

Environmentally Sensitive Maintenance for Dirt and Gravel Roads

- Better Roads
- Better Environment
- Better Community
- Less Maintenance



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Reissue
Ver: 1.1



NOTICE

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16. Abstract This is a nonpoint source pollution project that identifies, documents, and encourages the use of environmentally sensitive maintenance of dirt and gravel roads. Specifically, this project involved the development of a reference manual and related technical information sheets on <i>Environmentally Sensitive Maintenance of Dirt and Gravel Roads</i> for national use. The manual will provide insight into using natural systems and innovative technologies to reduce erosion, sediment and dust pollution while more effectively and efficiently maintaining dirt and gravel roads. The manual will address the environment of forests, mountainous terrain, and rolling hills. Various states already employ some of the more common practices, particularly forestry departments. These states and their local governments are prime targets for deploying the additional practices to be addressed in the manual. The manual will give the users a 'tool box' full of environmentally sensitive maintenance 'tools' or practices, recognizing that not one tool can fit every situation or site or solve all their problems in maintaining their dirt and gravel roads and protecting the environment.					
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Environmentally Sensitive Maintenance For Dirt and Gravel Roads

**A Manual to provide guidance
using natural systems and innovative technologies to reduce erosion,
sediment and dust pollution while more effectively and efficiently
maintaining dirt and gravel roads.**

**Compiled by
John A. Anderson, Ph.D.
Alan L. Gesford, P.E.**

**Sponsored by the
Pennsylvania Department of Transportation**



**with Funding Assistance from the
U.S. Environmental Protection Agency**



This manual is based on information and training products developed by

Pennsylvania State Conservation Commission



& the Penn State Center for Study of Dirt & Gravel Roads



December, 2007

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Major Manual Contributors:

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John Anderson, IUP
Steve Bloser, CD&GS/PSU
Woodrow Cobert, SCC [retired]
Dave Creamer, CD&GS/PSU
Alan, Gesford, PSU
Dave Shearer, CD&GS/PSU

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John A. Anderson, Ph.D.

Alan L. Gesford, P.E.

Barry E. Scheetz, Ph.D.

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Foreword

This manual was written for Road Maintenance Personnel.

To use this manual, do the following two things:

1. Review the underlying basis, mission and major objectives for this manual:

Basis of the Manual: The following facts are the driving force behind development of this manual:

1. Over 1.6 million miles of dirt and gravel roads exist within the United States, and they provide a vital service as part of the nation's transportation system.
2. Dirt and gravel roads will remain important and significant in mileage and use into the future.
3. The depositing of unwanted [sediments](#) into our streams and waterways represents one of the largest pollution problems in North America, and improperly maintained dirt and gravel roads are major contributors to this problem.

The Manual's Mission:

The mission of this manual is to address this pollution problem affecting our streams and stemming from our dirt and gravel roads in the form of [erosion](#), [sediment](#) and [dust](#).

Major Objectives to Accomplish the Mission:

1. Provide users with an understanding that *our road system is part of our overall environment, that a vital connection exists between the two, and that this connection needs to be considered in whatever actions we take in regards to constructing and maintaining our road system*. In doing so, we will be able to preserve our environment and more effectively and efficiently prolong the life of our transportation system.
2. Give users a 'tool box' full of [environmentally sensitive maintenance](#) 'tools' or practices that support both good roads and a good environment by offering a variety of simple, practical [environmentally sensitive maintenance](#) practices and by providing a means for using these practices in routine road maintenance.

The practices presented in this manual are inclined toward use for dirt and gravel roads in forested areas. The user may find, however, that many of the concepts and practices could prove applicable in various types of environments, and possibly require only minor research and development efforts.

2. Look at the Chapter Titles to determine how to effectively use the information presented:

Chapter:

- 1. Introduction**
- 2. Geology, Rocks and Soils**
- 3. Water, Erosion, Drainage and Road Basics**
- 4. Basics of Natural Systems**
- 5. Environmentally Sensitive Maintenance Practices: Roads and Road Drainage**
- 6. Environmentally Sensitive Maintenance Practices: Roadsides and Streams**
- 7. Environmentally Sensitive Maintenance Practices: Additional Techniques**

By looking at the Chapter titles, we see that the maintenance “guts” of this manual are contained in Chapters 5, 6, and 7 on “Environmentally Sensitive Maintenance Practices”. These are the chapters that you may want to read all the way through and then use this information with the accompanying “Technical Information Sheets” in implementing these practices for better roads and a better environment.

If this is all you do, however, you will not have a full understanding of why you are doing a particular practice a particular way or how these practices really work to better the road and the environment. This path is the traditional philosophy of telling someone what to do without any explanation of why it works or the reasons or factors upon which the practice is based. Without a full understanding of “why and how it works,” the wrong reasoning for doing any work may prevail - “this is the way we always did it.” On the other hand, if we fully understand the “why and how it works,” we become confident in doing it right and can use this knowledge to actually improve upon the practice and its use in maintaining our roads.

This is where Chapters 1, 2, 3, and 4 become most important. These chapters give background information that enables an understanding of “how and why it works.” We feel that it is important for road personnel to have “the whole story” or all the information behind the practices. This will enable them to implement the proper practice when needed or desired. Road personnel should know why and what they are doing, and why and how it benefits both the roads and the environment.

Environmentally Sensitive Maintenance For Dirt and Gravel Roads

Chapter 1: Introduction

1.1 Manual Mission & Scope

1.1.1 The Mission. The development of our national road system and the need to sustain it dictated governmental ownership from the start. Today, our state and local governments maintain the vast majority of roads. But our roads are part of our total environment, and just as we are the governmental trustees of our road system, we are also the trustees of our environment and all its resources.



1 - 01 Our roads are part of our total environment.

Beyond this trusteeship lies a greater calling: to be responsible stewards of our environment. The environment is under assault on many fronts, and many of those battles must be fought at the national and international level. But roads and their relationship to the environment are perhaps the one area where state and local governments can make a difference.

Unwanted [sediments](#) choke many streams and waterways, representing one of the largest pollution problems in North America. The culprits in many cases are dirt and gravel roads. Our mission, then, is to present proven methods of maintaining our dirt and gravel roads that reduce the [erosion](#), [sediment](#) and [dust](#) that pollute our streams.

1.1.2 Scope. This manual’s mission and philosophy are rooted in the Pennsylvania Program on “[Environmentally Sensitive Maintenance for Dirt and Gravel Roads](#).” (This Commonwealth program provides funding, training, and technical assistance and is highlighted as a case study for “Essential Programs” in [Appendix 1](#) at the end of this chapter.)

Based on the Pennsylvania model, the practices presented in this manual focus on dirt and gravel roads in forested areas, recognizing that, with only minor research and development, many of the concepts and practices can be applied in various types of environments.



1 - 02 Roads exist as unnatural structures in the natural environment.

This manual will show that our road system is part of our overall environment, that there is a vital connection between the two, and that this connection needs to be considered when we construct and maintain our dirt and gravel roads. By doing so, we will be able to preserve our environment and prolong the life of our transportation system.

Roads exist as unnatural structures in the natural environment. Natural forces continually take their toll on our roads, often resulting in degraded

roads and environmental damage. The challenge rests in simultaneously preserving our roads and streams in a safe and cost-effective manner. Using a combination of natural systems and road maintenance principles, [environmentally sensitive maintenance](#) practices can be integrated into an effective and efficient approach benefiting both the environment and our road transportation system.

Although this manual addresses [environmentally sensitive maintenance](#) for dirt and gravel roads, many of the practices, particularly in terms of drainage and vegetation, can be transferred to paved roads and result in benefits to both the paved road and the environment.

1.2 The Importance of Dirt and Gravel Roads

Over 1.6 million miles of dirt and gravel roads criss-cross rural areas of the United States, providing a vital service as part of the nation's transportation system. In many cases, our unpaved roads are the main access for major industries. Unpaved roads provide essential market access for farms, foresters depend on dirt and gravel roads to remove timber from the

Dirt & Gravel Roads Providing Vital Service to Residents and Industries:



1 - 03

forest, and the mining industry could not get minerals out of the mines without these valuable pathways.

In many areas, dirt and gravel roads play a major part in tourism, adding to the economic wealth of the region. Dirt and gravel roads also directly serve millions of rural residents living along them.

Many of our dirt and gravel roads remain unpaved for economic reasons, but, in many areas, residents do not want paved roads, desiring to preserve the rural nature of their area. Dirt and gravel roads are considered the lowest service level in any functional road classification system, usually serving the lowest volumes of traffic. But even as their numbers decline, giving way to more and more paved roads, dirt and gravel roads continue to be a significant part of our road system.

In fact, traffic on dirt and gravel roads is increasing. Further, the vehicles and equipment using these roads are getting larger, meaning the most safe, effective and efficient maintenance practices must be employed to keep pace with the stress these larger vehicles place on the roads.

1.3 The Problem: Roads and the Environment

1.3.1 A Historical Perspective. Read our country's history books and the accounts of our discoverers, trailblazers, pioneers, and early settlements and it becomes clear that roads and streams are connected by their imminent proximity.

Early settlements were built next to streams that became the essential water source for drinking, washing, domestic animals, crops, and power generation for sawmills or gristmills. Streams were also used as transportation corridors to haul goods between homesteads. Footpaths developed along these streams to connect the settlements by land. Streamside terrain offered relatively easy slopes for construction and subsequent use by horses and wagons. These footpaths became the roads, many of which survive today as our dirt and gravel roads. *This close proximity of roads and streams, dictated by historical development, began the conflict of [erosion](#) and [sediment](#) degradation affecting both roads and streams.*



1 – 04 Historical development dictated the close proximity of roads and streams.

1.3.2 The Connection. [Erosion](#) is a natural occurrence in the environment. When roads are constructed, however, they create an interference with the natural systems and collect water, increasing its volume and velocity, resulting in accelerated [erosion](#).

1.3.2.1 Factors Affecting Roads. When we look at all the factors affecting the



life of our roads (Figure 1-1), water has to top the list. Alone or combined with other factors, water can be disastrous. The [subgrade](#) of the road is what it is built on, the soils. If this foundation is poor, the road's life will be significantly reduced. If the [subgrade](#) is water saturated, the condition will be worse.

Most maintained dirt and gravel roads are quite old. Current maintenance crews were not involved in the construction. If poor quality materials were used or the workmanship was substandard, maintenance crews inherit numerous headaches with the road. And even when materials and workmanship are up to standards, the road may not have been built to handle today's heavier traffic loads. Traffic volumes and weights have both increased substantially in the last 20 years. The combination of water and increased traffic loads is potentially disastrous for our roads. That is why maintenance practices are so important. Poor maintenance equals poor roads. If there are drainage problems, however, even the best maintenance is doomed unless drainage problems are taken care of first.

The environment and climate also affect road conditions. The environment, as defined here, refers to vegetation, soil, sand, rocks, drainage conditions, and the overall stability of the area. Climate dictates the local weather conditions. Weather includes rain, freeze-thaw cycles, and hot sun that can dry out soils and road materials.

Looking at all these factors affecting roads, we should ask ourselves "What can we control?"

1.3.2.2 Factors Affecting the Environment. The same factors that affect the road affect the environment. Water feeds vegetation and streams and creates habitats, but also causes [erosion](#), flooding, and [sedimentation](#).

Our roads certainly affect the environment along with our maintenance practices. Poor road structure and material quality, increased traffic levels, and proximity to waterways lead to [erosion](#), [sediment](#) and [dust](#) pollution problems.

Again, we should ask, “What can we control?”

1.3.2.3 The Road-Environment Relationship.

Road conditions are deeply intertwined with the surrounding environment. Concentrated water flows accelerate [erosion](#), overloading natural systems. Excess [sediment](#) clogs our streams. [Dust](#) becomes [sediment](#) in our streams, generates complaints from residents and harms plants, animals, people and equipment. Chemical contamination complicates the picture even more because oils, nutrients, pesticides, herbicides, and other toxic substances bind to [dust](#) and [sediment](#) and go along for the ride to pollute our streams and waterways.

Figure 1-2
Factors Affecting the Environment



1 – 05 Dirt and gravel roads are a major source of erosion and sediment.

Dirt and gravel roads are a major potential source of these pollutants. Many roads have unstable surfaces and bases. Roads act like dams, concentrating flows that accelerate [erosion](#) of road materials and roadsides. Both unstable surfaces and accelerated [erosion](#) then lead to [sediment](#) and [dust](#).

The close proximity of roads and streams thus establishes the connection. Because road systems are situated close to streams within the natural environment, they affect the

natural systems as they are in turn affected by the natural processes that take place there. The two systems – roads and the environment – are interrelated. Thus, in order to fix road problems, we must understand some things regarding each system to find a solution beneficial to both our roads and the environment.

In addition, not only is there a relationship between the roads and the environment, but both the roads and the environment also have an effect on the overall quality of life within your region. John Muir, who has been called the father of our National Park system, summed it up in this statement: **“When we try to pick out anything by itself, we find it hitched to everything else in the universe.”**

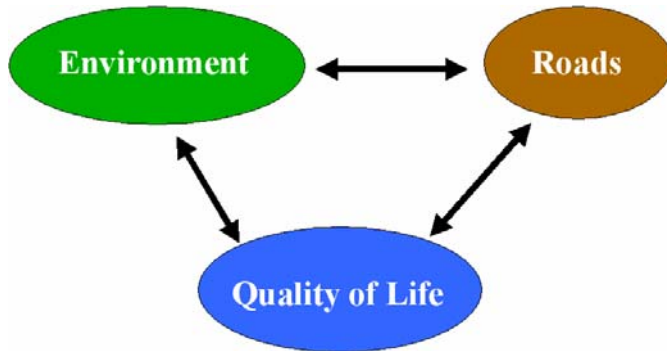


Figure 1-3: Relationship & Effect

1.3.3 Traditional Maintenance Practices.

Even though the goal of road maintenance personnel is to maintain good roads, accepted maintenance practices do not always adequately address the road’s relationship to the environment.

Why do we do what we do? Because we’ve always done it that way? There are many things that

we do that may not be the best way for the environment or the road. In fact, many existing practices cause damaging [sediment](#) pollution, impacting both the road and the environment.

Vegetation management is a major example where many existing practices become counterproductive. Traditional “[daylighting](#)” exposes bare soil, disrupts ecological succession and eliminates soil-stabilizing roots, all of which increase [erosion](#) and [sedimentation](#), damaging both the road and the environment. In addition, excessive sunlight can dry the roadbed, leading to excessive [dust](#) generation. Maybe we should consider leaving existing root structures undisturbed, thinning canopy cover to allow moderate sunlight, and avoid clearing banks just because they are there. Using nature’s patterns and forces can result in better roads, less [erosion](#) and [sediment](#) pollution and lower maintenance costs.

Bank cutting and undercutting results in extensive [sediment runoff](#), blocked ditches, and increased cyclical maintenance. On the other hand, refraining from cutting the toe of slopes, using headwalls to reduce pipe inlet and bank [erosion](#), and using [diversion](#) or [intercepting swales](#) preserve both road quality and the environment.

Conveying road and ditch [runoff](#) to the nearest stream using the most direct route possible has long been an established practice. Any type or amount of [sediment](#) being carried by that [runoff](#) is also dumped directly into the stream. But directing [culvert](#) and ditch outlets ([turnouts](#), [bleeders](#)) into a [vegetative filtering area](#) will help filter out the [sediment](#), allow water infiltration and [groundwater recharge](#), and protect the stream [ecology](#).

Road aggregate quality directly impacts both the survival of the road and the environment. *Covering the road with poor ‘low-bid’ material that may wash away is*

another way of paying for [sediment](#) pollution, not to mention increased road aggregate replacement costs. Using a good road material that remains in place and prolongs road life will also benefit the total environment.

Undersizing and oversizing water channels, [bank armoring](#), and [flow redirection](#) can disrupt stream energy, increasing maintenance costs and causing environmental harm. Understanding stream flows and the natural forces can help to establish better practices to again protect both the road and the environment.

Clearly, many traditional practices are counterproductive. They should be replaced with more productive measures that incorporate our knowledge of roads and natural systems. The result will be better roads, less [sediment](#) pollution, and lower maintenance costs.

1.3.4 Combining Goals. The goal of road maintenance personnel has always been good roads through proper maintenance at the lowest cost. We want to keep this goal, but expand our vision. We need to take a different look at our roads and see the total environment in which our roads are contained. This environment affects the life of our roads just as the road affects the environment.

If our goal within this project is to protect the environment through reduction of [erosion](#), [sediment](#) and [dust](#) pollution, then let's combine our goals. Let's use additional and improved maintenance techniques and practices that benefit both the roads and the environment.

1.3.5 Road Safety. Any effective road maintenance program needs to consider and address safety. A safe transportation system is essential and remains part of our overall goal. Maintaining our roads and environment, however, need not come at the expense of safety. In fact, roads maintained in an environmentally friendly way have more structural strength, suffer less deterioration, and have fewer defects, and, thereby, are also safer. The goals of low-cost, [environmentally sensitive maintenance](#) and improved road safety can be combined seamlessly.

1.4 The Manual: Philosophy, Objectives and Contents

1.4.1 The Manual Philosophy. This manual is titled *Environmentally Sensitive Maintenance for Dirt and Gravel Roads*. The mission, as stated, is to address the pollution problem of [erosion](#), [sediment](#) and [dust](#) stemming from our dirt and gravel roads and affecting our streams. To meet this mission, the manual centers on an important philosophy or rationale.

To municipal road maintenance personnel, the road has been “sacred.” Everything they have been taught about road maintenance has centered on what is good for the road, which has proven at times not to be correct. We need to initiate a change in this thinking. We can no longer afford to think only about the road. We need to understand the relationship between the road and the environment, that everything is interconnected, and

that there are practices that can be implemented that are not only good for the road, but also good for the environment. In addition, we need to make the connection that both good roads and a good environment are important to the welfare of local governments and their residents.

Only when this thinking changes can it be converted into action. In presenting “environmentally sensitive practices,” this manual will illustrate to the users how easy these practices are to use and how useful and beneficial they become in prolonging the life of the road and protecting the environment. To accomplish this, however, the practices need to be simple, practical, and easy to incorporate into a routine road maintenance program.

The manual will give the users a “tool box” full of [environmentally sensitive maintenance](#) ‘tools’ or practices, recognizing that no one tool or practice can fit every situation or site or solve all their problems. Because every road and every site along that road is different, we need a toolbox from which we can select the appropriate tool or tools to help solve whatever situation we encounter.

1.4.2 The Manual Objectives. To meet the mission and put “punch” into our philosophy, we set our objectives as follows:

1. Enable the user to recognize the connection between road maintenance and the environment and the importance of good roads and a good environment for good government.
2. Enable the user to recognize sources of [erosion](#), [sediment](#), and [dust](#) pollution associated with roads and the importance of preventing these pollution sources.
3. Enable the user to recognize that standards cannot fit every situation and that sound decisions require proper knowledge of basic principles and practices. (Most standards, although often dictated as requirements, should be presented as only guidelines that need to be adjusted or revised to fit each particular site or problem area in the field. To know, however, what “tool” to use or what adjustment is needed, one needs to recognize basic principles and practices not only related to road maintenance but also to the natural systems that influence these roads, leading to our 4th objective.)
4. Arm the user with knowledge on basic principles of nature and natural systems as applied to road maintenance and a healthy environment and on basic road maintenance materials and techniques. (The user needs to know the basics of nature and the natural forces, and how they can be applied to help establish good roads and protect the environment. In addition, to make sure we are “on the same road”; we want to cover the road basics of good materials and techniques.)
5. Arm the user with knowledge on [environmentally sensitive maintenance](#) practices and the effective use of these practices in road maintenance. (This is where we provide the “tools” for their toolbox – a variety of simple, practical [environmentally sensitive maintenance](#) practices and the means of using these

practices in routine road maintenance to keep both good roads and a good environment.)

1.4.3 The Manual Contents. To accomplish this comprehensive list of objectives, the manual contains 7 chapters.

[Chapter 1 – Introduction](#): Chapter 1 is simply an introduction to the manual. The mission and scope of the manual is introduced, followed by a discussion on the importance of dirt and gravel roads. We then start to make the connection between roads and the environment and discuss the shortcomings of traditional road maintenance practices. The chapter then shows the value of combining the goals of good roads and a good environment. The manual philosophy is then discussed, followed by the objectives and this description of contents. To close, the need for essential programs is covered, with an appendix to describe the Pennsylvania program as a case study.

[Chapter 2 – Geology and Soils](#): This chapter discusses geologic time and relentless natural forces, looking at geological regions, [topography](#), weather, rocks and soils. The chapter demonstrates how geology and natural forces give us what we have to work with and the conditions under which we have to work. Geology dictates the aggregates available for road materials and the soils available to support the natural vegetation.

[Chapter 3 – Water, Erosion, Drainage and Road Basics](#): This chapter starts with basic principles of [erosion](#) and how roads cause accelerated [erosion](#) and increased [sediment](#) and the importance of preventing this pollution, showing the connection between roads and the environment. This module hits hard on the importance of good drainage, discussing the characteristics and effects of water on roads. Discussion then turns to road materials, what's being used and what we need to be concerned with. We then review basic road maintenance techniques for dirt and gravel roads – basic grading operations, [road crown](#), etc. – and end with a discussion on winter maintenance operations.

[Chapter 4 – Basics of Natural Systems](#): This chapter sets the basics on the natural side, presenting guiding principles by defining [ecology](#) and discussing three distinct [ecosystems](#): the streams, [wetlands](#), and forests or [uplands](#). We stress the important benefits of these areas and set the stage to discuss, in a later module, how we can use these systems to help in road maintenance. This is unfamiliar area to most road maintenance personnel. The user should read this chapter with an eye to relating roads and road maintenance to natural systems.

[Chapter 5 – Environmentally Sensitive Maintenance Practices](#): Having set the basics for both roads and the natural systems, this chapter presents the [environmentally sensitive maintenance](#) practices, with emphasis on road profiles, ditches, [culverts](#), and bridges. Simple, straightforward, easy to implement practices are presented – some of which may already be familiar, or some that may be just tweaking something already in use. Others may be new, but still simple and easy to implement.

We start to fill the user's toolbox with the tools, emphasizing that not one tool or practice or technique will solve all their problems, but a toolbox full of tools will help greatly.

[Chapter 6 – Roadsides and Streams](#): This chapter discusses the value of roadside vegetation management and the important factors affecting bank stability. The chapter then builds on this discussion to show how we can use the forests and natural systems to help reduce road maintenance, introducing more [environmentally sensitive maintenance](#) practices. We review common practices and the associated problems that can be detrimental in the long term for both roads and the environment, followed by alternative methods to improve or enhance the existing conditions (e.g., traditional clearcutting practices, stream channel clearing practices). This leads to more [environmentally sensitive maintenance](#) practices for vegetation management and bank stabilization, ending with an introduction to a variety of [bioengineering](#) techniques for stream banks.

[Chapter 7 – Additional Maintenance Techniques](#): Chapter 7 continues to add tools to the toolbox, discussing three specific areas: [dust](#) control, [road stabilization](#) (full-depth reclamation), and the world of [geosynthetics](#). The [geosynthetics](#) section emphasizes [geotextile](#) separation fabrics along with other [geosynthetics](#) used in actual road projects including a drainage pipe project case study, demonstrating the variety of functions and uses that [geosynthetics](#) play in road maintenance.

1.5 Essential Programs

To successfully fulfill our mission of addressing the national problem of [erosion](#) and [sediment](#) pollution from our dirt and gravel road system affecting our streams, there is a need not only for a manual but also for comprehensive state programs providing funds, education and training, and technical assistance to the nation's road maintenance personnel.

No change in our environment will occur without a change in thinking. Roads do not exist in isolation. They are an integral part of the environment. A change to the road changes the environment. An environmental shift has consequences for the road. Until those performing maintenance on our roads understand this relationship, both the roads and the environment will continue to suffer.

The way to change thinking is through training and technical assistance, coupled with funding. The message must be clear, simple, and easy to administer. It must be targeted at local and regional road maintenance managers.

As a case study, Appendix 1 presents Pennsylvania's Program as a successful model and resource for other states in meeting this mission. Appendix 1 is a description of the program development and implementation, with a discussion of the essential criteria for a successful program.

APPENDIX 1

Case Study: The Pennsylvania Dirt and Gravel Roads Program

In 1997, Pennsylvania introduced a program that provides an annual \$5 million appropriation for “[Environmentally Sensitive Maintenance](#)” for our nearly 20,000 miles (38,180 km) of dirt and gravel roads. The program addresses three critical components: Thought and Attitude, Cost Effective Best Management Practices, and Technology Transfer. In developing an understanding of the problem, the program team, spearheaded by the State Conservation Commission, developed a philosophy that simplifies administration, holds the stream sacred, and strives for better roads and reduced maintenance. This exemplifies a major change in “thinking and doing” for road maintenance personnel, where traditionally the road had priority. The program leads them to consider both the road and the environment as important and how natural systems can help with overall road maintenance.

A1.1 Pennsylvania’s Dirt and Gravel Roads. Pennsylvania has over 117,000 total miles (188,253 km) of public roads, including both paved and unpaved. Local municipal governments own and maintain two thirds of that total mileage. Of that total mileage, nearly 20,000 miles (32,180 km) are unpaved dirt and gravel roads.

Local municipal governments own and maintain the majority of dirt and gravel roads with over 17,000 miles (27,353 km). The PA Department of Conservation and Natural Resources (DCNR), Bureau of Forestry owns and maintains over 2500 miles (4023 km). The PA Department of Transportation (PENNDOT) has less than 500 miles (805 km). This number continues to decline due to PENNDOT’s Turnback Program (PENNDOT pays \$2500 per mile as an annual sum added to a municipality’s liquid fuels funds for any state roads “turned back” to the municipality to own and maintain). Other agencies having nominal mileage are the DCNR Bureau of State Parks, the PA Fish and Boat Commission, and the PA State Game Commission. Dirt and gravel road mileage continues to decline as development and traffic volumes increase and more and more roads become paved, but dirt and gravel roads will remain a significant part of Pennsylvania road mileage into the future.

Pennsylvania’s dirt and gravel roads play an important role for the commonwealth. They provide vital direct access for over 3.6 million PA residents, although probably used by almost all of PA’s 12 million people. They also provide vital access to Pennsylvania’s industry, namely our top industries of agriculture, forestry, mining and tourism. In fact, tourism is projected to become our state’s number one industry, a position that has been held by agriculture. To emphasize, Pennsylvania’s dirt and gravel roads have always played an important role, are still playing that role, and will remain playing that role into the future.

A1.2 Program Origin: A Problem Recognized. In January 1991, a man by the name of James “Bud” Byron, active in Trout Unlimited, instigated a Northcentral Pennsylvania Conference of parties interested in protecting streams from [sediment](#)

pollution associated with dirt and gravel roads. The results and publicity of that meeting held in Pleasant Gap, PA, sowed the seeds of the program.

A1.3 Program Origin: A Problem Substantiated. Lead by Trout Unlimited, various individuals, organizations and agencies became active in addressing this problem on a statewide basis. In 1993, they formed the Dirt and Gravel Road Task Force, (Figure A1-1). The Task Force set out to substantiate the extent of the problem. They began by conducting field surveys of roads and streams to identify actual conditions in the affected watersheds. Using volunteers (no funding was available), they zeroed in on protected watersheds identified as Exceptional Value and High Quality. Just surveying these areas was a huge undertaking (Figure A1-2). A great number of volunteers were needed, and Trout Unlimited, with its 55 PA chapters, provided most of the manpower. A simplified manual card system was developed to record actual field conditions. The volunteers received onsite training to help ensure consistent results. These surveys identified actual “trouble spots” of sediment pollution into streams throughout the commonwealth. These pollution trouble spots became the initial worksites and, when viewed plotted on a map (Figure A1-2), substantiated the problem.

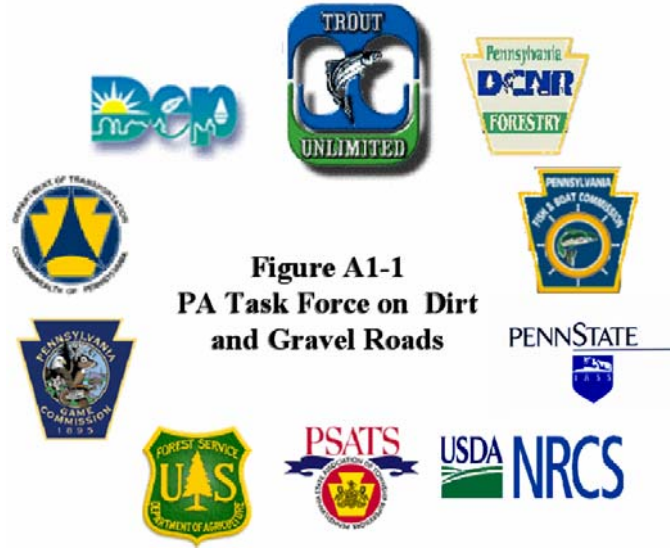
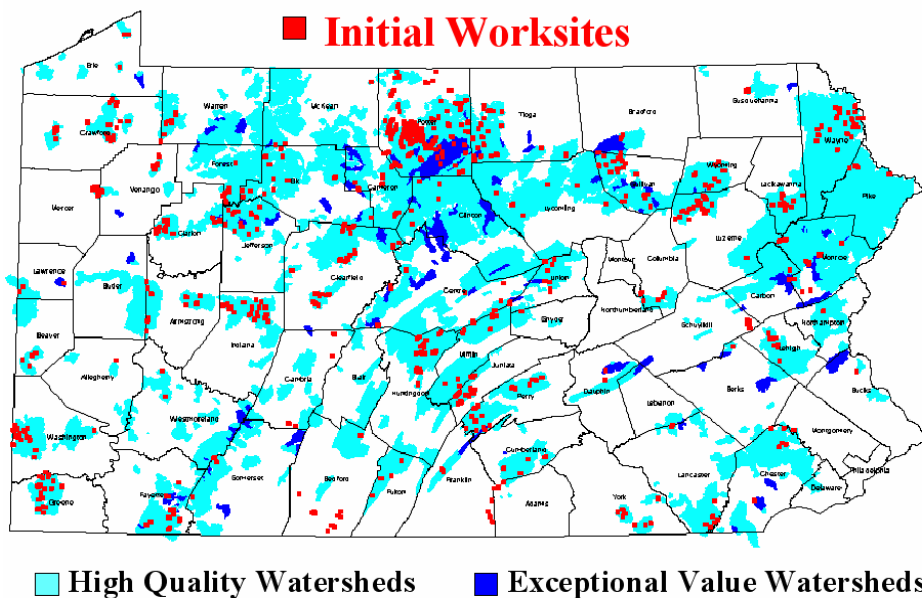


Figure A1-1
PA Task Force on Dirt and Gravel Roads

Figure A1-2: Result – A Problem Substantiated



A1.4 A Solution. With the problem substantiated, the Task Force needed to look at a solution. Who was maintaining these dirt and gravel roads? Why were the problems of [erosion](#) and [sediment](#) occurring? What did they need to do to correct the problems? Municipal governments owned the roads, so the Task Force looked to existing road maintenance. They found that even though the goal was to maintain good roads, existing accepted maintenance practices did not always adequately address environmental concerns. To solve the existing and continually occurring pollution problems required maintenance managers to change their thinking to see the road as part of the environment. This change in thinking had to lead to changes in procedures. Improved maintenance techniques that were good for both the roads and the environment had to be used. To initiate this change, the task force recognized two major needs – training and money.

Legislation was necessary to meet these needs. Pennsylvania Senator Doyle Corman became the program champion and drafted legislation, which became part of the PA Transportation Revenue Bill, signed into law as PA Act 3 of 1997. Section 9106 was added to the PA Motor Vehicle Code, initiating the Dirt and Gravel Road Program.

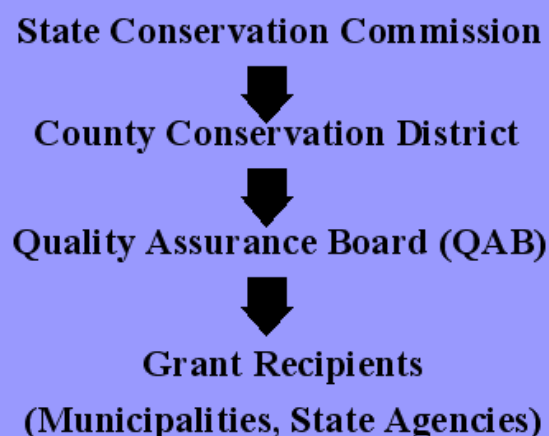
A1.5 The Legislation. Section 9106 created an annual, non-lapsing \$5 million appropriation for Dirt and Gravel Road Maintenance to address the pollution problems of [erosion](#), [sediment](#), and [dust](#). Section 9106 took effect July 1, 1997. The legislation provides that \$1 million go directly to the Bureau of Forestry for their roads and that the other \$4 million go to the State Conservation Commission, the lead agency for the program. This annual \$4 million was to be used as grants for [environmentally sensitive maintenance](#) projects on dirt and gravel roads.

The legislation stated that the identified “trouble spots” would be the top priority, recognizing the significance of the volunteer work that substantiated the problem and led to the legislation.

The legislation also **required grant recipients to receive training** as a prerequisite to applying for grant funds.

A1.6 Program Organization. The PA State Conservation Commission serves as the lead agency for the program (Figure A1-3). They allocate the money to the County Conservation Districts who are responsible for administering the program at the local level. Each County Conservation District is required to implement a Quality Assurance Board (QAB) who reviews and

Figure A1-3: Program Administration



prioritizes grant applications and provides assurance of project completion in accordance with the applications. This board provides recommendations back to the County Conservation District for formal approval. To benefit from a variety of background and experiences, the QAB is comprised of four members: a chairman from the County Conservation District (non-voting) and three voting members, one appointed by the County Conservation District, one appointed by the PA Fish and Boat Commission, and one appointed by the National Resource Conservation Service (NRCS).

Grant recipients are the local municipalities or state agencies that own and maintain dirt and gravel roads.

Two major points emphasized through the program legislation are simplicity and local control. The program organization meets these points with a requirement of a one-page grant application form and with the charge given to the County Conservation Districts to implement the program. What better way to keep it simple and have the program handled at the local level?

A1.7 Program Goal. The program's major goal is to reduce the pollution due to [erosion](#), [sedimentation](#), and [dust](#) associated with dirt and gravel roads in the commonwealth. To meet this goal, a strong program basis to protect the dirt and gravel roads was formulated. Several decisions were made by the program initiators and agreed upon through the legislation.

First, the program supports maintaining dirt and gravel roads as dirt and gravel. The program will not fund paving these roads. Second, to minimize road maintenance and stretch limited resources, cost effective maintenance practices that are not only good for prolonging road life but also for protecting the environment are essential.

This program goal and basis led to the required training with its own rationale and objectives.

A1.8 Program Training. The Pennsylvania State University, through the Pennsylvania Transportation Institute and the Environmental Resources Research Institute, were originally charged with development and delivery of the training associated with the Dirt and Gravel Road Maintenance Program. Since then, a Center for Dirt and Gravel Road Studies, in conjunction with Penn State University, was funded through contract with the PA State Conservation Commission. This Center now administers the education, training and technical assistance aspects of the program.

The major purpose of the training was simple – to meet the requirements of the legislation which required anyone who applies for program funding to attend a training course as a prerequisite.

The course was simply titled, following the legislation, “[Environmentally Sensitive Maintenance](#) for Dirt and Gravel Roads.” The program goal, as stated, is to reduce [erosion](#), [sediment](#), and [dust](#) pollution relating to dirt and gravel roads. To meet

this major goal, the training centers on the philosophy and rationale as discussed above in [Section 1.4.1](#) for this manual.

To meet the main program goal, objectives similar to the ones outlined above in [Section 1.4.2](#) for this manual were adopted along with an additional objective to provide the trainee with information on associated laws and regulations and with the information on grant funding procedures.

The training gives them a “tool box” full of [environmentally sensitive maintenance](#) “tools” or practices, recognizing that not one tool or practice can fit every situation or site or solve all their problems. These practices are mostly simple, practical, cost effective techniques that can be easily implemented. Municipal road crews with available equipment resources can perform most of the practices, incorporating them into their normal routine road maintenance program. Not all practices will apply to any one municipality’s roads, but having a full toolbox from which to choose the best tool or tools to address the problem or concern encountered tends toward a more successful solution. Many of these practices can be used in combination and will apply to most dirt and gravel roads in general

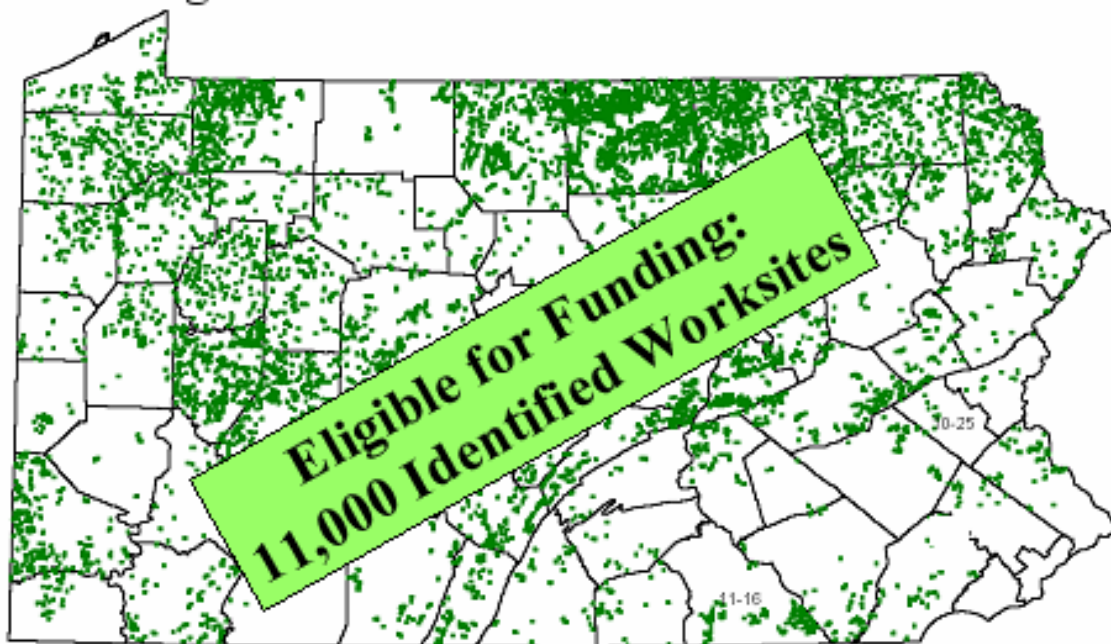
The training is a two-day course and consists of classroom training only. The possibilities of field trips to nearby roads were discussed, but weather and the logistics of coordinating transportation to the site does not lend to the feasibility. The time factor also comes to play an important deterrent.

The training uses PowerPoint® presentations with an LCD projector and projection screen. The PowerPoint® presentations contain all the digitized photos and several video clips to enhance, clarify, or show examples. Trainers also use various samples of products, particularly [geosynthetic](#) products.

Training evaluation sheets are distributed at each session. Results have been overwhelmingly favorable on all aspects of the training. Acceptance by municipal road personnel of the many practices presented has been greater than expected. This is a testament to the dedication and concern of local municipal government road personnel.

A1.9 Further Program Development. A new inventory and assessment of PA’s dirt and gravel roads were completed with the establishment of the new Center for Dirt and Gravel Roads. County Conservation Districts worked with the local governments to verify unpaved roads via municipal and county maps. All identified roads then received field assessments by the County Conservation Districts for pollution problems affecting streams. This new assessment identified over 11, 000 new sites across the commonwealth which then became eligible for program funding (Figure A1-4).

Figure A1-4: Assessment Phase II Results



County Conservation Districts inspected the roads and identified worksites

A1.10 Program Results. The program has been and continues to be a success. Projects undertaken and completed with program funds have been evaluated. A computerized GIS system is used for project tracking and central reporting with minimal paperwork. An implemented quality assurance/quality control (QA/QC) process continually monitors and evaluates completed projects, verifying that all but one project has met or exceeded expectations.

The following page is the 2006 Program Report reflecting a summary of the program data showing 1608 projects completed by the close of 2006. The summary gives a breakdown of program funding, completed project costs and major work items, and a training summary of sessions and attendees. It should be interesting to note the amount of in-kind contributions, which are the materials and services donated to the projects by the local government grantees. Although contributions are not required and the projects are 100% fundable with program grant monies within the prescribed parameters, the in-kind contributions have averaged 36%. Comparing this to the many federal and state grant programs that require 10 to 25% matching funds, we can see the substantial **voluntary** commitment made by the Pennsylvania local governments. This factor again speaks to the acceptance and success of the program.

2006 - DIRT AND GRAVEL ROAD PROGRAM SUMMARY DATA

-----All Data is CUMULATIVE Based on District Reports as of January 15, 2007-----

FINANCIAL SUMMARY TO DATE

Total Allocated to Districts -	\$35,187,000	<i>includes 10 years of funding</i>
Spent on administration -	\$2,203,000	<i>(6.3% of total allocated) limit of 10%</i>
Spent on education -	\$594,000	<i>(1.7% of total allocated) limit of 5%</i>
Spent on completed contracts (1,608)-	\$25,381,000	<i>(72% of total allocated) (In-kind not included)</i>
<u>Current contract commitments (196)-</u>	<u>\$3,796,000</u>	<u><i>(11% of total allocated) (Partially completed project included here)</i></u>
TOTAL SPENT/COMMITTED -	\$31,974,000	<i>(91% of total allocated)</i>

WORKSITE: a section of unpaved road that is a verified source of pollution to an adjacent stream.

*****In-Kind Contributions - \$9,147,000 (donated goods/services from participants) (Avg 36¢ per \$1 spent) *****

COMPLETED PROJECT COST SUMMARY

note that some worksites have multiple contracts complete

Contracts complete - 1,608 Length of contracts complete - 826 miles

BREAKDOWN of \$25,381,000 Program funds spent on completed contracts:

\$20,340,000 for materials (80%), \$3,725,000 for equipment (15%), \$1,316,000 for labor (5%)

BREAKDOWN of \$9,147,000 In-kind contributions for completed contracts:

\$1,451,000 materials (16%), \$4,045,000 equipment (44%), \$3,262,000 labor (36%), \$389,000 other (4%)

COMPLETED PROJECT WORK SUMMARY

5.7 Acres Eroded Stream Bank Stabilized	= a steam bank 5 feet high and 9.4 miles long
6.7 Acres Drainage Outlets Stabilized	= 2,918 outlets, each 10' x 10'
68 Acres Vegetative Management	= an area 10 feet wide 56 miles long
67 Acres Eroded Road Bank Stabilized	= a road bank 5 feet high and 110 miles long
71 Acres Eroded Road Ditch Stabilized	= a ditch 5 feet wide and 117 miles long
117 Acres Separation Fabric Used	= 54 miles of fabric placed 18 feet wide
773 Acres Road Surface Stabilized	= 354 miles of road 18 feet wide
4,610 Crosspipes Installed	= 5.6 pipes per mile of project
178,400 Feet of Crosspipes Installed	= 34 miles of pipe; average crosspipe length is 39'
581,700 Cubic Yards of Road Base Added	= 1 acre of ground covered to a depth of 360 feet

COMPLETED PROJECTS

YEAR	# Contracts Complete	Money Spent on Completed Projects*	Average Spent per Contract*
1998-2003	1,156	\$ 16,198,000	\$ 14,012
2004	173	\$ 3,253,000	\$ 18,803
2005	136	\$ 3,255,000	\$23,934
2006	143	\$ 2,675,000	\$ 18,706
TOTAL	1,608	\$25,381,000	\$ 15,784

**in-kind not included*

2-DAY TOWNSHIP TRAINING SUMMARY:

YEAR	# of Trainings	Municipal- ities Trained	Counties Represented	Total Attendees
1998-2002	115	na	all	3208
2004	8	142	53	294
2005	13	220	56	574
2006	12	254	57	465
TOTAL	148	na	all	4541

Document produced by: Penn State University – Center for Dirt and Gravel Road Studies
866-668-6683 www.dirtandgravelroads.org



The PA Dirt and Gravel Road Program is well established and continues to meet its goal of pollution reduction. The training is constantly under review and changes as more program work projects are completed. The program uses new experiences to develop new practices and test new materials. Environmentally Sensitive Maintenance Practices have been accepted and are being put to use, many of which apply to paved roads as well as unpaved gravel roads. This acceptance, as mentioned before, attests to the dedication and desire to do things better on the part of municipal road personnel. It is best put by one long-time Township Roadmaster who stated: “I wish I would have known these things 30 years ago!”

Resource: The Center for Dirt and Gravel Road Studies
The Pennsylvania State University
207 Research Unit D
University Park, PA 16802
Tel: 814-865-5355
Fax: 814-863-6787
Toll-free: 866-NO-TO-MUD (866-668-6683)
Email: dirtandgravel@psu.edu
Website: www.dirtandgravelroads.org

Environmentally Sensitive Maintenance For Dirt and Gravel Roads

Chapter 2: Geology, Rocks and Soils

2.1 Introduction

The term “geology” is used to describe the study of the planet earth, specifically the materials that make up the earth, the processes that affect these materials, the products formed, and the history of the planet. Geology, therefore, with its history, processes, and materials, becomes important in the operation and maintenance of our roads. Geology helps explain the physical setting in which roads are situated as well as the local road materials that are available for use in road building, for example, why limestone may be a prime road aggregate in one area and granite the prime material in another area.



2 – 01 Geology sets the stage

As solid rock breaks down into smaller particles from geological processes, natural forces, and weather, often mixing with decomposing plant and animal matter, it forms soil. Soils are also important in the operation and maintenance of our roads. As the type of soils varies from area to area due to the varying geology of the area, the influence on our road system will vary in different aspects. Roads are typically built directly on top of soils covering the underlying bedrock. The type of soil over which roads are built will influence the design, construction, and maintenance of the overlying portion of the road. In addition, the stability of roadside banks, both upslope and downslope, and the road drainage network are dependent upon the inherent behavior of the soils and vegetation that covers them. The vegetation is also directly dependent on the soil’s characteristics as to its type and growth.

In this module, our goal is to focus on geology, soils, and the natural forces that shape the surface of our land and give us the rocks, soils, and vegetation that make up the environment in which our roads exist and, therefore, influence many aspects of design, operation, and maintenance of our total road system.

2.2 Geology and Natural Forces

As mentioned above, geology is important to the construction and maintenance of roads because it defines the physical setting in which roads are situated and the road materials that are locally available. *In other words, geology gives us what we have to work with.*

The geologic history of the earth is complex and spans a period of approximately 4.5 billion years. This complex history has included processes that have drastically changed the characteristics of our planet. Different regions of the United States have very different geologic histories and consequently vary greatly in road conditions, materials, and construction and maintenance methods.

Geologists have divided the United States into different physiographic provinces. These provinces are areas of different geologic history based on the way the different types of rocks and landscapes were formed. The significance of physiographic provinces will be discussed in [Section 2.3.2](#).



2 – 02 Pennsylvania Ridge and Valley Province

once stood 2 ½ miles high over the ridge and valley province of Pennsylvania (Photo 2-02), is a good example of an [erosion](#) process that occurs over geologic time. The [erosion](#) of this mountain range, which continues today, is not likely to be noticed without careful observation and measurement over several decades. On the other hand, some geologic events happen relatively quickly. Volcanoes in Hawaii, the explosion of Mount St. Helens (Photo 2-03), or major landslides are geologic events that drastically change the landscape over a sufficiently short period of time, and humans are able to perceive the changes.

2.2.2 Types of Binding Forces. To provide background information that will assist in understanding some of the geological processes discussed later in this

2.2.1 Geologic Time. It is important to note that many of the geological processes that shape the earth occur at an extremely slow rate. Because our frame of reference only covers an average of a 70-to 80-year life span, it is often extremely difficult to notice or even comprehend the changes that take place over thousands, millions, or even billions of years. *This is geologic time.* The gradual [erosion](#) of the Alleghenian Mountains, a grand mountain range that



2 - 03 Mount St. Helens

chapter, we will introduce three types of binding forces that act to hold rock and soil particles together: chemical, physical, and electrical.

Elements are the basic building blocks with which everything is formed. There are approximately 110 different known elements, including things such as oxygen, carbon, hydrogen, sulfur, iron, potassium, nitrogen, gold, silver, and uranium. While we can see many of these elements with the naked eye, they are made up of tiny, individual particles called atoms. For example, a gold ring is an element. It is, however, made up of many minute gold atoms. The atom, in turn, is made up of smaller particles. Although the names of these sub-atomic particles are not important for this discussion, it is important to note that these particles influence the way atoms interact with each other.

When different elements are joined together through a chemical reaction, they form a separate and distinctly different compound composed of two or more elements. This type of bonding is referred to as chemical bonding. The joining of different elements in various proportions and combinations has produced an almost infinite number of compounds. For instance, compounds like our deicing rock salt, which is chemically referred to as sodium chloride, is formed via chemical bonds between sodium and chlorine atoms. The term “molecule” may be familiar to many, and it simply refers to the smallest unit of a compound that can exist. For example, a water molecule is made up of two parts of hydrogen and one part oxygen, H₂O. A bucket of water contains millions of water molecules.

In a geological setting, particles of different compounds may be physically bound together. When this physical bonding occurs, the identities of the original compounds are retained in the new bound material. Sandstone is an example of physical bonding, and you can see the individual grains of sand that are cemented together to form the rock.

The third type of bond, electrical bonding, occurs when particles of one kind “stick” to the surface of another kind of particle. The static electricity that causes pet hair to stick to clothes is an example of electrical bonds. With electrical bonds, the sub-atomic particles act like magnets and cause different elements and compounds to be stuck together. Many of the interesting properties associated with clay are a result of the electrical bonds that hold clay particles together. Because of the electrical bonds, clay particles are strongly attracted to each other, making clay “sticky.” These bonds are somewhat flexible or elastic, which also allows for some stretching between the clay particles, causing some clays to be highly plastic and flexible, as well as able to absorb water and expand when wetted.

Electrical bonding also comes into play when other substances attach themselves to [sediment](#) particles. These other substances can be toxic substances from chemicals or other materials that can substantially increase pollution when [sediment](#) washes into our streams.

2.2.3 Natural Physical Forces. At the same time binding forces are acting to hold things together as elements or compounds, other forces are acting to move or even tear

these bonds apart. Naturally occurring forces, such as wind, water, frost action, heat, gravity, etc. are constantly working to change the surface of the earth. Frequently these forces work very slowly to change the landscape. They are **relentless**, however, and the cumulative effect of billions of years of activity has worn down mountains, carved rivers and filled inland seas. Although these processes may act too slowly for us to see their effects, they are ongoing and continue to affect the earth's surface.

These processes not only shape the surface of the earth, but the habitat that humans need to survive. For example, many productive agricultural areas are dependent upon nutrients that are deposited when [sediment](#)-laden floodwaters spill onto adjacent floodplains. Many of these floodplains are used for farming and the deposited [sediments](#) act as natural fertilizers for the farmers. Roads are also a necessary part of our human habitat and the effect of the natural forces on our roads creates the need for road maintenance activities on a routine basis. As discussed in greater detail later, these gradual processes and forces are so intricately related to other natural systems that they act to sustain all life on earth.



2 - 04 The relentless force of gravity causes bank failures, downed trees, loss of road gravel and water erosion.



2 - 05 Gravity along with water, acting as a lubricant, causes slip planes.

On the other hand, acts of mankind frequently disrupt these natural processes and forces and thereby accelerate rates of [erosion](#). This increased rate of [erosion](#) is faster than naturally occurring rates and is referred to as accelerated [erosion](#). This manual, with its proposed practices, is intended to eliminate or at best alleviate accelerated [erosion](#). Understanding these processes and forces is the key to learning how to use them to reduce pollution and improve the stability of our roads.

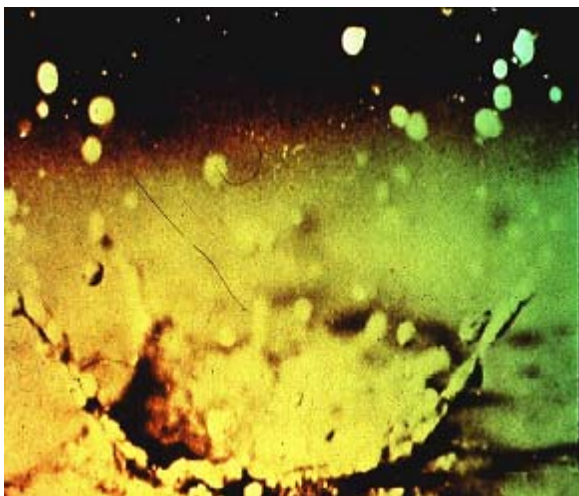
Gravity, water lubrication, [erosion](#), water currents and frost action are among the wide range of naturally occurring forces most frequently impacting our road systems. Gravity is the force that causes objects to fall or water to flow downhill. It is one of the most important natural forces because it influences many of the other forces. It is also an important maintenance factor

because it causes road bank failure, downed trees, loss of gravel from road surfaces and water [erosion](#).

When water gets between rocks or soil particles, it acts as a lubricant to help particles slide and roll about. When gravity enters into the picture, the slope of the material may be steep enough that the material may begin sliding along a slip plane. A slip plane is the movement of material in different directions along a plane of weakness, and is similar to the sliding that takes place between individual playing cards when stacked and slanted, (Photo 2-05). It is also common for hillside roads to contribute to their own failure by creating a dam to natural water flow, trapping and absorbing downhill flowing water, adding greatly to the weight of soil and causing the bank to slip or slump along a plane of weakness. Banks can fail slowly by creeping downhill ([sloughing](#)) or catastrophically, such as a landslide.

[Erosion](#) is defined as a wearing away and most often occurs with wind or water. The effects of winds can be seen in the phenomenon of shifting sands. At Cape Cod, for instance, the sands thrown ashore by the sea are driven inland by the winds, advancing upon the cultivated lands, burying them and destroying their fertility. The sands from the beach on the Pacific coast near San Francisco are driven inland in a similar manner again encroaching upon the more fertile soils. In the fairly dry regions of the interior of our country, high winds, laden with sand and gravel, are a powerful agent in sculpting the rocks into the fantastic forms so often found there.

[Erosion](#) due to water ranges from the impact of raindrops to water currents picking up particles and carrying them away from their original location. [Erosion](#) due to the movement of surface water is one of the major physical forces that have shaped our country's landscape. Water, in the form of rain or other precipitation, falls to the earth's surface and either soaks into or runs across that surface. Water, percolating through the earth, slowly disintegrates the hardest rocks initiating the work of soil-making, which we will address later in this chapter. A large portion of rainwater, however, never soaks into the earth, but runs off the surface.



2 - 06 Impact of each raindrop on bare soil initiates the erosion process.

[Erosion](#) is all about energy – soil and rock particles do not move unless a force or process has enough energy to pick up and carry the particle away. The ability of water to erode soil and rock materials depends on four factors:

1. Force of the raindrop impact;
2. Soil resistance;
3. Volume of accumulated water; and
4. Velocity (speed) of flow.

Vegetation plays a key role in [erosion](#) prevention. This will be discussed in detail in [Chapter 4](#). Briefly, vegetation facilitates soil resistance by breaking the impact force of raindrops, disrupting and slowing the flow of water across the soil surface, and reinforcing the soil with root structures to hold the soil in place.

While soil resistance helps prevent [erosion](#), the remaining three factors lead to [erosion](#). A single raindrop falling from the sky on bare soil creates a mini-explosion to dislodge and scatter soil particles, initiating the [erosion](#) process. Once on the ground, water from these raindrops collects and starts to flow downhill, growing in volume and velocity, forming rills and rivulets and producing furrows and gullies. The accumulated water has lots of energy to erode particles. The rivulets join to form torrents, creating ravines and gorges, and further uniting to form rivers that in turn deposit their load partly in their course and partly into the sea. As the accumulated water flows downhill, steeper slopes cause greater speed, increasing the energy and erosive capacity of the flowing water.



2 - 07 Flowing water picks up volume and velocity causing further erosion.

While each of these factors can cause [erosion](#), the impact from a combination of these factors can be great, causing everything from washouts and bank failures to flooding and complete roadbed failure. The width and depth of the Grand Canyon, which has been carved over millions of years by the Colorado River, is testament to the tremendous erosive power of water.



2 - 08 Deposition of sediment alters the landscape.

Our landscape is continuously being altered by water and [erosion](#) with material eroded from one location being transported and eventually deposited somewhere else. In this fashion, the landscape is altered in two locations, the point of original soil [erosion](#) and the location where the material is deposited as sediment.

Frost action, or the freeze-thaw process, has also helped to change the face of the earth. When water freezes, it expands and exerts pressure on anything that contains it – like the soda can that was stuck in the freezer and “exploded” when it froze. When water gets into the small cracks in rocks, the expanding ice can split the rock. Bear in mind that a large part of our climate

has drastically changed, swinging from temperate to near-arctic conditions during the advance and retreat of glaciers over several periods of time. As will be discussed in [Chapter 3](#), this freeze-thaw process also causes rocks to move upward through the road base and surface; causes potholes to form; and causes posts, poles and structural foundations to shift or tilt.

2.3 Rocks

2.3.1 Rock Families. In their study of the earth's history, geologists have identified three basic rock families: igneous, sedimentary, and metamorphic. What family a rock belongs to is determined by the way in which the rock was formed.

Igneous rocks form when molten rock (magma) cools and hardens. Lava is a form of magma that erupts from volcanoes, and when it hardens, forms volcanic rock. Hawaii and Iceland, both volcanic islands, are primarily made of volcanic igneous rocks. Other types of igneous rocks also form beneath the surface of the earth when magma oozes and intrudes between layers of existing rock. Igneous rocks are usually our older rocks underlying the stratified sedimentary rocks forming the great mass of the earth's interior



2 - 09 Sedimentary limestone layers.

and forming the axes and peaks of our great mountain ranges, such as the Sierras and the various Colorado ranges.

Examples of igneous rocks include granite and diabase.

Sedimentary rocks form when the elements (sun, wind, water temperature, etc.) wear away rock and soil and the eroded particles wash into low-lying depressions where they are deposited. Over time, these sediments may become fused together by natural cementing, compression, or other methods, forming sedimentary rocks. Common examples of sedimentary rocks include shale, sandstone, conglomerate, and limestone.

Metamorphic rocks make up the third family. These rocks have been changed from their original form by heat, pressure, or chemically active fluids to produce new rocks with different minerals and texture. These heat, pressure, or chemical processes may act on any of the three families of rock to produce a new metamorphic rock. Examples of metamorphic rocks include slate, schist, gneiss, quartzite, and marble. Shale often serves as a parent material that is metamorphosed into slate, while sandstone may become quartzite and limestone may become marble.

2.3.2 Geological Provinces. As mentioned in Section 2.2, geologists have divided the United States into physiographic provinces. Each province has a vastly different

geological history that has influenced the local geology and the shape of the landscape. Geological processes and natural forces take place on a number of different scales that range from individual hillsides to entire regions. Consequently, geologic conditions are not uniform across a province or their immediate subdivisions, geologic sections. Site conditions may even vary between locations within the same local government limits.

Surface water [erosion](#) has played an important role in shaping the landscape in all the physiographic provinces. Surface water draining from the landscape has eroded and carved many, if not all, of the river and stream valleys that we see today. In many locations, this [erosion](#) was tremendous and considerably increased the difference in elevation between the highest and lowest points. The stream [erosion](#) process will be discussed further in [Chapter 4](#).

Several periods of glaciation occurred across the northern part of our continent in which large masses of ice in the form of glaciers altered the landscape with their passage. These glaciers were part of a continental ice sheet that covered most of Canada and the northern part of the United States. These glaciers shaped the landscape by grinding away and lowering the tops of hills, producing rounded [uplands](#) and broad, flat-floored valleys. The first glaciers advanced approximately 800,000 years ago with the most recent glaciers advancing only 24,000 years ago.

Glaciers form when snow accumulates to a depth of many feet, compressing the snow at the bottom of the pile into ice. When snow accumulates on top of the glacial ice, the additional weight causes the glacier to slowly move downhill. Glaciers act like huge belt sanders and conveyor belts. Large quantities of rock and smaller fragments become frozen and trapped in the ice. These rocks frozen in the ice of the advancing glacier scrape, grind, and gouge across the landscape, carrying soil and eroding the underlying bedrock as the ice mass slowly slips downhill. This erosion is particularly effective when the underlying rock is as soft as many of the shales and limestones. When glacial ice melts, it leaves behind deposits made of till and outwash that can sometimes be greater than 100 feet in depth.



2 - 10 Glaciers shaped much of the landscape across the northern United States.

Till is an unsorted mixture of clay, silt, sand, gravel, and larger particles that was left in piles at the edges or beneath glaciers. Outwash, as the name implies, is composed of well-sorted gravel and sand [sediments](#) deposited by streams running away from the ice. Outwash often filled the bottoms of valleys leading away from the glaciers, leaving behind relatively shallow, broad, and level valley bottoms. These outwash deposits frequently serve as a source of low-cost bank run gravel for use on roads. This material,

however, is usually not good road material and can be a major source of [sediment](#) and [dust](#) pollution.

Local government road managers should become familiar with their state and local geology in order to gain a better understanding of their site conditions and the driving forces shaping those conditions. Additionally, they should have a good working knowledge of the types of rocks and materials available for road maintenance. As we shall see in future chapters, the geological provinces not only define the local [topography](#) and the existing rocks and soils, but also relate to other natural systems such as [ecoregions](#), vegetation, and forest types that impact the way we maintain our local road system. Many states have Web sites showing the physiographic provinces contained within their state with a description of the provinces and rock formations that are predominant for the region. [Appendix 2](#) maps Pennsylvania's physiographic provinces, showing the rock types and [topography](#) of each province. Other sources of information on local geology include local libraries, universities, agricultural extension offices, county farm service centers, and the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (formerly the Soil Conservation Service).

2.3.3 Rock as a Road Material. As previously discussed, the geological history of an area determines the characteristics of an area's underlying rock structure. Consequently, the characteristics of the locally available materials determine the suitability for road materials as well as the potential for creating environmental problems. Three important major material characteristics that often help determine the structural and environmental suitability for road use are hardness, durability, and the pH.

A gravel road surface material is directly subjected to vehicles traveling on the road, unlike a base or subbase material under a paved asphalt or cement concrete pavement. In this respect, the hardness of the surface material becomes important to withstand the constant grinding by vehicle tires. A material's hardness can be measured in comparison to a diamond. In roadwork, the Los Angeles Abrasion Test method can be used to measure the aggregate's hardness or abrasion resistance. This test measures the percent weight of material loss or abraded away by tumbling a specific sample of sized material in a drum with steel ball bearings at a fixed speed and for a fixed time (Photo 2-11). Results are abbreviated as LA-xx where xx is the relative hardness. For example, a type of rock with a LA-22 is abrasion resistant since it has only lost 22% of its weight, while another rock with a LA-70 is softer and less resistant to abrasion because 70% was worn away from the sample.



2 - 11 Los Angeles Abrasion Test Drum.

The hardness of a material is an important factor when selecting road material because it determines how easily the material will be physically broken down and worn away. Road materials are broken down by both vehicle traffic and environmental conditions, resulting in successively finer particles. These fine particles are then removed from the road as [sediment](#) or [dust](#), which can negatively impact the surrounding natural systems. The removal of fine particles as [dust](#) and [sediment](#) also means that road material is being lost.

Another measure of a rock's performance as road material is durability, a term used to express a rock's resistance to frost action. Durability can be measured by repeated saturation in a salt (sulfate) solution. Crystallization of the salt in cracks in the rock causes the rock to split. When the test results of a sulfate test are received, remember it is really expressing the reaction to frost. Because this characteristic is critical when aggregates are bound in cement or asphalt, the levels for these applications are more stringent (e.g., durability factor of 10) than those used where the aggregates are not bound (e.g., durability of 20).

The third characteristic is the pH of the rock used as a road material. Chemical tests for pH measures the acidity or alkalinity of a material, with the pH scale ranging from 0 to 14.0. values of less than 7.0 are acidic, while values greater than 7.0 are basic or alkaline, with a value of 7.0 being neutral. For the purposes of this manual, the pH measures the ability of a material to increase or decrease the acidity of soil and water. Fine particles worn from the road have chemical characteristics, and when this [dust](#) or [sediment](#) settle, the particles can change the pH of the surrounding soil or water. For instance, [dust](#) from crushed aggregate having a low pH can be washed into an adjacent trout stream. The acidic particles then mix with the water and increase the acidity of the stream. Because plants and animals can only tolerate a certain range of pH conditions, this increased acidity may decrease or eliminate the productivity of the trout stream. The health and productivity of terrestrial plants and animals can also be negatively impacted by changes in pH. Particles with a different pH may affect soils, thereby impacting plants, crops, and organisms utilizing these soils.

The harmful effects of acid rain is one of the major reasons why we must be careful not to further alter the natural pH of our rivers, streams, [wetlands](#), and soils with road materials. Acid rain is caused when moisture (raindrops, snow, fog, clouds) in the atmosphere is exposed to gaseous and particulate air pollutants that come from our vehicles, factories, and power plants. Normal rainwater is, by nature, slightly acidic, and exposure to these pollutants alters the chemistry of the moisture, causing it to become even more acidic. When the acidified moisture falls as precipitation, it brings the acid with it, where it can impact the natural pH of the soil and water. In many cases, acid rain is so harsh that numerous streams and lakes have become so acidic that they are devoid of almost all life. This form of environmental pollution is everywhere, but some areas are stressed more than others. Since many natural systems are already stressed by acid rain, the environmental impacts of even slight changes in pH caused by eroded road materials may be great.

Our ability to be environmentally conscious is based on attention to local conditions. The variety of both land and water communities necessitates choosing the right road material for each situation. There are roads in areas where rare, acid-loving plant species grow. Placing limestone on those roads could raise the pH of those areas, destroying the habitat that those species require for survival. Conversely, placing acidic shale on a road that is upslope from a clover field could drive the pH of the field's soil down below tolerable levels. It is critical for us to be aware of the potential impacts that our road maintenance activities have on our natural environment.

Local government road personnel should also be aware of threatened and endangered species living within their jurisdiction. These plant and animal species are not only protected by federal and state laws, but they also deserve every official's and citizen's protection so that they survive for their own benefit and for that of future generations. Just one thing such as changing the pH of their required habitat by not paying attention to discharges from road operations and maintenance activities, cannot be justified because both the liability and ethical concerns of such actions are tremendous.

The value of a good road aggregate along with other important road aggregate characteristics and specifications will be further discussed in [Chapter 3](#) with an appendix of example state specifications.

2.4 Soils

Soils play an important role in the construction, maintenance and operation of dirt and gravel roads because most of these roads are built directly on soil. Characteristics of these soils, such as particle size, type, and combinations, influence the properties of the soil. These soil properties, which can include things like drainage, erodability, suitability as a road [subgrade](#) material, and use as a growth medium, influence many of our necessary road maintenance activities discussed in this manual as well as those activities currently being performed.

2.4.1 Soil Formation. Soil formation is a component of the larger geologic cycle, and the rocks making up the local geology commonly serve as parent material for a region's soils. Parent material is the raw, intact rock that eventually breaks down into finer and finer pieces which, when combined, are called soil. This process of soil formation can take from 10 to 10,000 years. Soil formation also includes the addition of decomposing plant and animal matter brought by organisms living within the soil, which adds fertility to the newly formed soil.

Chemical and physical weathering are two types of mechanisms that transform parent material into soil. Chemical weathering is the decomposition, or chemical breakdown, of geological materials. Rainwater acts as the most important agent of the chemical weathering process because it is, by nature, mildly acidic. Rainwater, however, also contains other acids obtained from gases in the atmosphere (i.e., acid rain), vegetation, and from microorganisms, which boost the rainwater's ability to dissolve the chemical bonds that hold rocks and minerals together. As these bonds dissolve, fractures

form along zones of weakness. Limestone is dramatically impacted by chemical weathering, forming sinkholes and solution channels for underground streams.

Physical weathering can be thought of as the disintegration, or crumbling, of larger particles into smaller particles. Water also plays a large role in the disintegration process and the frost action discussed before is a common example of physical weathering.

These weathering processes often work hand in hand with one type of weathering occurring along zones of weakness created by the other type. Weathering typically occurs at or near the surface of the earth, with fractures in the rock allowing these weathering processes to penetrate to limited depths. The degree of weathering usually decreases with depth below the ground surface. The depth of weathering, however, may vary from area to area, and geological studies in the Piedmont physiographic province discovered weathered granite approximately 100 feet below the ground surface. Historical and recent climatic conditions also influence the degree of each type of weathering. During periods of glaciation, intense frost action near the glacial margins physically fractured many subsurface sedimentary rock formations. Currently, moderate chemical weathering with frost action is common.

Because of local geology's history and characteristics, parent material varies from one location to the next. This variation in parent materials, in conjunction with local weathering conditions, has resulted in the development of many different types of soils within a small area. The USDA Natural Resources Conservation Service has compiled county soil survey maps that contain information on the location and types of each county's soils.

2.4.2 Soil Particles. As rocks weather, they break down into smaller particles, forming sand, silt, and clay-sized particles. When physical weathering occurs, these particles are simply smaller-sized pieces of the parent material, while chemical weathering alters the nature of the parent material in the decomposition process. The following Table 2-1 contains information on the actual size of the different particles.

Table 2-1: Soil Particle Sizes

Particle Size	Diameter (mm)	Field Test
Clay	Less than 0.002	Feels sticky
Silt	0.002 to 0.05	Feels like flour
Sand	0.05 to 2.0	Feels gritty

The size difference between these particles is also significant for a number of reasons that will be discussed later. To put the particle sizes into perspective, if a clay particle were considered to be the size of the head of a pin, then a silt particle would be the size of a kernel of corn, and a sand particle the size of a basketball.

Clay has unique properties that frequently cause it to impact road construction and maintenance activities. Clay particles have a flat, plate-like structure that is unlike the irregular and more rounded structure of silt and sand, respectively. This flat shape gives

clay particles greater surface area for electrical bonding to take place between individual clay minerals. These electrical bonds give clay its tenacious, sticky properties. The shape and electrical bonds of clay are also responsible for many of clay's other interesting properties, including its ability to absorb water and swell, sometimes to great extents; be flexible; be slippery; and hold more nutrients than other particles types.

The different particle sizes and the type of material that make up those particles influence a number of important properties. The likelihood that a material will erode is affected by shape of the particles as well as the degree of bonding, or cohesion, between particles. For example, Table 2-2 below indicates that rounded sand particles are likely to erode, while sticky clay particles are not. Particle properties also influence how well it serves as a growth medium for vegetation. While clay holds nutrients, many of these nutrients are bound to the clay and not available for plants. Silt has the most nutrients available, and sand is relatively nutrient poor. Road managers are probably more familiar with the suitability of these types of materials for road stability and drainage purposes as shown in Table 2-2.

Table 2-2: Soil Type Properties

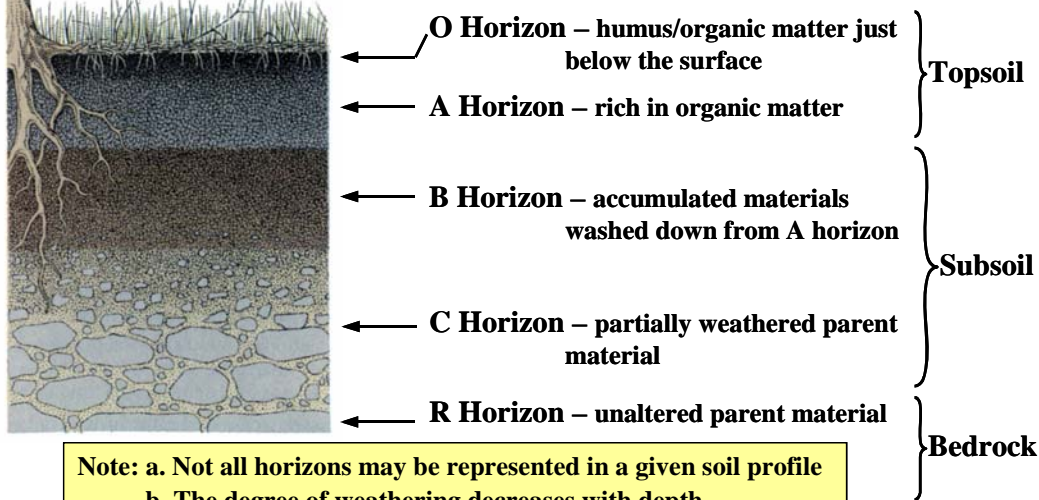
	Erodability	Growth Medium	Road Stability	Drainage
Clay	Stable	Holds nutrients	Soft, slippery	Holds water
Silt	Moderately stable	Rich	Soft	Moderately drained
Sand	Unstable	Poor	Poor compaction	Well drained

It is important to note that none of the individual particle sizes or types makes a good, stable road material. *Particle combinations are key!* Soils are formed from combinations of these different particles, and the relative proportions of sand, silt, and clay-sized particles determines soil types. The combination of different particle sizes and types, and their properties, influence the overall characteristics of the soils they form. Knowledge of these combinations and properties can aid decisions regarding management of dirt and gravel roads, and especially the stability of banks and ditches.

Appendix 6A, Soil Identification in the Field, gives a guide that allows road personnel to determine soil particle types in the field.

2.4.3 Soil Layers. Because soils are formed from parent material via weathering processes, they typically develop from the surface downward. Soil development forms layers in the soil, which are called soil horizons, and may be observed when a trench cuts through soils that have not been disturbed by agriculture or construction. Figure 2-1, Soil Horizons, shows an example of these horizons, though not all of these horizons may be represented in every given soil profile.

Figure 2-1: Generalized Soil Horizons in Undisturbed Soil Profile



The horizons develop hand in hand with the soils, frequently taking several hundred to several thousand years to become well developed. Changes in environmental conditions can lead to changes in the development of both the soils and the horizons within those soils. For example, soils that develop under the saturated conditions found in [wetlands](#) produce unique soil conditions, as will be discussed in [Chapter 4](#).



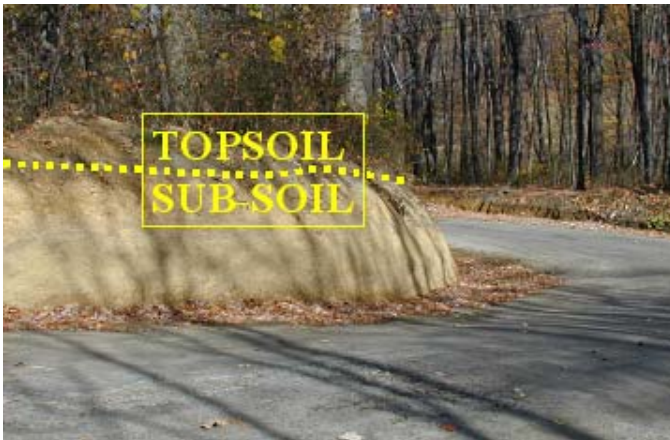
2 - 12 Earthworms live in the A Horizon, the first layer of “dirt.”

The upper layers of the soil are commonly referred to as topsoil. Topsoil is made up of the O and A horizons (refer to Figure 2-1). The O horizon consists of a collection of organic materials resting on the surface, including seeds, leaves, branches, vegetation, bacteria, insects, animal wastes, and deteriorating plant and animal remains. This organic matter serves as a valuable source of nutrients for the underlying soils.

The A horizon is the first layer of “dirt” and is made up of varying proportions of sand, silt, and clay mineral materials, along with a substantial amount of organic matter. Much of this matter has been washed down through the soil from the overlying O horizon. Plants utilize this layer for the germination of their seeds and the development of root networks for support and gathering food and water. Creatures such as insects, earthworms, fungi, and other microorganisms live within the A horizon and provide several vital functions. These insects, molds, fungi and bacteria help encourage the rotting of wood and leaves, thereby breaking down the organic matter into more usable forms. The insects and earthworms burrow through the ground, aerating the soil so that plant roots can breathe. The burrows of these creatures also help water to infiltrate the

soil. Infiltrating water can help plants grow, but it also helps recharge groundwater supplies.

The layer of soil beneath the topsoil is commonly referred to as subsoil. This layer of soil can be broken into the B and C horizons, as shown in Figure 2-1. In the B horizon, the parent material has been completely weathered, so few rocks are present. The B horizon lacks the organic matter that the A horizon has, but does contain extra silt and clay particles that have washed out of the overlying horizons by water percolating down through the soil profile. The C horizon is typically very rocky and consists of partially weathered parent material. The R horizon is the bottommost horizon and consists of hard bedrock that underlies the soil. Because these subsoil layers do not have organic matter and biological organisms that the A horizon does, they are not as suitable a growth medium for plants. Some plants, however, do send roots down into the subsoil layers to gather water and nutrients that have accumulated in these deeper soils. It is critical to understand that bank and ditch stability is aided by the plants and their root structures. Plants are dependent on the soil and thrive best when a natural soil profile is maintained. Mechanical removal of even leaf litter decreases a plant's chances of holding the bank or ditch together. The common practice of removing all topsoil materials and exposing subsoils is difficult to justify in light of the following valuable insights.



2 - 13 Topsoil provides the nutrients needed for plant growth.

topsoil, where they wait for an opportunity to sprout and grow. These dormant seeds often are the first to sprout when topsoil is disturbed by equipment. All of these things help new vegetation to become established quickly. As will be discussed in several other portions of this manual, established vegetation not only looks better, but also prevents [erosion](#) of both the road banks and ditches.

In addition, subsoil cannot develop overnight into a suitable growth medium for bankside vegetation. It requires a geological time scale to develop into topsoil. For these reasons, it is important to retain topsoil when performing ditch and other road maintenance activities so that it can be reused to revegetate the site at the completion of the work. Chapter 6 will cover this concept in more detail.

2.4.4 Topsoil Versus Subsoil. Plants normally grow in topsoil, and because of this, topsoil can be used to help road maintenance projects in several ways. Topsoil contains many of the nutrients that plants require for healthy and quick growth. The organic content of the topsoil also helps to retain soil moisture as well as the vital nutrients, which is then

available for plant uptake. Many kinds of seeds lay dormant in the

When we consider road construction and maintenance, however, subsoil for road [subgrades](#) becomes the material of choice. We do not need all the vital nutrients to support vegetation, but we do need a structurally sound material containing the proper combination of particles to properly drain water away from the road.

It all boils down to the fact that *what makes a good garden makes a poor road and what makes a good road makes a poor garden.*

2.5 Summary of Geology, Rocks, and Soils

The construction and maintenance of roads is closely tied into the local geology. Each region's geologic history has influenced the rocks and soils underlying and surrounding its roads. These underlying materials determine the road's design and maintenance requirements, and the surrounding materials determine the roadside's design and maintenance, affecting vegetation type and growth, bank and slope stability, and drainage. Geology also explains why some road materials are locally available and others are not.

Environmental and road problems stem primarily from several relentless, natural physical forces acting to change the landscape. These forces include gravity, water lubrication, water currents, [erosion](#), and frost action. Many human activities have greatly influenced the effects of these natural forces, often resulting in accelerated rates of [erosion](#) and [sediment](#). By understanding and limiting our influence on these natural forces and processes, we can slow this accelerated [erosion](#) and minimize our impact on the natural environment.

Igneous, metamorphic, and sedimentary rocks are formed over long periods of time by a number of different geological processes. These processes produce varying conditions that geologists identify as physiographic provinces. Each province has its own unique combination of geologic materials, [topography](#), drainage, and overall character. We have identified hardness, durability and pH as three important characteristics used to determine the suitability of rocks for use as road materials and their potential for environmental problems.

Rocks are subjected to physical and chemical weathering processes that break them down into finer sand, silt, and clay-sized particles. These three particle sizes combine to form soil. The various combinations of particles size and type influence the physical characteristics of soil, which then affects the soil's [erosion](#) and drainage characteristics, as well as its suitability as a growth medium and road [subgrade](#) material. Topsoil contains decomposing vegetation and animal materials and other vitals for plant establishment and growth, while the "dead" subsoil is better suited to road [subgrades](#).

Rocks and soils form over geological time scales of many thousands of years. Because our roads are situated within the context of the natural environment, they are not only subjected to the same physical and weathering forces, but also often act to accelerate and increase the effects of these forces. As such, it is important to be knowledgeable

about, respect, and consider the interactions between roads and natural systems in order to minimize disturbances to both systems.

When road managers understand their local geology, rocks and soils, they can develop appropriate maintenance techniques. The best maintenance techniques minimize disturbances while striving to retain the functions of the natural systems and facilitate the long-term stability of the road and its surrounding environment.

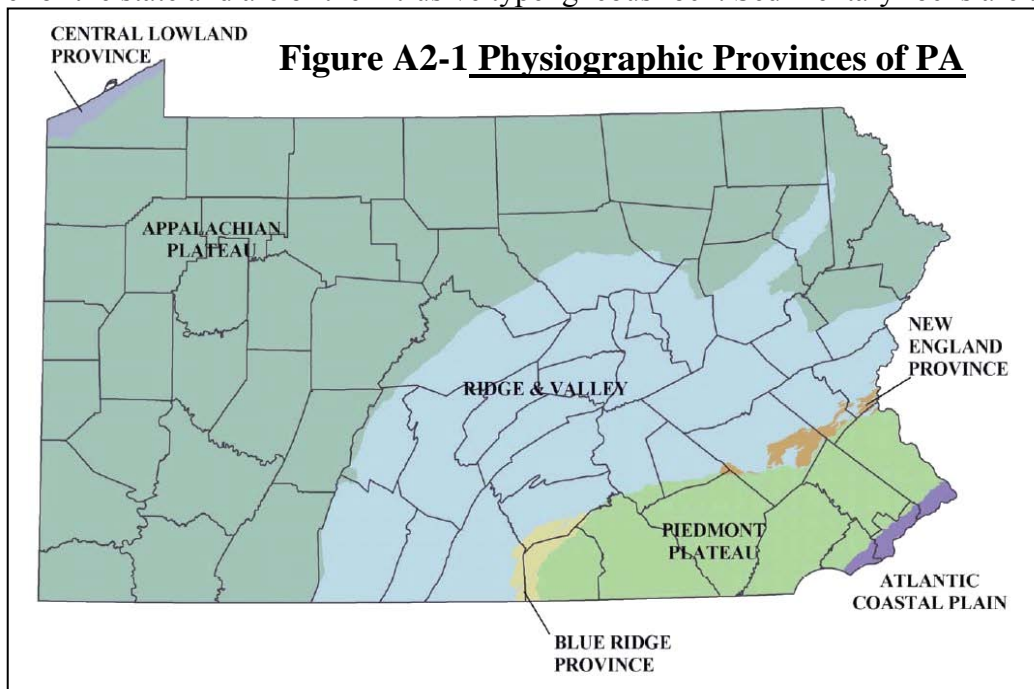


2 – 14 Understanding geology helps to develop good road maintenance practices.

APPENDIX 2. Case Study: Pennsylvania's Geology

Geologists have divided Pennsylvania into seven physiographic provinces (see Figure A2-1). Each province has a vastly different geological history that has influenced the local geology and shaped the landscape. In general, older rocks (more than 570 million years old) are found in southeastern Pennsylvania while younger rocks (less than 290 million years old) are found in the northwest parts of the state.

Thus, most of the igneous rocks in Pennsylvania are found in the southeastern corner of the state and are of the intrusive type igneous rock. Sedimentary rocks are the



most common type of rock in Pennsylvania and cover approximately 85 to 90% of the state. Metamorphic rocks are again present predominantly in the southeastern portion of the state.

Surface water was a major factor in shaping the landscape in all seven provinces, eroding and carving most of the river and stream valleys that can be seen today. The periods of glaciation occurring in northern Pennsylvania also altered the landscape. The following province descriptions provide a basic overview of Pennsylvania's landscape and its geologic history.

A2.1 Central Lowland Province. This is the northern most province in Pennsylvania, and is found along the Lake Erie shoreline in Erie County. This is only a small portion of the Central Lowland Province as it extends from northwestern Pennsylvania and western New York, northwestward to Minnesota and southwestward to Texas. The portion of the province located in Pennsylvania consists of a series of sand and gravel beach ridges that run parallel to Lake Erie. These ridges were formed by the lake during the last period of glaciation in the area, from approximately 24,000 to 18,000 years ago. As the glaciers retreated and melted, water levels in Lake Erie were higher than they are today. Waves piled up sands and gravels, forming these beach ridges at the then current water levels. As the lake's water levels declined, these beach ridges became inactive, with vegetation becoming established and stabilizing the mobile sand ridges. The ridges can now be viewed as the gently rolling land that is characteristic of the area. Additional wave [erosion](#) and relatively steady water levels have caused the more recent formation of a bluff along the Lake Erie shoreline. Surface water drains towards the lake in this area, forming steep-sided, narrow valleys that cut across the ridges and into the underlying shales and siltstones. Rocks in this province include gray and black shale, red sandstone, limestone, and chert.

A2.2 Appalachian Plateaus Province. This province covers the greatest part of Pennsylvania, approximately 60% of the state, including 42 counties and extends from Greene, Somerset, and Fayette counties in the southwest to Erie in the northwest and northeastward across the northern part of the state to Wayne and Pike counties. The province was covered by a series of salt and fresh water seas in which [sedimentation](#) occurred. [Sediments](#) laid down by these seas became cemented together, forming the 250- to 405-million-year-old sedimentary rocks that underlie this area. During periods when the land was not submerged, vast swamps and bogs developed. Dead vegetation from these swamps and bogs accumulated and formed thick beds of peat. Some of these peat beds were later covered by new layers of [sediment](#), which compressed the peat and caused it to metamorphose into coal, forming the vast coal deposits that have played an essential part in Pennsylvania's history. Surface water [erosion](#) has deeply carved an extensive drainage network across this province. Glaciers covered a large portion of the northern corners of the state, where they dramatically reshaped the landscape. Rocks in this province include red, gray and black shale, red and gray sandstone, limestone, conglomerate, coal, and chert.

A2.3 Ridge and Valley Province. The Ridge and Valley Province of central Pennsylvania is characterized by long, narrow mountain ridges separated by valleys of varying widths. This province encompasses approximately a quarter of the state and extends northeastward into New Jersey and southwestward through Maryland. The province is underlain by the many of same sedimentary rocks that underlie the Appalachian Plateaus Province and are approximately 290 to 570 million years old. The subsequent geological events, however, warrant separation of this area into a new physiographic province.

The earth's continental plates drift around the surface of the earth at a rate of about an inch per year, and about 290 million years ago, North America collided with Africa. This collision resulted in a period of mountain building as the two continents pushed together. The massive forces involved with this collision caused the relatively flat rocks within the province to wrinkle and become folded much like a carpet does when the ends are pushed together. This geologic upheaval resulted in the formation of a mountain range that was 150 miles wide and at least 2.5 miles high that is referred to as the Alleghanian Mountains. Approximately 250 million years ago, the Alleghenian Mountains began to erode away. Because some rocks are more susceptible to [erosion](#) than others, [erosion](#) rates differ. Extensive [erosion](#) of these mountains has since formed valleys in areas of soft rock (shales and siltstones) and left erosion-resistant ridges comprised of very tough sandstone. The ridges and valleys presently cutting across the state are all that remain of this former mountain range. Rocks in this province include gray and black shale, siltstone, red and gray sandstone, limestone, chert conglomerate, quartzite, and dolomite.

As with the Appalachian Plateaus Province, surface water [erosion](#) has played a major role in shaping the current [topography](#) of the province. The Susquehanna River, which cuts through many of the ridges of the province, is evidence of the impact of surface water [erosion](#) on shaping the landscape. The Susquehanna River was able to erode sufficient material to maintain its course while the underlying land was being uplifted by the collision of the continental plates. Glaciers have also acted on small portions of the province, primarily in Northampton, Carbon, Monroe, Luzerne, Columbia, Sullivan and Lycoming counties.

A2.4 Blue Ridge Province. The Blue Ridge Province is represented in south-central Pennsylvania in portions of Cumberland, York, Adams, and Franklin counties. Known locally as South Mountain, this mountain ridge extends southwestward into Maryland and Virginia, where it is known as the Blue Ridge Mountains. The quartzite and metamorphic volcanic rocks that make up this highland province are [erosion](#) resistant and more than 500 million years old. Rocks in this province include shale, sandstone, limestone, quartzite, dolomite, gneiss, granite, marble, and other metamorphic rocks.

A2.5 New England Province. The portion of this province extends southwestward into portions of Northampton, Bucks, Lehigh, Berks, Lancaster, and Lebanon counties in southeastern Pennsylvania. This portion of the province is known as the Reading Prong section, which consists of highly distorted metamorphic rocks that are

significantly more resistant to [erosion](#) than the surrounding sedimentary rocks. Rocks in this province include gneiss, marble, other metamorphic rocks, and granite.

A2.6 Piedmont Province. The Piedmont Province is located in Southeastern Pennsylvania and covers approximately 15% of the state. This area was influenced tremendously by the same collision of continental plates previously discussed and again formed the Alleghanian Mountains in this area. This mountain building process created metamorphic rocks that are at least 430 million years old. Younger sedimentary rocks containing intrusions of igneous rock formed in the northern portions of the province approximately 140 to 250 million years ago during the separation of the two continental plates. As with the Ridge and Valley Province, millions of years of surface water [erosion](#) has worn down the grand Alleghanian mountains to form the current [topography](#) characterized by broad valleys and gently rolling hills. Rocks in this province include quartzite, schist, slate, marble, serpentine, gneiss, other metamorphic rocks, red sandstone, shale conglomerate, limestone, dolomite, diabase, and granite.

A2.7 Atlantic Coastal Plain Province. This province is located in the extreme southeastern part of Pennsylvania, including almost all of Philadelphia County and southeastern portions of Bucks and Delaware counties. This province extends from Massachusetts to Florida, and includes most of Delaware and all of southern New Jersey. In higher elevations within this province (maximum elevation is about 200 feet above sea level), sand and gravels approximately 2 to 67 million years old overlie older metamorphic rocks. In lower elevations along the Delaware River, floodplain deposits of sand, gravel, silt, and clay are less than 2 million years old. In general, the geologic history of the province has produced rather flat lands with sandy soils. Many of the sand, gravel, silt, and clay deposits remain unconsolidated, as they have not had sufficient time to become cemented together.

A2.8 What Pennsylvania Has to Work With. These previous descriptions of Pennsylvania's geologic history with its physiographic provinces show what the local governments have to work with as far as rocks, soils and road materials. Comparing the province map with the geology map and a soils map shows the similar patterns (Figure A2-2 and Figure A2-3). And, of course, the soils will dictate types and growth of vegetation and the environment in which the roads exist. It explains why many unpaved roads through most of Pennsylvania use limestone as the aggregate road material available from local quarries. It also explains the lack of limestone across the north central part of the state where only softer shales are available, creating more problems of [erosion](#) and [dust](#) along with increased road maintenance. Geologic history shows how the steep hills and deep valleys in some sections were formed. Roads and banks in these sections are difficult to stabilize because they must fight gravity's relentless force. Pennsylvania still has approximately 20,000 miles of unpaved roads. [Sediment](#) and [erosion](#) from these roads represent major environmental problems. Part of Pennsylvania's rich geological legacy is its vast resources of coal. But this bounty has come at a price. Acid mine drainage into the streams costs taxpayers millions of dollars each year in cleanup expenses.

Figure A2-2: What do you have to work with?

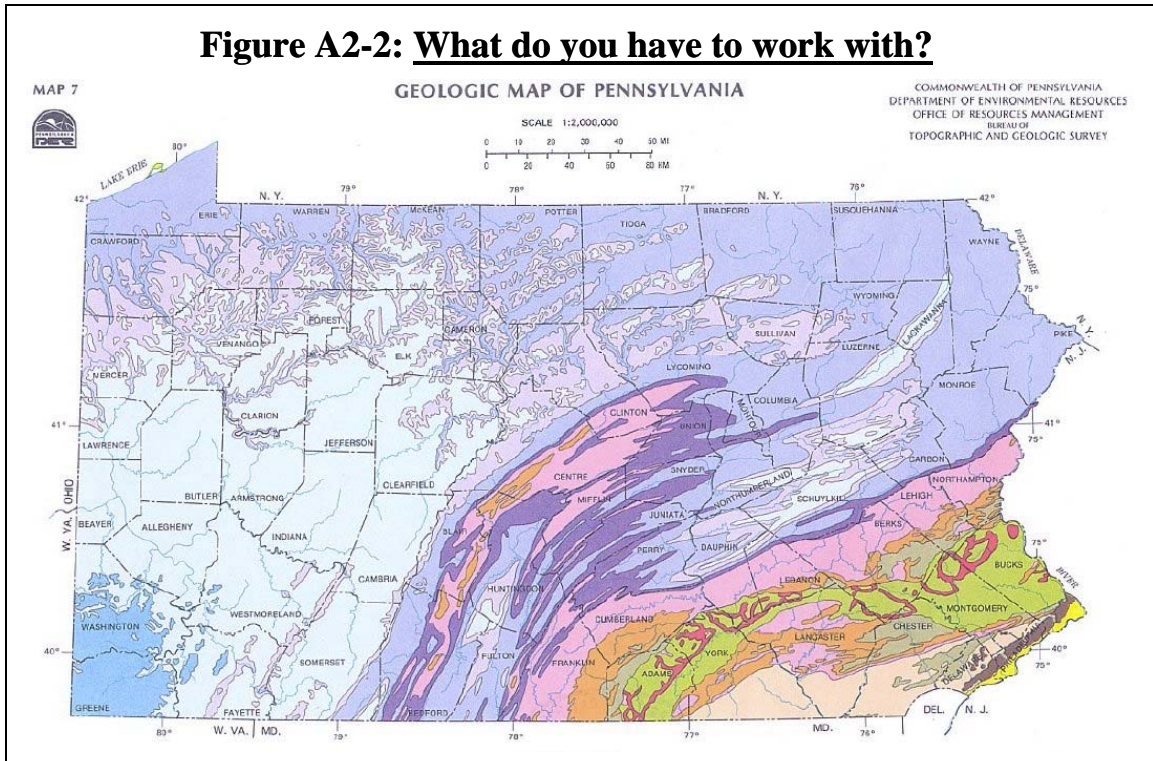
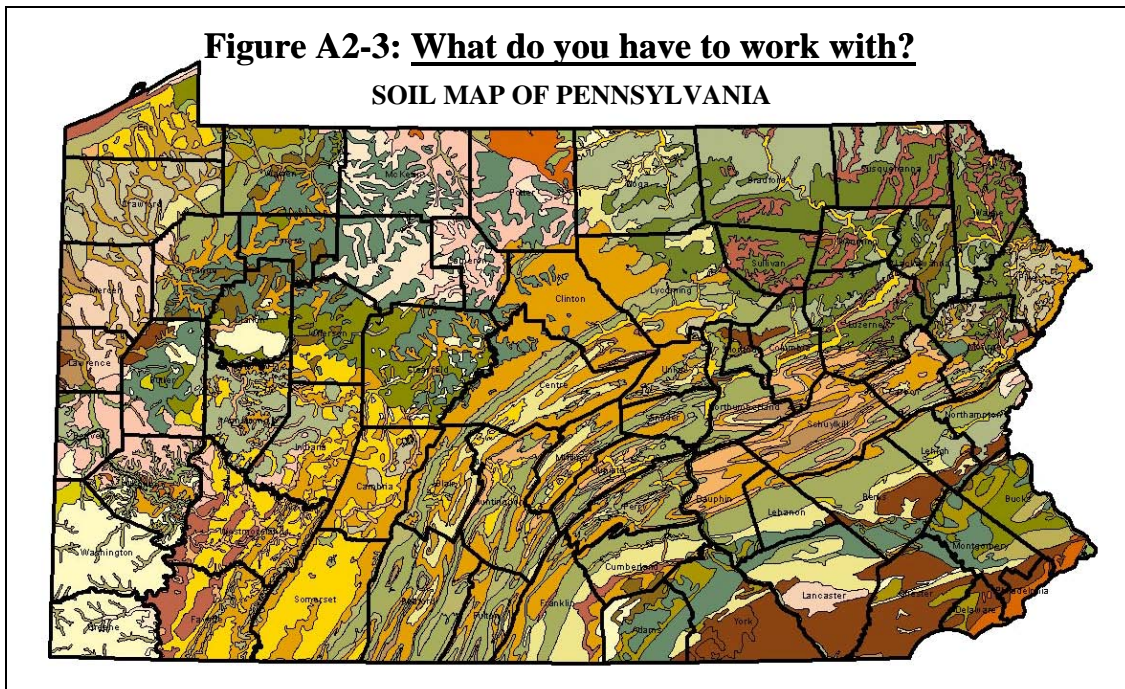


Figure A2-3: What do you have to work with?

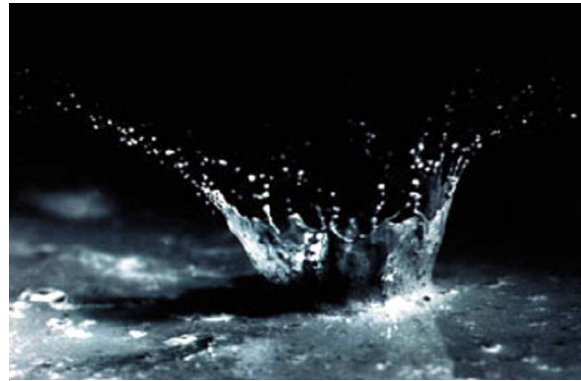


Environmentally Sensitive Maintenance for Dirt and Gravel Roads

Chapter 3: Water, Erosion, Drainage and Road Basics

3.1 Introduction

Water is essential for all life on earth. Water, however, can also cause devastation through [erosion](#) and flooding. In the first chapter, we detailed the historical relationship between roads and streams, the interrelationship of our roads and the environment, and the importance of good roads and a good environment for a good municipality. In Chapter 2, we discussed the relentless forces shaping the earth, specifically gravity and water. Now we need to discuss water, accelerated [erosion](#) and the importance of proper drainage in maintaining our roads and the environment.



