RURAL URBAN

Local Road Assessment and Improvement

Drainage Manual

Transportation Information Center
University of Wisconsin–Madison

Contents

This manual is intended to assist local officials in understanding and rating pavement drainage. It complements PASERWARE, the computerized pavement management program developed and supported by the Wisconsin Transportation Information Center (T.I.C.).

It was produced by the T.I.C. with assistance from the Federal Highway Administration, the Wisconsin Department of Transportation, and the University of Wisconsin–Extension. The T.I.C., part of the nationwide Local Technical Assistance Program (LTAP), is a Center of the College of Engineering, Department of Engineering Professional Development, University of Wisconsin–Madison.

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Local Road Assessment and Improvement

Drainage Manual

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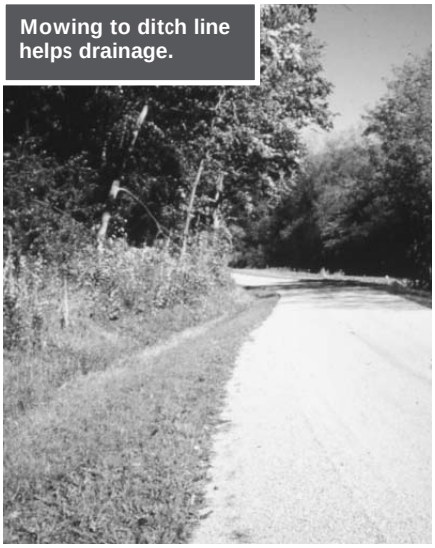
Drainage Manual

This manual is designed to help local officials evaluate drainage conditions along rural and urban roadways. It is part of the PASERWARE pavement management system. This manual can also be used to plan for road maintenance and improvements.

The manual includes background information on the importance of drainage and the impacts of poor drainage on roadway performance. It covers both rural roads with ditches and culverts and urban sections with curb and gutter and storm sewer. Drainage elements are explained and accompanied by representative photographs to aid field inspection.

Evaluation tools are a necessary part of pavement management systems. They aid in developing cost estimates and setting strategies for maintenance and improvement. This manual has a rating and evaluation section which you can use with PASERWARE, with another pavement management system, or simply as an inspection tool for your maintenance and improvement programs.

Most local officials can use visual inspection and common sense to evaluate and develop an effective roadway maintenance and improvement program. However, we strongly recommend using professional advice in redesigning and making major improvements in culvert sizes and in assessing the causes and solutions for flooding conditions. The cost and potential severity of problems caused by flooding and improper drainage design and construction make professional assistance a wise investment.



Mowing to ditch line helps drainage.

The state has regulations on erosion control and on constructing and maintaining local roads near wetlands and navigable streams. When you are planning work near navigable streams and wetlands and on larger projects that will uncover more than five acres of soil, you should contact the Department of Natural Resources (DNR) transportation liaison for your county. They welcome questions about the regulations and will help you meet state requirements. Sediment run-off and other non-point source pollution regulations are evolving. It is wise to keep abreast of these changes.

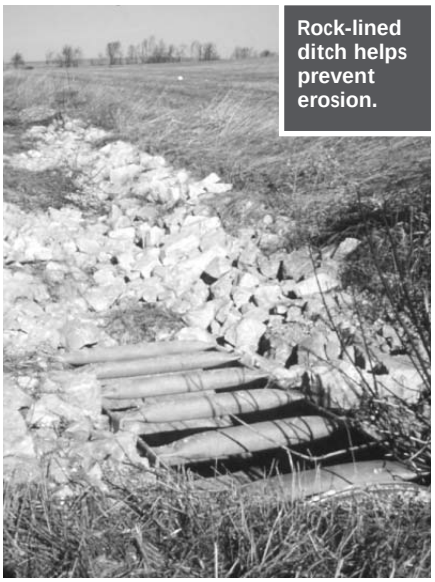
Good round-bottom ditch. Seed for erosion control.

Maintaining proper drainage

Even on roads built with all the proper drainage elements, neglecting maintenance is likely to result in flooding, washouts, and potholes. To keep a road in good condition, maintenance to the road surface and shoulder should retain and restore the original design as much as possible. On gravel roads, this involves smoothing and reshaping with a motor grader. Surfaced roads may need periodic patching or overlays.

Other conditions requiring maintenance to improve drainage include:

- Ditches clogged with debris or sediment need cleaning to avoid overflowing and washouts. Excavated sediments which are of the same quality as the aggregate mix on the road can be put back onto a gravel road and bladed into the surface. Well designed and built ditches have gentle side slopes which a grader can travel to clean the ditch bottom. Cleaning ditches with steep slopes requires a backhoe which is more expensive and time consuming to use than a grader.
- Vegetation and brush that obstruct water flow need to be mowed or cut. However, when removing sediment from ditches be careful to disturb vegetation as little as possible to limit erosion. It may be necessary to re-seed, mulch, or use other erosion protection methods on steep slopes or in areas sensitive to severe erosion. Sediments from eroding slopes can fill downstream road ditches and culverts or pollute streams and lakes.
- Culverts need to be kept free of sediment so water flows freely and doesn't wash out roads and flood adjacent property. Inspect periodically for sediment buildup and for cracks or corrosion that might lead to culvert failure. Clear clogged culverts with hand shovels or mechanized equipment. However, the best maintenance technique is to prevent sediment buildup in ditches so there is no material to run into and clog culverts.
- In urban areas, ponding behind curbs that saturates the street base needs to be corrected. Regrade soil in the terrace behind the curb to protect the street structure from localized ponding due to lawn watering or runoff. For more severe or persistent conditions, install underdrain behind the curbing. Repair or replace sunken inlets which collect standing water.



