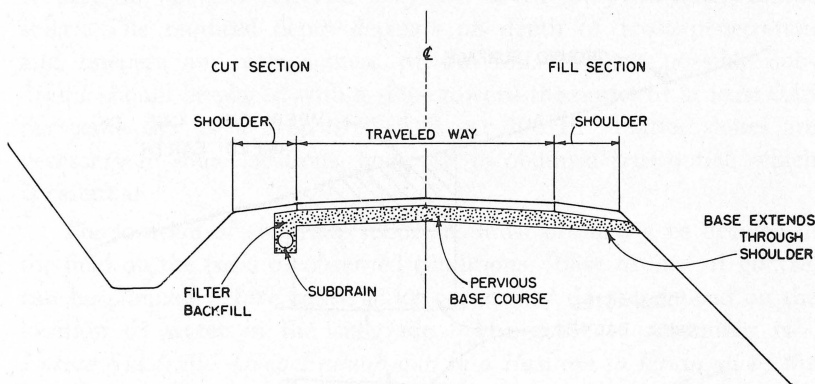


Fig. 40. In cut areas subdrains may be used to drain water that seeps into the base from the surface.

Drain Type

Subdrains, or underdrains, may be perforated pipe, porous concrete pipe, solid pipe laid with open joints or simply a free draining material in a trench with no pipe (French drains).

Perforated Pipe, Porous Pipe, or Open Joints

Generally the most satisfactory type of subdrain is perforated or porous pipe, laid in a trench, backfilled with a granular, free-draining

material, and covered at the surface with a relatively impervious soil. Pipe is usually 4 to 6 in. in diameter with holes in two or more lines on one side of the pipe. It may be metal, concrete, or vitrified clay. The same factors that are considered in choosing culverts will affect the choice of material for subdrains—cost, foundation conditions, corrosive substances.

Solid pipe, laid with joints unsealed, can effectively serve as a subdrain. Open joints are likely to permit silt and fine sand to enter the pipe unless special precautions are taken. Where open joints are used they should be covered with burlap, tarpaper, or broken tile, or they may be surrounded with gravel or crushed stone before backfilling.

French Drains

French drains are constructed with no open conduit in them. These drains depend on water flowing more readily through the porous backfill than through the surrounding material. As long as the filter is not clogged, this type of drain is satisfactory. However, it is far more likely to get plugged with fine material than is a pipe drain, and it then becomes a severe maintenance problem. Therefore, as a rule it is best to place a pipe in the trench to insure positive removal of water.

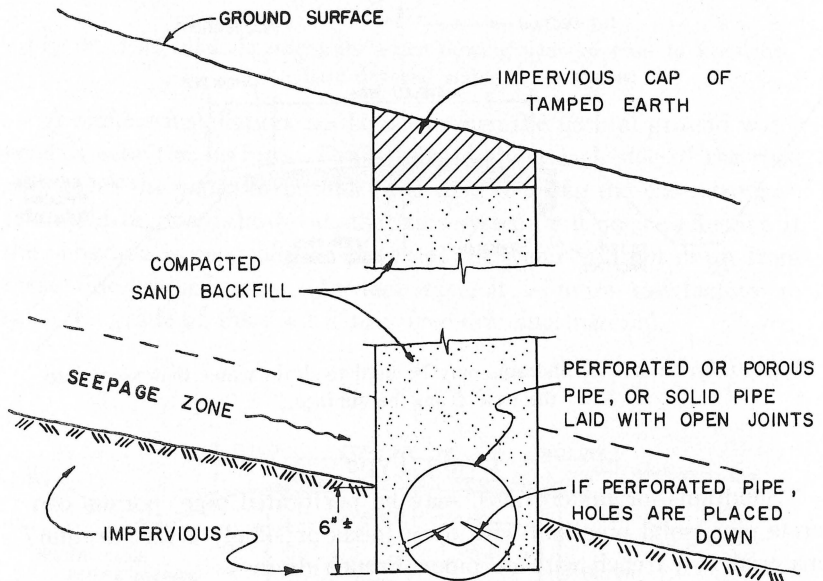


Fig. 41. Typical details of subdrains. Note especially that the invert of the drain is below the bottom of the water bearing material, the backfill is a clean sand, and holes are placed down.

Location

The location of subdrains is a critical part of their installation. In each case, careful attention must be given to exactly what job the drain is to perform.

In intercepting veins, or layers, of moving water, the drain must be placed at the bottom of the layer where water is flowing, and on the side of the structure nearest the source of the water. The trench is dug to a depth 4 to 6 in. below the pervious layer and shaped to fit the pipe. This will insure complete drainage of the pervious layer. The subdrain should extend the full length of the troublesome layer of soil and must run to a proper outlet.