3-01 Never underestimate the force of water.



3-02 Stability depends on percentages of rock, sand, silt, and clay.

We will cover basic road maintenance materials and techniques to ensure an understanding of accepted and proven practices in maintaining dirt and gravel roads and establish a basis for our [environmentally sensitive maintenance](#) practices.

3.2 Water and Erosion

3.2.1 Principles of Erosion. Never underestimate the force of a drop of rainwater. To recap what was discussed in Chapter 2, it is that water drop exploding when it impacts bare soil that starts the [erosion](#) process. Water's eroding force increases with its volume and flow velocity (how fast it is flowing).

How resistant soil is to [erosion](#) depends on several factors. First, soil type and particle size are important. Soil stability will depend on the

percentages of rock, sand, silt, and clay in the soil. A rock bank such as seen in the photo is stable with little [erosion](#) taking place.

A second factor is soil cover, specifically vegetation. Vegetation breaks the raindrop's fall, dissipating its destructive energy before it hits the soil. Vegetation also slows down surface water flow, keeping velocities low and minimizing [erosion](#).

Plant roots constitute the third factor. Never underestimate the value of root systems as soil reinforcement. Plant roots provide additional stability by removing water from the soil. The importance of plant roots and root systems



3-03 Vegetation provides many advantages in erosion control.

will be discussed more thoroughly in Chapter 4.



3-04 Roads interfere with natural systems, causing accelerated erosion

3.2.2 Accelerated Erosion.

Remember, the greater the velocity, the greater the erosive force. [Erosion](#) is a natural occurrence in nature. When roads are constructed, however, they interfere with natural systems and concentrate water, increasing its volume and velocity, causing **accelerated erosion**. It is this accelerated [erosion](#) that causes severe problems for both our roads and the environment.

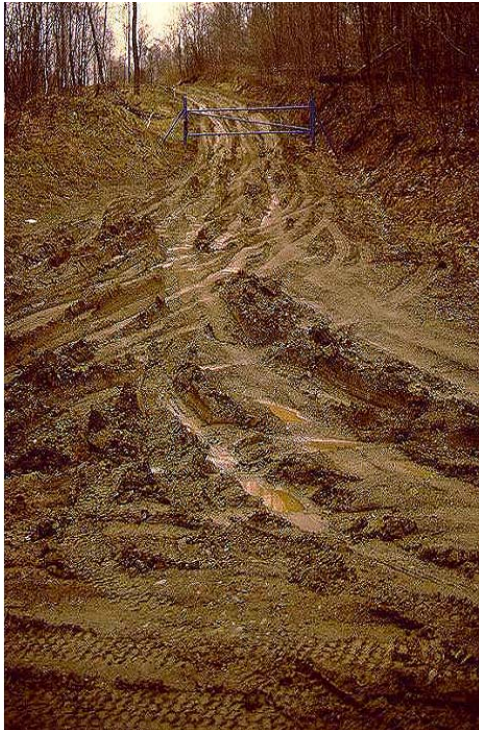
3.3 Water and the Importance of Road Drainage

3.3.1 The Importance of Drainage. Although water may be the life-giving liquid of our planet, it has long been recognized as the archenemy of our roads. Road literature provides a rich history of the disastrous effect water has on roads.

In 1820, the great Scottish road builder of the 19th Century, John Loudon McAdam, stated "...experience having shown that if water passes through a road and fills the native soil, the road, whatever may be its thickness, loses its support and goes to pieces." In 1909, Connecticut State Highway Commissioner, James H. MacDonald, remarked, "If there is no drainage, there will be no road, no matter what the material may be." In 1912, John Nathaniel Mackall in his Drainage, the Fundamental Principle of Road Construction discussed his conclusion after a seven-year study by stating, "Lay out your road with the object of draining it and never lose sight of this point. It is the ABC of road

building and maintenance.” A New Hampshire Highway Department Handbook in 1916 stated it this way: “Always remember and apply this most important rule: Keep water OFF your road, OUT of your road, and AWAY from your road.”

These statements are just as true today! Good road drainage and proper maintenance is the best way to combat water’s damaging influence – keeping water off, out of, and away from the road. Proper drainage cannot be over-emphasized in road maintenance and construction. Water affects all aspects of road serviceability.



3-05 Water acts as a lubricant, allowing material to move more freely.

3.3.2 Characteristics of Water. To

understand water and its effects, we must understand water’s three key characteristics that concern us in road maintenance:

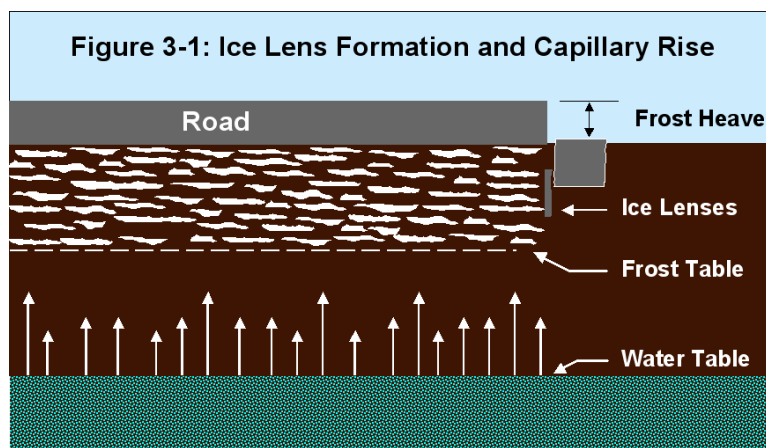
1. Water acts as a lubricant
2. Water expands upon freezing
3. Water runs downhill

Remember these factors as related to those relentless physical forces back in Chapter 2. A more detailed discussion of these characteristics is required to determine the concern for roads.

Water acts as a lubricant. Water’s presence allows materials to move more freely by decreasing the friction between particles. Photo 3-05 shows a well-lubricated road. When a road gets wet, aggregates are more likely to move or become displaced under traffic loads. This in turn causes surface depressions that collect more water and result in even more weakened areas and soft spots.

If water is within the road structure and freezes, it expands and forms ice lenses as shown in Figure 3-1. This freezing process starts at the road surface and moves

downward into the road structure. As the freezing takes place, more water is drawn up from the soils below. Thus, the road structure becomes supersaturated. The ice lenses formed from the expanded frozen water causes pressure in limited spaces – a pressure that is usually transmitted



upwards, deflecting the road surface, causing frost heaves or frost boils. As the first step in controlling this frost damage, we must recognize the three conditions required for frost damage to occur: freezing temperatures, frost-susceptible soils, and water. The elimination of any one of these three conditions will prevent frost damage.

Since the power to control temperature is beyond us, we can concentrate on the remaining two. Some soils are more susceptible to frost heave, such as fine-grained clay soils, as was described in Chapter 2, Geology and Soils. It may not be feasible to remove frost-susceptible soils depending on the extent of the problem. Small localized areas can be considered for removal while larger areas may use alternate treatments with [geosynthetics](#). [Geosynthetics](#), their properties and uses will be discussed in Chapter 7. A combined strategy of proper drainage and the use of [geosynthetics](#) is usually the most feasible and cost effective method.

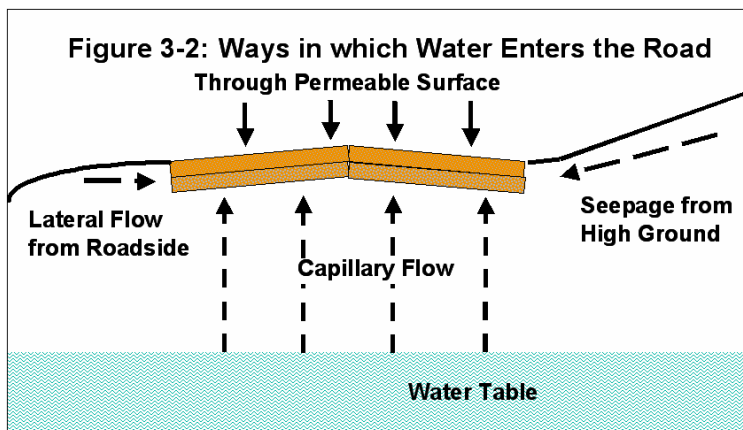
Springtime and thawing brings additional problems. During the spring thaw, ice lenses melt, releasing excess water to the base and [subgrade](#). The problem is compounded since melting will occur from the top down, trapping water from draining downward. This excess water, if it cannot drain off laterally, acts as a lubricant, softening our roads and killing their load-bearing capacity. Springtime, often referred to as “mud season,” can be a very trying for road maintenance crews.



3-06 Spring, “Mud Season,” can be a trying time for road maintenance crews.

The simplest and most obvious characteristic of water is that it runs downhill, subject to the relentless force of gravity. But we do not maintain our roads with this in mind. How many roads have ponding problems on the surface? We ignore this obvious characteristic at our roads’

peril. Like gravity, water’s devastating effects are relentless.



3.3.3 How Water Enters Our Roads. Figure 3-2 shows the many ways water can seep into our road structure. Road surfaces are not impervious to water, so water can seep through the surface. The longer water lays on the

surface, the more seepage takes place. Water may enter as lateral flow from the roadside or high ground. The [water table](#) may rise and enter the road base. If the [water table](#) is at a level higher than the road base, then we have to look at ways to lower the [water table](#) in the vicinity of the roadway structure using underdrain systems (discussed in a later section). Even if the [water table](#) is low, you may still get water into your road by “[capillary flow](#)” through the soil. The soil acts like a wick in a kerosene heater, drawing the water upward and into the road. This [capillary flow](#) also aids the freezing process as additional water is drawn up from below. Capillary rise can be quite substantial depending on soil type, as the following table illustrates.

Height of Capillary Rise through Soils	
Soil Type	Height of Rise (feet)
Small Gravel	0.1 - 0.4
Coarse Sand	0.5
Fine Sand	1 – 3
Silt	3 - 30
Clay	30 - 90

Given water’s destructive effect on our roads, good drainage must be our highest priority. Further, unless drainage issues are addressed first, all other maintenance work will not last as long as it should, resulting in a waste of time and money.

3.4 Road Drainage

3.4.1 Drainage Systems. There are two major road drainage systems: surface drainage and subsurface drainage. The surface drainage system controls surface water caused by direct rainfall, melted snow, or surface [runoff](#). The subsurface drainage system drains subsurface water from in our roads or from the subsurface areas surrounding our roads.

3.4.2 Surface Drainage. Surface drainage involves collecting the water from the road surface, road shoulders or berms, side slopes and adjacent areas and carrying it away via downhill slopes, roadside ditches and pipes. More complex surface drainage practices will be presented in later chapters; here we concentrate on road basics emphasizing the road and shoulder profile and the road cross-section or actual structure of the road.

3.4.2.1 Road Crown and Cross Slope. The road surface acts as our first line of defense against water, and the first component of a good surface drainage system is the [road crown](#). The [road crown](#) means the center of the road is higher than the outer edges of the road, as shown in



3-07A good road crown is our first line of defense against water.

Figure 3-3. The crown should be a flat “A” shape with a [cross slope](#) or drop from the center to the edge of ½” to ¾” per foot or a 4-inch to 6-inch drop for an 8-foot lane.

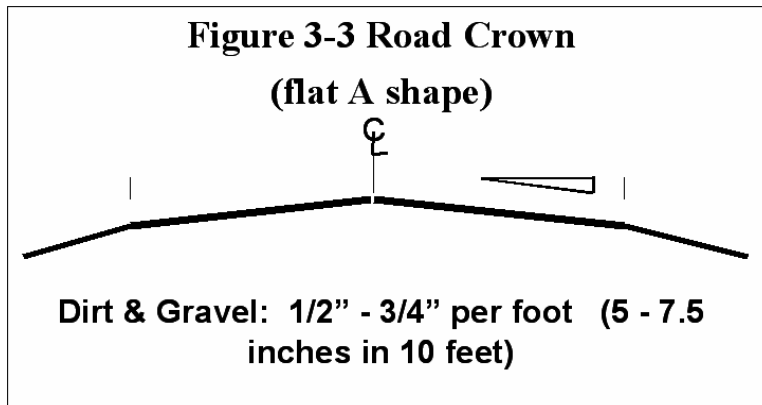
The crown must be maintained to allow water to flow off the road. Problems develop quickly when a gravel road has no crown, as evident in photo 3-08. Water will quickly collect on the road surface during a rain, softening the surface crust. This will lead to rutting, which can become severe if the



3-08 Water quickly collects when the road crown is lost.

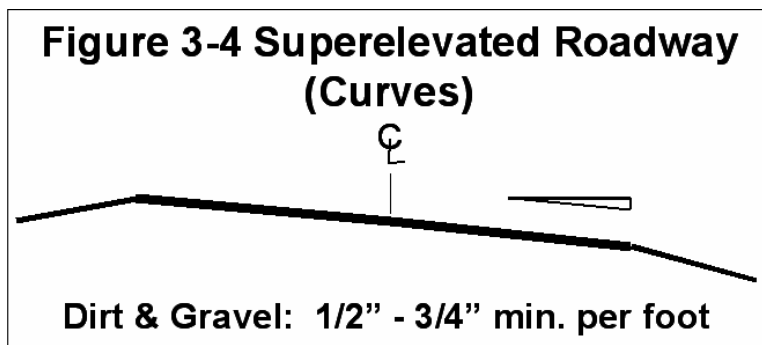
outer portions. This center area is somewhat flat, and water will collect and not drain from the middle adequately. Traffic will form potholes and ruts. A parabolic crown is often caused by a worn grader blade. Grader blades, which are worn down through the center portion of the blade, should be replaced or cut straight with a torch.

With curves, we need to slope the road from one side to the other to “bank” the curve. This banking of the curve, called [superelevation](#), provides for vehicle safety in traveling around the curve, as shown in Figure 3-4.



[subgrade](#) also begins to soften. Even if the [subgrade](#) remains firm, traffic will quickly pound out smaller depressions in the road where water collects, and the road will develop potholes. A dirt and gravel road must have crown.

A crown’s ideal shape is a straight line from the centerline down to each road edge, the flat “A” shape already mentioned. This shape can sometimes become rounded. The term for this is “parabolic crown,” and it is virtually always a problem. The middle portion of the road will have considerably less crown than the



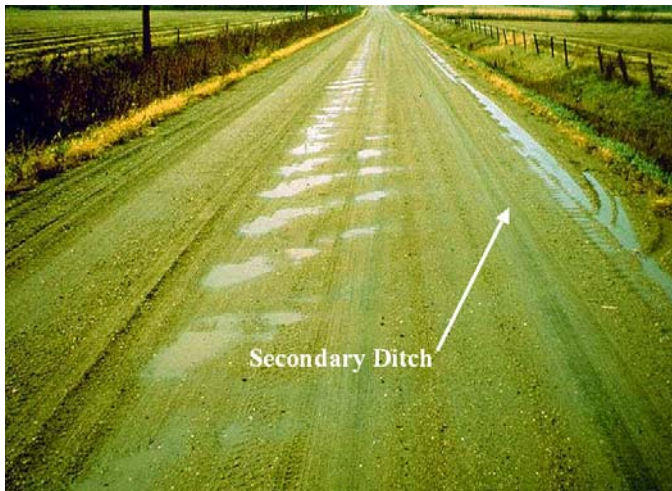
The sloped surface still provides for proper drainage, getting the water off the road. The [cross slope](#) of the superelevated section should be a minimum of ¼” to ¾” per foot. Sharper curves may demand steeper [cross slopes](#) for safety. Of course, the steeper we bank the curve, the faster the vehicles will go.



3-09 Banked (superelevated) curve.

3.4.2.2 Road Shoulders. Most of our dirt and gravel roads do not have defined shoulders. But shoulders provide some key advantages.

If you have shoulders or a berm area, keep it flush with the road edge with a slightly steeper [cross slope](#), avoiding “shoulder drop-off,” which becomes a safety hazard for the motorist. A vertical drop-off can cause a serious accident. The errant driver leaves the road’s travel way and drops to the shoulder area. When he attempts to return the wheel will catch on this “lip,” and the driver will end up over-steering, allowing the vehicle to jump the lip, taking the vehicle into the adjacent lane of oncoming traffic.



3-10 When water cannot drain off the road, the result is a “secondary ditch.”

Roads without a properly sloped shoulder or berm area often develop a “[secondary ditch](#)” that will not allow the water to drain off and away from the road. This [secondary ditch](#) develops when road material moves toward the edge of the road and catches in the vegetation, forming a barrier to road drainage, as shown in Photo 3-10. Improper grading techniques can also leave a windrow of road material along the edge that acts as a dam, keeping water on the roadway.

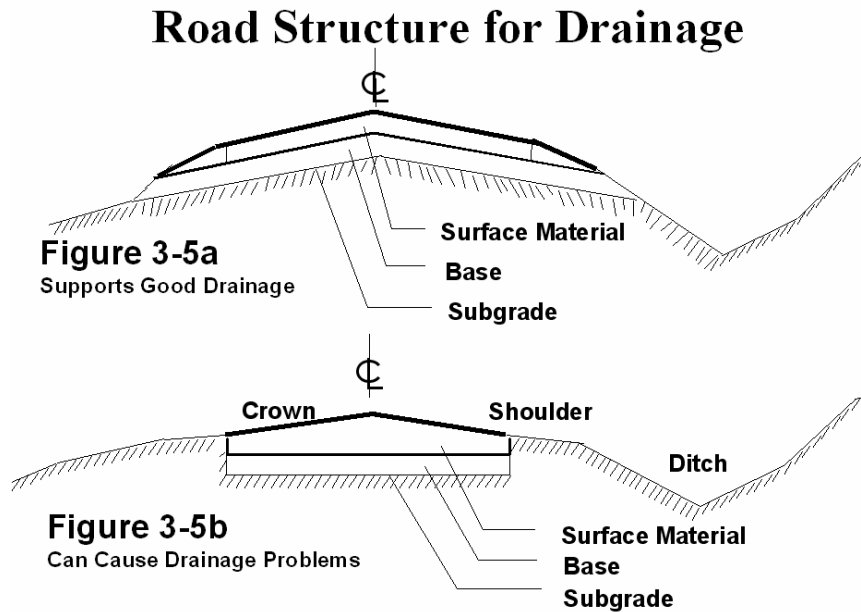
A shoulder or berm area also supports the road structure, preventing road edge breakdown. Look at a road where the roadside slope drops immediately from the road edge into the adjacent road ditch, and you will probably find road edge deterioration. Shoulders also allow the water to flow further away from the road, maintaining better drainage, getting the water off and away more effectively.

And finally, shoulders make the road safer by providing a more defined visible roadway for the motorist and more room for erratic vehicle maneuvers or pull-offs. With

all these advantages, developing and maintaining shoulders along our dirt and gravel roads, where feasible, should become a high priority in our road maintenance program.

3.4.2.3 Road Structure (Cross Section). The crown and [cross slope](#) are not only important for the road surface and shoulders, but also are important for the road base and [subgrade](#), or the soil on which the road is built. The configuration in Figure 3-5a supports good drainage.

The old “trench construction” method for building a road consisted of digging a trench with a flat bottom and then building your road, depicted in Figure 3-5b. Depending on geology and soil types, this procedure could actually trap water within the road structure.

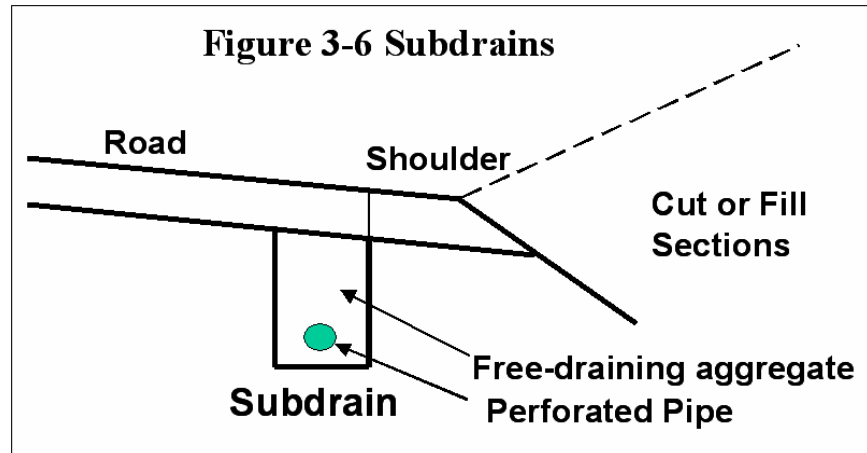


Proper construction maintains a [cross slope](#) for each layer including the [subgrade](#) and also carries the base materials through to the ditch slope to provide proper drainage of the road structure.

Notice in the figure that the bottom, or flow line, of the ditch is below the [subgrade](#) of the road. If a roadside ditch is required, this configuration with a 4:1 foreslope from the road into the ditch is the ideal ditch to drain the road surface and base properly and provide a safety factor for errant vehicles leaving the road. This construction, however, is not always feasible because of roadside terrain and right-of-way limitations often found on our dirt and gravel roads. Ditches will be discussed more thoroughly in Chapter 5 where we address ditch shapes and slopes and look at a variety of practices that can help us in maintaining our roads and ditches.

3.4.3 Subsurface Drainage. Surface drainage is only part of the overall drainage picture. We must drain the road subsurface as well. The free draining base of the road with a proper [cross slope](#) is a major component of the subsurface drainage system to drain the road structure, either into the roadside ditch or [subdrain](#) system. The ideal road structure would have a free draining base material topped with a good wearing course material, particularly in those areas where subsurface water is a concern.

The second major component of a subsurface drainage system is an underground collector system, usually referred to as a [subdrain](#). A typical subdrain, as shown in the Figure 3-6, consists of a trench parallel to the road with a free



draining aggregate and a perforated pipe to carry the water to an outlet and away from the road. All [subdrains](#) should have an outlet. Whether or not adequate ditching exists, [subdrains](#) may be necessary to remove the water from the road structure and the surrounding area and/or to lower the [water table](#).

But [subdrains](#) are subject to clogging over time. Soil fines, carried into the perforated pipe, can build up [sediment](#), eventually blocking water flow and causing the system to malfunction. Some perforated pipes have perforations halfway around the pipe. These pipes should be installed with the perforations on the down side to prevent fine particles from falling through the holes and clogging the system. Water will find its way into the pipe (the path of least resistance) and keep the bottom flushed more effectively, prolonging the life of the system. Traditionally, roofing paper has been placed over the free draining aggregate in the trench to reduce the amount of fine particles migrating into the pipe.

Chapter 7 will discuss the use of [geotextiles](#) and [geosynthetic](#) pre-fabricated [subdrains](#) as cost effective alternatives that prolong system life.

3.5 Road Materials

Road materials play an important part in a road's structural stability. Additionally, good quality road materials reduce [erosion](#), [sediment](#), and [dust](#) pollution. Road material is normally sorted by type, size, shape, and gradation. In addition, as discussed in Chapter 2, we need to be concerned about other factors such as hardness, soundness, pH, and plasticity (cohesiveness/stickiness) to adequately protect both the road and the environment.

3.5.1 Quality Aggregates. What do we mean by quality road aggregates? The answer to this question will vary depending on location (remember geology and the physiographic provinces), aggregate availability, intended aggregate use, and other factors. Some regions do not have good aggregate sources. Common available materials may include:

- granite
- quartzite

- limestone
- sandstone
- shale
- glacial deposits of stone, sand, silt and clay or
- river run gravels. One thing to remember – using the best material available will prolong the road’s life, decrease required maintenance work, and further protect the area’s natural environment.

3.5.1.1 Surface Aggregate versus Other Uses. Many times surface aggregate used for our dirt and gravel roads comes from stockpiles processed for other uses. For

example, the aggregate may have been produced for use as a base or subbase material beneath a paved road surface. But there are major differences between surface aggregates and base course aggregates. Base course aggregate is not designed to withstand traffic and the constant, direct grinding of wheels. A base aggregate may have larger sized stone and less fines than what is required for a good surface aggregate. Base aggregate may not be suited to



3-11 Road Aggregates

developing a hard crust surface and remaining bound and stable under traffic. A free-draining fill aggregate may be great as fill material for building sites, but the high sand content that allows for good drainage will remain loose and unstable as a surface aggregate on an unpaved road. A good surface road aggregate needs a fine binding material having more plasticity or stickiness than subbase aggregate.

There are still many local governments that use their State Department of Transportation (DOT) specifications for their road aggregates. But many states only have base/subbase course aggregate specifications and do not have an actual unpaved road surface aggregate specification. Aggregate meeting base material specifications will probably not meet unpaved road surface requirements.



3-12 A good road surface aggregate will be well graded from fine to coarse.

3.5.1.2 Road Aggregate Specifications. Dirt and gravel road aggregate must be a granular, well-graded, crushed (irregular) material. Well-graded means the aggregate has a variety of sizes from a maximum coarse material down to a fine material and everything in between. The fine material (passing a #200 sieve) fills all the voids between the larger particles and locks everything together in place. The fines hold the road together, obtaining good density and a hard crust surface to shed water. Most specifications will have a required content of 8% to 15% fines.

Another characteristic of good road fines is their plasticity, or binding quality. Although fines are needed to fill the voids between the large aggregate, a percentage of good plastic fines, such as natural clay, is needed to bind the material together and maintain a tight surface to shed water and prevent [dust](#). A plasticity index (PI) of 4 to 12 is a common specification requirement.

Please note that we are describing a gravel road “surface” material. The amount and plasticity of this fine material determines how effectively it locks in place to form a tight surface that will shed water and provide a smooth driving surface.

Road “base” material plays a different role in effective drainage. This role dictates that base material contain less fines and have a plasticity index of down to 0% to allow water to drain from the road structure. Large quantities of plastic fines in the road base will clog drainage channels in the base material and prevent proper drainage. A poorly drained road will lose strength and stability and ultimately fail.

We have discussed several times how common maintenance techniques can spell disaster for dirt and gravel roads. This is another example. Maintenance crews will commonly use only one type of material for both the road surface and the road base. But that results in either a weak road surface or a poorly drained road base. The best approach, particularly in those areas of poor drainage, would be to specify two types of road aggregates, one for the road surface and one for the road base.

The aggregate should also be angular or irregular in shape. In some regions, it is common to use material directly dredged from streams or by simply loading material from a site onto trucks without processing – hence the terms “river run” gravel or “bank run” gravel. These natural deposits will most likely not meet gradation requirements and will contain rounded natural shape material that will not lock up for stability. Have you ever tried to stabilize a hand full of marbles?

The benefits of processing the material by crushing cannot be overstated. Crushing insures that a good percentage of the stone will be fractured. This crushed, fractured material will lock together for better strength and stability under traffic loads. Quarried aggregates will be composed of virtually all fractured particles, resulting in the best specified road material.

The aggregate must be free of any other debris or contaminants such as soil, vegetation, or trash. Any contaminant material will only interfere in obtaining good consolidation and long-term stability.

The importance of additional material considerations of hardness, durability, and pH were discussed in Chapter 2, Section 2.3.3 in relation to not only the road’s structural stability, but also to the surrounding environment.

Quality road aggregate with good gradation, shape, plasticity, hardness, durability, and proper pH will compact well, developing a tightly bound surface to withstand traffic loads, and reduce washboarding, rutting, erosion, sediment, and dust for less maintenance and a better environment.

Appendix A for this chapter contains several state specifications for unpaved road surface aggregate material. Notice the great similarities and the relatively minor differences in the various parameters. Some titles such as Pennsylvania’s “Driving Surface Aggregate” say it all. In addition, the Pennsylvania specification reflects the environmental/structural combination qualities of hardness and pH.

3.5.1.3 Recycled Asphalt. As our paved roads wear out, the asphalt pavement materials can be recycled. Although there are various recycling methods to restore the asphalt paved road, this recycled material is many times used for gravel roads. Milling the old asphalt pavement is a common method used in the recycling process. The asphalt pavement can also be removed and then processed through crushing. This milled or crushed recycled asphalt material can create a good gravel road surface. The asphalt in this material, however, is still the binder, and depending on the age and oxidation (brittleness) of the material, can still form the characteristic asphalt pavement. This means that the road will be hard to maintain as a gravel road as far as blading or grading operations and may develop cracking, potholes and other typical asphalt pavement distresses. If the asphalt is still somewhat viscous and not hard and brittle, virgin aggregate can be mixed with the asphalt to overcome some of the asphalt binding quality and to provide a material that will still remain workable for blading and grading operations. A commonly used mix would have 50% virgin aggregate.

3.5.2 Sampling and Testing Aggregates. Aggregates can differ substantially from one area to another or from one quarry to another. Aggregates can also differ substantially within the same quarry and may depend on geology, or quarry operations and procedures in the handling and processing of the material.

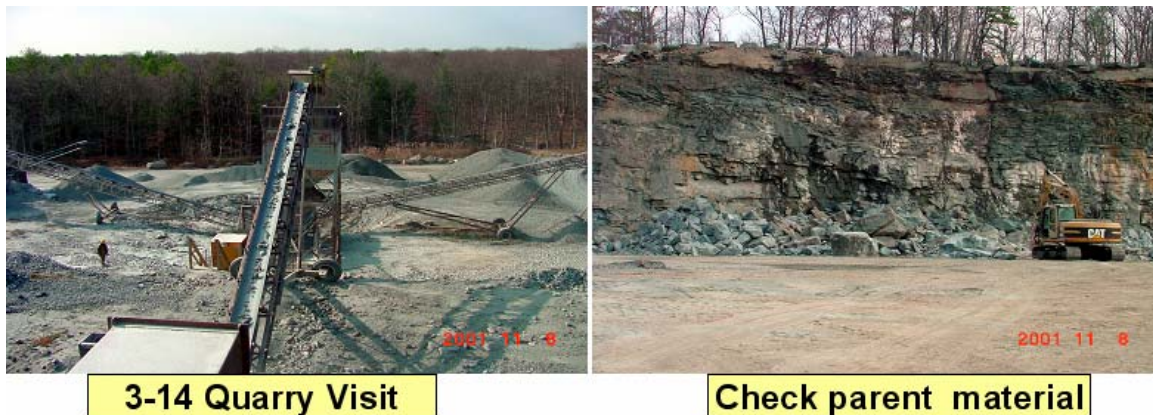
Road maintenance managers need to understand the necessity of sampling and testing aggregates to insure that they are getting a road material that meets the specifications and makes for a well-structured road. A visual inspection can tell very little about the quality of the aggregate.



3-13 Mechanical Sieves

National standards for aggregate sampling require a representative sample of the aggregate you intend to use. Using a representative sample helps to ensure reliable test results. A sieve analysis for the proper gradation blend along with other tests for the specified parameters (plasticity, hardness, pH) is essential to insure the quality of the aggregate.

Testing costs, when compared to the benefits of a structurally strong road, are nominal. Using quality aggregates greatly reduces overall maintenance costs and protects the environment.



3-14 Quarry Visit

Check parent material

3.5.3 Pit / Quarry Operations. As mentioned, handling and processing at the quarry has a significant influence on the aggregate quality. Road maintenance managers would be wise to visit the quarry and talk to the operator. Take a look at the parent material and check the pile. Observe the equipment operators as they remove the gravel



3-15 Check Moisture Content And Fines

from the face of the quarry pit, process the piles and mix and load the aggregate. As they remove material, are they getting a good blend? Is segregation of the aggregate visible on the belt loaders or on the surface of the piles?

Check the moisture content of the material. Grab a handful and compress into a ball. If the material sticks together when you open your hand, you've got a good moisture level. If it falls apart, it's too dry. If water runs out between your fingers, it's too wet.

Some separation of aggregate in a pile is normal. Coarse material will tend to end up on the surface. A good loader operator will view the pile and then work it appropriately to obtain a good blend of aggregate.

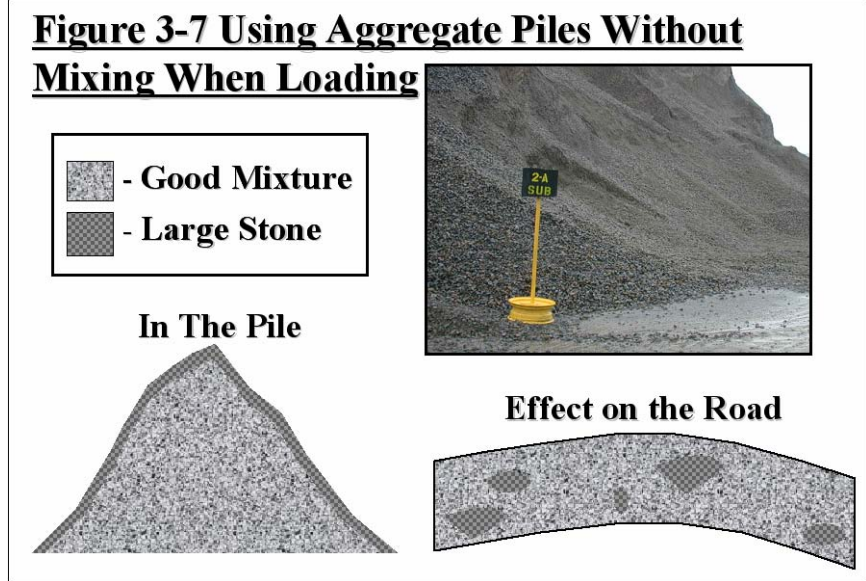


3-16 Aggregate Separation In A Pile Is Normal

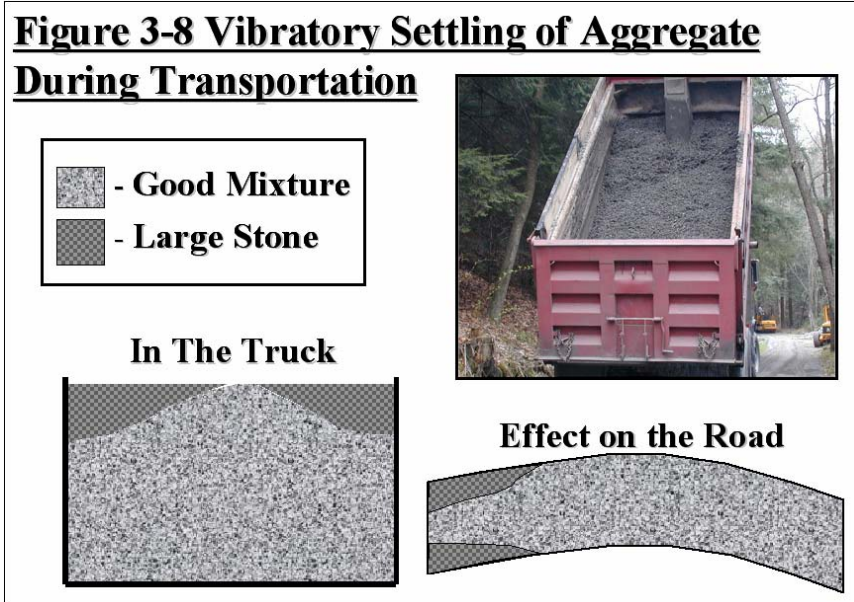
Mix The Pile!

Contamination of the aggregate can also become a problem. Has all the topsoil and vegetation been cleared from the top of the removal site? Are the stockpile sites well maintained, with an uncontaminated level working area? Does the loader operator start with a lowered bucket too far in advance of the pile, picking up soil or other contaminate material?

Loading and hauling of the material, even a good gravel road material, can affect the quality of the road. If the loader operator does not work the pile and obtain a good mix of material from the pile, normal aggregate separation will produce undesirable results on the road. This is depicted in Figure 3-7.



Long distance hauls can also cause problems. The continual vibrations created by hauling, especially over longer haul times, can cause aggregate settling in the truck bed producing a surface of larger stones, as depicted in Figure 3-8.





**3-17 Talk To The Quarry Operator
Establish The Spirit Of Cooperation**

Quarry visits, including observations and discussions with the operators, can establish good working relationships with the proper spirit of cooperation and can result in quality aggregate, good handling practices, and a stronger, longer-lasting road.

3.6 Basic Road Maintenance Practices

We will primarily discuss the use of the motorgrader for dirt and gravel road maintenance. We

recognize, however, that other equipment can work just as well. Front-or rear-mounted grading attachments for tractors, road rakes, and road drags of various designs are often used effectively. No matter what equipment is used, the principles of basic road maintenance remain the same.



3-18 Good road surfaces differ in appearance depending on aggregate type and gradation.

Basic road maintenance practices are designed to produce a structurally sound road capable of supporting traffic with a good hard crust surface and proper crown for good drainage. Good road surfaces vary in appearance depending on the type and gradation of the aggregate material being used, as

can be seen in the photos. This manual is not a basic gravel road surface maintenance manual. However, it does discuss effective maintenance techniques that ensure road stability. Further, the manual emphasizes the importance of proper basic road surface maintenance in protecting the environment. One of the best resources for gravel road maintenance is the Gravel Roads Maintenance and Design Manual, developed by the South Dakota Local Transportation Assistance Program (SD LTAP) in conjunction with the Federal Highway Administration (FHWA), November 2000. This manual provides valuable information for road maintenance personnel on gravel road materials and routine maintenance operations. The following section, Section 3.6, will provide brief coverage of the basics with several references from the South Dakota manual.

3.6.1 Basic Techniques. First, no matter what work is being done on the road, it should be planned when there is adequate moisture. This usually means that all work should be done after a rainfall unless there is an available water truck and water source. Adequate moisture is needed not only to achieve proper compaction for structural integrity and strength, but also to avoid [dust](#).

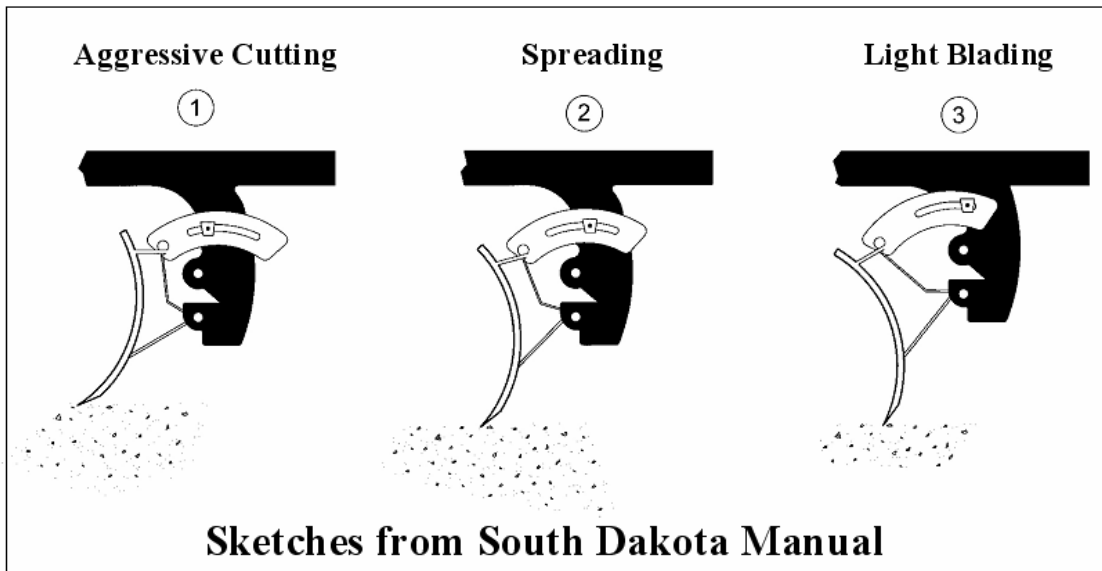
Dirt and gravel roads are usually maintained through three basic practices: blading or smoothing, reshaping or regrading, and adding new material. Gravel road deterioration, like any paved road, will develop in stages. Low severity surface distresses such as roughness, loose gravel, and minor ripples appear first. **Blading or smoothing the road surface frequently to correct these distresses will result in less intense efforts of reshaping or adding new material.** When the road loses crown and more severe distresses appear, a reshaping or regrading to re-establish proper crown is required. The more frequently we reshape using existing road material, the less often we will need to add new material. Sooner or later, however, the road loses crown and enough material has been lost off the roadside or by way of [erosion](#) and [dust](#) that there is not enough remaining material to simply regrade the road. Then we must add new material in order to re-establish the crown and have an effective road profile.

3.6.1.1 Blading or Smoothing. As described above, blading a road is needed when surface distresses appear but the road still has a good crown. We need to blade the road to smooth the rough surface to restore good rideability and prevent further more extensive distress.

When using the motorgrader, the moldboard angle and pitch is critical to doing good maintenance. The moldboard should be angled somewhere between 30 and 45 degrees, tilted forward, with light down pressure. A 10 to 15 degree tilt on the front wheels will help oppose the resisting forces and stabilize the operations. A speed of 3 to 5 miles per hour is considered average, but there are many conditions or variables that may require slower speeds for effective operations. With the blading or reshaping operations, compaction of the material is often left to traffic.



3-19 Blading or smoothing a rough surface restores rideability and prevents further more extensive deterioration.



Operating with proper pitch or tilt of the moldboard is important. Moldboard pitch or tilt refers to how much the moldboard is tipped forward or backward. The following excerpts and sketch are taken from the South Dakota LTAP Gravel Roads Maintenance and Design Manual:

3.6.1.2 Regrading or Reshaping. As stated above, when the road loses crown and more severe distresses appear, a reshaping or regrading to re-establish proper crown is required. With the moldboard tilted slightly backward and sufficient down pressure to produce a cutting action, the road is reshaped to restore proper crown and cross-slope for good drainage. A minimum of four passes may be required, with a first pass in each direction to cut and windrow the material to the road center and then a second pass in each direction to spread the material back across each lane. The cutting action should be deep enough to cut to the bottom of all existing distresses such as corrugations, ruts, and potholes or soft spots.

Since this operation is being performed to restore proper crown and cross slope, check the resulting cross slope to insure it meets the half inch to three quarters inch drop from the center of the road with the flat “A” shape.

This operation should include a compaction effort. Using rollers for proper compaction of the disturbed material will result in a stronger road for a longer period of time.



3-20 Checking Cross Slope to insure proper drainage.

3.6.1.3 Adding New Material. If there is not sufficient material remaining to regrade and restore proper crown and [cross slope](#) at the proper elevation, additional road material will have to be added. Prior to adding new material, the road should be in good shape with all other maintenance work performed. All distresses, such as corrugations



3-21 Adding new material.

and rutting, should be repaired and the road brought into the proper condition and shape to receive the new material. If the existing road surface is smooth or has a hard crust, the surface should be lightly scarified to loosen surface material to provide a good bond between the road surface and layer of new material. Compaction is again required to provide the proper density for structural strength and durability.

meet other profiles. Transitions are required at road intersections, driveways, road curves, railroad crossings, and bridges.

3.6.2.1 Road Intersections. When two unpaved roads intersect, we need to gradually eliminate the crown as we approach the intersection. This transition from normal crown to a flat profile at the intersection should be made within approximately one hundred (100) feet, resulting in a smooth gradual transition. The shoulder or berm area of the road should still maintain a slope for proper drainage of the road.

When a gravel road meets a paved road, we need to transition the crown into the existing edge elevation of the paved road. As we grade out toward the paved road, backdragging may be required in order to avoid leaving aggregate on the paved road. Depending on traffic conditions and safety or operations, working parallel to the paved road can be an advantage in tying into the edge of the paved road.



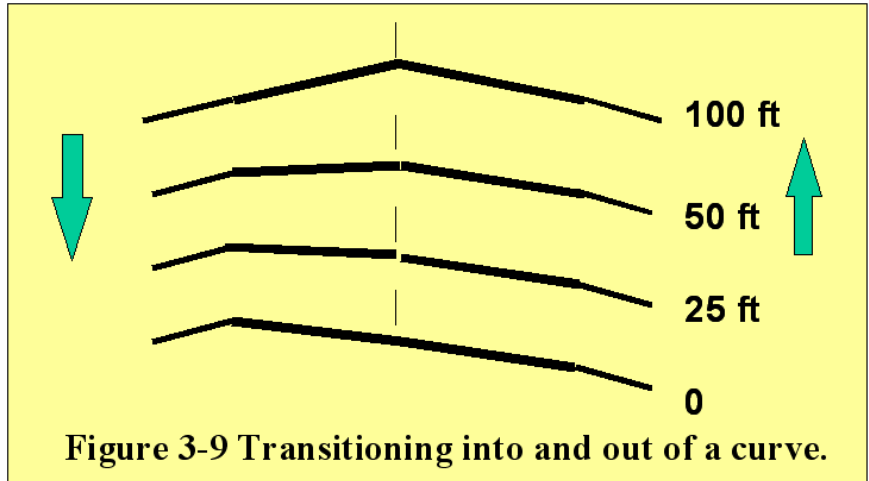
3-22 Working parallel to a paved road has advantages.

3.6.2.2 Driveways. Driveways will also cause a need for transitioning. We will be discussing driveways in more detail in later chapters as we look at [environmentally sensitive maintenance](#) practices. For now, the basic rules are that we need to grade the driveway, keeping the low point at the ditchline and not leaving a windrow of material

across the driveway. The low point at the ditch line insures drainage off of and away from the road.

3.6.2.3 Curves.

Back in Section 3.4.2.1, we discussed [superelevation](#) or banking the curve, sloping the entire road surface from one side to the other for vehicle safety in transversing the curve. Here again, we need to transition from the normal crown to the banked slope of the curve and then transition from the banked slope of the curve back to the normal crown. This should be accomplished within about 100 feet on each end of the curve, as shown in Figure 3-9.



3-23 Keeping rails clean of road material is essential for safety.

3.6.2.4 Railroad Crossings. Railroad crossings also require gradual elimination of the [road crown](#) as we approach the rails. It is important that our operations leave the rails clean, keeping aggregate off of the tracks and being careful not to damage the rails or the moldboard. Handwork could be required using a shovel and broom in order to insure a safe railroad crossing for both vehicles and trains.

3.6.2.5 Bridges. At bridges, we need to transition into the existing bridge deck profile. Many bridges on unpaved roads have flat decks that will require the gradual elimination of the [road crown](#). If the bridge deck is crowned, the task will be to transition the [road crown](#) gradually into the bridge crown.



3-24 Road crowns must transition into the existing bridge deck.

Although we will be discussing practices for better bridges in Chapter 5, good bridge maintenance dictates keeping

all road material off the bridge and keeping the bridge drainage facilities clear and open. Road material buildup on the bridge deck will only retain water or moisture that is detrimental to the bridge deck and structure no matter whether the bridge is constructed of metal, concrete or wood.



3-25 Drainage openings (scuppers) in bridge decks must be kept cleaned.

traffic moves from a rigid bridge deck to a more flexible dirt and gravel road surface, the impact forces of those vehicles can cause problems, resulting in significantly more maintenance for the approach areas.

3.6.3. Frequency of Maintenance Operations. No matter when operations are being performed, remember that the presence of moisture will avoid [dust](#) and aid in proper compaction. If a water truck or water source is not available, work should be planned after a rainfall if at all possible.

That brings us to the question of “how frequently do we blade or smooth the road?” We have already discussed the fact that the more we blade or smooth, the less often we will regrade or reshape, and the less often we will add new material. In other words, keeping the road in good condition by blading and smoothing prolongs the road’s life while cutting maintenance costs.

So maintenance operations are performed “as needed” depending on a number of variables such as road type and condition, drainage conditions, the weather, and traffic volumes. How many storms have occurred since the last maintenance was performed? How severe was the storm? What’s the traffic volume? Do we have a lot of truck traffic?

Bridges need to have good drainage. Usually drainage openings are provided in the deck, called [scuppers](#), which drain directly to the stream below. Keeping the deck clean is imperative not only for good drainage and longer bridge life, but also for prevention of [sediment](#) into the stream.

One of the more troublesome areas at bridges is the approach area where the road aggregate meets the deck. This approach area demands special attention and probably more maintenance. When



3-26 Bridge approach areas demand special attention and usually more maintenance.

Special events may dictate needs, requiring maintenance work in preparation before the event to put the roads in good shape, or after the event to repair damage.

If we accept the “as needed” scenario, we must inspect the roads frequently. Routine inspections, supplemented by special inspections after major storm events, are essential to determining road needs and performing the required maintenance at the right time.

Equipment operators play key roles in road inspection. The operator can also take note of other existing problems on the road or roadside, such as damaged drainage pipes or broken delineators, while he is working on the roads. Operators should keep a notepad and jot down problems with location details so they can be taken care of later, but in a timely fashion to prevent any major problems or costs.



3-27 Operators should note existing problems.

Look at the photos in 3-27. These are samples of what an operator could notice and jot down a note so that maintenance repairs can be planned and the problems taken care of.

On a last note, Photo 3-28 depicts the “sign” of a professional equipment operator. He carries a shovel and is not afraid to use it.

3.7 Summary

We have seen how the dirt and gravel roads and their surrounding environment are deeply entangled with one another. We have also seen how poorly maintained roads contribute to [erosion](#), pollution, and [dust](#). By using appropriate materials and techniques, local governments can reduce pollution and maintenance costs at the same time.



3-28 Using a shovel is the sign of a “professional operator.”

APPENDIX 3. Sample Aggregates Specifications

Following are sample specifications for gravel road aggregate surface courses from several different states. Road personnel should check with their State Department of Transportation or their Local Technical Assistance Program / Technology Transfer (T2) Center for specifications being used in their own state. Many state DOTs have their specifications readily available via their Web sites.

A3.1 Pennsylvania’s Driving Surface Aggregate

Material Specifications: All Driving Surface Aggregate (DSA) is to be derived from natural stone formations. Stone is defined as rock that has been crushed; rock is defined as consolidated mineral matter. For use in this program, both are restricted to that which has been mined or quarried from existing geologic bedrock formations.

All components of the aggregate mix are to be derived from crushed parent rock material that meets program specifications for abrasion resistance, pH and freedom from contaminants. Ninety-eight percent (98%) of fines passing the #200 sieve must be parent rock material. No clay or silt soil may be added. The amount of particles passing the #200 sieve shall be determined using the washing procedures specified in PTM No. 100.

Size: The required amounts and allowed ranges, determined by percent weight, for various size particles are shown in Table 1.

LA Abrasion: The acceptable limit as measured by weight loss is “less than 40% loss.” Los Angeles Abrasion test, AASHTO T-96 [ASTM C 131] shall be used to determine this property. Existing data obtained from tests made for and approved by PENNDOT will be accepted.

<i>Passing sieve</i>	<i>Lower %</i>	<i>High%</i>
1 ½ inches	100	
¾ inches	65	90
#4	30	65
#16	15	30
#200	10	20

Table 1. DSA Gradation

Sulfate Test: Soundness or resistance to freeze/thaw [*i.e., sulfate test*] is not specified for this application because a gravel road driving surface aggregate is not bound within a concrete or asphalt mix.

pH: Aggregate must be in the range of pH 6 to pH 12.45 as measured by EPA 9045C.

Optimum Moisture: Material is to be delivered and placed at optimum moisture content as determined for that particular source. The optimum percentage moisture is to be identified by the supplier in the bid/purchasing documents.

Transport: Tarps are to be used to cover 100% of the load’s exposed surface from the time of loading until immediately before dumping. This requirement includes standing time waiting to dump.

Aggregate producers are required by the program to certify that the aggregate they deliver conforms to the program specifications.

Road Surface Preparation: Driving Surface Aggregate will reflect the shape of the surface to which it is applied; therefore, all road surface preparation work is to be completed before delivery and placement of the aggregate.

1. Prepare underdrainage, including drain tile, French drains (porous fill) and crosspipes.
2. Address surface drainage features such as broad-based dips, [grade breaks](#), crown, and side-slope.
3. Establish proper cross-slope in existing base (Fig. 1). Recommended crown or slope is ½ to ¾ inch rise per horizontal foot. Proper shape may be a flat “A” crown profile, an in-slope or out-slope. If exposed bedrock or insufficient material prevents proper shaping of the road base, additional base material may be needed.
4. To bind aggregate with the road base, scarify impermeable smooth surfaces such as oil and chip, exposed bedrock or smooth tight aggregate. Do not loosen coarse aggregate or chinked stone roadbeds rough enough to permit binding with Driving Surface Aggregate.
5. If required, separation fabric should be placed according to manufacturer’s recommendations.

Placement: An un-compacted uniform depth of 8 inches of DSA is to be used to establish the driving surface. Placement is to be in a single 8-inch lift. The preferred method of application is through a paver. Set the paver adjustments on application thickness and width so it is unnecessary to use a grader. The required crown or side slope is to range from ½ to ¾ inch rise per horizontal foot. This slope is to be achieved by properly preparing base and placing aggregate in a uniform lift. When the paver is applying aggregate, care should be taken to keep the paver at or near capacity at all times.

To fill driving surface areas outside the specified width (e.g., driveway entrances, pull-offs, and passing lanes), additional DSA is to be added and tapered to grade or butted against a precut channel of the same depth. If berm or bank edges don’t exist to hold the new DSA surface, then sufficient material is to be placed, tapered and compacted to form protective edge berms. Material shall be compacted to a final thickness of approximately 6 inches.

<u>DSA CALCULATION FORMULA</u>			
DSA Needed (tons)	Road Width (ft)	Road Length (ft)	X X 0.042
=			
Applies to standard 8" lift, compacted to 6"			

Compaction Sequence: Verify that moisture is optimum for compaction. If the material has dried out, re-wet the DSA surface with a water truck. If clumps of aggregate adhere to the roller drum, the aggregate may be too moist. Allow drying time before rolling. Do not use the vibratory rolling mode if that action brings water to the surface of the aggregate.

Only self-powered machines designed specifically for compaction shall be used. Compaction with truck tires is not acceptable.

- 1A. Supported Edge: *If edge of placed aggregate is supported by an existing bank*

or berm: First pass: Roll slowly in static mode on the outside edge of placed aggregate.

1B. Unsupported Edge: *If the edge of the placed aggregate is not supported*:

First Pass: Roll slowly in static mode near but not over unsupported outside edges. Once that path is firm, move progressively closer to the outside edge with static passes until unsupported edge is firm.

2. Sequence: As in all rolling operations, compaction is achieved making overlapping lengthwise passes beginning at the ditch or berm-side and working toward the crown or the top edge (if it is a side-sloped or super-elevated section of road). In no case should the roller be run lengthwise on the top of the [road crown](#).

3A. Static Roller: The minimum acceptable weight of a static roller is 10 tons. Repeat the sequence of overlapping passes until desired compaction is achieved.

3B. Vibratory Roller: The minimum striking force of vibratory rollers is 20,000 lbs. When using a vibratory roller, the initial pass over un-compacted aggregate should be completed in static mode. All successive passes should be made using the vibratory mode until the desired level of compaction is achieved. The final pass over each area should be made in static mode to remove all roller edge marks. The vibratory roller should be set to deliver between 6 and 17 impacts per linear foot with the roller moving at the speed at which a person walks on each pass upgrade. **Vibration must be turned off during downgrade passes.** Vibrating the drum when rolling downgrade will cause aggregate to flow in “waves” in front of the roller, resulting in an uneven surface.

4. Desired Compaction: Unless more refined testing equipment is available, adequate compaction is indicated when no further depressions are created with a roller or loaded dump truck. Cracking of larger stones or rocks in the road surface is another reliable indication of adequate compaction.

A3.2 Illinois DOT Specifications. (excerpts)(www.dot.il.gov)

Section 402. Aggregate Surface Course

402.01 Description. This work shall consist of furnishing and placing one or more course of aggregate upon a prepared [subgrade](#).

402.02 Materials. Materials shall meet the requirements of Section 1000, Article 1004.04

1004.04 Coarse Aggregate for Aggregate Surface Course.

a. Description. The coarse aggregate shall be pit run gravel, gravel, crushed gravel, novaculite, crushed stone, crushed concrete, crushed slag or crushed sandstone.

a. Quality. The coarse aggregate shall be Class D Quality or better.

Quality Test	Class D
Sodium Sulfate Soundness ² 5 cycle, AASHTO T104 ^{1,2} , Max % loss	25 ³
Los Angeles Abrasion AASHTO T96, Max % loss	45

¹As modified by the Department

²Does not apply to crushed concrete.

³For aggregate surface course, the maximum percent loss shall be 30.

- b. Gradation.
1. For aggregate surface course Type B, Gradation CA6, CA9, or CA10 may be used. If approved by the Engineer, Gradation CA4 or CA12 may be used.
 2. For aggregate subbase Type B, Gradation CA6, CA10, CA12, , or CA19 shall be used. If approved by the Engineer, Gradation CA2 or CA4 may be used.
 3. For aggregate Subbase Type C, Gradation CA7 or combined size CA5 and CA7 shall be used.
 4. For granular aggregate courses (base, subbase, and shoulder except subbase Types B and C), Gradation CA6, or CA10 shall be used. If specified, Gradation CA2 or CA4 For aggregate surface course Type B, Gradation CA6, CA9, or CA10 may be used. If approved by the Engineer, Gradation CA4 or CA12 may be used.
 5. Stabilized aggregate courses (base, subbase, and shoulder), Gradation CA6 or CA10 shall be used. If approved by the Engineer, Gradation CA2, CA4, or CA12 may be used.
 6. For aggregate surface course Type A, Gradation CA6, or CA10 shall be used. If approved by the Engineer, Gradation CA2, CA4, CA9, or CA12 may be used.
- c. Plasticity. All material shall comply with the plasticity index requirements listed below.

Type of construction	Plasticity Index – Percent ¹	
	Gravel	Crushed Gravel, Stone, Slag
Aggregate Subbase Type A or B	0 to 9	-
Aggregate Base Course Type A or B	0 to 6	0 to 4
Aggregate Surface Course Type A or B ²	2 to 9	-
Stabilized Aggregate Material	0 to 9	0 to 9

¹Plasticity index shall be determined by the method given in AASHTO T90. Where shale in any form exists in the producing ledges, crushed stone samples shall be soaked a minimum of 18 hours before processing for plasticity index or minus #40 material. When clay material is added to adjust plasticity index, the clay material shall be a minus #4 sieve size.

²When Gradation CA9 is used, the plasticity index requirement will not apply.

402.03 Equipment shall meet the requirements of the following Articles of Section 1100:

- a. Tamping Roller.....1101.01
- d. Pneumatic-Tired Roller.....1101.01
- e. Three-Wheel Roller (Note 1)....1101.01
- f. Tandem Roller (Note 1).....1101.01
- g. Spreader.....1101.01
- h. Vibratory Machine (Note 2).....1101.04

Note 1. Three-wheel or tandem rollers shall weigh 6 to 10 tons and shall weigh not less than 200lb/in nor more than 325 lb/in of width of the roller.

Note 2. The vibratory machine shall meet the approval of the Engineer.

Construction Requirements

402.04 Subgrade. The [subgrade](#) shall be prepared according to Section 301 except that Article 301.06 will not apply.

402.05 Type A Requirements. Aggregate surface course, Type A shall be constructed according to Article 351.05(a) and (b) except the bearing ratio requirements shall not apply.

402.07 Type B Requirements. Any one or two gradations of the material specified in Article 1004.04 shall be used except where two gradations of material are used, the change shall not be made at more than one location on the section.

The surfacing material shall be deposited on the [subgrade](#) by means of a spreader.

The equipment used shall be such that the required amount of material will be deposited uniformly along the central portion of the roadbed.

The material which has been deposited shall be spread immediately to the plan cross section. Hauling shall be routed over the spread material so it will cover the entire width of surface. If the equipment used in hauling operations causes ruts extending through the spread material and into the [subgrade](#), and the [subgrade](#) material is being mixed with the surface material, the equipment shall be removed from the work or the rutting otherwise prevented as directed by the Engineer.

The Contractor shall keep the surface smooth by dragging or blading as many times each day as the engineer may direct.

Holes, waves, and undulations which develop and which are not filled by blading shall be filled by adding more material.

A3.3 Michigan DOT Specifications (excerpts) (www.mdot.state.mi.us)

Section 306. Aggregate Surface Course

306.01 Description. Construct an aggregate surface course on a prepared [subgrade](#) or an existing aggregate surface.

306.02 Materials. Use materials meeting the following:

Dense-graded Aggregate 21AA, 21A, 23A.....902

Use aggregate 21AA or 21A if the aggregate surface course will later receive a hot mix asphalt (HMA) surface. Use aggregate 23A if the aggregate surface course is to be constructed without an HMA surface. Use dense-graded aggregate 22A, 23A for temporary maintenance gravel.

902.06 Dense-Graded Aggregates for Base Course, Surface Course, Shoulders, Approaches and Patching. Michigan Class 21AA, 21A, 22A and 23A dense-graded aggregates will consist of natural aggregate, iron blast furnace slag, reverberatory furnace slag, or crushed concrete, in combination with fine aggregate as necessary to meet the gradation requirements in Table 902-1, the physical requirements in Table 902-2, and the following:

- A. Dense-graded aggregates produced by crushing Portland cement concrete will not contain building rubble as evidenced by the presence of more than 5.0%, by particle count, building brick, wood, plaster, or similar materials. Sporadic pieces of steel reinforcement may be present provided they pass the maximum grading sieve size without hand manipulation.

- B. Class 21AA, 21A, and 22A dense-graded aggregates produced from Portland cement concrete will not be used to construct either an aggregate base or aggregate separation layer when either of the following conditions apply:
1. When there is a [geotextile](#) liner or membrane present with permeability requirements.
 2. In a pavement structure with an underdrain, unless there is a filter material between crushed concrete and the underdrain. The filter material will be either a minimum of 12 inches of granular material or a [geotextile](#) liner or blocking membrane that will be a barrier to leachate.
- C. Class 23A dense-graded aggregate may be produced from steel furnace slag, but only for use as an unbound aggregate surface course or as an unbound aggregate shoulder.

Table 902-1 Grading Requirements for Dense-Graded Aggregates

Class	Sieve Analysis (MTM 109) Total Percent Passing (b)						Loss by Washing (MTM 108) % Passing #200
	1.5 in.	1 in.	¾ in	½ in	3/8 in	# 8	
21AA, 21A	100	85-100		50-75		20-45	4-8 (e)(f)
22A		100	90-100		65-85	30-50	4-8(e)(f)
23A		100			60-85	25-60	9-16(f)

(b) Based on dry weights

(e) When used for aggregate base courses, surface courses, shoulders and approaches and the material is produced entirely by crushing rock, boulders, cobbles, slag, or concrete, the maximum limit for Loss by Washing will not exceed 10%.

(f) The limits for Loss by Washing of dense-graded aggregates are significant to the nearest whole percent.

Table 902-2 Physical Requirements for Dense-Graded Aggregates

Class (j)	Crushed Material, % min. (MTM 110,117)	Loss, % max, Los Angeles Abrasion (MTM 102)
21AA	95	50
21A	25	50
22A	25	50
23A	25	50

(j) Quarried carbonate (limestone or dolomite) aggregate will not contain over 10% insoluble residue finer than Number 200 sieve when tested in accordance with MTM 103.

306.03 Construction.

- A. Preparation of Base. When required, blade, or scarify and blade, the existing aggregate surface to remove irregularities in the grade.
- B. Placing and Compacting. Provide a uniform aggregate mixture compacted in place with uniform density full depth. Provide a completed surface course conforming to the line, grade or plan cross section.
Place maintenance gravel to provide a flush transition between shoulders, driveways and other areas where traffic is maintained. Maintenance gravel may remain permanently as part of the work, if approved by the Engineer.
Do not place aggregate when the base is unstable. Maintain the aggregate in a smooth, stable condition and provide [dust](#) control until removed or surfaced.
- C. Use of additives. Use of additives to facilitate compaction and for [dust](#) control of the aggregate is acceptable.

A3.4 New York DOT Specifications (excerpts) (www.dot.state.ny.us)

Section 667 – Local Road Gravel Surface, Base, and Subbase Courses

667-1.02 Material Types. Provide materials as specified by the following options.

Type A. Surface quality material with a maximum particle size of 25mm.

Type B. Base quality material with a maximum particle size of 50 mm.

Type C. Subbase quality material with a maximum particle size of 75mm.

667-2.02 Material Requirements. Provide materials for road gravel surface, base and subbase courses that consist of Sand and Gravel, approved Blast Furnace Slag or Stone that meet the requirements contained herein. Provide materials well graded from coarse to fine, and free from organic or other deleterious materials. Any gravel material will be rejected if it is determined to contain any unsound or deleterious materials.

- B. Gradation, Perform sieve analysis in accordance with AASHTO procedures T27, T88 or T311. Provide materials meeting the gradation limits from Table 667-1.
- C. Soundness. Material will be accepted on the basis of Magnesium sulfate. Soundness Loss after four cycles performed according to NYSDOT procedures and Table 667-2.
- D. Plasticity. Determine plasticity using either of the following methods:
 1. Plasticity Index. The Plasticity Index of the material passing the #40 mesh sieve shall meet the values in Table 667-2. Determine plasticity using AASHTO tests T89 and T90.
 2. Sand Equivalent. The sand equivalence of the granular material shall meet the values in Table 667-2. Determine sand equivalence using AASHTO test T176.

Table 667-1: Percent passing by Weight of Gravel Materials

Sieve (US Sieve)	A (Surface)	B (Base)	C (subbase)
3"			100
2"		100	-
1.5"		85-100	70-100
1"	100	-	-
¾"	85-100	-	-
¼"	50-75	30-50	30-55
#40	15-35	5-20	5-25
#200	8-15	0-5	0-8

Table 667-2: Test and control Limits of Gravel Materials

Material Properties	A (Surface)	B (Base)	C (subbase)
Maximum Soundness loss (%)	20	20	25
Plasticity Index	2-9	0-5	0-8
Sand Equivalent	>25	>40	>35

- E. Elongated Particles Not more than 30%, by weight, of the particles retained on a ½" sieve shall consist of flat or elongated particles. A flat or elongated particle is defined herein as one which has its greatest dimension more than 3 times its least dimension. Acceptance for this requirement will normally be

APPENDIX 3. Sample Aggregates Specifications

Following are sample specifications for gravel road aggregate surface courses from several different states. Road personnel should check with their State Department of Transportation or their Local Technical Assistance Program / Technology Transfer (T2) Center for specifications being used in their own state. Many state DOTs have their specifications readily available via their Web sites.

A3.1 Pennsylvania's Driving Surface Aggregate

Material Specifications: All Driving Surface Aggregate (DSA) is to be derived from natural stone formations. Stone is defined as rock that has been crushed; rock is defined as consolidated mineral matter. For use in this program, both are restricted to that which has been mined or quarried from existing geologic bedrock formations.

All components of the aggregate mix are to be derived from crushed parent rock material that meets program specifications for abrasion resistance, pH and freedom from contaminants. Ninety-eight percent (98%) of fines passing the #200 sieve must be parent rock material. No clay or silt soil may be added. The amount of particles passing the #200 sieve shall be determined using the washing procedures specified in PTM No. 100.

Size: The required amounts and allowed ranges, determined by percent weight, for various size particles are shown in Table 1.

LA Abrasion: The acceptable limit as measured by weight loss is "less than 40% loss." Los Angeles Abrasion test, AASHTO T-96 [ASTM C 131] shall be used to determine this property. Existing data obtained from tests made for and approved by PENNDOT will be accepted.

<i>Passing sieve</i>	<i>Lower %</i>	<i>High%</i>
1 ½ inches	100	
¾ inches	65	90
#4	30	65
#16	15	30
#200	10	20

Table 1. DSA Gradation

Sulfate Test: Soundness or resistance to freeze/thaw [*i.e., sulfate test*] is not specified for this application because a gravel road driving surface aggregate is not bound within a concrete or asphalt mix.

pH: Aggregate must be in the range of pH 6 to pH 12.45 as measured by EPA 9045C.

Optimum Moisture: Material is to be delivered and placed at optimum moisture content as determined for that particular source. The optimum percentage moisture is to be identified by the supplier in the bid/purchasing documents.

Transport: Tarps are to be used to cover 100% of the load's exposed surface from the time of loading until immediately before dumping. This requirement includes standing time waiting to dump.

Aggregate producers are required by the program to certify that the aggregate they deliver conforms to the program specifications.

Road Surface Preparation: Driving Surface Aggregate will reflect the shape of the surface to which it is applied; therefore, all road surface preparation work is to be completed before delivery and placement of the aggregate.

1. Prepare underdrainage, including drain tile, French drains (porous fill) and crosspipes.
2. Address surface drainage features such as broad-based dips, [grade breaks](#), crown, and side-slope.
3. Establish proper cross-slope in existing base (Fig. 1). Recommended crown or slope is ½ to ¾ inch rise per horizontal foot. Proper shape may be a flat “A” crown profile, an in-slope or out-slope. If exposed bedrock or insufficient material prevents proper shaping of the road base, additional base material may be needed.
4. To bind aggregate with the road base, scarify impermeable smooth surfaces such as oil and chip, exposed bedrock or smooth tight aggregate. Do not loosen coarse aggregate or chinked stone roadbeds rough enough to permit binding with Driving Surface Aggregate.
5. If required, separation fabric should be placed according to manufacturer’s recommendations.

Placement: An un-compacted uniform depth of 8 inches of DSA is to be used to establish the driving surface. Placement is to be in a single 8-inch lift. The preferred method of application is through a paver. Set the paver adjustments on application thickness and width so it is unnecessary to use a grader. The required crown or side slope is to range from ½ to ¾ inch rise per horizontal foot. This slope is to be achieved by properly preparing base and placing aggregate in a uniform lift. When the paver is applying aggregate, care should be taken to keep the paver at or near capacity at all times.

To fill driving surface areas outside the specified width (e.g., driveway entrances, pull-offs, and passing lanes), additional DSA is to be added and tapered to grade or butted against a precut channel of the same depth. If berm or bank edges don’t exist to hold the new DSA surface, then sufficient material is to be placed, tapered and compacted to form protective edge berms. Material shall be compacted to a final thickness of approximately 6 inches.

<u>DSA CALCULATION FORMULA</u>			
DSA Needed (tons)	Road Width (ft)	Road Length (ft)	X X 0.042
=			
Applies to standard 8" lift, compacted to 6"			

Compaction Sequence: Verify that moisture is optimum for compaction. If the material has dried out, re-wet the DSA surface with a water truck. If clumps of aggregate adhere to the roller drum, the aggregate may be too moist. Allow drying time before rolling. Do not use the vibratory rolling mode if that action brings water to the surface of the aggregate.

Only self-powered machines designed specifically for compaction shall be used. Compaction with truck tires is not acceptable.

- 1A. Supported Edge: *If edge of placed aggregate is supported by an existing bank*

or berm: First pass: Roll slowly in static mode on the outside edge of placed aggregate.

1B. Unsupported Edge: *If the edge of the placed aggregate is not supported*:

First Pass: Roll slowly in static mode near but not over unsupported outside edges. Once that path is firm, move progressively closer to the outside edge with static passes until unsupported edge is firm.

2. Sequence: As in all rolling operations, compaction is achieved making overlapping lengthwise passes beginning at the ditch or berm-side and working toward the crown or the top edge (if it is a side-sloped or super-elevated section of road). In no case should the roller be run lengthwise on the top of the [road crown](#).

3A. Static Roller: The minimum acceptable weight of a static roller is 10 tons. Repeat the sequence of overlapping passes until desired compaction is achieved.

3B. Vibratory Roller: The minimum striking force of vibratory rollers is 20,000 lbs. When using a vibratory roller, the initial pass over un-compacted aggregate should be completed in static mode. All successive passes should be made using the vibratory mode until the desired level of compaction is achieved. The final pass over each area should be made in static mode to remove all roller edge marks. The vibratory roller should be set to deliver between 6 and 17 impacts per linear foot with the roller moving at the speed at which a person walks on each pass upgrade. **Vibration must be turned off during downgrade passes.** Vibrating the drum when rolling downgrade will cause aggregate to flow in “waves” in front of the roller, resulting in an uneven surface.

4. Desired Compaction: Unless more refined testing equipment is available, adequate compaction is indicated when no further depressions are created with a roller or loaded dump truck. Cracking of larger stones or rocks in the road surface is another reliable indication of adequate compaction.

A3.2 Illinois DOT Specifications. (excerpts)(www.dot.il.gov)

Section 402. Aggregate Surface Course

402.01 Description. This work shall consist of furnishing and placing one or more course of aggregate upon a prepared [subgrade](#).

402.02 Materials. Materials shall meet the requirements of Section 1000, Article 1004.04

1004.04 Coarse Aggregate for Aggregate Surface Course.

a. Description. The coarse aggregate shall be pit run gravel, gravel, crushed gravel, novaculite, crushed stone, crushed concrete, crushed slag or crushed sandstone.

a. Quality. The coarse aggregate shall be Class D Quality or better.

Quality Test	Class D
Sodium Sulfate Soundness ² 5 cycle, AASHTO T104 ^{1,2} , Max % loss	25 ³
Los Angeles Abrasion AASHTO T96, Max % loss	45

¹As modified by the Department

²Does not apply to crushed concrete.

³For aggregate surface course, the maximum percent loss shall be 30.

- b. Gradation.
1. For aggregate surface course Type B, Gradation CA6, CA9, or CA10 may be used. If approved by the Engineer, Gradation CA4 or CA12 may be used.
 2. For aggregate subbase Type B, Gradation CA6, CA10, CA12, , or CA19 shall be used. If approved by the Engineer, Gradation CA2 or CA4 may be used.
 3. For aggregate Subbase Type C, Gradation CA7 or combined size CA5 and CA7 shall be used.
 4. For granular aggregate courses (base, subbase, and shoulder except subbase Types B and C), Gradation CA6, or CA10 shall be used. If specified, Gradation CA2 or CA4 For aggregate surface course Type B, Gradation CA6, CA9, or CA10 may be used. If approved by the Engineer, Gradation CA4 or CA12 may be used.
 5. Stabilized aggregate courses (base, subbase, and shoulder), Gradation CA6 or CA10 shall be used. If approved by the Engineer, Gradation CA2, CA4, or CA12 may be used.
 6. For aggregate surface course Type A, Gradation CA6, or CA10 shall be used. If approved by the Engineer, Gradation CA2, CA4, CA9, or CA12 may be used.
- c. Plasticity. All material shall comply with the plasticity index requirements listed below.

Type of construction	Plasticity Index – Percent ¹	
	Gravel	Crushed Gravel, Stone, Slag
Aggregate Subbase Type A or B	0 to 9	-
Aggregate Base Course Type A or B	0 to 6	0 to 4
Aggregate Surface Course Type A or B ²	2 to 9	-
Stabilized Aggregate Material	0 to 9	0 to 9

¹Plasticity index shall be determined by the method given in AASHTO T90. Where shale in any form exists in the producing ledges, crushed stone samples shall be soaked a minimum of 18 hours before processing for plasticity index or minus #40 material. When clay material is added to adjust plasticity index, the clay material shall be a minus #4 sieve size.

²When Gradation CA9 is used, the plasticity index requirement will not apply.

402.03 Equipment shall meet the requirements of the following Articles of Section 1100:

- a. Tamping Roller.....1101.01
- d. Pneumatic-Tired Roller.....1101.01
- e. Three-Wheel Roller (Note 1)....1101.01
- f. Tandem Roller (Note 1).....1101.01
- g. Spreader.....1101.01
- h. Vibratory Machine (Note 2).....1101.04

Note 1. Three-wheel or tandem rollers shall weigh 6 to 10 tons and shall weigh not less than 200lb/in nor more than 325 lb/in of width of the roller.

Note 2. The vibratory machine shall meet the approval of the Engineer.

Construction Requirements

402.04 Subgrade. The [subgrade](#) shall be prepared according to Section 301 except that Article 301.06 will not apply.

402.05 Type A Requirements. Aggregate surface course, Type A shall be constructed according to Article 351.05(a) and (b) except the bearing ratio requirements shall not apply.

402.07 Type B Requirements. Any one or two gradations of the material specified in Article 1004.04 shall be used except where two gradations of material are used, the change shall not be made at more than one location on the section.

The surfacing material shall be deposited on the [subgrade](#) by means of a spreader.

The equipment used shall be such that the required amount of material will be deposited uniformly along the central portion of the roadbed.

The material which has been deposited shall be spread immediately to the plan cross section. Hauling shall be routed over the spread material so it will cover the entire width of surface. If the equipment used in hauling operations causes ruts extending through the spread material and into the [subgrade](#), and the [subgrade](#) material is being mixed with the surface material, the equipment shall be removed from the work or the rutting otherwise prevented as directed by the Engineer.

The Contractor shall keep the surface smooth by dragging or blading as many times each day as the engineer may direct.

Holes, waves, and undulations which develop and which are not filled by blading shall be filled by adding more material.

A3.3 Michigan DOT Specifications (excerpts) (www.mdot.state.mi.us)

Section 306. Aggregate Surface Course

306.01 Description. Construct an aggregate surface course on a prepared [subgrade](#) or an existing aggregate surface.

306.02 Materials. Use materials meeting the following:

Dense-graded Aggregate 21AA, 21A, 23A.....902

Use aggregate 21AA or 21A if the aggregate surface course will later receive a hot mix asphalt (HMA) surface. Use aggregate 23A if the aggregate surface course is to be constructed without an HMA surface. Use dense-graded aggregate 22A, 23A for temporary maintenance gravel.

902.06 Dense-Graded Aggregates for Base Course, Surface Course, Shoulders, Approaches and Patching. Michigan Class 21AA, 21A, 22A and 23A dense-graded aggregates will consist of natural aggregate, iron blast furnace slag, reverberatory furnace slag, or crushed concrete, in combination with fine aggregate as necessary to meet the gradation requirements in Table 902-1, the physical requirements in Table 902-2, and the following:

- A. Dense-graded aggregates produced by crushing Portland cement concrete will not contain building rubble as evidenced by the presence of more than 5.0%, by particle count, building brick, wood, plaster, or similar materials. Sporadic pieces of steel reinforcement may be present provided they pass the maximum grading sieve size without hand manipulation.

- B. Class 21AA, 21A, and 22A dense-graded aggregates produced from Portland cement concrete will not be used to construct either an aggregate base or aggregate separation layer when either of the following conditions apply:
1. When there is a [geotextile](#) liner or membrane present with permeability requirements.
 2. In a pavement structure with an underdrain, unless there is a filter material between crushed concrete and the underdrain. The filter material will be either a minimum of 12 inches of granular material or a [geotextile](#) liner or blocking membrane that will be a barrier to leachate.
- C. Class 23A dense-graded aggregate may be produced from steel furnace slag, but only for use as an unbound aggregate surface course or as an unbound aggregate shoulder.

Table 902-1 Grading Requirements for Dense-Graded Aggregates

Class	Sieve Analysis (MTM 109) Total Percent Passing (b)						Loss by Washing (MTM 108) % Passing #200
	1.5 in.	1 in.	¾ in	½ in	3/8 in	# 8	
21AA, 21A	100	85-100		50-75		20-45	4-8 (e)(f)
22A		100	90-100		65-85	30-50	4-8(e)(f)
23A		100			60-85	25-60	9-16(f)

(b) Based on dry weights

(e) When used for aggregate base courses, surface courses, shoulders and approaches and the material is produced entirely by crushing rock, boulders, cobbles, slag, or concrete, the maximum limit for Loss by Washing will not exceed 10%.

(f) The limits for Loss by Washing of dense-graded aggregates are significant to the nearest whole percent.

Table 902-2 Physical Requirements for Dense-Graded Aggregates

Class (j)	Crushed Material, % min. (MTM 110,117)	Loss, % max, Los Angeles Abrasion (MTM 102)
21AA	95	50
21A	25	50
22A	25	50
23A	25	50

(j) Quarried carbonate (limestone or dolomite) aggregate will not contain over 10% insoluble residue finer than Number 200 sieve when tested in accordance with MTM 103.

306.03 Construction.

- A. Preparation of Base. When required, blade, or scarify and blade, the existing aggregate surface to remove irregularities in the grade.
- B. Placing and Compacting. Provide a uniform aggregate mixture compacted in place with uniform density full depth. Provide a completed surface course conforming to the line, grade or plan cross section.
Place maintenance gravel to provide a flush transition between shoulders, driveways and other areas where traffic is maintained. Maintenance gravel may remain permanently as part of the work, if approved by the Engineer.
Do not place aggregate when the base is unstable. Maintain the aggregate in a smooth, stable condition and provide [dust](#) control until removed or surfaced.
- C. Use of additives. Use of additives to facilitate compaction and for [dust](#) control of the aggregate is acceptable.

A3.4 New York DOT Specifications (excerpts) (www.dot.state.ny.us)

Section 667 – Local Road Gravel Surface, Base, and Subbase Courses

667-1.02 Material Types. Provide materials as specified by the following options.

Type A. Surface quality material with a maximum particle size of 25mm.

Type B. Base quality material with a maximum particle size of 50 mm.

Type C. Subbase quality material with a maximum particle size of 75mm.

667-2.02 Material Requirements. Provide materials for road gravel surface, base and subbase courses that consist of Sand and Gravel, approved Blast Furnace Slag or Stone that meet the requirements contained herein. Provide materials well graded from coarse to fine, and free from organic or other deleterious materials. Any gravel material will be rejected if it is determined to contain any unsound or deleterious materials.

- B. Gradation, Perform sieve analysis in accordance with AASHTO procedures T27, T88 or T311. Provide materials meeting the gradation limits from Table 667-1.
- C. Soundness. Material will be accepted on the basis of Magnesium sulfate. Soundness Loss after four cycles performed according to NYSDOT procedures and Table 667-2.
- D. Plasticity. Determine plasticity using either of the following methods:
 1. Plasticity Index. The Plasticity Index of the material passing the #40 mesh sieve shall meet the values in Table 667-2. Determine plasticity using AASHTO tests T89 and T90.
 2. Sand Equivalent. The sand equivalence of the granular material shall meet the values in Table 667-2. Determine sand equivalence using AASHTO test T176.

Table 667-1: Percent passing by Weight of Gravel Materials

Sieve (US Sieve)	A (Surface)	B (Base)	C (subbase)
3"			100
2"		100	-
1.5"		85-100	70-100
1"	100	-	-
¾"	85-100	-	-
¼"	50-75	30-50	30-55
#40	15-35	5-20	5-25
#200	8-15	0-5	0-8

Table 667-2: Test and control Limits of Gravel Materials

Material Properties	A (Surface)	B (Base)	C (subbase)
Maximum Soundness loss (%)	20	20	25
Plasticity Index	2-9	0-5	0-8
Sand Equivalent	>25	>40	>35

- E. Elongated Particles Not more than 30%, by weight, of the particles retained on a ½" sieve shall consist of flat or elongated particles. A flat or elongated particle is defined herein as one which has its greatest dimension more than 3 times its least dimension. Acceptance for this requirement will normally be

APPENDIX 3. Sample Aggregates Specifications

Following are sample specifications for gravel road aggregate surface courses from several different states. Road personnel should check with their State Department of Transportation or their Local Technical Assistance Program / Technology Transfer (T2) Center for specifications being used in their own state. Many state DOTs have their specifications readily available via their Web sites.

A3.1 Pennsylvania's Driving Surface Aggregate

Material Specifications: All Driving Surface Aggregate (DSA) is to be derived from natural stone formations. Stone is defined as rock that has been crushed; rock is defined as consolidated mineral matter. For use in this program, both are restricted to that which has been mined or quarried from existing geologic bedrock formations.

All components of the aggregate mix are to be derived from crushed parent rock material that meets program specifications for abrasion resistance, pH and freedom from contaminants. Ninety-eight percent (98%) of fines passing the #200 sieve must be parent rock material. No clay or silt soil may be added. The amount of particles passing the #200 sieve shall be determined using the washing procedures specified in PTM No. 100.

Size: The required amounts and allowed ranges, determined by percent weight, for various size particles are shown in Table 1.

LA Abrasion: The acceptable limit as measured by weight loss is "less than 40% loss." Los Angeles Abrasion test, AASHTO T-96 [ASTM C 131] shall be used to determine this property. Existing data obtained from tests made for and approved by PENNDOT will be accepted.

<i>Passing sieve</i>	<i>Lower %</i>	<i>High%</i>
1 ½ inches	100	
¾ inches	65	90
#4	30	65
#16	15	30
#200	10	20

Table 1. DSA Gradation

Sulfate Test: Soundness or resistance to freeze/thaw [*i.e., sulfate test*] is not specified for this application because a gravel road driving surface aggregate is not bound within a concrete or asphalt mix.

pH: Aggregate must be in the range of pH 6 to pH 12.45 as measured by EPA 9045C.

Optimum Moisture: Material is to be delivered and placed at optimum moisture content as determined for that particular source. The optimum percentage moisture is to be identified by the supplier in the bid/purchasing documents.

Transport: Tarps are to be used to cover 100% of the load's exposed surface from the time of loading until immediately before dumping. This requirement includes standing time waiting to dump.

Aggregate producers are required by the program to certify that the aggregate they deliver conforms to the program specifications.

Road Surface Preparation: Driving Surface Aggregate will reflect the shape of the surface to which it is applied; therefore, all road surface preparation work is to be completed before delivery and placement of the aggregate.

1. Prepare underdrainage, including drain tile, French drains (porous fill) and crosspipes.
2. Address surface drainage features such as broad-based dips, [grade breaks](#), crown, and side-slope.
3. Establish proper cross-slope in existing base (Fig. 1). Recommended crown or slope is ½ to ¾ inch rise per horizontal foot. Proper shape may be a flat “A” crown profile, an in-slope or out-slope. If exposed bedrock or insufficient material prevents proper shaping of the road base, additional base material may be needed.
4. To bind aggregate with the road base, scarify impermeable smooth surfaces such as oil and chip, exposed bedrock or smooth tight aggregate. Do not loosen coarse aggregate or chinked stone roadbeds rough enough to permit binding with Driving Surface Aggregate.
5. If required, separation fabric should be placed according to manufacturer’s recommendations.

Placement: An un-compacted uniform depth of 8 inches of DSA is to be used to establish the driving surface. Placement is to be in a single 8-inch lift. The preferred method of application is through a paver. Set the paver adjustments on application thickness and width so it is unnecessary to use a grader. The required crown or side slope is to range from ½ to ¾ inch rise per horizontal foot. This slope is to be achieved by properly preparing base and placing aggregate in a uniform lift. When the paver is applying aggregate, care should be taken to keep the paver at or near capacity at all times.

To fill driving surface areas outside the specified width (e.g., driveway entrances, pull-offs, and passing lanes), additional DSA is to be added and tapered to grade or butted against a precut channel of the same depth. If berm or bank edges don’t exist to hold the new DSA surface, then sufficient material is to be placed, tapered and compacted to form protective edge berms. Material shall be compacted to a final thickness of approximately 6 inches.

<u>DSA CALCULATION FORMULA</u>			
DSA Needed (tons)	Road Width (ft)	X	Road Length (ft)
X 0.042			
Applies to standard 8" lift, compacted to 6"			

Compaction Sequence: Verify that moisture is optimum for compaction. If the material has dried out, re-wet the DSA surface with a water truck. If clumps of aggregate adhere to the roller drum, the aggregate may be too moist. Allow drying time before rolling. Do not use the vibratory rolling mode if that action brings water to the surface of the aggregate.

Only self-powered machines designed specifically for compaction shall be used. Compaction with truck tires is not acceptable.

- 1A. Supported Edge: *If edge of placed aggregate is supported by an existing bank*

or berm: First pass: Roll slowly in static mode on the outside edge of placed aggregate.

1B. Unsupported Edge: *If the edge of the placed aggregate is not supported*:

First Pass: Roll slowly in static mode near but not over unsupported outside edges. Once that path is firm, move progressively closer to the outside edge with static passes until unsupported edge is firm.

2. Sequence: As in all rolling operations, compaction is achieved making overlapping lengthwise passes beginning at the ditch or berm-side and working toward the crown or the top edge (if it is a side-sloped or super-elevated section of road). In no case should the roller be run lengthwise on the top of the [road crown](#).

3A. Static Roller: The minimum acceptable weight of a static roller is 10 tons. Repeat the sequence of overlapping passes until desired compaction is achieved.

3B. Vibratory Roller: The minimum striking force of vibratory rollers is 20,000 lbs. When using a vibratory roller, the initial pass over un-compacted aggregate should be completed in static mode. All successive passes should be made using the vibratory mode until the desired level of compaction is achieved. The final pass over each area should be made in static mode to remove all roller edge marks. The vibratory roller should be set to deliver between 6 and 17 impacts per linear foot with the roller moving at the speed at which a person walks on each pass upgrade. **Vibration must be turned off during downgrade passes.** Vibrating the drum when rolling downgrade will cause aggregate to flow in “waves” in front of the roller, resulting in an uneven surface.

4. Desired Compaction: Unless more refined testing equipment is available, adequate compaction is indicated when no further depressions are created with a roller or loaded dump truck. Cracking of larger stones or rocks in the road surface is another reliable indication of adequate compaction.

A3.2 Illinois DOT Specifications. (excerpts)(www.dot.il.gov)

Section 402. Aggregate Surface Course

402.01 Description. This work shall consist of furnishing and placing one or more course of aggregate upon a prepared [subgrade](#).

402.02 Materials. Materials shall meet the requirements of Section 1000, Article 1004.04

1004.04 Coarse Aggregate for Aggregate Surface Course.

a. Description. The coarse aggregate shall be pit run gravel, gravel, crushed gravel, novaculite, crushed stone, crushed concrete, crushed slag or crushed sandstone.

a. Quality. The coarse aggregate shall be Class D Quality or better.

Quality Test	Class D
Sodium Sulfate Soundness ² 5 cycle, AASHTO T104 ^{1,2} , Max % loss	25 ³
Los Angeles Abrasion AASHTO T96, Max % loss	45

¹As modified by the Department

²Does not apply to crushed concrete.

³For aggregate surface course, the maximum percent loss shall be 30.

- b. Gradation.
1. For aggregate surface course Type B, Gradation CA6, CA9, or CA10 may be used. If approved by the Engineer, Gradation CA4 or CA12 may be used.
 2. For aggregate subbase Type B, Gradation CA6, CA10, CA12, , or CA19 shall be used. If approved by the Engineer, Gradation CA2 or CA4 may be used.
 3. For aggregate Subbase Type C, Gradation CA7 or combined size CA5 and CA7 shall be used.
 4. For granular aggregate courses (base, subbase, and shoulder except subbase Types B and C), Gradation CA6, or CA10 shall be used. If specified, Gradation CA2 or CA4 For aggregate surface course Type B, Gradation CA6, CA9, or CA10 may be used. If approved by the Engineer, Gradation CA4 or CA12 may be used.
 5. Stabilized aggregate courses (base, subbase, and shoulder), Gradation CA6 or CA10 shall be used. If approved by the Engineer, Gradation CA2, CA4, or CA12 may be used.
 6. For aggregate surface course Type A, Gradation CA6, or CA10 shall be used. If approved by the Engineer, Gradation CA2, CA4, CA9, or CA12 may be used.
- c. Plasticity. All material shall comply with the plasticity index requirements listed below.

Type of construction	Plasticity Index – Percent ¹	
	Gravel	Crushed Gravel, Stone, Slag
Aggregate Subbase Type A or B	0 to 9	-
Aggregate Base Course Type A or B	0 to 6	0 to 4
Aggregate Surface Course Type A or B ²	2 to 9	-
Stabilized Aggregate Material	0 to 9	0 to 9

¹Plasticity index shall be determined by the method given in AASHTO T90. Where shale in any form exists in the producing ledges, crushed stone samples shall be soaked a minimum of 18 hours before processing for plasticity index or minus #40 material. When clay material is added to adjust plasticity index, the clay material shall be a minus #4 sieve size.

²When Gradation CA9 is used, the plasticity index requirement will not apply.

402.03 Equipment shall meet the requirements of the following Articles of Section 1100:

- a. Tamping Roller.....1101.01
- d. Pneumatic-Tired Roller.....1101.01
- e. Three-Wheel Roller (Note 1)....1101.01
- f. Tandem Roller (Note 1).....1101.01
- g. Spreader.....1101.01
- h. Vibratory Machine (Note 2).....1101.04

Note 1. Three-wheel or tandem rollers shall weigh 6 to 10 tons and shall weigh not less than 200lb/in nor more than 325 lb/in of width of the roller.

Note 2. The vibratory machine shall meet the approval of the Engineer.

Construction Requirements

402.04 Subgrade. The [subgrade](#) shall be prepared according to Section 301 except that Article 301.06 will not apply.

402.05 Type A Requirements. Aggregate surface course, Type A shall be constructed according to Article 351.05(a) and (b) except the bearing ratio requirements shall not apply.

402.07 Type B Requirements. Any one or two gradations of the material specified in Article 1004.04 shall be used except where two gradations of material are used, the change shall not be made at more than one location on the section.

The surfacing material shall be deposited on the [subgrade](#) by means of a spreader.

The equipment used shall be such that the required amount of material will be deposited uniformly along the central portion of the roadbed.

The material which has been deposited shall be spread immediately to the plan cross section. Hauling shall be routed over the spread material so it will cover the entire width of surface. If the equipment used in hauling operations causes ruts extending through the spread material and into the [subgrade](#), and the [subgrade](#) material is being mixed with the surface material, the equipment shall be removed from the work or the rutting otherwise prevented as directed by the Engineer.

The Contractor shall keep the surface smooth by dragging or blading as many times each day as the engineer may direct.

Holes, waves, and undulations which develop and which are not filled by blading shall be filled by adding more material.

A3.3 Michigan DOT Specifications (excerpts) (www.mdot.state.mi.us)

Section 306. Aggregate Surface Course

306.01 Description. Construct an aggregate surface course on a prepared [subgrade](#) or an existing aggregate surface.

306.02 Materials. Use materials meeting the following:

Dense-graded Aggregate 21AA, 21A, 23A.....902

Use aggregate 21AA or 21A if the aggregate surface course will later receive a hot mix asphalt (HMA) surface. Use aggregate 23A if the aggregate surface course is to be constructed without an HMA surface. Use dense-graded aggregate 22A, 23A for temporary maintenance gravel.

902.06 Dense-Graded Aggregates for Base Course, Surface Course, Shoulders, Approaches and Patching. Michigan Class 21AA, 21A, 22A and 23A dense-graded aggregates will consist of natural aggregate, iron blast furnace slag, reverberatory furnace slag, or crushed concrete, in combination with fine aggregate as necessary to meet the gradation requirements in Table 902-1, the physical requirements in Table 902-2, and the following:

- A. Dense-graded aggregates produced by crushing Portland cement concrete will not contain building rubble as evidenced by the presence of more than 5.0%, by particle count, building brick, wood, plaster, or similar materials. Sporadic pieces of steel reinforcement may be present provided they pass the maximum grading sieve size without hand manipulation.

- B. Class 21AA, 21A, and 22A dense-graded aggregates produced from Portland cement concrete will not be used to construct either an aggregate base or aggregate separation layer when either of the following conditions apply:
1. When there is a [geotextile](#) liner or membrane present with permeability requirements.
 2. In a pavement structure with an underdrain, unless there is a filter material between crushed concrete and the underdrain. The filter material will be either a minimum of 12 inches of granular material or a [geotextile](#) liner or blocking membrane that will be a barrier to leachate.
- C. Class 23A dense-graded aggregate may be produced from steel furnace slag, but only for use as an unbound aggregate surface course or as an unbound aggregate shoulder.

Table 902-1 Grading Requirements for Dense-Graded Aggregates

Class	Sieve Analysis (MTM 109) Total Percent Passing (b)						Loss by Washing (MTM 108) % Passing #200
	1.5 in.	1 in.	¾ in	½ in	3/8 in	# 8	
21AA, 21A	100	85-100		50-75		20-45	4-8 (e)(f)
22A		100	90-100		65-85	30-50	4-8(e)(f)
23A		100			60-85	25-60	9-16(f)

(b) Based on dry weights

(e) When used for aggregate base courses, surface courses, shoulders and approaches and the material is produced entirely by crushing rock, boulders, cobbles, slag, or concrete, the maximum limit for Loss by Washing will not exceed 10%.

(f) The limits for Loss by Washing of dense-graded aggregates are significant to the nearest whole percent.

Table 902-2 Physical Requirements for Dense-Graded Aggregates

Class (j)	Crushed Material, % min. (MTM 110,117)	Loss, % max, Los Angeles Abrasion (MTM 102)
21AA	95	50
21A	25	50
22A	25	50
23A	25	50

(j) Quarried carbonate (limestone or dolomite) aggregate will not contain over 10% insoluble residue finer than Number 200 sieve when tested in accordance with MTM 103.

306.03 Construction.

- A. Preparation of Base. When required, blade, or scarify and blade, the existing aggregate surface to remove irregularities in the grade.
- B. Placing and Compacting. Provide a uniform aggregate mixture compacted in place with uniform density full depth. Provide a completed surface course conforming to the line, grade or plan cross section.
Place maintenance gravel to provide a flush transition between shoulders, driveways and other areas where traffic is maintained. Maintenance gravel may remain permanently as part of the work, if approved by the Engineer.
Do not place aggregate when the base is unstable. Maintain the aggregate in a smooth, stable condition and provide [dust](#) control until removed or surfaced.
- C. Use of additives. Use of additives to facilitate compaction and for [dust](#) control of the aggregate is acceptable.

A3.4 New York DOT Specifications (excerpts) (www.dot.state.ny.us)

Section 667 – Local Road Gravel Surface, Base, and Subbase Courses

667-1.02 Material Types. Provide materials as specified by the following options.

Type A. Surface quality material with a maximum particle size of 25mm.

Type B. Base quality material with a maximum particle size of 50 mm.

Type C. Subbase quality material with a maximum particle size of 75mm.

667-2.02 Material Requirements. Provide materials for road gravel surface, base and subbase courses that consist of Sand and Gravel, approved Blast Furnace Slag or Stone that meet the requirements contained herein. Provide materials well graded from coarse to fine, and free from organic or other deleterious materials. Any gravel material will be rejected if it is determined to contain any unsound or deleterious materials.