Rock-lined ditch helps prevent erosion.

Good urban drainage system.

The text and photos that follow describe each drainage component and depict inadequate drainage conditions that can lead to road damage. This manual should serve as a guide to help you locate, assess, rate, and improve drainage conditions on your roads.

Assessing drainage systems

A drainage system includes the pavement and the water handling system. They must be properly designed, built, and maintained. The water handling system includes: shoulders, ditches and culverts; curb, gutter and storm sewer. When a road fails, whether it's concrete, asphalt or gravel, inadequate drainage often is a major factor.

Shoulders and embankments damaged by heavy rain or floods can allow water to stand on the road or seep back into the base, saturating it. Surface cracks allow water to penetrate and weaken the base. Poor design can direct water back onto the road or keep it from draining away. Too much water remaining in the surface, base, and subgrade combine with traffic action to cause potholes, cracks and pavement failure.

The basics of drainage are similar in both rural and urban settings. Some issues specific to certain drainage elements are discussed separately.

Crown

The road surface should be crowned so water will run off to the shoulders. As a general rule, the center of the road on paved surfaces should be 2½ inches higher than the shoulder, 5 to 6 inches higher for gravel surfaces. Shoulders should slope as much or more than the road to keep water moving to the ditches. For example, a paved roadway with an 11 foot lane and 4 foot shoulder should have a total crown (from centerline to outside edge of shoulder) of not less than 4 inches.

Gravel roads need special attention because they are more susceptible to rain damage. They will need higher crowns than paved surfaces to prevent the surface from absorbing too much water, becoming saturated, and not drying out. Traffic action on a saturated surface causes potholes and ruts.

Poor crown allows pavement saturation.

A good quality gravel surface absorbs minimal amounts of water, sheds the rest, and dries out quickly. Poor drainage may be caused by gravel with a poor gradation of stones, sand and fines. You can partially compensate for poor quality gravel with a higher road crown.

Steep roads may also require higher crowns since the water will tend to flow down the road flooding traffic lanes, rather than across the crown.

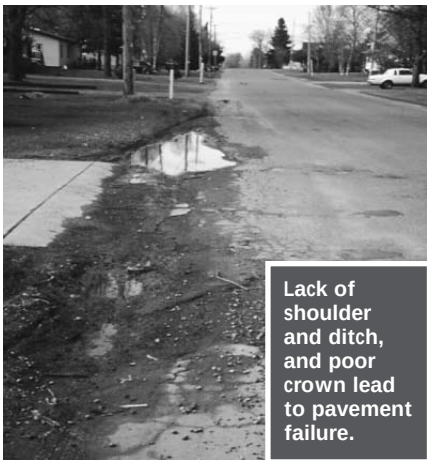
Shoulders

Shoulders extend the road surface, directing water flow to the ditches if they slope as much or more than the crown. If they slope less, water will build up during heavy rain at the join between shoulder and road, flooding traffic lanes. Make sure the shoulder continues the road crown smoothly.

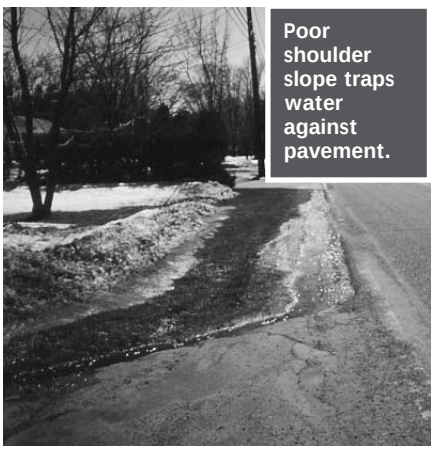
Springs or seepage areas will require special treatment. You can use french drains (rock filled trenches) or perforated pipes to drain this subsurface water into ditches or streams.

One common method for constructing gravel roads, the trench technique, causes poor drainage. It involves making a shallow excavation of just the intended road surface, then filling it with sub-base and base material. The shoulders are not fully excavated and the original soil is covered with a thin layer of gravel.

The problem with this method is that usually water can't penetrate beneath and through the shoulder's subsurface material. These impermeable shoulders keep water from draining out of the roadway's base. It is trapped and weakens the roadway.



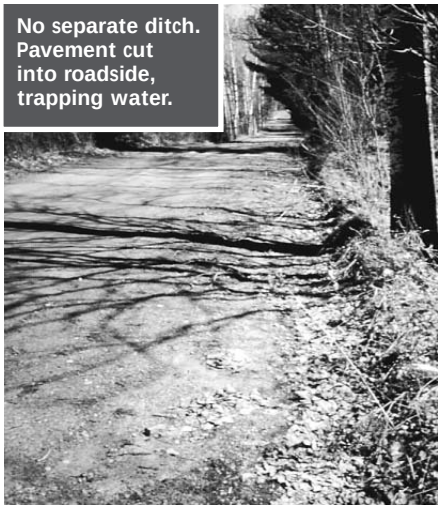
Lack of shoulder and ditch, and poor crown lead to pavement failure.



Poor shoulder slope traps water against pavement.

For proper drainage and longer roadway life, excavate the shoulders to the same depth as the roadway and use the same sub-base and base material. Use a gravel or crushed rock that drains well to remove any water which soaks through the surface or enters the subsurface.

High shoulder creates a secondary ditch and damages pavement.



No separate ditch. Pavement cut into roadside, trapping water.