Subdrains for protecting slopes are placed well back of the cut face. The trench is usually dug from a point above the top of slope. Subdrains used to intercept water which runs under a road are preferably installed under the shoulder, but they may be located at the ditch line. In order to lower the ground water table, subdrains should be installed close to the edge of the traveled surface. However, it is recommended that such drains not be installed across the road because settlements over the drains are likely to cause a series of dips. Subdrains installed to lower the water table have to be at least 4 ft deep to be effective, and they are useful only in fairly coarse soils. The required depth depends on depth of frost penetration and fineness and compactness of the soil. Where possible subdrains should be placed with a slope toward the outlet of at least 0.15 per cent—that is, a drop of 0.15 ft per 100 ft. Flatter slopes are necessary in some locations, however, to obtain a free outlet, which is essential.

The location of subgrade subdrains must ordinarily be decided in the field on the basis of observed conditions. Base drains, of course, can be planned before construction since they do not depend on the location of water in the subgrade. The guide to remember is—*Locate Subdrains Deep Enough and in a Position to Drain all of the Troublesome Water Away from the Roadway.*

Outlet

Every subdrain must have a free outlet in order to function properly. The best installation will fail if the end is underwater, plugged with debris, or if animals nest in it. For this reason subdrains should be carried to a discharge at a stream, culvert, or open ditch. The bottom of the pipe is kept above high water in the ditch and the end protected with a grate or screen. The outlet pipe may

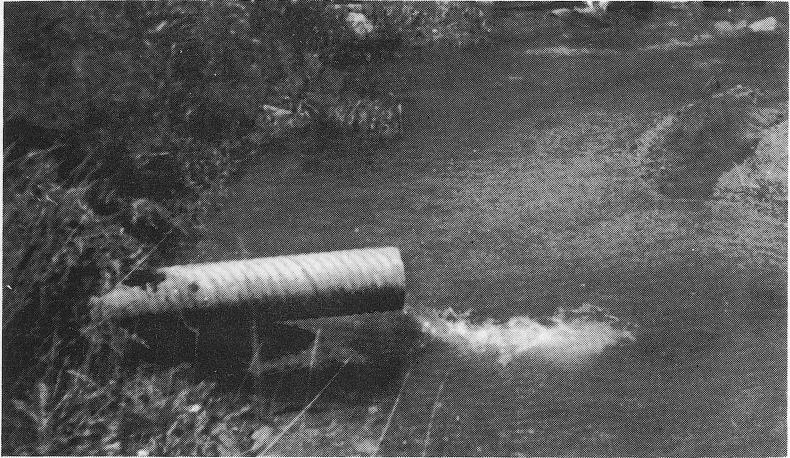


Fig. 42. This outlet discharges into deep water where there is no danger of erosion. Note the height above free water to insure that the outlet will not be submerged. (Courtesy Armco Drainage and Metal Products, Inc.)

project from the bank to keep it free of debris. If plowed snow covers the outlet it should be removed promptly to insure continuous drainage and prevent the pipe from filling and freezing.

An important principle for subdrains—*Provide an Unobstructed and Protected Outlet to a Stream or Open Drain.*

Filter

The backfill around subdrains must serve as a filter as well as provide support for the pipe. The essential requirements of filter material are that water flow through it more readily than through the surrounding soil, and that it not be plugged with fine particles from the surrounding soil. To satisfy the first requirement, the fill should be a clean granular material. To prevent clogging with fines it must not be too coarse. In most soils a clean sand such as used for concrete will serve satisfactorily as a filter material. Open joints must be protected to prevent the sand washing into the pipe. This can be done with tarpaper, burlap, broken tile, or crushed stone.

For permanent, effective underground drainage—*Surround Subdrains with a Clean, Pervious Filter Material.*

Installation

Installation procedures for subdrains are essentially the same as for pipe culverts. Firm, continuous bedding is essential to prevent

destructive settlements and/or crushing of pipe. The supporting earth should be shaped to fit the pipe. Pipe should be laid with the holes on the lower side.

The filter backfill provides the support for subdrains. It must be brought up equally on both sides of the pipe and thoroughly compacted. The top foot of backfill should be clay or other impervious soil unless the subdrain is intended to serve surface drainage as well as underground drainage.