- B. Gradation, Perform sieve analysis in accordance with AASHTO procedures T27, T88 or T311. Provide materials meeting the gradation limits from Table 667-1.
- C. Soundness. Material will be accepted on the basis of Magnesium sulfate. Soundness Loss after four cycles performed according to NYSDOT procedures and Table 667-2.
- D. Plasticity. Determine plasticity using either of the following methods:
 1. Plasticity Index. The Plasticity Index of the material passing the #40 mesh sieve shall meet the values in Table 667-2. Determine plasticity using AASHTO tests T89 and T90.
 2. Sand Equivalent. The sand equivalence of the granular material shall meet the values in Table 667-2. Determine sand equivalence using AASHTO test T176.

Table 667-1: Percent passing by Weight of Gravel Materials

Sieve (US Sieve)	A (Surface)	B (Base)	C (subbase)
3"			100
2"		100	-
1.5"		85-100	70-100
1"	100	-	-
¾"	85-100	-	-
¼"	50-75	30-50	30-55
#40	15-35	5-20	5-25
#200	8-15	0-5	0-8

Table 667-2: Test and control Limits of Gravel Materials

Material Properties	A (Surface)	B (Base)	C (subbase)
Maximum Soundness loss (%)	20	20	25
Plasticity Index	2-9	0-5	0-8
Sand Equivalent	>25	>40	>35

- E. Elongated Particles Not more than 30%, by weight, of the particles retained on a ½" sieve shall consist of flat or elongated particles. A flat or elongated particle is defined herein as one which has its greatest dimension more than 3 times its least dimension. Acceptance for this requirement will normally be

APPENDIX 3. Sample Aggregates Specifications

Following are sample specifications for gravel road aggregate surface courses from several different states. Road personnel should check with their State Department of Transportation or their Local Technical Assistance Program / Technology Transfer (T2) Center for specifications being used in their own state. Many state DOTs have their specifications readily available via their Web sites.

A3.1 Pennsylvania's Driving Surface Aggregate

Material Specifications: All Driving Surface Aggregate (DSA) is to be derived from natural stone formations. Stone is defined as rock that has been crushed; rock is defined as consolidated mineral matter. For use in this program, both are restricted to that which has been mined or quarried from existing geologic bedrock formations.

All components of the aggregate mix are to be derived from crushed parent rock material that meets program specifications for abrasion resistance, pH and freedom from contaminants. Ninety-eight percent (98%) of fines passing the #200 sieve must be parent rock material. No clay or silt soil may be added. The amount of particles passing the #200 sieve shall be determined using the washing procedures specified in PTM No. 100.

Size: The required amounts and allowed ranges, determined by percent weight, for various size particles are shown in Table 1.

LA Abrasion: The acceptable limit as measured by weight loss is "less than 40% loss." Los Angeles Abrasion test, AASHTO T-96 [ASTM C 131] shall be used to determine this property. Existing data obtained from tests made for and approved by PENNDOT will be accepted.

<i>Passing sieve</i>	<i>Lower %</i>	<i>High%</i>
1 ½ inches	100	
¾ inches	65	90
#4	30	65
#16	15	30
#200	10	20

Table 1. DSA Gradation

Sulfate Test: Soundness or resistance to freeze/thaw [*i.e., sulfate test*] is not specified for this application because a gravel road driving surface aggregate is not bound within a concrete or asphalt mix.

pH: Aggregate must be in the range of pH 6 to pH 12.45 as measured by EPA 9045C.

Optimum Moisture: Material is to be delivered and placed at optimum moisture content as determined for that particular source. The optimum percentage moisture is to be identified by the supplier in the bid/purchasing documents.

Transport: Tarps are to be used to cover 100% of the load's exposed surface from the time of loading until immediately before dumping. This requirement includes standing time waiting to dump.

Aggregate producers are required by the program to certify that the aggregate they deliver conforms to the program specifications.

Road Surface Preparation: Driving Surface Aggregate will reflect the shape of the surface to which it is applied; therefore, all road surface preparation work is to be completed before delivery and placement of the aggregate.

1. Prepare underdrainage, including drain tile, French drains (porous fill) and crosspipes.
2. Address surface drainage features such as broad-based dips, [grade breaks](#), crown, and side-slope.
3. Establish proper cross-slope in existing base (Fig. 1). Recommended crown or slope is ½ to ¾ inch rise per horizontal foot. Proper shape may be a flat “A” crown profile, an in-slope or out-slope. If exposed bedrock or insufficient material prevents proper shaping of the road base, additional base material may be needed.
4. To bind aggregate with the road base, scarify impermeable smooth surfaces such as oil and chip, exposed bedrock or smooth tight aggregate. Do not loosen coarse aggregate or chinked stone roadbeds rough enough to permit binding with Driving Surface Aggregate.
5. If required, separation fabric should be placed according to manufacturer’s recommendations.

Placement: An un-compacted uniform depth of 8 inches of DSA is to be used to establish the driving surface. Placement is to be in a single 8-inch lift. The preferred method of application is through a paver. Set the paver adjustments on application thickness and width so it is unnecessary to use a grader. The required crown or side slope is to range from ½ to ¾ inch rise per horizontal foot. This slope is to be achieved by properly preparing base and placing aggregate in a uniform lift. When the paver is applying aggregate, care should be taken to keep the paver at or near capacity at all times.

To fill driving surface areas outside the specified width (e.g., driveway entrances, pull-offs, and passing lanes), additional DSA is to be added and tapered to grade or butted against a precut channel of the same depth. If berm or bank edges don’t exist to hold the new DSA surface, then sufficient material is to be placed, tapered and compacted to form protective edge berms. Material shall be compacted to a final thickness of approximately 6 inches.

<u>DSA CALCULATION FORMULA</u>			
DSA Needed (tons)	Road Width (ft)	X	Road Length (ft)
		X	0.042
Applies to standard 8" lift, compacted to 6"			

Compaction Sequence: Verify that moisture is optimum for compaction. If the material has dried out, re-wet the DSA surface with a water truck. If clumps of aggregate adhere to the roller drum, the aggregate may be too moist. Allow drying time before rolling. Do not use the vibratory rolling mode if that action brings water to the surface of the aggregate.

Only self-powered machines designed specifically for compaction shall be used. Compaction with truck tires is not acceptable.

- 1A. Supported Edge: *If edge of placed aggregate is supported by an existing bank*

or berm: First pass: Roll slowly in static mode on the outside edge of placed aggregate.

1B. Unsupported Edge: *If the edge of the placed aggregate is not supported*:

First Pass: Roll slowly in static mode near but not over unsupported outside edges. Once that path is firm, move progressively closer to the outside edge with static passes until unsupported edge is firm.

2. Sequence: As in all rolling operations, compaction is achieved making overlapping lengthwise passes beginning at the ditch or berm-side and working toward the crown or the top edge (if it is a side-sloped or super-elevated section of road). In no case should the roller be run lengthwise on the top of the [road crown](#).

3A. Static Roller: The minimum acceptable weight of a static roller is 10 tons. Repeat the sequence of overlapping passes until desired compaction is achieved.

3B. Vibratory Roller: The minimum striking force of vibratory rollers is 20,000 lbs. When using a vibratory roller, the initial pass over un-compacted aggregate should be completed in static mode. All successive passes should be made using the vibratory mode until the desired level of compaction is achieved. The final pass over each area should be made in static mode to remove all roller edge marks. The vibratory roller should be set to deliver between 6 and 17 impacts per linear foot with the roller moving at the speed at which a person walks on each pass upgrade. **Vibration must be turned off during downgrade passes.** Vibrating the drum when rolling downgrade will cause aggregate to flow in “waves” in front of the roller, resulting in an uneven surface.

4. Desired Compaction: Unless more refined testing equipment is available, adequate compaction is indicated when no further depressions are created with a roller or loaded dump truck. Cracking of larger stones or rocks in the road surface is another reliable indication of adequate compaction.

A3.2 Illinois DOT Specifications. (excerpts)(www.dot.il.gov)

Section 402. Aggregate Surface Course

402.01 Description. This work shall consist of furnishing and placing one or more course of aggregate upon a prepared [subgrade](#).

402.02 Materials. Materials shall meet the requirements of Section 1000, Article 1004.04

1004.04 Coarse Aggregate for Aggregate Surface Course.

a. Description. The coarse aggregate shall be pit run gravel, gravel, crushed gravel, novaculite, crushed stone, crushed concrete, crushed slag or crushed sandstone.

a. Quality. The coarse aggregate shall be Class D Quality or better.

Quality Test	Class D
Sodium Sulfate Soundness ² 5 cycle, AASHTO T104 ^{1,2} , Max % loss	25 ³
Los Angeles Abrasion AASHTO T96, Max % loss	45

¹As modified by the Department

²Does not apply to crushed concrete.

³For aggregate surface course, the maximum percent loss shall be 30.

- b. Gradation.
1. For aggregate surface course Type B, Gradation CA6, CA9, or CA10 may be used. If approved by the Engineer, Gradation CA4 or CA12 may be used.
 2. For aggregate subbase Type B, Gradation CA6, CA10, CA12, , or CA19 shall be used. If approved by the Engineer, Gradation CA2 or CA4 may be used.
 3. For aggregate Subbase Type C, Gradation CA7 or combined size CA5 and CA7 shall be used.
 4. For granular aggregate courses (base, subbase, and shoulder except subbase Types B and C), Gradation CA6, or CA10 shall be used. If specified, Gradation CA2 or CA4 For aggregate surface course Type B, Gradation CA6, CA9, or CA10 may be used. If approved by the Engineer, Gradation CA4 or CA12 may be used.
 5. Stabilized aggregate courses (base, subbase, and shoulder), Gradation CA6 or CA10 shall be used. If approved by the Engineer, Gradation CA2, CA4, or CA12 may be used.
 6. For aggregate surface course Type A, Gradation CA6, or CA10 shall be used. If approved by the Engineer, Gradation CA2, CA4, CA9, or CA12 may be used.
- c. Plasticity. All material shall comply with the plasticity index requirements listed below.

Type of construction	Plasticity Index – Percent ¹	
	Gravel	Crushed Gravel, Stone, Slag
Aggregate Subbase Type A or B	0 to 9	-
Aggregate Base Course Type A or B	0 to 6	0 to 4
Aggregate Surface Course Type A or B ²	2 to 9	-
Stabilized Aggregate Material	0 to 9	0 to 9

¹Plasticity index shall be determined by the method given in AASHTO T90. Where shale in any form exists in the producing ledges, crushed stone samples shall be soaked a minimum of 18 hours before processing for plasticity index or minus #40 material. When clay material is added to adjust plasticity index, the clay material shall be a minus #4 sieve size.

²When Gradation CA9 is used, the plasticity index requirement will not apply.

402.03 Equipment shall meet the requirements of the following Articles of Section 1100:

- a. Tamping Roller.....1101.01
- d. Pneumatic-Tired Roller.....1101.01
- e. Three-Wheel Roller (Note 1)....1101.01
- f. Tandem Roller (Note 1).....1101.01
- g. Spreader.....1101.01
- h. Vibratory Machine (Note 2).....1101.04

Note 1. Three-wheel or tandem rollers shall weigh 6 to 10 tons and shall weigh not less than 200lb/in nor more than 325 lb/in of width of the roller.

Note 2. The vibratory machine shall meet the approval of the Engineer.

Construction Requirements

402.04 Subgrade. The [subgrade](#) shall be prepared according to Section 301 except that Article 301.06 will not apply.

402.05 Type A Requirements. Aggregate surface course, Type A shall be constructed according to Article 351.05(a) and (b) except the bearing ratio requirements shall not apply.

402.07 Type B Requirements. Any one or two gradations of the material specified in Article 1004.04 shall be used except where two gradations of material are used, the change shall not be made at more than one location on the section.

The surfacing material shall be deposited on the [subgrade](#) by means of a spreader.

The equipment used shall be such that the required amount of material will be deposited uniformly along the central portion of the roadbed.

The material which has been deposited shall be spread immediately to the plan cross section. Hauling shall be routed over the spread material so it will cover the entire width of surface. If the equipment used in hauling operations causes ruts extending through the spread material and into the [subgrade](#), and the [subgrade](#) material is being mixed with the surface material, the equipment shall be removed from the work or the rutting otherwise prevented as directed by the Engineer.

The Contractor shall keep the surface smooth by dragging or blading as many times each day as the engineer may direct.

Holes, waves, and undulations which develop and which are not filled by blading shall be filled by adding more material.

A3.3 Michigan DOT Specifications (excerpts) (www.mdot.state.mi.us)

Section 306. Aggregate Surface Course

306.01 Description. Construct an aggregate surface course on a prepared [subgrade](#) or an existing aggregate surface.

306.02 Materials. Use materials meeting the following:

Dense-graded Aggregate 21AA, 21A, 23A.....902

Use aggregate 21AA or 21A if the aggregate surface course will later receive a hot mix asphalt (HMA) surface. Use aggregate 23A if the aggregate surface course is to be constructed without an HMA surface. Use dense-graded aggregate 22A, 23A for temporary maintenance gravel.

902.06 Dense-Graded Aggregates for Base Course, Surface Course, Shoulders, Approaches and Patching. Michigan Class 21AA, 21A, 22A and 23A dense-graded aggregates will consist of natural aggregate, iron blast furnace slag, reverberatory furnace slag, or crushed concrete, in combination with fine aggregate as necessary to meet the gradation requirements in Table 902-1, the physical requirements in Table 902-2, and the following:

- A. Dense-graded aggregates produced by crushing Portland cement concrete will not contain building rubble as evidenced by the presence of more than 5.0%, by particle count, building brick, wood, plaster, or similar materials. Sporadic pieces of steel reinforcement may be present provided they pass the maximum grading sieve size without hand manipulation.

- B. Class 21AA, 21A, and 22A dense-graded aggregates produced from Portland cement concrete will not be used to construct either an aggregate base or aggregate separation layer when either of the following conditions apply:
1. When there is a [geotextile](#) liner or membrane present with permeability requirements.
 2. In a pavement structure with an underdrain, unless there is a filter material between crushed concrete and the underdrain. The filter material will be either a minimum of 12 inches of granular material or a [geotextile](#) liner or blocking membrane that will be a barrier to leachate.
- C. Class 23A dense-graded aggregate may be produced from steel furnace slag, but only for use as an unbound aggregate surface course or as an unbound aggregate shoulder.

Table 902-1 Grading Requirements for Dense-Graded Aggregates

Class	Sieve Analysis (MTM 109) Total Percent Passing (b)						Loss by Washing (MTM 108) % Passing #200
	1.5 in.	1 in.	¾ in	½ in	3/8 in	# 8	
21AA, 21A	100	85-100		50-75		20-45	4-8 (e)(f)
22A		100	90-100		65-85	30-50	4-8(e)(f)
23A		100			60-85	25-60	9-16(f)

(b) Based on dry weights

(e) When used for aggregate base courses, surface courses, shoulders and approaches and the material is produced entirely by crushing rock, boulders, cobbles, slag, or concrete, the maximum limit for Loss by Washing will not exceed 10%.

(f) The limits for Loss by Washing of dense-graded aggregates are significant to the nearest whole percent.

Table 902-2 Physical Requirements for Dense-Graded Aggregates

Class (j)	Crushed Material, % min. (MTM 110,117)	Loss, % max, Los Angeles Abrasion (MTM 102)
21AA	95	50
21A	25	50
22A	25	50
23A	25	50

(j) Quarried carbonate (limestone or dolomite) aggregate will not contain over 10% insoluble residue finer than Number 200 sieve when tested in accordance with MTM 103.

306.03 Construction.

- A. Preparation of Base. When required, blade, or scarify and blade, the existing aggregate surface to remove irregularities in the grade.
- B. Placing and Compacting. Provide a uniform aggregate mixture compacted in place with uniform density full depth. Provide a completed surface course conforming to the line, grade or plan cross section.
Place maintenance gravel to provide a flush transition between shoulders, driveways and other areas where traffic is maintained. Maintenance gravel may remain permanently as part of the work, if approved by the Engineer.
Do not place aggregate when the base is unstable. Maintain the aggregate in a smooth, stable condition and provide [dust](#) control until removed or surfaced.
- C. Use of additives. Use of additives to facilitate compaction and for [dust](#) control of the aggregate is acceptable.

A3.4 New York DOT Specifications (excerpts) (www.dot.state.ny.us)

Section 667 – Local Road Gravel Surface, Base, and Subbase Courses

667-1.02 Material Types. Provide materials as specified by the following options.

Type A. Surface quality material with a maximum particle size of 25mm.

Type B. Base quality material with a maximum particle size of 50 mm.

Type C. Subbase quality material with a maximum particle size of 75mm.

667-2.02 Material Requirements. Provide materials for road gravel surface, base and subbase courses that consist of Sand and Gravel, approved Blast Furnace Slag or Stone that meet the requirements contained herein. Provide materials well graded from coarse to fine, and free from organic or other deleterious materials. Any gravel material will be rejected if it is determined to contain any unsound or deleterious materials.

- B. Gradation, Perform sieve analysis in accordance with AASHTO procedures T27, T88 or T311. Provide materials meeting the gradation limits from Table 667-1.
- C. Soundness. Material will be accepted on the basis of Magnesium sulfate. Soundness Loss after four cycles performed according to NYSDOT procedures and Table 667-2.
- D. Plasticity. Determine plasticity using either of the following methods:
 1. Plasticity Index. The Plasticity Index of the material passing the #40 mesh sieve shall meet the values in Table 667-2. Determine plasticity using AASHTO tests T89 and T90.
 2. Sand Equivalent. The sand equivalence of the granular material shall meet the values in Table 667-2. Determine sand equivalence using AASHTO test T176.

Table 667-1: Percent passing by Weight of Gravel Materials

Sieve (US Sieve)	A (Surface)	B (Base)	C (subbase)
3"			100
2"		100	-
1.5"		85-100	70-100
1"	100	-	-
¾"	85-100	-	-
¼"	50-75	30-50	30-55
#40	15-35	5-20	5-25
#200	8-15	0-5	0-8

Table 667-2: Test and control Limits of Gravel Materials

Material Properties	A (Surface)	B (Base)	C (subbase)
Maximum Soundness loss (%)	20	20	25
Plasticity Index	2-9	0-5	0-8
Sand Equivalent	>25	>40	>35

- E. Elongated Particles Not more than 30%, by weight, of the particles retained on a ½" sieve shall consist of flat or elongated particles. A flat or elongated particle is defined herein as one which has its greatest dimension more than 3 times its least dimension. Acceptance for this requirement will normally be

APPENDIX 3. Sample Aggregates Specifications

Following are sample specifications for gravel road aggregate surface courses from several different states. Road personnel should check with their State Department of Transportation or their Local Technical Assistance Program / Technology Transfer (T2) Center for specifications being used in their own state. Many state DOTs have their specifications readily available via their Web sites.

A3.1 Pennsylvania's Driving Surface Aggregate

Material Specifications: All Driving Surface Aggregate (DSA) is to be derived from natural stone formations. Stone is defined as rock that has been crushed; rock is defined as consolidated mineral matter. For use in this program, both are restricted to that which has been mined or quarried from existing geologic bedrock formations.

All components of the aggregate mix are to be derived from crushed parent rock material that meets program specifications for abrasion resistance, pH and freedom from contaminants. Ninety-eight percent (98%) of fines passing the #200 sieve must be parent rock material. No clay or silt soil may be added. The amount of particles passing the #200 sieve shall be determined using the washing procedures specified in PTM No. 100.

Size: The required amounts and allowed ranges, determined by percent weight, for various size particles are shown in Table 1.

LA Abrasion: The acceptable limit as measured by weight loss is "less than 40% loss." Los Angeles Abrasion test, AASHTO T-96 [ASTM C 131] shall be used to determine this property. Existing data obtained from tests made for and approved by PENNDOT will be accepted.

<i>Passing sieve</i>	<i>Lower %</i>	<i>High%</i>
1 ½ inches	100	
¾ inches	65	90
#4	30	65
#16	15	30
#200	10	20

Table 1. DSA Gradation

Sulfate Test: Soundness or resistance to freeze/thaw [*i.e., sulfate test*] is not specified for this application because a gravel road driving surface aggregate is not bound within a concrete or asphalt mix.

pH: Aggregate must be in the range of pH 6 to pH 12.45 as measured by EPA 9045C.

Optimum Moisture: Material is to be delivered and placed at optimum moisture content as determined for that particular source. The optimum percentage moisture is to be identified by the supplier in the bid/purchasing documents.

Transport: Tarps are to be used to cover 100% of the load's exposed surface from the time of loading until immediately before dumping. This requirement includes standing time waiting to dump.

Aggregate producers are required by the program to certify that the aggregate they deliver conforms to the program specifications.

Road Surface Preparation: Driving Surface Aggregate will reflect the shape of the surface to which it is applied; therefore, all road surface preparation work is to be completed before delivery and placement of the aggregate.

1. Prepare underdrainage, including drain tile, French drains (porous fill) and crosspipes.
2. Address surface drainage features such as broad-based dips, [grade breaks](#), crown, and side-slope.
3. Establish proper cross-slope in existing base (Fig. 1). Recommended crown or slope is ½ to ¾ inch rise per horizontal foot. Proper shape may be a flat “A” crown profile, an in-slope or out-slope. If exposed bedrock or insufficient material prevents proper shaping of the road base, additional base material may be needed.
4. To bind aggregate with the road base, scarify impermeable smooth surfaces such as oil and chip, exposed bedrock or smooth tight aggregate. Do not loosen coarse aggregate or chinked stone roadbeds rough enough to permit binding with Driving Surface Aggregate.
5. If required, separation fabric should be placed according to manufacturer’s recommendations.

Placement: An un-compacted uniform depth of 8 inches of DSA is to be used to establish the driving surface. Placement is to be in a single 8-inch lift. The preferred method of application is through a paver. Set the paver adjustments on application thickness and width so it is unnecessary to use a grader. The required crown or side slope is to range from ½ to ¾ inch rise per horizontal foot. This slope is to be achieved by properly preparing base and placing aggregate in a uniform lift. When the paver is applying aggregate, care should be taken to keep the paver at or near capacity at all times.

To fill driving surface areas outside the specified width (e.g., driveway entrances, pull-offs, and passing lanes), additional DSA is to be added and tapered to grade or butted against a precut channel of the same depth. If berm or bank edges don’t exist to hold the new DSA surface, then sufficient material is to be placed, tapered and compacted to form protective edge berms. Material shall be compacted to a final thickness of approximately 6 inches.

<u>DSA CALCULATION FORMULA</u>			
DSA Needed (tons)	Road Width (ft)	X	Road Length (ft)
		X	0.042
Applies to standard 8" lift, compacted to 6"			

Compaction Sequence: Verify that moisture is optimum for compaction. If the material has dried out, re-wet the DSA surface with a water truck. If clumps of aggregate adhere to the roller drum, the aggregate may be too moist. Allow drying time before rolling. Do not use the vibratory rolling mode if that action brings water to the surface of the aggregate.

Only self-powered machines designed specifically for compaction shall be used. Compaction with truck tires is not acceptable.

- 1A. Supported Edge: *If edge of placed aggregate is supported by an existing bank*

or berm: First pass: Roll slowly in static mode on the outside edge of placed aggregate.

1B. Unsupported Edge: *If the edge of the placed aggregate is not supported*:

First Pass: Roll slowly in static mode near but not over unsupported outside edges. Once that path is firm, move progressively closer to the outside edge with static passes until unsupported edge is firm.

2. Sequence: As in all rolling operations, compaction is achieved making overlapping lengthwise passes beginning at the ditch or berm-side and working toward the crown or the top edge (if it is a side-sloped or super-elevated section of road). In no case should the roller be run lengthwise on the top of the [road crown](#).

3A. Static Roller: The minimum acceptable weight of a static roller is 10 tons. Repeat the sequence of overlapping passes until desired compaction is achieved.

3B. Vibratory Roller: The minimum striking force of vibratory rollers is 20,000 lbs. When using a vibratory roller, the initial pass over un-compacted aggregate should be completed in static mode. All successive passes should be made using the vibratory mode until the desired level of compaction is achieved. The final pass over each area should be made in static mode to remove all roller edge marks. The vibratory roller should be set to deliver between 6 and 17 impacts per linear foot with the roller moving at the speed at which a person walks on each pass upgrade. **Vibration must be turned off during downgrade passes.** Vibrating the drum when rolling downgrade will cause aggregate to flow in “waves” in front of the roller, resulting in an uneven surface.

4. Desired Compaction: Unless more refined testing equipment is available, adequate compaction is indicated when no further depressions are created with a roller or loaded dump truck. Cracking of larger stones or rocks in the road surface is another reliable indication of adequate compaction.

A3.2 Illinois DOT Specifications. (excerpts)(www.dot.il.gov)

Section 402. Aggregate Surface Course

402.01 Description. This work shall consist of furnishing and placing one or more course of aggregate upon a prepared [subgrade](#).

402.02 Materials. Materials shall meet the requirements of Section 1000, Article 1004.04

1004.04 Coarse Aggregate for Aggregate Surface Course.

a. Description. The coarse aggregate shall be pit run gravel, gravel, crushed gravel, novaculite, crushed stone, crushed concrete, crushed slag or crushed sandstone.

a. Quality. The coarse aggregate shall be Class D Quality or better.

Quality Test	Class D
Sodium Sulfate Soundness ² 5 cycle, AASHTO T104 ^{1,2} , Max % loss	25 ³
Los Angeles Abrasion AASHTO T96, Max % loss	45

¹As modified by the Department

²Does not apply to crushed concrete.

³For aggregate surface course, the maximum percent loss shall be 30.

- b. Gradation.
1. For aggregate surface course Type B, Gradation CA6, CA9, or CA10 may be used. If approved by the Engineer, Gradation CA4 or CA12 may be used.
 2. For aggregate subbase Type B, Gradation CA6, CA10, CA12, , or CA19 shall be used. If approved by the Engineer, Gradation CA2 or CA4 may be used.
 3. For aggregate Subbase Type C, Gradation CA7 or combined size CA5 and CA7 shall be used.
 4. For granular aggregate courses (base, subbase, and shoulder except subbase Types B and C), Gradation CA6, or CA10 shall be used. If specified, Gradation CA2 or CA4 For aggregate surface course Type B, Gradation CA6, CA9, or CA10 may be used. If approved by the Engineer, Gradation CA4 or CA12 may be used.
 5. Stabilized aggregate courses (base, subbase, and shoulder), Gradation CA6 or CA10 shall be used. If approved by the Engineer, Gradation CA2, CA4, or CA12 may be used.
 6. For aggregate surface course Type A, Gradation CA6, or CA10 shall be used. If approved by the Engineer, Gradation CA2, CA4, CA9, or CA12 may be used.
- c. Plasticity. All material shall comply with the plasticity index requirements listed below.

Type of construction	Plasticity Index – Percent ¹	
	Gravel	Crushed Gravel, Stone, Slag
Aggregate Subbase Type A or B	0 to 9	-
Aggregate Base Course Type A or B	0 to 6	0 to 4
Aggregate Surface Course Type A or B ²	2 to 9	-
Stabilized Aggregate Material	0 to 9	0 to 9

¹Plasticity index shall be determined by the method given in AASHTO T90. Where shale in any form exists in the producing ledges, crushed stone samples shall be soaked a minimum of 18 hours before processing for plasticity index or minus #40 material. When clay material is added to adjust plasticity index, the clay material shall be a minus #4 sieve size.

²When Gradation CA9 is used, the plasticity index requirement will not apply.

402.03 Equipment shall meet the requirements of the following Articles of Section 1100:

- a. Tamping Roller.....1101.01
- d. Pneumatic-Tired Roller.....1101.01
- e. Three-Wheel Roller (Note 1)....1101.01
- f. Tandem Roller (Note 1).....1101.01
- g. Spreader.....1101.01
- h. Vibratory Machine (Note 2).....1101.04

Note 1. Three-wheel or tandem rollers shall weigh 6 to 10 tons and shall weigh not less than 200lb/in nor more than 325 lb/in of width of the roller.

Note 2. The vibratory machine shall meet the approval of the Engineer.

Construction Requirements

402.04 Subgrade. The [subgrade](#) shall be prepared according to Section 301 except that Article 301.06 will not apply.

402.05 Type A Requirements. Aggregate surface course, Type A shall be constructed according to Article 351.05(a) and (b) except the bearing ratio requirements shall not apply.

402.07 Type B Requirements. Any one or two gradations of the material specified in Article 1004.04 shall be used except where two gradations of material are used, the change shall not be made at more than one location on the section.

The surfacing material shall be deposited on the [subgrade](#) by means of a spreader.

The equipment used shall be such that the required amount of material will be deposited uniformly along the central portion of the roadbed.

The material which has been deposited shall be spread immediately to the plan cross section. Hauling shall be routed over the spread material so it will cover the entire width of surface. If the equipment used in hauling operations causes ruts extending through the spread material and into the [subgrade](#), and the [subgrade](#) material is being mixed with the surface material, the equipment shall be removed from the work or the rutting otherwise prevented as directed by the Engineer.

The Contractor shall keep the surface smooth by dragging or blading as many times each day as the engineer may direct.

Holes, waves, and undulations which develop and which are not filled by blading shall be filled by adding more material.

A3.3 Michigan DOT Specifications (excerpts) (www.mdot.state.mi.us)

Section 306. Aggregate Surface Course

306.01 Description. Construct an aggregate surface course on a prepared [subgrade](#) or an existing aggregate surface.

306.02 Materials. Use materials meeting the following:

Dense-graded Aggregate 21AA, 21A, 23A.....902

Use aggregate 21AA or 21A if the aggregate surface course will later receive a hot mix asphalt (HMA) surface. Use aggregate 23A if the aggregate surface course is to be constructed without an HMA surface. Use dense-graded aggregate 22A, 23A for temporary maintenance gravel.

902.06 Dense-Graded Aggregates for Base Course, Surface Course, Shoulders, Approaches and Patching. Michigan Class 21AA, 21A, 22A and 23A dense-graded aggregates will consist of natural aggregate, iron blast furnace slag, reverberatory furnace slag, or crushed concrete, in combination with fine aggregate as necessary to meet the gradation requirements in Table 902-1, the physical requirements in Table 902-2, and the following:

- A. Dense-graded aggregates produced by crushing Portland cement concrete will not contain building rubble as evidenced by the presence of more than 5.0%, by particle count, building brick, wood, plaster, or similar materials. Sporadic pieces of steel reinforcement may be present provided they pass the maximum grading sieve size without hand manipulation.

- B. Class 21AA, 21A, and 22A dense-graded aggregates produced from Portland cement concrete will not be used to construct either an aggregate base or aggregate separation layer when either of the following conditions apply:
1. When there is a [geotextile](#) liner or membrane present with permeability requirements.
 2. In a pavement structure with an underdrain, unless there is a filter material between crushed concrete and the underdrain. The filter material will be either a minimum of 12 inches of granular material or a [geotextile](#) liner or blocking membrane that will be a barrier to leachate.
- C. Class 23A dense-graded aggregate may be produced from steel furnace slag, but only for use as an unbound aggregate surface course or as an unbound aggregate shoulder.

Table 902-1 Grading Requirements for Dense-Graded Aggregates

Class	Sieve Analysis (MTM 109) Total Percent Passing (b)						Loss by Washing (MTM 108) % Passing #200
	1.5 in.	1 in.	¾ in	½ in	3/8 in	# 8	
21AA, 21A	100	85-100		50-75		20-45	4-8 (e)(f)
22A		100	90-100		65-85	30-50	4-8(e)(f)
23A		100			60-85	25-60	9-16(f)

(b) Based on dry weights

(e) When used for aggregate base courses, surface courses, shoulders and approaches and the material is produced entirely by crushing rock, boulders, cobbles, slag, or concrete, the maximum limit for Loss by Washing will not exceed 10%.

(f) The limits for Loss by Washing of dense-graded aggregates are significant to the nearest whole percent.

Table 902-2 Physical Requirements for Dense-Graded Aggregates

Class (j)	Crushed Material, % min. (MTM 110,117)	Loss, % max, Los Angeles Abrasion (MTM 102)
21AA	95	50
21A	25	50
22A	25	50
23A	25	50

(j) Quarried carbonate (limestone or dolomite) aggregate will not contain over 10% insoluble residue finer than Number 200 sieve when tested in accordance with MTM 103.

306.03 Construction.

- A. Preparation of Base. When required, blade, or scarify and blade, the existing aggregate surface to remove irregularities in the grade.
- B. Placing and Compacting. Provide a uniform aggregate mixture compacted in place with uniform density full depth. Provide a completed surface course conforming to the line, grade or plan cross section.
Place maintenance gravel to provide a flush transition between shoulders, driveways and other areas where traffic is maintained. Maintenance gravel may remain permanently as part of the work, if approved by the Engineer.
Do not place aggregate when the base is unstable. Maintain the aggregate in a smooth, stable condition and provide [dust](#) control until removed or surfaced.
- C. Use of additives. Use of additives to facilitate compaction and for [dust](#) control of the aggregate is acceptable.

A3.4 New York DOT Specifications (excerpts) (www.dot.state.ny.us)

Section 667 – Local Road Gravel Surface, Base, and Subbase Courses

667-1.02 Material Types. Provide materials as specified by the following options.

Type A. Surface quality material with a maximum particle size of 25mm.

Type B. Base quality material with a maximum particle size of 50 mm.

Type C. Subbase quality material with a maximum particle size of 75mm.

667-2.02 Material Requirements. Provide materials for road gravel surface, base and subbase courses that consist of Sand and Gravel, approved Blast Furnace Slag or Stone that meet the requirements contained herein. Provide materials well graded from coarse to fine, and free from organic or other deleterious materials. Any gravel material will be rejected if it is determined to contain any unsound or deleterious materials.

- B. Gradation, Perform sieve analysis in accordance with AASHTO procedures T27, T88 or T311. Provide materials meeting the gradation limits from Table 667-1.
- C. Soundness. Material will be accepted on the basis of Magnesium sulfate. Soundness Loss after four cycles performed according to NYSDOT procedures and Table 667-2.
- D. Plasticity. Determine plasticity using either of the following methods:
 - 1. Plasticity Index. The Plasticity Index of the material passing the #40 mesh sieve shall meet the values in Table 667-2. Determine plasticity using AASHTO tests T89 and T90.
 - 2. Sand Equivalent. The sand equivalence of the granular material shall meet the values in Table 667-2. Determine sand equivalence using AASHTO test T176.

Table 667-1: Percent passing by Weight of Gravel Materials

Sieve (US Sieve)	A (Surface)	B (Base)	C (subbase)
3"			100
2"		100	-
1.5"		85-100	70-100
1"	100	-	-
¾"	85-100	-	-
¼"	50-75	30-50	30-55
#40	15-35	5-20	5-25
#200	8-15	0-5	0-8

Table 667-2: Test and control Limits of Gravel Materials

Material Properties	A (Surface)	B (Base)	C (subbase)
Maximum Soundness loss (%)	20	20	25
Plasticity Index	2-9	0-5	0-8
Sand Equivalent	>25	>40	>35

- E. Elongated Particles Not more than 30%, by weight, of the particles retained on a ½" sieve shall consist of flat or elongated particles. A flat or elongated particle is defined herein as one which has its greatest dimension more than 3 times its least dimension. Acceptance for this requirement will normally be

Environmentally Sensitive Maintenance for Dirt and Gravel Roads

Chapter 4: Basics of Natural Systems

4.1 Introduction

Today, road managers must operate and maintain public roads in a broad context that considers multiple social, political, and environmental objectives. This tough task is made more difficult by the fact that most roads were built within a much narrower context that focused only on short-term purposes such as engineering, cost, and convenience.



4-01 Many roads were built without regard to natural systems.

Through construction, our transportation systems were traditionally laid down across the entire fabric of the landscape. Nearly all roads were built without regard for the function of the natural systems that evolved in these locations. Roads built adjacent to and across streams, through [wetlands](#), farms, and forests inevitably disrupted both surface and subsurface drainage, vegetation patterns, and native animal communities.



4-02 Environmental problems bear witness to our disturbance and disruption of natural systems.

Potholes, ruts, road washouts, bank failures, ditch blockages, and fallen trees bear witness to our disturbance and disruption of natural systems. In addition, typical environmental problems also appeared, such as muddy streams, deteriorated habitat, and changes in the number and type of both plant and animal communities. But efforts to address these problems without understanding their causes have often been a waste of money.

As previously stated, road management is an increasingly complex task where managers must balance human expectations against intricate natural systems. This chapter will introduce some basic guiding principals of natural systems

so road managers can better understand the relationship between the roads and the environment. These basic guiding principles will focus on the three pertinent natural systems: streams, [wetlands](#), and forest/[upland](#) areas.

Chapter 4 starts with an introduction to [ecology](#) and [ecosystems](#). It will then provide more specific information on the three common [ecosystems](#) or communities: streams, [wetlands](#), and forests/[uplands](#), respectively. This information supports our objective to “arm the user with knowledge on basic principles of nature and natural systems...” so that we can apply that knowledge to our road maintenance programs through environmentally sensitive practices, resulting in better roads and a better environment.

4.2 Ecology, Ecoregions and Ecosystems

The term [ecology](#) stems from the Greek word “oikos,” which means “house.” [Ecology](#) can be defined as the study of interactions of organisms between one another and the physical and chemical environment. As indicated by the definition, all living organisms (plants, animals, fungi, and micro-organisms, such as bacteria and viruses) are dependent upon conditions present where they live (in their “house”). This range of ecological conditions, which describes where an organism lives, is termed “habitat.” Habitat is defined by a wide variety of physical and biological factors. Physical factors, such as local geology (elevation, slope, drainage, rock type, etc.), soil (nutrients, stability, etc.), [hydrology](#) (precipitation, [runoff](#), soil, moisture, evaporation, etc.), and climate (temperature, sunlight, day length, etc.), shape the setting in which biological organisms live. Biological factors, such as competition for food sources and mates, predation, disease, and social interaction, determines how well organisms survive and reproduce within the physical setting.



4-03 Physical factors such as geology, soil, hydrology, and climate shape the ‘habitat’.

Ecologists have studied many of the interactions that take place between biological and physical systems, and based upon their findings, divided the landscape into [ecoregions](#) or areas with similar characteristics. These [ecoregions](#) reflect the physical factors (geology, soil, [hydrology](#), climate) that help define their respective habitats, and in turn determine the type of animals and plants that live in that habitat. Geological provinces and [ecoregions](#) are closely linked. The comparison of geological and [ecoregions](#) maps demonstrates the boundary similarities. (Appendix 4. Case Study: Pennsylvania’s [Ecology](#) illustrates this comparison in Figure A4-1 using the geology province map and an ecoregion map of Pennsylvania.)

Vegetation is heavily dependent upon the area’s elevation, slope, drainage, stability, and nutrient availability conditions, in essence, the geology and soils. If plants

from one ecoregion are planted within another ecoregion, they will most likely not do as well as they would have in their own ecoregion. This is because plants (and animals) have developed and evolved under a certain set of physical conditions characteristic of their ecoregion, and if these conditions are not met, then they will have a difficult time surviving. In some instance, road locations and maintenance practices create conditions unnatural to that ecoregion, causing survival failures in otherwise viable animals or plants.

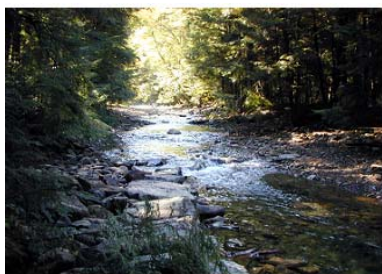
This ecoregion concept is critically important for “[environmentally sensitive maintenance](#) for dirt and gravel roads.” Road managers must understand natural systems to adopt effective road maintenance practices that provide sustainable roads without hurting the environment.



4-04 Plants develop and evolve under the physical conditions of their ecoregion.

One key is to use nearby natural systems as an example of what our project sites should look like and how they should function. Projects, whether construction or maintenance, will be more successful if they are modeled after nearby natural systems because nature has already done the research for us. These natural systems can be used to determine what slopes are sustainable for road and stream banks, as well as what plants grow well in a specific location. The relative size of local drainage features serve as a guide for sizing drainage structures for the roadway system. Projects modeled after natural systems will also look more natural

and aesthetic compared to more sterile engineering designs. And, as we shall see, we can learn how to use these natural systems to actually aid us in more effective and efficient road maintenance



Streams



Wetlands



Uplands

[Ecoregions](#) are broad areas that cover many different types of habitat, and because of this, [ecoregions](#) are often broken down into smaller units. Within each ecoregion, there are typically three types of [ecosystems](#), or communities: streams,

4-05 Ecosystems (Communities)

wetlands, and forests/uplands. The term upland commonly refers to areas of higher elevation that are well drained, covered with forests or cleared for farming or have reverted to meadows.

Each one of these ecosystems relate differently to maintaining dirt and gravel roads. In the stream ecosystem, sediments and their effect on stream life are a major concern. Sensitive plants and animals are a major concern with wetlands, in addition to other major benefits, such as flood storage. Strict laws and regulations govern roads built through and near wetlands so we can continue to receive these benefits. Finally, in forested or upland areas, improper trimming and clearing of vegetation associated with road maintenance causes a major concern and unwarranted expense.

4.3 The Stream Ecosystem (Community)



4-06 There are 3,692,830 miles of rivers and streams within the United States.

dependent upon a wide range of both physical and biological factors, as reviewed previously. These factors, how they are connected, and their importance to the stream will be discussed in the following sections.

4.3.2.1 Watersheds:

Streams are situated in the bottom of their valleys, draining water from the surrounding higher landscape. This area drained by the stream is referred to by several interchangeable terms: watershed, drainage basin, or catchment area. Although we typically perceive streams starting where sufficient water has accumulated to form a channel, streams actually begin at the highest points within their

4.3.1 Introduction: According to EPA's National Water Quality inventory, there are 3,692,830 miles of rivers and streams within the United States. This vast network of streams is a tremendous natural resource. There are a number of important interactions between our dirt and gravel roads and our stream networks. Precisely because our roads and streams are so closely linked, road managers must be extremely sensitive to the well-being of the stream.

4.3.2 Basics of Stream Ecology:

Stream ecosystems, or communities, are

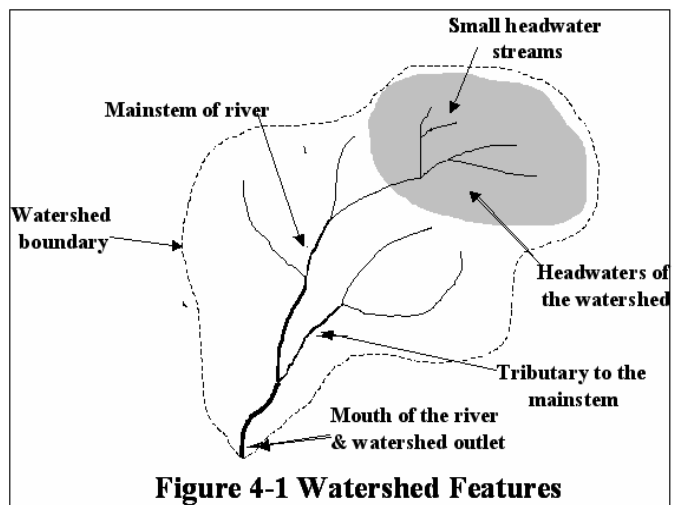


Figure 4-1 Watershed Features

[watersheds](#), the point where precipitation first contacts the ground. Once precipitation hits the ground, gravity causes the water to flow downhill, first as a very thin sheet of water similar to a sheet of water flowing over a paved road. Irregularities in the ground surface break up this smooth flow, causing the water to accumulate in increasingly greater quantities. This water accumulation begins to cut a channel, first forming small rills, then gullies, and then becoming small streams. Small streams are formed in the headwaters portion of the [watershed](#), as shown in Figure 4-1. Small streams join each other, accumulating more water until the flow eventually becomes a river.

Because streams obtain water from their [watershed](#), activities that take place in the [watershed](#) can negatively affect the quality of the water entering the stream. If the stream receives polluted water, then the life in the stream will also be impacted. The pollution of our nation's waterways and water quality issues over the past 100 years has created much public resentment. In response to this pollution, laws were passed to protect our water resources as early as the Federal Rivers and Harbors Acts of 1890 and 1899. Pollution, and our knowledge of its impacts, has increased since these early laws, and additional regulations govern activities along streams in an effort to protect and preserve stream systems and the benefits that they provide. It is important to know about and work within these necessary legal restrictions when conducting road maintenance work.

Traditional management of our water resources has been based on political divisions (e.g., township, county, state boundary lines). Water, however, flows across these jurisdictional boundaries, making management and protection of this valuable resource difficult. Effective management must involve the challenging task of coordinating efforts between multiple political jurisdictions. One of the best ways to make the management of our water resources easier and more effective is to manage it on a [watershed](#) or catchment area basis. Because planning at the local level is often at too small a scale to address [watershed](#) size resource problems, local governments are strongly encouraged to communicate and coordinate control efforts with neighboring municipalities and county agencies.

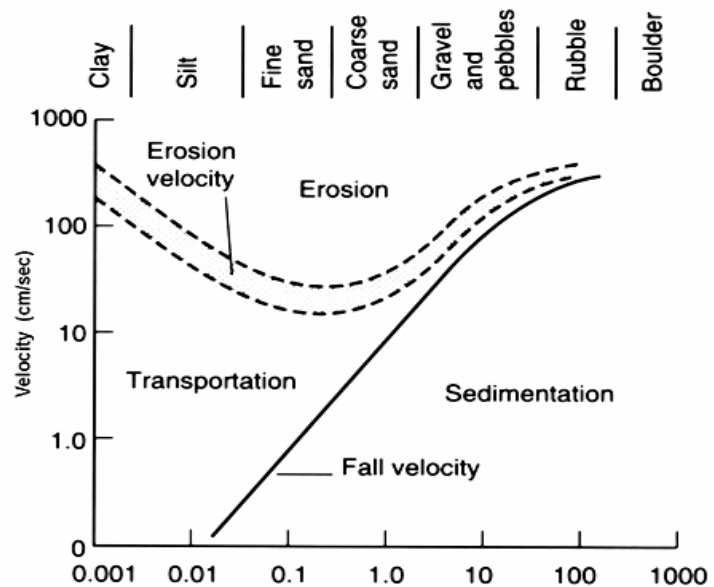


Figure 4-2 Average water velocities to erode, transport and deposit uniformly sorted particle sizes. Velocities between the dotted lines and higher will erode the indicated particle sizes. When velocities drop below the fall velocity line, there is insufficient energy to keep particles suspended in the water, so sedimentation occurs. Erosion velocities differ depending on the shape and bonding characteristics of the particles.

4.3.2.2 Stream Systems. As mentioned in our discussion of [watersheds](#), streams are formed when water flowing downhill concentrates and forms a channel. The volume of water, the velocity, or speed, of water flow, and the characteristics of the underlying material influence the size, shape, and path of the channel. Although the information in this section refers specifically to streams and stream channels, these processes also explain and describe the interactions between water and [sediment](#) in drainage ditches.

Flowing water picks up (erodes) material from the bottom (bed) and sides (banks) of the stream channel. This eroded material is called [sediment](#). The water's velocity determines how much material will be picked up, as larger sized particles, in general, require greater amounts of energy to erode or move them. Figure 4-2 shows the velocities necessary to erode, transport, and deposit uniformly sorted particle sizes. This figure also shows that clay sized particles require more velocity to erode than do larger, sand-sized particles. This is because electrical bonds associated with the clay particles help to hold them together, thus requiring more energy to pull this sticky material apart than to pick up the loose grains of the larger-sized sand.

The material that is eroded and carried by the water current is called suspended [sediment](#). If the material is too large to be fully suspended in the water, it may either

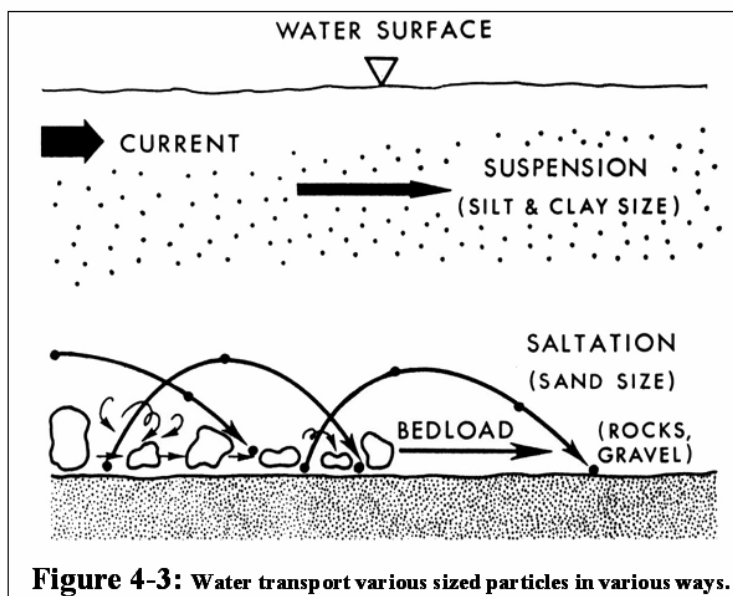


Figure 4-3: Water transport various sized particles in various ways.

bounce (saltation load) or roll along the bottom ([bed load](#)), as depicted in Figure 4-3. When water velocities slow (e.g., when a mountain stream leaves a hilly area and starts across a valley floor), larger, heavier particles are the first to drop out of suspension and are deposited on the bottom of the stream. As water velocities continue to slow, there is less energy to suspend particles, and finer and finer particles continue settling to the bottom. This process is called

[sedimentation](#). Because clay is the smallest and lightest particle, once the stickiness is overcome and the particles are suspended, they remain in suspension longer and travel further than any of the other particle sizes. It can even take several days or weeks for clay particles to settle from perfectly still water.

Stream channels are dynamic because [erosion](#) and deposition processes change their form and shape ([morphology](#)) over time. They change both their cross-sectional profile (width, depth, and slope) as well as their 'plan-view' path. It is important to note that stream paths are not fixed in place; stream channels often migrate sideways, either incrementally by eroding their banks or by carving whole new channels through low-

lying areas. These changes in the shape of the stream channel occur both site specifically as well as throughout the whole stream system.



4-07 Streams are constantly eroding, transporting, and depositing materials.

Natural channels are constantly eroding, transporting, and depositing materials. Normal daily flows tend to redistribute small amounts of materials within streams. Storm events, however, introduce large volumes of water in to the stream system, which can significantly alter the [morphology](#) of a river or stream by cutting new channels, eroding whole banks, and gouging out shallow river beds. [Sediment](#) generated during flooding from major storm events is often carried out of the channel by flooding waters, where it is deposited and stored on the floodplain.

These [sediments](#) enrich floodplain soils with nutrients, which enable plants to grow well in a floodplain environment. The plants and their roots also help to trap and hold the fine [sediments](#) in place. Over time, however, rainwater washing over the floodplain may erode and return some of this [sediment](#) to the stream.

As streams continue to erode, transport, and deposit materials, human activities anywhere within the [watershed](#) can interfere with these natural processes, creating conditions that alter habitat and disrupt the aquatic life that lives in the stream. For example, poor maintenance of a dirt or gravel road may cause excess [sediment](#) to wash into an adjacent stream. Excess [sediments](#) will be carried downstream until the water velocity slows and [sedimentation](#) occurs.

Individual streams are part of a network of channels that extend the whole length of a [watershed](#). Because networks extend from the top (highest elevation) of a [watershed](#) to its outlet (lowest elevation), changes in the headwaters of a stream can affect the entire network. For example, logging a hillside in the headwaters of a [watershed](#) can cause more storm water [runoff](#) to reach the stream at a faster rate than it ever has before (trees block water flow across the ground and help the water sink into the ground). This extra flow is added to the existing water and can lead to problems downstream. Suddenly the 24-inch [culvert](#) that you installed last year is no longer large enough to handle the extra volume of water, resulting in water backing up and flooding out the road. This extra volume of water can also cause additional bank [erosion](#) and the redistribution of [sediments](#) that destroy habitat and clog drainage facilities and bridges.

4.3.2.3 Hydrology. A major factor influencing stream systems is their source of water and its movements within the [watershed](#). [Hydrology](#) is simply the study of water distribution or movement within the [watershed](#). Precipitation landing within a [watershed](#) can enter the streams by two different pathways. The most obvious pathway is when surface [runoff](#) flows across the landscape directly into the stream system. The less

obvious route is when it seeps (infiltrates) into the ground, where it becomes groundwater. Groundwater flows through the pore spaces between soil and rock particles, and shallow groundwater near the surface may eventually drain into a stream channel. Water may also follow a combination of these pathways. For example, precipitation may flow as surface [runoff](#) down a hillside where it settles into a depression. In the depression, it may infiltrate into the ground and flow as groundwater into a stream.

The speed at which water flows through a [watershed](#) and enters a stream system helps shape the channel and the habitat found within the stream. Surface [runoff](#), especially after large storm events or when the ground is frozen, flows quickly over the land surface and enters the stream. This causes large amounts of water to enter the stream system within a short time period, exceeding the channel's capacity and resulting in flooding. Streams that receive a large portion of their water supply from surface [runoff](#) are susceptible to widely fluctuating water flows and levels. These fluctuating flows create a highly variable, stressful environment in which only specially adapted plants and animals may live.

Groundwater-fed streams have more stable flows and environments than surface fed streams. They fill slowly, accumulating groundwater as it makes its way through the tiny pore spaces in soil and rock. When large amounts of precipitation infiltrate into the ground and become groundwater, the surface [runoff](#) from the storm is drastically reduced. This water still may enter the stream system, but because it flows slowly through the ground, possibly taking days, weeks, or months to reach the stream, stream flows become more stable. More stable stream flows tend to result in more stable channel conditions and in turn, offers habitat for plant and animals that are adapted to these stable conditions.



4-08 Concentrated water flows cause many familiar maintenance problems.

Several landscape factors influence water flow across and through the landscape. As will be discussed further in our sections on [wetlands](#) and [upland](#) communities, a [watershed](#)'s vegetation usually slows the rate and decreases the volume of surface [runoff](#) by aiding infiltration of water into the ground. Plants are also able to diminish groundwater supplies by up taking water through their roots. Roads also influence water flow and can have a major impact on [watershed hydrology](#). By cutting across the landscape, roads block, constrict, and divert both surface and subsurface drainage patterns, artificially acting to collect and concentrate flows. These artificially concentrated flows cause many of our familiar road maintenance problems, including washouts, rutting, and flooding. Alterations in subsurface [hydrology](#) can also lead to soft spots in roads where additional concentrated water raises groundwater levels and

groundwater flow is blocked. These problems and others are discussed further and addressed elsewhere in this manual.



4-09 As turbidity increases, light penetration decreases.

4.3.2.4 Water Quality. Water in natural environments is not just pure water. As mentioned in the previous discussion on [watersheds](#), precipitation falls to earth where it moves over and beneath the ground's surface, down through the [watershed](#) and into the stream system. As the water moves through the [watershed](#), it picks up materials and transports these materials into the stream environment. Materials may be transported as suspended [sediment](#) or may become dissolved in the water and carried as dissolved load. The type and quantity of materials entering the stream system from

the [watershed](#) influence the overall quality of the water. This water quality is often evaluated by testing the water for specific chemical and physical characteristics, such as nitrogen, phosphorus, pH, dissolved oxygen, temperature, color, and [turbidity](#). [Turbidity](#) is the degree to which the passage of light through water is blocked by suspended [sediment](#), the cloudiness of the water.

Both the geology and the land use influence water quality. The rocks and soil in the underlying geology of a [watershed](#) have always influenced a basin's water. Rocks and soils add nutrients and minerals as well as filter excess materials from groundwater and surface [runoff](#). The type of natural vegetated cover and human uses of the land also influence a [watershed](#)'s water quality. Land uses such as roads, farming, construction, homes, industrial facilities, and urban areas have caused excessive materials to enter and harm stream systems. In particular, massive amounts of [sediment](#) have been eroded due to changes in land use over the past 200 years. These materials may either wash directly into the stream system or become bound to [sediment](#) particles and carried into the stream while attached to the [sediment](#). Both natural and artificial materials that wash into streams may include [sediment](#), fertilizers (nitrogen, phosphorus), animal wastes, human sewage, road salts, pesticides, herbicides, other chemicals, oil, and gasoline. The large number of roads crossing streams, unfortunately, has also provided opportunities to dump garbage, tires, appliances, and all sorts of other solid waste into our streams.

Water temperature is an especially important component of water quality for headwater streams. The temperature of the water in these headwater streams is largely influenced by the source of water. Groundwater-fed streams are fed by a relatively constant supply of cold water. Surface [runoff](#)-fed streams are fed by intermittent flows of water following storm events where the water flows across hot land in the summer and the cold (frozen) earth in the winter. These surface [runoff](#) streams have an irregular supply of water whose temperatures varies widely with ambient temperatures. Vegetation

along streams is also an important temperature influence because it helps to moderate water temperatures. In the summer, shading of streams by adjacent vegetation prevents warming, and in the winter months, forests can trap warmer air in valleys to delay cooling.



4-10 Life in a Stream

4.3.2.5 Stream Life. There are a wide variety (diversity) of organisms that utilize stream habitats, and each stream contains a mix of different species. This mix of species makes up the stream community. Types of organisms include plants, insects, crayfish, mollusks, fish, reptiles, amphibians, spiders, birds, and mammals. Some aquatic plants are microscopic and include things such as plankton and algae. Larger aquatic plants are very diverse, with some spending their life floating in the water, while others live by attaching to soil, rocks, or plants. Many different insects spend at least part of their

life cycle underwater (the larvae stage), including dragonflies, mayflies, stoneflies, caddisflies, beetles, and true flies (e.g., gnats, midges, black flies, horse flies, and crane flies). For example, mayflies live in the bottom of streams for a year before emerging as adults to reproduce and die within 2 to 3 days. Although numbers are swiftly declining, freshwater clams and mussels are important stream organisms. Streams can contain a wide diversity of fish, including minnows, sculpins, perch, trout, bass, and sunfish. Turtles (reptiles) and frogs (amphibians) are also found living in and near streams. Birds, such as herons, ducks, and hawks, frequently live along streams. Streams also provide habitat for mammals such as river otters, raccoons, deer, and beaver.

4.3.2.6 Stream Food Webs. All living organisms need a source of energy (food) to survive. In general, plants get their energy from the sun and produce their own food. Animals, on the other hand, get their energy from three different sources. One group of animals, the herbivores, gets their energy or food from the plants they eat. The second group of animals, the predators, eats other animals for their food energy. The third group are the decomposers, who get their energy from plant and animal remains. In stream systems, aquatic plants utilize sunlight and nutrients absorbed from the surrounding water and soil to help them grow. The energy found in aquatic plants, and sometimes more importantly energy from bank-side and [upland](#) vegetation ([outside inputs](#)), provides food for aquatic insects and some fish. While some fish and insects use plant material for food, many others are predators and gain their energy by eating other animals. This concept of who eats what and whom was originally known as a food chain, but biologists have realized that it is more complex than a simple chain of events. The interactions between who eats what is extremely interconnected and is more like a food web than a chain.



4-11 “Outside Inputs” are essential to a stream.

for other organisms, such as aquatic insects. Aquatic insects play a very large and important role in the aquatic food web. These insects are generally in their larvae stage of development. One group of insect larvae are grazers and wander around grazing and scraping algae and bacteria growing on the rocks and decomposing plant materials. Another group are shredders, tearing up and eating leaves and other plant material that has fallen into the stream. The filtering group strain small particles of suspended debris from the moving water. And finally, there are the predators (both larvae and adults) who eat other insects and small fish.

Fish are also important in the aquatic food web. Like the insects, fish have also become adapted to certain diets. Most stream fishes, like the trout, eat a variety of aquatic insects, while others, such as the northern pike, prey upon smaller fish for their survival. Other types of fish obtain their food from plants, decomposing material from the stream bottom, or are parasitic to other fish. All of this interaction of the various organisms illustrates the complexity of a stream food web.



4-12 Fish are an important part of the aquatic food web.

Stream systems also play an essential role in many terrestrial food webs. They provide vital habitat for creatures to catch food and obtain water. Many important, game and non-game species are directly dependent on the use of streams and the organisms within for survival. And we cannot forget that streams play a role in the human food web, as attested to by many anglers.

4.3.2.7 Outside Inputs. We need to further emphasize the importance of [outside inputs](#). Upper elevation streams are usually small, steep-sloped, fast moving streams.

These smaller headwater streams are less dependent upon materials generated within the stream and more dependent upon the outside source of nutrients and food to support aquatic life. Overhanging branches and bank-side vegetation serve as their primary source of nutrients. Leaves, branches, twigs, roots, and fruit fall into and are washed into the water and, as mentioned previously, become the basis for a food web in the stream. Thus, these [outside inputs](#) become vital to the health of the stream. The overhanging vegetation along the stream edges also shades the water so algae dependent on sunlight does not grow and is therefore not readily available as a food source for aquatic life. Shading also helps to moderate swings in temperature, which is an important benefit during hot summer days.



4-13 Clearing streambanks has many negative effects on streams.

with this traditional practice. These clean stream banks in fact shortchange the start of the food web, starving the entire system. In addition, without the vegetation to shade the stream, water temperature increases, and native organisms may not be able to tolerate this increased temperature. Clearing stream banks reduces the number of places for aquatic organisms to live because there are fewer roots and branches that extend over and into the stream. The bank side vegetation also helps slow the velocity of surface water and prevent [erosion](#) of the banks into the stream. Finally, without the vegetation along the stream to dissipate energy, trap [sediment](#) and floating branches and debris, this material can end up collecting and blocking openings of [culverts](#) and bridges or other drainage facilities. We will discuss alternative practices to the traditional stream bank cleaning in Chapter 6.

Human activities can interfere with this critical component of the food web by clearing vegetation from along the stream banks. Unfortunately, clearing stream banks has been a traditional form of stream bank maintenance. This practice was thought to be beneficial for a number of reasons, including that it cleared the floodway, improved drainage, was easy to maintain, and looked cleaner.

We now realize, however, that there are a number of problems associated

This manual focuses predominantly on these headwater types of streams as they are the most likely streams to interact with dirt and gravel roads. Impacts to these streams, however, which serve as a source of water, [sediments](#), nutrients and biological organisms for the stream system, can and will impact the larger downhill streams into which they run.

4.3.2.8 Stream Habitat. Each plant and animal species needs a certain set of physical and biological conditions to survive. The area within the stream where these conditions are present is the organism's habitat. Stream organisms have adapted to these conditions and subsequently have become dependent upon these habitat conditions for

survival. If one or more of these factors are missing, then the organisms dependent on those factors will have a harder time surviving. If the change is too great, the organism will die.

The suitability of the habitat also influences the abundance of a species. Abundance is critical because organisms need to be able to find mates to reproduce. If members of the same species are not abundant, fewer offspring will be produced, starting a downward population spiral. A decline of a species is significant for two reasons. First, as a living organism each individual and species has an inherent value. Second, declining populations of a species may upset delicate food webs by creating shortages for other species dependent on them for food, creating an imbalance in those populations, further disrupting the entire stream ecosystem.

4.3.3 Stream Management and Protection Goals. Streams are viewed as a public natural resource and, as such, are protected under various federal, state, and local laws and regulations in addition to many state constitutions. This protection covers the purity (quality) of the water as well as the organisms living in the stream. To this end, one of the primary goals of managing and protecting streams is to maintain a healthy and naturally producing fish community. Natural reproduction of fish is an important goal, and fish are dependent upon a clean, healthy stream environment in which to live. The lack of a naturally reproducing fish community is often an indication that conditions within the stream have degraded.

4.3.3.1 Indicator Species and Community Composition. Effective stream systems management requires some kind of indicator to help managers measure conditions within the stream. Although stream biologists have a wide range of tools and tests that can be performed to help measure stream health, stream [ecology](#) is a complex science. Stream ecologists have a strong understanding of the processes and interactions that take place in streams, but there is still much to be learned about these systems. Biologists have learned that instead of trying to monitor all the conditions that organisms require to survive, they can monitor the population of certain existing species and the community composition within the stream environment. These [indicator species](#) are sensitive to changes within the stream system, and if one of their habitat and resource needs is impacted, then changes in species abundance will indicate to biologists that something is wrong within the stream. Thus, [indicator species](#) are analyzed in the context of the overall abundance of organisms in assessing the condition of the aquatic system.

Trout are frequently used as an [indicator species](#) within headwater streams because, as a top predator, their survival is dependent upon a broad range of stream components. Some of the habitat needs of



4-14 Trout is a water quality indicator species.
(Photo courtesy of Trout Unlimited)

trout include cool, clean, well-oxygenated water, suitable invertebrate food sources, cover to hide from other predators and to rest, and spawning sites with gravel beds.

The life cycle of trout is important for their selection as an [indicator species](#). If we look at the brook trout as a common primary species, these trout use their tails to dig nests in gravel streambeds in October and November of each year. The eggs are deposited and then fertilized before they are covered over with loose gravel. These nests need large amounts of cool, clear water flowing through the gravel as it supplies the eggs with oxygen dissolved in the water and carries away waste products produced by the developing eggs, as illustrated in Figure 4-4. This is a critical period for the new trout population because [sediment](#) deposition at this point can smother and kill the entire year-class of fish. If all goes well, these eggs will then hatch in March and April.

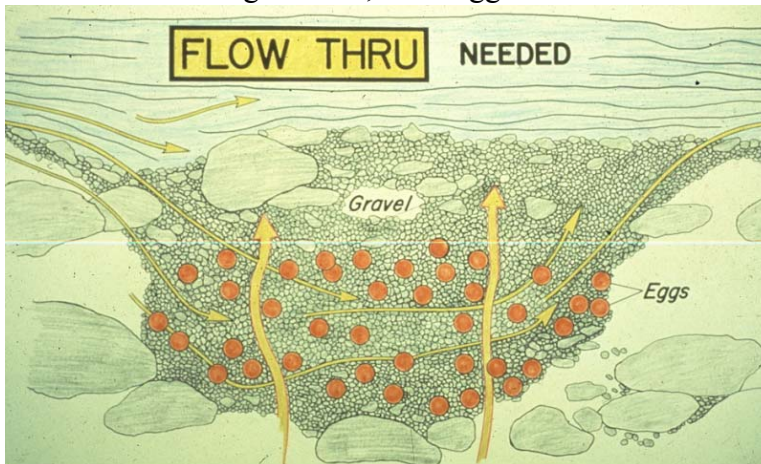



Figure 4-4: Trout eggs need clean flowing water for oxygen

Once the eggs hatch, the trout are initially called sac-fry because they carry their first month's supply of food in an attached yolk sac. At first, this yolk sac is quite large in relation to the size of the fish, which limits the ability of the sac-fry to move about and escape predation. The yolk sac is gradually absorbed during the first


month of the fish's life. After the yolk sac has been absorbed, the trout are then called fingerlings. These fingerlings are increasingly mobile and look for minute particles of food. Fingerlings will grow as juvenile trout until they reach sexual maturity at about one to three years of age. Maturity typically corresponds to about 8 inches in length, but depends on environmental factors such as food supply and stress.

Hatching trout fry are typically abundant, but because of the harsh competitive stream environment, less than one percent of the hatched fry will live longer than one year. As will be further discussed, [sediment](#) is one of the major environmental factors that decimate the newly hatched young of the year's trout population. Once past this one-year milestone, the death rate of young trout declines sharply because the older and larger trout are better equipped to survive.


Trout's Life Cycle



Trout spawn: Oct – Nov
Eggs hatch: Mar-April into Sac Fry



Newly hatched Sac Fry are very immobile



Sac absorbed & fry become Fingerlings, can now swim around

4-15 A Trout's Life Cycle

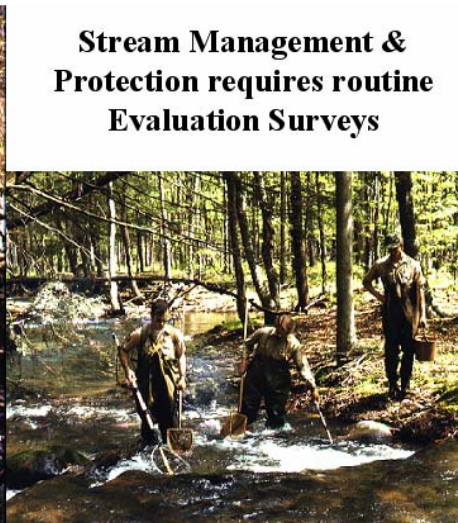
If done improperly, the initial grading of dirt and gravel roads in the spring time with the possible resulting [sediment](#) can totally wipe out an entire one year's population of newly hatched sac-fry trout for a nearby stream.



4-16 The stonefly larva is another indicator species.

Other useful [indicator species](#) of stream health are the “[macroinvertebrates](#)” such as stoneflies, mayflies, and caddisflies. Some of the stonefly species are particularly sensitive to changes in water quality and methods have been developed to use these insects to evaluate stream health. In general, the public is less aware of the importance of stoneflies and other [macroinvertebrates](#) as [indicator species](#) for a healthy stream because they are harder to identify and are definitely less charismatic and less tasty than trout.

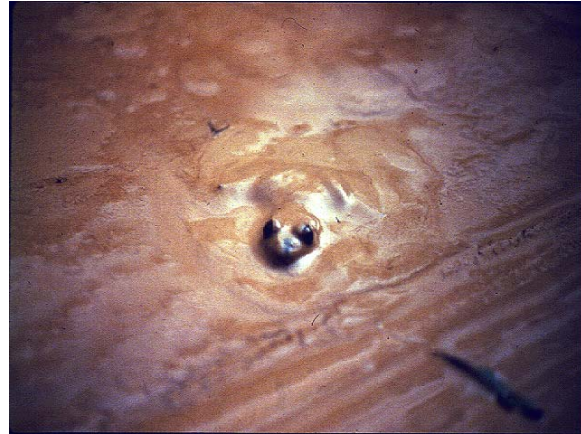
4.3.3.2 Stream Evaluation. State environmental agencies routinely monitor streams to ensure water quality and overall stream health. These agencies conduct biological and chemical surveys in an attempt to measure habitat conditions and see what pieces of the food web are present. This generally involves various techniques such as the use of electro-fishing gear to shock and temporarily stun fish, which are then collected, identified, measured, weighed, counted, and released. Various methods are used to collect, count, and identify invertebrates living in the streambed, floating in the water, and hiding in the vegetation. Data collected from these surveys are then analyzed and used to make management decisions.



Stream Management & Protection requires routine Evaluation Surveys

4.3.4 Impact of Erosion and Sediment on Streams. Excessive [erosion](#) impacts streams in a number of ways. Many of the physical effects, such as bank [erosion](#) and channel migration, have been discussed in Section 4.3.2. [Sediment](#) generated from this excess [erosion](#), however, critically harms the stream system as will be discussed here.

As we stated earlier, [sediment](#) in stream systems occurs naturally. Although these natural occurrences can be devastating, stream channels and stream life are more adapted to these natural influxes of [sediment](#) and can usually recover appropriately. It is the excessive amounts of [sediment](#) and selective particle types and sizes (commonly fine silt and clay) that end up in stream systems as a result of human activities that disrupt the stream ecosystem beyond their ability to recover. These disruptions can cause the original habitat to become unsustainable for the native organisms. These organisms will either die off or move to more suitable habitat. As the former occupants vacate this new habitat, new organisms that prefer the altered habitat will take over. The original nature and character of the stream will have been altered, perhaps changing the stream from a high-quality trout stream to a less valuable and productive stream polluted with what sportsmen call “trash” fish.



4-18 Excessive sediment causes distress for the stream’s inhabitants.

Timing of [sediment](#) and [erosion](#) events is not spread evenly over the course of a year. These events are highly seasonal, with heavy rains and stream flows coinciding with spring construction and road maintenance activities. This combination of events leads to a large percentage of the year’s total [sediment](#) ending up in stream systems within a short time period during these spring months. During other times of the year, generally drier weather conditions and better established vegetation that is able to hold soils in place or filter [sediment](#) from [runoff](#), result in less [erosion](#) and [sediment](#) into the streams. Although not always practical, shifting human activities (ditch and bank repair) from the spring to the summer or fall months can significantly reduce the [sediment](#) pollution entering streams.

However, even modest amounts of [sediment](#) entering streams during periods of drought or low-flows may cause problems. During drier periods, many streams are subject to low-flow conditions, with water only present in the deepest part of the stream channel. Summer storms can cause flash flooding and sudden influxes of [sediment](#) from disturbed earth into the stream. These floodwaters can quickly recede, leaving water levels low, with much of the [sediment](#) recently being left behind in the deeper parts of the channel. These [sediment](#)s remain for longer periods and reduce living space for aquatic organisms. This can be a real problem because it occurs at a time when water temperatures and other conditions are also very stressful.

4.3.4.1 Suspended Sediment (Turbidity). Earlier in this chapter we talked about suspended [sediment](#) and the fact that fine particles stay suspended for much longer periods of time than larger particles, and clay can stay suspended for days and weeks in still water. Once [sediment](#) is suspended in the water, it interferes with the habitat needs of both plants and animals. For plants, the [sediment](#) particles suspended in the water increase the [turbidity](#) of the water, blocking light as well as decreasing the depth to which light penetrates. Decreasing light, the source of energy for plants, results in less food production for plants and less plant growth. With less plant growth, there is less food available at the bottom levels of the food web. This food shortage can cascade through the food web, resulting in less food for top predators like the trout.



4-19 Suspended sediment interferes with both plants and animals within the stream.

Suspended [sediment](#) also impacts the aquatic insects and fish directly. Many fish and insects rely on their vision to detect prey and help avoid predators. As the suspended [sediment](#) decreases the visibility through the water, organisms will find less food and have a decreased ability to avoid being eaten. Fish and many types of insects breathe underwater by using gills to gather dissolved oxygen from the water. Gills are sensitive organs and suspended [sediment](#) can clog them, making it harder for the fish to breathe. Gills are also subject to abrasion from [sediment](#) particles. [Sediments](#) are particularly harmful to the relatively immobile sac-fry. These physical impacts to aquatic organisms are likely to make it harder for the individuals to find food, eat, and grow normally. With abnormal growth, organisms do not have the energy to fight off disease or to reproduce.

4.3.4.2 Sedimentation (Embeddedness). As water velocities slow within the stream environment, [sedimentation](#) occurs. The primary impact of excess [sediment](#) in the channel is the altering of habitat. The [sediment](#) settles down into the nooks and crannies between the gravel and rock substrate. Insects and small fish need these spaces to graze algae, hide from predators, hunt prey, and as shelter from the faster flowing currents above. Filling in these spaces with



4-20 Embeddedness refers to the sediment filling in all the nooks and crannies in the streambed.



4-21 Contaminants attached to sediment particles further degrades water quality.

[sediment](#) reduces the amount of living space available. Some plants and animals may also be buried and suffocate. [Sedimentation](#) is particularly harmful to trout reproduction because it kills the eggs while they are incubating in the gravel nests over the winter months.

This filling in of the nooks and crannies in a gravel streambed by [sediment](#) is referred to as [embeddedness](#). A typical trout stream is usually about 30% embedded, while one that is completely buried by [sediment](#) would be described as being 100% embedded.

4.3.4.3 Attached Contaminants: Another impact of [sediment](#) on streams stems from the materials such as road salt, fertilizers, pesticides, oils, greases, and other toxic compounds that are often attached to the [sediment](#) particles. Once in the water, these attached compounds may degrade water quality.

4.3.5 Fish Constituency: Fish, unlike many other organisms in the stream



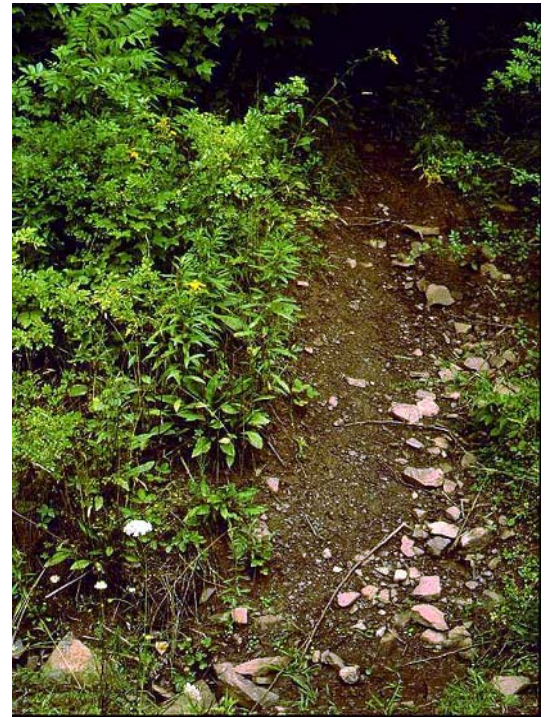
4-22 Anglers are avid fish advocates and can be a positive resource.

environment, are unique in that they have advocates who represent them – the sport fishermen. Angler groups have organized at the local, state, and national levels, where they effectively lobby for government action. These groups, such as Trout Unlimited and B.A.S.S. (Bass Angler Sportsmen’s Society), act as watchdogs to protect their fishing interests and aquatic resources. These groups can be a source of positive support for local governments or can make life difficult if inappropriate actions threaten our aquatic resources.

interests, they frequently create and use stream access points, footpaths, and car pull-offs. These places can often become a source of [erosion](#) and [sediment](#) or even interfere with [erosion](#) control measures that local governments have already put in place.

Anglers, however, do not always have a positive impact on the stream ecosystem. In their efforts to pursue their

Just as when dealing with any group of stakeholders, whether they are landowners, businesses, environmental groups, or angler organizations, the most effective approach is to collaborate, or work together. Collaboration between local governments and angler groups offers tremendous potential. If these stakeholders are included in the decision-making processes, they may be able to add constructive and helpful suggestions, provide resources to aid projects in the form of funds, materials or people, and positively influence other groups, agencies or elected officials as needed. Many of these groups have vast volunteer resources that can be tapped for construction and maintenance projects. It is also an additional opportunity for the community to become more knowledgeable about road maintenance concerns, activities and budgetary limitations.



4-23 Anglers can also have negative effects on stream ecology as stream access points, car pull-offs, and footpaths become erosion sources.

4.3.6 Stream Ecosystem Summary. Streams are an important natural resource. Stream communities are dependent upon the types of physical and biological habitat present within the stream system. Stream flows and water quality conditions shape this habitat and are strongly influenced by both the [watershed](#)'s underlying geology and land use. Trout and [macroinvertebrates](#), such as stoneflies, are considered good indicators of the health and quality of our headwater streams, as they are sensitive species dependent upon a number of factors that are likely to be impacted by adverse conditions within the stream system. Human activities, such as road maintenance, construction, logging, agriculture, development, and industry, can threaten the health of our streams and the organisms that live there. Excessive [erosion](#) and [sediment](#) from dirt and gravel roads is one of the primary threats to our streams, altering the entire stream ecosystem. Collaboration with stakeholders, such as anglers, farmers, and landowners, can help alleviate some of the problems and benefit local government in a variety of ways, especially in helping in the planning, construction, and maintenance of environmentally sensitive practices and projects.



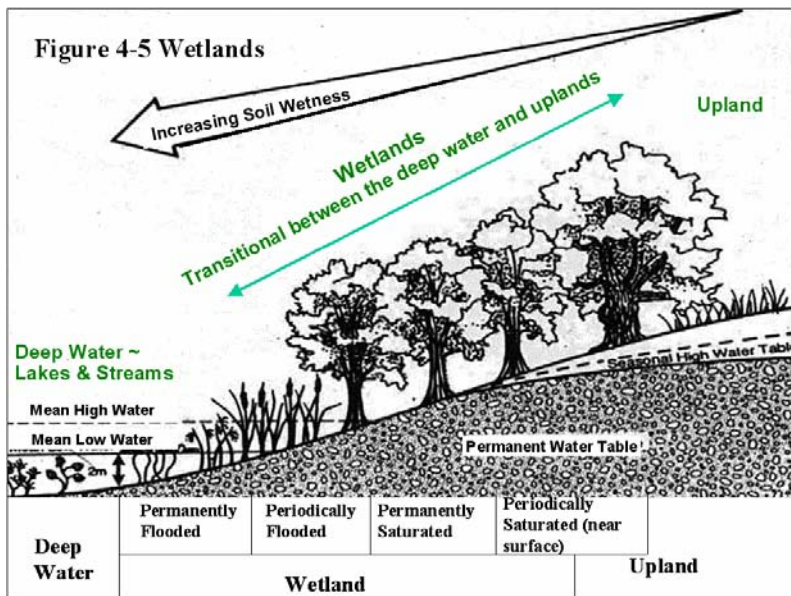
4-24 Wetlands are important ecosystems.

4.4 The Wetland Ecosystem (Community)

4.4.1 Introduction: The [wetland](#) ecosystem or community is an important one, with [wetlands](#) currently covering over one hundred million acres of land in the lower 48 states. Although the word "[wetland](#)" seems to conjure up visions of wasteland swamps inhabited by undesirable

creatures or fears of stifling regulations, [wetlands](#) provide valuable services and functions that are beneficial to both humans and the environment. This section will define and describe [wetlands](#), discuss the history of management, regulations and [wetland](#) loss, introduce the valuable benefits derived from [wetlands](#), and help road managers recognize [wetland](#) areas in order to avoid conflicts with existing regulations.

4.4.2 Definition of a Wetland: Under the Federal Clean Water Act, a [wetland](#) is defined as “those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.”



Simply put, a [wetland](#) is an area that meets a certain set of soil, plant, and moisture requirements. So there are three basic characteristics common to all [wetlands](#):

- a) For at least part of the year, water must be present at or near the ground’s surface.
- b) Plants must be adapted for wet soil conditions.
- c) Soil types must have developed under saturated conditions.

[Wetlands](#) are often the transitional area between the deep water and the [uplands](#) and can include permanently flooded areas to periodically flooded areas to permanently saturated areas to periodically saturated areas, as depicted in Figure 4-5.

4.4.3 Wetland Basics. A number of environmental factors affect these three [wetland](#) characteristics. For example, the amount of water found within a [wetland](#) can be influenced by either surface water or groundwater. The source of water plays an important role in providing outside nutrients to [wetland](#) systems. The underlying geology and [topography](#) of the landscape can influence the location and formation of [wetlands](#). Geology also dictates the rock types that serve as parent material for the initial [wetland](#) soils. These mineral soils, however, are often buried under thick layers of organic peat and muck common to many types of [wetlands](#). These moisture and soil factors, in addition to climate characteristics, directly influence the types of vegetation that are present within the [wetland](#). The water in a [wetland](#) is directly responsible for forming the hydric soils.

A hydric soil forms when soil is saturated with water for extended time periods. There are a number of biological and chemical processes that take place in soil that influence its formation and the types of plants that it is able to support. In drier soils, oxygen is typically abundant and leads to the formation of [upland](#) soils. When soils are saturated, however, natural processes deplete oxygen from the soil and produce very different [wetland](#) soils. Many [wetland](#) soils also have a much higher percentage of organic matter (decaying plant and animal life, etc.) than do [upland](#) soils, a factor that greatly increases the availability of nutrients and food for many [wetland](#) plants and animals. These hydric soils also have visible characteristics making them readily identifiable. Hydric soils mark [wetlands](#); recognize the soil and you identify a [wetland](#). The details of [wetland](#) recognition will be discussed later.

[Wetland](#) plants are those plants that have adapted to life under wet conditions. These plants have taken on a wide range of forms, from pond lilies to trees, in order to take advantage of the many different types of wet habitat. The major difference between these wet habitats is the variation in the amount or depth of water, which changes along an elevation and moisture gradient. For example, pond lilies can only grow in three to four feet of water, while red maples only tolerate periodic saturation. The moisture conditions within each of these habitats fluctuate according to seasons and weather patterns from year to year, with some locations wetter during the winter and spring months than during the warmer months. This variation in moisture or water levels is important because many of the [wetland](#) plants, especially grasses and herbs, require drier periods to produce seeds and germinate. Additionally, just as with stream systems, the variability of conditions within each habitat helps maintain a broader mix (diversity) of plant and animal species.

The presence of [wetlands](#) is dependent upon a delicate balance between the right soil, water, and vegetation characteristics. While natural variation within a [wetland](#) is normal and desirable, human induced disturbances can disrupt [wetlands](#) beyond their ability to recover. Human activities near [wetlands](#) may alter the flow of water into and out of [wetlands](#), and/or lead to excessive inputs of [sediment](#), nutrients, and chemicals. Care should be taken while conducting road construction and maintenance activities to prevent both short- and long-term impacts to these delicate [ecosystems](#). It is important to note that [wetland ecosystems](#) are protected by stringent state and federal laws that restrict activities in and around these areas, as will be discussed in Subsection 4.4.4.2.

4.4.4 Wetland Management. Historically, as mentioned, [wetland](#) areas have received a bad reputation as dismal, disease-ridden, unproductive wastelands. As early as the Swamp Land Act of 1849, Congress encouraged draining and filling [wetlands](#) for development. Since then, in the name of progress, amazing efforts were put forth to drain and fill vast marshes and swamps to give these lands a purpose. These former [wetlands](#) were converted for residential, agricultural, and industrial uses.

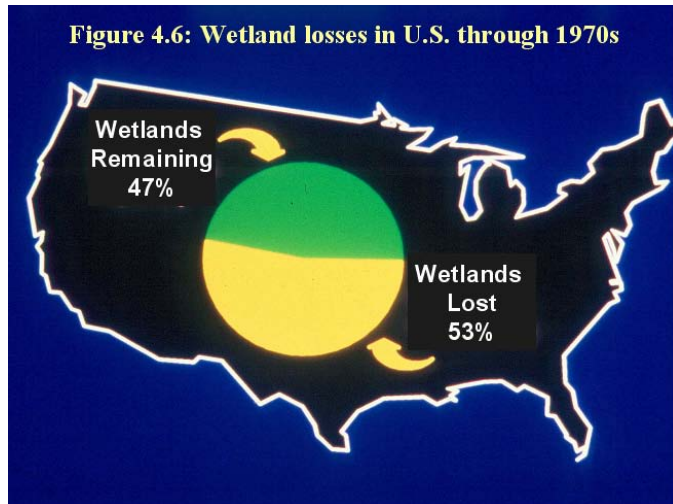
These negative attitudes towards [wetlands](#), however, have begun to change over the last several decades. We now realize that [wetlands](#) provide many physical, mechanical, and biological benefits that are useful not only to the natural environment,

but to humans as well. Consequently, we have begun to protect [wetlands](#) and even replace some of the ones that have been lost to development. So the management of [wetlands](#) has come full circle over the last century. Undisturbed [wetlands](#) are now viewed as very productive, valuable natural resources for many reasons as will be reviewed in Subsection 4.4.5.

4.4.4.1 Wetland Loss.

Over half of our original [wetlands](#) in the United States have been drained and converted to other uses. Major [wetland](#) losses occurred from the mid 1950s to the mid 1970s, with the rate of loss decreasing since then. Various factors have contributed toward this decline in [wetland](#) loss including the adoption of [wetland](#) protection laws and regulations.

“Public education and outreach about the value and functions of [wetlands](#), private land initiatives, coastal monitoring and protection programs, and [wetland](#) restoration and creation actions have also helped reduce overall [wetland](#) losses,” according to the U.S. Environmental Protection Agency.



We now understand that [wetlands](#) provide many beneficial services and host the most productive habitats on earth. [Wetlands](#), however, can be harmed by many different human activities including draining, dredging, stream channelization, filling, diking and damming, logging, mining, tilling for crops, and miscellaneous pollution discharges. The conversion of [wetlands](#) for development and agricultural purposes has probably resulted in the largest loss of [wetlands](#). The loss of [wetlands](#) results in a loss of all the benefits derived from them. And all [wetlands](#) are important, no matter what size, location, or quality.

4.4.4.2 Regulatory Protection. The regulatory protection of [wetlands](#) began early in the 1900s when people began to recognize their value as breeding and fishing habitat for waterfowl. One of the early protection measures was the establishment of many National Wildlife Refuges in which [wetland](#) habitat was protected and enhanced for waterfowl and other water birds. During the years since this initial recognition of the wildlife value of [wetlands](#), scientists, policy makers, and the public have also realized that [wetlands](#) provide society with many other benefits.

In the 1960s and 1970s, both the federal and state governments began to enact laws that protected [wetlands](#). There are a number of federal agencies that work to protect our [wetland](#) resources, including the Army Corp of Engineers, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. D.A. Natural Resources Conservation Service, along with the corresponding state and local agencies. This list of agencies represents a broad spectrum of program areas, ranging from navigation to water

quality and from wildlife management to soil conservation. This spectrum thus represents the complex array of issues associated with the protection of [wetlands](#) and each agency is responsible for portions of our federal and states [wetland](#) regulations.

The regulatory environment at the time these [wetland](#) laws were enacted utilized the permitting process as a major tool to protect [wetlands](#). This system of permits remains in place today. The permitting process is not intended to stop work activities; rather, it is designed to help people learn about [wetland](#) benefits as well as methods to lessen the impact of their activities on these important natural resources. In essence, permits are agreements between regulatory agencies and applicants governing work activities in and near [wetland](#) areas and outline necessary protection measures. Permits limit the loss of [wetland](#) area and help protect existing [wetlands](#) from excessive [erosion](#) and [sedimentation](#), disruption of [wetland hydrology](#), and pollution from sources such as mine acid drainage, toxic substances, and nutrient [runoff](#). When necessary, permits also provide regulatory agencies with a basis for levying fines and forcing remedial action against those who have failed to live up to the permit's terms.

These regulatory agencies also have procedures for dealing with people who either intentionally or unintentionally harm these valuable natural resources. Local governments and road managers cannot afford to be ignorant about the value of these resources, since ignorance is not a defense against the penalties that may be imposed. The replacement, or [mitigation](#), of [wetlands](#) is an expensive prospect, with engineering, land purchases, construction, and operational costs reaching into many thousands of dollars per acre.

[Wetlands](#) are also protected by many private groups. Conservation groups acquire land and provide education and volunteers at local, state, and national levels. Several major conservation organizations include The Nature Conservancy, Ducks Unlimited, the National Audubon Society, and the National Wildlife Federation. While these groups do not have the authority to develop their own regulations, they are considered “watchdog” groups and actively advise regulatory agencies of possible violations. Many of these groups also purchase property to protect and preserve sensitive habitat and /or species. Litigation is likely to be a possible response in a case where one of these properties is threatened by off-site sources of disturbance.

4.4.5 Wetland Benefits. Many valuable benefits are associated with [wetlands](#). It is important, therefore, to become familiar with these benefits so that we can take a common sense approach when dealing with roads and [wetlands](#). The following subsections describe the major benefits derived from our [wetlands](#).

4.4.5.1 Floodwater

Storage. A significant [wetland](#) benefit is the role that they play in floodwater storage. Since many [wetlands](#) form in low-lying areas, they are often the first areas to receive water when surface water [runoff](#) fills the streams to overflow their banks. The vegetation in these [wetland](#) areas slows the movement of the floodwaters, which are temporarily adsorbed, or held back, by the [wetland](#). The [wetland](#) acts like a sponge, holding the excess storm water. As time passes, water is slowly released



4-25 Wetland flood storage, a definite benefit

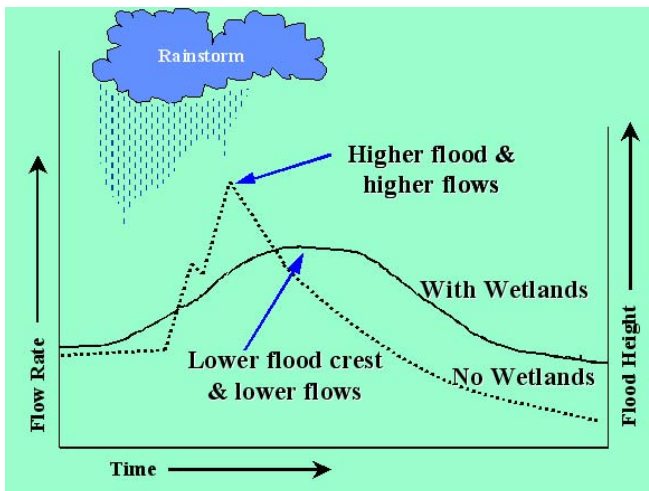


Figure 4-7 Hydrograph

from its temporary storage within the [wetland](#) and drains either into the ground to become groundwater or back into the stream network. An engineer's "hydrograph" shown in Figure 4-7, which depicts the amount of flow during a storm time period, illustrates the flood storage benefit of [wetlands](#). The [wetlands](#) spread out the flow of water into the stream over a longer period, decreasing flood flows and the peak flood flow that would occur without the [wetland](#). Thus, with less water to overwhelm the stream channel, the height of floodwaters and the area flooded will be reduced.

The Charles River in Massachusetts serves as a good example of the beneficial use of [wetlands](#) for floodwater storage. The Charles River [watershed](#) has approximately 8,400 acres (13 square miles) of [wetlands](#) located in the river's floodplain. The lower portion of the river flows right through Boston, posing a serious flood threat to the city. In the early 1970's, the U.S. Army Corps of Engineers studied flood control options to protect Boston. The Corps found that the [wetlands](#) were so effective at storing floodwater that the best flood protection option was to purchase the floodplain [wetlands](#) instead of building structural flood controls, such as levees and detention basins, saving millions of dollars in construction over and above the purchase of the [wetlands](#).

[Wetland](#) preservation can thus provide a level of flood control which would otherwise have to be provided by expensive structural facilities and/or dredging

operations. As another example, the bottomland hardwood-riparian [wetlands](#) along the Mississippi River once stored at least 60 days of floodwater, but, because of [wetland](#) loss due to filling and draining, they now only store 12 days' worth. (U.S. EPA)



4-26 Bank stabilization/ shoreline protection - another wetland benefit.

these soils can significantly impact stream systems, as discussed in the previous section on The Stream Ecosystem.

4.4.5.3 Energy Dissipation.

[Wetland](#) vegetation also helps reduce [erosion](#) by providing resistance to moving water currents and waves. The vegetation slows the flow of water as it is spread out over the [wetland](#) and dissipates its energy. Although vegetation is not able to stop all of the [erosion](#) associated with water currents, it can drastically reduce the impact by reducing the velocity of the water by up to 90%.



4.4.5.2 Bank Stabilization (Shoreline Protection). [Wetland](#)

plants typically help stabilize stream banks and shorelines. Both emergent plants, which grow up out of the water, and woody [wetland](#) vegetation have a complex root system that helps hold the plants in place in the soft, wet soils. This extensive root structure also helps to keep the soils in place. In areas where shoreline vegetation has been removed, water currents can swiftly erode the exposed soils. Once eroded,



4-27 Sediment study being conducted in a wetland.



4-28 Do NOT use wetlands as sediment traps!

4.4.5.4 Sediment Trapping.

Many [wetlands](#), especially those located along the edges of rivers and streams, act as natural [sediment](#) traps. As the water slows from spreading out over the [wetlands](#) and meeting the flow resistance of vegetation, the flow energy becomes insufficient to carry the suspended [sediment](#), and the larger and heavier particles begin to

settle out. The accumulation of [sediment](#) within [wetlands](#) is a naturally occurring process, and each [wetland](#) has its own [sedimentation](#) rate. For, example, one particular [wetland](#) may have two inches of [sediment](#) deposited each year, while another [wetland](#) may typically receive only a quarter of that amount. Studies are conducted to determine the amount of [sediment](#) received by [wetlands](#).

This natural [sediment](#) trapping [wetland](#) function does not mean that [wetlands](#) should be used as [sediment](#) collection basins. Human activities can seriously increase the natural [sedimentation](#) rate and when [wetlands](#) fill in, many of the associated benefits are lost.

4.4.5.5 Water Quality Improvement. [Wetlands](#) play an important role in improving and maintaining water quality. As mentioned previously, vegetation helps to filter [sediment](#)s from the water, making the water cleaner and better able to transmit light to underwater plants. These [sediment](#)s are often nutrient rich, which supports the growth of [wetland](#) plants. Materials dissolved in the water also provide a source of nutrients for [wetland](#) plants, as well as microorganisms within the soil.

Unfortunately, just as with stream systems, the water quality associated with [wetlands](#) is frequently harmed by excess nutrients and chemicals from agricultural and urban [runoff](#) and other human activities. These compounds can be dissolved in the [runoff](#) or attached to the [sediment](#) particles in the [runoff](#). Many of these compounds are filtered from the water by [wetlands](#) plants and are even transformed from toxic compounds into harmless compounds. Many [wetlands](#), however, must still process the materials that naturally end up within their boundaries, and excessive materials coming from human sources can easily overwhelm a [wetland](#)'s ability to improve the water quality.



4-29 Wetlands serve as “riparian buffers”

[Wetlands](#) also serve as “[riparian buffers](#)” for streams and rivers. The term riparian refers to the portion of the landscape that is located immediately beside the stream or river, while the term buffer refers to a type of filter or barrier. Simply stated, a [riparian buffer](#) is any strip of vegetation left intact along a stream or river that can filter out excess [sediment](#), nutrients and chemicals from [runoff](#) before the [runoff](#) enters the stream.

It is important to note that not all [riparian buffers](#) are [wetlands](#) because buffers can be constructed in [upland](#) areas and contain non-[wetland](#) plants. One type of buffer, vegetated filter strips, will be covered in Chapter 5.

4.4.5.6 Ecological Benefits. [Wetlands](#) possess a unique combination of physical and chemical conditions that provide ideal habitat for a diverse mix of plants and animals. Many of these [wetland](#) organisms have adapted to the unique conditions within [wetlands](#); and if the [wetlands](#) are lost, then so are the dependent species that may not be able to survive in any other type of habitat. More than one third of the threatened and endangered species in the United States live only in [wetland](#)s. Additionally, many other animals and plants depend on [wetland](#)s for survival.