Ditches

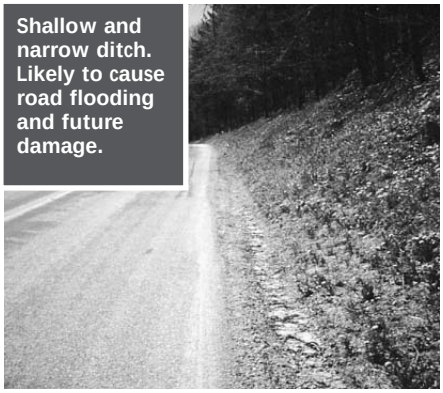
Ditches carry water away from the roadway and into streams or other natural waterways. To do this, ditches must be properly shaped for safety, maintenance, waterflow, and erosion control. The ditch should be at least one foot below the bottom of the gravel base in order to drain the pavement. Deeper ditches may be necessary to provide positive drainage patterns.

Use a smooth transition to the ditch. Sides that are too steep may cause errant vehicles to roll over. Side slopes of 4:1 are desirable while the maximum slope should be 2½:1. A gentle slope makes mowing and ditch cleaning easier, faster and cheaper, but, of course, they require a wider right of way.

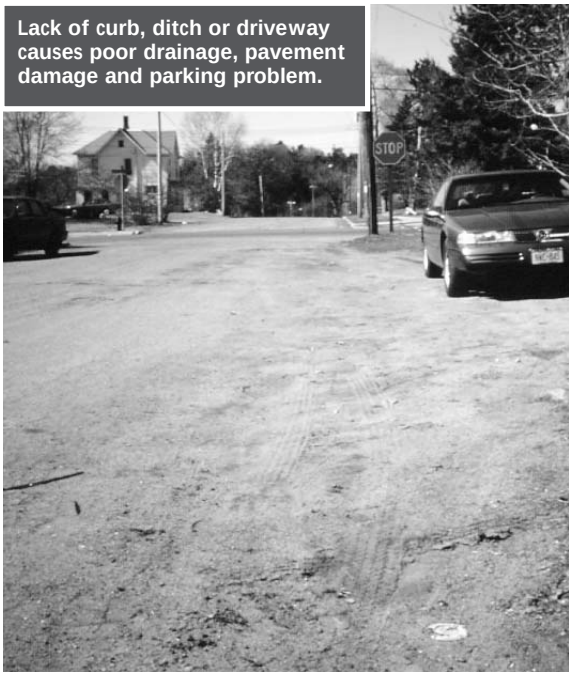
It's very important that water flow along ditches and not stand in them. Standing water may saturate the subsurface material beneath the roadway, preventing the road from draining during the next storm. Standing water also reduces the ditch's capacity to handle runoff. As a result, the next storm could wash out the roadway.

Ditches with 1% gradient are desirable (½% minimum) to insure proper flow. The flow of water in ditches should not erode the ditch itself or weaken the adjoining shoulder. Vegetation in ditches is necessary to help keep the soil in place and minimize erosion. Use rubble, riprap, or fabric to slow water flow on steep slopes, or pave them to prevent serious erosion. You may also consider installing a short section of storm sewer.

Poor ditch slope traps water.



Shallow and narrow ditch. Likely to cause road flooding and future damage.



Lack of curb, ditch or driveway causes poor drainage, pavement damage and parking problem.

No ditch or shoulder drainage can cause severe pavement damage.

Roadway culverts

Culverts channel water under the roadway from one side to the other. They help control water flow and slow it down to control erosion. In designing culverts consider loads and cover, durability and capacity, placement, and slope.

A culvert must be strong enough to support the fill material above it and the traffic that moves over it. Concrete culvert strength depends on its wall thickness and the amount of steel reinforcement it has. Steel culvert strength depends on the depth of corrugations, gauge of steel used, and, to a great extent, on the quality and compaction of backfill material on the sides and haunches of the pipe.

Culverts should be covered with at least 12 inches of soil from the top of the pipe to the top of the subgrade. Arched and elliptical pipes or shallow box culverts can be helpful where cover depth over the culvert is limited.

A culvert must be durable and have sufficient hydraulic capacity to carry away a predetermined quantity of water in a given time. Design charts are available for each type of culvert. A complete design involves reviewing the topography, predicting runoff, sizing the waterway and culvert, and comparing culvert cost to the risk of flood damage. For roadway cross culverts, the minimum recommended size is 18 inches. A professional designer with local experience can save you construction costs and damage claims.

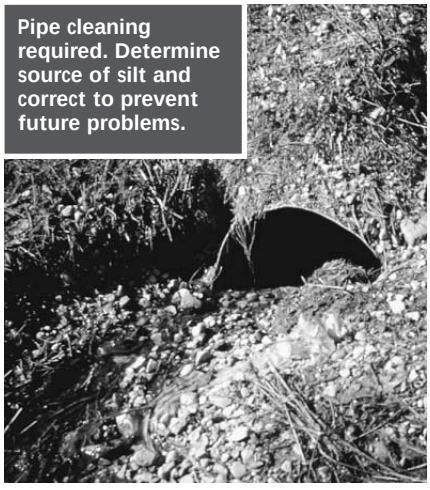
Altering the entrance configuration can significantly improve culvert capacity. Beveling the edge of the inlet or using side-tapers helps considerably.

Culverts should slope enough so water will flow at about 2½ feet per second. A minimum drop of 6 inches across the road is desirable. This will keep sediment from accumulating in the pipe but will not cause extensive erosion at the discharge end. Metal aprons or concrete headwalls improve the capacity, reduce erosion, and can shorten culvert length. For safety, headwalls should not project above the level of the roadway surface.