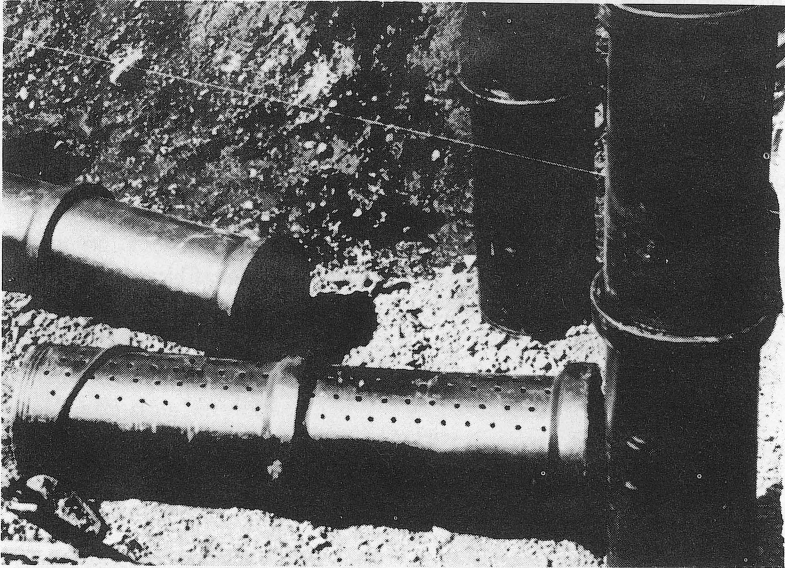


Fig. 43. In this installation of a subdrain perforated pipe is used and installed with holes down. Note the string line to assure installation to proper grade and alignment. (Courtesy Clay Products Association)

Where a deep subdrain is installed to intercept water in a pervious layer of soil, the filter backfill is sometimes used only for 1 to 2 ft above the pipe. The remainder of the trench is backfilled with the soil which was removed from the trench, or any suitable fill. However, if clean sand is available, it is desirable to use the filter material for the entire backfill, except the seal at the top. This provides a maximum area for seepage into the filter and least likelihood of clogging by fines washing into the filter.

To insure long-lived, maintenance-free subdrains—*Provide a Firm Foundation and Well Compacted Backfill.*

Maintenance

The inspection program in the maintenance of culverts should include inspection of subdrains to insure their continuous operation. Outlets should be well marked or mapped so they will not be overlooked on inspection trips. If outlets become covered by snow and ice, brush, or debris, it is essential that they be cleared if the drains are to work as planned. Subdrains that never carry any water are either ineffectively located, the pipe is plugged, or the filter clogged with fines. In any case, the only correction is removing and reinstalling the drain. It is evident, therefore, that care in installation is a most important factor in minimizing maintenance of subdrains.

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ADJOINING LAND

Drainage and erosion control problems are not restricted to the highway right-of-way. Water does not recognize boundaries of land ownership or political responsibility. Therefore, proper drainage and erosion control requires cooperation between highway personnel and owners of land adjacent to the highway.

One way to encourage landowners to use good conservation practice is to set an example of good management on the right-of-way. In addition, highway departments have a major responsibility to prevent damage to property adjacent to the road from concentrated streams of water running from the right-of-way. Outlets of drainage facilities should be established watercourses wherever possible, and should be protected from erosion so as to remain stable and effective in disposing of runoff.

Even though county highway departments have no direct control over property owners they can encourage good conservation practices. Choice of crops and method of cultivation can have a great influence on the amount of soil which is washed into roadside ditches and even onto the roadway itself. Assistance in planning and promoting erosion control is readily available from the Soil Conservation Service of the Department of Agriculture and from the Indiana Agricultural Extension Service.

Frequently, county officials may improve the highway drainage conditions and save money by assisting landowners in carrying out an erosion control plan. Highway department equipment might be



Fig. 44. This pond is created by using the highway embankment as a dam. Note the culvert outlet safely below road level at the far side of the pond.

used in grading, ditching or terracing operations to expedite a program. Landowners might contribute materials, and the highway department labor and equipment to improve a driveway or install a culvert. Some landowners will contribute right-of-way at little or no cost to the county for improving the drainage conditions, provided the county will provide a new fence.

Occasionally, a highway embankment may be made to serve as a dam for a farm pond. When such a dual purpose can be served by a planned improvement with proper design so the road is not undermined and the dam is effective, the benefits in good will and cooperation of landowners and the subsequent savings in maintenance cost may far outweigh the extra cost involved in construction.

Cooperative efforts of county highway personnel, landowners, and interested state and federal agencies, directed toward effective drainage and erosion control and guided by sound principles will reduce highway failures and make travel safer and more pleasant for all.