4-30 Wetlands provide vital habitat for a diverse mix of plants, including threatened and endangered species.

[Wetlands](#) offer numerous habitat benefits to insects, amphibians, fish, and birds alike. The thick [wetland](#) vegetation provides shelter from the elements as well as cover to hide from predators. [Wetlands](#) provide habitat for reproduction and developing young for many different terrestrial and aquatic species. The plant material within the [wetland](#) also serves as building material for nests and other types of homes. [Wetlands](#) provide required habitat for one third of the resident bird population in the United States. [Wetlands](#) provide vital habitat for amphibians such as frogs and salamanders, particularly the small



4-31 Wetlands provide Wildlife Habitat: Fish, amphibians, birds, animals. 1/3 U.S. resident bird species dependent on wetlands, especially important for waterfowl.



forested [wetlands](#), which are only wet during the spring months.

[Wetlands](#) also play an important role in the food web. [Wetland](#) vegetation serves as a source of plant material that is eaten by insects, fish, birds, and mammals. These animals, in turn, provide food for the predators. When [wetland](#) plants and animals die, their remains break down and decompose, where their nutrients replenish the [wetland](#) soils and provide nourishment for additional plant growth.

4.4.5.7 Economic and Social Benefits. Many of the plant and wildlife species that utilize [wetlands](#) are economically valuable. [Wetlands](#) are home for many commercially important plant species, such as blueberries and cranberries. Bass and other game fish grow and hunt among the [wetland](#) vegetation, which also provides critical nesting habitat for most of our waterfowl.

Groups such as Ducks Unlimited were among the first to recognize the importance of [wetland](#) habitat to ducks and geese. Because of this group's efforts, many thousands of [wetland](#) acres have been protected and restored.

One of the most important benefits of [wetland](#) habitat is their use by migratory species. Migratory animals, such as fish, waterfowl and other birds, and insects, use [wetlands](#) as places to temporarily rest and replenish food reserves on their long journeys. Many of the [wetlands](#) used by migratory animals are relatively small in size, but not in their importance to serve as sanctuaries in our increasingly developed landscape. Because many of these [wetland](#) sanctuaries are not large or easily identified, there is a danger that little patches of [wetlands](#) will be lost as a result of road maintenance practices and decisions.

[Wetlands](#) provide a number of social benefits and opportunities to those who live in and near communities with [wetlands](#). These benefits are largely social in nature, however; just as with stream systems, many of these social benefits also help to support local economies. These economic benefits stem, either directly through creating demand for education or recreation related jobs and services, or indirectly through related spending for gas, lodging, and meals.

[Wetlands](#) provide great locations to educate children and adults on a number of different topics. [Wetlands](#) provide space that can be used as outdoor classrooms for teaching biology, [ecology](#), natural history, photography, bird watching, painting, arts and crafts, hunting, fishing, trapping, and many other topics and activities.



**4-32
Wetlands
provide
many
social and
economic
benefits**

- Education
- Recreation
- Bird Watching
- Hunting
- Fishing
- Photography
- Painting



4.4.6 Types of Wetlands.

There are several systems for classifying [wetland](#) types, and each has its own merits. For our purposes, and ease of recognition in the field, we will discuss a system that divides [wetlands](#) into three different categories or types. These three types are classified based upon where they are located in the landscape and are more closely associated with the road environments in the forested areas that are the focus of this manual. Some [wetlands](#) form in depressions, some form on slopes, while others form along floodplains.

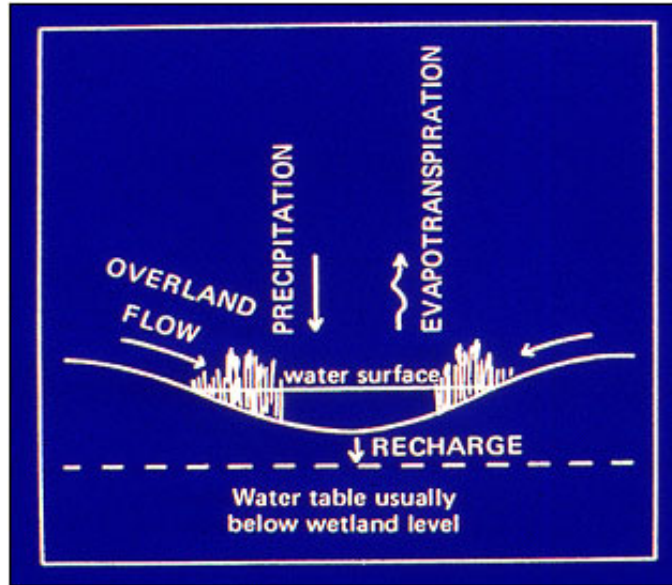


Figure 4-8: Depression Wetland

Depression [wetlands](#) form in low lying, bowl-shaped areas. Water enters these [wetlands](#) from surface water sources and sometimes ground water sources as well. Figure 4-8 illustrates that these



4-33 Depression Wetland (Vernal Pool)

into the soil. In forested areas, these “vernal pools” are a prime habitat for a diverse population of amphibians.

[Wetlands](#) that form in these depressions are often the most vulnerable to [sedimentation](#) caused by human activities because it is difficult for the [sediment](#) to be flushed out of the depression. When excessive [sediments](#)

these [wetlands](#) can have a permanent pool, but in many cases will have various fluctuating water levels depending on precipitation and actually become dry on the surface in times of little or no precipitation. Typically, these [wetlands](#) do not have streams or other obvious exits, so water in these [wetlands](#) must exit either by evaporation, plant uptake, or by draining

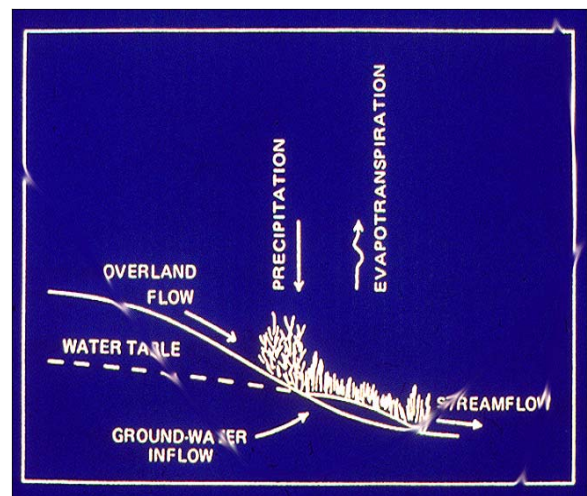


Figure 4-9: Slope Wetland

accumulate in these depressions, it buries plants and animals and can quickly fill in the entire [wetland](#) area. This can cause the moisture and soil conditions to change, forcing the plant community to rapidly transition to a more [upland](#) mix of species. The [wetland](#) plants are then lost along with the [wetland](#) and associated benefits.

Sloped [wetlands](#) are those [wetlands](#) that form on the side of hills and gentle grades. These [wetlands](#) typically develop on slopes that have about a 3% grade. This is a common type of [wetland](#) found in forested areas where the groundwater emerges at the surface of a slope to supply the [wetland](#), as shown in Figure 4-9. Streams may also enter and leave these [wetlands](#) and carry excess [sediments](#) during periods of high flows out of the [wetland](#) area to locations downhill and downstream. Although still vulnerable to impacts from excess [sediment](#), this ability to remove [sediments](#) means that these [wetlands](#) are less vulnerable to filling than depression-type [wetlands](#).



4-34 Slope (Seepage) Wetland

Floodplain [wetlands](#) are found along the fringes of lakes, rivers, and streams. This [wetland](#) type includes vegetation that is commonly submerged by water, as well as vegetation that is temporarily covered with water during periods of high water. This is the most easily recognized and common type of [wetland](#) in most areas, as depicted in Figure 4-10. Fluctuating water levels brought about by periodic flooding are critical to the continued survival of these [wetlands](#). Flooding generally occurs during spring months; however, these [wetlands](#) can be either dry during much of the year or fairly wet. Sometimes floodplain [wetlands](#) also receive water from groundwater sources, and these [wetlands](#) tend to be wetter over longer periods. Although all [wetlands](#) can be impacted by excessive [sediment](#), [sediment](#) and other pollutants in floodplain, [wetlands](#) are often only temporarily stored until the next storm event flushes them out.

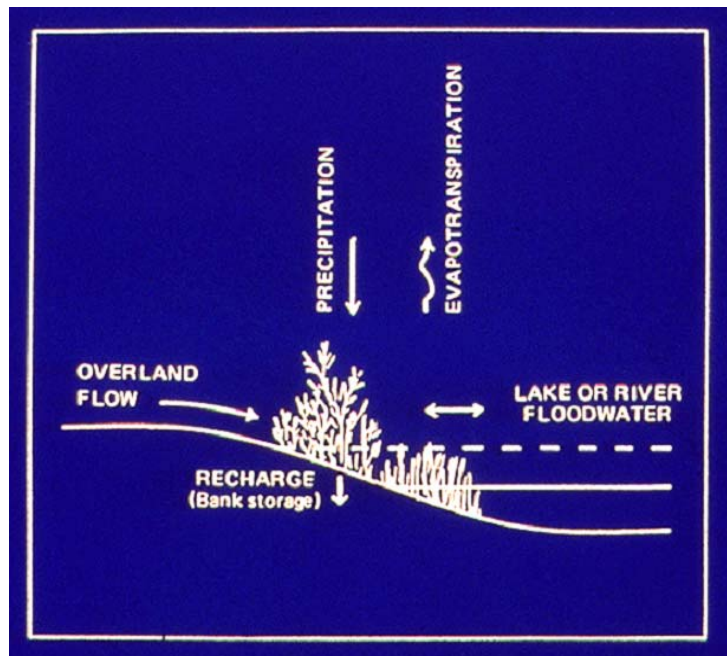
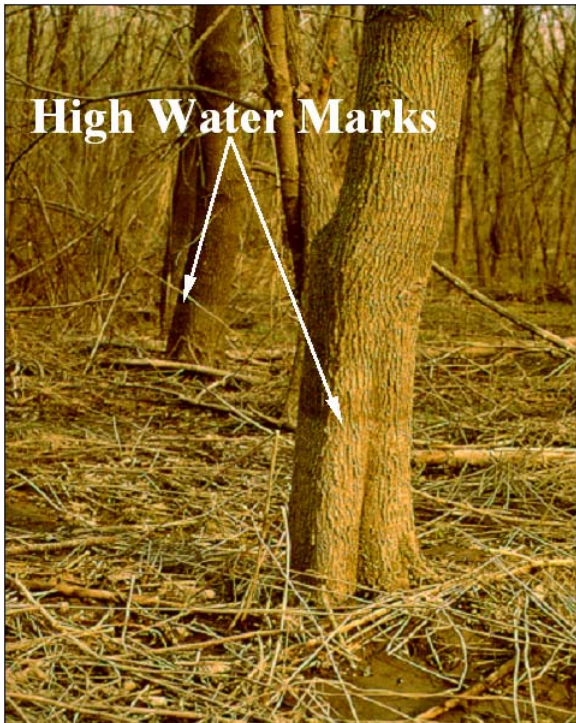


Figure 4-10: Floodplain (Riverine) Wetland



4-35 Floodplain (Riverine) Wetland



4-36 Wetland Indicators

4.4.7.2 Wetland Characteristics:

Although each of the [wetland](#) types discussed previously is different, they share similar characteristics. Based on the regulatory definition of [wetlands](#) previously discussed, each [wetland](#) must be wet during part of the year, must have soils that are saturated with water, and contain

4.4.7. Wetlands and Road

Maintenance. Now that we have discussed the major benefits and regulatory issues regarding [wetlands](#), it is important to provide some tools to help road personnel recognize [wetland](#) areas and provide guidance on what to do when these sensitive areas are encountered during road maintenance activities.

4.4.7.1 Recognizing Wetland Areas.

When you hear the word [wetland](#), an image of a marsh with cattails might come to mind. [Wetlands](#), however, are not created equally and they vary in size, shape, position in landscape, amount of water present, mix of plants and animals, appearance, and benefits. While cattail marshes are one kind of [wetland](#), there are many other kinds. Many of the [wetlands](#) in forested areas are referred to as forested or shrub [wetlands](#). Although there are a variety of [wetland](#) types, several relatively easy clues are available to aid in their identification. These clues are based upon the three criteria for [wetlands](#) previously discussed: [hydrology](#) (drainage), soils, and vegetation. These clues can be used to help road managers know which portions of their jurisdiction might contain [wetlands](#), as well as identify specific areas that regulatory agencies consider [wetlands](#).



4-37 Wetland Indicators

plants that are adapted to wet conditions. These factors - [hydrology](#), soils, and vegetation - provide characteristics and clues that we can recognize while we are in the field.

Although the presence of standing or flowing water is an obvious indicator of a [wetland](#), many [wetlands](#) are only wet during part of the year. There are, however, telltale signs that water has been there. High water leaves silt lines on tree trunks,



Debris Wracks

4-38 Wetland Indicators



Surface Roots

4-39 Wetland Indicators

pile up against trees and rocks, forming wrack lines. These wrack lines indicate water once covered this area and again could indicate a [wetland](#).



Soil Sample (typical gray, gray-blue, gray-green color)

Hydric Soils

4-41 Wetland Indicators

similar to a ring around a dirty bathtub. These high water marks are a good indicator that you may have a [wetland](#). Fine [sediment](#) particles suspended in water frequently settle and are deposited on vegetation, leaving silt-covered or silt-stained leaves, another [wetland](#) indicator. When water flows through [wetlands](#), especially floodplain [wetlands](#), floating debris tends to



Buttress Roots

4-40 Wetland Indicators

The roots of trees and plants living in the area provide another clue. Many [wetland](#) plants have shallow roots because the roots need oxygen. Soils that are saturated by a high [water table](#) do not supply this much-needed oxygen, so the roots remain closer to or

at the surface to get the oxygen they need. Wet soils are also very soft and do not provide much support for large trees. Some [wetland](#) trees thereby adapt by developing large bases or buttressed trunks and root systems that provide better support. These buttressed trunks indicate soft, saturated soils that may be a [wetland](#).



4-42 Wetland Indicators

The second characteristic of [wetlands](#) is saturated soils. Interesting things happen to soils when they become saturated with water. Saturation causes oxygen levels to become depleted, resulting in changes to the soil's normal chemical reactions. In submerged or very saturated conditions, the decomposition of dead vegetation is practically halted because there is little oxygen available to support decomposing organisms and reactions. Without decomposition, partially decomposed plant material accumulates into thick layers of organic soils called peat. This peat is similar to the peat that is dried and sold in stores for use in our gardens. Other [wetland](#) soils do not have as much organic matter present and consist mainly of mineral soils derived from parent material. These saturated mineral soils are referred to as hydric soils and sometimes produce gleyed soils that are greenish or blue-gray in color. If these mineral soils form in a seasonal [wetland](#), where the area is alternately wet and dry, metals such as iron and manganese react with oxygen to form oxides (rust) and becomes a mottled soil with orange/reddish brown or dark reddish brown/ black spots in the otherwise gray or greenish gleyed soils. The familiar rather unpleasant rotten egg odor that is sometimes given off by [wetlands](#) is caused by the release of hydrogen sulfide gas when [wetland](#) soils and [sediments](#) are disturbed.



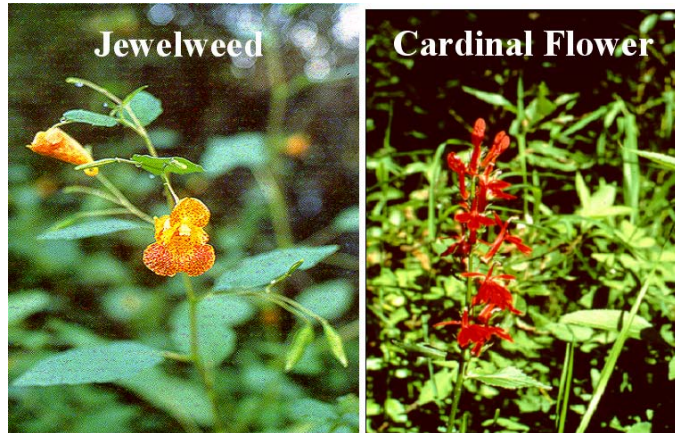
4-43 Wetland Indicators: Common Wetland Plants

4-44 Wetland Indicators: Common Wetland Plants

The third [wetland](#) characteristic is the vegetation. Most plants cannot tolerate the wet conditions within [wetlands](#). Some species, however, have adapted to wet habitats. These water-loving [wetland](#) plants are referred to as hydrophytes and based on their tolerance for standing water can be further lumped into three groups:

1. Those that are dependent upon permanent water for their survival such as cattails, water lilies, skunk cabbage, buttonbush, and arrowhead. This group includes those plants that most of us would associate with [wetlands](#).

2. Those that can live in standing water but prefer moist soils such as black ash, cinnamon fern, joe-pye weed, jewel weed, cardinal flower, pin oak, and pussy willow.



4-45 Common Wetland Indicator Plants

3. Those that do best in moist to somewhat dry soils such as red maple, catalpa, slippery elm, and arrowwood viburnum.



4-46 Less Known Wetland Indicator Plants

Wetland scientists and regulatory personnel use this differentiation of plants to identify and map [wetland](#) areas.

It is important to note that not all [wetland](#) plants are beneficial. The invasion of purple loosestrife is an example. Just as we are gaining an appreciation for the qualities and benefits provided by [wetlands](#), a terrible foreign invasive plant is destroying our [wetlands](#). Purple loosestrife is a [wetland](#) plant with pretty purple flowers that was imported from

Europe and Asia. This plant spreads rapidly and, when established, completely out-competes and takes over the [wetland](#) within a year. This invasive species became a real problem in New England and quickly spread south and west into many other states.

Purple loosestrife establishes dense, impenetrable stands that are unsuitable as cover, feed, or nesting sites for many [wetland](#) animals, including ducks, geese, rails, bitterns, muskrats, frogs, toads and turtles. It also drives out endangered and rare plant species. Purple loosestrife frequently establishes on moist soils that are disturbed by construction activities. Once established, it is very difficult to remove because

each plant can dispense 2 million seeds per year. The plant is also able to resprout from roots and broken stems that fall onto the ground or into water. Mowing purple loosestrife often makes the problem worse because it spreads the seeds and scatters bits of plants, which resprout.

4-47 Purple Loosestrife



◆ Listed on many states' Noxious Weed Lists

- ◆ Aggressive, invasive species
- ◆ Out competes native plant species





◆ Useless to wildlife

4.4.7.3 Encountering Wetlands. Because many of our roads were built along streams and through low-lying areas, it is very likely that [wetlands](#) will be a concern for many road managers. It is probably not a question of “if” you encounter [wetlands](#) in your work but “when” you encounter [wetlands](#).



4-48 Mandate by Federal Government

As mentioned, there are federal and state laws and regulations governing the protection of [wetlands](#). In many cases, compliance with these laws requires biological and engineering studies and permits with any encroachment onto a [wetland](#). If roadwork interferes with a

[wetland](#), the result can be major costs, delays, and potentials for litigation.

A real opportunity exists, however, for local road officials in the realm of [wetland](#) regulation. Currently routine maintenance work is usually not a point of enforcement emphasis and, to some degree, permits are waived for such routine items as ditch cleaning. The opportunity is for local road officials to take the information presented here to heart and through their daily maintenance activities prove that no further regulation or increased enforcement is needed in this area. While these opportunities exist, it is critical

to remember the possibility of severe penalties for those that do not follow these [wetland](#) protection rules.

4.4.7.4 Wetland Strategy.

We hope that a strategy of “avoid, minimize, and mitigate” will help road managers as they attempt to work through encounters with [wetlands](#). This strategy involves, in order, avoiding impacts to [wetlands](#) wherever possible, minimizing those impacts that cannot be avoided, and mitigating damages where they occur.

Avoid. The ideal way to deal with [wetlands](#) is to identify

them in advance and then plan improvements and maintenance activities that will avoid impacting these sensitive areas. Traditionally we probably would have drained a whole hillside into a single [culvert](#) that discharges water directly into a [wetland](#) or stream, dumping more water, [sediment](#), road fines, and chemicals into a [wetland](#) than it is capable of handling. Using a combination of the tools presented in this manual, however, we can avoid discharging these excesses into [wetlands](#). For example, stabilizing banks, maintaining vegetated ditches, and installing turnouts and broad-based dips at frequent intervals could prevent significant amounts of [sediment](#) and quantities of water from accumulating and carrying material into the [wetland](#). Many tools or practices will be described in subsequent chapters.

Minimize. We recognize the fact that it is not always feasible to avoid impacting [wetlands](#) near our roads. In these instances, it is best to minimize those impacts as much as possible. Continuing with the hillside and single [culvert](#) illustration used in our discussion of avoiding impacts, we can use a combination of tools to minimize disruption and damages to [wetlands](#). We can set the [culvert](#) discharge back from the lowest point and divert water through a vegetated filter strip of grass or other vegetation, thereby trapping excess [sediment](#) before it gets to the [wetland](#). [Sediment](#) traps can also be used in place of filter strips, but they need to be inspected and cleaned out on a routine basis.

Although only temporary, practices such as the use of [silt fences](#) can also provide significant short-term benefits. Straw bale barriers have also been used, but their effectiveness is questionable and are not recommended by the U.S. Environmental Protection Agency. These materials should only be used for short-term activities and must be maintained and cleaned out regularly until the work site is stabilized. These practices and proper use will also be described in more detail in Chapter 5.



4-49 Adopt a Wetland Strategy

Mitigate. [Mitigation](#) involves the creation of artificial [wetlands](#) in order to replace the lost function and habitat of a natural [wetland](#). This is often an expensive prospect and should only be used as a last resort when avoidance and minimization techniques are insufficient to prevent the destruction of an existing [wetland](#). The biological and engineering studies and design and required permits, along with site acquisition and actual construction, all lend to the extreme costs and time required for [mitigation](#) projects. Given the scale and scope of the projects that are likely to be carried out under maintenance activities, it is unlikely that [mitigation](#) will be a necessary and/or a viable option.

4.4.7.5 Working with Regulatory Agencies. This section on [wetlands](#) is not intended to turn road experts into [wetland](#) experts. Rather, its intent is to provide background information on [wetlands](#) and help road managers recognize the importance and value of these sensitive habitats. Using the clues discussed above, road managers should be able to recognize areas that might be considered as [wetlands](#). When these potential [wetlands](#) are encountered during road maintenance activities, it is highly recommended that local governments contact their local county or state agencies for further guidance on appropriate actions. Local county conservation agencies are familiar with the local conditions and they are familiar with state and federal environmental regulations and agencies, and will be able to help you directly or help you direct inquiries to the appropriate agency.

4.4.8 Wetland Ecosystem Summary. [Wetlands](#) are an important natural resource located between full aquatic and [upland](#) environments. For an area to be considered a [wetland](#), it must be saturated with water at least part of the year, have soils that have developed under saturated conditions, and contain plants that are adapted to those wet conditions. Many different types of landscape features meet these conditions, of which three were discussed – depression [wetlands](#), slope [wetlands](#), and floodplain [wetlands](#). Most of these areas are relatively easy to recognize using the [hydrology](#) (drainage), soils and vegetation clues as potential indicators for a [wetland](#) area.

[Wetlands](#) benefit natural systems by providing habitat for fish and wildlife and supporting the food web. They also provide important benefits in terms of floodwater storage, bank and shoreline stabilization, [sediment](#) trapping, water quality improvements, and opportunities for education and recreation activities. Linked to many of these values are economic benefits as well. Unfortunately, we have been slow to recognize all these benefits and have lost over 50% of our [wetlands](#). Our federal, state, and local environmental regulatory agencies have reacted to this loss and enacted strict measures to protect the remaining [wetlands](#) and the benefits they provide. Road managers are advised to adopt a strategy of avoiding [wetlands](#) or minimizing the impact and using [mitigation](#) only as a last resort as they encounter [wetlands](#) in their road maintenance activities.

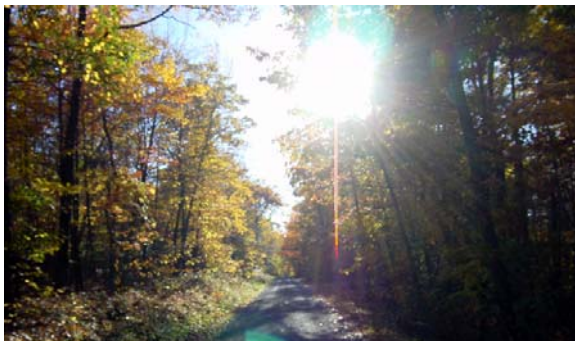
4.5 The Upland / Forest Ecosystem (Community)



4-50 Uplands produce different challenges for road managers.

managers develop a strategy to deal with vegetation that takes advantage of nature and natural systems instead of trying to overpower these forces. Trying to overpower nature is unrealistic, costly, and temporary at best.

4.5.2 Plant Basics. In order to effectively manage roadside plants, it is important to understand some basic information including the way plants grow, their life cycles, root structures, and general plant [ecology](#).



4-51 Plants use the sun's energy (light) with carbon dioxide from the air combined with water and nutrients to produce sugars (food) through the process of "Photosynthesis."

sugar maple. The sugar maple stores excess sugar developed during the summer in its roots. As the plant begins to grow in early spring, the sap containing these dissolved sugars is transported to the buds. "Tapping" holes in the trunk of the sugar maple allows collection of this sap, which can be boiled to evaporate the water and concentrate the sugar into maple syrup. This is how the sugar maple got its name, because of the sap's particularly high concentration of sugar.

4.5.1 Introduction. As the third ecosystem or community, the [uplands](#) present drier conditions and different challenges for road managers. In [upland](#) areas, nature's purposes may conflict with road maintenance just as they do in stream and [wetland](#) areas. Because significant portions of local government budgets are spent maintaining roadside vegetation, road managers need a more complete understanding of plants. A better understanding of the natural reaction plants have toward outside impacts such as their reaction to injury can help road

4.5.2.1 Plant Growth and Photosynthesis. Unlike animals, which gather energy by eating other plants and animals, plants are able to produce their own food through a complex process called "[photosynthesis](#)." If we can recall from the high school science class where we were introduced to this "big word," [photosynthesis](#) is the process by which plants convert sunlight, carbon dioxide from the atmosphere, water, and nutrients into sugars. Plants then use these sugars as food, and extra sugar is stored throughout the plant. A familiar example of this energy storage is the

4.5.2.2 Vegetation

Groupings: There are many different types of vegetation. As road managers, we will look at three groupings: woody plants, herbaceous plants, and seedless plants, with a brief discussion of each.

Woody plants contain hard, ligneous fibers in their trunk, stem, and root tissues, which collectively are called wood. Trees (beech, birch, maple, oak, white pine, hemlock, etc), shrubs (mountain laurel, rhododendron, low bush blueberry, etc), and many vines (honeysuckle, grape, etc.) are classified as woody plants.



4-52 Plant Groupings

Herbaceous plants are seed-bearing plants that have fleshy stems instead of woody ones. These plants are typically shorter than woody plants and include broadleaf species and grasses. Common herbaceous plants include goldenrod, milkweed, grasses, daylilies, and skunk cabbage. The life span of herbaceous plants varies by species. A discussion of plant life cycles follows in the next subsection.

Grasses are herbaceous plants that have some unique adaptations that make them of special interest to road managers. Unlike other plants that grow at the tips, the growing point of grasses is located at the base, or ground surface; so as new tissue is added, the plant extends itself upward. Many grasses also reproduce in multiple ways. Grasses do flower and produce seeds for sexual reproduction, but many grasses also reproduce and spread by extending horizontal tillers called rhizomes (underground) and stolons (above ground), which act to fill in the spaces between plants, as new grass shoots extend forth from these tillers, as depicted in Figure 4-11.

The ability of grass to reproduce in this fashion makes it very valuable as a roadside plant since the frequent mowing of grassy roadsides removes the flowers/seed structures, but not the growing points. The rhizomes and stolons also

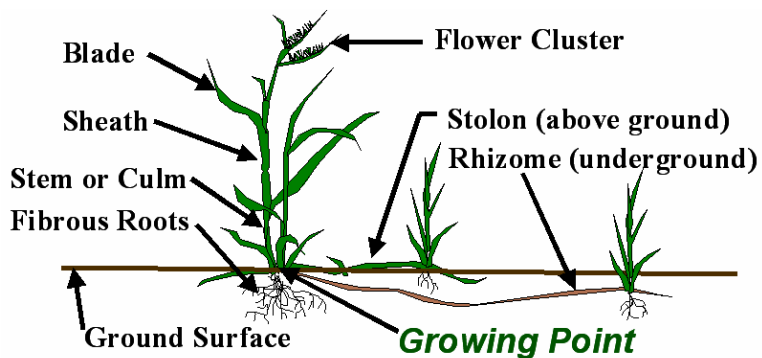


Figure 4-11 Grasses

create a fibrous root system, which holds the soil in place and reduces water [runoff](#) velocity.

Seedless plants reproduce by tiny spores that drift on the wind, settle on a surface, and begin to grow. Common seedless plants include mosses, ferns, and puffballs. Mosses are often one of the first plants to become established on barren soil. Ferns are very common roadside plants, and many have deep roots that provide good soil anchorage.

4.5.2.3 Plant Life Cycles. In general, herbaceous plants can be grouped in terms of three basic life cycles. The plant life cycle begins with the germination of a seed and is the time required for the plant to grow, mature, produce seeds, and die. One type of plant has an annual cycle because they complete their seed-to-seed life cycle within a year. Some annuals, called summer annuals, sprout from seeds in the spring, flower, produce seeds by the end of the fall, and then die. Winter annuals sprout in the late summer, lay dormant over the winter, flower, produce seeds in the early summer, and then die.

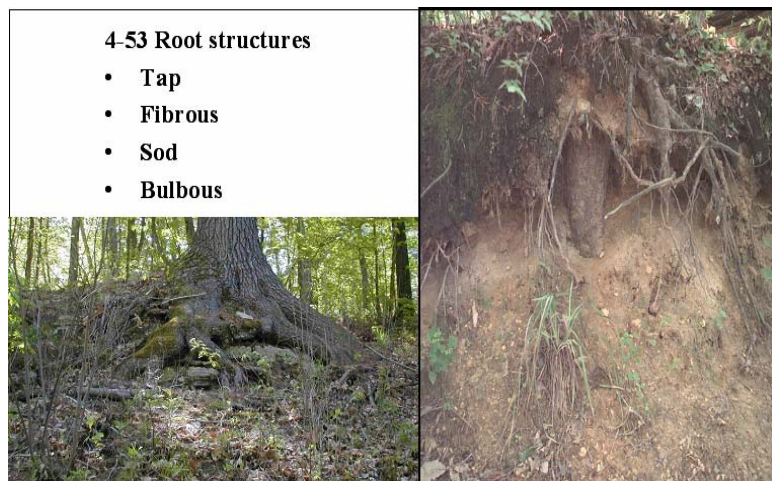
Biennial plants require two years to produce seeds and complete their life cycle. Typically, they germinate in the spring or early summer, grow until fall, and then go dormant for the winter. The following spring, a second growing season begins and the plant grows to maturity, flowers, produces seeds, and then dies during its second fall. Canada thistle is a common biennial plant. If this thistle is continually mowed to prevent flowering and seed production, the plants will die in two years with no replacements to contend with.

Perennial plants live for an indeterminate number of years. Daylilies and skunk cabbage are common perennial plants. These plants keep coming back year after year, typically going dormant in the winter months.

4.5.2.4 Root

Structures. Roots provide anchorage for plants and act as a collection system for water and nutrients from soil. The structure of plant roots varies from species to species. Some plants have a large main taproot that penetrates deep into the ground. Tap rooted trees like hickory also have fine feeder roots near the surface of the soil where oxygen is more abundant.

Taproots act like reinforcing bars and can be very effective in stabilizing banks that are seasonally saturated and potentially unstable.



Some plants have a fibrous root system. Maple trees are prime examples of plants with fibrous roots. Fibrous root systems provide excellent soil reinforcement.

Some grasses form thick, matted roots called sod, while other grasses grow from a central point and form clumps. Turf type sod grasses act as a natural [erosion](#) control fabric by holding soil in place, trapping soil moisture, slowing [runoff](#), and increasing infiltration. Grasses that grow in clumps, like tall fescue, tend to hold soil closer and more securely to the plants' center. With clump type grasses, surface [erosion](#) tends to remove soil from between clumps while plant growth builds the clump higher. Clump grasses are thereby not as effective at retarding soil [erosion](#) as turf type grasses unless they are seeded densely and are well maintained.

Other plants have a bulbous root system of bulbs or tubers. Daylilies are a bulbous root plant and can be great roadside bank stabilizers without interfering with the road.

4.5.2.5 Plant Ecology. Plants have characteristics that cause them to act very different from animals. These differences involve the way plants gather resources, develop, and grow. We already discussed [photosynthesis](#), the process with which plants produce their own food. In addition, plants are strongly influenced by their stationary, rooted nature. Plants cannot move. They can only react to the environment that exists where they are growing. Animals, by comparison, can simply seek the environment that they like best.

The growth of plants is affected by soil, light moisture, and climatic/weather conditions. Plants require a certain mixture of these factors to thrive, depending on the plant species. While some plants prefer or even require full sunlight to do well, others prefer partial sunlight or shady conditions. Similarly, some plants require lots of water and others prefer drier conditions. For example, the vegetation found along dry, hot ridge tops is very different than the low-lying, lush vegetation found in [wetlands](#). [Topography](#), or the shape of the landscape, is a major factor in plant growth because of its influence on light and moisture conditions. Flat land receives direct sunlight while slopes receive more or less sunlight according to their orientation to the sun. Sloped areas also dry faster because precipitation runs off quickly, with less infiltration into the ground.

Since light, soil and moisture conditions vary across regions, plant species are not uniformly distributed. In areas where the right combination of conditions exist, species that favor those conditions will dominate the landscape. Forest types are commonly named for the species predominant within them. The significant point is that plants grow and thrive in direct relation to the amount of light, quality of soil, quantity of water and type of weather conditions. Where the conditions are similar across the landscape, similar plants will dominate.

Plants are very dependent upon the underlying soil for a number of their critical needs. Although plants' water requirements vary by species, no plant can survive without water. Moisture stored in the soil serves as a steady supply of this vital requirement. Soils

also provide nutrients that are necessary for plant growth. Water collected by the roots carries these soil nutrients up into the leaves, where together with sunlight and carbon dioxide, they enable the plant to transform these materials through [photosynthesis](#) into sugars for food.

Soils also provide anchorage for plants. By providing support, roots and soil work together to allow plants to grow vertically. By increasing in height, which varies by species, plants can collect more sunlight for greater food production.

As stated, the ability of plants to collect resources and grow is limited by their location since they cannot move. Plants aid themselves in this limitation through recycling. Leaves, branches, and bark fall in close proximity to the plant, where insects, worms, bacteria, and fungi digest them. The decay of this fallen organic matter creates an excellent growth medium. By providing habitat for other creatures, plants also attract nutrients and growth enhancers in the form of animal wastes to their location.

Since plants cannot move like animals, they cannot flee from danger. If they could, there would be a lot fewer trees along our roads with cavities that result from road grader injury. Plants have developed numerous adaptations to deter and prevent insect, animal, and physical damage and even intrusion of other plants. These adaptations range from physical factors, such as fire resistant bark, sticky sap, thorns, and very hard seeds, to chemical factors, such as bad tasting leaves, strong and offensive odors, and toxins released to soil. Some plants, such as ferns, black walnut trees, goldenrod and a few grasses, release toxins into the soil, a process called alleopathy. These toxins released into the soil discourage competing plant species from germinating and growing nearby.



4-54 Plants cannot move, cannot flee from danger.

Earlier it was mentioned that plants form the foundation of a stream's food web. This lead role is carried through to the whole earth's food webs. The ability of plants to effectively transform the sun's energy into another form of energy (i.e., sugar) is one of the basic building blocks of life. Sunlight is the key ingredient, supplying an inexhaustible supply of energy, while the other necessary raw materials for [photosynthesis](#) are found practically everywhere in the environment. The availability and abundance of these raw materials explains why plants are so widespread across the planet. Consequently, plants serve as a ready and almost limitless source of food for plant-eating insects and animals, forming the foundation of our earth's food webs.

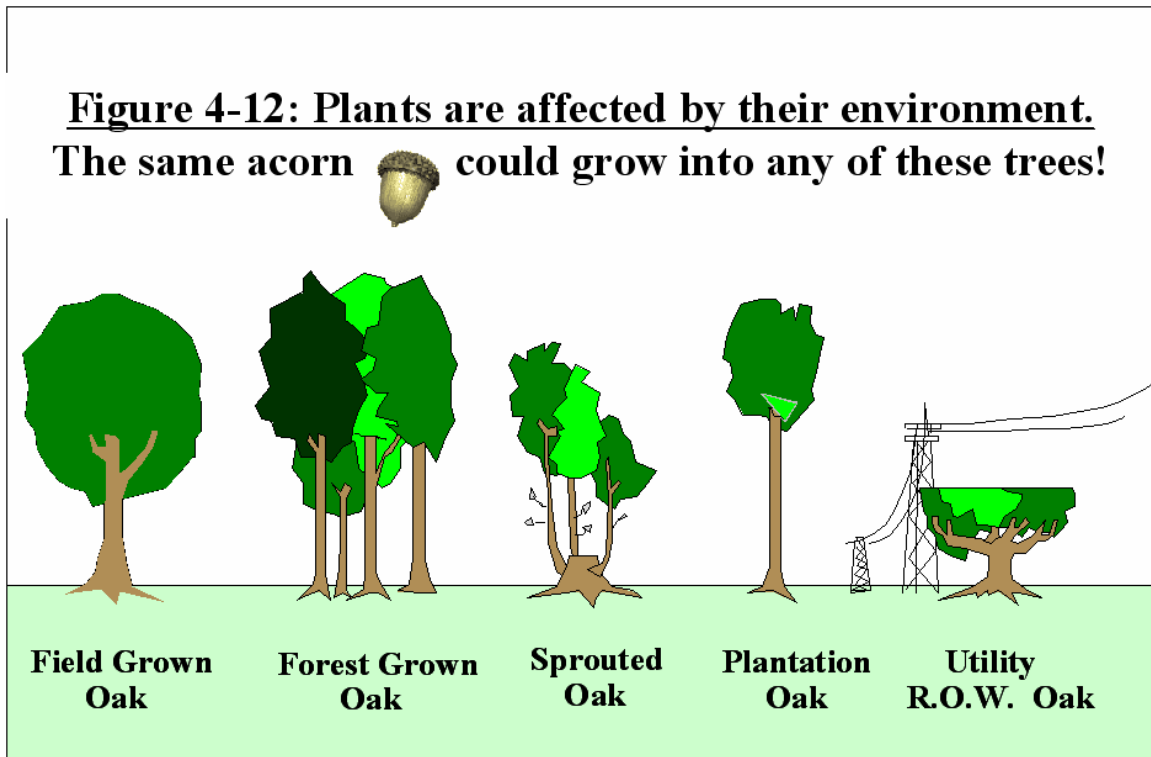
4.5.3 Understanding Trees. Trees are present along many roadsides. Efforts to manage roadside vegetation consume fantastic amounts of money and effort. In order that road managers might better integrate their vegetation management programs with the natural and relentless growth of vegetation, a better understanding of trees is necessary. A discussion of tree growth and their reaction to injury follows.

4.5.3.1 Tree Growth. Trees grow in diameter by adding a new layer of wood each year. This new wood forms in the cambium layer immediately behind the inner bark. These annual layers of new growth form the “rings” that most all of us have seen on tree stumps. These rings of growth, if examined closely, can be counted to determine the age of the tree. In addition, the width of the ring indicates the condition of the growing season, a wider ring meaning more growth from a good growing season with plenty of moisture and positive conditions.

The outermost layer of the tree is the bark. Similar to our skin, bark is a protective layer of tissue on the outside of the tree that stabilizes temperature and forestalls insects and disease from damaging the more delicate, actively growing layers beneath it. Bark is adapted to allow the annual increase in diameter of the tree. Some species of trees have bark that can be described as striped or occurring in vertical rows. On trees with this type of bark (e.g., chestnut, oak) the bark accommodates the annual increase in trunk diameter by expanding between the ridges. Other species of trees have smooth bark that actually stretches as the tree expands in diameter. This bark is then replenished in late summer during a period of less vigorous growth. The point here is that bark is very valuable to the tree. It is a highly adapted tissue that performs numerous functions critical to the tree’s survival. We need to be aware of the value of bark so that we can avoid damaging it with our maintenance activities.

When trees grow, they increase their height by extending new tissue at the end of branches. This is why a barbed-wire fence nailed to trees does not become higher off the ground with each year of tree growth. The base of the tree is simply growing outward, not upward. The annual increase in diameter is how objects become embedded in trees.

Although all trees add new tissue in the same manner, they do not all look alike. While each tree species has its own growth patterns, individual plants adapt to their surrounding conditions. The oak trees in Figure 4-12 have all taken on different forms based on their specific site conditions. The field grown oak standing alone in full sunlight grows to a different shape than a forest grown oak. The field oak must withstand the wind and elements all by itself and therefore needs a lot more structural root support than the forest oak that is sheltered from the wind by surrounding trees. Forest trees grow upwards in an attempt to gather sunlight, resulting in taller trees with fewer low branches. When trees are cut down, some will resprout new growth from the newly cut stumps. These stump sprouts grow in clusters, which result in yet another growth shape. Trees grown under utility wires continuously have their tops removed, producing an unnatural tree shape that is structurally unsound.



4.5.3.2 Tree Injury. As we discussed earlier, bark is the protective layer of tissue on the outside of the tree. When bark is damaged, the tree is permanently wounded. **Trees do not heal, they seal.** Many things can damage the bark of trees. Fire, animals, and equipment are common causes of tree wounds.

Fire is an enemy of some trees and a friend to others. The heat of fire is an obvious enemy to most trees. Some trees, however, require the heat of a forest fire to open pinecones, expose mineral soil, initiate seed germination, or stimulate new growth. Some species, such as scrub oak, have a high oil content, which cause them to catch fire quickly and generate very high temperatures. The hot fires generated when these species burn kills other species, reducing competition. This suppression of species intolerant of fire is an important component in maintaining the diversity and function of many [ecosystems](#).

Animals are a major source of injury to trees. Insects burrow under the bark,



4-55 Trees do not heal, they seal!



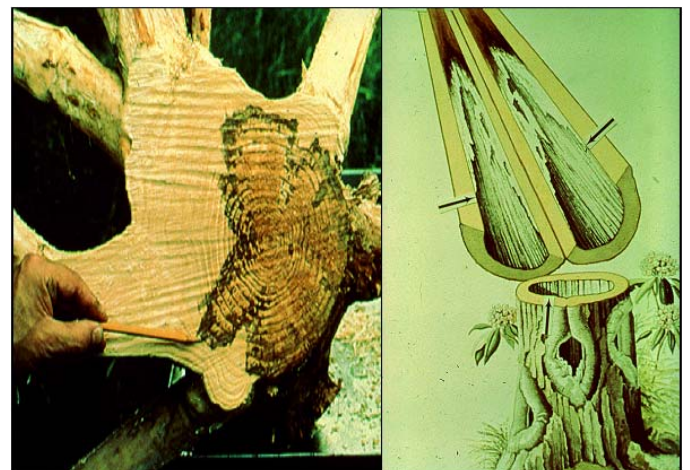
4-56 Fungi attacking wounded tree.

which cuts the trees' lifelines and can allow pathogens into the tree. Insects, like the tent caterpillar, can strip the tree of its leaves, resulting in severe injury or death since the tree cannot process food without green leaves. Birds, such as woodpeckers, peck holes in trees to get bugs and suck sap. Beavers cut trees down for food and building materials, porcupines munch on trees, and deer rub their antlers on trees, damaging the bark.

Road maintenance activities can also cause significant damage to trees. Trees are frequently wounded when heavy equipment bangs into them, ripping sections of bark loose or disturbing the roots. In addition to the physical damage caused by cutting and tearing of the roots, filling and compaction of soils damages roots by cutting off some of their oxygen supply. Any activity that disturbs the tree bark is injurious. Vegetation control measures, which result in indiscriminate injury to roadside trees cause permanent injury. The natural reaction plants have to injury may cause more problems for road managers than the temporary benefit realized by indiscriminant cutting.

4.5.3.3 Tree Reaction to Injury. When trees are wounded, they are not able to heal from the inside as people do. As already mentioned, the growing tissue of the tree is immediately beneath the bark. When a tree is wounded and the growing tissue under the bark is exposed to air, the tissue dries out and dies. Trees attempt to seal these wounds by forming new wood around the edges where bark remains intact. This gradual sealing, or growth of the cambium layer, causes the characteristic callusing around a wound's edges. This sealing process can take years depending on the size of the wound.

As soon as the tree is damaged, natural pathogens attack the exposed tissue. Bacteria and fungi begin to infect and digest the wood. Larger animals like birds and bears dig into the tree to eat the insects that live in the decaying wood. The way trees grow creates ready avenues for rot to spread. When rot invades the tree, it spreads in three directions: radially outwards from the center, vertically up and down, and circularly. The tree rots from the inside out, thus the hollow trees that finally die and always seem to fall onto the road.



4-57 What's happening inside?



4-58 Once rotted, another natural force causes additional damage: freeze cracks.

Even after a tree has sealed the wound, the internal rot does not stop. Rotting wood attracts water. In freezing weather, this saturated wood freezes, expands, and cracks outward, breaking the seal and re-injuring the tree. These frost cracks can extend deep into the center of the tree and, with repeated freeze-thaw cycles, the tree's seal is continuously broken, exposing the new tissue to additional bacteria and fungi.

4.5.3.4 Proper Pruning. While pruning trees is a necessary maintenance activity, it also wounds a tree by creating openings in the protective bark layer. By understanding the way trees grow and react to injury, we can minimize the unintended damage frequently done by ill-advised and improperly executed pruning. Proper pruning of trees becomes one of our [environmentally sensitive maintenance](#) practices that will be discussed in Chapter 6.

4.5.4 Plant Establishment and Succession. In our discussion of geology, we talked about geological time scales because natural processes and forces act to change the surface of the landscape over time. The composition of plant communities (i.e., types of species present) also changes over time and is referred to as ecological succession. Ecological succession takes place in a much shorter time frame than geological processes. Like most things in nature, ecological succession is a complex process. There are some basic principles, however, that are important for road managers to understand. Once understood, these natural principles can be utilized to make roadside vegetation management efforts more successful and less costly.

In ecological succession, the composition of a plant community changes as physical and biological processes act to alter the condition of the habitat. As habitat conditions change, plant communities change. [Plant succession](#) can be defined as the gradual and orderly process of ecosystem development brought about by change in the community composition and the production of a climax characteristic of a particular geographic region. In other words, [plant succession](#) starts with bare earth and, over time, transitions towards mature forest.

Rates of succession vary depending on site conditions. Succession proceeds most slowly in bare, unshaded, nutrient-poor rock and subsoil conditions. On the other hand, disturbed areas where the topsoil is not removed or is saved and re-used are able to revegetate quickly. This is why old strip mines remain barren for so long, while abandoned pasture is quickly vegetated and often quickly forested.

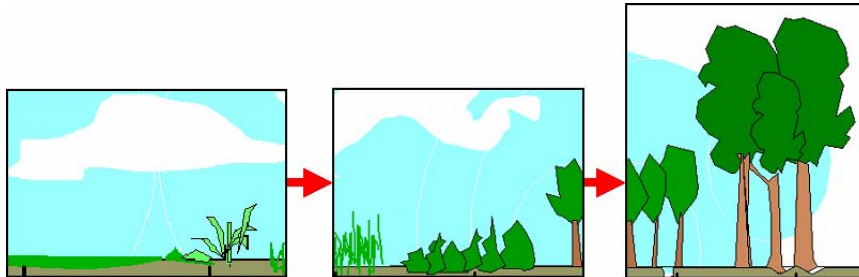


Figure 4-13: Plant Succession


For road managers, roadside trees become a major item within the realm of roadside vegetation management. The following sections describe tree characteristics as they relate to both new and mature successional stages.

4.5.4.1 Colonizer Species. Succession begins with bare soil. The trees that are best adapted to conditions of full sun and nutrient-poor subsoil are called colonizer or pioneer species. Common pioneer species familiar to road managers may include aspen, locust, sumac, grey birch and black locust. These types of trees have certain characteristics for adaptation to the conditions described.

4-59 Colonizer or Pioneer Species

- Structurally weak & short-lived
- Fast growing
- Early maturity
- Shade intolerant

EXAMPLES:
Sumac
Multiflora rose
Aspen
Birch
Locust




CONSTANT MAINTENANCE!

Generally, colonizer species produce massive quantities of lightweight seeds. Although colonizer seeds are not durable, the massive quantities produced and their ability to be transported by the wind assures that some seeds will find barren ground in full sun and germinate. Since they are shade intolerant, roadside banks laid bare during construction and maintenance activities are classic examples of sites prime for colonization.

Although colonizer species are very valuable plants, serving as nature’s pioneers, colonizing the harshest environments, and paving the way for successional changes towards [intermediate and climax](#) species, they can be problematic for road managers. These trees are fast growing, reaching an early maturity. Thus, they are structurally weak and short-lived. As roadside trees, these factors tend to make them a recurring maintenance problem. These are the trees that will lean out over the road due to their weak structure and end up falling onto the road as wind and storms take their toll or as the trees reach maturity and start to age and die.

4.5.4.2 Intermediate and Climax Species. Ecological succession is a process that never ends. The modification of the soil by the colonizing species results in an environment that is more attractive to sturdier and longer-lived species, causing better suited plants to gradually take over. This rate of transition between species groups and plant communities varies over time. As slow growing, long-lived species become

4-60 Intermediate/Climax Species	
<ul style="list-style-type: none"> • Structurally strong & long-lived • Slow growing • Long term for seed production • Shade tolerant <p>EXAMPLES: Oak Hickory Maple Dogwood Redbud Serviceberry</p>	

established, the process of succession slows down. As the rate of change slows and stabilizes, we describe it as an intermediate successional stage. Intermediate plant communities offer greater stability for roadside trees. Intermediate stages are typically followed by climax stages, although in many areas few climax forests are found because they were cut down for lumber and have not had sufficient time to progress from intermediate forests to the climax stage. Examples of [intermediate/climax trees](#) include oak, hickory, beech, dogwood, redbud, and serviceberry.

Intermediate and climax species typically produce heavy seeds, like oak and hickory, which remain relatively close to their parents. This is an advantage, since the seeds from these species prefer soils that are shaded and rich in organic material. These ideal conditions are typically found underneath the [intermediate/climax trees](#) because they shade the ground, trap moisture, and their fallen leaves, branches, and bark reproduce large quantities of organic material.

The slow-growing, strong structure of these [intermediate and climax trees](#) make them better roadside plants. Hemlock, beech, and sugar maple all have these characteristics. Because they are stronger than colonizers, they are less apt to lean out over the road or snap under a heavy snow load. The slow growth of these long-lived species also means that they do not need to be trimmed as frequently as the faster growing colonizers.

4.5.4.3 Significance of Plant Succession for Roadside Maintenance. As succession continues and intermediate species become established, the modifications to the soil and environment continue, thereby promoting and encouraging additional intermediate species. As more and more intermediate species establish, the particular site becomes less and less attractive to the colonizer species. This natural process can be used to reduce roadside vegetation maintenance workload by shading out the fast growing, light-dependent colonizers.

Soil laid bare by grading, [daylighting](#) and other common maintenance activities is always going to be subject to the natural process of succession. Road managers need to be aware of this process because the natural reaction to many of their maintenance activities creates colonizer growth. In addition, traditional maintenance activities to control the growth of these colonizers typically encourage its re-growth, effectively resetting the clock on an endless cycle of cutting and re-growing.

Although succession proceeds at varying rates, it is ongoing. Even the modest efforts at encouraging the establishment and growth of properly adapted plants along our roadsides can pay large dividends. Properly selecting the plants you remove, the plants you leave, and the species planted can control and accelerate the revegetation of our disturbed roadsides.

The goal for roadside vegetation management should be stability with as little maintenance as possible. A road built through an [intermediate or climax](#) plant community can be less costly to maintain if we learn how to use the forest system to our advantage. The use of the forest system to benefit road maintenance will be further discussed in Chapters 5 and 6.

4.5.5 The Importance of Plants. The fact that plants form the basis of the earth's food webs was already mentioned. In addition to food, plants provide valuable habitat for wildlife. Plants also provide numerous other benefits to human society as part of their role in [ecology](#). These benefits are widespread and occur wherever plants grow, whether in forests, fields, or along our roadways. Many of the benefits have been discussed previously, so the following descriptions will both summarize and add to the benefits that plants provide.

4.5.5.1 Ground Cover and Erosion Prevention. Plants act as groundcover and prevent [erosion](#) in several ways. The foliage and physical structure of the plant reduces the direct impact of raindrops on the soil. Plants hold soil in place with their network of roots. Plants also act to slow surface flow, decreasing [erosion](#) energy, trapping [sediment](#), and allowing more infiltration into the soils. The shaded or partially shaded soils under plants are cooler and more moist than more exposed soils and therefore more permeable to rainfall. Obviously, the more water that soaks into the ground, the less that runs off and causes [erosion](#) problems.

Plants also soak up water out of the soil. This process dries the soil and decreases the lubricating effect of water and again decreases the amount of [runoff](#) and [erosion](#).

4.5.5.2 Air Conditioning. The water drawn up from the soil and into and throughout the plant carries the nutrients for plant food production. Excess water is then evaporated from the leaves and released into the atmosphere. This release process, called transpiration, cools the leaves and the surrounding atmosphere. Just as perspiration cools us, transpiration cools the plants, adding humidity and cooling the air. Trees are nature's air conditioners, which is a great advantage to humans. Where would you rather be on a hot summer day: a paved parking lot at the mall or sitting on a park bench under a giant oak tree?

Plants also provide shade that cools the area by reducing sunlight and the drying effect that it has on soil. In this way, plants act to modify the environment to their own benefit, too.

4.5.5.3 Air Purification. The air cleaning characteristics of plants improves the quality of air. As part of the process of [photosynthesis](#), plants take carbon dioxide from the air as a raw material and give off oxygen as a natural by-product. Animals, including humans, require oxygen to live. When animals inhale, their lungs extract the oxygen from the air and exhale the carbon dioxide. By using the by-products of each other's life processes, plants and animals are fundamentally tied to one another, with each providing a critical, life-giving element for the other.

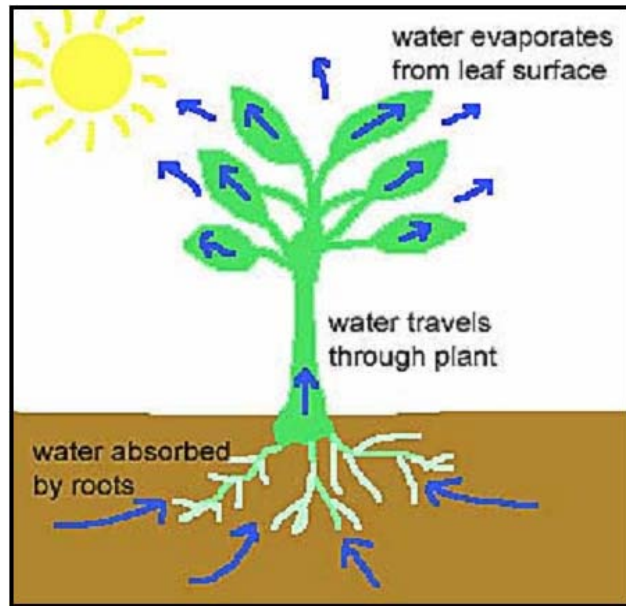


Figure 4-14 Transpiration

Plants can also provide physical cleaning of the air. Airborne particles are filtered out as air drifts through vegetation. The leaves act to slow the air velocity down, which allows [dust](#) to settle. This is why leaves on roadside trees are commonly coated with [dust](#) (until it rains and the [dust](#) is transported as [sediment](#) to the nearest stream or [wetland](#)).

4.5.5.4 Water Purification. The value of [wetland](#) plants in water quality was discussed in the section on the [Wetland](#) Community. Plants soak up water along with any chemicals and other contaminants that may be dissolved in the water, thereby having a cleansing effect.



4-61 Value of Plants: Aesthetics and Economics

4.5.5.5 Aesthetics and Economics. The first impression visitors get of a community is what they see along the roads. Nicely vegetated and diverse roadsides give an impression of comfort and relaxation. Management of roadside vegetation in harmony with nature benefits us visually and economically. It looks good (better for tourism), and it is easier on the local government budget than an unending cycle of invasive growth and removal.

4.5.6 Upland Ecosystem Summary. The management of roadside vegetation is traditionally an expensive and time-consuming task. A general understanding of the way plants grow and react to our maintenance efforts can help road managers to utilize natural processes to reduce the frequency and cost of vegetation management efforts.

In this section, we talked about plant basics, their growth factors and the process of [photosynthesis](#) that allows plant to produce their own food. We discussed different groupings of plants and their characteristics, along with the different plant life cycles. We looked at plant root systems and their importance in soil stabilization. We then looked at plant [ecology](#) and how plants are influenced by light, soil, water, and climate, factors that vary from site to site. Changing any of these primary influencing factors can have a dramatic effect on the plant community. We discussed how plants react to injury, particularly roadside trees. We covered [plant succession](#), differentiating between the colonizer or pioneer plants that are high maintenance items and the [intermediate and climax](#) species that can reduce maintenance.

Finally, we discussed the overall importance of plants, noting their value for soil reinforcement and [erosion](#) prevention, as air cleaners and conditioners, as water cleaners, and for general roadside aesthetics.

As road managers, the more we know about plants and natural systems, the more we can use this knowledge toward a more efficient and effective roadside vegetation management program.

4.6 Summary of Natural Systems

Because dirt and gravel roads are located amidst natural biological systems, the stream, [wetland](#), and [upland](#)/forest communities that these roads pass through are likely to interact with the daily maintenance and operation of these roads. These interactions can affect both the road and the natural systems. Therefore, if road managers are to provide better roads while complying with today's complex environmental regulations, it

is important for them to understand the importance of these natural systems and some of the major processes that take place.

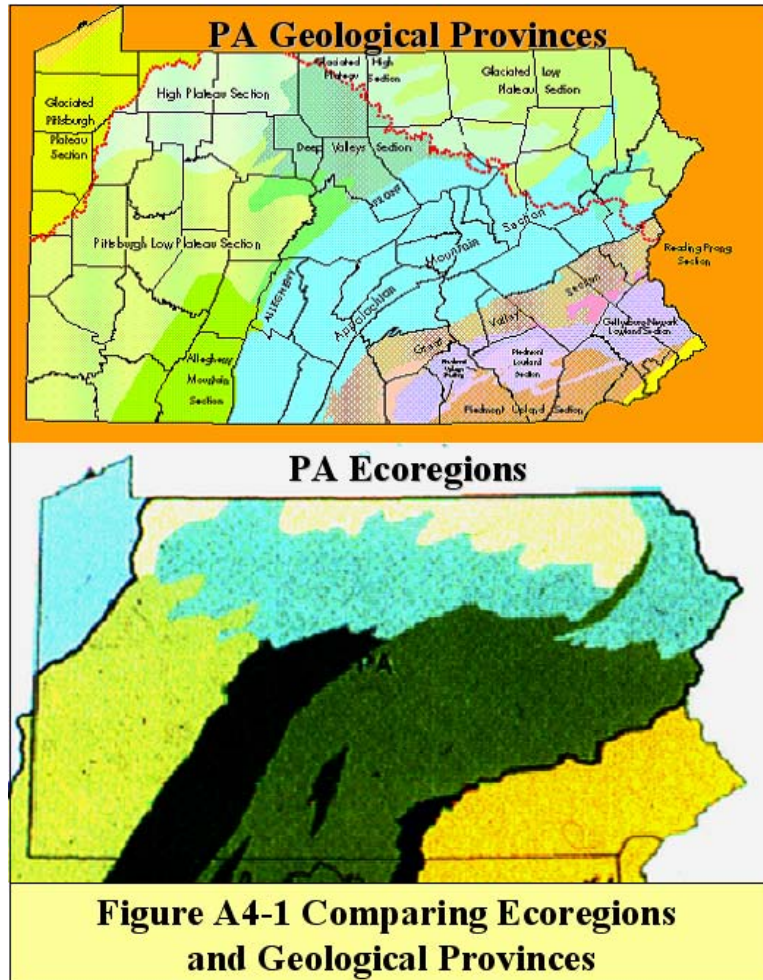
This chapter contains a significant amount of information on natural biological systems. This information should be useful as we move into the remaining chapters and begin to discuss [environmentally sensitive maintenance](#) practices that will benefit both the road and the environment and help prevent [erosion](#), [sediment](#), and [dust](#) pollution. We will spend less money and do less environmental harm if we understand and work with, not against, nature and the natural systems.

These natural systems have been discussed and summarized individually, but it is critical to note that these systems do not exist individually. Just as they interact with roads, these natural systems interact and depend on each other, with processes and functions blending across the boundaries between each system, making up the total environment in which we live and work. Remember, as John Muir put it, “When we try to pick out anything by itself, we find it hitched to everything else in the universe.”

APPENDIX 4. Case Study: Pennsylvania's Ecology

A4.1 Ecoregions and Geological Provinces.

The Commonwealth of Pennsylvania encompasses a whole range of ecological conditions or habitats. As discussed, [ecoregions](#) reflect the physical factors that help define the type of habitat present and in turn determines the type of animals and plants that live and survive in that habitat. For example, vegetation is heavily dependent upon the area's elevation, slope, drainage, stability, and nutrient availability, in essence, the geology and soils. Comparing geology and ecoregion maps and noting the similarity of boundaries demonstrates this association. Figure A4-1 illustrates this comparison using the geology province map and an ecoregion map of Pennsylvania.



The ecoregion map shows that there are eight [ecoregions](#) in Pennsylvania. These [ecoregions](#) have been delineated primarily according to vegetation types – each ecoregion contains similar types of vegetation. This is because plants (and animals) have developed and evolved under a certain set of physical conditions characteristic of their ecoregion. The three typical community types or [ecosystems](#) within each ecoregion – streams, [wetlands](#), and [uplands](#) – are all represented in Pennsylvania.

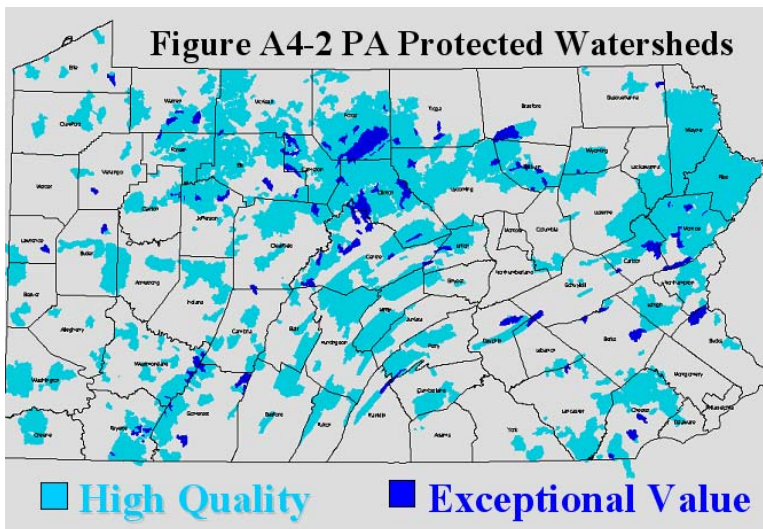
A4.2 Pennsylvania's Stream Ecosystems. The commonwealth has approximately 83,260 miles of streams. Streams systems have played a very large role in shaping the landscape of Pennsylvania, primarily through [erosion](#) and deposition of [sediments](#). Much of this activity takes place at a rate that spans thousands to hundreds of thousands of years or geologic time as discussed in Chapter 2, and these processes continue today. For example, approximately 290 million years ago, much of western and northern Pennsylvania was relatively flat and covered with lake-bottom [sediments](#), which later hardened into sedimentary rock. Since that time, [erosion](#) has carved numerous stream valleys through these former lake-bottom [sediments](#) that are sometimes more than

1000 feet below the level of the surrounding terrain. The process of landscape modification continues today as [sediments](#) eroded from a [watershed](#) are transported until the water velocities slow and [sedimentation](#) occurs as bars in the middle and along the edges of the streams. [Sediments](#) are also deposited when floodwaters transport particles outside of the stream channel, depositing them on the floodplain, where they replenish soils along the stream margins.

Pennsylvania derives a number of significant recreation and economic benefits associated with its stream systems. Streams and rivers provide places and opportunities for numerous recreation activities such as fishing, tubing, canoeing, whitewater rafting, bird watching, hunting, and outdoor education. In turn, people who participate in these activities must spend money for gas, lodging, food, sporting equipment, licenses, guides, and many other associated costs. This demand helps provide jobs for local residents. Since many participants live outside the community where the activities take place, there is a significant influx of outside money to the local economies. However, there are costs associated with this tourism, especially their impact on a local government's road system. The timing of tourist activities may be unfortunate – muddy dirt and gravel roads during hunting season can cause tremendous maintenance challenges. The number of tourists viewing the autumn colors may also overwhelm the capacity of less traveled roads. Thus, the condition of a local governments' transportation system can be a great influence – advantage or disadvantage – to the economic growth of the area.

Streams are viewed as a public natural resource in the commonwealth, and, as such, are protected under Pennsylvania's Constitution. To this end, one of the primary goals of managing and protecting streams in Pennsylvania is to maintain a healthy and naturally reproducing fish community. As we have learned, natural reproduction of fish is an important goal because fish are dependent upon a clean, healthy stream environment in which to live. The lack of a naturally reproducing fish community is often an indication that conditions within the stream are degrading.

Pennsylvania has targeted two types of water bodies and their [watersheds](#) for



“special protection” in order to maintain their existing quality. These two [watershed](#) types are described as “Exceptional Value” and “High Quality.” They are delineated on a PA map in Figure A4-2. An Exceptional Value (EV) water body is considered to have outstanding water quality, and no degradation of the water is permitted. This is the most stringent protection within the

commonwealth. High Quality (HQ) water bodies are considered to be relatively unaffected by humans. No degradation of the water is allowed unless the PA Department of Environmental Protection (PA DEP) agrees that the project's social and economic benefits justify lowering the quality of the water. HQ protection is slightly less stringent than the EV protection status.

Streams designated as EV or HQ are primarily located in the headwater portions of many Pennsylvania streams. Natural reproduction within these streams is a vital function in order to maintain fish populations and trout is the especially good [indicator species](#). As discussed back in Chapter 1 as a historical perspective, many of the state's roads were laid down next to streams in order to take advantage of the gentle gradient and existing routes of travel. The location of these roads often results in [erosion](#) and [sediment](#) impacts to the adjacent streams, and resulted in the development and implementation Pennsylvania's Dirt and Gravel Road Program.

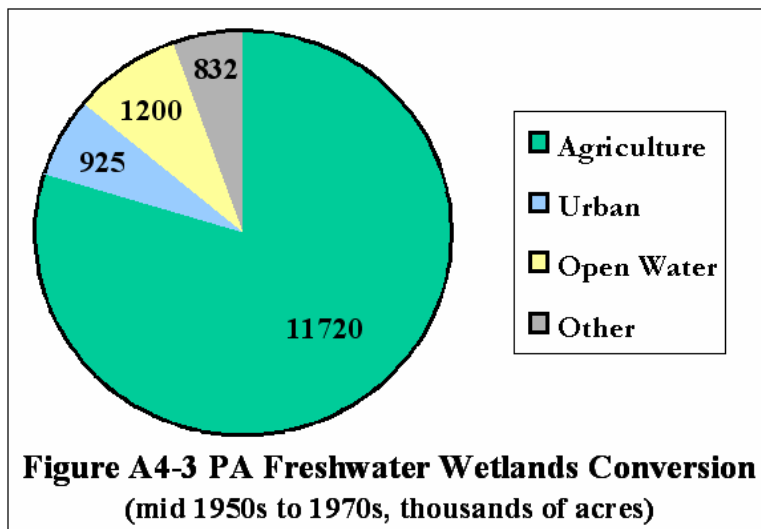
Pennsylvania's streams are evaluated by the PA DEP's Bureau of Watershed Conservation, whose focus is maintaining water quality and overall health, and the PA Fish and Boat Commission, who manage the state's recreational fishery. These agencies conduct biological and chemical surveys in their evaluation of the streams and rivers. Data collected from these surveys are then analyzed and used to make management decisions.

A4.3 Pennsylvania's Wetland Ecosystems. The [wetland](#) community is an important component of Pennsylvania's [ecoregions](#), with [wetlands](#) currently covering approximately ½ million acres, or two percent of the commonwealth. These [wetlands](#) provide many valuable services and functions that are beneficial to humans and wildlife, as described in Section 4-4 above.

At the time of European settlement in the late 1700's, there were an estimated 1.127 million acres of [wetlands](#) within Pennsylvania, or 4.5% of the state. Back then, as mentioned under Section 4.4, these [wetlands](#) were looked upon as wasteland and

unproductive land. A great deal of [wetlands](#) has been lost in Pennsylvania, with conversion of approximately 56% of the pre-settlement [wetlands](#) to human land uses.

Typically, [wetlands](#) have been converted through dredging, draining, and filling, for a number of different human uses. The conversion of [wetlands](#) for agricultural purposes has probably resulted in the



largest loss. Figure A4-3 shows that [wetlands](#) in Pennsylvania have also been converted for urban development, creation of ponds, reservoirs, and lakes, and other forms of development. The loss of [wetlands](#) has resulted in a loss of all of the various benefits that they provide.

These valuable natural resources are not evenly distributed across Pennsylvania. The northeastern and northwestern corners contain almost half of the state's [wetlands](#). These relatively small portions of the state contain a large concentration of [wetlands](#) primarily because of the impact of glaciers on the underlying geology, [topography](#), and soils. Floodplain [wetlands](#), as previously described, are found along the fringes of lakes, rivers, and streams. This is the most common [wetland](#) type in Pennsylvania.

Along with the federal agencies, Pennsylvania has a number of state and local agencies that work to protect the [wetland](#) resources, including the PA Department of Environmental Protection, the PA Department of Conservation and Natural Resources, the PA Fish and Boat Commission, and the PA County Conservation Districts.

A4.4 Pennsylvania's Upland Ecosystems. The vast majority of Pennsylvania is [upland](#)s. As discussed throughout Chapter 4, plants have physical resource requirements needed to grow and survive. Each species has its own climate, light, moisture, and soil needs. As these conditions vary across the state, plant species are not uniformly distributed. Forest types are commonly named for the species predominant within them.

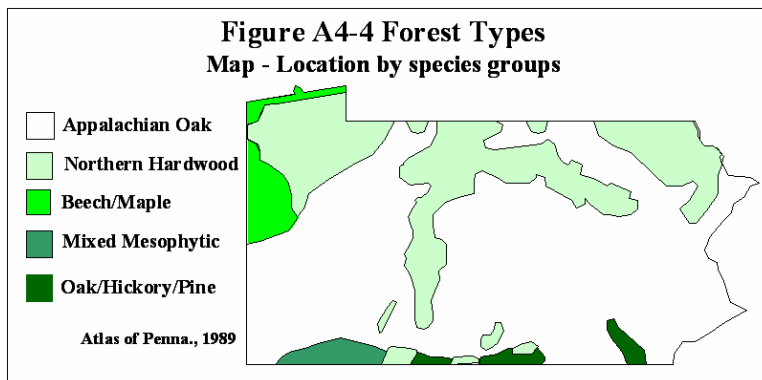


Figure A4-4 shows the forest types of Pennsylvania. Notice the similarity to the previous maps in figure A4-1 showing the geological provinces and [ecoregions](#). Trees are the rule, rather than the exception, along the dirt and gravel roads in Pennsylvania. Management of the forest systems

becomes a predominant factor in dirt and gravel road maintenance for Pennsylvania's road managers. Selective tree trimming and limiting shading as described in Chapter 6 are a major component of [environmentally sensitive maintenance](#) practices taught through the Pennsylvania Dirt and Gravel Road Program.

Environmentally Sensitive Maintenance for Dirt and Gravel Roads

Chapter 5: Environmentally Sensitive Maintenance Practices: Roads and Road Drainage

5.1 Introduction

Like when building a good road, we started with a sound foundation. We described the pollution problem from a historical perspective, discussed traditional road maintenance practices, and defined our goals and objectives. We then discussed geology, rocks, and soils as raw materials (giving you what you have to work with) for road maintenance, and continued building on that foundation with road maintenance and natural systems basics. Now, combining and using all that information, we are ready to examine good, sound, specific “[Environmentally Sensitive Maintenance](#) Practices” that will benefit both the road and the environment.

Once adopted, these practices will become commonly used tools in your road maintenance toolbox. In some cases, you may already be using the practice we discuss. In others, you may just need to tweak the practice to make it more sensitive to the environment, but still be effective for the road. Some practices may be new, but may fit a need or a particular site.

As with all maintenance and maintenance projects, we need to make that field inspection, evaluate the conditions and decide what needs to be done. The more practices or “tools” available in our toolbox, the better we will be able to perform the required tasks to prevent pollution and prolong the life of the road. Not one tool or practice will solve all your problems, but with a full toolbox, you will be able to select the most appropriate tool or tools for the job.

5.2 Erosion Prevention and Sediment Control

When we talk about [erosion](#) and [sediment](#), we should emphasize [erosion](#) prevention. If we prevent [erosion](#) from happening in the first place, there is no [sediment](#) to pollute. [Erosion](#) prevention becomes our first line of defense. Look at the badly eroded road in Photo 5-01. Notice the banks on each side of the road. At what elevation do you think the road surface was forty years ago? The road



5-01 Typical entrenched eroded road.

would not have been built at the present elevation. If the road surface was originally at the top of the banks, where did all the material go? This is only one small section of road. We have many miles of forested roads with similar profiles. From this photo, we can see why [sedimentation](#), by volume, is the largest pollutant of our streams. Typically, roads with higher banks on each side cause can be improved by filling the road cross section. This technique, although involving major fill work, will be discussed in Section 5.3.7, along with all its advantages.



5-02 Once erosion takes place, the sediment needs to be addressed.

When [erosion](#) does take place, for whatever reasons, then we have to control the resulting [sediment](#). Otherwise, we can end up polluting our streams and have serious problems both for our roads and the environment.

5.2.1 Managing Your Erosion Prevention and Sediment Control Systems. Whether temporary or permanent controls, managing your control systems is important. Periodic inspections of your roads, drainage facilities and work sites

allow you to keep an eye on potential problem areas and identify problems when they first start. For example, a vulnerable spot around a [culvert](#) is a danger sign. If ignored, it could create major road problems, damage the environment, and escalate costs. The following sections include sound practices that can make your control systems more effective and efficient.

5.2.2 Temporary and Permanent Erosion Prevention and Sediment Control Measures. Road managers have a wide variety of control methods or practices at their disposal to combat [erosion](#) and [sedimentation](#). They range from the simple to the complex. In some cases, it may be as simple as widening a ditch or flattening a slope to reduce water velocity.

[Erosion](#) prevention and [sediment](#) control can be broken into two areas or conditions that we have mentioned before:

Temporary Practices: Practices used before or during construction or maintenance work to prevent and control only for those activities. These include emergency work situations. Some practices serve as either temporary or permanent solutions. Other temporary practices can be used during maintenance and construction activities and become permanent after the work is completed.

Permanent Practices: Practices uses as long-term prevention controls, often requiring little or low maintenance. These practices may be simple or complex in construction and costs.

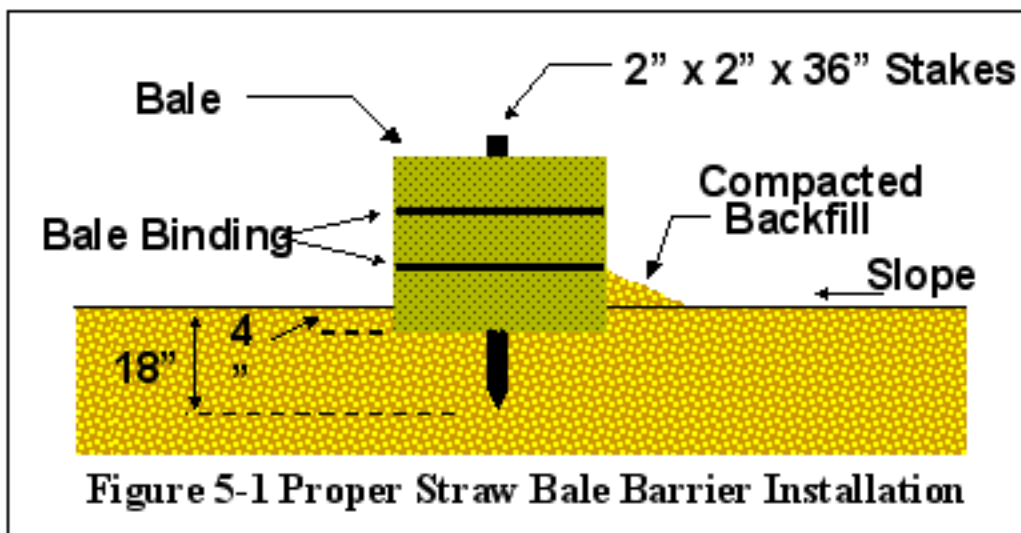
5.2.3 Basic Temporary Practices. Two of the most common temporary controls are straw bales and filter fabric fence ([silt fence](#)). Unfortunately they are also the most improperly used techniques on road construction and maintenance work sites. Although the use of bales has traditionally been a popular method of [sediment](#) control from work sites, the fact remains that they are relatively ineffective. **Straw (or hay) bales are not recommended for use.** Bale barriers have more failures than successes and are expensive to install and maintain. The Federal Environmental Protection Agency (EPA) does not recognize bale barriers as an appropriate control method. Since straw bale barriers are still being used in many areas, the most effective installation practices are described below, followed by the recommended commonly used [silt fence](#) (fabric filter fence) barrier.

5.2.3.1 Straw Bale Barriers (not recommended by EPA). Straw bales are for temporary use only. Bales should not be used for more than 3 months. They should not be used in concentrated flow conditions. They should only be used for sheet or shallow flows.

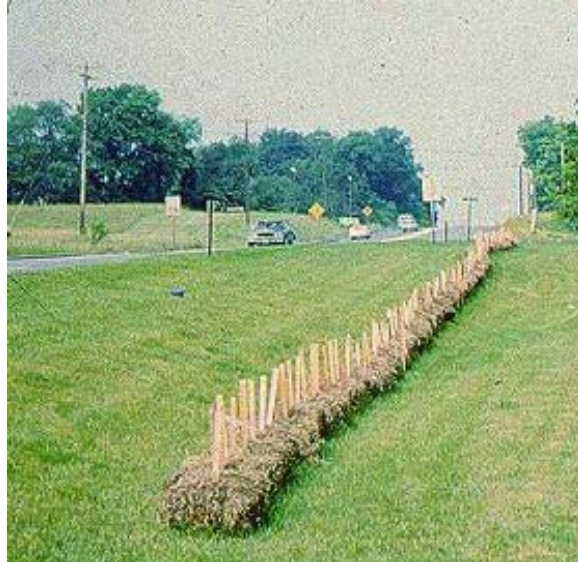


5-03 Improper bale installations doomed to fail!

Proper installation is essential as shown in Figure 5-1.



They should be placed in an excavated area approximately four (4) inches below the ground surface and the excavated soil compacted on the upslope side of the bales. Each bale should be anchored securely by 2 support stakes with straw being wedged between the bales. Notice in the figure that the bale bindings are horizontal, not vertical, where they would be in contact with the ground and susceptible to rot or degradation. Photo 5-04 shows a proper installation immediately prior to a major construction project.



5-04 Proper bale installation prior to start of a major construction project. (Note: Bale barriers not recommended by EPA.)

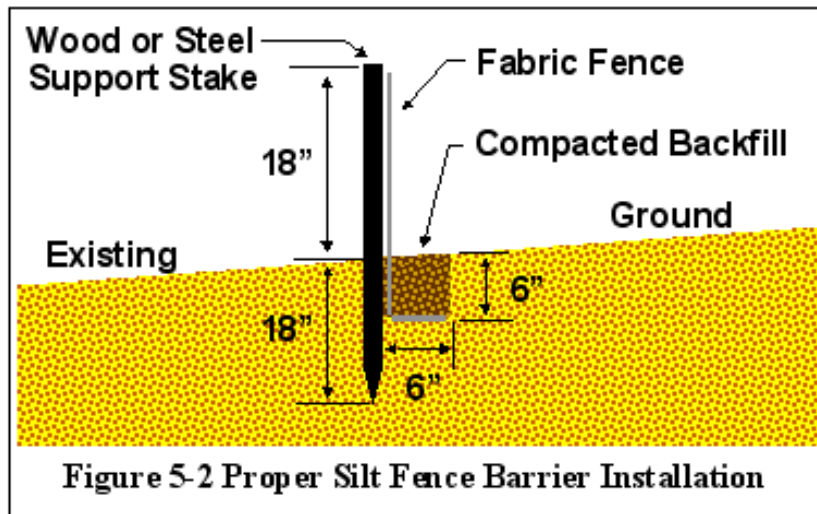
They need to be inspected at regular intervals and cleaned or replaced as needed. Cleaning should take place when the [sediment](#) reaches 1/3 above the ground height of the barrier.

5.2.3.2 Silt Fence Barrier. [Silt fence](#) or filter fabric fence is a [geosynthetic](#), or specifically a [geotextile](#) fabric, designed for the filtration function needed in [sediment](#) control. Again, this fabric is for temporary use only and should not be used for concentrated flow conditions, as can be seen in the photos. [Silt fence](#) is normally used at the toe of slopes for sheet [sediment](#) flows.



5-05 Improper silt fence installations.

Proper installation is essential, as shown in Figure 5-2. The fence needs to be anchored by digging a small trench and burying the toe of the fabric as shown. Wood or metal stakes need to be placed on the downslope side of the fabric to properly support the installation against the load.



5-06 This installation will not control much sediment!

Photo 5-06 shows an improper installation with the bottom of the fabric above ground level (this will last a long time but won't control much [sediment](#)). Photo 5-07 shows a good installation in a new paved road subdivision that has not been maintained. Although this photo shows the strength of a [silt fence](#) barrier, the risk of a system failure is imminent, and the consequences of pollution and cleanup required could be quite substantial. Filter fabric fence should

be cleaned when the [sediment](#) reaches one-half the height of the barrier.

Like straw bales, frequent inspections followed by proper cleaning or repairs are necessary for proper performance. Filter fabric fence is much more effective and has a much longer life than straw bale barriers but still must be installed properly, inspected regularly and properly maintained.



5-07 Cleaning is required when sediment reaches one-half the height of the fence.

5.3 Environmentally Sensitive Maintenance Practices

Let's turn our attention to more permanent practices that both prolong road life and are good for the environment. Specifically we will look at environmentally sensitive practices involving the road profile, driveways, drainage ditches, [culverts](#), [end structures](#), stream crossings, and bridges. Roadsides and banks will be specifically addressed in Chapter 6.

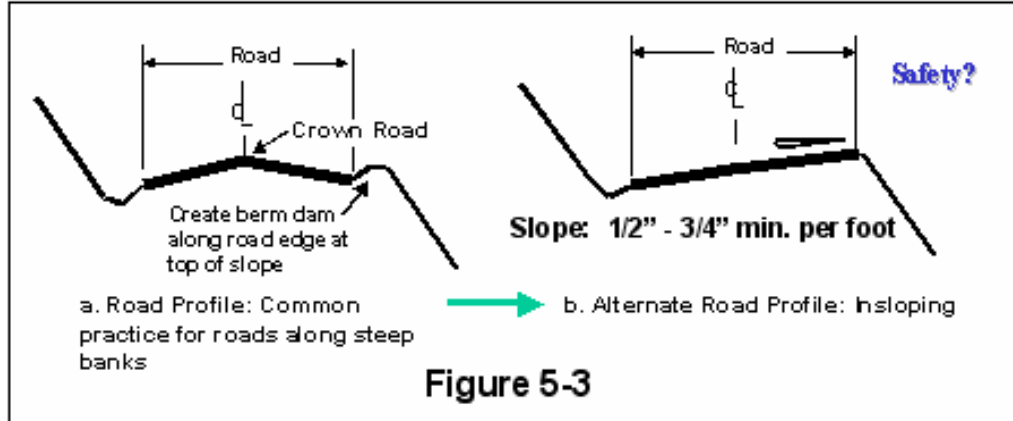
These practices, as stated before, are mostly simple, practical techniques that can be easily implemented. Local government road crews can perform most of the practices with available equipment resources, incorporating them into their normal routine road maintenance program. Not all practices will apply to any one road or one road system, but having a full toolbox to address any problem encountered lowers overall costs. Many of these practices can be used in combination and will apply to most dirt and gravel roads in general. And many practices are also useful on paved roads.

As we discuss these practices, keep in mind that proper drainage is absolutely essential to prolonging road life and protecting the environment. Drainage means handling flowing water. Greater volume and greater velocity (speed) of that water result in greater [erosion](#) and [sedimentation](#). In other words, if we can limit the volume of water and slow it down, we diminish the energy and [erosion](#) potential of the flow. Many of the practices to be discussed are based on this “divide and conquer” premise. By limiting the drainage area contributing to the flow, we reduce water volume, thus allowing smaller sized drainage facilities (ditches, pipes, etc.). This reduced area also reduces the flowing water's ability to pick up speed, reducing energy and the likelihood of [erosion](#).

Common practices will be mentioned without elaborate detail but with some explanation of the rationale for inclusion. Other more uncommon practices will include a short description and associated sketches as necessary for clarification. For discussion purposes, the practices are organized into related groups.

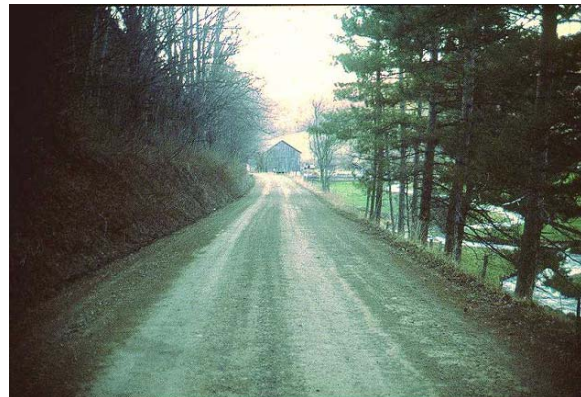
5.3.1 Practices Related to Road Profile. In Chapter 3, we discussed the importance of [road crown](#) and [cross slope](#), road shoulders, good road materials, and proper road drainage. Following those basic practices will result in a better road and promote a better environment. But beyond those basics, we now introduce several alternate road profile practices.

5.3.1.1 Insloping. “[Insloping](#)” of the road can be applied when the road runs along a steep bank. With a steep uphill bank on one side and a steep downhill bank on the other, common practice is to install a normal crown (see Figure 5-3a). This practice concentrates the water volume and flow, causing [erosion](#) with the possibility of a severe washout down over the bank and normally into the adjacent stream below. Sometimes a berm dam is installed along the edge of the road at the top of slope. The berm dam can also cause a [secondary ditch](#) with poor road drainage and a build-up of water volume and flow that could result again in a severe washout.



Insloping the road using normal cross slopes may take care of this problem (see Figure 5-3b). The entire road is sloped toward the uphill side, eliminating flow over the steep downhill slope and the possible erosion and washout into the stream. The only water reaching this downhill slope will be the rain that falls directly onto the surface. The water draining from the road and the uphill slope still should be collected via a ditch on the uphill side and carried to a cross culvert. The only additional water, however, that is draining into this ditch is from the other half of the roadway surface. This limited additional water volume will not require changes in ditch and culvert sizes. Culverts can be placed strategically with outlet flow protection as needed. The berm on the downhill side can still be built up if desired for safety of vehicles.

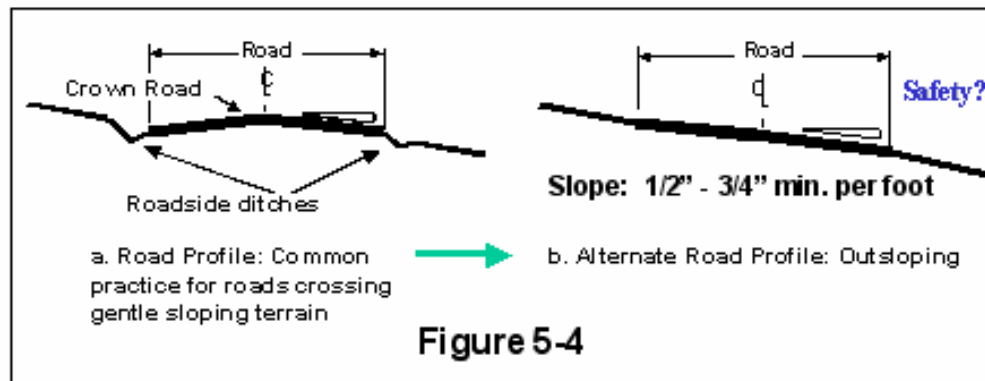
Photo 5-08 depicts the typical conditions for insloping. We can prevent water from flowing over the face of the downhill slope by sloping the entire roadway toward the uphill embankment on the left side of the photo. We need to collect this water into a side ditch and to a cross pipe to outlet away from the road. In this photo, we can see how the stream meanders close to and then away from the road. The cross pipes can be strategically located where the vegetative grass strips are the widest to filter out any potential sediment prior to entering the stream. At this particular site, a cross pipe can be installed further down the road where its outlet would be at a flat rock outcrop. This rock configuration will spread the flow, acting as an energy dissipater prior to a grass filtering strip and the stream.



5-08 Road candidate for insloping.

Vehicular safety has to be considered in this approach. Keeping the [cross slope](#) at a minimum and considering low traffic volumes, we can still maintain a berm dam on the downhill side for extra safety perception since everything is draining away from that side.

5.3.1.2 Outsloping. “[Outsloping](#)” of the road can be applied when the road crosses a **gentle sloping terrain**. Common practice is to install a crown with side ditches. This configuration (see Figure 5-4a) creates a dam and concentrates the overland sheet flow with possible [erosion](#) of ditches and ditch outlets. This profile also requires cross pipes to outlet the uphill side ditch with the potential clogging and flooding concerns. The volume of water to be handled can become substantial.



With [outsloping](#), we slope the entire road with a normal [cross slope](#) from one side to the other, similar to [superelevation](#) on a curve, but with no ditching. With this [outsloping](#) of the road, as shown in Figure 5-4b, and blending it into the surrounding terrain, concentrated flows are eliminated with no ditches or cross pipes required. The existing general slope sheet flow continues across the road with no interference. This technique should be used with **gentle sloping terrain and low overland sheet flow conditions**. Low traffic flow (low [ADT](#)) should also be a prerequisite.

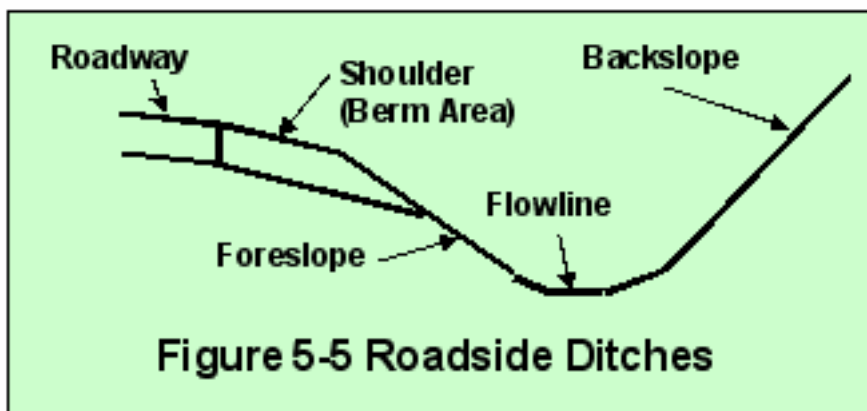
Photo 5-09 shows a typical outsloped road. The terrain is gentle with low sheet flows, which are carried across the outsloped road blending into the natural drainage. This will eliminate concentrating the water flow in ditches and cross pipes and the maintenance of these facilities. Site selection for this practice is critical. A heavy storm may require road maintenance afterward if the flows are substantial enough to cause road surface degradation.



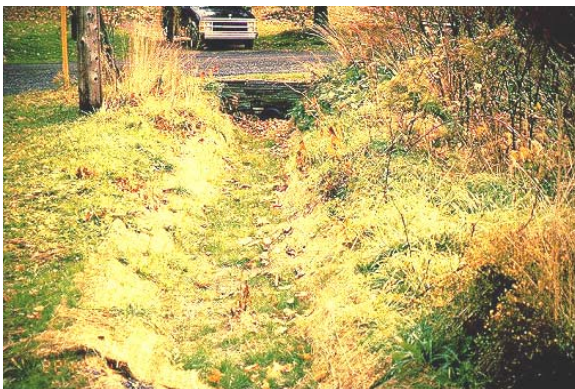
5-09 Outsloping this road proved beneficial, eliminating ditches and cross pipes.

Again, safety should be a concern. Normal [cross slopes](#) can be used, alleviating the concern of vehicle safety. Depending on the road surface and amount of flow along with the temperature conditions for the area, however, icing of the road surface may become a problem. This has not happened on the various sites where [outsloping](#) has been implemented, but the concern should be recognized and conditions monitored during the winter months.

5.3.2 Practices Related to Roadside Ditches. Ditches drain water away from the road, but often cause various [erosion](#) and [sediment](#) problems. A typical ditch sketch is shown in Figure 5-5 with common ditch terms of foreslope, backslope, and [flowline](#). In discussing ditches, there are several [environmentally sensitive maintenance](#) practices that can be considered.



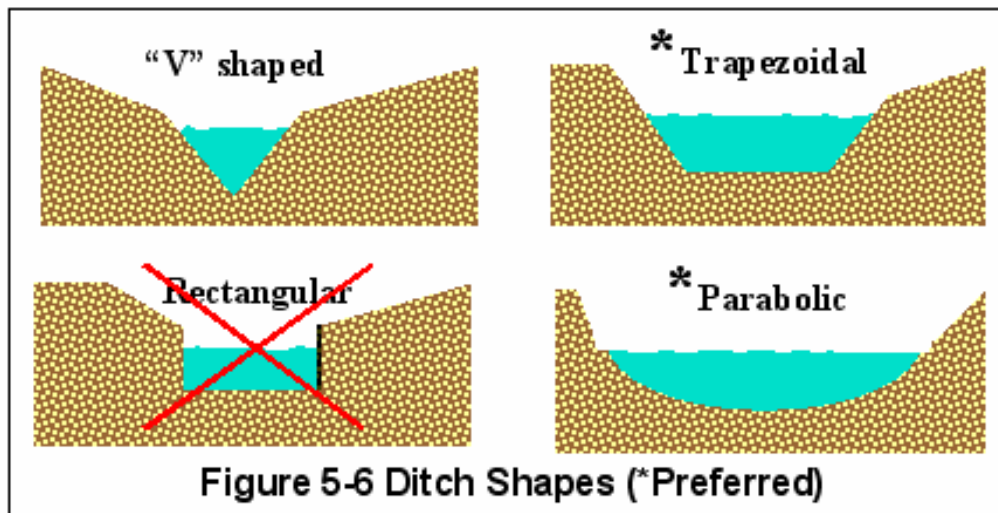
5.3.2.1 To Ditch or Not To Ditch? The first question in ditching should always be “Do we need a ditch?” If the road surface drainage can continue to sheet flow away from the road without causing any problems, then a ditch only becomes an impediment, concentrating the sheet flow and compelling further handling through ditches and/or pipes to an outlet along with all the required maintenance. If we can let the road drain naturally by sheet flow into a vegetated area, flows are spread out and thereby slowed down, resulting in the least [erosion](#) and [sediment](#) potential. At many sites, however, this natural sheet flow drainage conditions is not possible, and ditching is still going to remain the option of choice.



5-10 Trapezoidal shaped ditch.

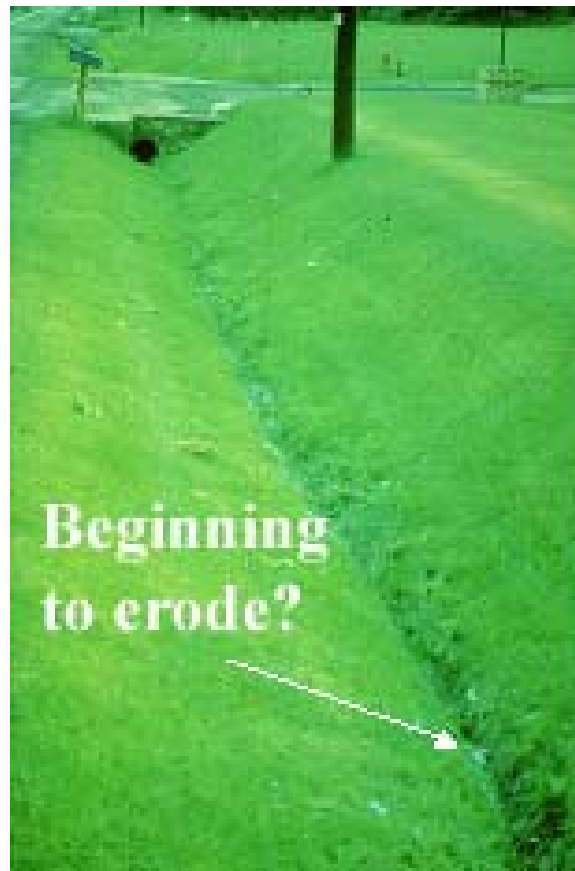
5.3.2.2 Ditch Shape. Ditches should be shaped and sloped to prevent standing water and must have an outlet. Safety for errant vehicles should also be a consideration. There are many ditch shapes, with common shapes shown in Figure 5-6 with different advantages and disadvantages. For purposes of [erosion](#)

prevention and the environment, ditch cross sections with a trapezoidal or parabolic shape are desired. These shapes tend to spread water flow and slow it down, which will reduce the [erosion](#) potential and subsequent [sediment](#).