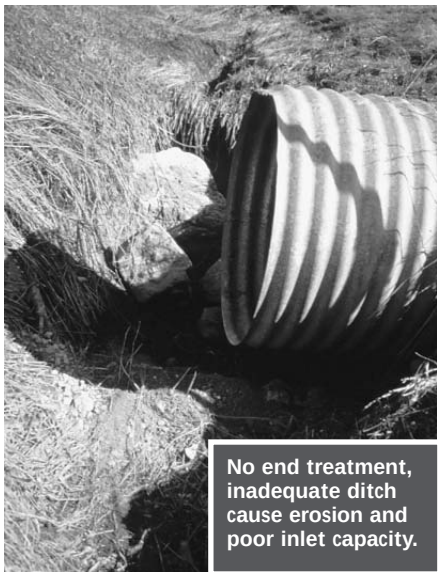
Culvert lacks proper cover. No end treatment. Ditch cleaning needed.

Place culverts so they match existing contours, or in the existing channel, if possible. Be extremely careful about changing culvert locations, capacities or drainage patterns. Section 88.87 of the Wisconsin Statutes requires that highways not impede the general flow of surface water. Drainage Districts must be notified if any changes or major maintenance work are being planned *(Wis. Stat. 86.075).* Before replacing culverts located in established flood plains you must also secure prior approval from the DNR.

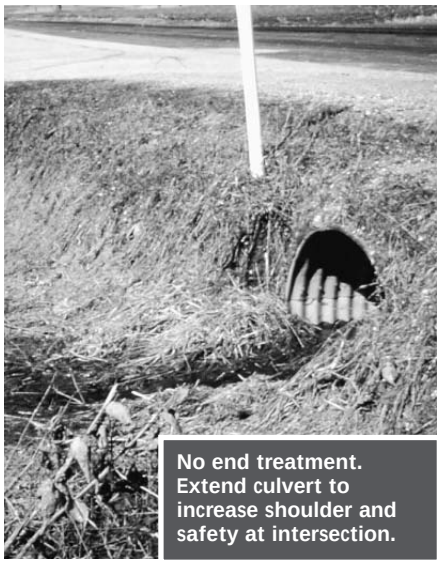
The state has regulations on erosion control and on constructing and maintaining local roads near wetlands and navigable streams. When you are planning work near navigable streams and wetlands and larger projects that will uncover more than five acres of soil, contact the county transportation liaison from the Wisconsin DNR.



Pipe cleaning required. Determine source of silt and correct to prevent future problems.



No end treatment, inadequate ditch cause erosion and poor inlet capacity.



No end treatment. Extend culvert to increase shoulder and safety at intersection.

Pipe too long. Discharge near top of side slope will cause erosion.

Driveway culverts

Driveways can block drainage and cause flooding. Culverts should be required to maintain normal ditch drainage. A minimum 15-inch diameter is recommended.

Driveways should be built so that they either slope away from the road or are graded with the low point over the culvert. This prevents water from washing onto the road from driveways.

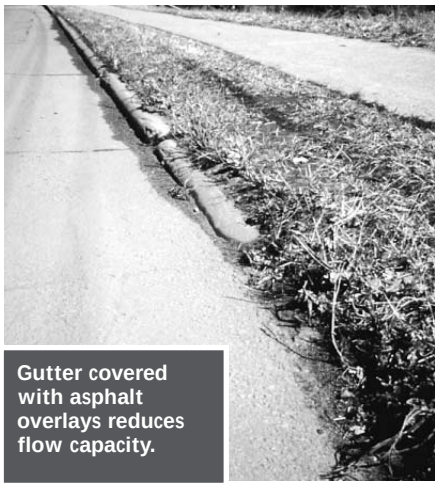
Drainage from improperly constructed driveway can cause road damage.

Cleaning and replacing driveway culverts is an ongoing priority.

Curb and gutter

Good drainage and maintenance practices are similar in both rural and urban areas. However, using curb and gutter and storm sewer raises additional considerations.

Curb and gutter may be preferable to an open ditch in areas with limited right-of-way or where open ditches are unacceptable. Short sections of curb and gutter may be used at spot locations without requiring storm sewer.

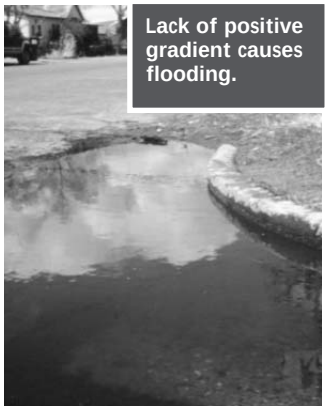


Gutter covered with asphalt overlays reduces flow capacity.

Curb settlement causes ponding and pavement damage.

Broken and failed curb.

Silt from adjacent property causes flooding.



Lack of positive gradient causes flooding.

Remove silt and debris to improve drainage.

Pavement settlement causes ponding.