APPENDIX

GLOSSARY

- AASHO** American Association of State Highway Officials.
- Alignment** The horizontal direction of a road, ditch or other structure as shown in a plan view.
- Asphalt** A solid or semisolid material generally obtained as a residue in the refining of petroleum.
- ASTM** American Society for Testing and Materials.
- Backfill** Earth fill surrounding a structure and providing support for the sides.
- Backslope** That part of the roadway, in a cut section, from the ditch line to the original ground surface.
- Base course** A layer of granular material which lies immediately beneath the wearing surface of a pavement.
- Bedding** The foundation materials and condition for pipe.
- Bell and spigot** Pipe designed so that the end of one section fits inside the end of the next section.
- Bituminous material** A general term used to indicate a material containing asphalt or tar.
- Bridge** A structure with a span equal to or greater than 20 ft for carrying a road over a stream, another road, railroad or other obstruction. (See Culvert).
- Clay** A fine grained soil (passing the No. 200 sieve) which has considerable strength when dry and is plastic, or putty-like, at some water contents.
- Cross drain** A culvert which carries an accumulation of water from a roadside ditch to the opposite side of the road.
- Culvert** A structure for carrying water, beneath a road. The term is usually restricted in application to structures less than 20 feet long measured parallel to center line of roadway.
- Cut slope** Backslope; the limit of excavation from the ditch line to the surface of undisturbed ground.
- Deposition** Accumulation of soil and/or debris deposited by a stream.
- Ditch** A depression or trough in the ground for carrying water.
- Drainage** Structures and facilities for collecting and carrying away water. Also, the water that is carried away.
- Drainage area** Of a given point, that area of land from which all water drains past that point.

- Embankment** An earth, or rock and earth, fill for carrying a road above the surrounding ground.
- Endwall** A structure, usually concrete or rubble masonry, at the downstream end of a culvert, which retains the fill and anchors the culvert.
- Erosion** Movement of soil by the action of water and wind.
- Filter** A backfill which readily permits the flow of water but restricts the washing of fines from the soil.
- Foundation** The material on which a structure is placed, or the lowest part of a structure, which distributes the load to the underlying material.
- Grade** The rate of rise or fall in the profile of a road, ditch, or other structure.
- Gravel** That fraction of soil consisting of particles smaller than 3 in. which will not pass through a No. 4 sieve.
- Ground water level** The elevation of the free water surface—the elevation to which the water surface will rise in an observation well.
- Headroom** The distance from the top of a pipe or other structure to the road surface.
- Headwall** A structure, usually concrete or rubble masonry, at the upstream end of a culvert, which retains the fill and anchors the culvert.
- Impervious** A property of soil or other material which prevents or inhibits the flow of water through the material.
- Intercepting ditch** A trough or gutter, at the top of a slope, which collects surface water and prevents it from washing over the slope face.
- Invert** The inside bottom surface of a culvert.
- Mulch** A covering over the soil which temporarily protects it from erosion and maintains temperature and moisture conditions favorable to germination of seeds.
- Multiplate** Pre-curved corrugated metal sheets which are bolted together to form a pipe or arch structure.
- Permeable** A property of soil or other material which permits the flow of water through the material.
- Pervious** A property of soil or other material which permits the flow of water through the material.
- Profile** The vertical direction of a road, ditch, or other structure; a view of a vertical section of the structure.
- Portland cement** A product obtained by pulverizing a clinker that is made by burning a carefully proportioned mixture of calcareous and argillaceous material, usually limestone and clay.
- Riprap** A layer of large stones placed to protect soil from erosion.
- Rubble masonry** A type of construction using stone or broken rock laid dry or cemented in place with mortar.

- Sand** That fraction of soil which passes a No. 4 sieve but will not pass a No. 200 sieve.
- Scour** The washing away of soil around and beneath a structure.
- Scupper** An opening in a bridge floor or curb to permit water to drain from the surface.
- Silt** A fine grained soil (passing the No. 200 sieve) which has little or no strength when dry and is not plastic or putty-like at any water content.
- Silting** The depositing in a stream or ditch of fine soil carried from higher ground.
- Skew** The angle a stream or structure makes with a line perpendicular to the roadway.
- Slope** The surface of an earth fill or cut, or the grade of that surface expressed as the ratio or horizontal to vertical distance.
- Sluice** A channel, with a protective lining, which carries water over a slope.
- Sod** A layer of grass and soil cut in sections or strips from an established turf.
- Span** The length of the opening of a bridge or culvert, from support to support, in the direction of the road. For pipe culverts, the greatest width of the pipe.
- Subbase course** A layer of material beneath the base course of a pavement and above the subgrade.
- Sudrain** A structure beneath the ground surface for collecting underground water and carrying it to an outlet.
- Subgrade** The natural ground or an embankment upon which a pavement is constructed.
- Subsurface drainage** Collection and removal of underground water.
- Surface drainage** Collection and removal of water from the surface of the road and the ground.
- Tar** A liquid or semisolid material generally obtained as a by-product of the production of coke from coal.
- Underdrain** A structure beneath the ground surface for collecting and removing underground water.
- Vegetal cover** A continuous growth of grass, legumes, vines, shrubs or other plants which protect surface soil from washing or blowing away.
- Vitrified clay** A product of clay which has been formed under pressure and hardened at high temperature.
- Waterway area** The area of the opening in a culvert or bridge through which water may flow.

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J.

Principles of Highway Drainage and
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