V-shaped ditches are common due to motor grader use in dirt and gravel road maintenance and may not be a problem. A deep V-shape, however, concentrates water flow, increasing its velocity, possibly eroding the ditch's bottom. Deep sharp V-shaped ditches are more prone to this bottom [erosion](#) and should be inspected regularly. If water flows and velocity are starting to cause [erosion](#), the ditch can simply be flattened to a wider V-shape. This will again spread the water out and slow it down, diminishing the energy and thereby the [erosion](#) potential. Photo 5-11 shows a good grass-lined, v-shape ditch. On close inspection, however, the bottom of the ditch is showing signs of initial [erosion](#). The [erosion](#) may not get any worse, but the ditch needs to be watched. If the [erosion](#) continues and gets worse, a possible solution may be a simple flattening of the ditch, which would spread the water and slow it down, decreasing energy and [erosion](#) potential.

Rectangular shapes give a vertical surface prone to destabilization and

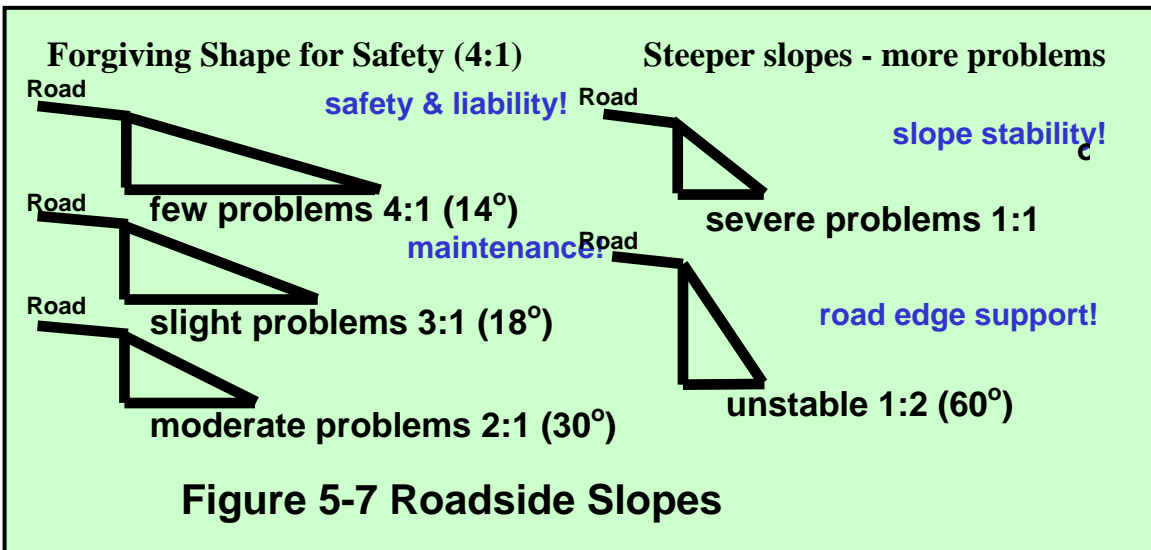


5-11 Grass-lined, V-shaped ditch.

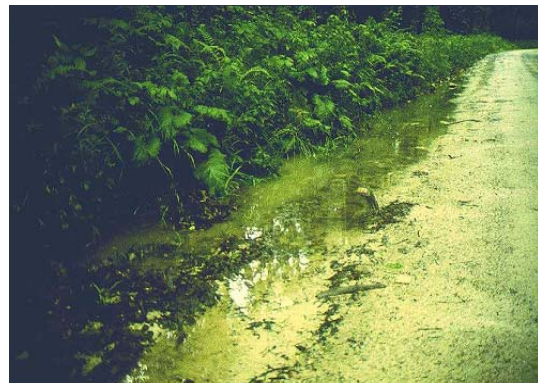
[erosion](#) without a more substantial surface protection. Rectangular-shaped ditches may also pose a vehicular safety hazard and are not recommended for use.

5.3.2.3 Ditch Slope. Ditch side slopes often dictate the amount of maintenance due to instability and resulting [erosion](#) and [sediment](#). The recommended side slope is 4 to 1 (4 foot horizontal to every 1 foot vertical drop). This slope provides greater stability, better support for the road, and is easier to maintain. In addition, this 4:1 slope is a forgiving shape for safety. A vehicle running off the road onto a 4:1 slope will not turn over and has a better chance to recover control without a serious accident.

On many existing roadsides, the terrain or right-of-way limitations do not allow for a proper slope and ditch. We need to keep in mind, however, that the steeper slopes mean greater instability, less road support, harder maintenance, and lower safety levels (see Figure 5-7).



Ditches should have minimum longitudinal slopes of 1% or 1-foot drop in 100 feet of ditch. For proper drainage, we need to keep ditch water flowing to an outlet away from the road. Standing ditch water will only result in additional road maintenance. The water will seep back into the road structure, creating the road softening lubricating effect described in Chapter 3 along with freezing and frost heave problems.



5-12 Standing water can only lead to problems.

Flatter slopes slow the water, decreasing ditch [erosion](#) while steeper slopes increase velocity, raising ditch [erosion](#) potential. On the other hand, flatter slopes will allow [sediment](#) accumulation resulting in

increased ditch cleaning, but, remember, if there is no [erosion](#), there is no [sediment](#). Find the source of the [erosion](#), fix the [erosion](#) problem, and eliminate the [sediment](#).

5.3.2.4 Alternative Ditch Cleaning Practices. By tweaking traditional practices, ditches can be cleaned in an environmentally sensitive way that benefits the road as well. Again, please note that these practices may not be entirely new, but just a modification of something we are already doing.

Watch Weather Conditions. You can avoid potential devastating [erosion](#) and [sediment](#) events by only cleaning ditches when no substantial rain or storms are predicted.

Conduct Erosion and Sediment Control During Maintenance. Temporary [erosion](#) prevention and [sediment](#) control practices (refer to Section 5.2.3 for common basic practices) should be used as necessary during the maintenance operation and until vegetation is completely reestablished. Vegetation reestablishment is critical – including seeding and soil supplements and mulching. Seeding for re-vegetation and other vegetative stabilization practices will be thoroughly covered in Chapter 6.

Sectional Cleaning. Common practice is to clean the entire ditch along the entire section of road right to the outlet and directly to a stream. We will look at that direct outlet to the stream and better alternatives, such as outletting into a [vegetative filter strip](#) below. However, we will now look at some alternative cleaning practices that can be used in combination with other practices. For example, cleaning upgrade sections first and leaving the last section before the outlet until later avoids excessive [erosion](#). Similarly, cleaning alternating sections of long ditches accomplishes the same result, and if [erosion](#) does take place prior to re-establishment of vegetation, the [sediment](#) will be trapped in the uncleaned sections that can be cleaned later.

5.3.2.5 Ditch Widening and Slope Flattening. Preventing ditch [erosion](#) may be as simple as widening the ditch to spread water flow and slow velocity or flattening the ditch side slopes to slow water velocity entering the ditch. Remember, the slower the water, the less erosive force it has with less potential for [sediment](#) pollution. These practices go right back to the parabolic or trapezoidal shapes discussed before.

5.3.2.6. Reuse of Topsoil and Vegetative Root Mats. In ditch cleaning, ditch widening and slope flattening operations, we usually clean out the established vegetation and end up with subsoil conditions. In Chapter 2 we saw that “dead” subsoil poses a problem for reseeding to establish vegetation. Ditch work can strip existing vegetation and topsoil, which is usually hauled away and discarded. With a little more work and effort, this material could be reused, and re-vegetation will become easier and more timely. Depending on the natural conditions and the equipment used, the existing vegetative root mass can be stripped, laid aside while subsoil is removed to the proper elevations, and then the root mass reused on the newly constructed surface. This root mass, with proper moisture, will re-establish and may need no other seeding or soil supplements added, thus saving additional maintenance work for revegetation and repair

of eroded areas. This practice will be further discussed in Chapter 6 when we look at roadside banks.

5.3.2.7 Ditch / Channel Linings. The water volumes and velocities of ditch and channel flows may necessitate different stabilization methods using different ditch/channel linings. Higher velocities usually dictate a more substantial ditch lining. Each site has to be analyzed to determine what may be required. Charts showing maximum velocities for different linings are available and are good guidelines. A typical chart for natural soil, vegetation and several “paved” linings with the maximum velocities sustained by these linings is shown in Figure 5-8.

Figure 5-8 Maximum Velocities for Various Types of Ditch/Channel Linings	
Natural Soil Linings	Max Velocity (fps)
- Clean gravel	6 - 7
- Silty gravel	2 - 5
- Clean sand	1 - 2
- Silty sand, clay	2 - 3
- Clayey sand, silt	3 - 4
Vegetative Linings	Max Velocity (fps)
- Avg. turf, erosion resistant soil	4 - 5
- Avg. turf, easily eroded soil	3 - 4
- Dense turf, erosion resistant soil	6 - 8
- Gravel bottom, brushy sides	4 - 5
- Dense weeds	5 - 6
Paved Linings	Max Velocity (fps)
- Gravel bottom, concrete sides	8 - 10
- Rip-rap sides & bottom	15 - 18
- Concrete or asphalt	18 - 20

As velocities increase, more substantial linings are required to prevent [erosion](#). Remember, however, to keep in mind that if we can spread the water out by widening the ditch/channel and flatten the



5-13 Seeding and mulching may be sufficient to revegetate the ditch.

ditch/channel grade, we can slow the water (reduce the velocity) and possibly negate the need for a more substantial paved lining. Vegetative linings are less costly over the long run when compared to paved linings. Vegetative linings also provide for infiltration and better aesthetics.



5-14 A biodegradable netting will prevent erosion until vegetation is established.

For stabilizing new or disturbed roadside ditches with vegetation, practices can range from seeding and mulching only or in combination with biodegradable mats, netting or blankets, to [geosynthetics](#). These materials provide [erosion](#) prevention until the vegetation becomes re-established. They usually come in rolls with directions for pinning or anchoring. Many different products are available with many different designs depending on soil characteristics and water flow conditions. They allow vegetation to grow while providing the necessary [erosion](#) protection either temporary as for the biodegradable types to more permanent reinforcement provided by the [geosynthetics](#). Keep in mind that [geosynthetics](#) are not biodegradable and will remain for an indefinite period of time.

The type of lining is selected based on the steepest grade of the channel or ditch. Velocity and volume of water in



5-15 Many geosynthetic products are available for erosion prevention.

the ditch and the potential for [sediment](#) also need to be considered. If the flow is too slow, [sedimentation](#) is the major factor; if the flow is too fast, [erosion](#) of the ditch and lining material is the major factor.

Of course, any lining should be installed properly. Photo 5-16 shows a biodegradable netting installation. But look at the [erosion](#) behind and around the [culvert](#) with [sediment](#) on top of the netting. We need to make sure we examine the entire area and stabilize accordingly.



5-16 Good netting installation, but problems at pipe outlet need to be addressed.

Vegetation lined ditches offer several advantages including low-cost maintenance. (Refer back to Figure 5-8 for maximum allowable velocities for different types of vegetation-lined ditches.) Vegetation not only protects the soil from [erosion](#) by covering the surface and slowing the water flow with the root structure reinforcing the soil layers, but it also removes silts and fines and attached chemicals from storm water allowing infiltration for ground water replenishment. Keeping suspended solids in side ditches improves water quality.



5-17 Use caution when deciding to line ditches with rock riprap.

Here is one word of caution. [Riprap](#) is not a good ditch/channel lining choice if further [erosion](#) and [sediment](#) is likely. The rock [riprap](#) will fill with [sediment](#) resulting in major cleanup problems. Most likely, the [riprap](#) will have to be removed and replaced at considerable expense. This type of operation can strain limited local government budgets. When considering [riprap](#) for ditch linings, factor in future maintenance costs as well. Photo 5-18 shows a typical rock [riprap](#) use as ditch lining placed during construction. If this area is not stabilized immediately, the [riprap](#) will end up filled with [sediment](#) during the first rainstorm. Keep future

We must keep ditches from filling with [sediment](#). Always look to the source of the [erosion](#) and [sediment](#) to determine what corrective measures can be taken.

Higher water velocities may demand more substantial linings such as [riprap](#), as seen in the chart. Reducing water velocity should always be a priority. For instance, widening the ditch allows you to use a less expensive lining.



5-18 Riprap placed during construction—looking at the sediment potential, was this a good idea?



5-19 Do not outlet ditch directly to stream—use turnouts into vegetative filter strips!

maintenance in mind when considering any materials or practices at any given site.

5.3.2.8 Ditch Turnouts and Vegetative Filter Strips. Do not outlet ditches directly to streams. Photo 5-19 shows a common situation with ditch outlets. They carry water along with any [sediment](#) directly to the stream, which is the low point on the road. We need to change our way of thinking and doing in this regard. We need to

consider turning the ditch out prior to that low point or that stream into a vegetative filtering area or “filter strip.”

[Ditch turnouts](#) and [vegetative filter strips](#) should automatically go together. Vegetation filter strips spread the water flow, slow velocity, decrease erosive force, and filter out [sediment](#). The slower water allows [sediment](#) to settle. Other pollutants that may have attached to the [sediment](#) will also be contained and may break down and dissipate, as described in Chapter 4.

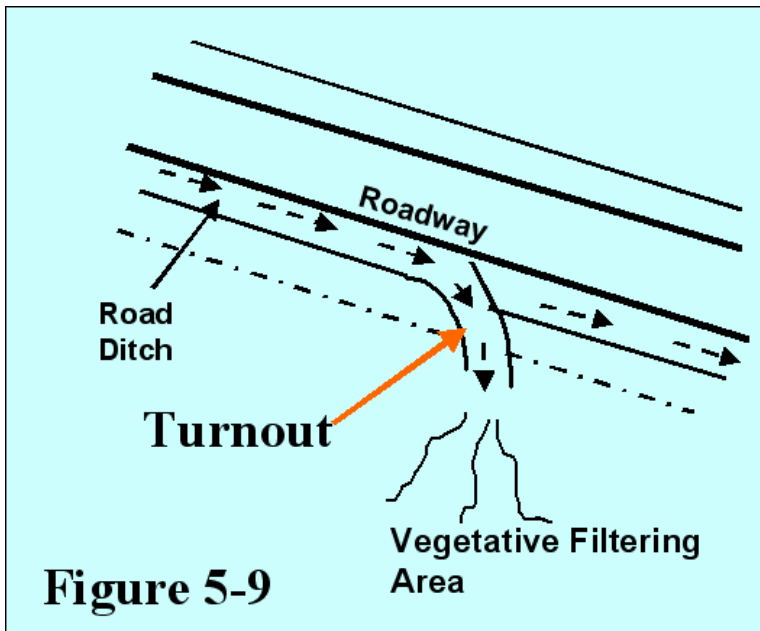


Figure 5-9

In addition, **more** **turnouts** should always be an option. Limiting the length of the ditch to a turnout will reduce the amount of water and flow in the ditch, keeping ditch size nominal and reducing water velocity and [erosion](#) potential (remember “divide and conquer”). Numerous turnouts may be the answer to the private property flooding/wet area problem created by one long ditch with one turnout at that location. Dumping a huge

volume of water with possibly a high velocity from a long downhill ditch can cause [erosion](#) and flooding problems on private property. Installation of additional turnouts will break the volume of water into smaller quantities, reducing velocity and [erosion](#) and flood potential.

As in other techniques, there are no exact spacing or size requirements for turnouts. Charts are available but usually are based on only one condition such as the longitudinal grade of the ditch. They do not take into consideration the many variables that are different from site to site. Other factors to consider are water volume, ditch slope, right-of-way conditions, and ownership. Water volume can vary considerably depending on the terrain – does the ditch just drain the road surface or the road surface plus the entire hillside adjacent to the road?

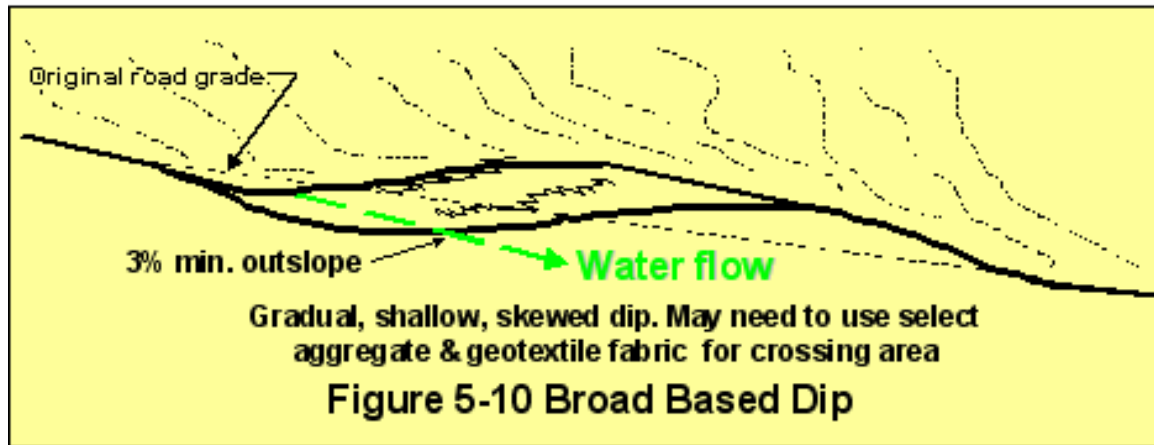
Photo 5-20 shows a simple turnout of nominal dimensions and a large turnout that apparently takes a lot of water. In the case of this large turnout, the terrain and off right-of-way conditions created no problems or concerns. But every site will be different. We need to remember that more turnouts mean less water, less [erosion](#), and fewer ponding or flooding problems, meaning less future maintenance.



5-20 Multiple small turnouts mean less water, less velocity, less erosion potential.

Working with Residents. Do you have a problem concerning drainage and private property and dealing with residents? Working with property owners is always a requirement for road maintenance personnel. Most people will respond better if they are approached beforehand with a thorough explanation of the work or project to be completed. A resident whose lawn is saturated from a [ditch turnout](#) may not be too enthused about putting in additional turnouts. But if approached prior to the work with a positive attitude and explanation of the benefits, the resident may be willing to at least try the solution to see how it works. The additional turnouts may solve the problem by dissipating the water in smaller amounts over a greater area with no adverse effects anywhere. Maintenance workers should promise to reestablished original conditions if the situation does not improve. Establishing good relationships with residents enhances the road department's ability to implement new practices to get the job done.

5.3.3 Practices Related to Ditches and Road Profile



5.3.3.1 Broad Based Dips. “[Broad based dips](#)” are shallow gradual dips skewed across the road in the direction of water flow, as depicted in Figure 5-10. “[Broad based dips](#)” are used when there is a high embankment on one side of the road with a downhill grade. The high embankment does not allow for ditch outlets and would normally require a cross pipe to carry the water to the other side and then to an outlet. These cross pipes are expensive to maintain because of their great potential for blockage and other problems to occur. Without “[Broad Based Dips](#),” the water is carried all the way to the bottom of the downhill grade in large volumes at high velocity. The only way to deal with it then is to build large-sized ditches. But this approach creates [erosion](#) and [sediment](#)-laden flows that usually outlet directly into a stream. Water also tends to drain down the road surface, building in volume and velocity, producing severe surface [erosion](#).



5-21 Severely eroded road – ideal conditions for broad based dips.

(“Water bars” may be a familiar term and are similar to [broad based dips](#), but with a significant difference. Water bars are short, abrupt drainage ways to get water across a road without using a cross pipe. They eliminate water from flowing down the road and can be used to actually block traffic use of the road. They have been most often used on retired logging roads to block traffic and divert water away from the road. [Broad based dips](#) can be thought of as water bars stretched out into gradual slopes in order not to interfere with vehicles using the road.)



5-22 Broad based dips can be used in lieu of cross-pipes.

the road is eliminated within this area. The use of multiple [broad based dips](#) on a long downhill stretch of road also allows a smaller ditch size to carry the limited volume of water from a shorter section of road, which will not build in volume or velocity within the area between these crossings. This limited water volume and flow should not be substantial enough to do any damage to the reinforced road surface crossing.

[Broad based dips](#) can be graded into the road rather easily with existing road materials. Depending on road materials and conditions, an hour of grading and shaping time should be sufficient to complete a [broad based dip](#). For general guidelines, water volume must be contained in the channel with no overtopping the dip, longitudinal road slopes must be gradual to prevent vehicles from dragging. The best way to test the safe traverse of a [broad based dip](#) is to drive the road after installation. If the bounce is too great or dragging is experienced, it may be necessary to reshape the skewed dip.



5-23 Broad based dip reinforced with large aggregate.

The dip may have to be reinforced or stabilized with a select aggregate and [geotextile](#) separation fabric, since we have water and traffic crossing perpendicular to one another. The need for this reinforcement/stabilization will depend on water volume and flow and the type of existing road material. These fabrics will be discussed in Chapter 7.

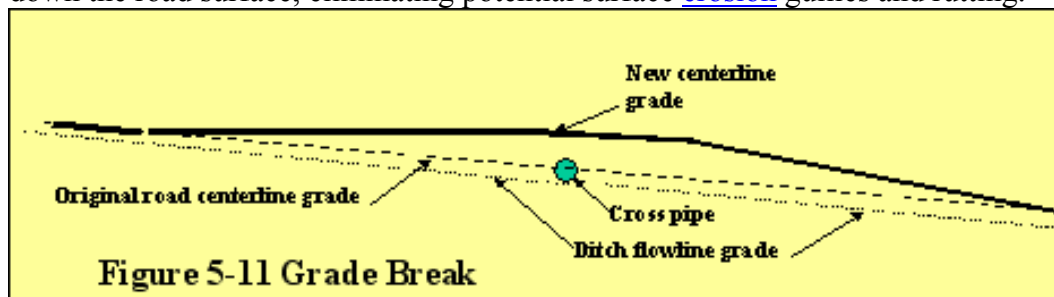
[Broad based dip](#) spacing and size will vary from site to site depending on road and ditch slopes, volume of water, traffic, terrain, etc. Experienced road personnel know the roads and the water conditions encountered from storms. Their knowledge of the site should be sufficient to establish size and spacing required for [broad based dips](#).

On very low traffic volume roads, [broad based dips](#) present an alternative to the costly cross pipes without creating large [erosion](#) producing flows. **Used only for ditch flows**, [broad based dips](#) should not be used for perennial streams with permanent or intermittent flows. [Broad based dips](#) allow the ditch water to flow to the other side joining that ditch flow to a joint outlet or turnout to a [vegetative filter strip](#). The “dip” channel is skewed in the direction of water flow, and the crown of

Remember, a greater number of dips decreases the length of road being drained and thereby decreases the volume and the velocity of the water to be handled within each [broad based dip](#).

Road grader operators have to be aware of the [broad based dip](#) installations so that they do not think they are washouts or problem areas and reshape the road back to a normal crown. In addition, winter plow operators should be aware of these installations for proper and safe plowing operations.

5.3.3.2 Grade Breaks. “[Grade Breaks](#)” are long, gradual breaks in grade on a road with a relatively gradual downhill slope. [Grade breaks](#) retain the [road crown](#) and require appropriately placed cross pipes. [Grade breaks](#) limit water flow by decreasing concentration and velocity from a reduced area of road section, resulting in limited ditch and cross pipe size. This reduction in water volume and flow in turn helps alleviate problems at the pipe outlet. [Grade breaks](#) also limit the length of flow and thus velocity down the road surface, eliminating potential surface [erosion](#) gullies and rutting.

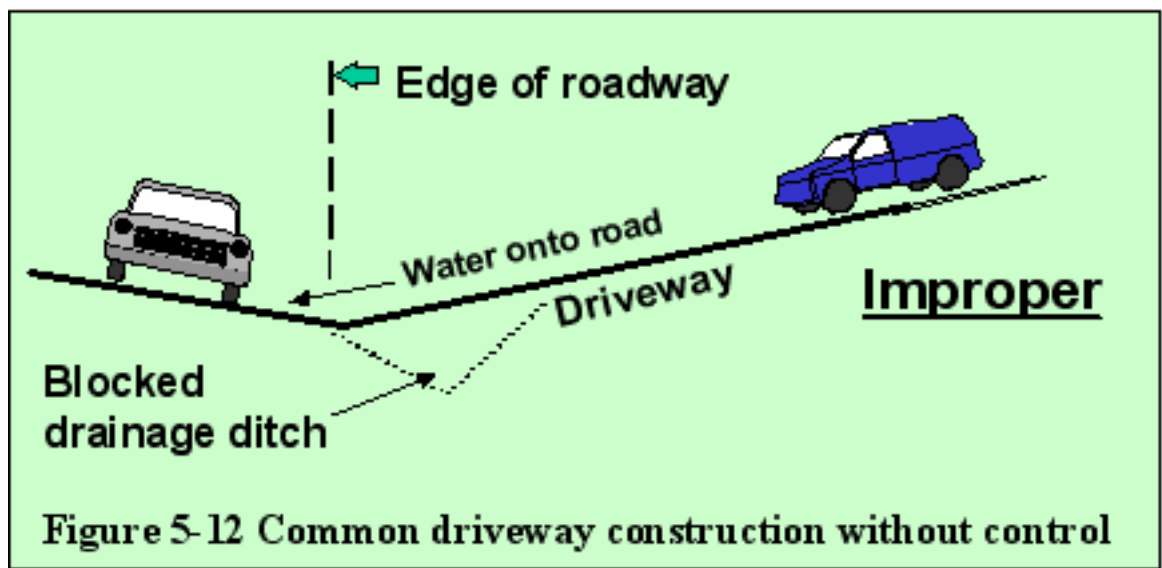


5-24 Grade breaks result in short road sections with reduced water volume and flow velocity.

Photo 5-24 depicts typical [grade breaks](#) on a road with a long downhill slope. Like broad base dips, there are no exact formulas for spacing or size, again depending on slopes, traffic, volume of water, terrain, etc. Although the photo shows cross pipes at the road low points, cross pipes can be strategically placed and can actually be used to create the [grade break](#). A cross pipe can be installed to effectively meet the ditch gradient, as shown in Figure 5-11, and the road would be built up and over the pipe to create a [grade break](#). Otherwise, cross [culverts](#) would have to be installed at a much deeper elevation than the road ditch, resulting in additional potential for pipe blockage, road flooding, or road and ditch [erosion](#). Pipe outlet areas

should be continually monitored and [erosion](#) protection established as needed. Alternative [erosion](#) prevention measures at pipe outlets will be discussed in a later section.

5.3.4 Practices Related to Driveways. Driveways can only be controlled through an ordinance or regulations and a permit system. Each local government should adopt policies and procedures appropriate to their particular situation and resources. Many local governments provide for a cost sharing arrangement with the property owner. The local government may pay for and supply a cross pipe to continue ditch flow, or may do the pipe installation at no cost to the owner. Options as to who does what work and who pays vary considerably from one local government to the next one, but the decision must be set by ordinance or regulation. The main factor is “to have control” so road personnel are free to review the site and determine the best approach to protect both road and environment while providing safe ingress and egress for the property owner and a safe roadway for the motorist.



5.3.4.1 Proper Profile.

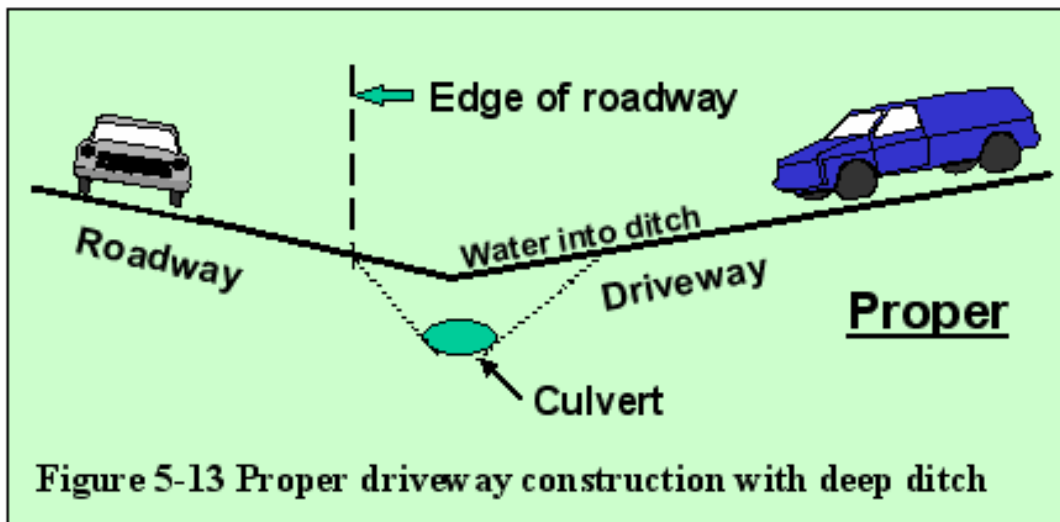
Although driveways should not interfere with normal road and shoulder profile, driveway profiles pose additional problems for proper road drainage. The worst condition results when the driveway slopes downward toward the road and is constructed right to the road edge obliterating the roadside ditch (see Figure 5-12). Even if a pipe is installed to maintain ditch flow, the water draining from the driveway flows onto the road, deteriorating the road surface and causing possible hydroplaning in the summer and icing



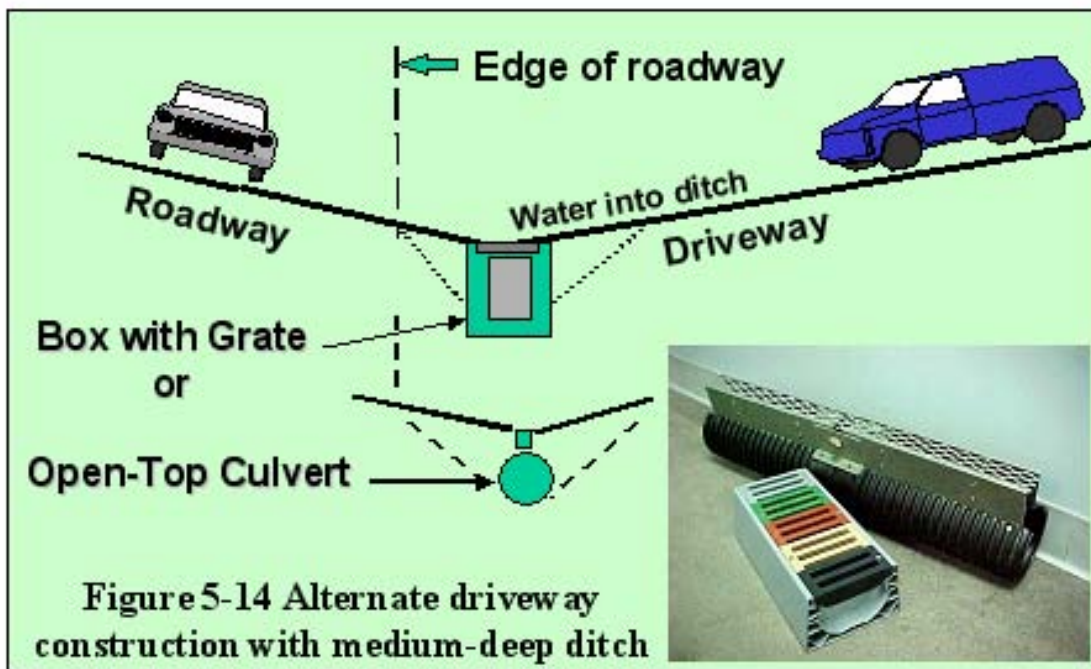
5-25 Improperly constructed driveways create recurring road maintenance problems.

in the winter. Continuing ditch flow to drain the road while properly draining the driveway is imperative to ensure vehicle safety, prolong the life of the road and protect the environment. Uncontrolled driveway construction can result in high levels of maintenance, costs, liability, and frustrations, as seen in Photo 5-25. **The low point should be over the ditch line** and the ditch flow maintained.

5.3.4.2 Driveways Over Deep Ditches. There are several options for maintaining good drainage. The most common practice is to install a pipe to carry the ditch flow under the driveway. With the low point remaining over the ditch line, the road and the driveway will both drain to the ditch off either side of the drive (see Figure 5-13).



An alternate method for medium-depth ditches is to use an open-top [culvert](#) or a box with an open grate (see Figure 5-14). These can be pre-fabricated items or homemade. The photo inset in the figure pictures two types of pre-fabricated units, one all-plastic type with a choice of colored grates. Pre-fabricated units are built to withstand truck traffic when installed following the respective manufacturer's requirements.

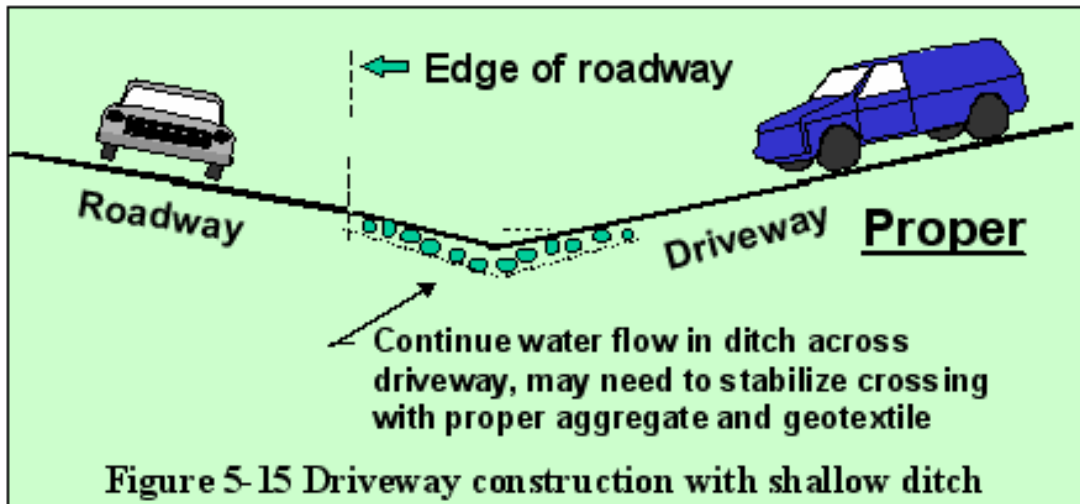


Several cautions should be noted in using these alternatives. First for safety, consider animals and bicycles in determining the appropriate sized openings for drainage in homemade installations. Secondly, although these are definitely beneficial in paved road and driveway conditions, they can be applied for paved driveways to unpaved roads. Water coming off an unpaved driveway may cause problems with clogging the openings or drainage way with eroded driveway material. A paved driveway usually does not present this problem. Photo 5-26 shows an ideal condition for an open-top grate across the drive to collect any water without having to alter the driveway grade.



5-26 Open-top grates may be used on paved driveways.

5.3.4.3 Driveways Over Shallow Ditches. Of course, if ditches are shallow and water flow is not substantial, the ditch may be continued across the drive, as shown in Figure 5-15.



Carrying only ditch flows during storm events, the shallow ditch should be no problem for vehicles to traverse. This area may need to be stabilized with proper aggregate and a [geotextile](#) separation fabric for crossing traffic. [Geotextile](#) separation fabrics will be discussed in Chapter 7. Photo 5-27 shows a newly constructed access driveway to a gas facility. The driveway was graded to drain away from the road and



5-27 Gas facility access driveway designed to drain away from road.

away from the gas facility to a low point on the driveway and then off into the wooded area (vegetative filter area) on either side.

Of course, every road and driveway site will have different conditions with different problems. Sometimes good solutions are hard to find, as shown in Photo 5-28. Each site should be evaluated and designed for the best drainage and greatest safety.



5-28 Sometimes good solutions are hard to find!

5.3.5 Practices Related to Culverts. [Culverts](#) or pipes are enclosed channels designed to direct stream or ditch water away from the roadway. [Culverts](#) come in various materials and shapes. Selection depends on specific applications or particular needs such as durability, strength, cost, corrosion resistance, abrasion resistance, flow characteristics, and installation requirements.

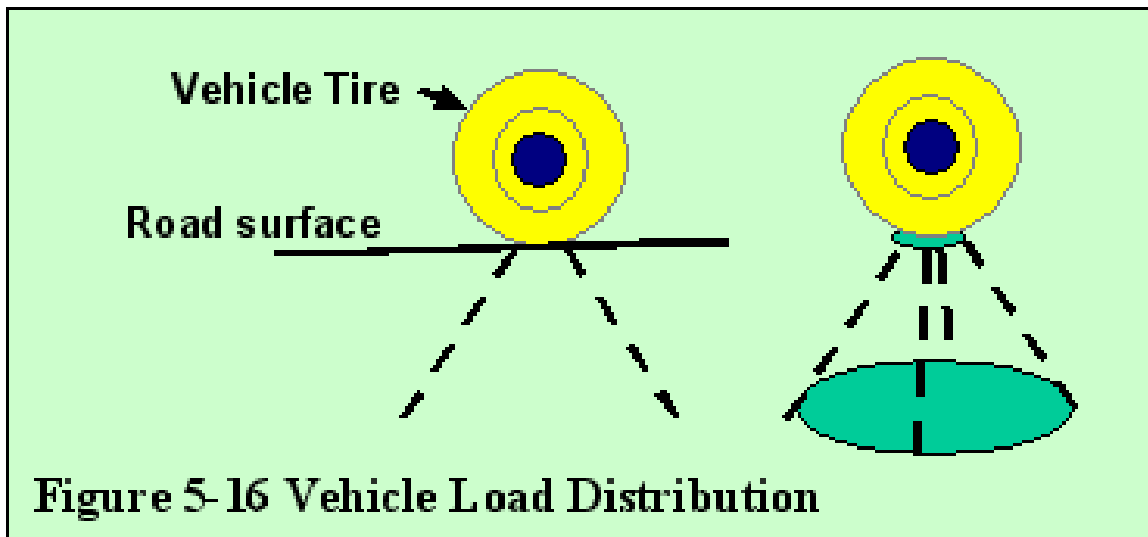


5-29 Common Pipe Materials

The three common materials available are concrete pipe, corrugated metal pipe, and plastic pipe, as shown in the photos. Whatever the shape or material, the [culvert](#) has to have adequate strength for support of both fill material and traffic loads. Deep installations have to support the fill material above the pipe. Traffic loads are a minor concern with deep installations. However, with shallow installations traffic is *the* major concern.

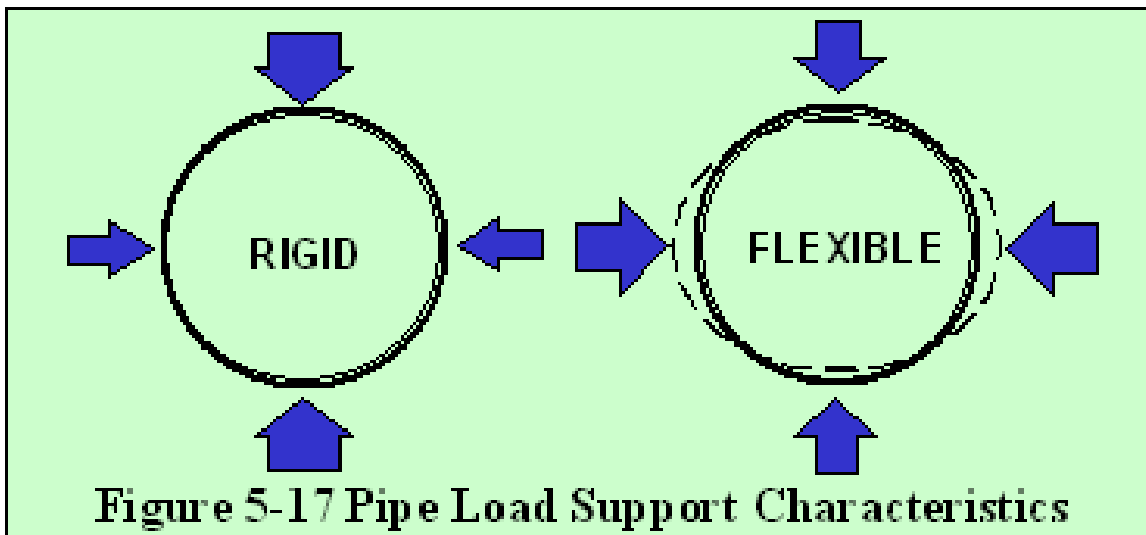
First, we need to understand how vehicle loads are distributed to the road. All vehicle weight is transferred to the road through the tires. But the area where the tire contacts the road is small. The pounds per square inch over these tire contact areas are at the maximum. However, the load is distributed out over a greater area as it is transmitted down into the road structure, as depicted in Figure 5-16. The greater the road structure

depth, the less pounds per square inch loading occurs because the same amount of load is distributed over a larger area.



In addition to load distribution, it is also important to understand the impact of moving traffic. Traffic exerts a vertical force due to weight and a horizontal force due to motion. These two forces combine to produce an impact force hitting the road surface. The more shallow the pipe, the greater the traffic impact force. It is important to keep a minimum of twelve (12) inches cover over the pipe below the [subgrade](#) of the road to minimize the effect of this impact factor. Pipes larger than 24-inch diameter may need additional cover.

Concrete pipe is considered a rigid pipe while corrugated metal and plastic pipes are considered flexible. Rigid concrete pipe cannot flex, and the pipe itself carries most of the load, but it is important that the pipe be given uniform support throughout its entire length to develop its maximum strength. The load-carrying capacity of flexible pipe depends on the support it gets from the surrounding earth. Proper compaction of the backfill material in layers is critical to develop maximum strength. Many pipe failures



occur due to improper backfill material compaction. Traffic loads, particularly in shallow installations, will cause the pipe to flex, causing cavities to form around the pipe, eventually undermining the whole installation. Properly compacted backfill provides the necessary support to limit flexing movement and possible resultant failure. Figure 5-17 depicts the pipe load support characteristics of rigid and flexible pipes.

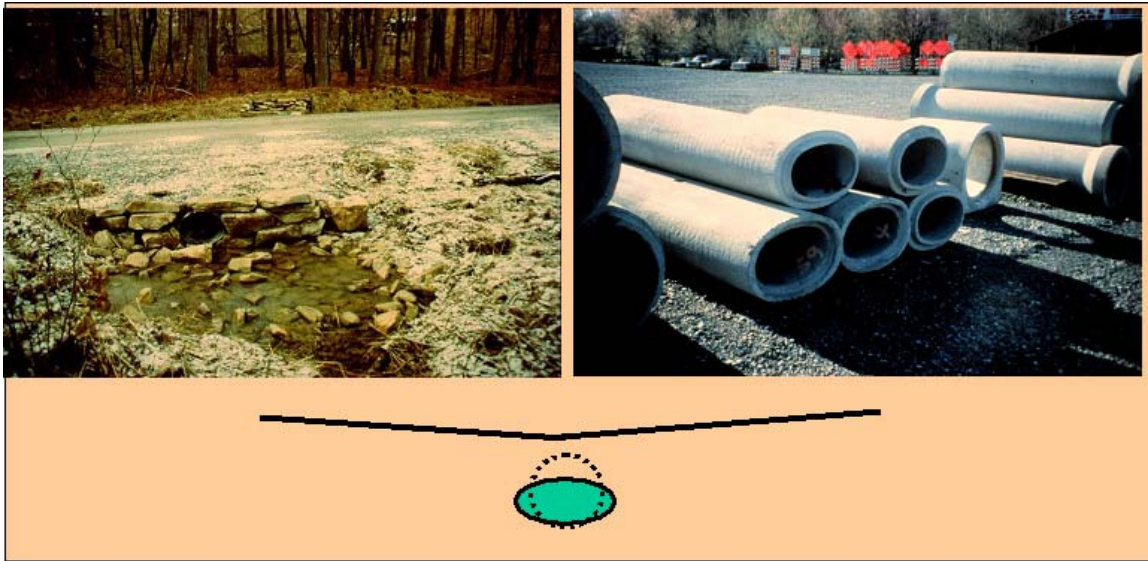
[Culverts](#) can be a primary cause of [erosion](#) and [sediment](#). [Culverts](#) normally restrict water flow as it enters the [culvert](#), increasing velocity, causing turbulence, and increasing energy at the outlets. Shallow installations across the road can also cause continual road maintenance work. With a little understanding and consideration, these problems can be alleviated.

5.3.5.1 Shallow Culvert Installations. Most cross road shallow [culvert](#) installations are dictated by the surrounding conditions and terrain. But when the [culvert](#) is too shallow, heavy traffic can cause problems. As discussed above, flexible type pipe tends to deflect under traffic, causing road materials to shift and eventual road deterioration to occur. Cross-pipes of 24-inch diameter or less need that minimum of one foot of cover material over the pipe beneath the structure of the road. This will protect the pipe from the impact forces of moving traffic.



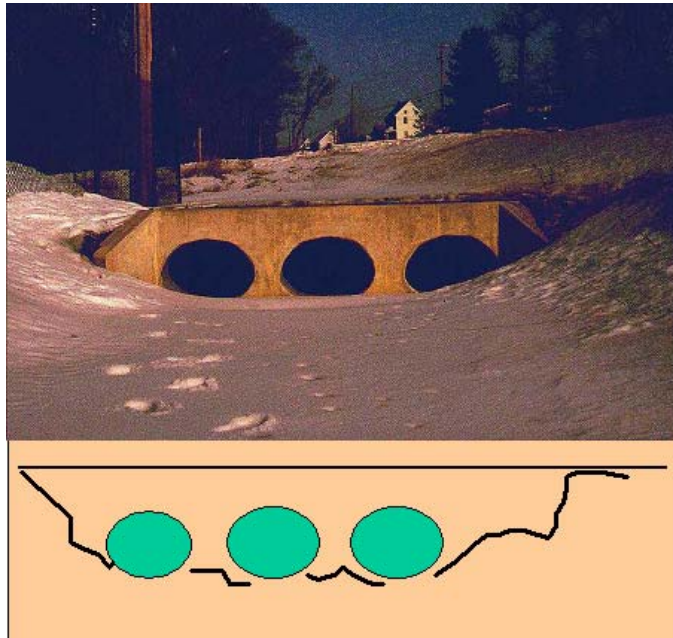
5-30 Shallow pipe installations can cause continual road deterioration.

When adequate cover cannot be maintained, there are alternatives. A rigid pipe (concrete, cast iron, steel) will not deflect to the detriment of the road. A “squash pipe” or elliptical pipe will allow for proper flow capacity but will give additional cover for protection. An equivalent 18-inch diameter corrugated metal “squash pipe” is 15 inches in height. This extra three inches of cover can be significant when it comes to traffic loads and resulting road degradation. Rigid concrete pipe does come in an elliptical shape, giving a double advantage of pipe rigidity and extra cover.



5-31 Shallow installations: use rigid pipe, squash pipe, or elliptical concrete (rigid) pipe.

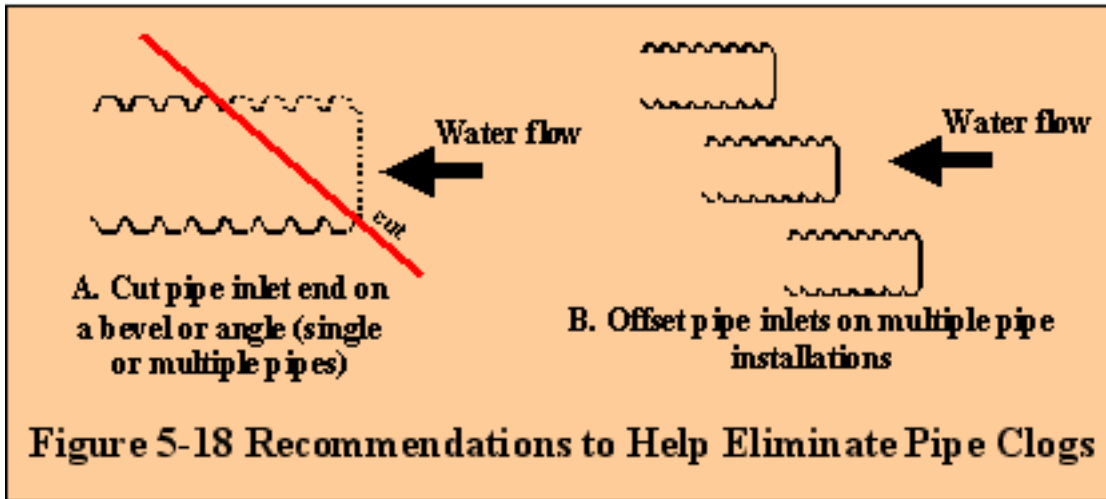
Another consideration is the use of multiple pipes of smaller diameter, allowing more cover but still providing adequate flow capacity. To use multiple pipes, there are a few rules to keep in mind. Flow capacity is directly related to the area of the pipe opening. This means that two 12-inch diameter pipes do not equal the flow capacity of one 24-inch diameter pipe. (Remember back in high school mathematics, the area of a circle is πr^2 or 3.14 times the radius squared.) Another rule is to make sure the pipes are installed far enough apart to enable adequate compacting of the backfill material between the pipes.



5-32 Shallow installation: Use multiple pipes of smaller diameter, allowing more cover with same capacity.

The use of multiple pipes usually brings comments regarding clogging. Any pipe can clog. One of the simplest solutions, particularly with metal or plastic pipe, is to cut the inlet end of the pipe on a slant or bevel. Any debris flowing toward the pipe will tend to ride up the slant, and water will continue to flow through the pipe. If multiple pipes are used, staggering the inlet ends so that they are not parallel in one line perpendicular to flow will reduce the probability of clogging. Each pipe inlet end is extended a little further (offset) than the pipe beside it. When large debris, such as tree

limbs, comes down stream, it will be forced to an angle that is skewed across the pipes, allowing water to continue flow through the pipes (see Figure 5-18).



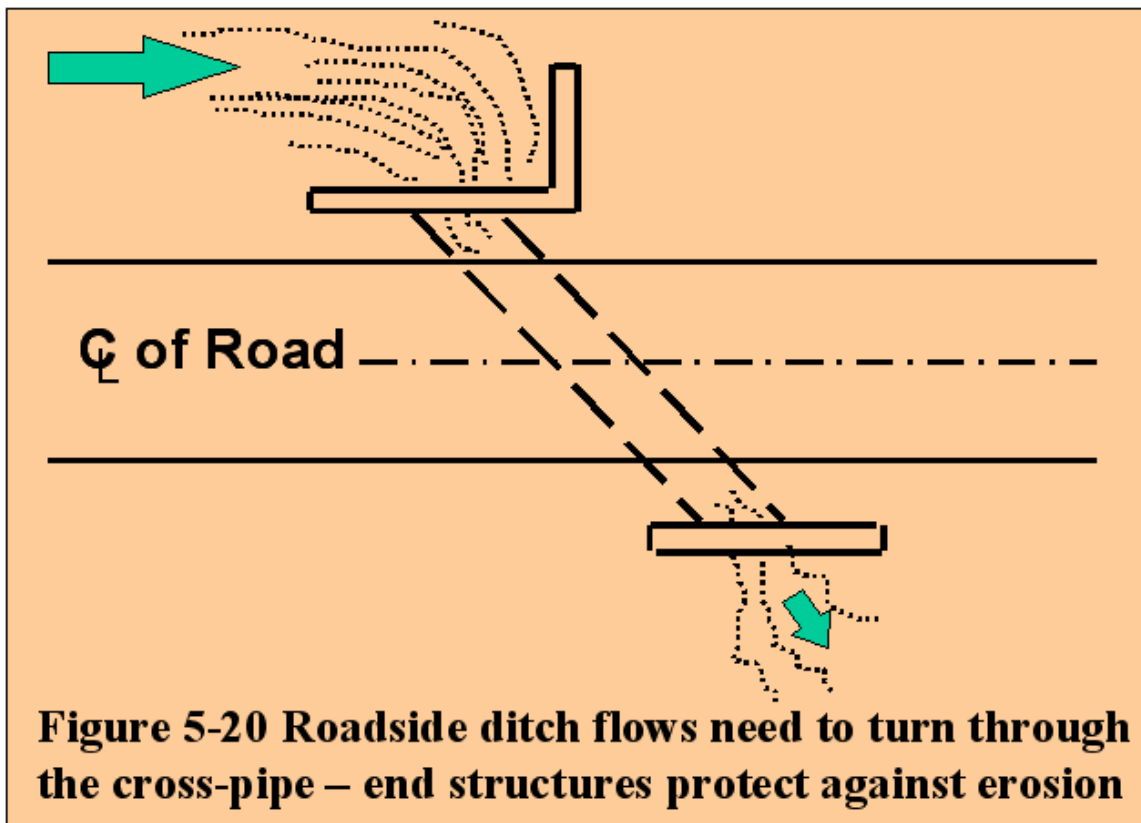
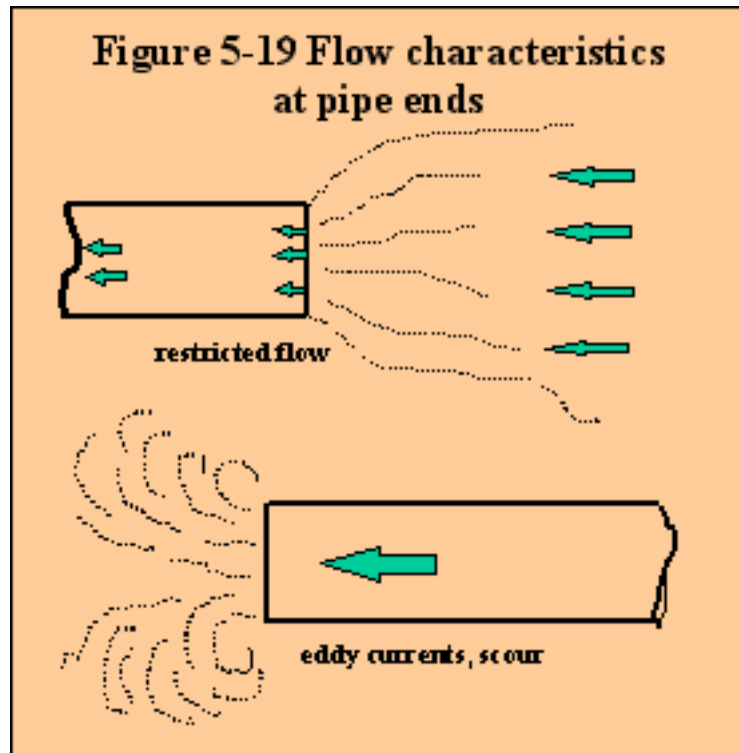
5.3.5.2 Fords on Perennial streams. Ford crossings eliminate the need for a pipe. Several states have numerous existing fords along with related [erosion](#) and [sedimentation](#) problems. If there is a ford crossing, and it is to remain, the crossing needs to be stabilized and area drainage altered to flow away from the site. Stabilization can be accomplished with select aggregate and [geosynthetics](#) with several variations being available (e.g., aggregate and [geotextile](#) separation fabric, perforated geoweb filled with aggregate – discussed in Chapter 7).



5-33 Existing fords should be stabilized to prevent erosion and stream degradation.

5.3.5.3 Culvert End Structures. Here are some ideas to reduce future maintenance problems. As mentioned above, when water flows into a pipe, it normally is restricted, as shown in Figure 5-19. This restriction increases the velocity of the water and its erosive force. When water flows out of the pipe, eddy currents develop, swirling water back around at the sides of the pipe, as also shown in Figure 5-19, causing [erosion](#) and scour. Straight, smooth transitions into and out of the pipe reduce turbulence and [erosion](#) at [culvert](#) ends.

Straight transitions in and out of the pipe, however, are not always possible. Roadside ditch water flowing parallel to the road must be turned to flow through a cross pipe. Even in straight



transitions, circumstances may cause [erosion](#) problems on either pipe end. [Culvert](#) inlet and outlet protection is important in the prevention of [erosion](#) in these areas.

Inlet and outlet structures not only protect the embankment from undercutting water currents and eddies, but also help anchor the [culvert](#) and help prevent crushing of the pipe ends from heavy traffic or equipment. A variety of materials can be used for [end structures](#), from prefabricated units and [gabions](#) to cement concrete and flagstone to native stone that may be available on site. Native stone not only becomes cost effective but also is environmentally aesthetic, blending in with the natural conditions. The series of photos show different types of [end structures](#).



5-34 Various materials can be used for end structures.

5.3.5.4. Aprons at Culvert Outlets. [Culvert](#) outlets, even with an [end structure](#), may still pose a problem with the flow discharge energy. It may be necessary to create a conveyance channel to establish a stable discharge point. For example, a simple pre-



5-35 Typical flared end sections.

fabricated [flared end section](#) (concrete, metal, plastic), as shown in Photo 5-35, provides an [apron](#) to spread the water flow and dissipate energy. Photo 5-36 shows a metal [flared end section](#) on plastic pipe.

Rock [riprap](#) can also be used at [culvert](#) outlets effectively. The first photo is a new installation with seeding and mulching around the rip-rap. The vegetation, once established will enhance the area aesthetics. The size of rock and the dimensions of an [apron](#) will depend on pipe size, discharge volume and velocity, and slope of the outlet channel or terrain. Charts providing guidelines are available. Using [riprap](#) for an [apron](#), however, should not be so technically challenging. Experienced road personnel know the water flow amounts and the potential



5-36 Metal flared end section on plastic pipe.

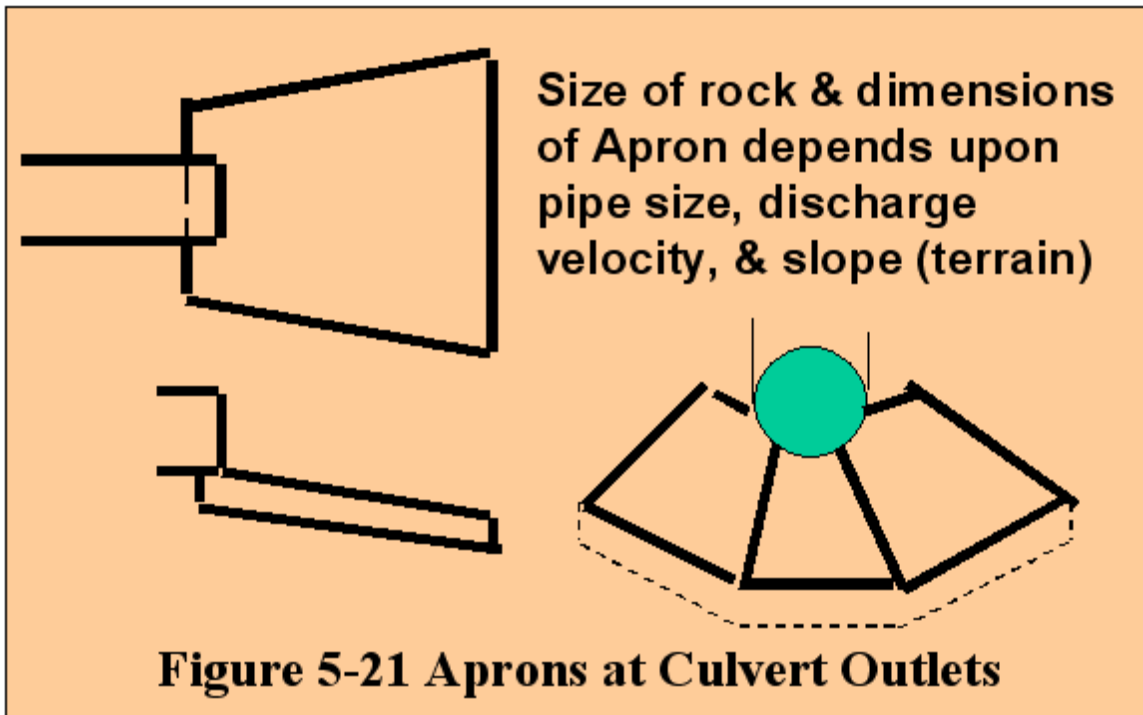


5-37 Rock rip-rap at pipe outlets spreads flow and dissipates energy.

problems at each specific pipe outlet site. They can size the [apron](#) based on their past experience. Then, road personnel should follow up with field inspections during and after the next several rainstorms. If [erosion](#) is evident past the [riprap](#) limits, expand the [apron](#) and inspect again. In Photo 5-38, rip-rap was placed from the pipe outlet down the slope as an energy-dissipating channel.



5-38 Using rip-rap for erosion prevention at culvert outlet.



Although native stone may be the aesthetic choice of material, depending on location, even brush and tree stumps can be effective in dissipating flow energy of water.

5.3.5.5 “Through Drains.” [Through drains](#) are cross [culverts](#) installed strategically to handle springs or spring seeps flowing perpendicular to the road. These drains carry the flow under (through) the road to the other side. [Through drains](#) allow water to continue down the path it traveled before the road was built. Because this usually clean water never enters the ditch, it stays clean. The photos depict typical [through drain](#) placements. The drains prevent roads from intercepting native ground water flows. If we establish a [through drain](#) to allow this natural flow to continue without entering the road ditch, we solve several problems. In addition to keeping the spring water clean, we do not have to handle the water via the road ditch. This reduces ditch flow and potential [erosion](#) problems in the ditch and at the ditch outlet. With reduced flow we also may be able to reduce the size of the roadside ditch.

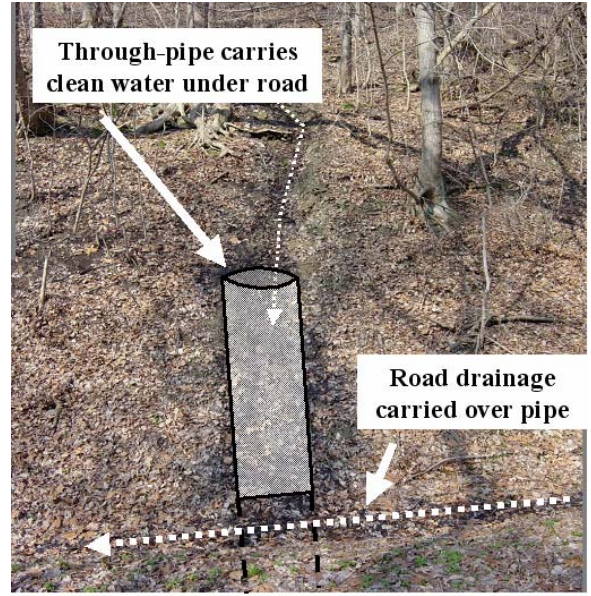


5-39 Brush, tree stumps, etc. can be effective energy dissipaters.



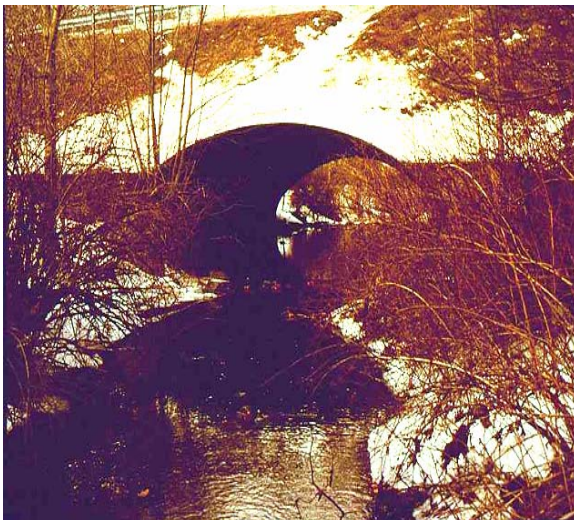
5-40 Through drains keep springs and spring seeps out of road drainage facilities.

If the spring flowing into the ditch has existed for a number of years, the spring's natural downhill channel may no longer exist. This channel may have to be reestablished, keeping proper [erosion](#) prevention in mind.



5-41 Through drains keep water clean.

5.3.5.6 Large Culverts in Perennial Streams. Large [culverts](#) in perennial (continual flow) streams provide a prime opportunity to enhance the natural stream environment. With new or replacement installations, a pipe [culvert](#) or box [culvert](#) can be sized to accommodate both flow and the natural streambed. Observe the existing streambed grade and average surface elevation. Set the bottom of the [culvert](#) at the required depth to establish a natural streambed through the [culvert](#). Add stream-like material in type and size to minimize disturbance.

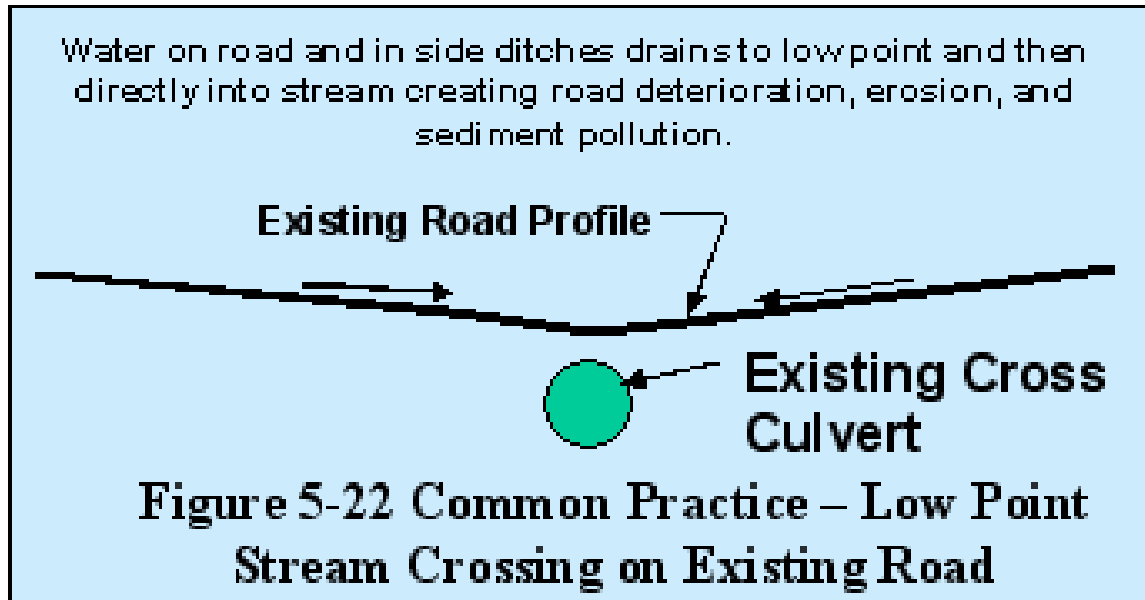


5-42 Over sizing culverts to allow natural streambed conditions through the culvert maintains the stream ecosystem.

Another option is to use a metal plate arch without a bottom. The arch spans the stream, resting on footers at each side. This practice maintains the stream ecosystem and still provides the necessary conveyance for proper drainage. This option also enhances protection against undermining of the [culvert](#) due to seepage around the pipe (don't underestimate those little crayfish "critters" from burrowing alongside a [culvert](#) in their attempt to move up stream, creating water channels along the outside of the [culvert](#) that can initiate an undermining process).

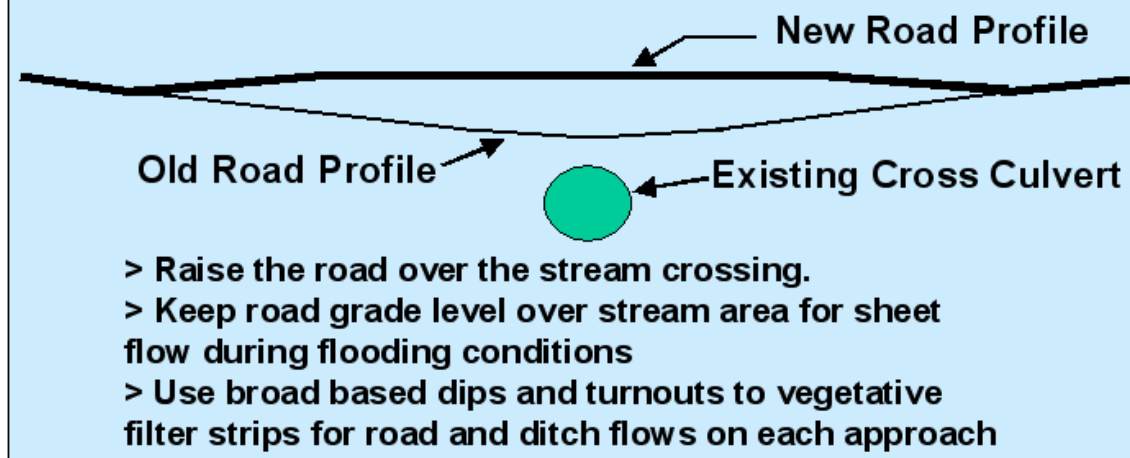
5.3.6 Combination Practices. The next two practices combine new techniques with practices described previously. The use of any of the various practices in combination will depend on analysis of the existing site conditions.

5.3.6.1 The Stream Saver System. Commonly, a road's low point is directly over the stream. For many years, this condition seemed to be the most practical and effective way of draining the road. Roadside ditches could be carried directly to the low point and outletted directly to the stream with a cross [culvert](#) carrying the stream under the road.



But this concept centered on the road only. An analysis of its total impact revealed some problems. First, everything drains directly to the stream, including any and all [sediment](#) and other pollutants. A deeper look revealed it wasn't really all that good for the road, either. Under the scenario illustrated in Figure 5-22, if the stream flow exceeds the [culvert](#) capacity and overflows the road, we have created a v-shaped channel, although flat, to concentrate the flow and increase the erosive energy. This condition can cause [erosion](#) of the road material and continual road maintenance with every major storm.

Figure 5-23 Stream Saver System

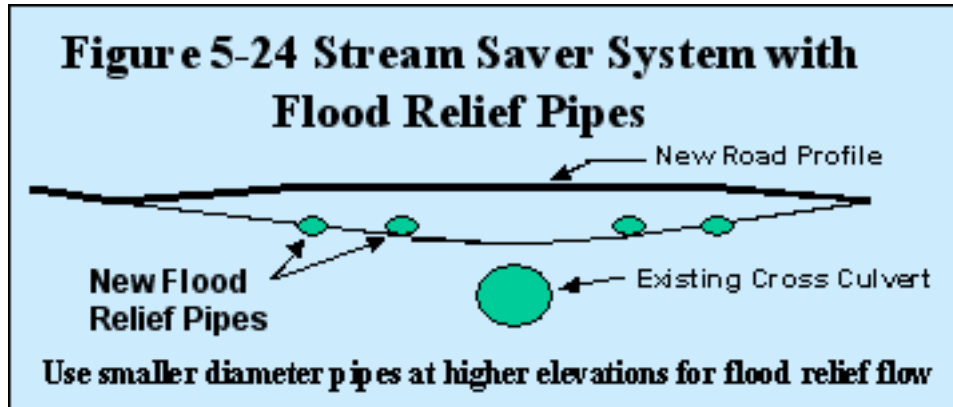


The solution is to implement a “Stream Saver System.” Raise the road over the stream crossing, creating a level area extending away from the stream on both sides. This level road grade will allow sheet flow during flooding conditions, if the cross pipe cannot handle the flow. Using [broad based dips](#) and turnouts to [vegetative filter strips](#) for the road and ditch drainage on each approach as conditions warrant will avoid direct [sediment](#) input into the stream and alleviate some flood flow. If pipe capacity is severely limited, a flood flow relief crossing can be established away from the stream depending on the existing terrain and land uses. This crossing can be stabilized as a low water crossing (refer to Chapter 7 for a description of a stabilized low water crossing using [geosynthetics](#)).



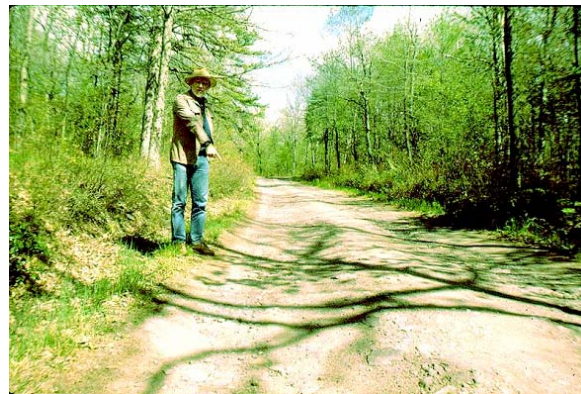
5-43 Stream Saver System – raised level road with ditch turnouts to vegetative filters.

In raising the road, additional smaller cross pipes could be installed at higher elevations than the flood flow relief cross pipes. Depending on depth of new material to raise the road, these pipes may need only to be laid on the existing road surface or partially excavated into the existing surface. In certain storms, these pipes would handle the additional flow without overtopping the road. Although additional pipes mean more maintenance, these flood relief pipes will only come into use when substantial storms exceed the capacity of the main cross pipe and will keep the road intact.



5.3.6.2 Multiple Culverts. Under certain conditions, multiple [culverts](#) at various elevations may be the answer. As an example, an existing road traversing a [wetland](#) area had existing cross [culverts](#) to carry the perennial flow from the naturally formed channels. Both sides of the road, however, had substantial [wetland](#) areas abutting the road embankment. Under normal conditions, the pipes handled flow adequately. The [watershed](#), however, being quite extensive, guaranteed that almost any storm would overtop the road, causing some washout of road material into the stream and [wetland](#). A stream saver system was implemented. The installation of smaller pipes at higher elevations and at locations across the extent of the adjacent [wetlands](#) gave an additional benefit to the [wetlands](#). As the water level rose during storm conditions, the additional pipes handled flow and kept velocities and currents to a minimum, maintaining a more stabilizing effect on the [wetland](#) habitat.

5.3.7 Major Reconstruction: Raising the Road. Raising the road involves major filling of the road cross section between high banks. Before we get into the details for this work, we should understand the reason and basis for the road being in this condition. Referring back to the beginning of this chapter in Section 5.2, we mentioned the typical cross section of many roads depicts a low road surface with high roadside banks on each side. This is particularly the case in forested areas. In almost all cases, this condition is the result of years of traditional road maintenance.



5-44 Remember this photo? Look at the banks on either side of the road.

Routine road maintenance practices (road grading, snow removal, shoulder cutting, ditch cleaning, etc.) combined with the wear and tear of traffic and natural erosive forces have the cumulative effect of lowering the road elevation in relation to the surrounding terrain. As the road profile drops, or becomes entrenched, water draining to the road is trapped and concentrated in parallel ditches, and the road begins to function as

a channel for water flow. This entrenched road profile makes installation of crosspipes, turnouts, and other drainage features to get the water away from the road increasingly challenging. Raising the road can eliminate the persistent maintenance difficulties associated with this entrenched condition.

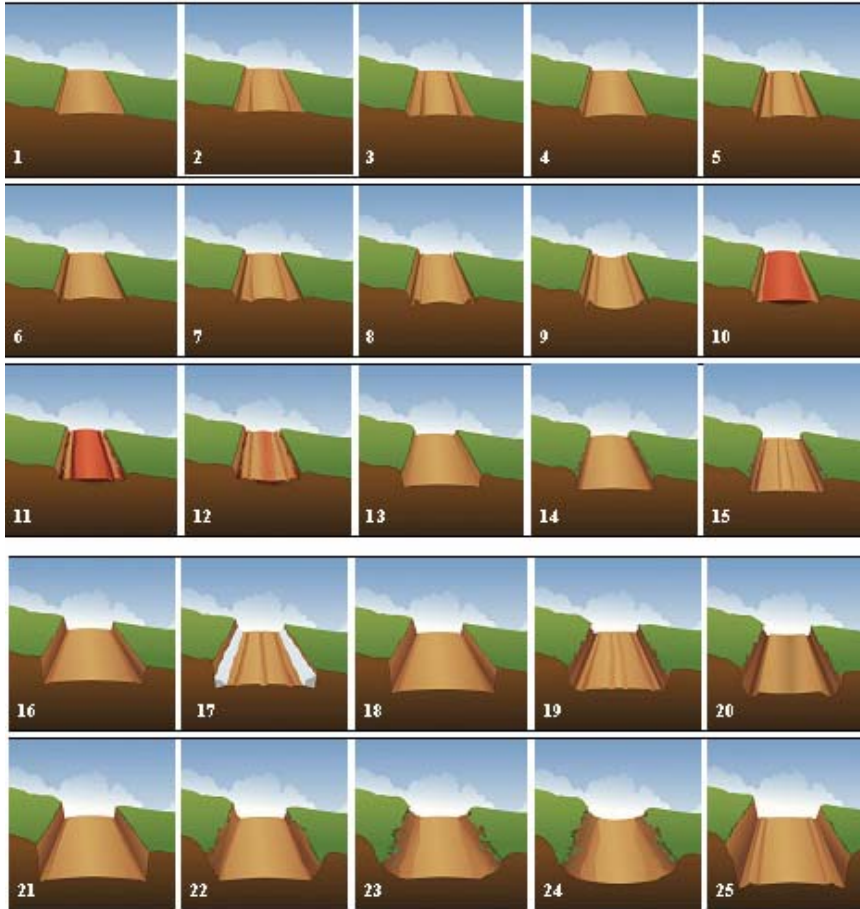


Figure 5-25 The Sequence of Road Entrenchment

Looking at the sequence of photos in Figure 5-25, one can view the lowering of the road surface through the years establishing those high banks on either side. The new road (#1) starts to show surface rutting (#2). The ruts get worse (#3) until grading operations re-establish the profile and attempt to create a better ditch gouging into the bank for drainage (#4). The banks' vertical surfaces start to fall in, and, along with the eroded road materials, create the need for ditch cleaning. Repeated maintenance

operations of blading and grading along with ditch cleaning (#5-8) finally results in a need (#9) for additional material as the [road crown](#) is lost. Material is added (#10) and the process starts again. This repeated maintenance over the years as more material is lost causes the road to become more and more entrenched (#11-16). Snow removal becomes a problem with the snow being piled along the banks, aggravating the problem (#17). This entrenchment causes the road to act as the drainage conveyance channel, resulting in enhanced [erosion](#) of the road and banks and [sediment](#)-laden ditches. This, of course, leads to greater road maintenance as the road becomes deeper and wider year after year (#18-25).

5.3.7.1 Raising the Entrenched Road. We can break this cycle. We need to restore the road to its original surface elevation. This could mean substantial fill and a major work effort. Fill material becomes a prime cost in this practice. There are local governments, however, that can obtain free fill and can load and haul the material with their own equipment. Free fill and use of in-house equipment reduces the cost although it will still be a major work effort. Photo 5-45 shows two roads that would be ideal candidates for road raising. Both of these roads have severe drainage, [erosion](#), and [sedimentation](#) problems requiring substantial and continual maintenance. But returning



5-45 Good candidates for “raising the road.”

these roads to their original elevation could significantly cut maintenance costs. Many roads could be raised to eliminate the banks on both sides, providing excellent road drainage conditions with much less [erosion](#) and [sediment](#) pollution.

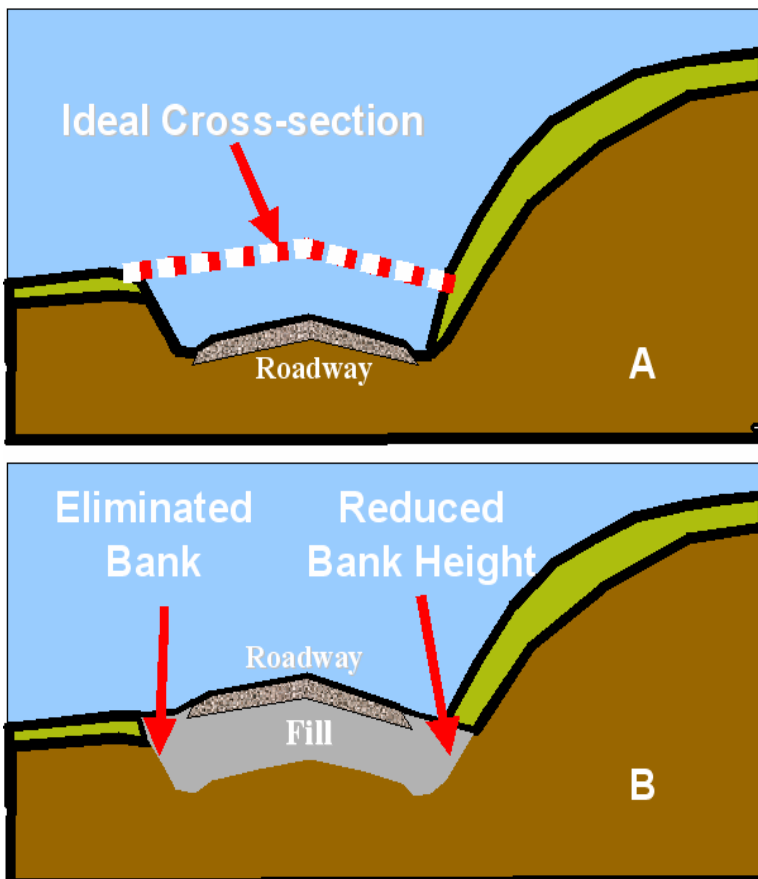


Figure 5-26A shows a typical existing entrenched roadway. Figure 5-26B shows the filled roadway, completely eliminating a bank on one side and reducing the height of the bank on the other side. Depending on terrain, etc, drainage could be sheet-flowed off the road without a ditch on the one side. The road no longer serves as the drainage channel and will experience far less surface [erosion](#), rutting or other degradation. Snow removal no longer becomes a problem since we now have a place to plow it.

Figure 5-26 Raising the Road.

The series of photos shows Red Rose Road in Huntington County, Pennsylvania. The road was raised with free fill shale from a nearby pit. This road then received a final road surface aggregate. (Refer to Appendix 5, Worksites in Focus, to review this Pennsylvania Dirt and Gravel Road Program Project.) Raising the road improves drainage resulting in less [erosion](#) and road degradation and thus less road maintenance and a better environment. Winter snows can now be plowed totally off and away from the road, providing better protection from melting snow water seeping back into the road structure.

5-46 Red Rose Road, Huntington County, PA



Before, an entrenched road



During placement of shale fill



After finishing the shale



Final road with driving surface aggregate

Use of Recycled Material. Commonly used fill materials include native rock and mining spoil. Other fill material such as concrete or demolition waste, tire shreds, ground glass, spent sandblasting sand, and coal combustion waste has also been used to aid in recycling programs. Select fill material carefully. Some materials may need special use permits or require special handling. Work closely with your local conservation agencies and state environmental agencies.

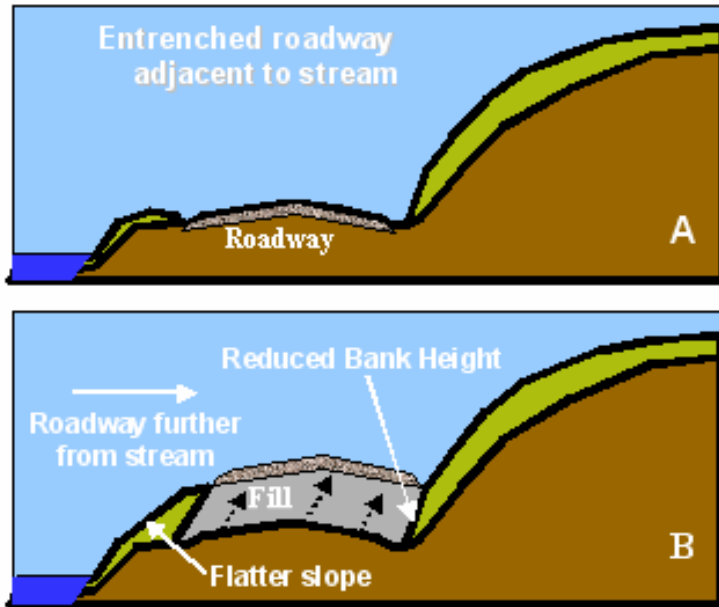
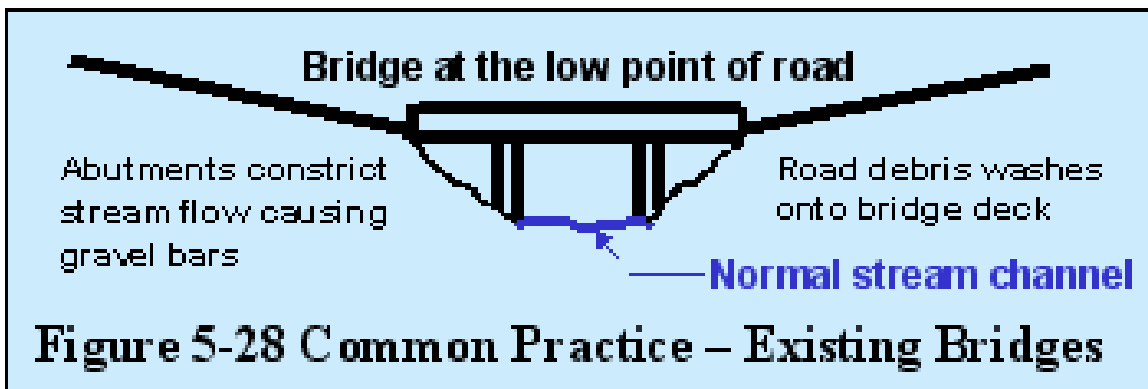


Figure 5-27: Raising the road and moving away from the stream.

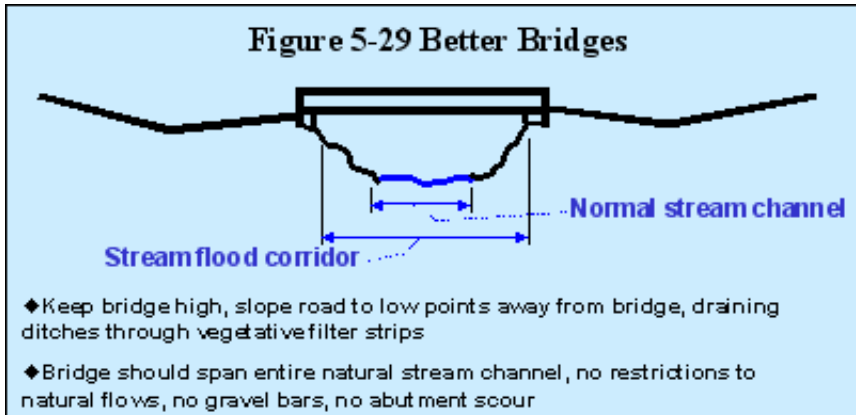
5.3.7.2 Raising the Road and Moving Away from a Stream. Figure 5-27 shows a road raising variation where the road has a high embankment on one side and falls steeply off directly to a stream on the other side. The road is entrenched with side ditches. The road is raised upslope away from the stream. We eliminate the entrenchment on the stream side, allowing for sheet flow across additional vegetated area. On the other side, we reduce the embankment height for better stability and drainage control. Depending on the

various conditions, [insloping](#) could be combined with raising the road, providing additional benefits.

5.3.8 Practices Related to Bridges. Although bridge replacement is neither simple nor inexpensive, sometimes there is simply no alternative. But there are several environmentally sensitive techniques available that will protect the environment and prolong bridge life. Common practice, once more, places the bridge at the low point of the road grade across the stream. The road drains directly onto the bridge, carrying road material and [sediment](#) that then drains directly into the stream through the bridge “[scuppers](#)” or drainage openings. In addition, abutments built to support the bridge are placed so as to constrict the water flow to the main channel. This scenario poses several maintenance problems. Scour and [erosion](#) at bridge abutments shorten bridge life. Further, the constricted water flow frequently results in [gravel bars](#) that must be continually removed.



5.3.8.1 The Stream Saver Bridge System. The Stream Saver Bridge System reduces maintenance by raising the bridge and sloping the road away from it. Roadside ditches are then turned out into [vegetative filter strips](#) well away from the bridge approaches.



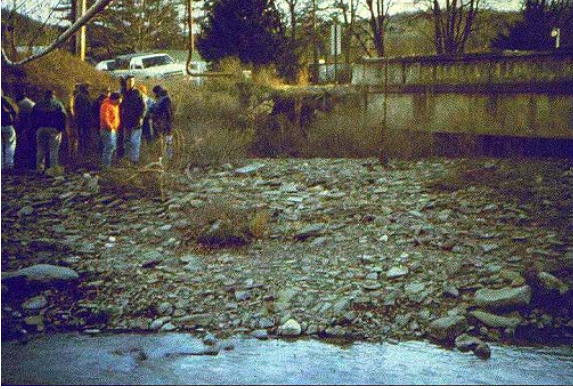
Ideally, the stream saver bridge spans the entire natural stream flood flow channel. Spanning the natural stream corridor reduces interference in stream flows, eliminating abutment scour and [gravel bar](#)

problems. This system better protects both the environmental stream ecosystem and the bridge structure.

Raising the bridge also allows better drainage off and away from the bridge structure prolonging its life. Bridge drainage can also be carried away from the stream to the same [ditch turnout](#) through a [vegetative filter strip](#). Bridge drainage [scuppers](#) (openings in the bridge deck – remember the photo from Chapter 3) normally empty the flow directly to the stream along with all the accumulated [sediment](#) on the bridge deck. A raised bridge surface that drains off the bridge longitudinally keeps [sediment](#) and debris from washing onto the bridge and the bridge surface drainage water clean. This clean water will be much less detrimental to the stream if the bridge has [scuppers](#) draining directly into the stream.



5-47 Eliminate this maintenance and environmental problem with Stream Saver Bridges.



5-48 Gravel Bar Removal is a costly maintenance task.

material, this “gravel” does not meet the specifications for good road material. It commonly has a rounded shape with little fines and does not lock together to stay in place.

[Gravel bar](#) removal also poses several problems other than the cost of removal. Operations cause stream disturbance with resultant [turbidity](#) and [sediment](#) downstream. This can also result in 100% [embeddedness](#), as described in Chapter 4, to the detriment of stream life. This [turbidity](#) and [sediment](#) continues for an extended period of time until natural conditions can re-establish the equilibrium.

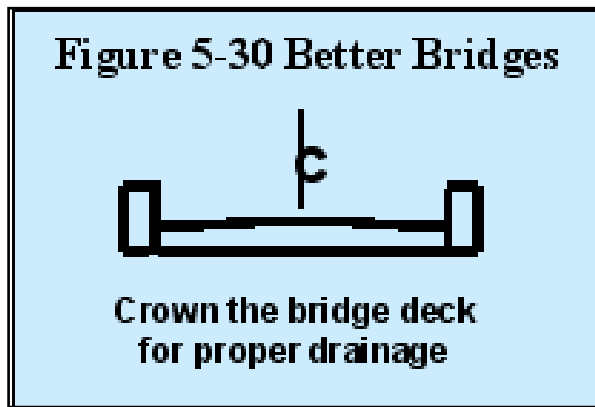
If [gravel bar](#) removal is necessary, there are a few factors to be aware of. Do not use the removed gravel for road material. Keep stream disturbance at a minimum by working in low flow conditions and keeping equipment tires and tracks “dry.” Work with your conservation agencies to secure the necessary permits.

If [gravel bars](#) are extensive and form rapidly after each removal operation, this material has to be coming from somewhere. Look at the stream flow and upstream terrain conditions to determine the source and what may be causing the material deposition, and see if there is a remedy that can prevent future [gravel bars](#) from forming.



5-49 Gravel bar removal causes turbidity and sediment for extended time periods detrimental to the stream ecology. Would you want to fish here?

5.3.8.3 Bridge Decks. Crowning the bridge deck similar to the road will also enhance bridge drainage. Many of our rural bridges have flat decks that aggravate the problem of water and debris on the deck, particularly when the road approaches on either side drain directly to the bridge.



Incorporating these techniques allows for longer bridge life by providing better drainage of the bridge deck and away from the total bridge structure. It also reduces maintenance costs because less material accumulates on the bridge, drainage [scuppers](#) are not blocked, less choking [sediment](#) flows into the stream, and no [gravel bars](#) have to be removed. Just as importantly, the whole stream ecosystem is not affected

by these activities, leaving a better environment.

5.4 Summary

This chapter started to fill your toolbox with many various tools or practices that are environmentally sensitive and good for your roads. These practices, for the most part, are simple, practical techniques that can easily be adopted as part of your daily routine maintenance work. Of course, the more major practices of raising the road and replacing bridges can also reap major benefits for your road system and the environment.

Many of these practices, particularly concerning proper drainage, can be adopted for paved roads and will prove to be just as beneficial as they are for unpaved gravel roads.

As you begin to use these practices, you will begin to see the long-range continual benefits for your roads and your environment and thereby for your community.

The following Appendix 5 reviews actual projects in which a combination of practices has been used to solve [erosion](#) and [sediment](#) pollution problems stemming from dirt and gravel roads.

APPENDIX 5. Worksites in Focus

This appendix reviews several actual projects funded through the Pennsylvania Dirt and Gravel Road Program, as described in Appendix A-1. The first worksite on Red Rose Road was a Demonstration Project for the Pennsylvania Dirt and Gravel Road Program that became the “Drive Thru Classroom Self-Guided Tour” Project to demonstrate various [environmentally sensitive maintenance](#) practices being taught to local governments under the program. The next two worksites were actual projects undertaken by Pennsylvania local governments with major funding through the Pennsylvania Dirt and Gravel Road Program. At each local government worksite, the problem(s) is identified, with objectives, considerations, and solutions, followed by a cost summary for the project. The accompanying photos give an insight into the before and after conditions at each site, demonstrating the benefits of using [environmentally sensitive maintenance](#) practices to the road and the environment and to the overall aesthetics and to a better community.

raising the road profile before, during & after



Please contact the center with any questions:
toll free: 1-866-668-6683
e-mail: dirtandgravel@psu.edu

For more information visit:
www.dirtandgravelroads.org



environmentally
sensitive
maintenance

red
rose
road

Drive-Thru Classroom Self-Guided Tour


The Problem:

Because the road was lower than the surrounding terrain, rainfall and runoff were captured and concentrated in the roadway, gaining energy and eroding road surface and bank materials. This concentrated flow exited the road with tremendous force, directly into the stream. The stream, consistently inundated with a high-velocity input of sediment-laden water, was eventually incised to the point that it was totally disconnected from its floodplain.

The Solution:

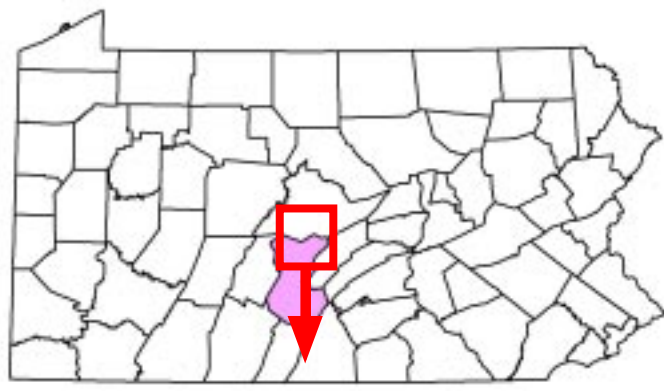
The road profile was raised to eliminate ditches and allow road runoff to flow gently from the road surface into the surrounding porous forest soils. One particularly problematic section of road was shifted uphill, away from the stream, to protect an already damaged and fragile stream reach from further harm. Selective thinning of the tree canopy allows the road to dry out while promoting healthy forest growth patterns.

How to enjoy the outdoor classroom:

- Follow along with this brochure
- Look for matching numbered signs ( The icon indicates picture location and direction)
- Stop and have a look around

red
rose
road

Site Location & Directions

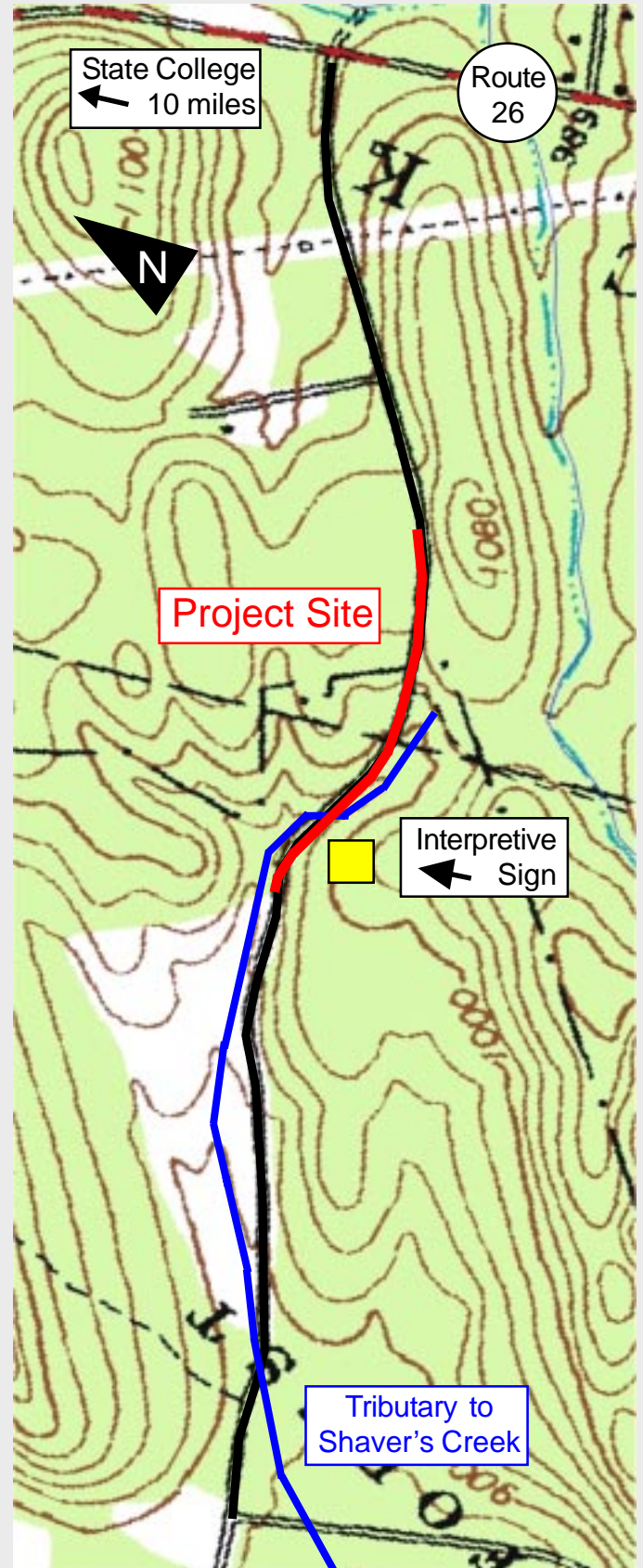


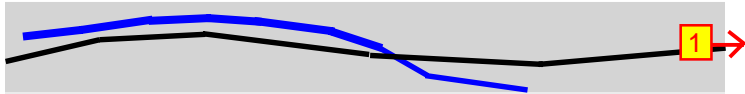
DIRECTIONS

RED ROSE ROAD is located in Huntington County 10 miles south of State College. From the north, take Rte. 26 south from State College. Red Rose Road is on the right 3.5 miles past the summit of Tussey Mountain. From the south, take Rte. 26 north from Huntington approximately 19 miles. Red Rose Road is the first road on the left after passing the entrance to Whipple Dam State Park.

red
rose
road

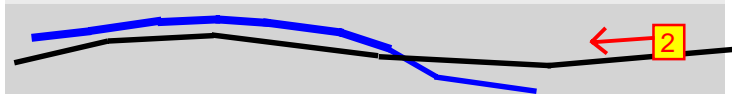
Site Map





ENTRENCHED ROAD BEHAVES LIKE A DITCH

Years of wear and tear, machine maintenance and erosion caused the road surface to become entrenched below its banks. This captures all water from surface and near-surface drainage. The captured water gains energy as it flows down the road causing it to erode the road surface and side ditches. Road banks collapse into ditches mandating more machine work, which further lowers the road. Observe how the natural surface drainage has been restored by filling the road back to its original elevation and stopping the endless cycle of erosion and repair.