Storm sewers and inlets

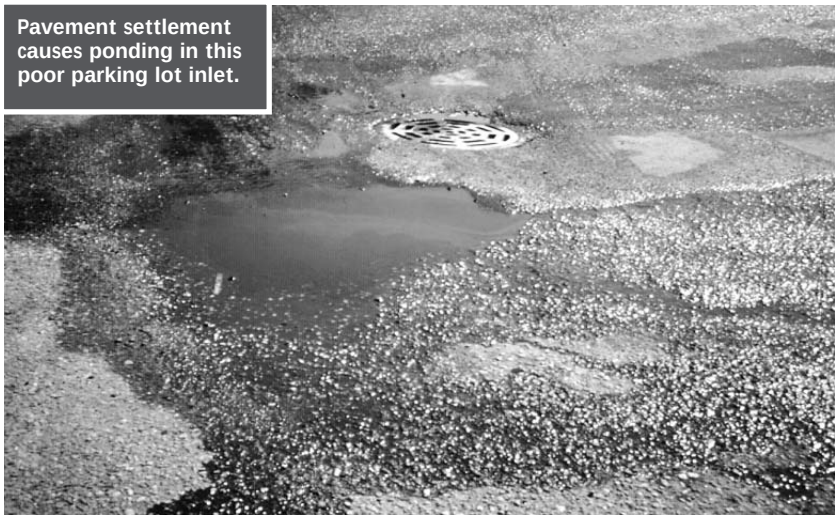
Storm sewer systems collect water from the street and adjoining property and deliver it to open surface waterways—streams, rivers, lakes. Short sections of storm sewer may be useful in rural areas with steep slopes where runoff is eroding open ditches, causing a problem. Storm sewer is also helpful at intersections and other locations.

It is important to maintain curb, gutter, inlets, and storm sewer systems. They should be inspected every five years. Inspecting storm sewer either visually or through TV remote systems is obviously more difficult and expensive than inspecting surface facilities. Consider scheduling this on a regular basis or in areas with visible surface problems. Catch basins, and manholes must be cleaned once or twice a year as part of maintaining an urban storm water system.

Storm water pollution is receiving increased attention nationally and in Wisconsin. Surface water collects a wide range of pollutants as it travels over a roadway surface, across lawns, and into ditches and storm sewer systems. Unfortunately, many of these pollutants are carried directly into waterways and ground water. Since control and monitoring of storm water quality is becoming more complex, local agencies must review their practices and be aware of controls, regulations, and effective pollution abatement practices.

In general it has been found that open drainage systems with vegetated ditches are helpful in reducing the pollutants in runoff from roadways. This suggests that open ditch sections, where possible, are preferable to storm sewers for pollution abatement. A more detailed discussion of this topic is beyond the scope of this publication.

Routine cleaning improves drainage.



Pavement settlement causes ponding in this poor parking lot inlet.

Clogged inlet causes flooding.

Rating and evaluating roadway drainage

Periodic inspection, rating and evaluation of roadway drainage is required as a part of pavement management. It is considered good practice even without a formal pavement management program. A regular inspection program allows managers to identify and schedule necessary improvements on a timely and cost-effective basis.

Routine maintenance can often avert more serious drainage-related problems. While casual observation is frequently used, a scheduled and organized evaluation system produces more consistent results.

These more formal evaluations also promote good recordkeeping which is very helpful in planning projects and reducing time and information loss due to staff turnover.

The basic rating system used in this manual is based on common sense and is intended to be easy to use. It describes four rating categories: excellent, good, fair, and poor. The ratings are described by the general condition, typical defects, and the recommended improvements.

Each category is illustrated by a series of photographs. It is unlikely that all defects will be present. There may be only one or two in a specific section of road. The extent of work required should help determine if the rating is poor, fair, or good. Annual costs associated with the necessary maintenance and improvements for each rating can be developed and used with a pavement management system for programming both short-range and long-range improvements.

Rating	*Condition*	*Improvement*
Excellent	Wide adequate ditches or like-new curb, gutter and storm sewer system. All culverts clean and sound.	No improvement necessary.
Good	Overall, pavement and shoulder have adequate crown, ditching or storm sewer on the majority of the section. May need localized cleaning of ditches, storm sewers and culverts; minor repairs to curbs, inlets and culverts. No drainage-related pavement damage.	Minor or localized repairs.
Fair	Minimal crown on pavement. Some areas need shoulder slope improvement. Ditching improvement or cleaning needed on up to 50% of ditches. Pavement distress from localized flooding or ponding indicates improvements are needed in some storm sewer, inlets or ditching. Some culverts need cleaning or minor repairs.	Several improvements necessary.
Poor	No pavement crown. Shoulders create secondary ditch. Frequent ponding. Significant ditching improvements needed on more than 50% of roadway. Frequent localized flooding or erosion with pavement distress or failure. Significant improvement in storm sewer, curb or inlets and/or major culvert replacement or improvement needed.	Major improvement in drainage required.

☑ Excellent

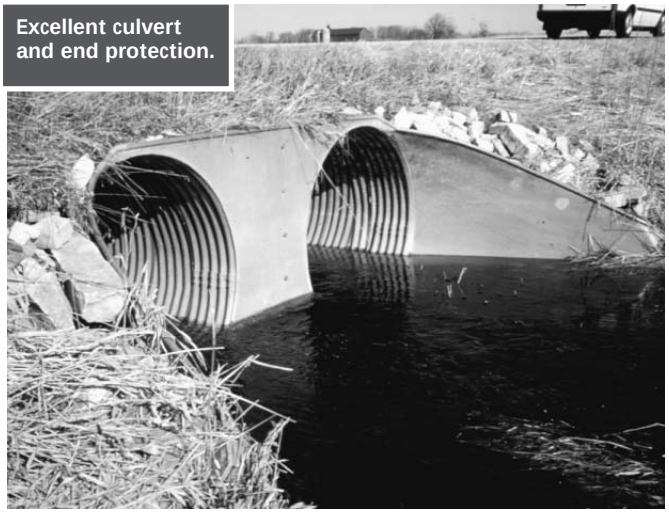
Wide adequate ditches or like-new curb, gutter and storm sewer system. All culverts clean and sound.