ERODED BANK & SHADE

In addition to the sunken road surface, notice the density of vegetation shown in this photo. The shade is so dense, plants whose roots could have held the bank's soil in place did not have enough light to grow. Also, look at how the treetops lean over the road shading it. Individual trees, which were not structurally sound or vigorous were removed. If not disrupted by deer browsing, vigorous strong young plants will now grow with more full light and provide protection for the soil. Trees growing close to the road will receive light from both sides and develop even crowns.



CONTRASTING DRAINAGE TURNOUTS

Road drainage constructed without concern for increasing environmental harm and maintenance costs frequently cuts banks vertically and makes steep drainage patterns. The maintenance practice at this location was to dig excess material out of the turnout and pile it beside the drainage course, constricting the width of flow causing the water to move faster and be more erosive. Now, observe how drainage from the restored road height does not require a ditch, and how flow is dispersed over a wide area at a shallow angle.

before

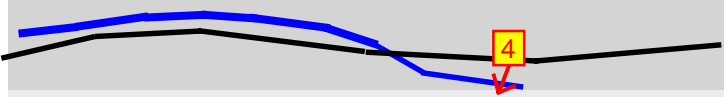


before



before



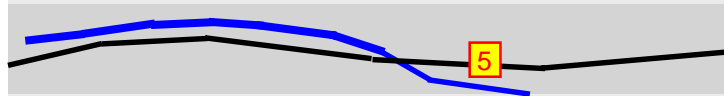


NATURAL ENERGY MANAGEMENT

In a natural landscape it is difficult for water to concentrate. Organic material, including branches and logs, and rocks disrupt and slow the water's flow. Porous forest soils reduce the amount of surface runoff by allowing water to infiltrate.

The natural pattern of organic debris was successfully emulated at the discharge end of this pipe. This simple use of organic materials not only dissipates the energy of the pipeflow but also provides life-supporting food for plant roots and the microbes living in conjunction with them. The roots, in turn, further stabilize the soil and increase infiltration.

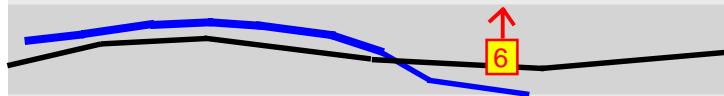
before



MAINTAINABLE ROAD SURFACES

The bank-run shale used on the previous road surface had pieces in it that were too large for available grading machines to work into a drivable surface. Left un-graded, the road deteriorated. Shale has two other disadvantages. It "slacks," or breaks down into silt or clay soil particles when exposed to air, and it does not resist the abrasion of traffic well enough to be rated as a suitable road surface material. Clay and silt are the soil types most prone to make dust and sediment. The Driving Surface Aggregate visible now is a specially formulated mixture of abrasion resistant limestone. Contrast this surface with that of nearby off-site locations.

before

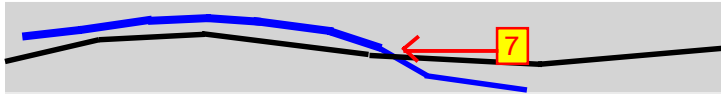


GRADE BREAK

The pipe here was installed at an elevation high enough to allow the pipeflow to discharge at natural ground level. In order to get the required 12" of cover over the plastic pipe, a grade break was constructed. Grade breaks are inexpensive to build, easy to maintain, and serve several purposes. The additional road material used to construct the grade break provides cover for the pipe, slows traffic, and acts to divert water flowing down the road surface into the road ditch. This disruption of water flow prevents road deterioration from water movement on steep road grades and lengthens maintenance cycles.

after





HIGH-CAPACITY DITCH

The picture shows evidence of fast moving water. Tangled brush mattresses and large rocks washed clean indicate a strong erosive force generated by concentrated swift flow. Contrast how wide and deep the pictured ditch is compared to the present ditch.

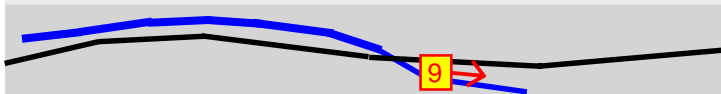
Large rocks were placed in the ditch before the road was filled in. Known as a “French Drain”, it serves to conduct clear sub-surface water downgrade without forcing it to come to the surface, where soil particles can be carried as unwanted sediment to the stream. To some extent, sub-drains help keep the road base drained, and therefore stronger.



BANK WASHOUT OVERLOADED DITCH

Concentrated flow washed out the road bank at this location sending a plume of sediment to the stream. Over time, that concentrated flow further eroded 400 ft. of ditchline discharging even more sediment directly into the stream.

A non-corroding cross-pipe was added under the road to harmlessly direct this flow to the forest floor on the other side of the road. The pipe entrance was raised to lessen the energy the water gained by falling into the pipe. On the other side, the pipe discharges at natural ground elevation. Dispersed there in a natural pattern, the water can infiltrate into the ground as if the road had never been built.



A STREAM AND ITS FLOODPLAIN

A stream will naturally form a channel with the width and depth to contain average flows while allowing naturally-occurring high flows to spill over its bank and onto its floodplain. By spreading high flows out over the floodplain, the excess energy and force of the water is released. Compare the size and shape of the stream channel here to that below the road crossing. The concentrated volumes and velocities of the road drainage have cut a deep gully-shaped channel disconnecting the stream from its floodplain thereby preventing energy dissipation. When all the energy of high flow events is confined within the channel, the cycle of repeated “down cutting” results.

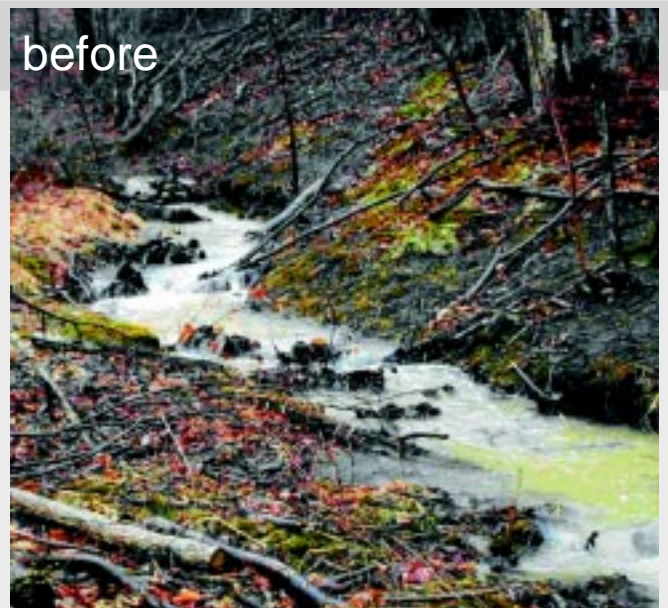
before

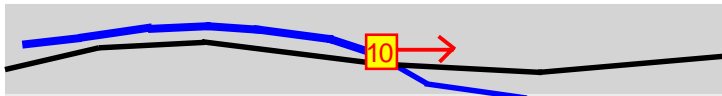


before



before



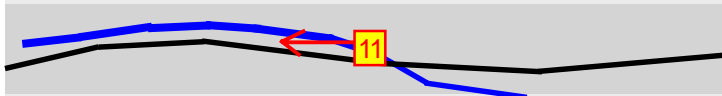


RAISING THE ROAD PROFILE

Excavated shale and limestone from the abandoned pit was trucked and spread on the entrenched road. A D-8 bulldozer crushed, spread and compacted the fill material.

Work sequence was as follows:

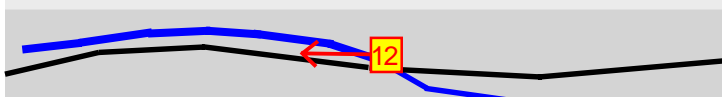
- Dump and spread stone of all sizes;
- Track over and crush material to 12" & less;
- Blade resistant larger stone to ditch line to create a subsurface French drain along road;
- Blade forward fines in approximate 8" lifts;
- Track compact and build surface shape into road with each lift, repeat until natural drainage is restored.



NEW ROAD LOCATION

Sediment from the original road, indicated on the photo at right, flowed directly to the adjacent stream reach. The road base would eventually have failed as storm flows continued to erode the stream banks. This is a very common problem wherever roads are located too close to streams.

The road was relocated to demonstrate the value of respecting and using the forces of nature to correct long-term environmental problems. The pit was reclaimed, surface drainage was restored to its original pattern and a buffer zone was created between the road and the stream.

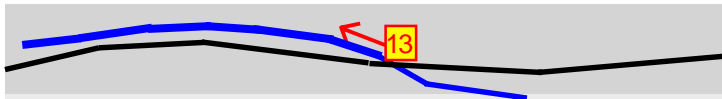


READY FOR NATURE TO ADOPT

Pictured here shortly after project completion is the newly created buffer area immediately after seeding and mulching. Note the naturalized uneven surface with stump, log and rock obstructions to overland water flow. High stumps were placed near the road to provide a visual marker of the road edge.

Contrast during your visit how growth patterns are influenced by water and leaves trapped upslope of the obstructions. As organic matter builds up from leaf litter, more water will be retained over these dry soils. In turn, the numbers of microbes and small creatures like earthworms will increase. As they do, growth capacity of this abandoned shale pit will increase.

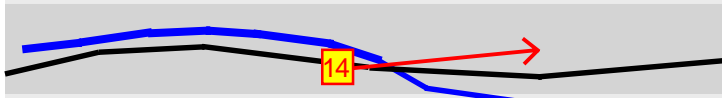




DESTRUCTIVE IMPACT ON STREAM

This section of stream channel should look similar to the stream channel above the road which is generally very stable, producing only small amounts of sediment from the bed and bank materials (# 9). The channel shape, characterized by a series of cascades and irregularly spaced scour pools, is normally 12-15 times wider than it is deep.

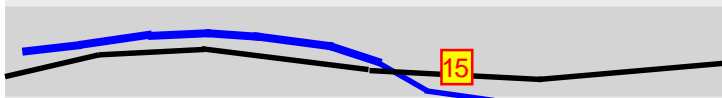
In contrast, the stream channel immediately below the road reflects the long-term effects of concentrated road drainage. Notice the severe down cutting that causes the channel to be deeper than it is wide and the complete physical separation of the stream from its floodplain.



LOOKING EAST AT SHALE PIT

The road at its new alignment and elevation shows several features that prevent pollution. Compare this to previous photos.

In the right foreground see the bank bench (1) and how it intercepts and redirects water toward the camera at a nearly level slope. On the left, the extra space between the road and the stream acts as an effective buffer. In the background, notice the ditch to the left (2) is located farther from the road preventing the bank drainage from mixing with road material.



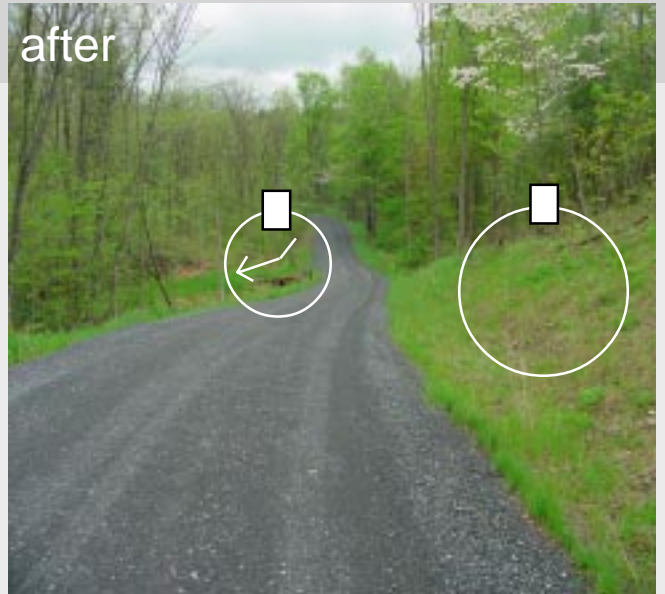
AGGREGATE PLACEMENT

Drainage patterns such as crown and grade breaks, visible in the surface of the road, are reflected in every layer of fill to enhance subsurface water movement under the road base. The top layer is Driving Surface Aggregate (DSA), a specially formulated abrasion resistant mixture of crushed limestone. DSA has a carefully blended size distribution from 1½" stone to fine particles small enough to pass a screen with 200 holes per square inch. The fines act to fill all voids and create strength from increased density. Placement through a paving machine to a uniform 8" depth enables compaction with fines in place. This placement method avoids aggregate separation.

before

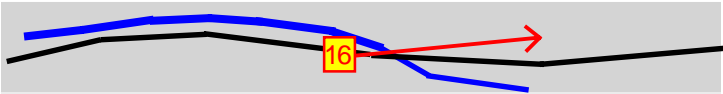


after



during



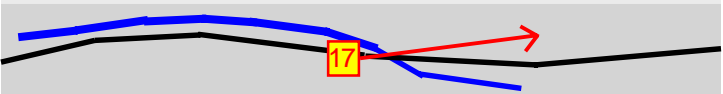


LOOKING EAST AT SHALE PIT

Easily available shale was periodically removed in uneven patterns, extending back over 120' to the right. It was taken from around the underlying hard limestone protrusions, shown here near the road. The road at this spot curved around the end of the abandoned pit, immediately adjacent to the stream (by the people in the photograph).

Contrast this "BEFORE" image with photos #12 and #14 showing the new road at its higher elevation and alignment. The actual point from which this photo (#16) was taken is now under 6' of fill and would be on the bank closest to the stream.

before

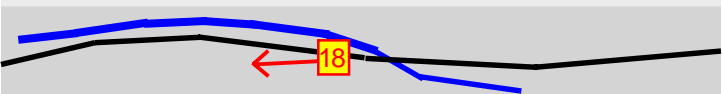


LOOKING EAST AT SHALE PIT

The steep bank on the right, shown being cleared of trees, is now under the left edge of the road. This bank was partially lowered, and the road was built at a steeper angle allowing it to pass over the old bank at a higher elevation.

These actions prevent the creation of a typical 1:1 uphill road bank or "cut" slope and the erosion consistently associated with such steep road banks. When native vegetation is thoroughly established, this more natural land shape will blend in with the beauty of the surrounding forests even better than pictured in photo #12.

during



WORK IN PIT

Excavating material from the abandoned pit produced fill to raise the road and correct the entrenched drainage pattern. By removing shale from the pit, a less steep and therefore less erodible profile was created. The more naturally appearing shape was formed with machinery normally used in road-work.

A D-8 bulldozer with ripping teeth and "U" blade loosened the shale and limestone domes left behind by the smaller machinery used to originally excavate the pit. A track hoe was used to load trucks, shape the final grade and set the stumps.

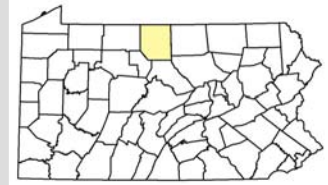
during



Worksite in Focus

Potter County Horseshoe Road

6/10/04



Problem Identification

Routine maintenance operations and the wear and tear of traffic had the cumulative effect of lowering the road elevation in relation to the surrounding terrain (see photo). The resulting entrenched road trapped road drainage. Confined by the road, this water concentrated in parallel ditches and gained velocity. As the volume and velocity increased, more and more valuable road material was washed away, polluting nearby Pine Creek.

Project Objectives

1. Prevent direct discharge of sediment-laden road drainage to Pine Creek.
2. Reduce concentrated drainage from parallel ditches.
3. Filter road runoff using existing roadside vegetation.

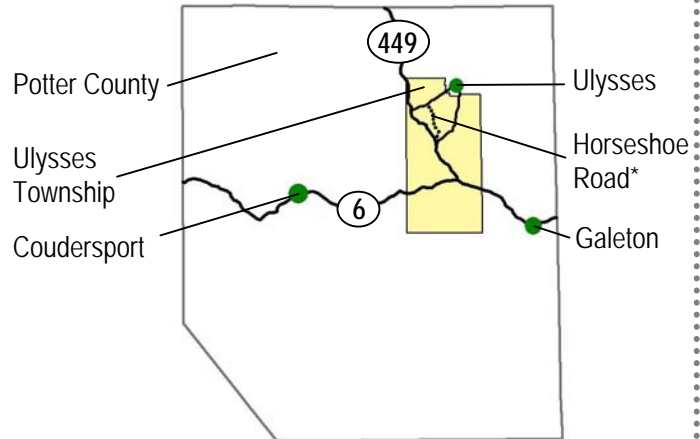
Project Considerations

Off right-of-way (ROW) drainage input from an adjacent driveway compounded the problems on Horseshoe Road. Existing drainage structures (ditches and crosspipes) were inadequate to handle flow volumes.

Spring seeps in the road bank drained directly onto the road surface resulting in a soft road base and observable ditchflow year-round.

Adequately addressing drainage on Horseshoe Road required an additional drainage outlet, installation of under-drain, and elevation of the road itself.

Project Statistics



Road:	Horseshoe Road
Road Owner:	Ulysses Township
Affected Watershed:	Pine Creek
Project Length:	1600 ft
Cost:	\$53,829
Date Completed:	September 2002



Before: The entrenched road trapped road drainage resulting in fast-moving concentrated ditchflow. This water eroded road material and deposited it directly into Pine Creek.

The publishers of this publication gratefully acknowledge the financial support of the Pennsylvania State Conservation Commission. For additional information or assistance, contact: Center for Dirt & Gravel Roads Studies, Penn State University, 207 Research Unit D, University Park, PA 16802 (Toll-Free Phone: 1-866-668-6683, Fax: 814-863-6787, Email: dirtandgravel@psu.edu). Additional copies available on our website at: www.dirtandgravelroads.org



Project Solutions

Adding a cross-pipe: Installing a new cross-pipe on the road provided an extra drainage outlet and shortened the flow length of parallel road drainage. By minimizing the distance water has to travel before it is removed from the road corridor, the velocity and erosivity of the water are reduced.

Adding perforated underdrain: Underdrain, or drain tile, was added in the ditch to collect water flowing from spring seeps. This eliminated perennial ditchflow and corrected the soft road base problem.

Filling the road: The elevation of the road was raised by filling the road profile. The added elevation eliminated the need for parallel ditches and allowed drainage to sheet flow into the surrounding terrain through vegetated buffers, removing sediment-laden surface flow to Pine Creek.

Adequate Culvert Size: A hydrologic & hydraulic analysis was used to determine the proper size of the culvert needed for the stream crossing. The existing 30" round concrete pipe was replaced by a 77"x 52" squash pipe. The road was raised to ensure proper cover over the new pipe.

Cost Summary

Total Project Value:	\$53,829
District Funding:	\$31,769
Materials	\$28,428
Contracted Work	\$3,341
In-Kind from twp:	\$22,060
Materials	\$3,837
Labor & Equip.	\$18,223



After: The road profile was raised eliminating ditchflow on the downslope side of the road. Drainage that was trapped on the entrenched road can now sheet flow freely off the road into surrounding vegetation. Because the water does not have the opportunity to gain velocity, its erosive potential is greatly reduced.



After: The pipe was re-sized and the road raised for proper cover over the new installation.

For More Information

The Center for Dirt and Gravel Road Studies
(814) 865-5355
www.dirtandgravelroads.org

Potter County Conservation District
Eric Potter
(814) 274-8411

* Directions to Horseshoe Road worksite: From Coudersport: Take U.S. Route 6 east approximately 13 miles to State Highway 449. Follow 449 north to Brookland; just past Brookland veer right at the Y-junction onto SR 1001. Horseshoe Road (T450) is 4/10 of a mile ahead on the left. The project begins at the intersection with SR 1001 and continues for 1600'.

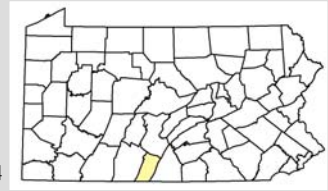
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Worksite in Focus

Fulton County Dutch Corner Road

4/13/04



Problem Identification

Dutch Corner Road contributed concentrated, sediment-laden water to Patterson Run, a tributary of Licking Creek. Three primary issues caused this impairment: steep road slopes, deeply entrenched road segments, and significant off right-of-way (ROW) water inputs. Long steep road segments bordered by high banks on either side served to trap stormwater water increasing its volume and velocity thus making it highly erosive. Off ROW inputs from driveways and connecting paved roads contributed more water to already concentrated erosive flows.

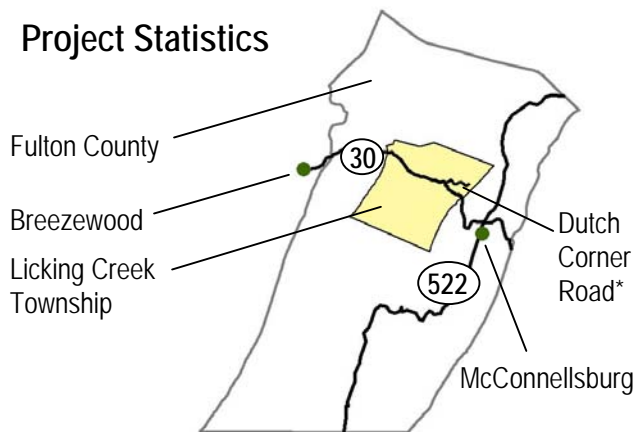
Project Objectives

1. Minimize the entrenchment of the road.
2. Separate off ROW drainage and prevent it from flowing onto the road.
3. Divide and minimize concentrated water flow on steep road segments.

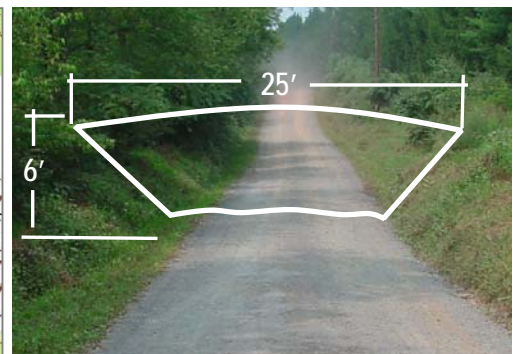
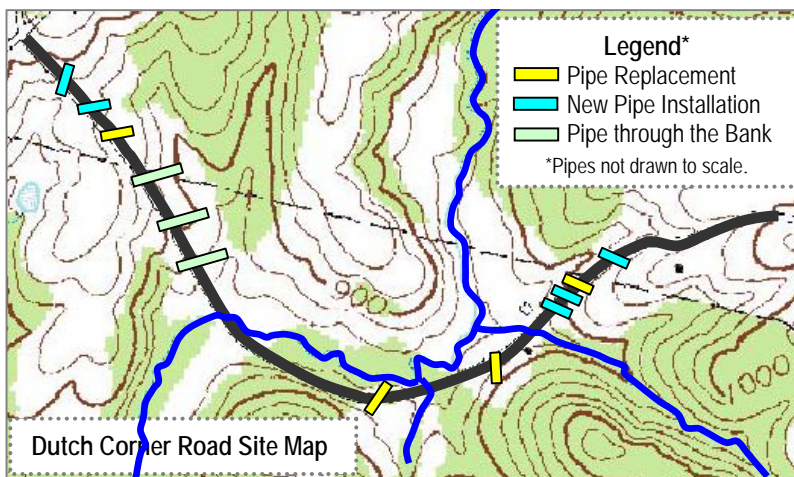
Project Considerations

The deep road entrenchment made raising the road elevation to the height of the surrounding landscape impractical and expensive. The topography lent itself on the steep entrenched road segments to pipe installation through the road banks at a slope of 2% and discharging road drainage on the other side of the bank. Drainage routed in this way is directed into adjacent vegetation where it encounters resistance, can release energy and infiltrate slowly.

Project Statistics



Road: Dutch Corner Rd
Road Owner: Licking Creek Township
Length: 4,835 ft
Date Completed: November 2003



Raising the road elevation to the elevation of the surrounding landscape was impractical because of the amount of material required (above).

The publishers of this publication gratefully acknowledge the financial support of the Pennsylvania State Conservation Commission. For additional information or assistance, contact: Center for Dirt & Gravel Roads Studies, Penn State University, 207 Research Unit D, University Park, PA 16802 (Toll-Free Phone: 1-866-668-6683, Fax: 814-863-6787, Email: dirtandgravel@psu.edu). Additional copies available on our website at: www.dirtandgravelroads.org





Before and After Shale Placement. Before, severely entrenched road slopes steeply to stream at the bottom of the hill. After, cross-pipes are added to divide drainage and reduce concentrated flow and the road elevation is raised 2' to cover the new pipes.

Project Solutions

Road profile. Shale was placed on steep entrenched areas to a maximum depth of 2 feet to obtain adequate cover on new crosspipes. Road surface was topped with Driving Surface Aggregate (DSA) for improved performance.

Adding crosspipes and installing pipes through the bank. 3 existing crosspipes were replaced and 9 new drainage pipes were added. 3 of the 9 were installed through the bank. Increased road drainage capacity minimizes concentrated flow before sufficient volume and velocity can build to strong erosive force.

Re-profiling driveways. Driveways were re-shaped at the point where they entered the roadway to eliminate any direct discharge to the road.

Grade breaks and broad-based dips. On steep driveways at points of concentrated flow, grade breaks and broad-based dips were installed to direct drainage off the driveway surface into surrounding vegetation for infiltration.



Pipes Through the Bank. Note the depth of the trench during construction. After construction the pipe has been covered and stabilized with vegetation.

Cost Summary

Total Project Value:	\$70,962
District Funding:	\$63,712
Materials	\$46,970
Contracted Work & Equipment	\$16,742
In-Kind from twp:	\$7,250
Materials	\$4000
Labor & Equipment	\$3250

For More Information

The Center for Dirt and Gravel Road Studies
 (814) 865-5355
www.dirtandgravelroads.org
 Fulton County Conservation District
 (717) 485-3547

* Directions: From U.S. 30: Take Breezy Point Road north 0.4 miles, turn right on Dutch Corner Road. Dutch Corner Road is located 12 miles east of Breezewood, 6 miles west of the intersection of U.S. 522 and U.S. 30 north of McConnellsburg.

Environmentally Sensitive Maintenance Practices for Dirt and Gravel Roads

Chapter 6: Environmentally Sensitive Maintenance Practices: Roadsides and Streams

6.1 Introduction

Throughout the previous discussions of natural systems and road maintenance, we have shown how the road and environment are deeply intertwined. That is particularly true of the relationship between roadsides and streams. Traditional road maintenance activities for shoulder, ditch, and roadsides frequently include undercutting stable slopes, removing valuable vegetative cover from roadside banks, and a failure to re-stabilize unprotected soil.

The greatest failing of traditional maintenance practices is in the underlying belief of many road managers that roadside vegetation is unwelcome. When road maintenance activities leave bare soil, the resultant [erosion](#) and deposition of [sediment](#) into critical drainage facilities creates the need for more frequent maintenance cycles. This becomes a self-perpetuating cycle of maintenance and pollution with unacceptable costs to local governments and unacceptable detrimental results to the environment.

As our machinery has become larger and more powerful, in many cases, we have lost touch with basic principles of nature and natural systems; we have fallen into a belief that we can work to set standards, forcing nature to comply to our will. Often the natural consequence of our actions is in direct conflict with our maintenance goal. [Environmentally sensitive maintenance](#) practices take into account road maintenance goals and natural principles to provide cost effective longer-term solutions to traditional cyclical maintenance activities.



6-01 Typical roadside erosion problems.

In this chapter, [environmentally sensitive maintenance](#) practices will be presented to deal with the necessary activities of roadside vegetation management and bank stabilization. A short discussion of stream bank maintenance around cross pipes and bridges for stream crossings is also included.

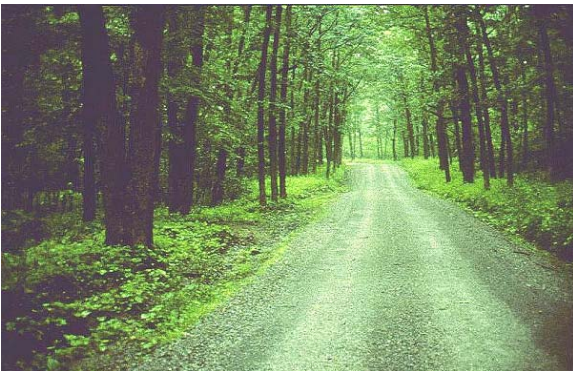
6.2 Expectations of a Finished Product

Even without an understanding of natural systems, road managers usually are well aware of the roads in their network that require less maintenance. Roads requiring less maintenance frequently are working in harmony with natural principles. The road manager would be wise to “read” these roads, comparing them with their problem roads with excessive maintenance.

In this section we want to step out of the box of traditional standards and expectations. Roads that look like they are in harmony with nature, require less money to maintain, pollute less, and offer the additional benefit of being beautiful.

Most of us have been around long enough to witness the incredible advances in machinery over the last forty years. Although some local governments move forward faster than others, most counties and townships are vastly better equipped today than they were twenty-five years ago. As our equipment has gotten better, so too have our projects gotten larger. Generally, local governments have effectively updated their dirt and gravel road networks that so well serve the citizens and industries of their communities.

The development of our state and federal highway systems has in many ways provided guidance and expectations to local governments and citizens for how their roads should look. We as local officials and road managers, however, need to look at and develop guidelines for our roads that fit the use and needs of our own communities. These local roads provide a very different link in our national highway system.



6-02 When a road is working well within the environment, minimal maintenance will be required.

A natural systems approach to road maintenance requires changing expectations and behaviors. When a road is working well within the environment, minimal maintenance should be required. A road that requires continual maintenance attention is probably working against natural principles. Simply asking the question, “Does it look right?” can provide terrific insight. However, the “right” that forms the comparison must be a road that is in harmony with nature. Herein lies a problem if we try to use standards and practices developed for superhighways and interstates.

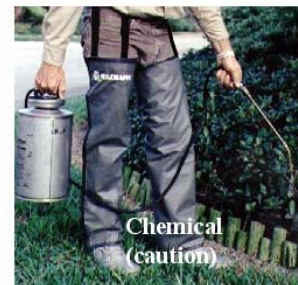
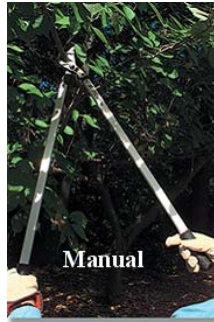
6.3 Practices Related to Roadsides

6.3.1 Vegetation Management. Tree trimming and removal, brushing, brush cutting, right-of-way clearing are all terms for vegetation management. These activities are common, and road managers may need to perform these activities for a variety of reasons. We need to look at these common practices and reasons and determine what is best for our roads and our municipality.

Roadside vegetation plays an important part in our road maintenance program. Understanding the natural systems allows us to use these systems to help in more effective road maintenance.

6.3.2 Equipment and Methods. First, let's examine typical roadside maintenance equipment and methods and evaluate their effectiveness in all areas of road maintenance, the environment, and community relations.

The normal methods used to trim trees, remove brush and cut vegetation along roadsides include manual methods with manual equipment such as chainsaws, string trimmers, and hand pruners; mechanical methods with mowers and brush cutters; and chemical methods with chemical application equipment and herbicides. All of these methods and equipment have their place in an integrated vegetation management program and can be used effectively. There are some cautions, however, that should be noted.



6-03 Roadside Vegetation Management Options.

In an [environmentally sensitive maintenance](#) program, chemical methods using herbicides are certainly the first concern. There are many potential problems associated with the use of herbicides. As a result, numerous federal laws and regulations govern their use. States have also adopted regulations, patterned after the federal laws, regarding the use of chemicals for vegetation control. These regulations require local government applicators to become certified through testing. [Environmentally sensitive maintenance](#) does not promote the use of herbicides. If you do use herbicides, you need to become familiar with the laws and follow all the requirements and regulations associated with herbicides use.

Because roadside vegetation management is labor-intensive, boom mowers have become increasingly popular. The boom mower, properly used, is a labor saver and can be safer than other equipment such as chainsaws. However, one only has to travel down a road on which a boom mower was used to totally destroy the roadside vegetation, leaving a hurricane-aftermath look, to realize that the use of this equipment can get out of hand. Damage to large tree limbs can eventually kill the total tree. Refer to the discussion in Chapter 4 on understanding your trees and the effects of wounds.

Boom mowers also raise some roadside safety issues. Using a boom mower to cut down young saplings, leaving those “spikes” behind, can result in a very unsafe condition. Motorcyclists or bicyclists who may skid off the road and upset can be impaled on these “spikes,” causing severe injury or death, not to mention the resulting tort liability claims.

Boom mowers and their resulting destruction can also be a public relations headache. Many complaints have been lodged against both state and local governments about the “butchering” of roadside vegetation.



6-04 Boom mower impalers!

6.3.3 Roadside Clearing. Traditional right-of-way clearing, or “[daylighting](#)” practice, often creates problems for roadside vegetation for our dirt and gravel roads. These practices may have their place on the interstates and superhighways, but often they cause increased maintenance work on gravel roads in forested areas.

Common accepted reasons for clearing the roadside of trees and bushes are:

1. Eliminate shade
2. Improve roadside visibility
3. Establish a safety “clear zone”
4. Reduce routine trimming.

All of these reasons have some merit and may apply for some roads, but a more thorough understanding of the conditions encountered on dirt and gravel roads, and the consequences of inappropriate roadside clearing, is necessary to make effective decisions.

6.3.3.1 Shading, Good or Bad? Brush cutting, trimming, and tree removal for the purpose of eliminating or reducing shading is probably the most common roadside management practice, other than roadside mowing of grass. A great deal of money is invested in vegetation management for shade reduction each year. The goal of improved public safety is universal and laudable. On low traffic dirt and gravel roads, however, excess tree removal can have the dire consequences of increasing speeds to unsafe limits.



6-05 The disadvantages of shade: retains moisture to promote icing, reduces visibility.

Why should we eliminate shading? Here are the reasons:

1. Shading retains road moisture, promoting unsafe conditions such as icing in the winter.
2. Shading also reduces visibility and limits the “clear zone,” again affecting safety.

An abrupt transition from bright sunlight to dense shade or vice versa can be a great safety hazard. Extreme changes in light can have a devastating effect on the motorists’ visibility and be a direct cause of accidents. Extreme changes in light conditions should be avoided.

Shading, however, also has advantages. Shading:

1. helps retain road moisture, reducing [dust](#);
2. reduces growth of colonizer plant species and encourages desirable herbaceous plant growth (discussed below);
3. is more aesthetically pleasing, contributing to tourism and the economy.



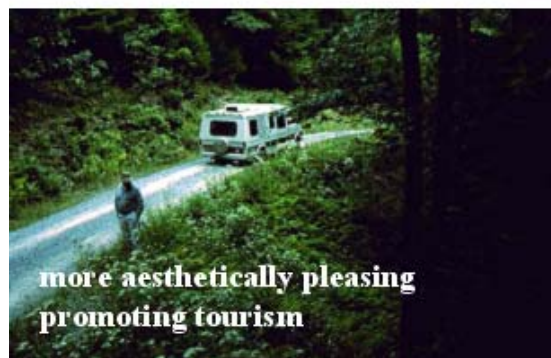
6-06 Bright sunlight to dense shade or vice versa – major visibility safety hazard – should be avoided.

With this information, we may want to look at shading with a new perspective. A limited amount of shading may be more effective and efficient for our road maintenance and the environment.

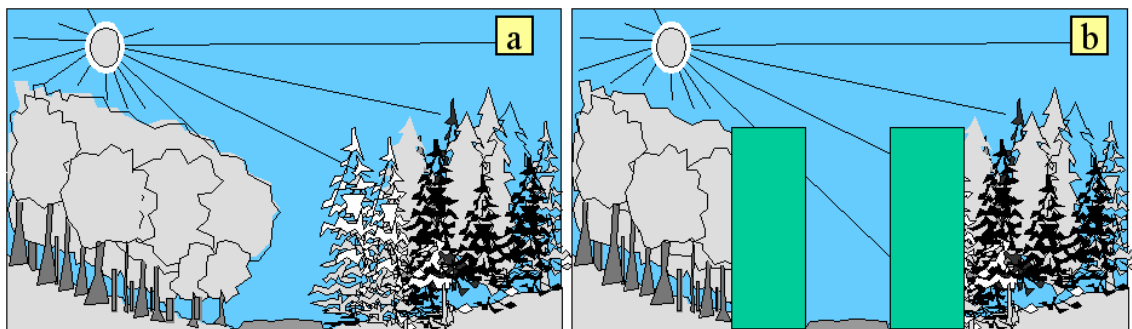
6.3.3.2 Problems with Traditional Clearing Techniques. Traditional clearing techniques involve total removal of brush and vegetation along the roadside from right-of-way line to right-of-way line, typically resulting in vastly increased sunlight along the edge of the road. So, if increased sunlight is the goal, what is the problem?

If we could view time-lapse photos of the road and its surrounding environment following a traditional roadside clearing before doing it, we would see it is not the best or most effective practice. If the roadside is wooded or forested and the road well shaded and we automatically go in and cut everything down, as shown in Figure 6-1a to 1b, on each side of the road for whatever distance we consider necessary, let's observe what happens.

The forest trees, by nature, have grown structurally as a forest, meaning that each tree can depend on surrounding trees for protection against the elements. When a section of trees is cut down, the remaining trees along the cut edge are open to storms and wind and may not be structurally strong enough to withstand these conditions. Wind damage, broken branches, and even uprooting can result, as shown in Figure 6-2a.



6-07 The advantages of shade.



Traditional clearing practice for a shaded road would be from right-of-way line to right-of-way line

Figure 6-1

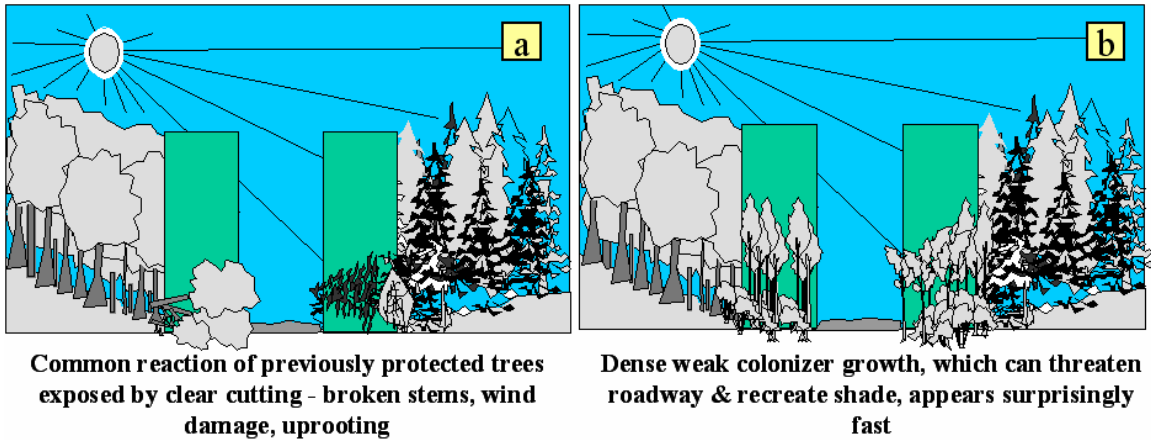


Figure 6-2

Additional problems with common clearing practices include the rapid regrowth of the removed trees through stump sprouting. These stump sprouts are weak in structure and can become a continual maintenance problem.

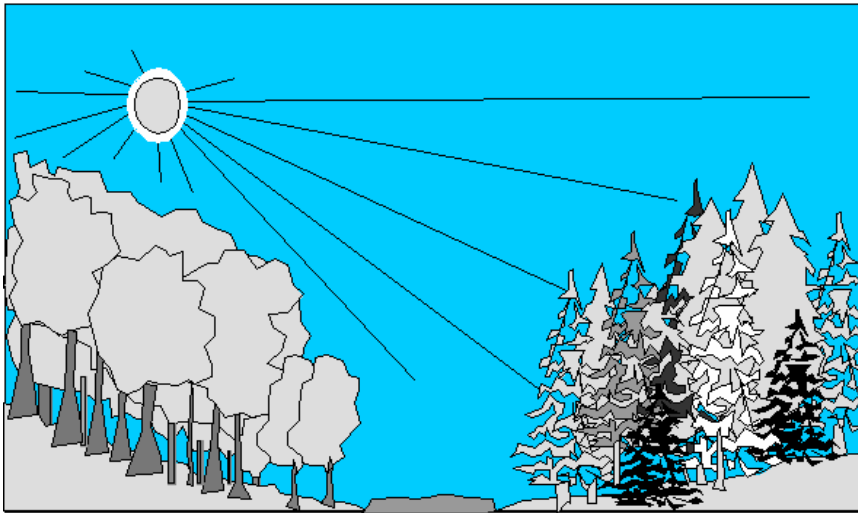
When large quantities of trees and vegetation are removed, previously protected plants, now exposed to full sun, begin to fail. A formerly shaded roadside with low growing, broad-leafed ground cover vegetation becomes a completely different ecosystem when exposed to full sun. Exposing low growing, broad-leafed, shade-tolerant plants to full sunlight typically kills them, with the potential of soil [erosion](#).

Unfortunately, when the roadside, which was previously shaded, receive full sunlight, nature produces vigorous growth, as depicted in Figure 6-2b. This vigorous growth is due to the invasion of colonizer species that are most attracted to this environment, but are the worst possible roadside plants. Colonizer species, which we described in Chapter 4, Section 4.5.4 on succession, are fast-growing, weak growth types. [Colonizer trees](#) can threaten the roadway safety and recreate shade. These [colonizer trees](#) then become extremely high maintenance roadside plants. In many cases the plants we most want to remove are the plants most encouraged by our efforts. This creates the need to mow and trim in increasingly frequent cycles.



6-08 You do not need fast-growing weak-structured colonizer-type roadside trees!

So in this scenario, the mowing/removal of trees and brush in the interest of safety and visibility, have the opposite effect, starting an endless cycle of cutting and re-cutting of this colonizer growth.



Selective trimming retains some shading to protect roadside soils and forest edge & still allow drying of road bed

Figure 6-3

6.3.3.3 Alternative Techniques. The solution is to **use the forest system to reduce maintenance.** By taking advantage of natural principles, it is possible to create safe clearances, provide enough shade to control [dust](#) and invasive species, and eliminate the invasive rapid re-growth of colonizer

species and frequent mowing cycles. We need to develop a strategy following some basic guidelines.



6-09 Remove dead, diseased, unstable, or dying trees first.

Be selective! When doing roadside trimming and tree removal, remember to remove the dead, dying, unstable, or damaged trees first. Trees that have been damaged by previous maintenance activities, automobile accidents, etc. will eventually die and become hazards.

The second priority should be to remove the existing [colonizer trees](#). These trees, even if they are healthy, are not good roadside trees. They are very rapid growers and have weak wood and short lives. They commonly fall onto the road or drop limbs, which create maintenance and hazards.

After removing the damaged trees and the colonizers, it is advisable to look the situation over and evaluate the rest of

the trees. Maintaining strong, slow-growing, deep-rooted climax species should be an objective (refer to chapter 4, Section 4.5.4). Avoid straight-line cutting, however, favoring instead an irregular edge. Traffic will tend to travel more slowly on a road with an irregular edge. Speed has always been a major safety problem for our dirt and gravel

roads. Clearing the roadside completely or cutting back on a straight line parallel to the road gives the motorist the safe illusion to increase speed.

Maintaining a uniform level of shading is best. One of the greatest dangers from shading comes from winter conditions where pockets of deep shade create irregular icing conditions. The objective should be to thin the canopy to achieve the desired shade density.

Sometimes it is necessary to thin back off the edge of the right-of-way, as the desired sunlight may only be available from the side, not from above. Obviously it is necessary to discuss any plans and objectives with property owners to receive permission to work off the right-of-way.



6-10 Pockets of deep shade can create irregular winter icing conditions.

6.3.3.4 Adjacent Residents and Off Right-of-Way Work. Local governments must have a public relations strategy. Road managers should meet with the property owners where brush cutting/trimming is proposed. This local government representative should discuss the plan to do brush cutting with the property owner, offering to walk the roadside and specifically discuss the goal of the project and to take into consideration the property owner's concerns. This one-on-one contact with the property owner prior to the actual cutting of brush or trees is critical. It establishes a level of respect for the property owner, something that is commonly overlooked. It is especially helpful to walk the road with the property owner. When a tree is infringing on the travel-way or an obvious threat of falling into the roadway, it is easier to recognize the problem when both parties are standing right there looking at it. Listening to the property owner's concerns and developing a plan that meets both parties' needs is vital to the success of a roadside management plan.



6-11 Before and after look at selective tree trimming during a road project – letting in more sunlight with less shade – striking a balance.

6.3.3.5 Advantages of Using the Forest System. In a situation where a dirt and gravel road is heavily lined with trees or passes through forested areas, a vegetation management program that uses the forest system to take advantage of natural principles can save time and money in several ways.

1. Moisture is nature’s stabilizing agent. Allowing enough shade to hold some moisture on dirt and gravel roads helps to hold the surface together and reduce [dust](#). Although few road managers would readily identify moisture retention as a benefit of shaded roads, they will almost always tell you they use less dust control in shaded areas.

2. Maintaining shade along our roads reduces the establishment of colonizer species (aspen, birch, poplar, sumac, striped maple, etc.). These rapidly growing, weak-wooded trees create the biggest maintenance problems, especially during winter maintenance operations. (They lean out in the roadways with snow load.)



6-12 Would anyone want to plow this road?

3. The trees that are removed are less likely to return as stump sprouts if shade is retained. All of us have witnessed the rapid return of vegetation under new power line cuts. This is usually a combination of stump sprouts and colonizer species. This scenario can be avoided by simply allowing the road to remain partially shaded.

6.3.3.6 A Common Pitfall in Tree Removal. All of these techniques will reduce the frequency and cost of roadside vegetation maintenance. Importantly, at no time in our discussion of vegetation management has a diameter or size been mentioned as a criterion

for what to remove and what to leave. Herein lies one of the biggest problems with boom mowers. Boom mower operators are frequently instructed to cut “everything you can reach and everything small enough that you can cut.” This direction and practice will ultimately have, as its consequence, roadsides vegetated only by large trees. If these trees are the right species and are in good health, this might be a defensible practice.

Boom mowers may be effective in maintaining right-of-way, but great care should be exercised when using them to re-establish those long neglected rights-of-way. When decisions are based solely on size, damaged and potentially hazardous trees are left while the potentially stronger, healthier replacement trees are removed. Often this leaves a roadside stimulated into vigorous growth by excessive sunlight. In the case of boom mowers, what is perceived as the “easiest way” may actually be the most expensive.

Additionally, some of the most beautiful, slow-growing, strong, wildlife-friendly trees along the roads are being systematically removed because they have the misfortune of being small. Dogwood trees and serviceberry trees are some of nature’s finest work and are frequently chosen as roadside trees by planners. Yet they are often removed by boom mower operations just because of their size. Would it not have been better to remove the big old damaged or dead trees and save those small dogwoods? The dogwood makes an excellent roadside tree with the added value of blossoms to beautify the roadside in the spring.



6-13 Dogwoods are a good roadside tree with the added value of spring blossoms.

6.3.3.7 Tree Leaves. What road maintenance person hasn’t uttered unmentionable language concerning leaf problems? Leaves in ditches, leaves on the road - leaves! leaves! leaves! Fall can be a beautiful time of the year with the diverse coloration of the landscape from the changing of the leaves. This seasonal occurrence concludes, however, with the leaves falling to the ground and filling ditches and covering roadways. If we are adding road material, the layer of leaves can become a problem if not removed. If the layer is substantial, the slow composition of the leaves can result in a slip plane for road material to slide. In addition, leaves fill the roadside ditches and interfere with proper drainage, clogging ditches and crosspipes when the rains come.

Leaf removal can be labor intensive and burdensome to the road maintenance crews. Backpack blowers or wheeled walk-behind power blowers are often used to blow leaves off the road prior to aggregate placement. Leaf cleaning in the ditches can be accomplished by the usual grading of ditches, removing the leaves and possibly the existing vegetation lining that may not have time to re-establish prior to winter.



6-14 Leaf Blowers to Clean Ditches and the Roadway

The job can be made easier with a three-point hitch leaf blower. These are the same machines used by many golf courses. By using this type of blower, we can save time and effort. The machine is easy to use and relatively inexpensive considering the amount of leaf blowing needed on many road systems.

Blowing the leaves off the road and out of the ditches and leaving them to decompose in the natural roadside environment is definitely environmentally sensitive. In addition, we reap the benefit of not losing soil and existing vegetation through a ditch grading operation, which would open the potential for additional [erosion](#) and [sediment](#).

6.3.4 Using Other Plants for the Roadside. In addition to maintaining limited shading, there are many low maintenance plants that readily grow on roadsides. Deciding what plants to encourage on a given site involves many factors. Often maintenance practice, such as mowing, can be timed to encourage some plants while discouraging others. Plants such as day lilies and ferns are examples of low maintenance plants that do a terrific job of holding soil in place and limiting growth of invasive species. Day lilies and ferns do not benefit from mowing. Wherever possible, care should be taken to leave these plants intact during a mowing cycle. Unless they create a visibility problem, there is no benefit to mowing these plants. If invasion of woody plants into fern or day lilies is a concern, time mowing operations for the dormant seasons of the year. Visibility is better at this time also.



6-15 Day lilies or ferns are good roadside plants – low maintenance, aesthetically pleasing

When doing shoulder cutting or ditch cleaning, if the berm or spoil material is full of sod with day lilies or ferns, we should use this material to our advantage. Pick a bank where there have been problems holding the soil in place and coat it with six inches or more of dirt full of sod and weeds and lilies and whatever else. In no time at all these plants will become established on the new soil. Obviously care should be taken to provide some type of temporary [erosion](#) control for the time it takes the plants to become established. It is a lot easier to vegetate soil, which is naturally full of plants, than to get plants to grow from seed on hand-polished subsoil. Remember our discussions in Chapter 2 on topsoil and subsoil.

Grass, of course, is a wonderful roadside plant. Because of how it grows, (refer to Chapter 4, section 4.5.2 Plant Basics) grass is usually not affected by mowing. Grass holds soil in place and helps slow the speed of surface [runoff](#). Grass also traps [sediment](#) that is moving with the water. The benefits of grass from an environmental point of view are obvious. The benefit of grass from the perspective of a road manager should also be obvious, but frequently it is unrecognized.



6-16 Grasses make good roadside plants, establishing surface erosion protection

Other vegetation can be used to reduce maintenance in many roadside situations. By encouraging appropriate plants for the location and terrain, maintenance can be minimized and the environment enhanced. Deep-rooted species can be used for soil reinforcement. Ground covers can be used for surface [erosion](#) prevention. Species selection for these applications should consider low or no maintenance.

Working with our local and state conservation agencies on appropriate plants for specific sites is always a good idea. We'll be discussing site evaluation in a little more detail below.

6.3.5 Clearing Stream Banks at Cross Pipes. In Chapter 2, we discussed the historical aspects of how so many roads were built close to streams. With so many roads adjacent to streams, we have many stream crossings with associated [culvert](#) pipes and bridges. Maintenance around these structures consumes great quantities of time and money for local governments. As science has learned more about water and how it behaves around restrictions in flow, better bridges and [culverts](#) have been designed and built. The stream saver system along with the section on better bridges described in Chapter 5 is a great step forward in reducing maintenance and pollution at stream crossings.

6.3.5.1 Common Practice and Associated Problems. We need to zero in on the specific maintenance operation of clearing brush and trees from stream or channel banks adjacent to these crossings. Traditionally, common practice has been to clear stream banks upstream and downstream from a roadway cross [culvert](#) or bridge to clear the floodway and improve drainage. Doing so left the crossing with a cleaner look and presumably easier maintenance. But are these assumptions really valid?



6-17 Clearing stream banks for a road crosspipe replacement can have devastating effects on the stream and future maintenance.

Although taken during different seasons of the year, look at the before and after, Photo 6-17, of a crosspipe replacement project and consider some of the potential problems. Referring back to Chapter 4, the stream shading is reduced, affecting stream temperature, which in turn affects the stream habitat. [Outside inputs](#) of vegetation debris vital to stream life are eliminated, and the streamside habitat is reduced. Look at the stream width upstream of the work area and within the work area. Would fisherman fish this area, or would they go upstream to find the natural shady 'holes'? These are all environmentally related.

Widening the stream causes the water flow to spread out and slow down, resulting in deposition of material immediately prior to the new crosspipe. It should also be apparent that any debris coming down the stream will be deposited at the road [culvert](#) or bridge, with possible blockage of drainage openings and subsequent flooding damage at the road or bridge.

Clearing the floodway to improve drainage could also have the unintended consequence of causing flooding downstream. The fact is that improved drainage usually means faster water. Faster drainage of a [watershed](#) means more water at one time with potential flooding downstream.

6.3.5.2 Alternative Practices. The alternative technique, or [environmentally sensitive maintenance](#) practice for stream bank/stream crossing vegetation is very easy: “DO NOTHING!” The natural stream channel will have less influence on the road crossing and cause less maintenance. The “before” Photo 6-17 emphasizes the fact that any large debris will get hung up long before it gets to the crosspipe.

Sometimes it is impossible to do nothing; some streams produce so much debris that large pieces upstream from the road have to be removed. Common sense dictates that some vegetation maintenance such as selective thinning may be required. The message is to look at what is being done and ask if it is necessary or it has any benefit. The less we disturb streams and stream bank vegetation around our pipes and bridges, the better for the environment and reduced future maintenance. If vegetation has to be removed at the immediate worksite for room to work, trim to the ground. The vegetation will grow back and again create a more natural low-maintenance site. So the solution is to either do nothing (avoid) or do only what is absolutely necessary (minimize).

6.3.5.3 Benefits of a New Approach. Vegetation in the floodway catches a lot of the debris in high water flows, spreads and slows the water flow, allowing gradual escape or release of water without letting the debris clog the drainage pipe or bridge opening

There are other benefits of woody type vegetation around pipes and bridges. Although grass has roots and does act as an [erosion](#) preventer by holding soil in place, these roots are shallow surface roots. Woody vegetation commonly has deeper roots and offers greater soil reinforcement around stream and road banks. This extra reinforcement is especially needed at bridges and pipes where water is forced to change direction or speed, causing much more turbulence and the potential for [erosion](#) and scour.

Streamside vegetation also shades the stream. The stream ecosystem is very temperature sensitive. Raising the water temperature can have dire consequences for species living in the stream. Additionally, vegetation along streams provides habitat for numerous species critical to the aquatic ecosystem along with those important [outside inputs](#) vital as the food link in the aquatic food web.

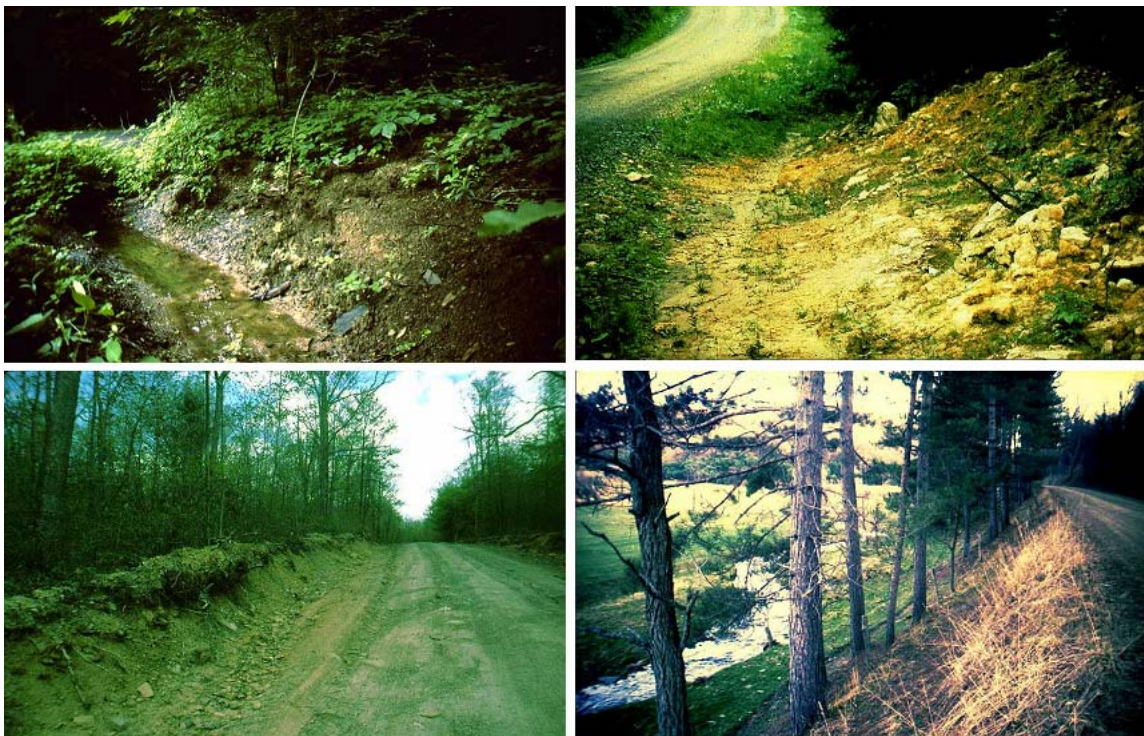
All of these benefits result in a better environment, less maintenance in keeping the banks cleaned or mowed and the pipes clear and open, and less potential of flooding at the site or downstream.

Although this section dealt with clearing of stream or channel banks at a roadway cross pipe, the next section deals with the stabilization of road and stream banks.

6.4 Practices Related to Road and Stream Banks

In discussing roadsides, roadside banks and stream banks are always a large issue. Our road and streams banks are constant sources of [erosion](#). Road banks, in particular, are constantly being disturbed and stripped of ground cover, waiting for [erosion](#) to occur. [Erosion](#) from these bare soil road banks creates ongoing maintenance headaches by filling drainage ditches and clogging pipes.

There are a few general factors that should be noted in re-establishing a stabilized bank, be it a road bank or a stream bank. Large, obvious sites with bank [erosion](#) can be easily targeted and are commonly the only ones that get taken care of. There are, however, numerous small sites of unstable eroding banks that are left unattended. An effort should be made to do a bank restoration program and include all of these small sites. When we began to add up all the existing small sites across our own local road system and then add those to all of the other sites in other local road systems, we realize that even the small ones can add up to significantly contribute [sediment](#) pollution. In addition, these small sites will only continue to get worse with time if left unattended and will eventually become the large site.



6-18 Eroded roadside banks are common sights, but add up to a large erosion and sediment pollution problem affecting both roads and the environment.

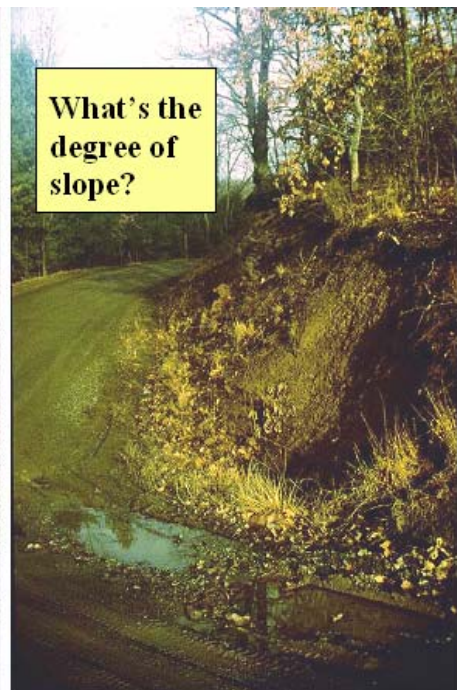
The type and physical structure of the soil is the first obstacle of plant establishment. We have already discussed the advantages of topsoil over subsoil. We also need to note that the use of heavy equipment should be limited to avoid **excessive packing** of the soil. Soil compaction can affect the amount of water penetration versus [runoff](#) and the ability of roadside vegetation to survive. Remember, when we reseed an area of our lawn, it is always recommended that we till the soil, breaking up the hard surface. Roadsides tend to have very compacted soils due to vehicles and equipment and construction and maintenance activities for the road.

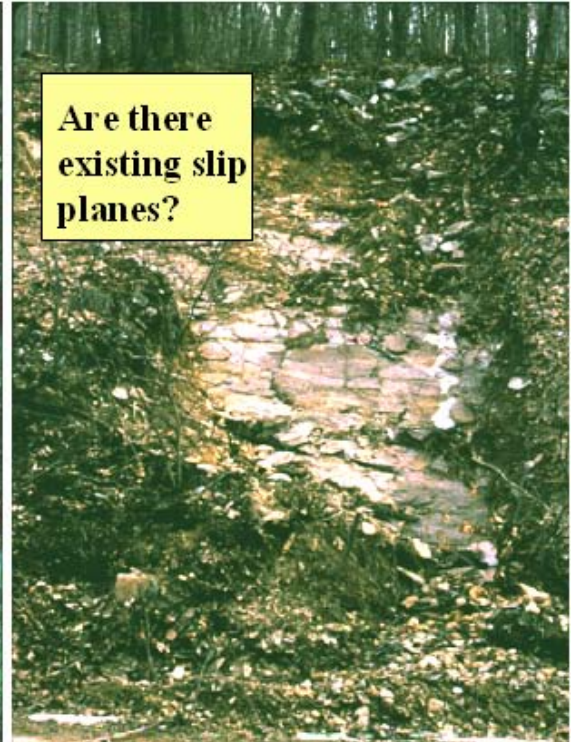
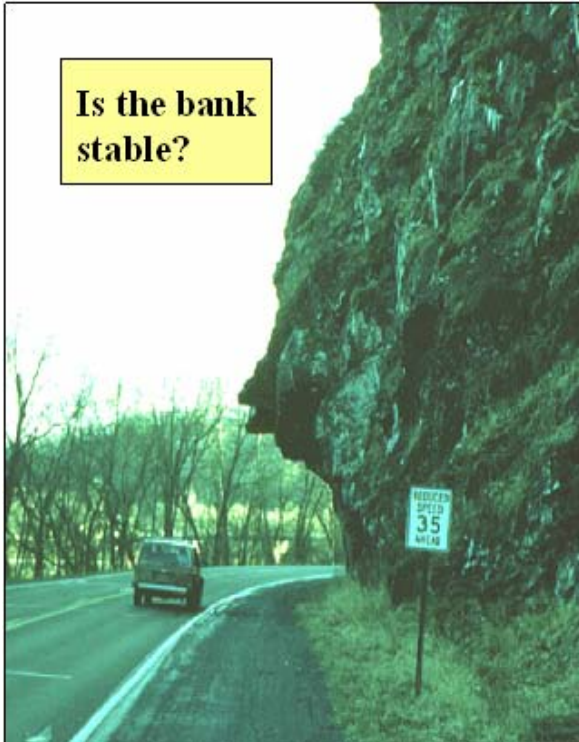
6.4.1 Initial Site Visit. To initiate [environmentally sensitive maintenance](#) practices for bank stabilization, a thorough investigation of the site is required. When we think about what makes a bank stable, there are several conditions that we need to determine. First, what type of material and slope do we have? Second, what is the drainage condition? And third, what is the existing vegetation, if any? These important characteristics are all interrelated and should be considered during an initial site visit.

At this initial site visit, we need to ask ourselves the specific questions listed below. Look at each of the following sets of photographs. Do these banks look familiar?

Soils:

1. What soil types are present?
2. What is the degree of slope?
3. Is the bank stable?
4. Are there existing slip planes undercutting the surface?





6-20

Hydrology:

1. Is the slope wet or dry?
2. Is there seepage or over the bank flow?
3. What is the condition of nearby banks?
4. What is the surrounding terrain?



6-21



6-22

Vegetation:

1. What is the existing vegetation?
2. What vegetation occurs naturally in the area?
3. Are tree roots reinforcing the bank?
4. Is it shady or sunny?

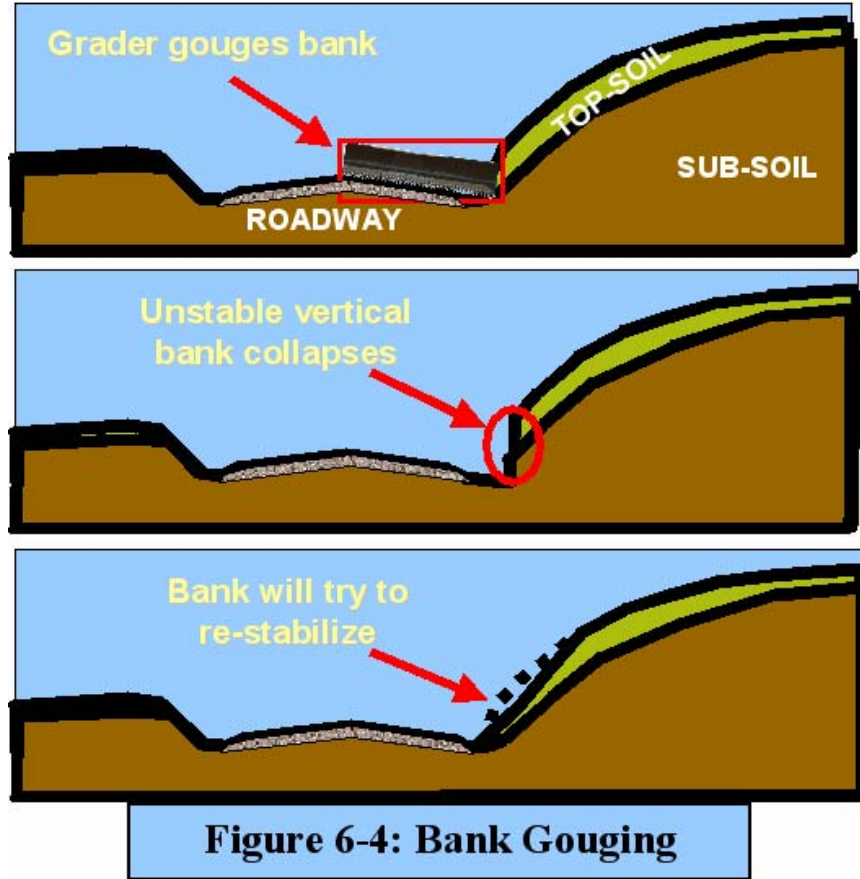


6-23



6-24

In pursuing this initial site evaluation for road and stream banks, it is wise to observe and follow the natural patterns and not disturb a stable bank. One of the most common problems is “[bank gouging](#)” during grading operations or ditch cleaning. The grader operator cuts into a stable bank and creates a vertical surface at the toe of the bank as shown in Figure 6-4. This vertical bank is unstable and will slough off as the bank tries to return to a stable angle.



As this occurs, the ditch is filled back in and the whole process starts over again with the next grading operation. Photos 6-25 show to what extremes this operation can lead and clearly indicate that, as these banks collapse, grading operations will again be required – the recurring maintenance in an endless cycle.



6-25 Unstable vertical bank will collapse.

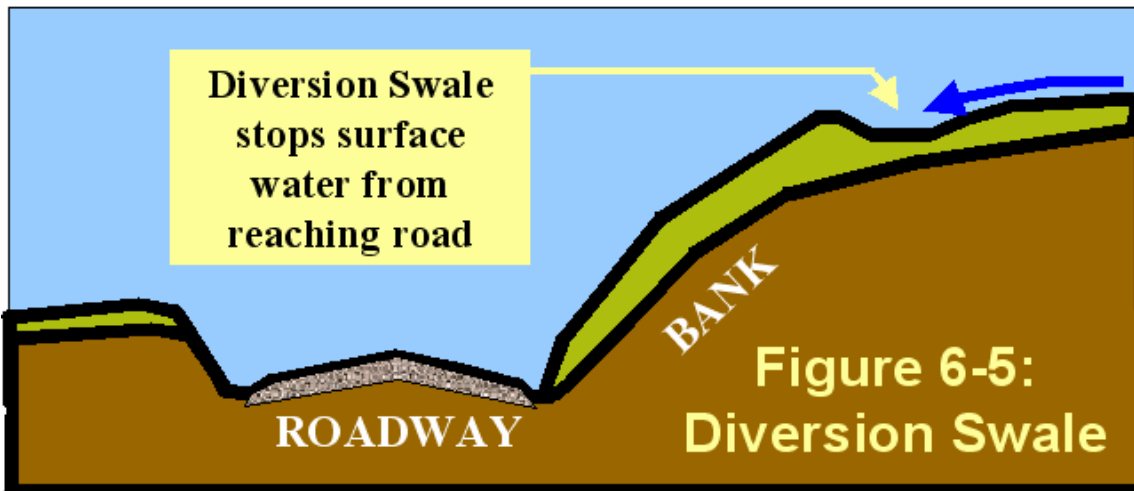


6-26 Tree Roots: Mother Nature's Rebar.

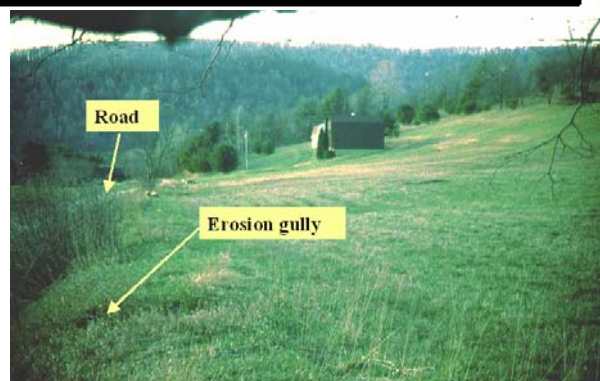
Keep in mind that tree removal can result in bank failure. The soil reinforcing roots will no longer be effective. Tree roots are mother nature's reinforcing bars, as discussed in Chapter 4, Section 4.5.2.4

6.4.2 Proven Techniques for Banks. Once the site investigation is complete, then the selected technique or techniques can be effectively implemented. Always keep in mind the possibility of using a combination of practices. Several of these practices are commonly known and used but are still worth mentioning as good "tools" to protect both the road and the environment.

6.4.2.1 Diversion Swales. Diversion or interceptor swales divert upslope surface water before it washes over the top of the road bank and into the road's drainage ditch. [Diversion swales](#) reduce the volume of water to be handled by the road ditch, decreasing the size of the road ditch and potential [erosion](#) problems. They also stop the erosive forces on the face of the bank.



[Diversion swales](#) must be stable, with a level longitudinal grade for infiltration back into the soil or sloped to an adequate discharge area. They must contain the overland flow and not be overtopped. Diversion ditches are effective for draining low gradual vegetative slopes. Referring to Photo 6-27, this would be the ideal location to



6-27 Ideal Location for a Diversion Swale.

create a [diversion swale](#). The surface [runoff](#) from the entire upward slope could be drained into a swale at the top of the road embankment. The road bank would then be protected against the [erosion](#) gullies that are now present.



6-28 Diversion Swale: Wider swales and gradual slopes result in more infiltration and less water volume to handle.

[Diversion swales](#) are usually outside the right-of-way but need not interfere with agriculture. The wider and more gradual the sideslopes and longitudinal slope, the more infiltration and less accumulation of flows will result. By eliminating washouts and [erosion](#) gullies

that form down over the road bank and start to “eat” back into the hillside, the swale can actually improve drainage of the landowner’s property.

6.4.2.2 Slope Geometry. Slope geometry is an important aspect of bank stabilization. Flattening the slopes gives greater stability and less [erosion](#) by spreading water flows out and slowing the flow velocity, in much the same way as flattening roadside ditches reduces flow velocity, as discussed in Chapter 5.

Observing and following existing natural patterns can be beneficial. Do not disturb stable areas if at all possible. And remember the value of tree roots in maintaining a stable slope. Look at the two photos. The first one shows a patchy, vegetated road bank. Vegetation has already started, but is having difficulty establishing on dead subsoil. Notice the flush of growth in the ditch area. Perhaps with a little topsoil, seed, and mulch, this area could flourish. No need for any grader work. If cleaning the ditch, make sure to clean only to the toe of slope and not to cut into that toe of slope. The second photo shows a stable revegetated bank. Here, a “Do not disturb” technique is needed.

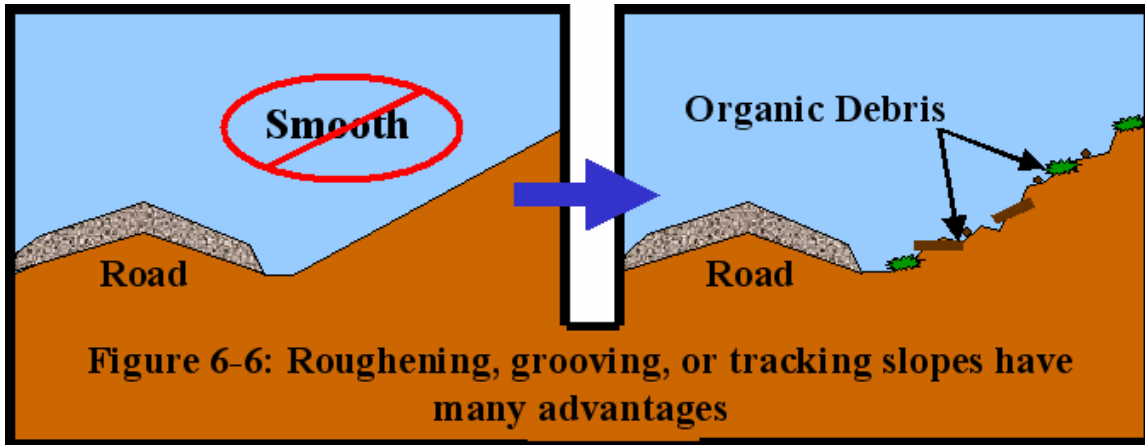


A little help is needed!



“Do not disturb!”

Roughening, grooving, or [tracking](#) slopes have distinct advantages. First, however, we need to change our perception of what a “well-dressed” bank should look like. We need to think in terms of existing natural banks. Natural banks are not regular or consistent as to surface and slope, and they are not polished and shiny. A natural appearing slope as shown in Figure 6-6, offers numerous advantages. The shined bank offers none.



As stated above, roughening, grooving, or [tracking](#) of slopes have many advantages:

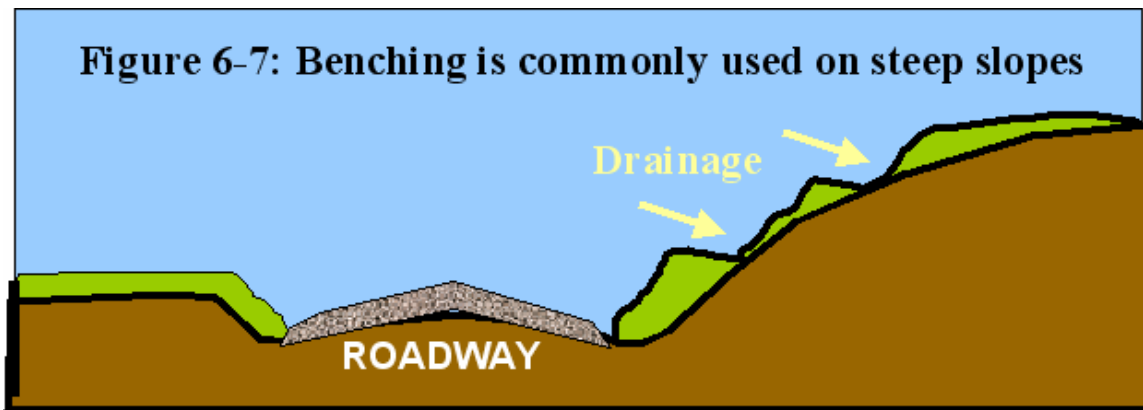
1. Catching rain water
2. Slowing surface water flow
3. Reducing [erosion](#)
4. Increasing filtration
5. Trapping [sediment](#)
6. Holding water, seeds, and mulch for enhanced vegetative growth.

These techniques require light equipment in order to prevent packing the soil to the detriment of plant growth. Track equipment should be used up and down the slope, not across, so the grooves catch water and hold seeds and mulch.

6.4.2.3 Benching. Benching, commonly used effectively on long, steep slopes, provides the same benefits as roughening the sloped surface. The top of the bank may have to be moved back and may be off the right-of-way. A good working relationship with property owners is required.



6-30 Tracking the newly constructed banks.



To be effective, the [bench](#) must collect water. The outside edge must be higher than the inner edge to prevent over the bank flow, as shown in Figure 6-7. The [bench](#) then should have a gradient to drain the [bench](#) to a proper outlet. Some benches can be gradually run out to the road ditch grade for drainage. Do not overlook the use of smaller multiple benches or steps and keeping some irregularity for a more natural appearance, if appropriate, for the site. Photo 6-31 shows some newly constructed low-gradient bank benches.

6.4.2.4 Seeding and Mulching. In all these practices, proper seeding is essential. Seeding requires:

1. An initial site evaluation (physical condition, soil tests)
2. Soil preparation (tilling & soil supplements)
3. Selection of species (temporary and permanent cover)
4. Timing of seeding (spring, fall preferred)
5. Establishment procedures (seeding methods, mulching).

The purpose of the initial site evaluation is to determine all site factors, both physical and chemical, which may limit the adaptability of various plant species to the site – moisture, temperature conditions, deficiency of vital soil nutrients, and any materials in the soil which are toxic to plants.



6-31 Newly constructed low-gradient bank benches.



6-32 Soil: Grab a handful, squeeze; does your hand stay “dirty”?

Soil tests determine a majority of this information. You can also get an idea about the soils by getting your hands dirty. Grab a handful, squeeze to check for moisture and clay content. Does it stick together? Does your hand stay “dirty” due to clay? (Refer to Appendix 6A: Soil Identification in the Field.) The optimum condition would be to work lime and fertilizer into the top 12 inches of soil for planting. The soil does need to be loosened by tilling with proper supplements added for good plant growth.

Selection of species is also important. In most applications, a seed mix of fast-growing nurse grass and the desired long-term plants will work well. Nurse grasses, such as rye grass, rye grain, and redtop, grow fast, binding the soil and sheltering slower germinating seeds, and give a good first impression of re-vegetation.

Legumes are a good component of the seed mixture. Legumes fertilize the soil by adding nitrogen to the soil, aiding the other plant types. Examples of legumes would be clover, flat pea, and bird’s foot trefoil.

Time of seeding varies on geographical location. Generally, prior to mid-June and from mid-August to mid-September are the best times. This is somewhat a function of soil temperature, so summer can work, but make sure enough water is added with a good layer of mulch.

Establishment procedures refer to seeding methods and mulching. Broadcast spreaders are commonly used for road banks and the scale of most projects. Seeds can be sown by hand or a cyclone spreader as well. Hydroseeding is a spray mix of water, seed and fertilizer onto the bank. Hydromulching takes the above mixture and adds mulch.

Mulching is a requirement to hold and protect the seed. After mulching, the ground should not be visible. More mulch should be used in the summer and fall to protect from heat and frost, respectively. As another rule of thumb, if using hay or straw bales and the job requires more than thirty bales, get (rent) a power mulcher. Anyone who has shaken bales for mulching will gladly accept this rule of thumb.

Straw is cleaner than hay (no seeds) and provides good coverage with a mulcher. Hay is loaded with seeds and is easier spread by hand. Hydromulching, usually green in color, put in the hydroseed mix, may also be used.

The photo shows a vertical slope that has been seeded and mulched. This is a drainage inlet construction site where the bank had to be removed for inlet installation. The terrain and other conditions such as trees and a driveway directly above dictated the vertical slope. But it was not left bare to erode away with the first rainstorm. This is actually a straw mat, straw stitched into a flat mat and manufactured in rolls, and pinned to the bank. Wet down the mat, sprinkle seeds on it and then pin it to the bank. There are mats that are already impregnated with seed that can be used effectively. Leaving bare soil will only result in [erosion](#) and [sediment](#) and additional maintenance work and cost.



6-33 Rolled seed-impregnated straw blankets can be pinned to steep slopes for re-establishment of vegetation.

Started plants can be used, but are normally limited to small sites where it is hard to get plants to grow from seed. Started plants include pachysandra, day lilies, and periwinkle and are commonly available.

Although this was only a quick overview of seed mixtures and seeding, there are some valuable resources and expertise available. Working closely with the local and state conservation agencies, Departments of Agriculture, College/University Extension Offices is necessary for most local road departments, since road personnel do not generally have expertise in this area. As an additional advantage to consulting the experts, some species are invasive and should not be used.

6.4.3 Bioengineering Techniques. [Bioengineering](#) techniques are being used effectively in restoration of many stream and [upland](#) banks. [Bioengineering](#) combines the biological elements of using live plants with engineering design concepts for slope protection and [erosion](#) reduction. Although not the solution to all slope failure and surface [erosion](#) problems, many [bioengineering](#) techniques can be used in combination with other techniques and practices.

[Bioengineering](#) takes a holistic approach, gauging factors such as environmental compatibility, use for difficult sites, cost effectiveness, and the biotechnical strengths of the systems. Many [bioengineering](#) practices can be used in wet areas with minor disturbance to the site, enhancing the environmental sensitivity benefit. Hand labor is usually a necessity, but this becomes a benefit for those difficult sites where the use of machinery may not be feasible. That same labor lends again to the cost effectiveness

where labor rates are reasonable. The cost effectiveness of these practices really stems from the resulting low/no maintenance conditions when the work is completed. As the vegetation becomes established, the initial biotechnical strength of these systems only enhances. Growing roots reinforce the soils and extract excess moisture, while the foliage breaks raindrop impact, reduces surface water velocity, and prevents surface [erosion](#).

[Bioengineering](#) makes use of local vegetation. Local vegetation is already suited to the climate, soil, and moisture conditions. Installation is accomplished during the dormant season, making the plants easier to handle. A few of the more common plant materials are bank willows and shrub dogwoods, which have been very successful in these installations. Willows would serve well in the practices described below.



6-34 Bank willows are commonly used in bioengineering practices.

Common techniques are live stakes, live fascines, brushlayers, branchpacking, and joint planting. These are the more simple techniques that lend themselves to volunteer labor. These techniques and others are thoroughly described in the **U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), Engineering Field Handbook, Chapter 16, Streambank and Shoreline Protection, and Chapter 18, [Bioengineering](#) for Upland Slope Protection and Erosion Reduction**. This handbook provides the data and details on many [bioengineering](#) practices. In addition, NRCS personnel can be quite helpful in providing advice and assistance in these techniques for any site or project being contemplated.

To clarify the use of these techniques and show the advantages and benefits, we will discuss a few of the more common practices accompanied by several photos.

6.4.3.1 Live Stakes. This practice consists of inserting and tamping live, rootable vegetative cuttings into the ground, as shown in Figure 6-8. Once the dormant stakes begin to grow, they create a living root mat and foliage. The primary function of this technique is to reduce soil [erosion](#) by slowing water velocities and by reinforcing the soil with root masses. Construction can be inexpensive and accomplished in a short time frame.

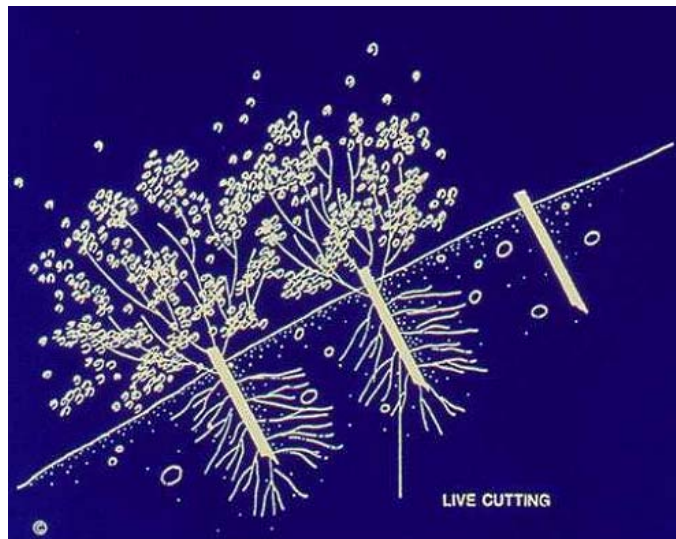


Figure 6-8: Live Stakes



6.35 Cutting the stakes and Preparing the site.

The live stakes are cut to the required length. The site is prepared. The project site depicted in the photo shows some [riprap](#) armoring at the water edge and rolled biodegradable [erosion](#) protection matting being laid. The tops of the live stakes are then driven into the ground.



6-36 Driving the Stakes.



6.37 Completed site and after one season's growth.

The top of the stake is usually the slightly smaller diameter end and will make driving it into the ground a little easier. The plant will produce roots and foliage appropriate to its orientation. A pilot hole can be made and a dead blow hammer can be used to reduce damage to the cutting. If the end of the stake is damaged (flattened

and splayed), simply cut off the damaged part. The final photos show a completed site and one after a season's growth.

6.4.3.2 Live Fascines. Live fascines are long bundles of branch cuttings bound together and placed in shallow contour trenches on the slope. The function is to protect the slope from shallow slides and reduce surface [erosion](#). This technique is suited to steep, rocky slopes where digging is difficult.



6.38 Tying the bundles and digging the trench.

The branches are cut and the cuttings tied together to form long fascine bundles. Beginning at the base of the slope, a trench is dug on the contour of the slope. The fascine bundle is placed in the trench and staked. Live stakes can be used in combination with this technique.



6.39 Placing the fascine and backfilling.

The live stakes are placed on the downslope side of the bundle as shown in Figure 6-9. Backfill soil is then used to fill around the bundles keeping the top of the fascine slightly exposed. The last photo shows a completed spring site after a summer's growth.

As with many of the [bioengineering](#) practices, this technique lends itself to volunteer labor, as one can see in the above photos. These projects seem particularly desirable to many different groups with the volunteers receiving substantial satisfaction from a job well done and the continued satisfaction of the continual site enhancement.

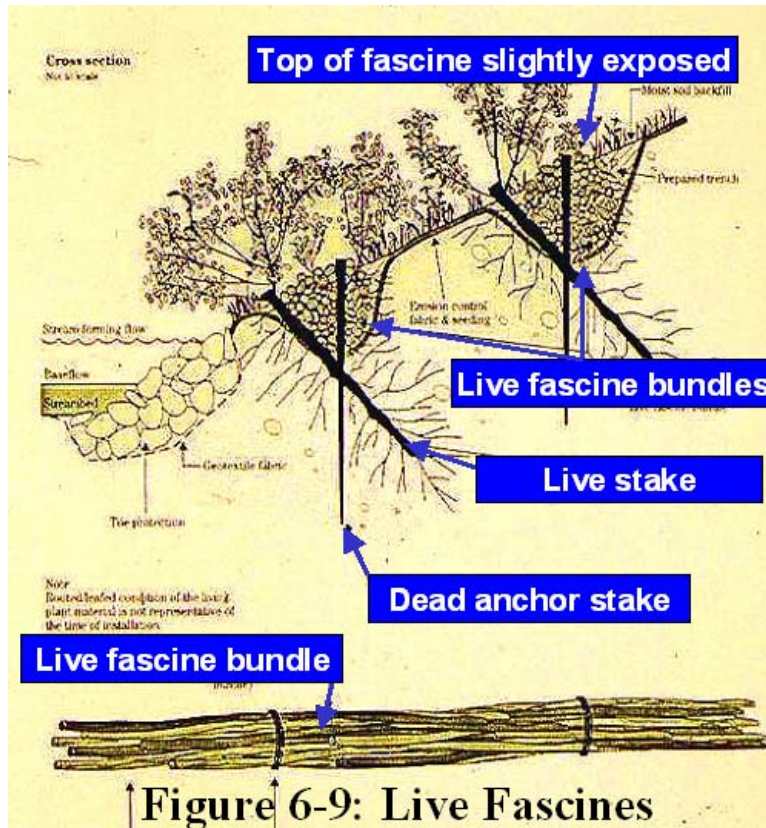


Figure 6-9: Live Fascines



6-40 Fascines after one season's growth.

Media publicity can also be a positive factor in promoting the volunteer group and the project. From Boy Scouts and Girl Scouts to 4H Clubs, from service organizations (Rotary International, Kiwanis, etc) to [watershed](#) and conservation groups, volunteers are a great resource for accomplishing these projects.

6.5 Summary

Throughout this chapter, the importance of roadside vegetation was emphasized. Roadside vegetation prevents [erosion](#) and [sedimentation](#) pollution and results in lower road maintenance costs. Additionally, a well-vegetated roadside is naturally beautiful and can be a draw for tourists.

We not only discussed the importance of roadside vegetation, but we demonstrated how we can effectively use vegetation to our advantage in reducing maintenance and costs and prolonging road life. We can actually use the forest system and other plants to create benefits for the environment, the roadway, and local governments.

We covered various proven techniques that can be utilized, particularly for bank stabilization. We pointed out that if all the eroded banks along our roads would be revegetated, both the large and small sites, a substantial reduction in pollution and associated road maintenance would result. We mentioned easy to use [bioengineering](#) techniques that can be accomplished with in-house crews or volunteer work from the many available groups and organizations.

We talked about seeding and the important steps in the revegetation process. And particularly in this area, we emphasized using the available valuable resources in your respective geographical location.

To again see these practices used in actual projects, we refer back to Appendix 5, Section 5A-1 for Worksite #1, Red Rose Road, Huntington County, PA. Adding to that site, Appendix 6B provides an additional project site utilizing vegetation practices. As in Appendix 5, this “Worksite in Focus” reviews an actual Pennsylvania worksite in which a combination of practices has been used to solve the [erosion](#) and [sediment](#) pollution problems.

We also need to re-emphasize that all of these practices can be adopted for paved roads and will prove to be just as beneficial as they are for unpaved gravel roads. And by using these practices, you will again see the long-range continual benefits for your roads and your environment and thereby for your community.

APPENDIX 6.

Appendix 6A: Soil Identification in the Field

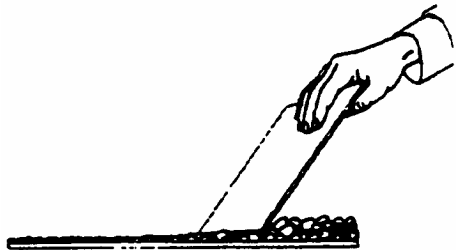
Distinguishing Soil Types in the Field

When laboratory facilities are not available, some simple field tests can help you distinguish soil types and determine gradation, plasticity and dispersion:

Gradation

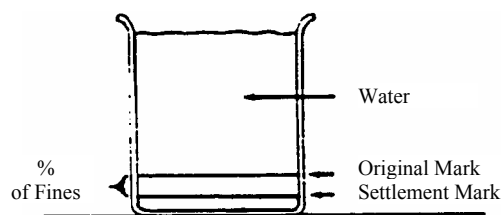
To judge gradation of dry soil, spread a sample on a flat surface. Separate the larger and smaller particles with a piece of stiff paper or cardboard. Estimate the percentage of particles larger than 1/4 in. (6mm) and the percentage of fines - individual grains too small for you to see with the unaided eye. Finally, gauge whether the larger particles are uniform in size (poorly graded) or have an assortment of sizes (well graded).

Figure 1 - Gradation Test



If the soil is wet, break a lump apart. Estimate the percentage of large particles as in the dry soil method. To find the percentage of fines, put just enough water in a clear glass to cover the bottom and fill the glass 1/4 full with soil. Then add enough water to just cover the soil and mark this level with a rubber band.

Figure 2 - Percent of Fines



Now add water to the 3/4 mark and stir the mixture vigorously. After it settles for a minute and a half, mark the height of soil that has settled out. The difference between the two marks as a portion of the height of the upper mark approximates the percentage of fines.

Plasticity

Here are four field tests for estimating a soil's plasticity.

The Shaking Test: Knead a sample of the soil to work out as many large grained particles as possible. Add water gradually and knead the soil until it begins to get sticky.

Figure 3 - Shaking Test



Then hold the ball in one hand and tap the back of the hand with the other. If the ball becomes wet and shiny, it is mostly fine sand or silt. No reaction suggests clay.

The Toughness Test: Use the ball from the shaking test. Knead about half of it until it's dry. Then roll the soil sample into a 1/8 in. (3mm) thread or "worm". If you can't form a worm, the soil is sand or silt or fine sand (low plasticity).

Highly plastic soils take a long time to dry and become hard and waxy. You have to exert a lot of pressure to form a worm that breaks at about 1/8 in. diameter.

Figure 4 - Toughness Test

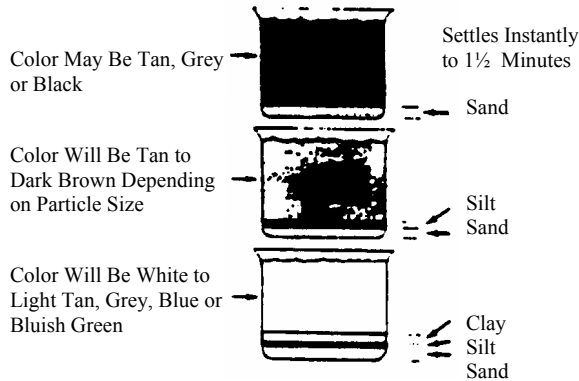


The Dry Strength Test: Knead the other half of the sample into a ball and let it air dry. Then break it apart and select a jagged, pointy fragment. Try to crush this fragment between your thumb and forefinger. A silt will turn to powder with little effort. A clay will be hard and almost impossible to crush.

Hand Washing: After handling silts and sands, your fingers will feel dusty. Rubbing them together will almost clean them. Gently flowing water will rinse them.

If you've been handling clay, you'll find a crust on your fingers you cannot rub off. Water will not rinse it off. You have to rub your hands together under water to cleanse them.

Figure 5 - Dispersion Test



Dispersion

Use a dispersion test to support your gradation estimates. It will also give you an idea of how difficult the soil will be to compact. First fill a glass 1/4 to 1/3 full with soil and then add water to within 1/2 in. (13mm) of the top. Stir the mixture well and set it aside.

The mixture will settle in three layers: sand at the bottom, silt in the middle and clay at the top. Besides showing the relative amounts of the three soils, the results will indicate whether the soil is well or poorly graded.

Although silt and clay particles are smaller than the eye can see, gradation difference will show up as color differences. Also, the longer it takes a layer to settle, the smaller the particles. Usually, a single particle size (poor gradation) and a small particle size mean more difficult compaction than a mix with good gradation.

Summary of Identifying Clues

To summarize how various soil types react to the field tests:

- Clay - No reaction to the shaking test; a tough worm that dries out slowly; a crusty dry residue that is hard to remove from the hands.

- Silts - Rapid reaction to the shaking test; a weak or crumbly worm; powdery residue that is easily wiped or washed off the hands.
- Silt and Clay Mixtures - Intermediate or conflicting reactions to hand tests.
- Sand or Gravel with a few Fine Clays - Enough clay to soil the hand when you knead a wet sample, but not enough to form a lump.
- Sand or Gravel with Silt Fines - Dusty or gritty fines.
- Clean Sands and Gravels - Added water sinks in immediately without making mud.

Soil Test Checklist

Watch for these possible reactions when you are using in-field do-it-yourself soil tests.

1. No reaction to the shaking test, a tough worm that dries slowly, and a crusty residue that is hard to remove from your hands indicates the soil is clay.
2. Rapid reaction to the shaking test, a weak or crumbly worm, and powdery residue that washes easily from your hands indicates silt.
3. Intermediate or conflicting reaction to hand tests indicate silt as well as clay mixtures.
4. Enough clay to soil your hands when you knead a sample, but not enough to form a lump indicates sand or gravel with a few fine clays.
5. Dusty or gritty fines indicates sand or gravel with silt fines.
6. When added water sinks in immediately without making mud, you will have clean sands and gravels.