No improvement necessary.

Excellent urban drainage.

Excellent rural drainage.

Excellent culvert.



Excellent culvert and end protection.

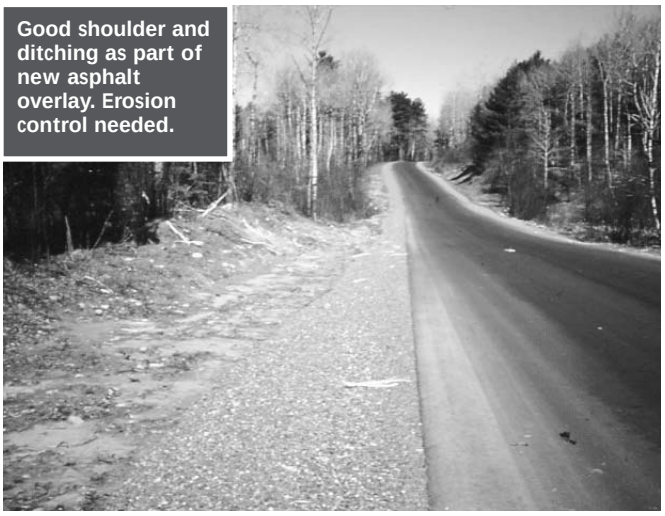
✔ Good

Overall, pavement and shoulder have adequate crown, ditching or storm sewer on the majority of the section. May need localized cleaning of ditches, storm sewers and culverts; minor repairs to curbs, inlets.

Minor or localized repairs. No pavement damage related to poor drainage.

Good urban drainage. Local curb failure needs replacement.

Good shoulder and ditching as part of new asphalt overlay. Erosion control needed.



Adequate ditch and good erosion control.

Good rural ditch and driveway culvert. Culvert end needs cleaning.

Good culvert with apron end walls.

☑ Fair

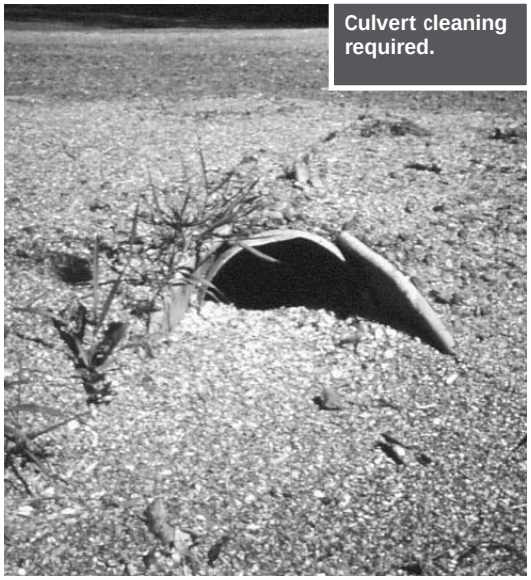
Minimal crown on pavement. Some areas need shoulder slope improvement. Ditching improvement or cleaning needed on up to 50% of ditches. Pavement distress from localized flooding or ponding indicates improvements are needed in some storm sewer, inlets or ditching. Some culverts need cleaning or minor repairs.

Several improvements necessary.

Localized ponding and deteriorating curb and gutter.

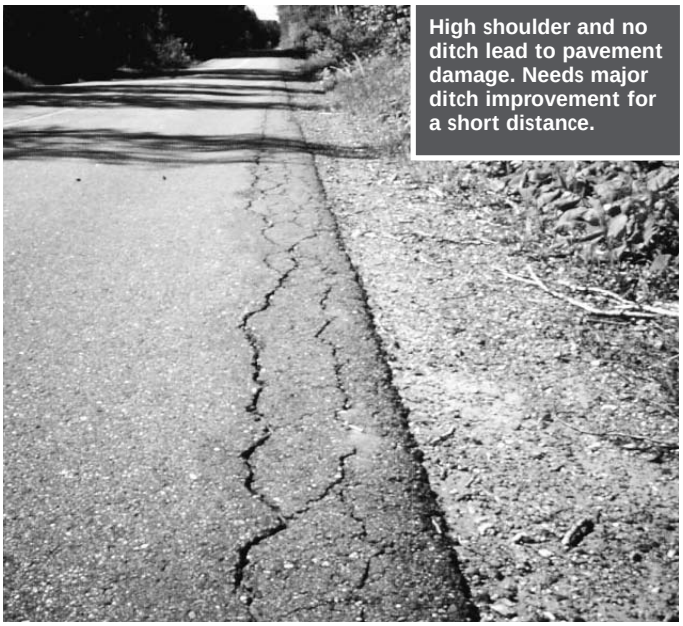
Clean drain and sewer to prevent localized flooding.

Needs localized curb repair.