The above article and graphics were reprinted from Caterpillar Inc. and are available from Caterpillar Dealers. Ask for their "Compaction Manual," Form No. TECB8081© Caterpillar or see Better Roads, May 1991. The "Soil Test Check-list" was reprinted from Michigan Technological University's publication, "The Bridge," Vol. 6, No. 2, Winter 1992.

Appendix 6B: Additional Worksite in Focus

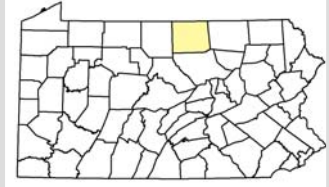
The following worksite is an additional project undertaken by a Pennsylvania local township with major funding through the Pennsylvania Dirt and Gravel Road Program. This worksite reused berm and ditch dirt to provide the needed topsoil cover for coalmine spoil to form a new wide vegetated buffer roadside area. The area was then fertilized and seeded. Although additional road and drainage work were part of the combination of practices used, the new, well-vegetated roadside buffer area reduces [dust](#) generation and keeps [sediment](#) out of nearby Fall Brook stream.

In addition, please refer back to Appendix 5 to the first Worksite on Red Rose Road in Huntington County, PA, to view the selected tree removal and bank stabilization practices utilized on that project.

Worksite in Focus

Tioga County Fall Brook Road

4/13/05



Project Background

Fall Brook Road was used as a coalmining operations haul road until the early 1980's. Constructed of coalmine spoil, the road width, in some places, exceeded 60' wide. When coal trucks quit using the road, Ward Township was left with a problem road that could not maintain crown and had constant potholes. The road surface of coalmine spoil was very acidic, very soft and fine, holding and pumping water. Additionally, the coalmine spoil would not support vegetation, so the berms, ditches and banks were barren and a constant source of erosion. The road had inadequate cross pipes, groundwater in the road, and direct sediment discharges into Fall Brook.

Project Considerations

This segment of road has 2 stream crossings. One of these crossings, inadequate for flood flows, saw high water bypass the existing stream crossing and spill across the road about 300' away.

Project Facts

Project:	Fall Brook Road
Project Owner:	Ward Township
Affected Watershed:	Fall Brook, Tioga River
Project Length:	1100 ft
Date Completed:	September 2001

Cost Summary

Total Project Value:	\$24,960
District Funding:	\$21,185
Materials	\$17,070
Equipment	\$3,965
Labor	\$150
In-Kind Contributions:	\$3,775
Labor	\$3,775

For More Information

The Center for Dirt and Gravel Road Studies
(814) 865-5355
www.dirtandgravelroads.org

Tioga County Conservation District
Ralph Brugger
(570) 724-1801



Before: Fall Brook Road was so wide, the township could not keep the road crowned. The road surface of coalmine spoil held water and was full of potholes during wet periods and was a constant source of dust in the summer. High flows sent water flooding across the road eroding the surface material directly into Fall Brook. Although already impacted by acid mine drainage, Fall Brook did not need an additional source of impairment.

The publishers of this publication gratefully acknowledge the financial support of the Pennsylvania State Conservation Commission. For additional information or assistance, contact: Center for Dirt & Gravel Roads Studies, Penn State University, 207 Research Unit D, University Park, PA 16802 (Toll-Free Phone: 1-866-668-6683, Fax: 814-863-6787, Email: dirtandgravel@psu.edu). Additional copies available on our website at: www.dirtandgravelroads.org



Project Solutions

Construct new road base: To solve the problem of the wide flat road, the township used the existing road surface of coalmine spoil to construct a new crowned road base.

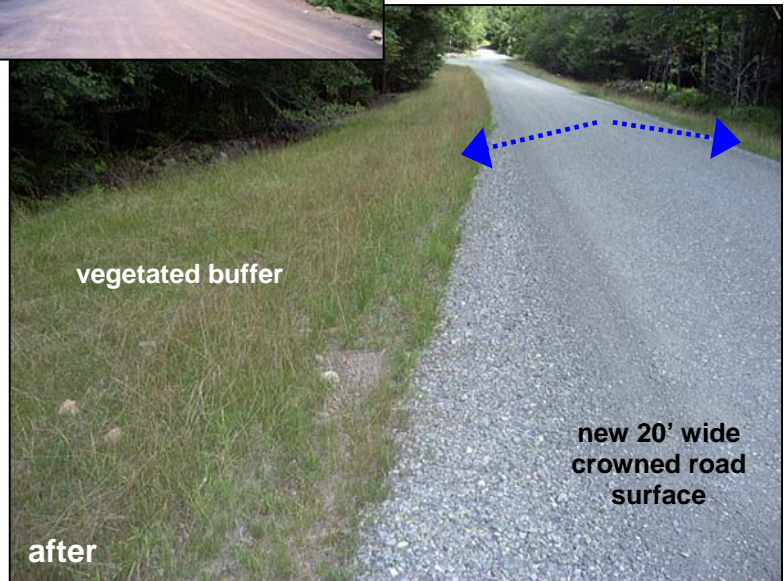
Re-surface the road: The centerline of the new roadway was laid out and a 20-foot wide layer of limestone Driving Surface Aggregate (DSA) was placed and compacted. The newly crowned road surface sheds water to either side as sheet flow.

Vegetate road berms: With the extra width to work with, the township hauled berm and ditch dirt from other roads in the township and covered the coalmine spoil with 6" of topsoil, forming wide buffer areas (see photo at right). Buffer areas, banks and ditches were limed fertilized and seeded.

Stabilize stream crossings: One of the two stream crossings on this project needed to be replaced. A new pipe and head- and endwalls were installed. The township poured its own 2'x2'x4' concrete blocks to construct the headwalls (see photo at right). Additional cross pipes were added to direct ditch water to the vegetated buffer, removing a direct discharge to the stream. At the other crossing, high flows flooded the road 300' away. Where high water crossed the road, the road and road base were armored with R5 rip-rap to allow water to flow over the road without major damage.

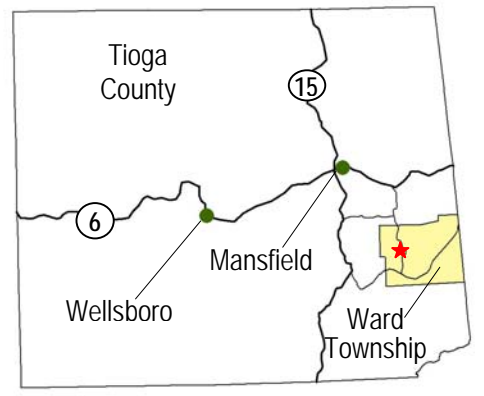
Project Results

Previously, Fall Brook Road required frequent regular maintenance and emergency maintenance following high water flooding. Since project completion in 2001, the township has only had to grade twice. The road itself has a new durable driving surface. Well-vegetated buffer areas reduce dust generation and keep sediment out of Fall Brook.



Site Map & Directions

From U.S. Route 6, turn left on to State Route 2029 in Mainesburg. State Route 2029 turns into State Route 2022, then into Fall Brook Road. The project begins approximately 3 miles down Fall Brook Road at the intersection of the road with Fall Brook.



Environmentally Sensitive Maintenance for Dirt and Gravel Roads

Chapter 7: Environmentally Sensitive Maintenance Practices: Additional Maintenance Techniques

7.1 Introduction

In the two previous chapters we introduced numerous maintenance practices as tools for the toolbox. In this chapter, we provide additional tools relating to three major topics:

Dust Control: We will define road [dust](#) and learn about its effects on roads and the environment. Armed with this information, we will then discuss [dust](#) control materials and methods.

Road Stabilization: We will define [road stabilization](#) and introduce the materials and techniques most commonly used. Many [dust](#) control materials can also be used as additives in [road stabilization](#).

Geosynthetics: We will then introduce the world of [geosynthetics](#) and their many various functions and uses in environmentally sensitive road maintenance.

7.2 Dust Control

Unpaved roads are considered the largest source of particulate air pollution in the country. According to the Environmental Protection Agency, unpaved roads produce almost five times as much particulate matter as construction activities and wind [erosion](#), which are the next two largest sources, combined.

Many local governments do some sort of [dust](#) control. This maintenance task is usually performed as a result of public complaints, and the resultant work consists of doing some sort of [dust](#) control in front of residences. This action typifies the common thoughts of [dust](#) as a nuisance. [Dust](#), however, is much more than a nuisance. We need to understand exactly what [dust](#) is and how it originates.



7-01 Unpaved roads are the largest source of dust pollution in the country.

7.2.1 What is Dust and Where Does It Come From? First, look at a commonly accepted statement about [dust](#):

“[One car making one pass on one mile of dirt or gravel road one time each day for one year creates one ton of dust.](#)”

What is this [dust](#)? Where does this [dust](#) come from? This [dust](#) is part of the road, it's the fines being ground down by traffic and blowing off in the wind. Recalling earlier discussions about road materials, we wanted a well-graded aggregate with fines to lock everything together and keep it in place. If we lose the fines, we lose the road. The above statement translates to losing 50 tons of fine road material a year for each mile of road with an average of 50 vehicles per day.



7-02 Just what is dust? Where does it come from?

When these fines are lost as [dust](#), it deteriorates the gravel surface. Larger aggregate pieces become exposed and are then scattered by vehicles or washed away. The unstable road surface becomes rough, developing potholes and washboarding. These distresses hold water that infiltrates and damages the base. In addition, the eroded material damages ditches and drainage systems. Repairs and maintenance can be frequent and costly.

[Dust](#) indicates the road is deteriorating, and the [dust](#), as it settles out and becomes additional [sediment](#) in the streams or blankets the vegetation, causes deterioration to the environment. Thus, [dust](#) causes excess road maintenance and environmental pollution.

7.2.2 The Necessity of Dust Control. Successful treatment can significantly reduce [dust](#) conditions and help preserve road surfaces. Various studies show that control measures can reduce [dust](#) by 30% to 80% and cut aggregate loss by 25% to 75%. Such treatments, however, will not last forever, and repeated applications may be necessary.

We must view [dust](#) control as a necessary routine maintenance item for all unpaved roads – not only to prolong road life, but also to protect the environment. [Dust](#) control means that the roads will stay intact; the fines will remain interlocked with the larger aggregates and keep everything in place. Similar to the cut in aggregate loss, studies report that one can expect a 25% to 75% cost reduction in blading, reggrading, and re-graveling by implementing a [dust](#) control program.

How often we do [dust](#) control and to what extent will depend on many variables. What are the road surface materials? What is the road condition? What is the drainage

condition? What are the environmental conditions – severe storms, rain, droughts, etc.? What is the volume and speed of traffic? What are the objectives or goals for [dust](#) control?

Without traffic, [dust](#) is not a problem. According to commonly accepted “guidelines,” roads with an average daily traffic ([ADT](#)) between 15 and 500 vehicles per day are good candidates for [dust](#) control. With fewer than 15 vehicles per day, there is probably not a substantial [dust](#) problem. Conditions on these roads, however, must be evaluated on an individual basis to determine the potential for [dust](#)-related problems. Generally speaking, roads carrying more than 500 vehicles per day will require multiple treatments. In these cases, options range from a more substantial surface treatment to an actual asphalt pavement. Again, each road must be evaluated individually based on specific road and roadside conditions.

7.2.3 Benefits of a Dust Control Program. Let’s look at the benefits of a [dust](#) control program. The first two major benefits are what we have already discussed above – prolonged road life with less maintenance and less particulate matter polluting our streams.

But there are many other benefits to a [dust](#) control program, such as reduced respiratory and associated health problems, not only from the [dust](#) itself, but also possibly from other organisms attached to the [dust](#) particles through electrostatic forces.

[Dust](#) on plants can hamper their growth and development. When the farmer calls and wants something done about the [dust](#) because it is affecting his crops, that is a valid complaint. [Dust](#) shades necessary light from plants, hindering [photosynthesis](#) (plants producing their own food), resulting in stunted plant growth.

In general, a good [dust](#) control program reduces cleaning costs associated with homes, clothes, and vehicles. [Dust](#) control can mean a better quality of life and higher property values for those living and working adjacent to your roads.



7-03 Dust can affect crops.

Dust poses road safety hazards as well because it reduces visibility for motorists.



7-04 Dust creates visibility problems for the motorists.

Dust control can mean reduced vehicle accidents and improved road safety. If the driver cannot see properly, it is unsafe to drive.

A good dust control program can also reduce vehicle maintenance costs. Dust plays total havoc on moving parts. Maintaining a vehicle that drives an average of 40 mph exclusively on gravel roads costs 40% more than maintaining the same vehicle traveling the same speed on paved roads.

If the road fines are lost, the coarse aggregate ravel and loosens and can be kicked up by vehicles, causing windshield breakage and vehicle damage. Good dust control means less vehicle damage.

And, of course, there is the public and public relations. What municipal official has not received the phone call from the irate resident demanding, “You have to do something about this dust!”

A good dust control program means a better road, a better environment, and thus a better community.

7.2.4 Dust Control Options. Road managers have several dust control options available to them depending on specific road conditions. Traffic creates dust. Limiting traffic volumes, however, is really not feasible. After all, that is what the road is there for. Limiting traffic speed could have an effect. But erecting speed limit signs does not always slow traffic down, and no matter what the speed is, traffic will still create dust. Heavy truck traffic creates more dust, but limiting traffic weight is not an efficient dust control alternative. Usually weight restrictions are imposed on roads that are incapable of supporting heavy traffic without significant road deterioration especially in the spring “mud season.”



7-05 Traffic weight and speed increase dust.

Although paving the road is the only permanent solution to dust problems, using effective controls can significantly reduce dust and cut required maintenance. That leaves

us with [dust suppressants](#) and a few other more substantial methods using [road stabilization](#) and [geosynthetics](#), both of which can help in alleviating the [dust](#) problem.

[Dust suppressants](#) are classified as routine [dust](#) control maintenance items. Of course, different materials will provide different service intervals depending on many variables. We also need to be concerned with the environmental effects of the materials used.

7.2.5 Evaluation of Dust Suppressant Materials. Before we discuss [dust suppressant](#) materials, we need to talk about evaluation of the materials to be used. What should you know? What do you need to consider?

The following list provides the basic considerations:

Environmentally compatible

Effective at controlling [dust](#)

Easily applied with common road maintenance equipment

Workable and responsive to maintenance

Not degrading to ride quality

Relatively harmless to vehicles using the road

Posing little hazard or inconvenience to adjacent residents

Cost competitive

There are several information sources available to help in evaluation of [dust suppressants](#).

Every chemical has to have a Material Safety Data Sheet ([MSDS](#)). Right-to-Know Laws, originating at the federal level and adopted at the state level, require all manufacturers to provide an [MSDS](#) for every chemical and require all employers to have [MSDS](#) sheets for each chemical used in the workplace available to employees.

The [MSDS](#) deals with safety in handling the material, listing the manufacturer's name, address, and phone number; the major components of the chemical; its characteristics such as flammability, volatility, reactivity; safety equipment needed to handle the chemical; and emergency procedures in case of spills or exposure.

The Federal Clean Water Act along with respective state acts set the requirements as to toxicity for fish and other aquatic stream life. The material or chemical must meet all of these requirements. But we also should be concerned with effects on vegetation. We now realize how important roadside vegetation is and the important part it plays in [erosion](#) and [sediment](#) pollution prevention and helping reduce road maintenance. We certainly do not need chemicals that would harm or destroy our roadside vegetation.

It is imperative that road managers evaluate [dust](#) control products in light of all of these factors. Road managers need to seek out all information on the product, check referenced users as to their experiences, concerns, and problems, and possibly do trial

applications to develop an effective, efficient and safe [dust](#) control program that will protect their roads and the environment.

7.2.6 Common Dust Suppressants. The following list of commonly used [dust suppressants](#) along with their attributes and limitations as to effective [dust](#) control and environmental compatibility will be discussed.

- Water
- Sodium Chloride (salt)
- Calcium Chloride
- Magnesium chloride
- Brines (natural, semi-processed)
- Lignin Derivatives
- Asphalt Emulsions & Cutbacks (oils)
- Resins

7.2.6.1 Water. Water is a [dust suppressant](#). Water will do the job but it is short-lived. Road personnel would have to be out there continually each day applying water during the dry summer weather. Water, however, is readily available and safe for the environment.

A notice of “caution” is required here concerning the “safe for the environment” statement. A caution comes with using potable “tap” water from a public water system. A public water system treats water with chlorine for disinfecting to kill all organisms. There is always a chlorine residual in the water. If a tankload of this water would be dumped directly into a stream, you may end up with a detrimental effect on the fish and other aquatic life depending on the volume dumped, the amount of stream flow, the amount of chlorine residual, and other conditions.

Water’s real limitations relate to evaporating readily and thereby its short-term control. This means it becomes very labor intensive and costly due to the need for repeated applications for effective control. Contractors use water trucks on large construction sites continually to cut [dust](#) during work. Not only do they do this to ward off complaints from adjacent residents, but they also know the savings in equipment maintenance. Water as a temporary control during construction or maintenance work does have merit.



7-06 Although environmentally sensitive, water affords only short-term dust control.

7.2.6.2 Sodium Chloride. Sodium chloride is our deicing salt or rock salt used all over the snow-belt states for paved roads in winter. Salt, however, is not an effective [dust](#) control. It begins to absorb water at 76% relative humidity, reduces the rate of water evaporation by a factor of 1.3 times, and it does lower the freezing point of water. However, all of these positive [dust](#) control characteristics are not substantial, especially when compared to other available materials.

There are significant environmental concerns with the use of chlorides. Whether the chlorides come from sodium chloride or from magnesium or calcium chloride, they still pose environmental challenges. When these materials are used, the sodium, calcium or magnesium attach themselves to other materials, but the chlorides become free agents and are able to leach out of the road and into nearby streams or ground water sources.

Chlorides can cause serious problems. They can be detrimental to animals and plants, and they are corrosive. With these limitations and the fact that sodium chloride is not effective as a [dust](#) control, we do not recommend using sodium chloride for this purpose.

7.2.6.3 Calcium and Magnesium Chlorides. Calcium and magnesium chlorides, on the other hand, can be effective [dust suppressants](#). Calcium chloride begins to absorb moisture at 29% relative humidity, which is very dry and when we need [dust](#) control the most. It also reduces water evaporation by a factor of 3.4 times and lowers the freezing temperature of water to -60° F.

Magnesium chloride is very similar and begins to absorb water at a dry 32% relative humidity, reduces water evaporation by 3.1 times, and lowers the freezing point of water to -27° F.

Even with these attributes, calcium and magnesium chlorides are still chlorides, which again can be detrimental to plants and animals and corrosive to metals. Site conditions, particularly where roads are immediate adjacent to streams, must be evaluated carefully if chlorides are being considered for use.

7.2.6.4 Brines. Brines are usually a by-product of gas production wells and consist of a combination of chlorides. Brines, as a by-product, can be less costly than many other materials. Natural or semi-processed brines should be tested and approved for use as a [dust](#) control agent. The manufacturer should be responsible for testing and assuring a non-contaminated product.

Brines, being mostly chlorides, give us the same positive attributes and the same concerns as the other chlorides. Brines can be detrimental to animals and plants, but may be worse in that they could be contaminated with other materials – oils, heavy metals, etc. For this reason, brines need to be tested and approved before use.

7.2.6.5 Lignin Derivatives. Lignin derivatives are a by-product of the paper manufacturing industry. They are highly acidic, usually foul-smelling when spread, and

very sticky, clinging to vehicles. Complaints are common because of these problems, so be sure to give advance notice to residents and businesses before treatment. There is dried processed lignin sulfonate available commercially, which does not have these problems. In addition, certain manufacturing processes may make them more or less effective in controlling [dust](#). For example, ammonium lignin sulfonate refers to the process and is one of the more effective agents.



7-07 Lignin derivatives are a by-product of the paper manufacturing industry.

With lignin derivatives, the road should have a silt/clay content of 4% to 8% for them to take the proper effect in controlling [dust](#). Lignins are slippery when wet and brittle when dry, which is not really conducive to good [dust](#) control. Rain tends to re-emulsify the material, increasing the potential for run-off. And, although lignins could be called a natural substance, if they leach into the stream, they will deplete the oxygen and destroy stream life. Lignins, because of their acidity, are corrosive. Repeated applications will be needed as lignins decompose over time.

7.2.6.6 Asphalt Emulsions and Cutbacks. An asphalt emulsion is asphalt and water with an emulsifying agent (soap) added to allow them to mix. When used, the water evaporates, leaving asphalt. An asphalt cutback is asphalt thinned with a solvent such as naphtha or kerosene. When used, the solvent evaporates, leaving asphalt. These materials act as adhesives and binders that physically glue soil particles together.

They form a hard crust, and repeated applications can develop into a “paved” road. Depending on the number of applications per year, the road conditions and maintenance operations between applications, and the number of years used, the road can start to look and act like a paved asphalt road.



7-08 Asphalt emulsions and cutbacks are still being used for dust control, but...

Using emulsions and cutbacks gives us the asphalt to combine with the gravel road aggregate, forming a paving-like condition, which begins to build an asphalt pavement. Considering that a hot asphalt mix used to pave roads is just asphalt and aggregate mixed and heated in an asphalt plant, one can realize that under continual use of “asphalt oils,” a dirt and gravel road can become that “pancake” paved road. Periodic regrading of the road tends to be more expensive and more

difficult when it has been treated with these products.

These “oils” provide some [dust](#) control. Medium cure cutbacks such as MC30 and MC70 are commonly used. A significant problem related to health and air pollution is the volatile organic compounds (VOCs) released by the asphalt cutbacks. Because of this problem, the use of cutbacks has been limited in many states and will probably continually decrease in the future.

Although they can be applied to a broad range of soil types and are good at waterproofing an aggregate surface, [tracking](#) can be a problem, particularly if the road surface has a lot of fines. [Tracking](#) can be a real nuisance for vehicle owners and nearby residents. Another concern during application is the potential for run-off from excessive application or related to a quick rainstorm.



7-09 With the use of asphalt “oils,” tracking and/or run-off can become problems.

7.2.6.7 Resins and Other Materials. Numerous other [dust](#) control materials are available, including various resins and enzymes, some of which are by-products of a manufacturing process. Vegetable oils including soybean soapstocks and sugar beet extract are also being used. New products are continually being researched and marketed. Once again, all products need to be evaluated in terms of effectiveness and safety in light of site-specific road conditions.

7.2.7 Use and Application of Dust Suppressants. The two main objectives in [dust](#) control, however, remain (1) to develop and implement a program and (2) to use a [dust suppressant](#) that will not only be effective, but also environmentally safe.

7.2.7.1 Environmentally Sensitive Materials. When evaluating [dust suppressant](#) materials, road managers must pay particular attention to each material's environmental impact. Road managers must seek out all information on the product, checking referenced users as to their experiences, concerns, and problems, and then do trial applications to develop an effective, efficient and safe [dust](#) control program that will protect their roads and the environment.

The Pennsylvania State Conservation Commission has addressed the issue of [dust suppressants](#) by making it clear to manufacturers and vendors that they are responsible for determining the acceptability of their materials. [Appendix 7A](#) discusses the Commission's testing protocols and lists the products that have been approved for use in the Pennsylvania Dirt and Gravel Road Program

7.2.7.2 Application Process. No matter what we are using to control [dust](#), the product must match the existing road materials. We should not be doing [dust](#) control with any threat or prediction of rainfall. And remember this important statement:

[Dust](#) control will not make a bad road good, but will keep a good road good.

This leads right into the three major tasks in application of a [dust suppressant](#).

1. Determine the product to be used and application rate. The product may depend on the road and type of wearing surface. Application rate depends on the product; the condition of the road; type, volume and speed of traffic; degree of [dust](#) control required; climatic conditions; frequency of maintenance; and cost.
2. Perform all required maintenance and repairs to the road. Bring the road to a good condition with a good crown and [cross slope](#). Repair unstable areas, remove unsuitable material and replace with select material, make necessary drainage improvements, clean ditches, grade the road, and restore proper crown.
3. Apply the [dust suppressant](#). An application in spring followed by another application in late summer or early fall may give good [dust](#) control for the year. Again, this is dependent on all the variable conditions. Remember, application should be made when there is no threat or prediction of rain for at least 36 hours. Most [dust](#) control agents can be applied when the road surface is damp (not wet), except for the asphalt cutbacks, which require a dry surface.

The following are general application guidelines. Use the recommended application rates from the manufacturer for the first spring application. You may want to reduce this rate by half for roads that have been previously treated. With most products, (asphalt cutbacks are an exception) we can pre-wet the surface with water at rates ranging from 0.03 to 0.3 gallons per square yard to reduce surface tension, to develop capillary

action that allows maximum penetration of the suppressant, and to ensure uniform application. If a [dust](#) coat has already developed on the road, regrade and moisten.

Avoid [runoff](#) or puddling when applying liquids. Use several light sprays if the surface is tight. Follow dry applications with enough water to ensure the pellets or flakes are completely dissolved. Allow the treated road to cure. Curing may take longer for roads with finer grained materials.

A second treatment may be required in late summer or early fall. Treat the road a second time before the first treatment becomes totally ineffective. You may need only half the application rate as used in the spring application.

7.3 Road Stabilization

7.3.1 What is Road Stabilization? We can define [road stabilization](#) as the uniformly crushing, pulverizing and blending of the road materials, adding a stabilizing agent, mixing the agent with the blended material, spreading and regrading the road with proper crown, and compacting. Compaction is a requirement in this process. Stabilization can also be performed without a stabilizing agent but is more commonly done with an agent for better strength and stability.



7-10 Road stabilization or full-depth reclamation works well with a stabilizing agent

The newer terminology for [road stabilization](#) is “full-depth reclamation.”

7.3.2 Advantages of Stabilization. There are numerous advantages to [road stabilization](#). First, stabilization unifies and strengthens the roadbed, prolonging road life. Through stabilization, we are actually recycling existing road materials to reconstruct a new road. The stabilizing materials obtain the desired moisture, increase cohesion by producing a cementing action, and act as a waterproofing, providing greater road strength and stability. The road also becomes more resistant to [dust](#). Depending on the agent added (calcium chloride for example), we can aid in reducing frost action or frost heaves.

Stabilization is nothing new but went by the wayside when asphalt paving and cement concrete paving were introduced for road surfaces. Now we are again discovering

the advantages of stabilization not only for improving our dirt and gravel roads, but also for stronger bases for paved roads.

7.3.3 Stabilization Additives: The common stabilization additives include many of the [dust suppressants](#) with some additional materials added to the list:

- Calcium Chloride
- Magnesium Chloride
- Resins
- Lime
- Cement
- Asphalt
- Fly Ash

Many times these materials are used in combination for stabilization.

Caution: Certain materials may require permits or approval from state environmental agencies for use as a road stabilizer. For example, the use of fly ash in Pennsylvania requires the PA Department of Environmental Protection approval – source, quality, quantity, and how it will be used, stemming from the origin of the fly ash and a potential of unwanted contaminants such as heavy metals.

The same concerns exist for these materials as for [dust](#) control materials, particularly since we are talking about some of the same materials. We do need to be concerned with environmental sensitivity and the effectiveness as a road stabilizer. The same information, testing and evaluation should be a priority, with the manufacturer being responsible for verification of their product being environmentally sensitive. See [Appendix 7A](#) for Pennsylvania’s testing requirements and approved products.

7.3.4 The Stabilization Process. Selecting a stabilizing agent is the first step in the process. Selection of the proper stabilizing agent requires knowledge of the road soils or aggregates and of the agent being used. The stabilizing agent must be of the correct type and used in the correct quantity for satisfactory results.

The stabilization process consists of:

- scarifying and pulverizing the existing road materials;
- adding new material if you need to beef up the road structure;
- mixing in the stabilizing agent; and
- then regrading and shaping the road with the proper crown followed by good compaction.

The process can be accomplished with just a road grader and roller. A good grader operator can scarify and mix the materials and reprofile the road, which can then be rolled for compaction.



7-11 Stabilization can be accomplished with a road grader – scarifying the road, mixing in a stabilizing agent, regrading and shaping.

Another viable option is a “reclaimer.” A “reclaimer” has a drum with carbide teeth and a down-cutting action for pulverizing and proper sizing of the material. Stabilizing agents come in liquid or solid form, and are either sprayed using a tank truck or spread using various methods and equipment. The same equipment, such as the reclaimer, can then be used for mixing the stabilizer uniformly with the road material.



7-12 The “reclaimer” has a down-cutting drum with carbide teeth.

With newer systems, a tanker truck connected by a hose to the reclaimer, introduces the liquid stabilizer agent directly into the roadbed material as it is being pulverized. The reclaimer has a computer-controlled liquid injection system, which is capable of accurately regulating additive application rates.

A road grader can then be used to regrade and restore a proper crown and a roller for compaction. Compaction is a requirement in this process.

Stabilization or full-depth reclamation can be an effective tool to reconstruct a poorly maintained road. The end result is a uniform road material strengthened by the added stabilizer agent and properly shaped and crowned for good drainage. Reusing existing road materials is very cost effective.

Full-depth reclamation is recommended for roads like the one in Photo 7-13. The road has a varied look due to a variety of materials that have been used over the years. Different



7-13 A mish-mash of road surface materials lends itself to a full-depth reclamation project.



7-14 A sheep's foot roller is used for soil compaction.

aggregates, different materials for patching, different treatments for [dust](#), or sectional surface treatments all on the same road can be a continuous maintenance headache for the road manager. This type of road is an excellent candidate for full-depth reclamation.

As a side note on compaction, different types of compaction equipment are better suited for different types of materials. If you are compacting soils, a sheep's foot compactor, shown in Photo 7-14, is ideal. This machine compacts the soil from the bottom up. As the soil becomes compacted, the roller will "walk" right out.



7-15a A steel grid-type roller fractures large coarse shale material.



7-15b A rubber tired roller with environmentally friendly ballast.

Large coarse shale materials can be compacted using a grid-type roller, Photo 7-15a, that will tend to fracture and break the larger pieces, helping to consolidate and compact the material into a tight mass. Compaction rollers do not have to be fancy. Photo 7-15b shows a trailer-hitch type with natural ballast materials.

7.4 Geosynthetics

The world of [geosynthetics](#) continues to expand with new products and uses in all types of applications. [Geosynthetics](#) takes in the whole realm of materials such as [geotextiles](#), geogrids, geoweb, geocells, and other geocomposites. Many local governments are using plastic drainage pipe, so they are already into [geosynthetics](#). There are, however, many other products that could prove useful in a variety of areas associated with dirt and gravel road maintenance. This section will zero in on [geosynthetics](#) for pipes and [subdrains](#), for soil [erosion](#) protection and embankment reinforcement, and for road separation fabrics.



7-16 The world of geosynthetics and road maintenance.

First, let's examine just what [geosynthetics](#) are. The prefix “geo” means relating to the earth. The word “synthetic” means man-made. So a [geosynthetic](#) is a man-made material used on or under the earth. The concept of earth stabilization using various materials is not new and can be traced back in history to reed mats in ancient Egypt, bamboo baskets for rice paddies in Asia, and “corduroy” log roads in England. In the United States, woven cotton was used for slope stabilization in South Carolina in the 1930s. All of these materials, however, were from natural products and were biodegradable. Modern [geosynthetics](#) began in the 1950s with trials and experiments, but

really came into existence in the 1970s with the introduction of certain polymers. Today the realm of [geosynthetics](#) is greatly expanded, using many polymers such as polypropylene (PP), polyester (PET), polyethylene (PE), polyvinyl chloride (PVC), nylon, polystyrene, and ethylene interpolymer alloy (EIA), all of which are non-biodegradable.

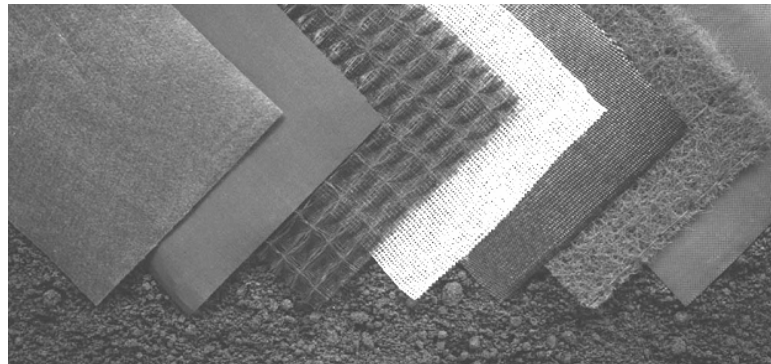
7.4.1 Why Use Geosynthetics? [Geosynthetics](#) are easy to place because virtually all installations can be accomplished with in-house crews. Additionally, [geosynthetic](#) materials cost very little. Low installation costs and low material costs means more bang for the local government buck. Further, [geosynthetics](#) may be used in a wide variety of applications and are durable and long-lasting.

7.4.2 Functions and Applications. [Geosynthetics](#) serve a variety of functions in many useful applications as follows:

Functions	Applications
Drainage / Infiltration	Subsurface Drainage
Stabilization	Subgrade Stabilization
Reinforcement	Soil Reinforcement
Separation	-Embankments
Erosion Control	-Steep Slopes
Sediment Reduction	-Vertical Walls
Waterproofing	Erosion / Sediment Control
Stress Relief	Base Reinforcement
	Bridge Deck Waterproofing

Selection of a particular product depends on the function and application. This becomes extremely important in [geotextile](#) fabrics.

7.4.3 Geotextile Fabrics. There are numerous fabrics on the market; each one designed to perform a specific function. You cannot tell one fabric from another by visual inspection only. Therefore, it becomes imperative that the manufacturer or vendor know how you are going to use the fabric or what function it is supposed to perform.



7-17 Different fabrics are designed to perform various functions and for various applications.

There are two major fabric types: woven and non-woven. The manufacturing process of these two types is similar. Plastic polymer beads are melted down and extruded through dies. For non-woven fabrics, the extruded threads are sprayed in random patterns, and then thermally bonded in layers and needle punched. They commonly have high permeability and conformability with high elongation. For woven

fabrics, the extruded threads are woven on machine looms and have a woven appearance. They have high tensile strength and low elongation.

There are woven slit-film fabrics that are melted plastic beads sprayed in sheet films and then slit into long narrow strips of varying width. These strips are then woven together. They also have high tensile strength and low elongation.



7-18 Fabrics come in rolls of various widths

Fabrics normally come in rolls of various widths. Widths of twelve, fifteen, and eighteen feet are common for use as separation fabrics.

7.4.4 Geosynthetic Applications in Road Maintenance. We have already discussed various [geosynthetics](#) - plastic pipe for drainage applications in directing collected surface flows, perforated plastic pipe for subsurface drainage, [erosion](#) control fabrics for lining ditches or channels, and fabric [silt fence](#) for [sediment](#) control. We will expand on those applications as we discuss further drainage applications, [erosion](#) and [sediment](#) control, separation fabrics, and some other [geosynthetics](#) as used in special applications.

7.4.4.1 Drainage / Infiltration Fabrics. Fabrics can be specifically used in conjunction with [subdrains](#).

Recalling the cross-section sketch of a [subdrain](#) as again shown in Figure 7-1, the

typical construction was a trench with well-graded aggregate and a perforated pipe. Clogging of the system over time has been the major problem with these [subdrains](#), as shown in Photo 7-19. Looking at the photo, one can imagine how much [sediment](#) passed through this pipe prior to reaching this totally clogged condition? And where did all that material go? The [subdrain](#) probably outletted to a stream, and we ended up with stream pollution.

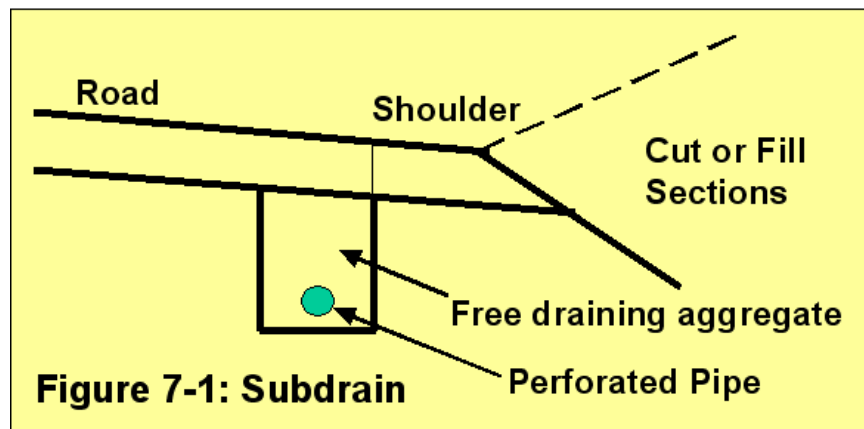
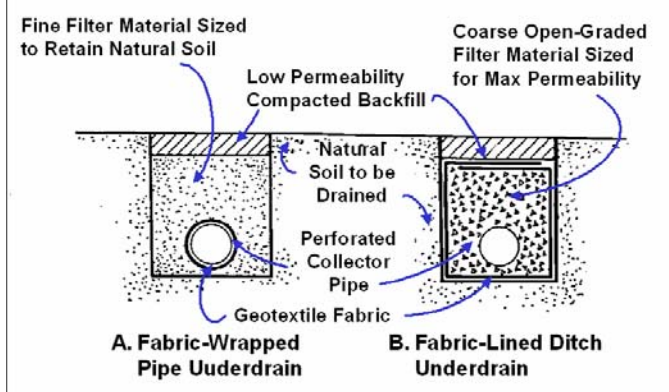


Figure 7-2: Geotextile Fabrics for longer lasting subdrains!



Geotextiles can play a valuable part in preventing this [sediment](#) and the eventual clogging of the system. You can use a roll of [geotextile](#) drainage/infiltration fabric to line the trench. We could also wrap the perforated pipe or purchased pipe already wrapped in a [geotextile](#) sock, as shown in Figure 7-2. Lining the trench, however, is just as easy and more effective.

The fabric is designed to let the water through and into the trench and pipe and then to the outlet, but it will not let the fine soils through to clog the system.

Caution: *There have been some problems in heavy clay soils – the clay, when wet, becomes very*

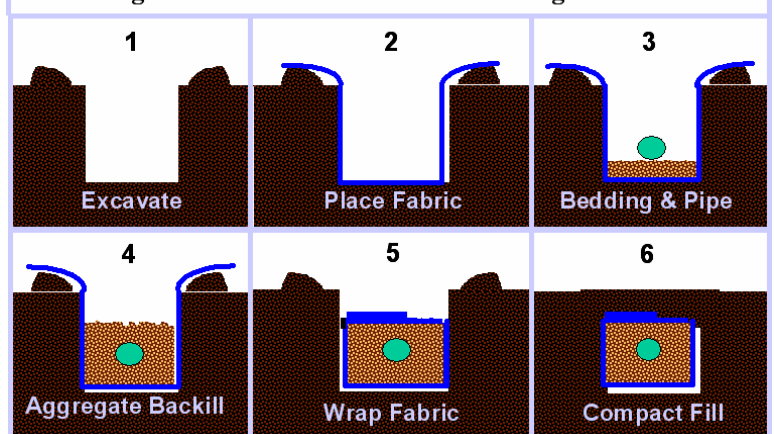
plastic and sticky and has caused some problems when fabric is placed in direct contact with the clay soil.

Lining the trench with fabric is a simple procedure, as shown in Figure 7-3 and the accompanying photos. Dig the trench, roll out the fabric, place bedding, place the perforated pipe, backfill with a one-size aggregate, overlap the fabric on top, and backfill the trench. The result is a better [subdrain](#) system that will last a long time.



7-19 Clogged subdrain!

Figure 7-3: Subdrain construction with geotextiles



7-20 Subdrain construction - dig trench, roll out fabric, add pipe and aggregate, overlap fabric, backfill.

7.4.4.2 Prefabricated Subdrains. Prefabricated [subdrain](#) systems consist of a hard plastic perforated core covered in a [geotextile](#) fabric. The perforated plastic core becomes the pipe. It is installed vertically, giving you a greater area for draining the road structure. It commonly comes in 12-, 18-, and 24-inch heights. All sorts of connectors are made to accommodate connections and installation. In addition, there are rigid and flexible systems, the flexible system being manufactured in rolls.



7-21 Pre-fab Underdrains: Rigid Type



7-22 Pre-fab Underdrains: Flexible Type



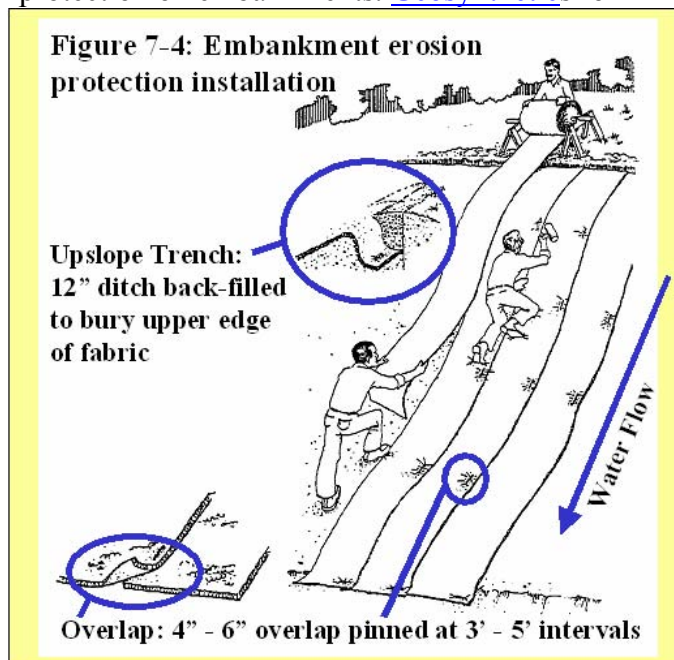
7-23 All subdrains need an outlet.

7.4.4.3 Subdrain Outlets. Like any [subdrain](#) system, whether lined with a fabric or a pre-fabricated, all [subdrains](#) must have an outlet. The pre-fab systems, as mentioned, have various connectors to allow the outlet to run in whatever direction is needed.

7.4.4.4 Erosion and Sediment Control. [Geotextiles](#) and other [geosynthetics](#) are used for channel linings and [erosion](#) protection on embankments. [Geosynthetics](#) for

these applications are usually manufactured in rolls and are easily installed with in-house crews, following manufacturer's recommendations.

We already mentioned the use of [geosynthetic](#) in this area in Chapter 5 for ditch and channel linings, where we discussed water flow velocities and the possible need for stabilizing the ditch or channel for faster flows. Many various products are produced for this type of application.





7-24 Installation of an erosion control fabric.

This factor applies to embankment protection, too. Again, there are many products on the market for embankment slope protection against [erosion](#).

Normal installation is depicted in Figure 7-4 and consists of rolling out the material, overlapping at seams, pinning, and anchoring the top of the material in a small trench. Again, follow the manufacturer's recommendations for each specific product. Photo 7-24 shows an extensive [erosion](#) control fabric installation, which will be covered with a large-size aggregate.



7-25 Geotextile silt fence barrier.

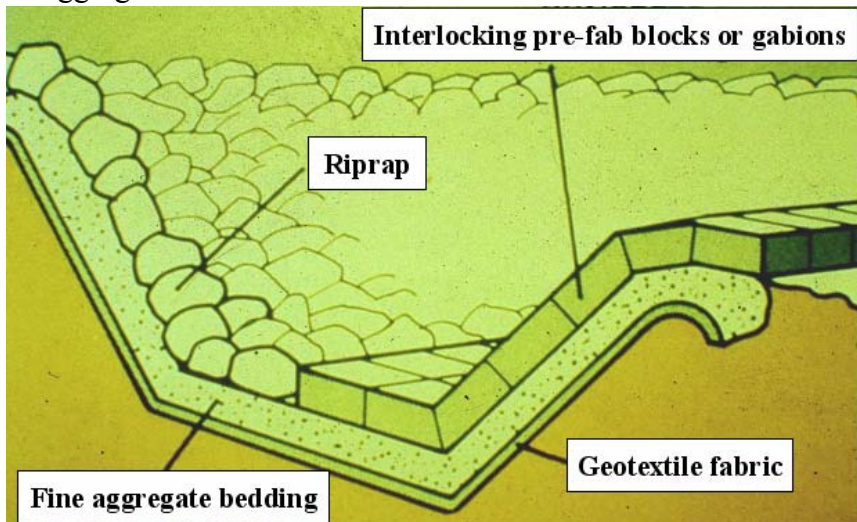


Figure 7-5: Geosynthetic linings serve as reinforcement and separation as well as erosion control

Remember, any type of [geosynthetic](#) is non-biodegradable. If we use these materials for temporary [erosion](#) prevention until vegetation is re-established, we must make sure that they are compatible with that vegetation since they will remain in place.

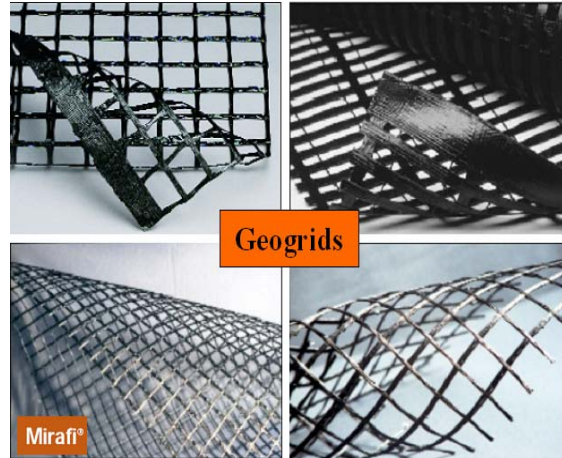
[Silt fence](#) is another [geosynthetic](#) used for temporary [erosion](#) control. [Silt fence](#) is discussed in Section 5.2.3.2 of Chapter 5, describing the proper installation practices and required maintenance.

[Geotextile](#) fabrics are also used underneath other types of channel linings such as [riprap](#) (as in the above Photo 7-24),

[gabions](#), or interlocking pre-fabricated blocks, as shown in Figure 7-5. In this installation, however, they are also serving as reinforcement and separation fabrics that will be discussed below.

7.4.4.5 Embankment Soil

Reinforcement. Both [geotextiles](#) and geogrids are used for embankment soil reinforcement. Geogrids come in many patterns and have proven their ability to perform in this type of application. Reinforcement applications usually entail embankments in which fabric or geogrids are placed horizontally at designed intervals during construction, as shown in Figure 7.6. Alternate layers of fill and rolled-out geogrid are placed as the embankment is constructed.



7-26 Geogrids come in various patterns designed for specific applications.

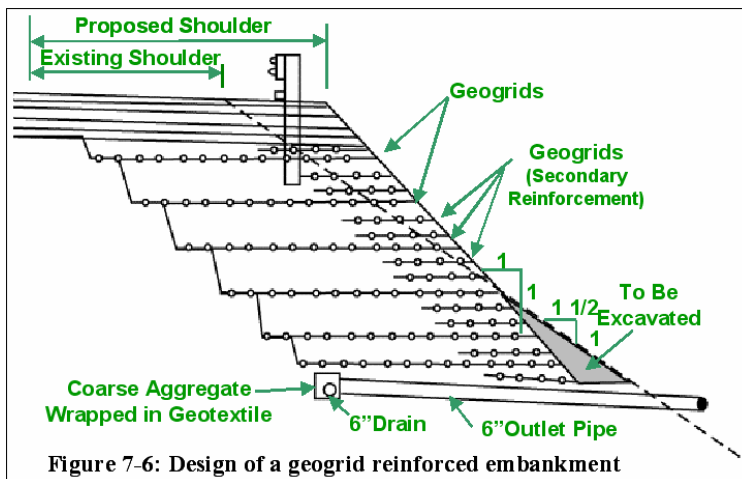


Figure 7-6: Design of a geogrid reinforced embankment

The material can be extended over the face of the embankment for additional protection, a method commonly intrinsic to any design. Photo 7-27 shows an actual road construction site using geogrid for reinforcement - an extensive project, but the applicability is there for any size project.

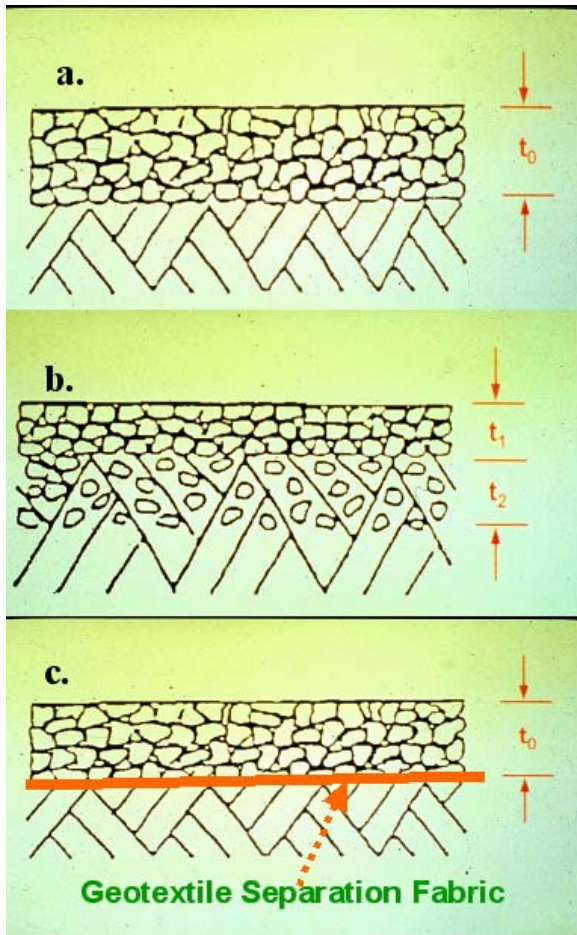
7.4.4.6 Separation Fabrics. Separation fabrics are among the most commonly used and cost-effective type of [geotextile](#) fabrics on dirt and gravel roads. These fabrics separate the subsoil from the road, provide reinforcement, improve drainage, and reduce [dust](#).

When roads are built, the subsoil or [subgrade](#) is prepared with a crown, then a specified thickness of aggregate is laid down and compacted, (Figure 7-7a).

Over time, however, depending on conditions (water and traffic), the aggregate gets pushed down into the soils, and the soils pump up through the aggregate. We end up



7-27 Construction of a geogrid reinforced embankment.



with a transition zone not as strong as the aggregate, and the road can no longer support the traffic loads with deterioration as the result (Figure 7-7b).

With the separation fabrics, we prepare the subgrade, roll out the fabric, and build the road on top of the fabric. The aggregate cannot be pushed into the soil and the soil cannot pump up into the aggregate. Everything stays in place, and the road remains as strong as designed for the traffic loads (Figure 7-7c).



7-28 Separation fabrics keep the soil and road aggregate in place.

Figure 7-7: Separation Fabrics

Water can travel either way, but if it gets into the road, it can drain downward or out laterally due to the crown into side ditches or subdrains. The prevention of soil fines from pumping up through the aggregate to the road surface eliminates the mud in wet weather and the dust in dry weather associated with these fines.



↑ Rolls of fabric waiting for installation ↑



↑ Rolling out the fabric ↑



↑ Backdumping the aggregate ↑



↑ Spreading the aggregate ↑



↑ Compacting the aggregate ↑

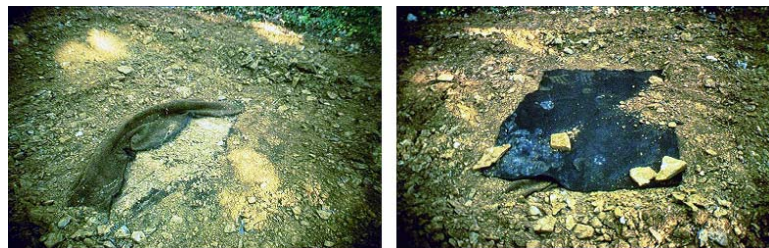


↑ Final grading ↑

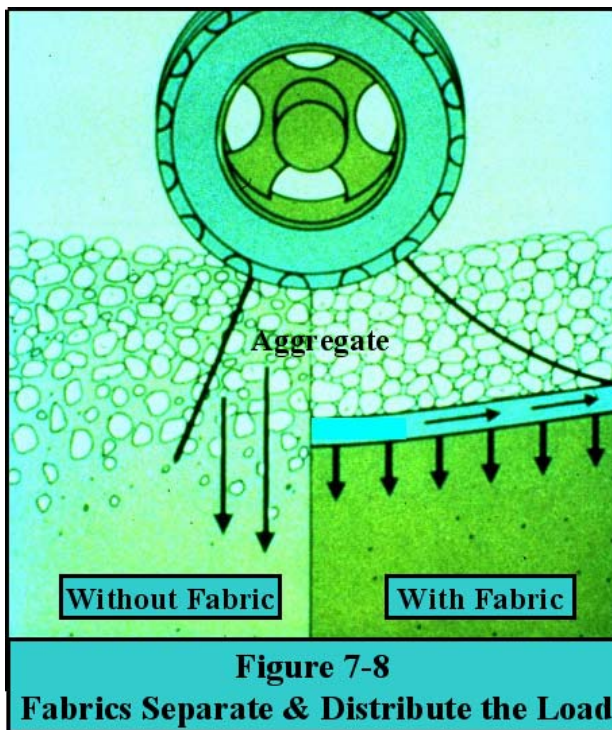
7-29 Installation of a Separation Fabric.

Fabrics come in woven or nonwoven types for this application. The existing road conditions, particularly the aggregate, rock outcrops, water and saturated subsoils, must be evaluated when selecting fabric type. Transverse joints should be overlapped a minimum of 18 inches in the direction of traffic. Fabrics come in standard 12-, 15-, and 18-foot widths (or customized to any width), eliminating the need for longitudinal joints. Aggregate should be backdumped from the truck to a minimum depth of 6 inches, preferably 8 inches. Compacting the aggregate along with grading and re-establishing the crown completes the project. The photos depict fabric installation on a typical dirt and gravel road. This was a demonstration project where both woven and non-woven separation fabrics were used along with different road aggregates. In some areas, filling of the road with shale material to raise the road elevation took place. The different road materials can be seen in the photos.

If the fabric gets damaged during placement, simply patch with another piece of fabric making sure that an 18” overlap on all sides is maintained. Tears can happen, as shown in Photo 7-30, where the blade of the dozer caught the fabric by accident.



7-30 If damaged, use a fabric patch with 18” overlap.



Fabrics also help to distribute traffic loads over a greater area, making them advantageous to use over soft, saturated soil conditions. Figure 7-8 shows this load distribution effect of the fabric. Traffic load distribution was discussed in Chapter 5, Section 5.3.5, Practices Related to [Culverts](#) in regards to [culvert](#) installations.

Many separation fabric applications are in place throughout the states and proving effective in substantial reduction of road deterioration and the required maintenance. The use of fabrics for stabilizing water crossing areas in conjunction with [broad based dips](#) and driveways was mentioned in Chapter 5. In these applications, they perform a reinforcement function and a separation

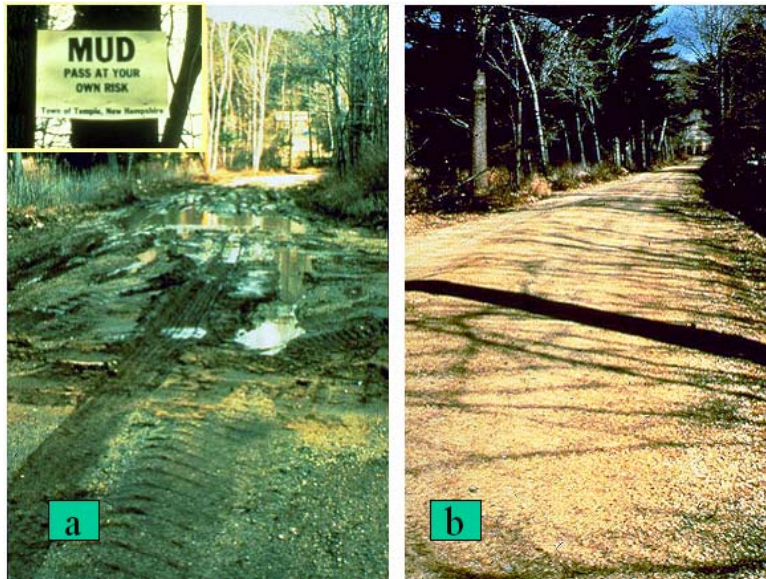
function to strengthen and keep these areas intact.

The use of separation fabrics, in general, provides us with a number of advantages. Stabilization

1. [Subgrade](#) pumping prevention
2. Drainage improvement
3. Excavation reduction
4. Rutting and pothole reduction
5. [Dust](#) reduction
6. Reduced maintenance and costs
7. Longer road life.

The excavation reduction refers to those areas where we find unsuitable saturated soils for [subgrade](#) material. The common practice is to remove the unsuitable material.

This can lead to excavating several feet depending on conditions. With a separation fabric, we can prepare the [subgrade](#) surface and roll out the fabric over these soft soil areas and let the fabric handle the problem. Would you rather have a road looking like “a” or “b” in Photo 7-31? With separation fabrics, we can eliminate the sign as seen in the photo inset.



7-31 Before & after fabric installation – let’s eliminate the sign!

7.4.4.7 French Mattress. The French mattress refers to the old “French drains” used in

many locations to drain storm water. The French mattress is a mattress-shaped structure of coarse aggregate wrapped in a [geotextile](#) fabric. This structure is placed under the road and allows water to pass freely through the roadbed without moving soil particles.

The primary purpose of the mattress is to equalize the subsurface water on both sides the road while providing the needed load support for the road and traffic. Support strength is provided by the large aggregate in the lower portions of the mattress spreading the load.

7.4.4.8 Geocells and Geowebbs.

Geocells or geowebbs, as they are also called, are an innovative [geosynthetic](#) product used in ground stabilization, road [subgrade](#) stabilization, slope [erosion](#) control, embankment reinforcement and retaining walls, stream crossings, and channel [erosion](#) control. The geocell is a lightweight, flexible mat with a honeycombed structure that is spread and pinned and then filled. A variety of fill materials can be placed within the cellular system, such as soil, sand, aggregate, concrete, etc. The geocell confines the native or select fill materials, adding to the structural strength of the system. Geocells with the appropriate fill material creates various opportunities for economical solutions in the applications listed above.

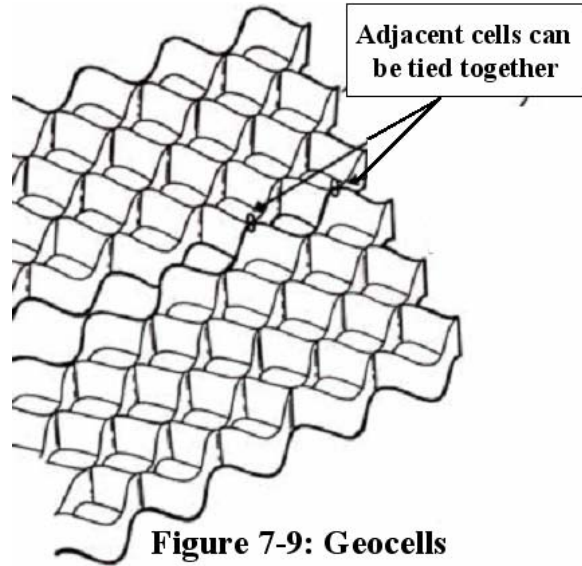


Figure 7-9: Geocells



7-32 Geocells can be filled with a native or select fill material. (Photo: WebTec, Inc. - TerraCell®)

The cells come in various heights with different cell sizes. They can be solid wall or perforated to allow flow between cells. Most manufacturers will also customize sizes for specific requirements. Anchoring systems vary according to the manufacturer.

We will look at a few different applications that could benefit the maintenance of dirt and gravel roads and roadsides.



7-33 Geocells for road base stabilization. (Photos: WebTec, Inc. - TerraCell®)

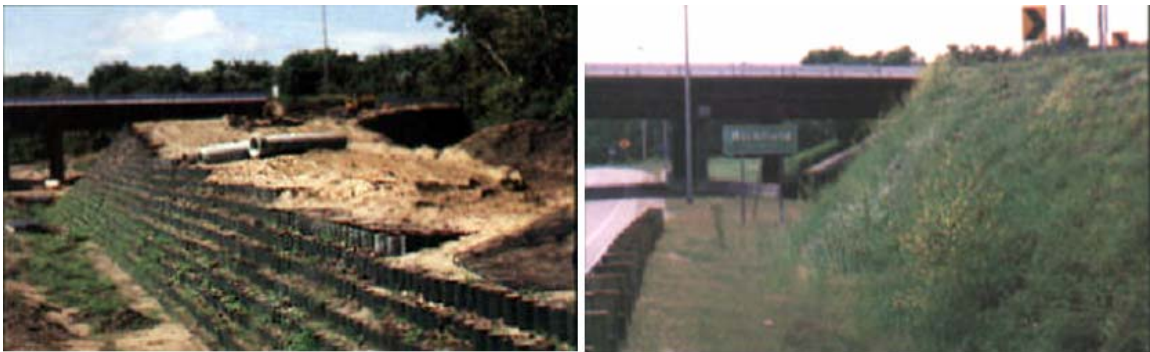
7.4.4.8.1 Road Stabilization. Geocells have been used to stabilize road base aggregates and give additional structural support to the road. The geocell is spread, pinned, and filled with aggregate, as can be seen in the photo. Common practice uses a [geotextile](#) fabric placed on the [subgrade](#) prior to spreading and pinning the geocell. The [geotextile](#) separation fabric

prevents fines from pumping up through the geocell and aggregate and to prevent the aggregate from sinking into the subsoil underneath and to keep a uniform geocell surface across the road. A final surface aggregate would then be spread over the base aggregate and geocell system.

7.4.4.8.2 Retaining Walls. Geocells can be stacked to form almost vertical walls for embankments. As with geogrids, the structural strength of the geocell wall allows for steeper slopes than most soils would sustain without the geocell confinement system. Typical wall installations are shown in Photo 7-34. Each layer of geocell is stepped back from the underlying one.



7-34 Geoweb retaining wall installations (Photos: WebTec, Inc. - TerraCell®)



7-35 Geoweb embankment retaining wall during construction and after vegetation established (Photos: WebTec, Inc. - TerraCell®)

The cells can be filled with soil and vegetation established to actually conceal the wall cellular structure. A vegetated geocell wall is shown in Photo 7-35

7.4.4.8.3 Low Water Road Crossing. A low water crossing can be used in lieu of a cross [culvert](#) being installed. This practice should be used on a very low volume road and will depend on the conditions of the surrounding terrain and the expected flows.



↑ Excavating trench ↑



↑ Placing fabric ↑



↑ Placing geocell ↑



↑ Pinning geocell ↑



↑ Geocell ready for fill ↑



↑ Dumping aggregate fill ↑



↑ Raking fill ↑



↑ Raising road elevation ↑



↑ Compacting ↑



↑ Completed low water crossing ↑

7-36 Installation of a low water crossing.

The series of Photos 7-36 depicts the installation of a typical low water crossing using a geocell. This site was on a road having less than 10 vehicles a day (<10 ADT). The road was in the [watershed](#) of a potable water reservoir. The storm water accumulated and crossed the road at this point during most storms, causing a great amount of [erosion](#) and road deterioration. The project was designed to raise the elevation of the road but still allow the water to cross naturally at this point through a stabilized low water crossing. A cross pipe installation would create major problems due to elevations of the surrounding terrain. On the downhill side the pipe would have to be extended several hundred feet to outlet at ground level. A low water crossing allowed the water to cross the road in lieu of a cross pipe and sheet flow through the wooded vegetated area without the resulting [erosion](#) and road washouts.

A shallow trench excavation is made to install the crossing. As in the road base reinforcement, a [geotextile](#) separation fabric is placed prior to the geocell. The geocell is then spread and pinned. Large aggregate is dumped into the cell to an elevation slightly higher than the cell in order that the vehicle wheels do not strike the cell.

7.4.4.8.4 Road Stream Ford Crossing. A [geosynthetic](#) reinforced ford crossing enhances the environmental sensitivity of an existing crossing in lieu of a costly bridge construction project. The reinforced crossing provides a stabilized hard aggregate surface

for vehicles that will not wash out and will not create the continual [sediment](#) and disturbance of the stream that the existing unstabilized crossing causes with each vehicle crossing.



7-37 Stream fords cause erosion and sediment, degrading stream habitats. A perforated geoweb offers a stabilizing solution with proper hydraulic and stream ecology protection.

The existing ford crossing shown in Photo 7-37, depicts the [erosion](#) potential with each vehicle crossing, with the resultant [sediment](#) degradation of the stream [ecology](#) (the stream community or [ecosystems](#) was discussed in Chapter 4, Section 4.3, and particularly the effect of [erosion](#) and [sediment](#) on streams in Section 4.3.4). Using a perforated geoweb with one-inch holes allows hydraulic equalization and migration of stream life. The surface of the crossing should match the streambed surface in order not to cause any disturbance in flow by creating a dam effect across the stream.

7.4.4.9 Prefabricated Geosynthetic Pipe Endwalls. Prefabricated [geosynthetic endwalls](#) consist of polyethylene sections that can be easily installed by road maintenance



- Low Density Polyethylene
Easy to install



- Consists of 3 preformed sections
+ a pipe adapter

crews. The [endwalls](#) come in three preformed sections with a pipe adapter for 12", 18", and 24" diameter pipe. One person can position and assemble the sections using a power drill or screwdriver and galvanized screws. The sections are filled with

7-38 Pre-Fab Geosynthetic Endwall Systems.

soil, sand, aggregate, or cement and a cap is placed on top. Additional sections can add height as required. A poured concrete footer is recommended. The [geosynthetic](#) end wall comes in three natural stone colors, and, from the motorists' point of view, look like laid stone [endwalls](#).

The photos (HartmanEW™ System) show an installation sequence for the [endwall](#).



7-39 Pre-Fab Geosynthetic Endwall Installation.

7.5 Summary

This chapter has discussed the importance of implementing a [dust](#) control program. Since [dust](#) is actually the fines in your road that lock everything together should be reason enough to have a [dust](#) control program. A [dust](#) control program prolongs road life, protects the environment, and provides many additional benefits to your community.

We also discussed the importance of evaluation of [dust](#) control products as to their effect on the environment and their effectiveness as a [dust](#) control, followed by a review of common [dust suppressants](#) with their advantages and limitations. We concluded with general application procedures for [dust](#) control products.

In the second section, we delved into [road stabilization](#) (or full depth reclamation) and the benefits derived from this technique. [Road stabilization](#) can add strength to the

road, prolonging its life and reducing maintenance. At the same time, keeping the road intact reduces [erosion](#) and [dust](#), thereby helping the environment.

The third section introduced the world of [geosynthetics](#), describing the functions and applications applicable to dirt and gravel roads. This world is constantly expanding with new products and applications. But products like the separation fabrics have had wide use and success in road maintenance.

Appendix 7B continues, as in Appendices 5 and 6, to review actual Pennsylvania worksites in which a combination of practices has been used, including [geosynthetics](#), to solve the [erosion](#) and [sediment](#) pollution problems stemming from dirt and gravel roads. The first site used pre-fabricated [subdrains](#) to collect subsurface water stemming from spring seeps. The second site was a nature reserve where separation fabrics were used for driveway re-construction and geogrids provided the structural strength for a bus parking lane and a French mattress system provided the required subsurface drainage flows. The third site was a demonstration project where [geotextile](#) fabric was used to reinforce and stabilize a stream crossing having an inadequate crosspipe.

All of these topics and the products and practices discussed are good “tools” for your toolbox and need to be considered as integral parts of an overall environmentally sensitive dirt and gravel road maintenance program.

Appendix 7

Appendix 7A. Pennsylvania's Testing and Approval Program for Dust Suppressants and Road Stabilizers.

The Pennsylvania State Conservation Commission has addressed the issue of [dust suppressants](#) and road stabilizers by making it clear to manufacturers and vendors that they are responsible for determining the acceptability of their materials in conjunction with accepted toxicity testing protocols. Before a product can be approved for use in the PA Dirt and Gravel Road Program, it must undergo toxicity testing according to federal EPA protocol at a laboratory certified by the EPA. The test results are then interpreted with the requirements of the PA Clean Streams Law, specifically Title 25, Chapters 16 and 93. That interpretation is the basis of whether or not the product is acceptable to the Pennsylvania State Conservation Commission.

Tests are required on all commercial products. The tests are to determine toxicity based on identification, quantity, and behavior of elements and compounds found. The tests will include the 7-day rainbow trout (*Oncorhynchus mykiss*) survival and growth test. Tests with fat head minnows (*Pimephales promelas*) are not acceptable. The 7-day cladoceran (*Ceriodaphnia dubia*) survival and reproduction test is also required. Guidelines for the tests must use the federal EPA protocols. Each test must produce two "No Observed Effect Concentrations" (NOEC), one for survival and growth of rainbow trout and one for survival and reproduction of cladocerans.

In addition, Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values must be obtained for the product. These values are not intended for use in determination of the environmentally acceptability of the product but are reference values for use in any potential emergency. (Source: Administrative Manual, Dirt and Gravel Road Maintenance Program, PA State Conservation Commission, March 3, 2005.)

Under the above criteria, the Pennsylvania State Conservation Commission has approved nine different products from six different companies for use at approved application rates in the PA Dirt and Gravel Road Program – four products classified as petroleum emulsion [dust suppressants](#), two products classified as synthetic fluid [dust suppressants](#), and three products classified as acrylic polymer [dust suppressants](#). The products, companies, and approved application rate are as follows:

Petroleum Emulsion [Dust Suppressants](#)

PennSuppress "D", American Refining Group, Inc., Bradford, PA

1:4 emulsion to water or more dilute

Ultrabond 2000, JMG Enterprises, Inc., Seward, PA

1:4 emulsion to water or more dilute

Coherex, D&D Emulsions, Inc., Mansfield, OH

1:10 emulsion to water or more dilute

[Dust](#) Bond, D&D Emulsions, Inc., Mansfield, OH

1:10 emulsion to water or more dilute

Synthetic Fluid [Dust Suppressants](#)

EK35, Midwest Industrial Supply, Inc., Canton, OH

100% active, no water for application

EnviroKleen, Midwest Industrial Supply, Inc., Canton, OH

100% active, no water for application

Acrylic Polymer [Dust Suppressants](#)

Pave-Cryl Suppress, Rohm & Haas Company, North Andover, MA

As-received (51% solids)

Pave-Cryl Suppress Plus, Rohm & Haas Company, North Andover, MA

As-received (51% solids)

DirtGlue, DirtGlue Enterprises, Wakefield, MA

As-received (>50% solids)

APPENDIX 7B. Worksites in Focus

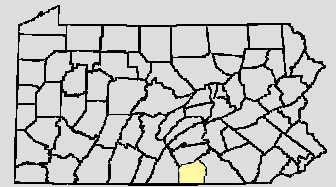
The following worksites are actual projects funded through the Pennsylvania Dirt and Gravel Road Program. The first site was an entrenched township road with saturated ditches, surface [erosion](#), and spring seeps. The project raised the road profile and added pre-fabricated [subdrains](#) to collect subsurface water from under the road and both ditches.

The second site was a Nature Reserve experiencing increased traffic loads from the increase in visitors. This project added a new driveway and parking areas, including bus parking reinforced with a geogrid and French mattress construction for two small drainage ways. The third site was an early demonstration site for the Dirt and Gravel Roads Program. The spotlight is on one aspect of this site, entailing the resetting of an existing 3-foot diameter cement concrete drainage pipe.

Worksite in Focus

Adams County Miltenberger Road

7/16/05



Problem Identification

Miltenberger Road was an entrenched road with few outlets for drainage and spring flow to leave the road area. Water was concentrated in parallel ditches and directed 1,200' downhill and under State Route 233 into Conococheague Creek. Water entering the road area had nowhere to go but down the ditches, gaining velocity and erosive force. Adding additional drainage outlets was impossible with the road at an elevation much lower than that of the surrounding landscape. The entrenched road profile also left little room to plow snow (*Photo 1*).

Project Facts

Project: Miltenberger Road
Project Owner: Franklin Township
Watershed: Conococheague Creek,
Potomac River
Project Length: 800 ft
Date Completed: June 2005

Cost Summary

Total Project Value: \$15,689
District Funding: \$15,689
Materials: \$670
Equipment: \$4,292
Shale: \$10,727



Project Objectives

1. Restore natural drainage by raising the road to achieve sheet flow.
2. Reduce stream impact by providing additional outlets for water currently trapped in road ditches.
3. Address maintenance problems such as saturated ditches and lack of space for snow storage.

Project Considerations

Although over 3,000 feet of Miltenberger Road was entrenched, cost limitations only allowed for enough shale to raise about 800 feet of the roadbed. Spring water entered the road profile as subsurface flow. This excess water saturated the road and ditches, softening the road base (*Photo 1*). The land surrounding the road is owned by the Bureau of Forestry.

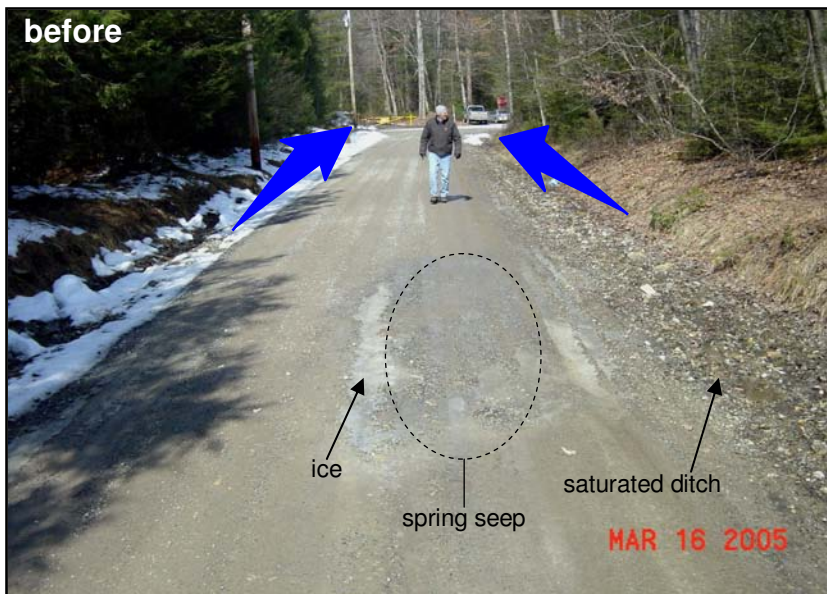


Photo 1. Notice the ice in the middle of the road from a spring seep. The entrenched road profile made it impossible to get water or snow off of the road.



Photo 2. Pre-fabricated underdrain was used to collect subsurface water from under the road and both ditches.

Miltenberger road was raised an average of 3' using shale fill.



Photo 3. The entrenched road traps water in the road area and conveys it down to the stream. Note the elevation of the road relative to the utility pole on the right compared to *Photo 4*.



Photo 4. The road was elevated to eliminate the ditch on the left and achieve sheet flow. The added material also provided the necessary cover to install new crosspipes.

Project Solutions

Install underdrain: Pre-fabricated underdrain (4" perforate pipe wrapped in geotextile fabric) was placed under the road and ditches to collect subsurface water (*Photo 2*). The underdrain will keep clean subsurface water from mixing with road drainage. It will also reduce maintenance by allowing the road and ditches to dry.

Raise the road elevation: Shale was purchased for use as road fill (*Photos 3 & 4*). The shale was spread with a bulldozer and compacted using a vibratory roller in approximately 8" lifts. The road was filled an average of 3' over an 800' length and tapered into the existing road grade on both ends. Filling the road completely eliminates one ditch, and provides the cover necessary to install crosspipes to outlet water from the remaining ditch (*Photo 5*).

Install crosspipes: Because Miltenberger road was so severely entrenched, no crosspipes existed on the road before this project. Crosspipes were needed to divert drainage into vegetated areas and keep runoff from entering the stream. The new road elevation provided the extra cover needed for two shallow crosspipe installations. These crosspipes were outletted at the existing ground elevation to avoid creating an "outlet trench" into the woods. Gradebreaks were constructed over each crosspipe to obtain adequate pipe cover and divert water from running down the roadway (*photo 5*).

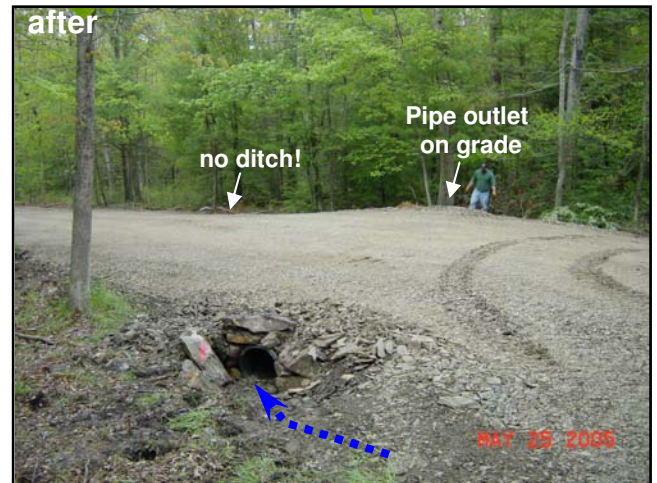


Photo 5. One of two new crosspipes installed. Notice the grade-break in the road over the pipe to get water off the road.

For More Information

The Center for Dirt and Gravel Road Studies

1-866-668-6683 (toll free): www.dirtandgravelroads.org

Adams County Conservation District

(717) 334-0636: user.pa.net/~adamscd/

Site Map & Directions:

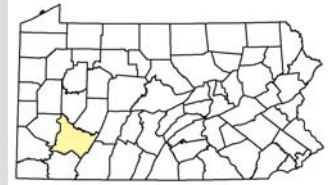
From U.S. Route 30 at Caledonia State Park, follow State Route 233 north approximately 5.5 miles to Miltenberger Road. The worksite begins at the intersection with State Route 233 and continues for 800 feet.



Worksite in Focus

Westmoreland County Powdermill Nature Reserve

11/2/04



Project Background

In need of additional parking, Powdermill Nature Reserve sought an environmentally sensitive solution that handles increased visitors and related traffic loads without an ugly scarring of the surrounding landscape. To accomplish this, the Reserve added:

- A new driveway with Driving Surface Aggregate* (DSA-as modified) to improve circulation and provide second access to Rte. 381;
- 2 new parking areas: a bus parking lane underlain with Geogrid® (see photo below) and a pervious grassed automobile lot (60' x 100').

Project Considerations

Where the new driveway crossed two small drainage ways (see Site Plan below), French mattresses*, constructed of clean stone wrapped in non-woven geotextile fabric, were installed. This low-cost, low-maintenance technique connects the hydrology on either side of the road allowing water to percolate through the stone while the fabric prevents sediment movement.



Above: Construction of the bus parking lane. Geogrid® was used to add support and tensile strength.

* For more information on DSA and French Mattress construction please see the DSA Informational Bulletin and the French Mattress Technical Bulletin available at www.dirtandgravelroads.org.

Project Facts

Project:	Nimick Nature Center Driveway & Parking Lot
Project Owner:	Powdermill Nature Reserve
Affected Watershed:	Powdermill Run, Youghiogheny River
Project Length:	550 ft
Date Completed:	October 2003

Cost Summary

Project Cost:	\$35,049
Geoblock® Parking Lot	\$26,833
Contract	\$1,980
Materials (geosynthetics)	\$1,580
Stone	\$4,056
Tree Removal	\$600
In-Kind Contributions:	\$8,300

This project was completed with monies raised by the Powdermill Nature Reserve.

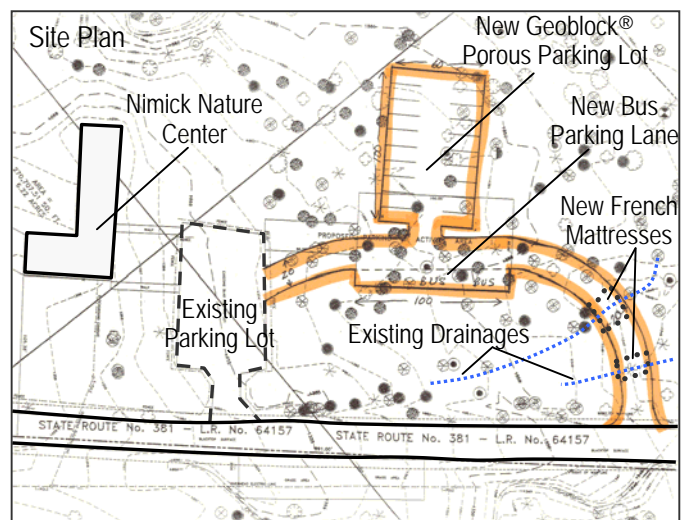
For More Information

The Center for Dirt and Gravel Road Studies
(814) 865-5355
www.dirtandgravelroads.org

Powdermill Nature Reserve

1847 Route 381
Rector, PA 15677

Theresa Gay Rohall
(724) 593-6105



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Driveway Construction Sequence

1. Trees were cleared along the proposed right-of-way and non-woven geotextile fabric was rolled out. Additional lengths of fabric were laid perpendicular to the driveway at two locations to allow construction of the French mattresses (see photo 1).
2. #3 stone was tailgated on top of fabric along the entire length of the right-of-way.
3. The perpendicular fabric sections were wrapped over the #3 stone to create the French mattresses (see photos 2 & 3).
4. #2b stone was tailgated over the entire length of the driveway, including the French mattresses. A modified version of DSA was placed over the #2b stone and rolled to create the driving surface (see photo 4).



Project Results

Environmentally sensitive maintenance practices were employed to minimize cost, reduce future maintenance demands and expand visitor infrastructure while staying in tune with natural surroundings. This collaborative project brought together several diverse partner organizations to reinforce Powdermill’s environmental ethic that teaches respect for nature by showcasing how human handiwork can “lay lightly on the land.”



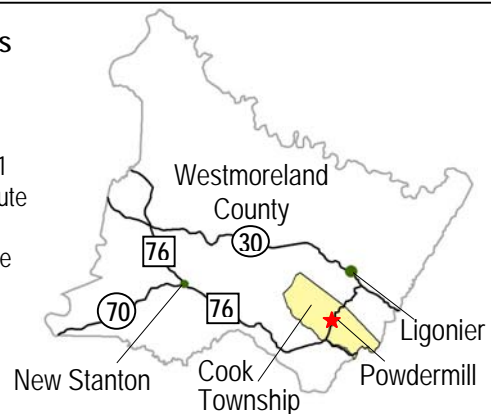
Project Partners

- Powdermill Nature Reserve
- Center for Dirt & Gravel Road Studies
- Westmoreland Conservation District
- Sustainable Forestry Initiative of PA
- Kennametal Inc



Site Map & Directions

From the PA Turnpike (Interstate 76), exit at Donegal/Ligonier/PA 711 (#91). Turn left onto Route 31 after the toll booth. Follow Route 31 to Route 381 north. The Nimick Nature Center is 6 miles ahead on the left.



A7B-3. Worksite #3: Hell Hollow Road, Monroe County, PA:

This site was a demonstration project for the Pennsylvania Dirt and Gravel Roads Program on which various practices were demonstrated. One of the sub-sites involved a 36"-diameter cement concrete pipe installed for a stream crossing Hell Hollow Road. Viewing the original site, one can see the voluminous [erosion](#) that had taken place, uncovering the outlet side of the pipe, which had actually lifted, causing water to run uphill through the



A7-01 Hell Hollow Road Demo Site: Existing site conditions prior to project.



A7-02 Excavation of existing pipe during dry conditions.

The pipe could not handle the flows, particularly during the spring rains, causing overflow and damage to the road and continual [erosion](#) of the entire site. This township road with daily traffic of less than 10 cars (<10 [ADT](#)) was in the [watershed](#) of a potable water reservoir. Building an adequately sized bridge was not economically feasible. The solution was to reset the existing pipe and stabilize the entire area to protect against further [erosion](#).

pipe to the outlet side. The inlet side of the pipe was at an elevation that caused water to drop approximately 15" into the pipe entrance, which was causing changes in the stream's profile on the upstream side and thereby affecting the stream [ecology](#). The pipe was also out of alignment with the stream flow, causing tremendous [erosion](#) on the downstream bank, which was in direct line of the pipe outlet flow.



A7-03 Geotextile separation fabric laid in new trench.



A7-04 Bedding material added



A7-05 New line and grade checked

The pipe was excavated and sections set aside. A new line and grade was established to better meet the stream flow conditions. Notice from the photos that all work was done during a dry period with no flow. The new pipe trench was prepared, and a [geotextile](#) separation fabric was then laid in the trench and extended both upstream and downstream. Bedding material was added, and the pipe sections were reset. Since the old pipe joints were not sealed and no sealing was available, the pipe was wrapped in a [geotextile](#) fabric to prevent losing fines through the joints with possible undermining of the material surrounding the pipe. Duct tape held the fabric in place for backfilling.



A7-06 Fabric wrap covers pipe joints, prevents fine material from entering.

backfill area was encased in fabric. Water could move through the pipe and through the

After backfilling, the extended fabric was brought up and over the pipe ends, cutting out for the pipe inlet and outlet, and overlapped on top with a road separation fabric. Thus the whole pipe and



A7-07 After backfilling, fabric brought up and over pipe ends to encase entire installation.

surrounding backfill, but the fabric prevented material removal, eliminating the [erosion](#) potential. The pipe end areas received large [riprap](#) to face off the embankment and further protect against [erosion](#).



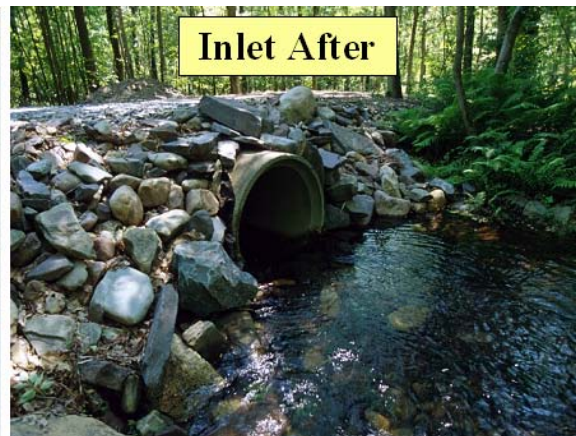
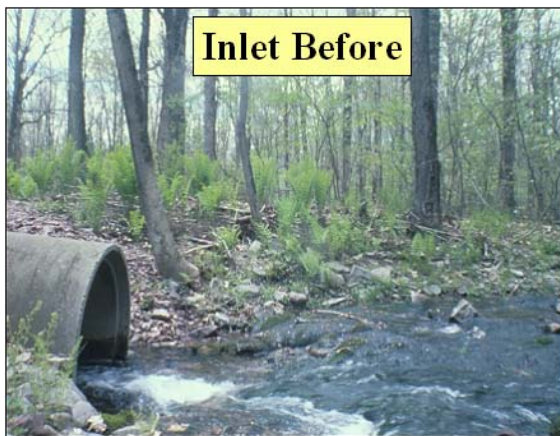
A7-08 Placing large size riprap at ends of pipe.

The road was leveled for a short distance on each side of the pipe crossing using the Stream Saver System discussed in Chapter 5, Section 5.3.6.1. The project was completed in the fall of the year.

The following spring brought the rains, which once more proved too much for the pipe to handle. The road has sustained overflows on several occasions each spring with minimal road damage. The site remains essentially [erosion](#) free. Road overflows are spread out over the



A7-09 Completed project with a leveled road stream saver system.



A7-10 Inlet conditions before and after project.

level road, reducing the velocity and energy of the water. The pipe is better aligned with the stream flow protecting the downstream banks against [erosion](#). The last photos, A7-10 and A7-11, show before and after conditions at each end of the pipe. The project demonstrates one innovative use of [geotextile](#) fabrics in solving the [erosion](#) and [sedimentation](#) pollution at this site.



A7-11 Outlet conditions before and after the project.

Glossary

Note: These terms are defined in relation to their use in this manual for [environmentally sensitive maintenance](#) for dirt and gravel roads

ADT: Average Daily Traffic.

Bank Gouging: A problematic practice during grading operations or ditch cleaning where the grader operator cuts into the toe of a stable bank and creates a vertical surface, destabilizing the bank and creating erosion and [sediment](#).

Bed Load: Larger particles on the stream bottom that move by sliding, bouncing, or rolling along the bottom in response to stream flow.

Bench: A step or series of steps cut into and across a steep embankment to catch water and prevent it from running over the face of the bank, creating [erosion](#) and [sediment](#) pollution. The bench should be sloped to prevent over the bank flow and drain to an appropriate outlet.

Bioengineering: Techniques combining the biological elements of using live plants with engineering design concepts for slope protection and [erosion](#) reduction, used effectively in restoration of many stream and [upland](#) banks.

Broad Based Dip: Shallow gradual dips skewed across the road in the direction of water flow, used to outlet ditch flows to the other side of the road where outletting is prevented by a high embankment on one side of the road with a downhill grade.

Capillary flow: the percolation or vertical seepage of water through soil. (Fine soils tend to increase capillary flow, with the soil acting like the wick of a kerosene heater sucking water upward.)

Colonizer Trees: Those species that are shade intolerant and thereby first to grow in cleared areas, having the characteristics of being fast-growing, short-lived, and weak-structured, making them undesirable roadside trees, as compared to the [intermediate](#) or [climax](#) species.

Culvert (pipe, drainage pipe): Enclosed channels of various materials and shapes designed to convey stream or ditch water away from the roadway.

Daylighting: A traditional practice of removing all trees from the roadside to allow sunlight to penetrate through to the road surface in order to dry the road to prevent road deterioration from water and to prevent snow and ice buildup. This practice is also used to improve motorists' sight distance for greater safety. (Caution: This may not be the best practice for dirt and gravel roads in forested areas – refer to Manual Chapter 6.)

Ditch Turnout (ditch outlets, tail ditch, bleeders): A formed channel that diverts ditch water away from the road, usually angled in the direction of water flow and placed at locations to empty into a vegetative filtering area.

Diversion Swale (diversion channel, interceptor ditch): A water conveyance channel constructed across the bottom of a slope for the purpose of intercepting surface [runoff](#) to minimize [erosion](#) and prevent excess flows into lower lying areas. Most often diversion swales intercept water from an uphill slope and divert it away from the road and roadside ditch to a stabilized outlet area or infiltration back into the ground.

Dust: Fine road material ground down by traffic and blowing off in the wind, indicating that the road is deteriorating.

Dust Suppressant: Any of the variety of materials used as a successful treatment to significantly reduce dust conditions on unpaved roads and helps preserve road surfaces.

Ecology: The study of interactions of organisms between one another and the physical and chemical environment in which the organisms dwell.

Ecoregions: Areas with similar characteristics reflecting the physical factors (geology, soil, [hydrology](#), climate) that help define respective habitats, and in turn determine the type of animals and plants that live in that habitat.

Ecosystems: A smaller unit within an ecoregion. Within each ecoregion, there are typically three types of ecosystems: streams, [wetlands](#), and forests/[uplands](#).

Embeddedness: the degree to which pebbles, cobbles, etc. (the larger pieces of the stream bottom) are surrounded by fine [sediments](#). Normal embeddedness is about one third; higher degrees of embeddedness relate to problems such as lack of living space for invertebrates and lack of free-flowing water for fish eggs in gravel beds.

Endwall, End Structure: A structure placed at a pipe inlet or outlet to prevent [erosion](#) and scour around the pipe, protect the embankment, and help anchor the pipe. Endwall may be constructed from a variety of materials.

Energy Dissipater: Any device or installation of material used to reduce the energy of flowing water.

Environmentally Sensitive Maintenance: Effective practices that will not only be beneficial in protecting the natural environment, but also result in less road maintenance and associated costs.

Erosion: the eating away of a surface by water, wind, abrasion, etc.

Flared End Section (pipe end section): A manufactured flared drainage piece that fits on the end of a pipe to enhance [hydraulics](#) (water flow); can be metal, concrete, or plastic.

Flowline: The bottom of the ditch or pipe, the invert of the pipe.

Gabions: Manufactured woven wire baskets filled with stone and tied together to form a structure. Gabions are used for bank stabilization and armoring, retaining walls, [culvert end structures](#), channel linings (gabion mattresses), etc.

Geosynthetic: Stemming from “geo” meaning “of the earth” and “synthetic” meaning “man-made”; geosynthetics are man-made materials used on or under the ground, non-biodegradable, for various purposes ranging from reinforcement and separation to drainage filtration and [sediment](#) control.

Geotextile: A [geosynthetic](#) fabric or textile manufactured from synthetic plastic polymers, non-biodegradable, in woven or non-woven types, and used for various purposes ranging from reinforcement and separation to drainage filtration and [sediment](#) control.

Grade Break: A long, gradual break in grade on a road with a relatively gradual downhill slope that improves drainage. Grade breaks limit water flow by decreasing concentration and velocity from a reduced area of road section, resulting in limited ditch and cross pipe size.

Gravel Bar: An accumulation of gravel and rock material normally occurring at a bridge structure, which interferes with the natural conditions of stream flow but can occur naturally anywhere along the stream.

Hydraulics: The mechanics of fluids, primarily water. (Engineers use [hydrology](#) to determine the amount of water that will accumulate at a particular point and then use [hydraulics](#) to determine the size of pipe channel or pipe needed to carry that amount of water.)

Hydrology: the science of water and its distribution in the air, on the surface, and underground.

Indicator Species: Certain species that are sensitive to changes within the stream system and can be analyzed in the context of the overall abundance of organisms in assessing the condition of the aquatic system.

In sloping: Sloping the entire surface of the road toward the steep uphill bank on one side of the road to eliminate drainage and [erosion](#) over the steep downhill embankment into any adjacent stream.

Intermediate or Climax Trees: Shade tolerant species having characteristics of being slow-growing, long-lived, and structurally strong, making them more desirable roadside trees for greater roadside stability and less maintenance.

Macroinvertebrates: Organisms within a stream ecosystem lacking a spinal column (invertebrate) but large enough to be seen by the naked eye (macro) – usually referring to species such as insect larvae (stoneflies, caddisflies, mayflies) that are used in evaluation of a stream's health.

Mitigation: The act of reducing or eliminating an adverse environmental impact, such as [wetland](#) mitigation where the destroyed [wetland](#) area is replaced with a new [wetland](#) of similar size and function.

Morphology: The form and structure or shape, as of a stream or rocks, in relation to the development of erosional forms or topographic features.

MSDS (Material Safety Data Sheet): A form required for all chemicals, dealing with safety in handling the material. The MSDS lists the manufacturer's name, address, and phone number; the major components of the chemical; its characteristics such as flammability and volatility, its reactivity, safety equipment needed to handle the chemical, and emergency procedures in case of spills or exposure.

Outside Inputs: Streamside vegetation such as leaves, branches, twigs, roots, and fruit that falls into or is washed into the water and becomes the basis for a food web in the stream.

Outsloping: Sloping the entire surface of the road toward the downhill side with a normal [cross slope](#), applied when the road crosses a gentle sloping terrain. Outsloping is similar to [superelevation](#) or banking of a curve, but on a straight section of road and with no ditching. The outsloped road blends into the gentle slope of the terrain with no ditching or cross pipes, allowing the natural sheet flow conditions to prevail.

Photosynthesis: The process by which plants are able to produce their own food, using sunlight and carbon dioxide from the air with the green chlorophyll of the plant to produce sugars (food) and give off oxygen back into the air.

Pipe Apron: The area immediately adjacent to a pipe outlet, which may need to be stabilized to prevent [erosion](#) and scour.

Plant Succession: The gradual and orderly process of ecosystem development brought about by change in the plant community composition and the production of a climax characteristic of a particular geographic region. In other words, plant succession starts with bare earth and over time transitions towards mature forest.

Riparian Buffer: A strip of undisturbed vegetation between sensitive areas, such as rivers, streams, [wetlands](#), ponds, etc., and areas of land disturbance and /or bare ground such as unpaved roads, work sites, etc.; protecting these sensitive areas from [sediments](#) and other pollutants carried by surface [runoff](#). [Wetlands](#) often serve as riparian buffers along streams, protecting the streams from direct [sediment](#) input.

Riprap: Stones or rock placed in locations such as ditches, channels, embankments, and pipe outlets, sized to resist movement and to prevent water [erosion](#) and scour of the underlying soils.

Road Cross Slope: The slope of the road surface from the road center to the outer edges, the normal unpaved road cross slope being ½” to ¾” vertical drop for every horizontal foot of road width.

Road Crown: The center of the road being higher than the outer edges, creating a flat A-shape with a normal [cross slope](#) of ½” to ¾” per foot for unpaved gravel roads. Road crown serves the major purpose of drainage the road surface, getting the water off of the road.

Road Stabilization: The process of uniformly crushing, pulverizing, and blending of the road materials, adding a stabilizing agent, mixing the agent with the blended material, spreading and regrading the road with proper crown, and compacting.

Runoff: surface drainage due to precipitation or snow melt.

Scuppers: Bridge deck drainage systems, usually openings that allow deck surface [runoff](#) to drop directly into the stream below.

Secondary Ditch: A problematic ditch formed along the edge of the road due to a build-up of material and vegetation immediately adjacent to the road edge, preventing water from effectively running off the road surface and into the roadside ditch or swale.

Sediment: Fine particles of inorganic and /or organic matter carried by water.

Sediment Load: The amount of [sediment](#) a stream carries under the existing flow conditions.

Sedimentation: The process of deposition of [sediment](#) in areas where water velocity is not high enough to carry the [sediment](#) along.

Silt Fence (silt fence barrier, filter fabric fence): A temporary [sediment](#) control measure used to intercept [sediment](#)-laden [runoff](#) from disturbed earth areas, typically made of a porous [geotextile](#) fabric and supported by wood or metal posts.

Subdrain (subsurface drain, underdrain): A subsurface drainage facility whose prime purpose is to drain the subsurface water out of and away from the road structure to an outlet. Effective subdrains consist of a [geotextile](#) lined trench with a perforated pipe and well-draining aggregate backfill, or other prefabricated systems.