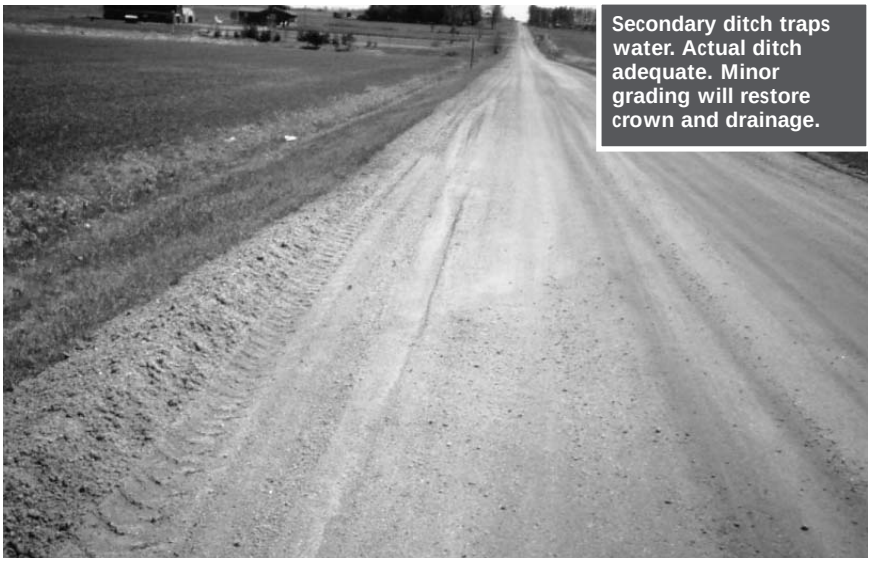
Culvert cleaning required.

Reshape terrace behind curb to restore drainage and prevent damage to curb and street.



High shoulder and no ditch lead to pavement damage. Needs major ditch improvement for a short distance.

Shallow ditch will not adequately drain pavement. Needs ditch cleaning.



Secondary ditch traps water. Actual ditch adequate. Minor grading will restore crown and drainage.

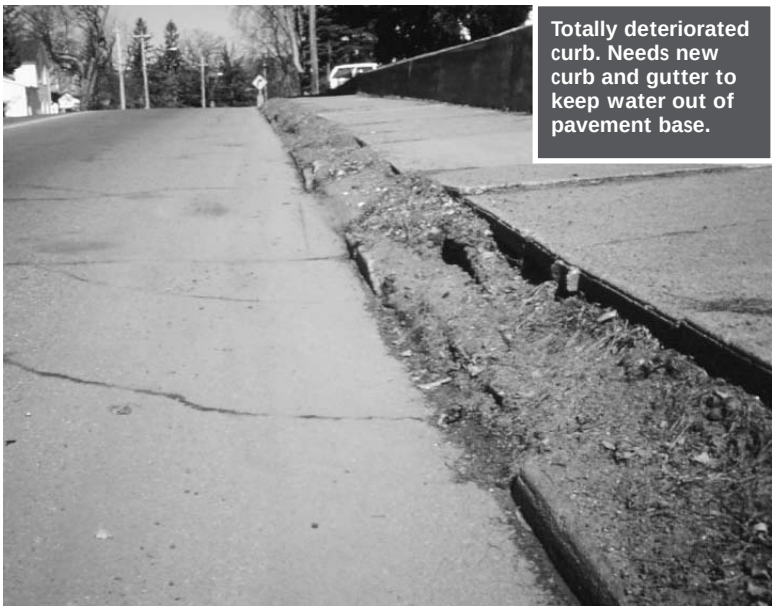
High water table and localized flooding cause premature pavement failure for a short distance.

Good culvert but ditch needs cleaning.

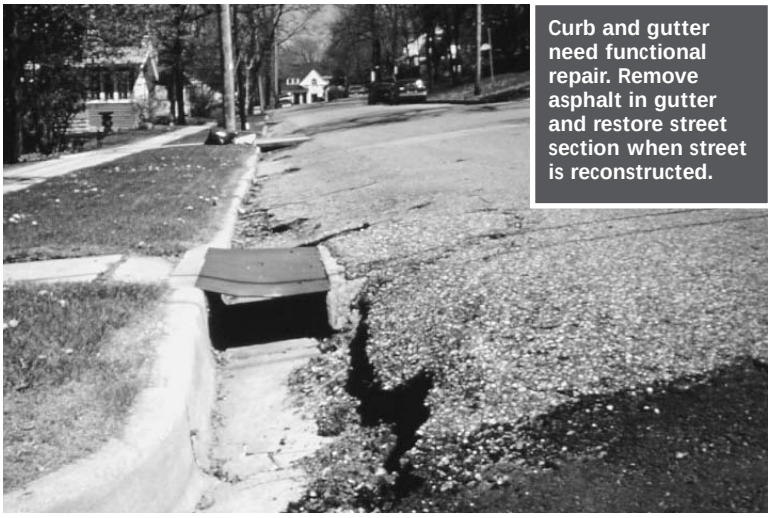
✔ Poor

No pavement crown. Shoulders create secondary ditch. Frequent ponding. Significant ditching improvements needed on more than 50% of roadway. Frequent localized flooding or erosion with pavement distress or failure. Significant improvement in storm sewer, curb or inlets, and/or major culvert replacement or improvement needed.

Major improvement in drainage required.



Totally deteriorated curb. Needs new curb and gutter to keep water out of pavement base.

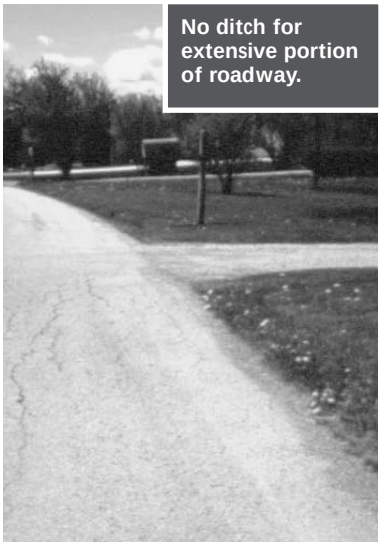


Curb and gutter need functional repair. Remove asphalt in gutter and restore street section when street is reconstructed.

Flooding. Curb and gutter need reconstruction.

Poor curb and gutter with damaged pavement. Need complete replacement.

No drainage leads to failed pavement.

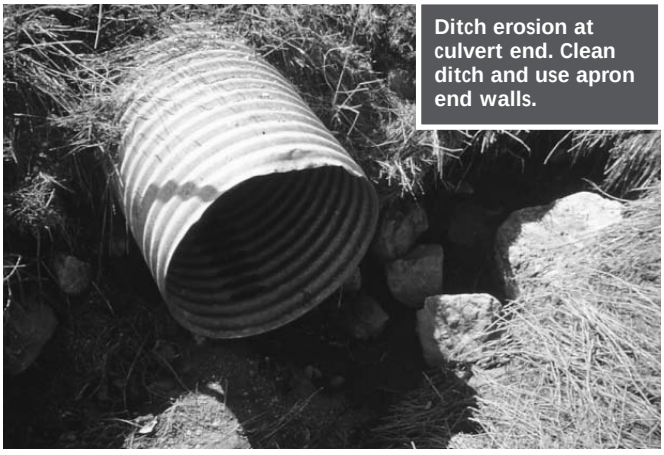


No ditch for extensive portion of roadway.

Inadequate drive-way culvert. Will cause local flooding.

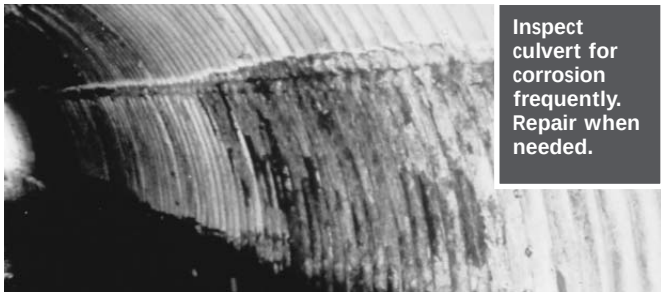
High water has damaged pavement.

No crown or ditching. Reconstruction required.



Ditch erosion at culvert end. Clean ditch and use apron end walls.

Severe roadside erosion causes silting downstream.



Inspect culvert for corrosion frequently. Repair when needed.

Summary

The value of proper drainage design and maintenance on roads cannot be over-emphasized. The drainage system includes the roadway; the shoulders, ditches, and culverts; and the curbs, gutters and storm sewer systems. These elements work together as a system to prevent water from infiltrating the road surface, remove it from the driving lanes to the side ditches or gutter, and carry it away from the roadway. Even roads with all the proper drainage design elements will flood, wash out, and develop cracks and potholes if maintenance is neglected.

- Build and maintain a roadway crown to drain water from the surface: ¼ inch per foot of width for paved roads, ½ inch per foot of width for gravel roads, more under certain conditions.
- Avoid the trench technique of construction. Extend the roadway base to the outer shoulder edge.
- Use ditches with gentle side slopes for vehicle safety, to minimize erosion, and to aid maintenance.
- Design culverts to handle soil and traffic loads with appropriate drainage capacity. Good design saves money. Professional help is recommended.
- Maintain the pavement and culverts to perform as originally intended.
- Keep ditches clean for efficient water flow.
- Inspect culverts regularly. Inspection after a heavy rain will give the most information on your drainage problems.
- Maintain natural surface water flow conditions and coordinate improvements with local drainage boards and with the DNR transportation liaison.
- Avoid placing asphalt overlays on concrete gutter. Mill so overlay matches gutter level.
- Inspect and clean storm sewer inlets and sewers.

Regular annual evaluation of drainage systems is an important part of maintaining and managing our roadways. Using the simple evaluation system outlined here will help local officials in their pavement management responsibilities. This can be incorporated into a formalized pavement management system such as PASERWARE or done manually to have a simple ongoing record of drainage maintenance needs. Before investing in pavement surface improvements, make drainage improvements. It is most economical and effective to plan and upgrade drainage as part of road surface improvements.

Transportation Information Center Publications

Asphalt PASER Manual
Pavement Surface Evaluation and Rating, 1987, 39 pp.

Gravel PASER Manual
Pavement Surface Evaluation and Rating, 1989, 32 pp.

Concrete PASER Manual
Pavement Surface Evaluation and Rating, 1989, 48 pp.

Sealcoat PASER Manual
Pavement Surface Evaluation and Rating, 2000, 16 pp.

Drainage Manual
Local Road Assessment and Improvement, 2000, 16 pp.

SAFER Manual
Safety Evaluation for Roadways, 1996, 40 pp.

Wisconsin Transportation Bulletins

#1 Understanding and Using Asphalt
#2 How Vehicle Loads Affect Pavement Performance
#3 LCC—Life Cycle Cost Analysis
#4 Road Drainage
#5 Gravel Roads
#6 Using Salt and Sand for Winter Road Maintenance
#7 Signing for Local Roads
#8 Using Weight Limits to Protect Local Roads
#9 Pavement Markings
#10 Seal Coating and Other Asphalt Surfaces
#11 Compaction Improves Pavement Performance
#12 Roadway Safety and Guardrail
#13 Dust Control on Unpaved Roadways
#14 Mailbox Safety
#15 Culverts-Proper Use and Installation
#16 Geotextiles in Road Construction/Maintenance and Erosion Control
#17 Managing Utility Cuts
#18 Roadway Management and Tort Liability in Wisconsin
#19 The Basics of a Good Road
#20 Using Recovered Materials in Highway Construction
#21 Setting Speed Limits

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