Subgrade: The surface or soils upon which the road is constructed, usually shaped with a normal crown and [cross slope](#).

Superelevation: Sloping or “banking” the curve in the road with a uniform [cross slope](#) from one edge of the travelway to the other to offset centrifugal forces on vehicles for safer travel.

Through Drain: Cross [culverts](#) installed strategically to handle springs or spring seeps flowing perpendicular to the road, carrying the flow under (through) the road to the other side.

Topography: The configuration of a surface (land area) and the position of its physical and natural features and respective elevations.

Tracking (grooving, roughening): The practice of creating an irregular surface on a smooth bank by tracking up and down the bank with a track vehicle or any method of roughening or grooving the surface to catch rain water, reduce [erosion](#), increase water infiltration, trap [sediment](#), and enhance vegetative growth.

Turbidity: The degree to which suspended [sediment](#) interferes with light passage through water, the cloudiness exhibited by water carrying [sediment](#).

Upland: Areas of higher elevation that are well drained, covered with forests or cleared for farming or that have reverted to meadows. One of the three typical [ecosystems](#) – uplands, streams, [wetlands](#) - within an ecoregion.

Vegetative Filter Strip: Any vegetated area receiving water flows in order to spread the flow, reduce flow velocity, and filter out [sediment](#) from the flow prior to the water reaching a stream.

Wetland: “Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions,” as defined by the Federal Clean Water Act.

Water Table: The top surface of the free water in the ground and below is completely saturated.

Watershed (drainage basin, drainage area, catchment area): The area of land that drains all collected precipitation to a common low point or outlet.

References

Major Resource References: The following items are highlighted as major resources to accompany this manual:

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Technical Information Sheets



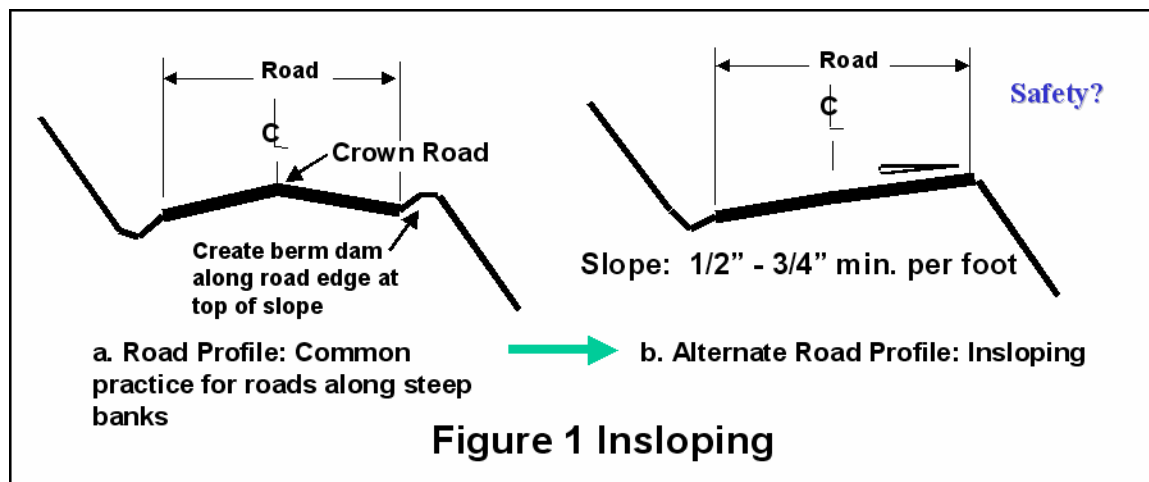
Technical Information Sheet Environmentally Sensitive Maintenance PRACTICES (ESMPs)

Practice: *ESMP #01 Insloping*

Category: Practices Relating to Road Profile

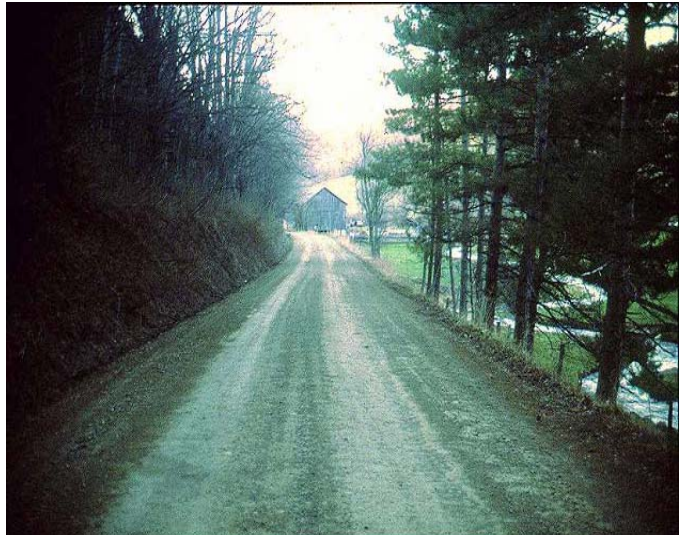
Refer to: Manual Chapter 5, Section 5.3.1.1

Description: [Insloping](#) is applied when the road has been constructed along a steep bank, with a steep uphill bank on one side and a steep downhill bank on the other side, ending at the edge of a stream. [Insloping](#) means the entire surface of the road slopes toward the uphill embankment side to eliminate drainage over the steep downhill embankment into the adjacent stream, as shown in Figure 1.



Common Practice and Associated Problems: With a steep uphill bank on one side and a steep downhill bank on the other, common practice is to install a normal [road crown](#). This practice concentrates drainage from half of the road toward the downhill side, causing [erosion](#) or severe washouts down over the bank, resulting in [sediment](#) into the stream. Sometimes a berm dam is installed along this edge of the road at the top of the slope. The berm dam creates a [secondary ditch](#), building up water volume and flow that will result in a washout over the embankment and again into the stream. The photo shows a prime candidate for [insloping](#).

Installation: The road is sloped entirely toward the uphill side using a normal [cross slope](#) (1/2" per foot). A roadside ditch collects the water and carries it to a strategically located cross [culvert](#) with proper outlet protection. Pipe flows should be directed to a [vegetative filter strip](#). A berm barrier can be constructed along the road at the top of the downhill embankment, if desired, for vehicle safety. Multiple crosspipes will lessen the amount of water to be handled by each pipe, keeping ditch and pipe sizes to a minimum along with minimizing the [erosion](#) potential at the pipe outfall.



Advantages:

- Eliminates flow over the downhill embankment
- Eliminates [erosion](#) on bank and [sediment](#) flow into stream
- Adds only one half of road surface [runoff](#) to ditch along uphill bank, eliminating need to increase size of ditch or cross pipes
- Allows all road drainage to strategically place cross pipes outletting to [vegetative filter strips](#), filtering out [sediment](#) and attached pollutants
- Additional crosspipes minimize volume and velocity of water, minimizing ditch and pipe size, adding to roadside safety

ESMP#01-01 Road candidate for insloping. Crosspipes can be strategically placed to outlet into the vegetative areas between the stream meanders.

Safety Considerations: Vehicle safety has to be considered. This practice should be used on a low volume road with a minimum [cross slope](#). A higher berm along the downhill side creates an additional safety factor. Attempting to keep shallow ditches on the uphill side with flattened foreslopes and additional crosspipes will add to safety regarding vehicles sliding on winter ice.

Related Practices:

- ESMP #02 Outsloping
- ESMP #11 Stream Saver System



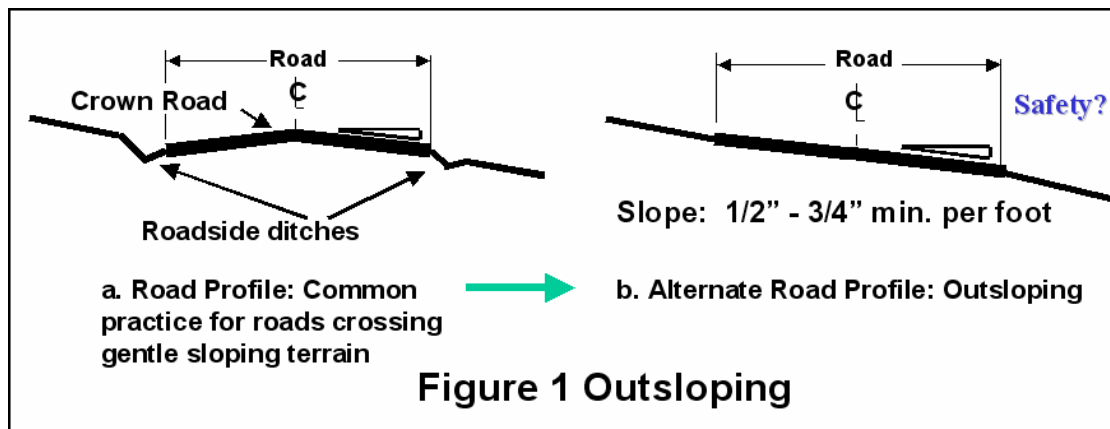
Technical Information Sheet Environmentally Sensitive Maintenance Pactices (ESMPs)

Practice: *ESMP#02 Outsloping*

Category: Practices Relating to Road Profile

Refer to: Manual Chapter 5, Section 5.3.1.2

Description: [Outsloping](#) is applied when the road crosses a gentle sloping terrain. [Outsloping](#) means the entire surface of the road slopes toward the downhill side with a normal [cross slope](#). [Outsloping](#) is similar to [superelevation](#) or banking of a curve, but on a straight section of road and with no ditching. The outsloped road blends into the gentle slope of the terrain with no ditching or cross pipes, allowing the natural sheet flow conditions to prevail, as shown in Figure 1. This technique should be used with *gentle sloping terrain and low overland flow conditions*.



Common Practice and Associated Problems: Common practice dictates a road with a normal crown and side ditches. This configuration creates a dam and concentrates the overland sheet flow, causing potential [erosion](#) of ditches and ditch outlets. This profile also requires cross pipes to outlet the uphill side ditch with the potential clogging and flooding concerns. The volume of water to be handled can become substantial.

Installation: The road is sloped entirely toward the downhill side using a normal [cross slope](#) (1/2" per foot). The outsloped road profile blends into the sloping terrain and there are no ditches or cross pipes. The uphill natural sheet flow continues down across the road and through lower vegetative filtering areas ([vegetative filter strip](#)).

The photo depicts [outsloping](#) of a road. The wooded area on the uphill side results in low surface [runoff](#). This [runoff](#) continues to sheet flow across the road and into the vegetative area on the other side. No ditches and no ditch maintenance required.



ESMP#2-01 Outsloped road showing no ditches and vegetative filtering areas for overland sheet flows.

Advantages:

- Eliminates concentrating the natural overland sheet flow. Eliminates [erosion](#) on bank and [sediment](#) flow into stream
- Eliminates ditches and cross pipes, eliminating [erosion](#) potential and maintenance
- Allows all road drainage to blend into the natural drainage system
- Has been successfully used for driveways crossing gentle sloping terrain, eliminating driveway ditch flows onto the main gravel road and ditches

Safety Considerations: Vehicle safety should be considered. Although the use of a normal [cross slope](#) helps in safety, the road surface condition, amount of flows and temperatures may cause icing of the road surface. Although this has not been the case on actual sites where [outsloping](#) has been constructed, conditions should be monitored closely during the winter months. In addition, a heavy storm may require road maintenance afterward if flows are substantial enough to cause road surface degradation. Again, this practice should be used on a low volume road crossing gentle sloping terrain with low overland flow conditions.

Related Practices:

- ESMP #01 Insloping
- ESMP #11 Stream saver system



Technical Information Sheet Environmentally Sensitive Maintenance Practices (ESMPs)

Practice: ESMP #03 Ditch Turnouts and Vegetative Filter Strips

Category: Practices Relating to Roadside Ditches

Refer to: Manual Chapter 5, Section 5.3.2.8

Description: All roadside ditches should be outletted to carry the water away from the road. Otherwise, the water will pond in the ditch, seeping back into the road structure, reducing its structural capacity and leading to road degradation.

Terminology varies from region to region with various descriptive terms used for outletting ditches. Ditch outlets, [ditch turnouts](#), tail ditches, and bleeders are all commonly used terms. Whatever you call it, the [ditch turnout](#) carries the ditch flow from the ditch, away from the road, and into a [vegetative filter strip](#). The

[vegetative filter strip](#) is an area of vegetation that filters out the [sediment](#) laden ditch water, increases water infiltration into the ground, and permits only clean [runoff](#) into a nearby stream. [Ditch turnouts](#) and [vegetative filter strips](#) should automatically go together.



ESMP#3-01 Standing water can only lead to problems!

Common Practice and Associated Problems: Do not outlet ditches directly to streams! Ditches carry surface [runoff](#) from the road and from the surrounding terrain along with any [sediment](#) and any contaminants attached to the [sediment](#). Outletting directly to the stream is common since the stream is usually at the low point of the road. But this allows [sediment](#) and pollution to go directly into the stream, adversely affecting the stream [ecology](#). Road personnel should turn ditches out prior to that low point into a vegetative filtering area to prevent stream pollution.

Installation: Turnouts can be installed during ditch cleaning operations. Turnouts should be skewed in the direction of water flow into a vegetative area. There are no exact spacing or size requirements for turnouts. Available charts do not take into consideration the many variables of specific sites, but may be used as guidelines. Road personnel need to consider the volume of water and ditch slope and the off right-of-way conditions and ownership. The volume of water can vary considerably depending on the terrain. The ditch may just drain the road surface or it may drain the road surface plus a major hillside area adjacent to the road. Road personnel should use their knowledge and experience when locating and constructing turnouts.

It is important to note that installing more turnouts limits the length of the ditch to each individual turnout. This in turn reduces the amount of water and flow within the ditch reducing water velocity and [erosion](#) potential and keeping the size of both the ditch and the turnout nominal. Limiting the amount of water that has to be handled should always be a consideration in any drainage situation. Refer to *ESMP#10 Through Drains*, for reducing water volume in ditches stemming from natural roadside springs.

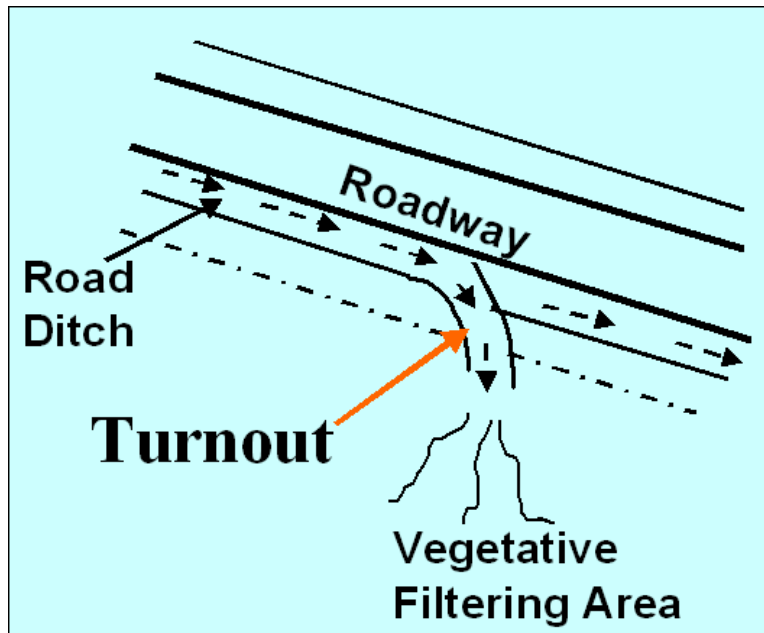


Figure 1: Ditch turnout into vegetative filter strip.

[Ditch turnouts](#) should be strategically located to direct flows to vegetative areas. Vegetative filters strips will spread the water flow, slow velocity, decrease energy, and



ESMP#3-02 Multiple small turnouts mean nominal size ditches with less water, less velocity, less erosion potential, although large sized turnouts may be the only option on certain sites.

filter out the [sediment](#). Other pollutants that may have attached to the [sediment](#) will also be contained and may be broken down physically or chemically by the soil or plants (refer to Manual, Chapter 4).

Advantages: The combination of [ditch turnouts](#) and [vegetative filter strips](#):

- Carries the water away from the road and keeps streams clean
- Multiple turnouts decrease the volume and velocity of the water that the turnout handles, thereby decreasing the energy and [erosion](#) potential and keeping a nominal size on ditch and turnout
- [Vegetative filter strips](#) slow the water, dissipate energy, and filter out [sediment](#) and other attached pollutants

Safety Considerations: [Ditch turnouts](#) and [vegetative filter strips](#) carry the water away from the road providing effective road drainage to prevent flooding and road structural deterioration.

Related Practices:

ESMP #04 Broad Based Dips

ESMP #05 Grade Breaks

ESMP #10 Through Drains

Manual Chapter 5, Section 5.3.2, Practices Relating to Roadside Ditches



Technical Information Sheet Environmentally Sensitive Maintenance PRACTICES (ESMPs)

Practice: *ESMP #04 Broad Based Dips*

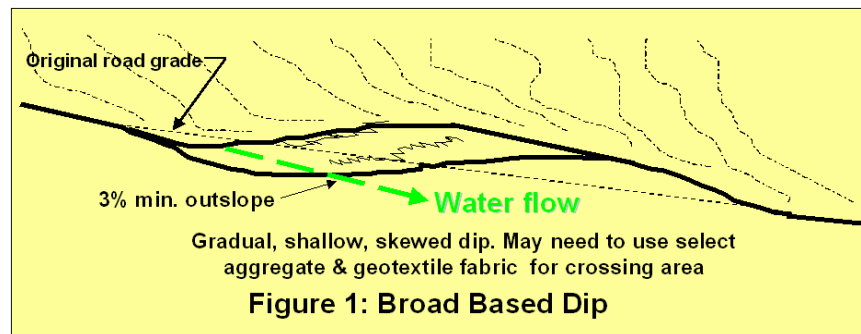
Category: Practices Relating to Ditches and Road Profile

Refer to: Manual Chapter 5, Section 5.3.3.1

Description: [Broad based dips](#) are shallow, gradual dips skewed across the road in the direction of water flow, as depicted in Figure 1. This practice is used where there is a

high embankment on one side of the road with a downhill grade. The high embankment does not allow for [ditch turnouts](#) and requires a cross pipe to carry the water to the other

side and then to an outlet. [Broad based dips](#) allow the ditch water to flow to the other side joining that ditch flow to a joint outlet or turnout to a [vegetative filter strip](#). The “dip” channel is skewed in the direction of water flow, and the crown of the road is eliminated within this area.



[Broad based dips](#) present an alternative to installing and maintaining cross pipes on very low traffic volume roads. [Broad based dips](#) should be used only for ditch flows and not for perennial streams with permanent or intermittent flows.



ESMP#3-01 Broad based dips can be used in lieu of cross-pipes.

Common Practice and

Associated Problems: Many roads have long downhill sections with a steep embankment on the uphill side, requiring ditches to be outletted through cross pipes or run from the top of the grade all the way to the bottom before they are outletted. Water volume and velocity continually increase as the flows run downhill, necessitating larger ditches and cross pipes to outlet the flow. Increased volume and velocity results in increased

[erosion](#) potential and flooding. In addition, water runs down the road surface, again picking up volume and velocity, and causes [erosion](#) gullies and rutting to occur. All of these factors lead to ever-increasing road maintenance and the associated increased costs.

Installation: [Broad based dips](#) can be graded into the road rather easily with the existing road materials. The bottom of the dip has to pick up the ditch flow, carry it across the road, and outlet to a [vegetative filter strip](#). [Broad based dips](#) eliminate the [road crown](#) within the dip area. Water volume must be contained in the channel with no overtopping, and longitudinal slopes must be gradual to prevent vehicles from dragging. Proper



ESMP#3-02 Broad based dip reinforced with large aggregate.

transitions must be constructed to blend to and from the [road crown](#). Test the dip by driving the road after installation.

There are no exact formulas for spacing or size for [broad based dips](#). These factors will depend upon many variables, such as road grade, traffic, volume of water, terrain, etc. The use of multiple [broad based dips](#) on a long downhill stretch of road also allows a smaller ditch size to carry the limited water volume from a shorter section or road. This limited volume of water should not have

substantial flow or velocity to do any damage to the road surface crossing. Steeper road grades require placing more [broad based dips](#) closer together to limit water volume and velocity. [Broad based dips](#) can be easily constructed with a grader or small dozer within a short time period using the existing road materials.

Select larger sized aggregate to fill the dip. [Geotextile](#) separation fabric may be required to reinforced and stabilize the dip, since we have traffic and water crossing perpendicular to one another. The need to reinforce the dip depends on water volume and velocity and the type of road material. (See Manual Chapter 7 and ESMP #15 for using [geotextile](#) separation fabrics.)

Road grader operators have to be aware of the [broad based dip](#) installations so that they do not think they are washouts or problem areas and reshape the road back to a normal crown. In addition, winter plow operators should be aware of these installations for proper and safe plowing operations.

Advantages:

- Breaks road into smaller sections for better drainage, handling less water with less velocity
- Allows the ditch to outlet across the road without a cross pipe
- Multiple [broad based dips](#) allow use of smaller sized ditches
- Reduces road surface water flows, eliminating damaging [erosion](#) gullies and ruts

- Outlets smaller volumes of water into vegetative filtering areas, providing for less [erosion](#) and greater [sediment](#) control

Safety Considerations: [Broad based dips](#) have a calming effect on traffic speed. [Broad based dips](#) also break the downhill momentum of vehicles, reducing the operator's chance of losing control.

Related Practices:

- ESMP #05 Grade Breaks
- ESMP #03 Ditch Turnouts and Vegetative Filter Strips
- ESMP #15 Road Separation Fabrics



Technical Information Sheet Environmentally Sensitive Maintenance Practices (ESMPs)

Practice: *ESMP #05 Grade Breaks*

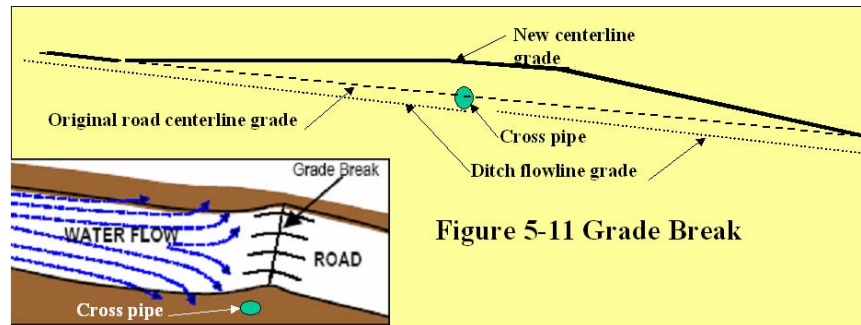
Category: Practices Relating to Ditches and Road Profile

Refer to: Manual Chapter 5, Section 5.3.3.2

(Adapted from the Pennsylvania Dirt and Gravel Roads Program, Technical Bulletin, 2/21/04)

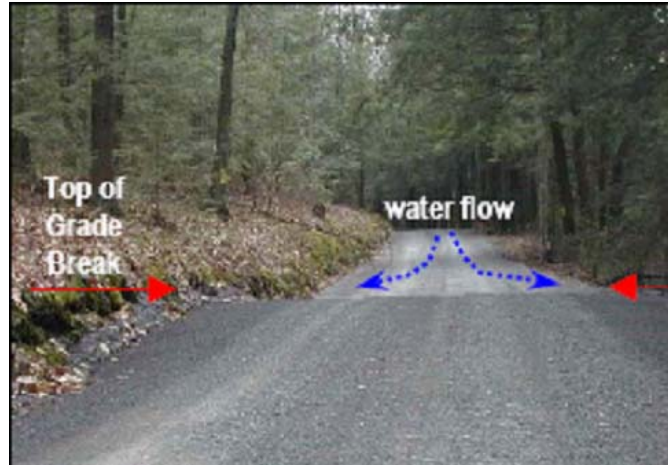
Description: [Grade breaks](#) are long gradual breaks in the longitudinal grade of a road on a downhill slope, as depicted in Figure 1, breaking the road into shorter lengths for more efficient drainage. [Grade breaks](#) retain the [road crown](#) and require appropriately placed cross pipes.

[Grade breaks](#) limit water flow by limiting the road section area to be drained. A shorter section of road decreases concentration and velocity, resulting in a smaller ditch cross pipe size. This reduction in water volume and flow in turn helps alleviate problems at the pipe outlet. [Grade breaks](#) also limit the length of flow and thus velocity down the road surface, eliminating potential surface [erosion](#) gullies and rutting.



Common Practice and Associated Problems: Many roads have long downhill sections where the ditches run from the top of the grade all the way to the bottom before they are outletted. Water volume and velocity continually increase as the flows run downhill, necessitating larger ditches and cross pipes to outlet the flow. Increased volume and velocity results in increased [erosion](#) potential and flooding. [Erosion](#) can be combated with additional ditch armoring, but that is very costly. Large flows through large pipes cause potential problems at the pipe outlet to dissipate the flow energy. In addition, water runs down the road surface, again picking up volume and velocity, and causes [erosion](#) gullies and rutting to occur. All of these factors lead to ever-increasing road maintenance and the associated increased costs.

Installation: There are no exact formulas for spacing or size for [grade breaks](#). These factors will depend upon many variables, such as road grade, traffic, volume of water, terrain, etc. Multiple [grade breaks](#) keep the road sections shorter for effective drainage and less [erosion](#) potential. Steeper road grades require placing more [grade breaks](#) closer together to limit water volume and velocity. [Grade breaks](#) can be constructed with a grader or dozer. It is important to gradually taper the [grade break](#) back into the road grade. Testing the longitudinal slopes by driving through the break at a reasonable speed will indicate whether additional work is needed. The [grade break](#) also needs to accommodate snow plowing without road surface damage.



ESMP#5-01

As shown in the above figure, a [grade break](#) can be installed at the location of the cross pipe. This allows the cross pipe to effectively meet the ditch gradient with the road being built up and over the pipe to create the [grade break](#). This eliminates the need to install the cross pipe at a much deeper elevation than the road ditch, resulting in additional potential for pipe blockage and road flooding. Pipe outlet areas need continual monitoring and [erosion](#) protection established as needed.

Road maintenance personnel, specifically the grader operator, must be aware of [grade breaks](#) and their purpose. An uninformed operator may see the [grade break](#) as a road surface deviation or consider the [grade break](#) as a source of extra road material to use elsewhere.

Advantages:

- Breaks road into smaller sections for better drainage, handling less water with less velocity
- Allows use of smaller sized ditches and cross pipes
- Smaller cross pipes decreases pipe outlet problems
- Eliminates damaging road surface water flows, eliminating gullies and ruts
- Outlets smaller volumes of water into vegetative filtering areas, providing for less [erosion](#) and greater [sediment](#) control

Safety Considerations: [Grade breaks](#) can actually have a calming effect on traffic speed. Grade breaks also break the downhill momentum of vehicles, reducing the operator's chance of losing control.

Related Practices:

ESMP #04 Broad Based Dips

ESMP #03 Ditch Turnouts and Vegetative Filter Strips



Technical Information Sheet Environmentally Sensitive Maintenance PRACTICES (ESMPs)

Practice: *ESMP#06 Driveways*

Category: Practices Relating to Driveways

Refer to: Manual Chapter 5, Section 5.3.4

Description: Driveways pose several problems or concerns not only for the road user, but also for road maintenance personnel. Safety for the road user and the property owner served by the driveway should be a priority. Safe ingress and egress with minimal interference with other traffic should be a goal in driveway construction. Many states have regulations regarding driveways entering the state road system. These regulations are good resources for local governments, since the only way to insure effective driveway construction and rehabilitation is through the adoption and enforcement of policies and regulations, necessitating a driveway permit system. This provides the needed control allowing the road manager to review the site and determine what needs to be done for proper drainage to protect the road and the environment and provide safe access for the property owner and a safe road for other drivers. With that said, this technical information sheet will deal with the one specific problem for road maintenance personnel that also affects road safety and the environment – *Drainage*.

Common Practice and Associated

Problems: If property owners are under no regulations and do not need to obtain a permit or notify the governing entity, the end result of driveway construction will most likely cause continual drainage problems and road safety hazards. Roadside ditches will be filled in, and driveways sloping down to the road will continue on a down slope right to the road edge. This condition will drain the driveway onto the road, creating hydroplaning in the summer and icing in the winter. Blocked drainage ditches, likewise, will flood the road and again cause these unsafe situations. Water ponding on the roadway and in the roadside ditch will seep into the road structure and began the degradation that will plague the road crew and shorten the life of the road.



ESMP#6-01 Improperly constructed driveways not only cause road drainage and road safety hazards, but also cause degradation of the environment through erosion and sediment.

Installation: Driveway installation must follow a few rules – the first of which is maintaining proper road and shoulder and ditch profile. Ditch flow has to be maintained.

For driveways sloping down toward the road, the low point should be over the ditch line, allowing both the road and driveway to drain into the ditch off either side of the driveway, as shown in Figure 1.

For driveways with deep ditches, a pipe under the driveway continues to carry the ditch flow. These driveway drainage pipes may have nominal cover and have to be strong enough to support the vehicle loads. Refer to ESMP#09 for alternatives in shallow [culvert](#) installations.

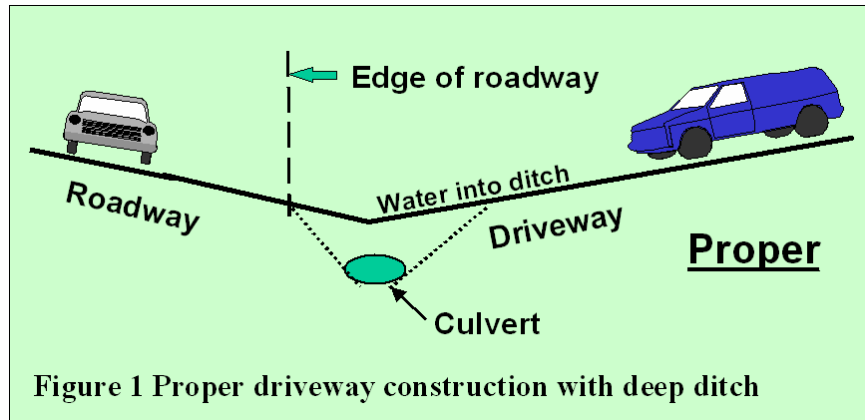


Figure 1 Proper driveway construction with deep ditch

For driveways with medium depth ditches, an open-top [culvert](#) or a box with an open grate may suffice, as shown in Figure 2. These units can be prefabricated or homemade. The photo insert in the figure pictures two types of prefabricated units, one all-plastic and one of a combination of plastic and metal.

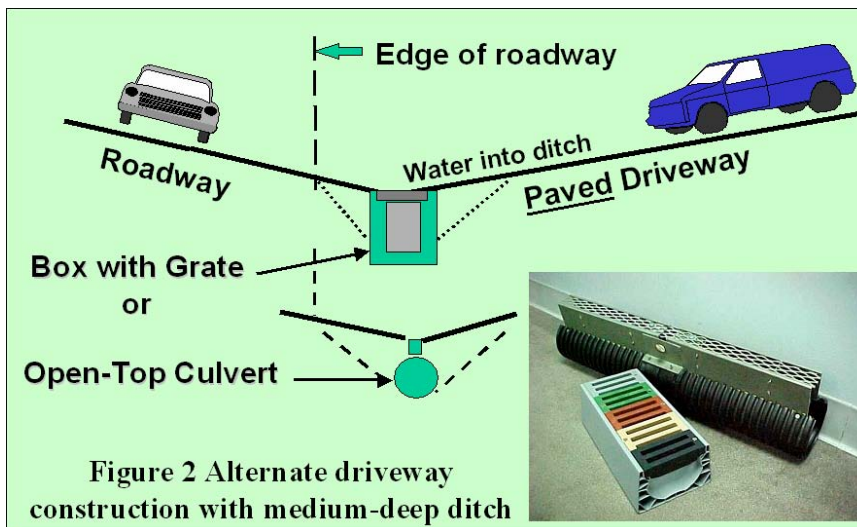


Figure 2 Alternate driveway construction with medium-deep ditch

one of a combination of plastic and metal. This system should only be employed for paved driveways, which will only drain clean surface [runoff](#) into the channel without clogging the grate.

In many instances, the roadside ditch will be shallow with nominal flows. In this case the ditch may continue across the driveway, as shown in Figure 3. Vehicles should not have any problem traversing a shallow ditch carrying only ditch flows during storm events. This area may require stabilization and reinforcement through the use of larger aggregate and/or a [geotextile](#)

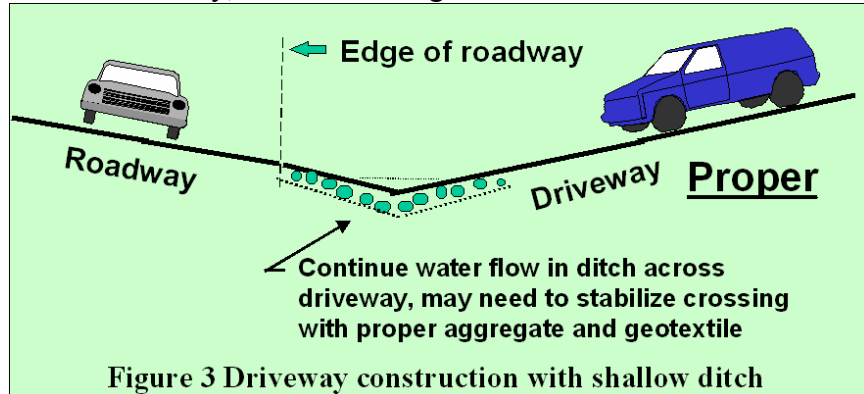


Figure 3 Driveway construction with shallow ditch

separation fabric. The need to reinforce the crossing depends on water volume and velocity and the type of driveway material. [Geotextile](#) separation fabrics are discussed in the Manual, Chapter 7 and ESMP #15.

Advantages:

- Regulations and driveway permits give the road manager the authority to enforce proper conditions at the driveway site to meet drainage and safety requirements
- Properly constructed driveways:
 - Maintain roadside ditch flows, preventing blockage and flooding
 - Maintain proper road surface drainage off of the road
 - Eliminate water on the road surface which could cause hydroplaning or icing
 - Maintain road structural adequacy by keeping water out of the road structure.
 - Eliminate [erosion](#) and [sediment](#) from block ditches or road surface ponding, thereby protecting the environment.

Safety Considerations: These practices maintain proper drainage off, out of and away from the road, keeping the road safe, eliminating the potential hydroplaning and icy conditions. The driveway will also be safer due to proper drainage and less degradation.

One safety factor to keep in mind: if a box with grate facility is homemade, use appropriately sized openings in the grate that will not be a safety hazard to animals or bicycles.

Related Practices:

- ESMP #07 Culvert End Structures
- ESMP #08 Aprons at Culvert Outlets
- ESMP #09 Shallow Culvert Installations
- ESMP #15 Road Separation Fabrics



Technical Information Sheet Environmentally Sensitive Maintenance Pactices (ESMPs)

Practice: *ESMP #07 Culvert End Structures*

Category: Practices Relating to Culverts

Refer to: Manual Chapter 5, Section 5.3.5.3

Description: A [culvert end structure](#) is simply a structure built at a pipe opening, either at the pipe's entrance or outlet end. The terms headwall and [endwall](#) are also used interchangeably, again referring to [end structures](#) for the drainage pipes or [culverts](#).

Common Practice and Associated Problems: Many pipes are installed without any consideration for [end structures](#). The end areas of roadway cross pipes transporting ditch water from side of the road to the other are prime targets for [erosion](#) and [sediment](#). The pipe redirects the water flow, turning it through the pipe and across the road. This redirection of flow causes turbulence resulting in [erosion](#) around the pipe opening. Where there are close roadside embankments, gouging out the bank to install the crosspipe enhances the [erosion](#) potential if bare soil remains, as shown in the photo.



ESMP#7-01 Typical process of gouging out the roadside bank to install a cross pipe for ditch flow with no end structure leads to continual erosion and maintenance.

Even when water flows directly into and out of a pipe, these straight transitions are prone to [erosion](#). Water flow into the pipe is usually restricted by the pipe opening, causing turbulence and possible [erosion](#) around the pipe entrance. Since the pipe restricts flow, the water travels faster through the pipe and out the other end. As the flow emerges from the pipe, eddy currents cause swirling flows on each side, leading to [erosion](#) around the pipe, as depicted in Figure 1. [End structures](#) can solve the [erosion](#) problem and provide other benefits as well, as described below.

Installation: Materials vary from concrete, flagstone or native stone to [gabions](#) or prefabricated units. Consequently, the cost of installation can vary as much as the material being used. Native stone not only becomes cost effective since it may be available on site, but it is also environmentally aesthetic, blending into the natural



conditions. Several factors may influence the choice of materials, including local availability, skill and time required for construction, durability, cost, and volume and velocity of water to be handled. The photos show different types of [end structures](#), including a [geosynthetic](#), prefabricated unit.

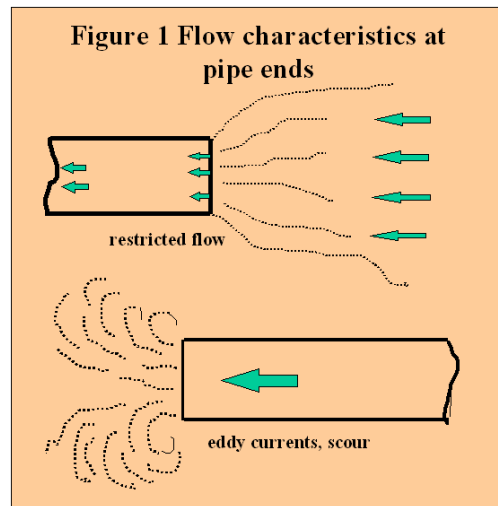
The shape of the [end structure](#) is important to direct water flow, protect the road and embankments, and improve drainage. The [end structure](#) should funnel the water into the pipe while protecting the

ESMP#7-02

surrounding area from [erosion](#). On the inlet side, [end structures](#) direct the flow into the pipe, reducing turbulence and maximizing the flow capacity of the pipe. Outlet structures prevent erosive back eddy currents from undermining the pipe and road structure.

Cross pipes should be installed on an angle (skewed – not perpendicular) across the road in the direction of water flow for smoother flow transitions into and out of the pipe to further reduce [erosion](#) potential.

[Culvert end structures](#) may not be enough to protect against [erosion](#) at the pipe outlet. Further [erosion](#) protection may be needed in this “[apron](#)” area past the structure. [Culvert aprons](#) including the use of [flared end sections](#) are covered in Technical Information Sheet ESMP#08 referenced below.



Advantages:

- Prevents [erosion](#) from occurring around the pipe opening
- Provides a low-cost, long lasting solution to [erosion](#) problems at pipe openings
- Reduces continual maintenance needed to address the [erosion](#) and [sediment](#) and clogging of the pipe
- Provides structural support for the road

- Anchors the [culvert](#) providing structural support and preventing crushing of the pipe end by heavy vehicles

Safety Considerations: [Culvert end structures](#) increase safety by providing structural support to the roadway and to the [culvert](#). There are also many designs to enhance roadside safety as to errant vehicles, as well as providing the other benefits described above. One such design is depicted in Figure 2.

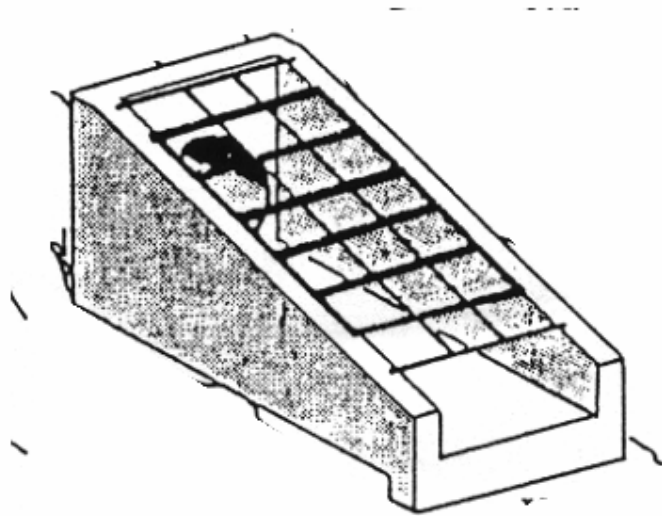


Figure 2: Vehicle safe end structure for roadside embankment

Related Practices:

- ESMP #08 Aprons at Culvert Outlets
- ESMP #09 Shallow Culvert Installations



Technical Information Sheet Environmentally Sensitive Maintenance PRACTICES (ESMPs)

Practice: *ESMP #08 Aprons at Culvert Outlets*

Category: Practices Relating to Culverts

Refer to: Manual Chapter 5, Section 5.3.5.4

Description: Aprons at culvert outlets refer to the immediate area at a pipe outlet. Culvert outlets, even with an end structure, may still pose a problem with the flow discharge energy. A conveyance channel may need to be created to a stable discharge point. A simple flared end section may suffice as an apron to spread the water flow and dissipate the erosive energy. Other materials, however, can be used as culvert aprons, or used in conjunction with flared end sections to extend the stabilizing apron area.

Common Practice and Associated Problems: Many pipes are installed without any consideration for erosive energy potential of the exiting water. Since flow is usually restricted by a pipe, the water travels faster through the pipe and out the other end. As the flow emerges from the pipe, dissipation of the flow energy is often needed to prevent erosion. This apron area is often neglected and can lead to severe erosion and maintenance headaches, as shown in the photo.



ESMP#8-01 Severe erosion at a pipe outlet.

Installation: This is one area where rock riprap can be very effective. The rip-rap will spread the water flow, slowing it down and dissipating energy. Native stone becomes the cost effective aesthetic material choice, but, depending on location, even brush and tree stumps can be effective. The size of rock and the dimensions of the apron

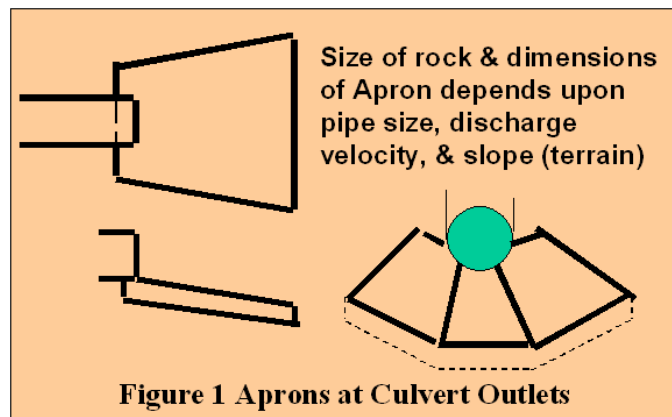


Figure 1 Aprons at Culvert Outlets

depend on many variables such as pipe size, soil type, the discharge volume and velocity,

and the slope of the outlet channel or terrain. Although there are charts available that can be used as guidelines, [apron](#) installation should not be technically challenging. Experienced road personnel know the amount of water flow and the potential problems at a specific site. They can size the [apron](#) based on their past experience. Then, they need to follow up with field inspections during and after the next several rainstorms. If [erosion](#) is evident past the [riprap](#) limits, expand the [apron](#) and inspect again.



[Flared end sections](#) can be metal, concrete or plastic. As mentioned, these pre-fabricated sections may be enough to transition the flow to a stable discharge, or may be used in conjunction with other materials, such as [riprap](#). The [flared end section](#) initiates spreading the flow and protects against those swirling eddy currents on each side of the pipe opening, while the [riprap](#) further spreads the flow and dissipates the flow energy eliminating the [erosion](#) potential. Typical [flared end sections](#) are shown in the photo.

ESMP#8-02 Rock riprap makes an effective apron to dissipate energy and prevent erosion at the pipe outlet.

- Provides a low-cost, long lasting solution to [erosion](#) problems at pipe openings
- Helps anchors the [culvert](#), providing structural support

Advantages:

- Prevents [erosion](#) from occurring around the pipe opening, reducing maintenance

Safety Considerations: [Culvert aprons](#) prevent [erosion](#) of outlet ditches, eliminating the vehicle drop-off potential in roadside ditches.

Related Practices:

ESMP #07 Culvert End Structures

ESMP #09 Shallow Culvert Installations



ESMP#8-03 Typical Flared End Sections.



Technical Information Sheet Environmentally Sensitive Maintenance Practices (ESMPs)

Practice: ESMP #09 Shallow Culvert Installations

Category: Practices Relating to Culverts

Refer to: Manual Chapter 5, Section 5.3.5.1

Description: Roadway cross pipes are subjected to a variety of forces and loads. The weight of the backfill material above the pipe is a concern in deep installations. Many drainage cross pipes, however, are placed at a shallow depth to better accommodate the flow of water from roadside ditches. Vehicle loading due to the weight and movement of the vehicle is significant in these shallow installations. (See Manual Chapter 5, Section 5.3.5 for a discussion on traffic load distribution.) Road managers should consider various alternatives in those installations where proper cover cannot be maintained. This technical information sheet addresses several alternatives for shallow pipe [culvert](#) installations.

Common Practice and Associated Problems: Because of site conditions, depth of drainage ditches, water flow, etc., many cross pipes are installed without sufficient cover and with no consideration of the traffic loading. These shallow installations are subject to failure under traffic loads. In particular, flexible type pipe tends to deflect under traffic



ESMP#9-01 Shallow pipe installations can cause continual road deterioration.

loads, causing road materials to shift resulting in road surface degradation and possible pipe failure. The more shallow the pipe, the greater the direct force from vehicles, and the greater the deflection and resulting damage. A minimum of 12 inches of cover material over the pipe and below the road material minimizes or dissipates the traffic loads. Pipes larger than 24-inch diameter may need additional cover. The required cover, however, cannot always be met in many situations, and the pipe becomes a shallow installation. In

addition, the road surface area directly above the pipe becomes a maintenance headache with continual surface degradation.

Installation: There are several alternatives to improve shallow installations:

Rigid Pipe: A rigid pipe (concrete, cast iron, steel) has the strength to resist deflection under the traffic loads to the detriment of the road.



Figure 1: For shallow installations, use rigid pipe, pipe arch, or elliptical concrete (rigid) pipe



Elliptical Pipe or Pipe Arch (“Squash Pipe”): Pipe arch not only allows proper flow capacity but also allows additional cover. An equivalent 18-inch diameter corrugated metal pipe arch is only 15 inches in height. That extra three inches of additional cover is significant in further distribution (reduction) of traffic loads. Rigid pipe also comes in an elliptical shape allowing extra cover in addition to the extra

strength factor of the pipe itself. See Figure 1 with accompanying photos.

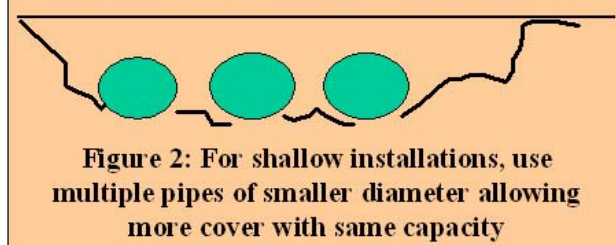
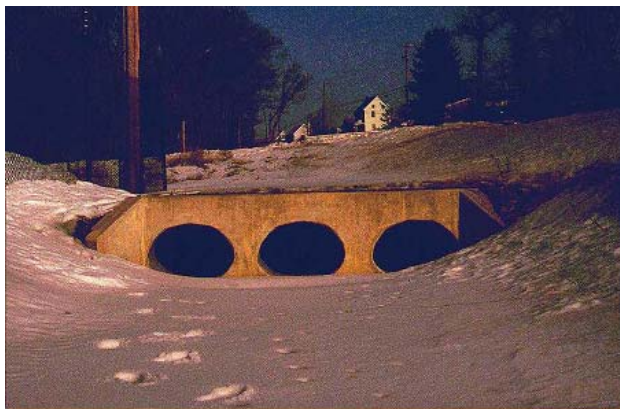


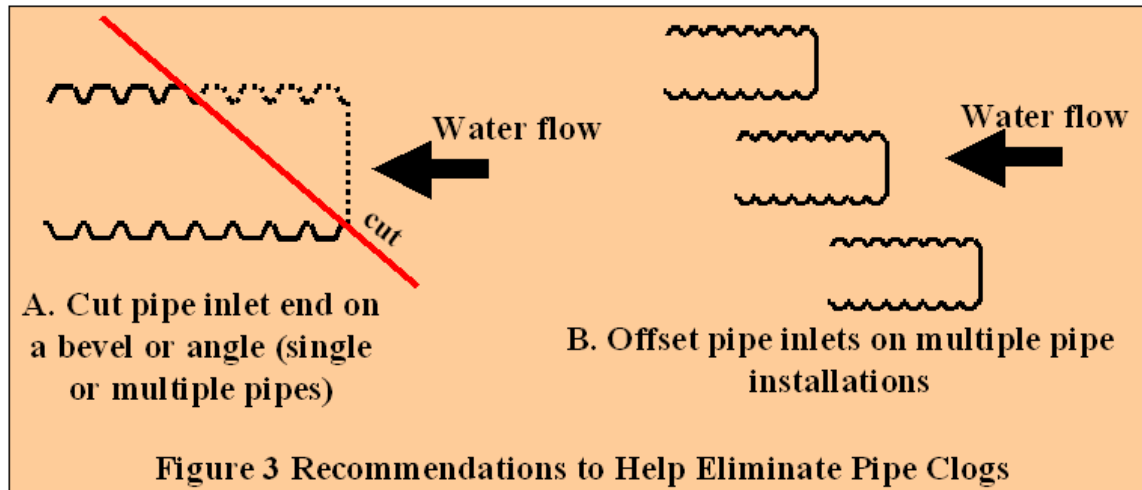
Figure 2: For shallow installations, use multiple pipes of smaller diameter allowing more cover with same capacity

Multiple Pipes: Multiple pipes are another alternative. Multiple pipes of smaller diameter allow more cover but still provides adequate flow capacity (see Figure 2). To use multiple pipes, however, road mangers must keep a few rules in mind. Flow capacity is directed related to the area of the pipe opening. This means that two 12-inch diameter pipes do not equal the flow capacity of one 24-inch diameter pipe. The area of a circle (the opening of the pipe) is πr^2 or 3.14 times the radius squared. A 24-inch diameter pipe has 452 square inches of opening ($3.14 \times 12 \times 12$). A 12-inch

pipe has 113 square inches, or two 12-inch pipes have a total of 226 square inches of opening. It would take four 12-inch pipes to equal the flow of one 24-inch pipe ($4 \times 113 = 452$ square inches). Using three 15-inch pipes or two 18-inch pipes would give additional flow capacity and still maintain greater cover over the pipes.

Another rule for multiple pipes is to make sure they are installed far enough apart to allow adequate backfill compaction between the pipes for the compaction equipment being used.

One of the concerns voiced in multiple pipe use is clogging. Any pipe can clog. One of the simpler solutions for metal or plastic pipes is cutting the inlet end of the pipe on a slant or bevel. Any debris flowing toward the pipe will tend to ride up the slant, which will allow water to continue through the pipe. For multiple pipes, staggering the inlet ends so that they are not parallel in one line perpendicular to flow will lessen the probability of clogging. Each pipe inlet end is extended a little further (offset) from the pipe beside it. When large debris, such as tree limbs or logs, come downstream, they will either block only one pipe or be forced to an angle, skewing across the pipe entrances, but allowing water to continue to flow through the pipes (see Figure 3).



Advantages:

- The use of rigid pipe diminishes the potential of pipe failure and road surface degradation.
- Elliptical or pipe arches allow adequate cover over cross pipes to protect the pipe and the road.
- Multiple pipes allow adequate cover over cross pipes to protect the pipe and the road.
- Cutting pipe inlet ends on a slant and offsetting multiple pipes reduces potential clogging and the resulting flooding of the road and environment.

Safety Considerations: Shallow [culvert](#) alternatives will keep the road and cross pipe(s) in good condition, eliminating the safety factors surrounding road degradation or pipe failures.

Related Practices:

- ESMP #07 Culvert End Structures
- ESMP #08 Aprons at Culvert Outlets



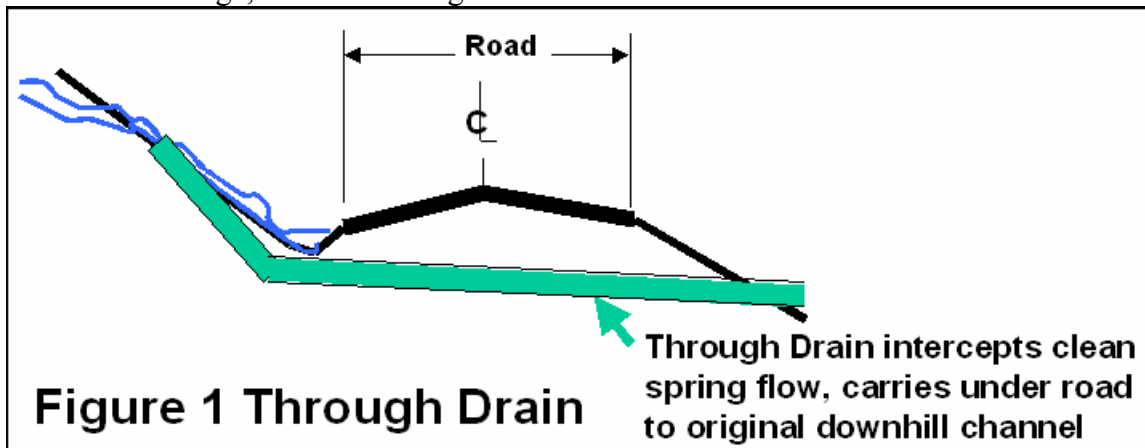
Technical Information Sheet Environmentally Sensitive Maintenance Practices (ESMPs)

Practice: *ESMP #10 Through Drains*

Category: Practices Relating to Culverts (and Roadside Ditches)

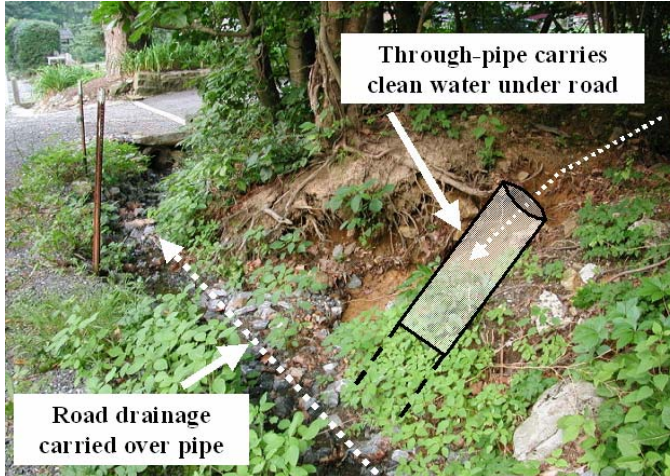
Refer to: Manual Chapter 5, Section 5.3.5.5

Description: Through drains are cross culverts that are strategically placed to handle natural springs or spring seeps flowing perpendicular to the road and carry them under (through) the road to the other side to continue in the original channel prior to the road's existence. Many roads intercept native ground water flows in this manner. The through drain allows this natural flow to continue without entering the road ditch or interfering with road drainage, as shown in Figure 1.



Common Practice and Associated Problems: Common practice allows natural springs of clean water to flow into the road ditch, mix with often sediment-laden ditch flows, and then flow directly to a stream. The additional flows can be substantial during certain periods of the year, such as during the spring rains, causing flooding of the road ditch and road degradation. Even if flooding does not occur, this added volume has to be handled by oversized ditches, increasing the erosion and sediment potential of the combined ditch and spring flows. In addition, substantial flows diverted into streams could adversely affect the stream ecology.

Installation: [Through drain](#) should be installed wherever natural spring flows are intercepted by the road and are carried by the roadside ditch and the surrounding terrain and off right-of-way conditions allow installation. The [through drain](#) pipes are placed to pick up the natural spring waters and carry them under the road, outletting on the other side into the original downhill flow channel. This eliminates the usually clean water from



entering the road ditch, thus keeping the water clean as it continues in its original path prior to the road's existence. The photo depicts typical placement of a [through drain](#).

The [through drain](#) outlet has to be stabilized as to flow volume and energy. If the natural spring waters have been flowing into the ditch for a number of years, the natural channel on the downhill side may be nonexistent. This channel may have to be reestablished, providing proper [erosion](#) prevention until the channel is stabilized.

ESMP#10-01 Through Drains keep springs and spring seeps out of road drainage facilities.

Advantages:

- Maintains clean natural spring waters as clean water
- Eliminates handling of this water volume via the road ditch, reducing ditch size
- Reduces ditch flow reduces [erosion](#) potential and resulting [sediment](#)

Safety Considerations: [Through drain](#) will decrease ditch size and reduce the flooding and road degradation potential, keeping the road and roadside safer for vehicles.

Related Practices:

- ESMP #07 Culvert End Structures
- ESMP #08 Culvert Aprons



Technical Information Sheet Environmentally Sensitive Maintenance PRACTICES (ESMPs)

Practice: *ESMP #11 Stream Saver System*

Category: Combination Practices

Refer to: Manual Chapter 5, Section 5.3.6.1

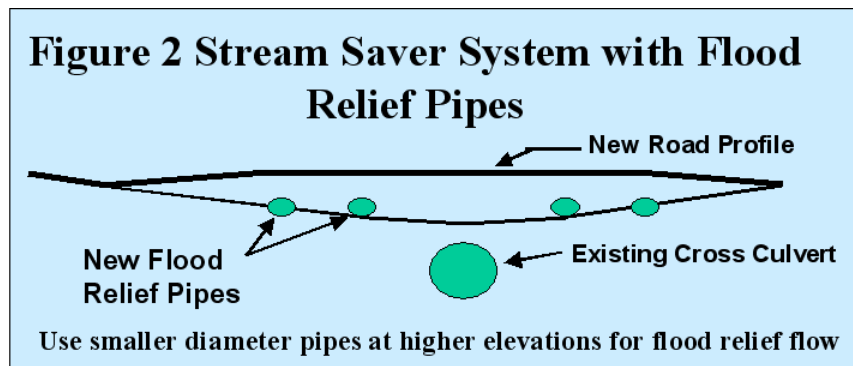
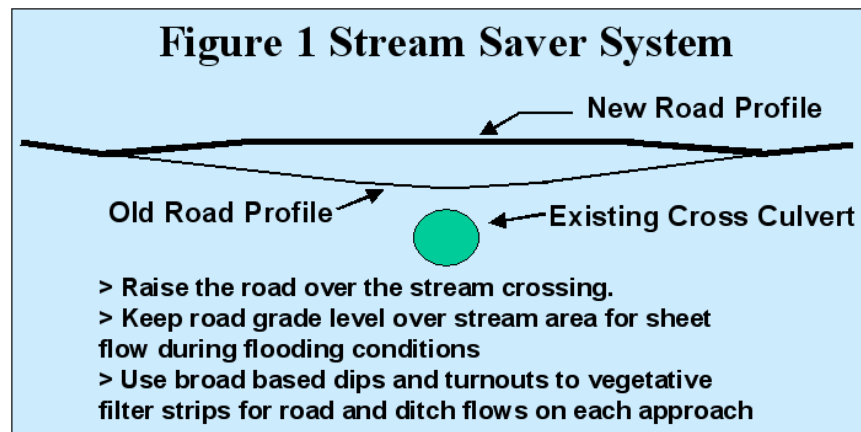
Description: The Stream Saver System raises the road profile over the low-point stream crossing; the road surface remains level for an extended area away from the stream on both sides, as

shown in Figure 1.

If the cross pipe cannot handle the flow, this level road allows sheet flow across the road during flooding conditions with less [erosion](#) potential.

Using [broad based dips](#) and turnouts into vegetative filtering areas for the road and ditch drainage on each approach as conditions warrant

avoids direct discharge into the stream and alleviates some flood flow. If pipe capacity is severely limited, a flood relief crossing can be established away from the stream depending on the existing terrain and land use. This crossing should be a stabilized low water crossing (refer to Chapter 7, Section 7.4.3.8.3 for a description of a stabilized low water road crossing using [geosynthetics](#)).



In raising the road, additional pipes installed at higher elevations allow for flood flow relief, as shown in Figure 2. Depending on the depth of material used to create the new road profile, the additional flood

relief pipes can be laid with minimal or no excavation. During major storms, these flood relief pipes handle the extra flow, minimizing overtopping the road thus preventing road deterioration.

Common Practice and Associated Problems: Common practices followed the traditional topographical site conditions where the road's low point was directly over the stream. This condition seemed to be the most practical way of draining the road. Roadside ditches could be carried to the low point and outletted directly to the stream with a cross [culvert](#) carrying the stream under the road. In analyzing the existing problems at these sites, however, this procedure was not the best for the road and definitely not the best for the environment. When all surface and ditch flows drain directly into the stream, they carry all of the road's [sediment](#) and pollutants with them. When major storms hit, creating flows beyond the [culvert](#)'s capacity, the low point of the road became the v-shaped channel, narrowing the overflow across the road, increasing the flow energy and causing [erosion](#) of the road surface, again directly into the stream.

Installation: Every site will have different requirements. The installation basics, however, are the same. Add enough road material to raise the road over the stream with a level grade extended in each direction for 50 to 100 feet. Use [ditch turnouts](#) into [vegetative filter strips](#) for roadside ditches on each approach. Use [broad based dips](#), [grade breaks](#), or additional cross [culverts](#) as needed on each approach to break up the surface [runoff](#) from the road and surrounding terrain and handle effectively prior to the stream. Refer to the individual technical information sheets on these additional techniques for more detailed information.



ESMP#11-01 Stream Saver System – raised level road with ditch turnouts to vegetative filters.

Advantages:

- Eliminates surface drainage and any [sediment](#) from the road and roadside ditches directly into the stream, protecting the stream and the environment
- Raises the road to reduce flooding and surface [erosion](#), establishing a level surface for lower energy sheet flow, with much less road deterioration
- Provides additional flow capacity for flood flows as needed (by installation of additional flood relief pipes)

Safety Considerations: Stream Saver Systems protects the structural stability of the road, keeping the road safer. Road deterioration from flooding and surface [erosion](#) will be minimal.

Related Practices:

ESMP #03 Ditch Turnouts and Vegetative Filter Strips

ESMP #04 Broad Based Dips

ESMP #05 Grade Breaks

ESMP #07 Culvert End Structures

ESMP #08 Culvert Aprons

ESMP #12 Raising the Entrenched Road

Many other practices can be used in conjunction with the Stream Saver System as the site conditions may warrant.



Technical Information Sheet Environmentally Sensitive Maintenance Practices (ESMPs)

Practice: ESMP #12 Raising the Entrenched Road

Category: Major Reconstruction

Refer to: Manual Chapter 5, Section 5.3.7

Description: Raising an entrenched road involves major filling of the road cross section between high banks, bringing the road surface back up to the original road surface elevation. When you look at the photo, you see a typical entrenched road in a forested area. Usually entrenchment results from years of traditional road maintenance involving road grading, shoulder cutting, ditch cleaning and widening. As the road profile drops, or becomes entrenched, water draining to the road is trapped and the road begins to function as a channel. Restoring the road to its original surface elevation eliminates a multitude of problems and maintenance headaches.



ESMP12-01 A typical entrenched road.

Common Practice and Associated Problems: Although common road maintenance practices naturally lead to an entrenched condition, we continue year after year making the situation worse. (Refer to chapter 5, Section 5.3.7, for a detailed description and photo sequence of road entrenchment over the road's life.) An entrenched road becomes the stream channel, even as ditch size continues to increase in an attempt to handle the entrenched flows. Flooding and surface deterioration along with a saturated road structure create ongoing maintenance to keep the road usable. Snow removal becomes an increasing problem with the plowed snow piling up against the high banks, adding to the water problem. As the above photo depicts, these roads have severe drainage, [erosion](#) and [sedimentation](#) problems requiring continual maintenance. All these problems can be eliminated by bringing the road surface back up to the original elevation.

Installation: Installation involves substantial fill and a major work effort. Fill material is expensive, but obtaining free fill material and using in-house equipment and operators can offset costs. Various types of fill material can be used. A new road with good road material can then be built on top of the fill material. The road surface is built back up to its original elevation, eliminating the banks on both sides and providing for excellent road drainage conditions with much less [erosion](#) and [sediment](#) pollution. Figure 1 shows the typical entrenched roadway before and after filling, completely eliminating the bank on one side and reducing the bank height on the other side.

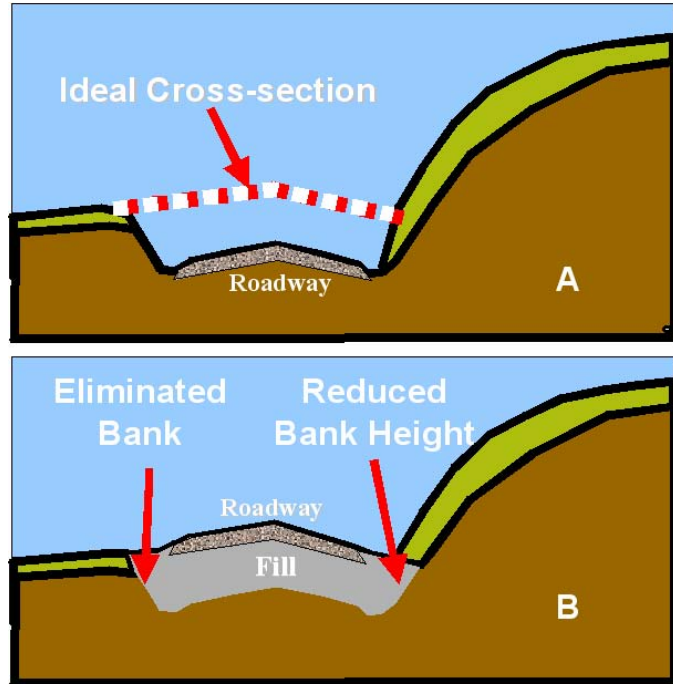


Figure 1: Raising the Road

Drainage can then sheet flow off the road without a ditch on the one side.

The road will no longer be a drainage channel, experiencing far less road surface deterioration. Snow removal becomes easier, and the removed snow will not be a future source of water back into the road.

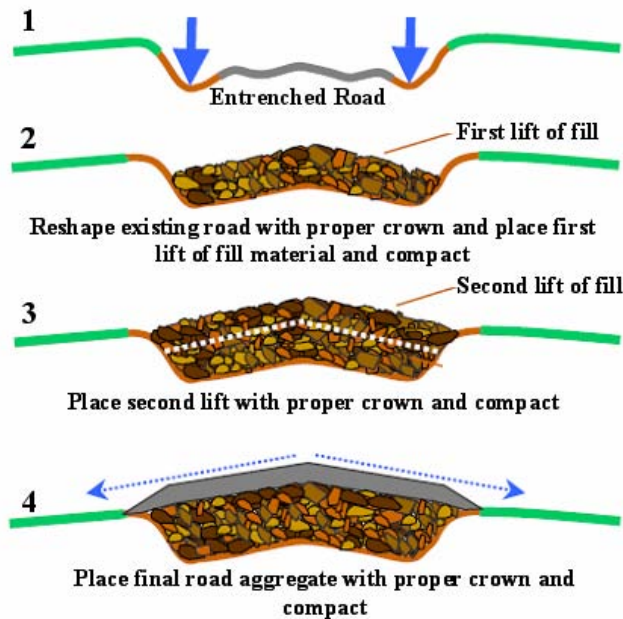


Figure 2: Construction Sequence

Figure 2 shows the construction sequence, beginning at the top with an entrenched road cross section. The entrenched road traps road drainage on the road and in the parallel ditches. To prepare for raising the road, proper crown is needed on the existing road. Then each lift of material is placed in uniform 8- to 12-inch lifts with proper crown of $\frac{1}{2}$ -inch to $\frac{3}{4}$ -inch per foot and compacted. Compaction is critical. A large static roller, vibratory roller or sheep's foot roller should be used to thoroughly compact each lift of fill material. [Geotextile](#) separation

fabrics or geogrids between lifts will add strength to the road base. (See Chapter 7, Section 7.4.4.6 and ESMP #15 for using separation fabrics and Section 7.4.4.8 for geogrids.) The road is then reconstructed on top of the fill using good road aggregates.

The road material is placed with the proper crown and compacted the same as the fill material.

The photos show an entrenched road project from the start of the filling operation to the final road surface being compacted.



ESMP12-02 Raising the entrenched road—step-by-step.

When the road is immediately next to a stream, the procedure is slightly different. In this example, the road has a high embankment on one side and falls steeply off directly into the stream on the other side.

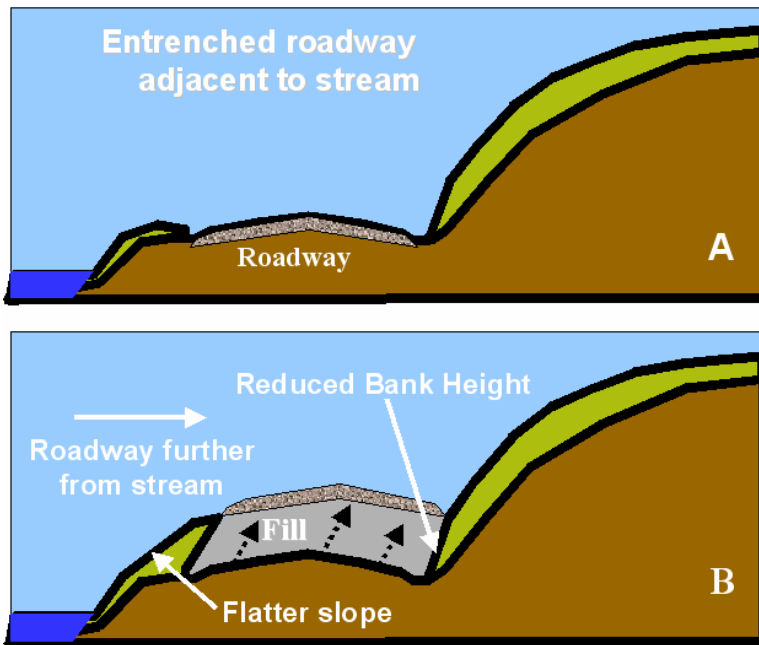


Figure 3: Raising the Road & moving away from the stream

The road is entrenched with side ditches, as shown in Figure 3. As also depicted in the figure, the road is raised upslope away from the stream, eliminating the entrenchment on the stream side. This allows for sheet flow across additional vegetated area. The high embankment on the other side is reduced with better stability and drainage control. Depending on site conditions, the implementation of [insloping](#) would provide additional benefits.

Advantages:

- Allows road surface drainage to sheet flow off the road through vegetated areas reducing [erosion](#) and the resultant [sediment](#) pollution
- Eliminates ditches and ditch maintenance in terrain where sheet flow can be established
- Eliminates concentration of water trapped in an entrenchment, prolonging the life of the road with less maintenance
- Allows for more efficient snow plowing, removing the snow away from the road and eliminating snow melt back into the road structure

Safety Considerations: Raising the entrenched road helps maintain the road in a safe condition with no flooding and far less surface [erosion](#) and rutting.

Related Practices:

ESMP #11 Stream Saver System

ESMP #15 Road Separation Fabrics

Manual Chapter 7, Section 7.4.4 Geosynthetic Applications in Road Maintenance

Many other practices can be used in conjunction with raising the Entrenched Road as the site conditions may warrant.



Technical Information Sheet Environmentally Sensitive Maintenance PRACTICES (ESMPs)

Practice: ESMP #13 Slope Geometry, Benching, and Diversion Swales

Category: Practices Related to Road and Stream Banks

Refer to: Manual Chapter 6, Sections 6.4.2.1, 6.4.2.2, 6.4.2.3

Description: Slope geometry, benching, and [diversion swales](#) are all related to bank stability. Whether the bank requires stabilization and what practice or practices will be the most appropriate remedy can only be ascertained from a initial site visit that includes a thorough review and analysis of conditions. To determine the stability of a bank, we



ESMP#13-01 Eroded roadside banks are common sights, but add up to a large erosion and sediment pollution problem effecting both roads and the environment. Site investigation and corrective actions are essential.

must consider the site's [topography](#) along with the soils, drainage conditions, and vegetation (Chapter 6, Section 6.4.1). Based on this site investigation, the selected practices can be effectively implemented. [Diversion swales](#) are used where a vast area drains down toward the road, adding significant surface drainage flows down over the road embankment to the roadside ditch. The [diversion swale](#) will divert the upslope surface flow away from the road and roadside ditch. Slope geometry has to do with the degree or steepness of the bank itself and the bank's surface condition. Flattening slopes and roughening or grooving the bank surface are practices that alter the slope geometry for greater stability. Benching is the establishment of a [bench](#) or step or multiples steps across a steep bank to aid in stability. Each practice is described in detail below.

Common Practice and Associated Problems: Common road maintenance practices tend toward cutting the toe of slopes ([bank gouging](#)), cutting or cleaning banks for better

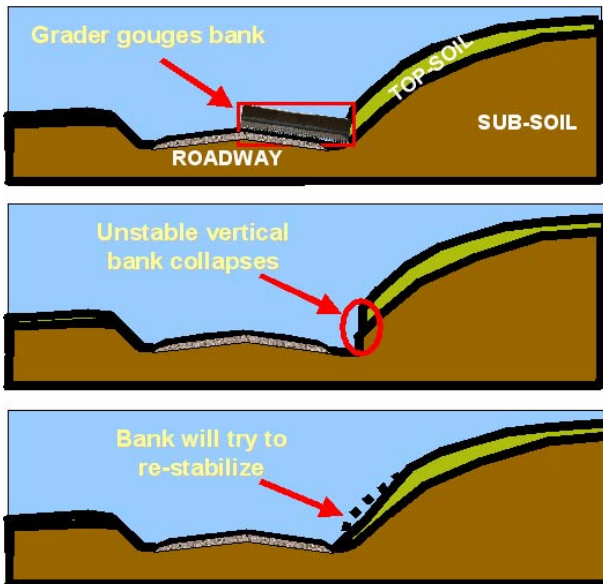


Figure 1: Bank Gouging

sight distance, and smoothing the surface until it “shines,” all of which can lead to bank instability, resulting in [erosion](#) and [sediment](#) pollution, and eventually to road deterioration as ditches fill and flood. Cutting the toe of slope leaves a certain-to-erode vertical surface, unable to withstand gravity’s relentless force as the bank attempts to re-stabilize itself. In most maintenance work involving bank cleaning or cutting for whatever reasons, the work ends with bare soil remaining, subject to [erosion](#) from the impact of raindrops and surface flows, carrying the [sediment](#) into the roadside ditches or downhill into the adjacent stream.

Reestablishing vegetation is a necessary part of this work and should not be

overlooked. Bank cutting often results in a smooth bank surface. The equipment operator’s expertise used to be defined by how well the operator could “shine” the bank surface. Then, if we did try to seed and mulch this extra smooth sloped surface, the results were much less than desired.

Installation: [Diversion swales](#) divert upslope surface water before it washes over the top of the road bank and into the road’s drainage ditch. [Diversion swale](#) profiles can vary, but are normally wide with gradual side slopes. Swales must contain the overland flow and not be overtopped. [Diversion swales](#) must be stable, with a level longitudinal grade for infiltration back into the soil or sloped to an adequate discharge area.

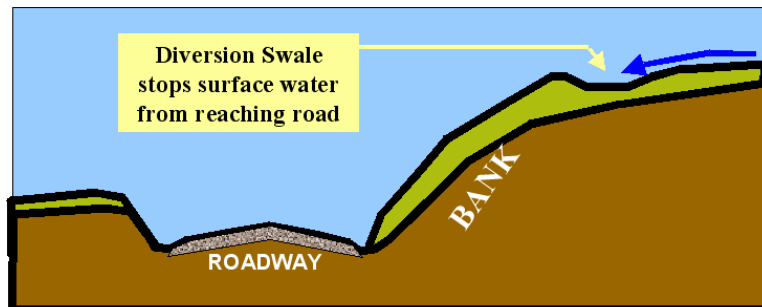


Figure 2: Diversion Swale

[Diversion swales](#)

effectively drain, low, gradual vegetative slopes. The surface [runoff](#) from the entire upward slope drains into a swale at the top of the road embankment. The road bank would then be protected against [erosion](#) gullies. The volume of water to be handled by the road ditch decreases along with the size of the road ditch and potential flooding and [erosion](#) problems. [Diversion swales](#) are usually outside the right-of-way but need not interfere with agriculture. Wider and more gradual, the sideslopes and longitudinal slope will result in more infiltration and less flow accumulation. By eliminating washouts and

erosion gullies that form down over the road bank and start to “eat” back into the hillside, the swale can actually improve drainage of the landowner’s property.



ESMP#13-02 Diversion Swale: Wider swales and gradual slopes result in more infiltration and less water volume to handle.

Begin by examining the slope. Flattening a steep slope and roughening or grooving the surface slows the water flow down the surface and with properly re-established vegetation can eliminate the erosion potential. On the uphill side, flattening the slope will move the top of the bank further away from the road and possibly beyond the right-of-way limits. The same may hold for flattening the slope on the downhill side as we add material and extend

the toe of the embankment further away from the road. Right-of-way limits, land use, and property owner expectations all need to be considered.

Roughening, grooving, or tracking slopes are simply methods to simulate natural conditions. We need to think in terms of existing natural banks. Natural banks are not regular or consistent as to surface and slope and they are not polished and shiny. These techniques require light

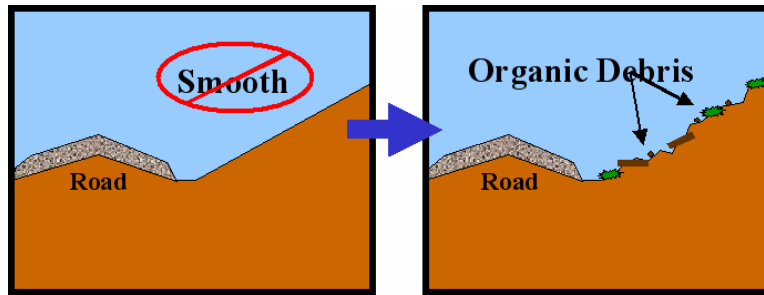


Figure 3: Roughening, grooving, or tracking slopes have many advantages in stabilizing banks

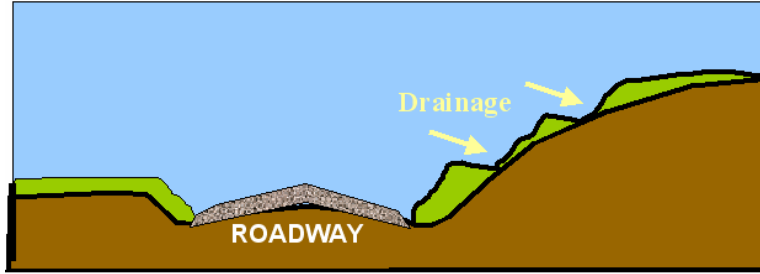
equipment in order to prevent packing the soil to the detriment of plant growth. Track equipment should be used up and down the slope, not across, so the grooves catch water and hold seeds and mulch. Roughening, grooving, or tracking of slopes catch rainwater, slow surface water flow, reduce erosion, increase infiltration, and trap sediment. In addition, by holding water, seeds, and nutrients, the rough surface enhances vegetative growth.



ESMP#13-03 Tracking newly constructed banks.

Benching is commonly used effectively on long, steep slopes with the same benefits of holding soil, water, seed, and mulch for enhanced vegetation growth, as listed above for roughening the sloped surface. The top of the bank may have to be moved back and may be off the right-of-way. A

good working relationship with property owners is again required.



The [bench](#) needs to collect water. The outside edge needs to be higher than the inner edge to prevent over the bank flow, as shown in Figure 4. The [bench](#) then should have a gradient to drain the [bench](#) to a proper outlet. Some benches can

Figure 4: Benching is commonly used on steep slopes

be gradually run out to the road ditch grade, for drainage. Do not overlook the use of smaller multiple benches or steps, and keeping some irregularity for a more natural appearance, if appropriate for the site.



ESMP#13-04 Newly constructed low-gradient bank bench.

Advantages: All of these practices result in improved bank stability, tending to do all of the following:

- Catching rain water
- Slowing surface water flow
- Reducing [erosion](#)
- Increasing filtration
- Trapping [sediment](#)
- Holding water, seeds and mulch for enhanced vegetative growth.

Whether [diversion swales](#), flattened slopes, rough surfaces, or benches, there will be less [erosion](#), less [sediment](#), and less maintenance.

Safety Considerations: Bank stability results in better roadside conditions and less road deterioration, resulting in safer roads.

Related Practices:

- Manual Chapter 6, Section 6.4.1 Initial Site Visit
- Manual Chapter 6, Section 6.4.2.4 Seeding and Mulching
- Manual Chapter 6, Section 6.4.3 [Bioengineering](#) Techniques



Technical Information Sheet Environmentally Sensitive Maintenance PRACTICES (ESMPs)

Practice: ESMP #14 Roadside Trees – Using the Forest System to Reduce Maintenance

Category: Practices Related to Roadsides

Refer to: Manual Chapter 6, Sections 6.3

Description: By taking advantage of natural principles when managing roadside trees, it is possible to provide safe clearances, enough shade to control [dust](#) and invasive species and eliminate the rapid re-growth of colonizer species and frequent mowing cycles. Roads that look like they are in harmony with nature, require less money to maintain, pollute less, and offer the additional benefit of being beautiful. We need to develop a strategy following some basic guidelines to **use the forest system to reduce maintenance.**



ESMP#14-01 Following some guiding natural principles, we can use the forest system to reduce maintenance.

Tree trimming and removal, brushing, brush cutting, and right-of-way clearing are all terms for roadside vegetation management. These activities are common, and road managers may need to perform these activities for a variety of reasons. We need to look at these common practices and reasons, however, and determine what is best for our roads and the environment.

Common Practice and Associated Problems: The normal methods used to trim trees and remove brush along roadsides include manual methods ranging from chainsaws to hand pruners; mechanical methods using mowers and brush cutters; and chemical methods with chemical application equipment and herbicides. All of these methods and equipment have their place in an integrated vegetation management program and can be used effectively. There are some cautions, however, that should be noted.

In an [environmentally sensitive maintenance](#) program, chemical methods using herbicides are certainly a concern. Due to the many hazards associated with herbicides, federal and state governments have adopted various laws and regulations governing their use. These regulations require local government applicators to become certified through

testing. [Environmentally sensitive maintenance](#) does not promote the use of herbicides. If you do use herbicides, you must become familiar with the laws and follow all the requirements and regulations associated with herbicides use.

Boom mowers bring up an additional caution. Boom mowers, when properly used, can be labor saving. One only has to travel, however, down a road on which a boom mower was used, destroying the roadside vegetation and leaving a hurricane-aftermath look, to realize that the use of this equipment can get out of hand. Damage to large tree limbs can eventually kill the total tree. Refer back to the discussion in Chapter 4 on understanding your trees and the effects of wounds. In addition, boom mower operators are frequently instructed to cut “everything you can reach and everything small enough that you can cut.” This direction and practice will ultimately have, as its consequence, roadsides vegetated only by large trees. Some of the most beautiful, slow-growing, strong, wildlife-friendly trees along the roads are being systematically removed because they have the misfortune of being small. Planners frequently choose trees such as dogwood and serviceberry as roadside trees. Yet they are often removed by boom mower operations just because of their size. Would it not have been better to remove the big old damaged or dead trees and save those small dogwoods? The dogwood makes an excellent roadside tree with the added value of blossoms to beautify the roadside in the spring.



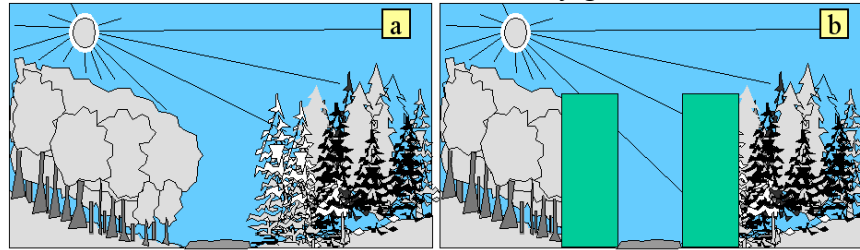
ESMP#14-02 Dogwoods are a good roadside tree with the added value of aesthetics.

A third caution is the common practice of traditional right-of-way clearing and its use for dirt and gravel roads. Traditional clearing practices may have their place on the interstate and superhighways, but they can cause continually more maintenance work when used on our gravel roads in forested areas. Common accepted reasons for clearing the roadside of trees and bushes are to eliminate shade, improve visibility, establish a safety clear zone and reduce routine tree trimming. Although all of these reasons have some merit and may apply for some roads, we need to look closely at the conditions created and the need for future maintenance.

Although shading is viewed as negative, it also has advantages. Shading retains road moisture, cutting [dust](#). Shading reduces the growth of unwanted [colonizer trees](#) and encourages desirable plant growth. A limited amount of shading may be more effective and efficient for our unpaved road maintenance and the environment.

Regarding visibility, one of the greatest safety hazards results from an abrupt transition from bright sunlight to dense shade or vice versa. This extreme change in light can have a devastating effect on the motorists' visibility and be a direct cause of accidents. This type of extreme change in light conditions should be avoided.

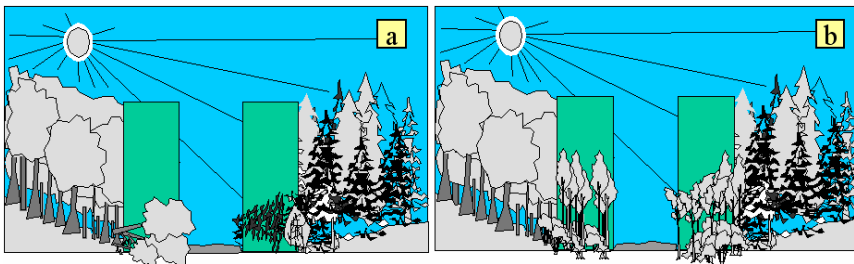
Traditional clearing techniques involve total removal of brush and vegetation along the roadside from right-of-way line to right-of-way line, typically resulting in vastly increased sunlight along the edge of the road. Looking at the sequence of events in a traditional cleared roadside, however, this may not be what is desired. If the roadside is wooded or forested and the road well shaded and we automatically go in and cut everything down, as shown in Figure 1a to 1b, on each side of the road for whatever distance we consider necessary, the results may lead to increased maintenance.



Traditional clearing practice for a shaded road would be from right-of-way line to right-of-way line.

Figure 1

When a section of trees is cut down, the remaining trees along the cut edge are open to storms and wind and may not be structurally strong enough to withstand these conditions. Wind damage, broken branches, and even uprooting can result, as shown in Figure 2a. Other problems include the rapid regrowth of the removed trees through stump sprouts, which are structurally weak and can become a continual maintenance problem. In addition, exposing low growing, broad-leaved, shade-tolerant plants to full sunlight typically kills them, with the potential of soil [erosion](#).



Common reaction of previously protected trees exposed by clear cutting - broken stems, wind damage, uprooting.

Dense weak colonizer growth, which can threaten roadway & recreate shade, appears surprisingly fast.

Figure 2

When the roadsides, previously shaded, receive full sunlight, nature produces vigorous growth, as depicted in Figure 2b. This vigorous growth is due to the invasion of colonizer species that are most



ESMP#14-03 You do not need fast-growing, weak-structured colonizer-type roadside trees!

attracted to this environment, but are the worst possible roadside plants. Colonizer species, which we described in Chapter 4, Section 4.5.4 on succession, are fast-growing, weak growth types. [Colonizer trees](#) can threaten the roadway safety and recreate shade. These [colonizer trees](#) then become extremely high maintenance roadside plants. In many cases the plants we most want to remove are the plants most encouraged by our efforts. This creates the need to mow and trim in increasingly frequent cycles.

So in this scenario, the mowing/removal of trees and brush in the interest of safety and visibility, have the opposite effect, starting an endless cycle of cutting and re-cutting of this colonizer growth.



ESMP#14-04 Remove dead, diseased, unstable, or dying trees first.

Alternative Practices: The solution is to **use the forest system to reduce maintenance.** Be selective! When doing roadside trimming and tree removal, remember to remove the dead, dying, unstable or damaged trees first. Trees that have been damaged by previous maintenance activities, automobile accidents, etc. will eventually die and become hazards.

The second priority is to remove the existing [colonizer trees](#). These trees, even if they are healthy, are not good roadside trees. They are very rapid growers, have weak structures and short lives. They commonly fall onto the road or drop limbs, which create maintenance and hazards.

After removing the damaged trees and the colonizers, it is advisable to look the situation over and evaluate the rest of the trees. Maintaining strong, slow-growing, deep-rooted climax species should be an objective (refer to chapter 4, Section 4.5.4). Avoid straight-line cutting, however, favoring instead an irregular edge. Traffic will tend to travel more slowly on a road with an irregular edge. Speed has always been a major safety problem for our dirt and gravel roads. Clearing the roadside completely or cutting back on a straight line parallel to the road gives the motorist the safe illusion to increase speed.

Maintaining a uniform level of shading is best. One of the greatest dangers from shading comes from winter conditions where pockets of deep shade create irregular icing conditions. Thinning of the canopy to achieve the desired shade density should be the objective. Remember, deciduous trees will lose all their leaves in the winter, letting more sunlight penetrate to the road. Sometimes it is necessary to thin back off the edge of the right-of-way, as the desired sunlight may only be available from the side, not from above. Obviously it is necessary to discuss your plans and objectives with property owners to receive permission to work off the right-of-way.

Advantages: In a situation where a dirt and gravel road is heavily lined with trees or passes through forested areas, a program of vegetation management that seeks to use the forest system and take advantage of natural principles can save time and money in several ways.



ESMP#14-05 A before and after look at selective tree trimming during a road project – using the forest system to reduce maintenance.

1. Allowing a level of shading helps to retain moisture. Moisture is nature’s stabilizing agent. Allowing enough shade to remain to hold some moisture on dirt and gravel roads helps to hold the surface together and reduce [dust](#). Although few road managers would readily identify moisture retainage as a benefit of shaded roads, they will almost always tell you they use less [dust](#) control in shaded areas.

2. Maintaining shade along our roads reduces the establishment of colonizer species (aspen, birch, poplar, sumac, striped maple, etc.). These rapid growing, weak-wooded trees are the ones which create the biggest maintenance problems, especially during winter maintenance operations when they lean out into the road laden with heavy wet snow.

3. The trees that are removed are less likely to return as stump sprouts. All of us have witnessed the rapid return of vegetation under new power line cuts. This is usually a combination of stump sprouts and colonizer species, resulting in increased mowing cycles. This scenario can be avoided by simply allowing the road to remain partially shaded.

A well-maintained roadside forest system also adds to the aesthetics, which in turn enhances tourism.

Safety Considerations: Safety factors were discussed throughout the above. Well-managed roadsides with structurally strong, deep-rooted, long-lived trees will be safe roads. These roads will also be easier to keep clear and safe through the winter snows. And irregular edges have a tendency to reduce traffic speeds for additional safety.

Related Practices:

Manual Chapter 6, Section 6.3.3.7 Tree Leaves

Manual Chapter 6, Section 6.3.4 Using Other Plants for the Roadside



Technical Information Sheet Environmentally Sensitive Maintenance Practices (ESMPs)

Practice: *ESMP #15 Road Separation Fabrics*

Category: Practices Using Geosynthetics

Refer to: Manual Chapter 7, Sections 7.4.4.6

Description: Road separation fabrics are [geosynthetic](#) fabrics that separate the subsoil from the road aggregate, providing improved road stability and reinforcement, improved drainage, prevention of [subgrade](#) pumping of fines, and thereby [dust](#) reduction.

How They Work: When roads are built, the subsoil or [subgrade](#) is prepared with a crown, then a specified thickness of aggregate is laid down and compacted (*Figure 1a*). Over time, however, depending on conditions (water and traffic), the aggregate gets pushed down into the soils and the soils pump up through the aggregate (*Figure 1b*). We end up with a transition zone not as strong as the aggregate, and the road can no longer support the traffic loads with deterioration as the result.

With the separation fabrics, we prepare the [subgrade](#), roll out the fabric, and build the road on top of the fabric (*Figure 1c*). The aggregate cannot be pushed into the soil, and the soil cannot pump up into the aggregate. Everything stays in place, and the road remains strong enough as designed for the traffic loads. Water can travel either way, but if it gets into the road, it can drain downward or out laterally due to the crown into side ditches or [subdrains](#). The prevention of soil fines from pumping up through the aggregate to the road surface eliminates the mud in wet weather and the [dust](#) in dry weather.

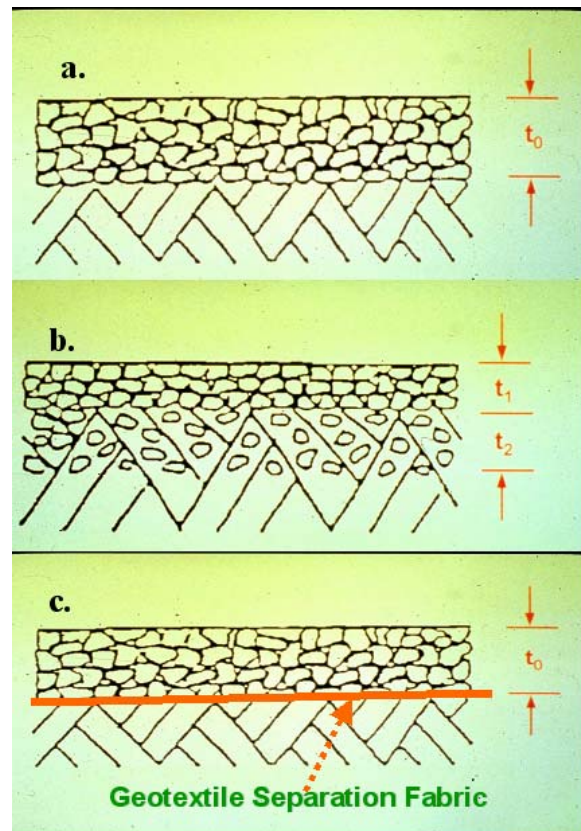


Figure 1: The value of Separation Fabrics

Installation: Fabrics come in woven or non-woven types for this application. The existing road conditions, particularly the aggregate, rock outcrops, water and saturated subsoils, are considered in selection of the fabric type. Transverse joints should be overlapped a minimum of 18 inches in the direction of traffic. Fabric rolls come in standard 12-, 15-, and 18-foot widths (or customized to any width), eliminating the need for longitudinal joints.



ESMP#15-01 Separation fabrics keep the soil and road aggregate in place.

Installation steps include surface preparation with an established crown, rolling out the fabric, placing the road aggregate, and compacting. Aggregate should be backdumped from the truck to a minimum depth of 6 inches, preferably 8 inches. Grading and re-establishing the crown followed by compaction of the aggregate completes the project, as depicted in the series of photos. On this project, sections of the road received additional



↑ **Rolls of fabric waiting for installation** ↑



↑ **Rolling out the fabric** ↑



↑ **Backdumping the aggregate** ↑



↑ **Spreading the aggregate** ↑



↑ **Compacting the aggregate** ↑



↑ **Final grading** ↑

ESMP#15-02 Installation of a separation fabric.

shale material to raise the road elevation (refer to Tech Sheet #ESMP 12, Raising the Entrenched Road).

If the fabric gets damaged during placement, simply patch with another piece of fabric making sure that an 18" overlap on all sides is maintained. Tears can happen, as shown in the photo, where the blade of the dozer caught the fabric by accident.

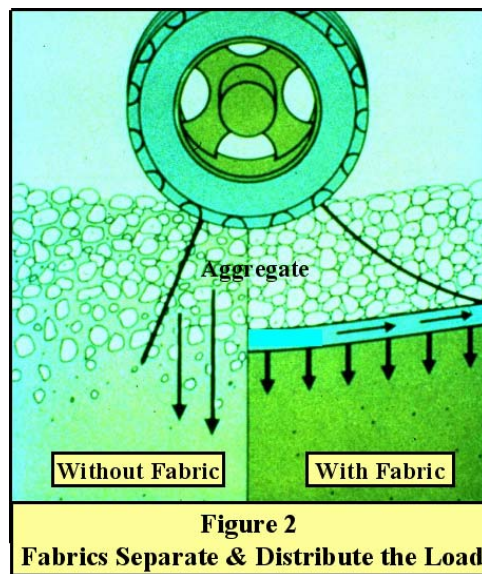


ESMP#15-03 If damaged, use a fabric patch with 18” overlap on all sides.

Advantages: The use of separation fabrics provides us with a number of advantages:

- Stabilization
- Prevention [subgrade](#) pumping
- Drainage improvement
- Rutting and pothole reduction
- [Dust](#) reduction
- Reduced maintenance and costs
- Longer road life

Fabrics also help to distribute traffic loads over a greater area, making them advantageous to use over soft, saturated soil conditions. Figure 2 shows this load distribution effect of the fabric. (Traffic load distribution was discussed in



Chapter 5, Section 5.3.5, Practices Related to [Culverts](#) in regards to [culvert](#) installations.)

Separation fabric applications prove effective to substantially reduce road deterioration, resulting in reduction of road maintenance.

The use of fabrics for stabilizing water-crossing areas in conjunction with [broad based dips](#) and driveways was mentioned in Chapter 5. In these applications, they perform a reinforcement function and a separation function to strengthen and keep these areas intact.



ESMP#15-04 Separation fabrics have proven to be effective.

Safety Considerations: Structurally strong roads that remain in place with minor maintenance will be safer roads.

Related Practices:

ESMP #04 Broad Based Dips

ESMP #06 Driveways

ESMP #12 Raising the Entrenched Road

ESMP #11 Stream Saver System

Manual Chapter 7, Section 7.4.4 Geosynthetic Applications in Road Maintenance