HANDBOOK

2008-20

Best Practices Handbook for Roadside Vegetation Management

LRRB
LOCAL ROAD RESEARCH BOARD

Take the steps... Research...Knowledge...Innovative Solutions!

Transportation Research

Technical Report Documentation Page

1. Report No.	2.	3. Recipients Accession No.
MN/RC 2008-20		

4. Title and Subtitle	5. Report Date
Best Practices Handbook for Roadside Vegetation Management	July 2008
	6.

7. Author(s)	8. Performing Organization Report No.
Ann M. Johnson, P.E.	

9. Performing Organization Name and Address	10. Project/Task/Work Unit No.
Professional Engineering Services, Ltd. 213 Townes Lane Wayzata, MN 55391	11. Contract (C) or Grant (G) No. (c) 90053

12. Sponsoring Organization Name and Address	13. Type of Report and Period Covered
Minnesota Department of Transportation Office of Research Services 395 John Ireland Boulevard, Mail Stop 330 St. Paul, MN 55155	Final Report 14. Sponsoring Agency Code

15. Supplementary Notes
http://www.lrrb.org/pdf/200820.pdf
http://www.lrrb.org/pdf/200019.pdf (prior related handbook)

16. Abstract (Limit: 200 words)

Maintaining roadsides for safety and aesthetics is an important issue for all levels of government throughout Minnesota. Vegetation is one important element of roadside maintenance. A healthy roadside environment reduces maintenance needs and costs, reduces erosion and improves water quality, improves water infiltration and reduces runoff, preserves the roadside surface, maximizes safety for vehicles and travelers, limits liability for the governing agency, maintains good public relations, improves the overall driving experience, and provides habitat for wildlife populations. This handbook was written to provide guidelines for effective management of roadside vegetation for local agencies, and highlights eight best management practices (BMPs) that were identified through research, literature review, surveys, and discussion with industry experts. The eight best management practices for roadside vegetation are:

(1) develop an integrated roadside vegetation management plan, (2) develop a public relations plan, (3) develop a mowing policy and improved procedures, (4) establish sustainable vegetation, (5) control prohibited and restricted noxious weeds, (6) manage living snow fences, (7) use integrated construction and maintenance practices, and (8) manage roadside vegetation for wildlife and vehicle safety.

The main conclusion from the handbook is that successful roadside vegetation management depends on an integrated approach. This includes a wide variety of best management practices to address the many issues involved. This integrated approach includes an assessment of the existing conditions and determination of the type of roadside environment desired. Other construction operations, including proper seeding techniques, selection of the correct plant in the right area, selection of salt-tolerant plant species where needed, and erosion control, will greatly affect the roadside condition. Use of integrated construction and maintenance practices is one of the most important best management practices identified in the handbook.

17. Document Analysis/Descriptors		18. Availability Statement
Integrated Roadside Vegetation Management Plan, tree care, woody vegetation, pruning, noxious weeds, landscaping, topsoil conservation, erosion control, living snow fence,	roadside vegetation, noxious weeds, mowing, sustainable vegetation, native grasses, wildflowers, brush control, salt-resistant grasses, staged seeding, vegetation maintenance, vehicle safety, wildlife habitat	No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161

19. Security Class (this report)	20. Security Class (this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	156	

Best Practices Handbook for Roadside Vegetation Management

Final Report

Prepared by:

Ann Johnson, P.E.

Professional Engineering Services, Ltd.

July 2008

Published by:

Minnesota Department of Transportation
Office of Research Services
395 John Ireland Boulevard, Mail Stop 330
St. Paul, Minnesota 55155

Acknowledgements

We thank the Minnesota Local Road Research Board for the financial support to fund this handbook. We thank the Technical Liaisons directing the Technical Advisory Panel (TAP), Paul Walvatne and John McDonald, whose support and creative ideas from the outset made this project possible. We thank the members of the TAP that were instrumental in development and without whose comments and advice this resource would not have been possible; their expertise was invaluable.

Technical Advisory Panel:

Paul Walvatne	Mn/DOT (Technical Liaison)
John McDonald	Fairbault County (Technical Liaison)
Jason Alcott	Mn/DOT - Environmental Services
Dennis Distad	Mn/DOT - Dodge Center Truck Station
Debra Fick	Mn/DOT Research Service Section OIM (Administrative Liaison)
Gabe Guevara	Mn/DOT – Maintenance Operations
Daniel Gullickson	Mn/DOT - Environmental Services
Scott Hansen	Mille Lacs Band Ojibwe
Kurt Haroldson	MDNR – Farmland Wildlife Populations & Research Group
Bob Hummel	Jackson County Highway Department
Daniel Leister	Mn/DOT – Detroit Lakes District Office
Mike Moilanen	Mille Lacs Band Ojibwe
Carmelita Nelson	MDNR – Coordinator, Roadsides for Wildlife
Randy Reznicek	Mn/DOT – Maintenance Operations
Kathleen Schaefer	Mn/DOT – CTAP Coordinator
Dwayne Stenlund	Mn/DOT - Environmental Services
Tom Struve	City of Eagan
Thomas Tri	St. Louis County
Robert Weinholzer	Mn/DOT – Traffic, Security, & Operations

Project consultation provided by Ann Johnson, P.E., Professional Engineering Services, Ltd.

Table of Contents

List of Tables

List of Figures

Executive Summary

Maintaining roadsides for safety and aesthetics is an important issue for all levels of government throughout Minnesota. Vegetation is one important element of roadside maintenance. A healthy roadside environment reduces maintenance needs and costs, reduces erosion and improves water quality, improves water infiltration and reduces runoff, preserves the roadside surface, provides safety for vehicles and travelers, limits liability for the governing agency, maintains good public relations, improves the overall driving experience, and provides habitat for wildlife populations. This handbook was written to provide guidelines for effective management of roadside vegetation for local agencies, and highlights seven best management practices (BMPs) that were identified through research, surveys, and discussion with industry experts.

The eight best management practices for roadside vegetation are:

1. Develop an integrated roadside vegetation management (IRVM) plan
2. Develop a public relations plan
3. Develop a mowing policy and improved procedures
4. Establish sustainable vegetation
5. Control noxious weeds and prevent the establishment of new invaders
6. Manage living snow fences
7. Use integrated construction and maintenance practices
8. Manage roadside vegetation for wildlife and vehicle safety

Since this manual was originally published, the Minnesota Pollution Control Agency has significantly changed requirements for the control of sediment and stormwater runoff. Mn/DOT has published a new Erosion Control Handbook (number II), which is available through the Office of Environmental Services at (651) 366-3600.

This updated handbook includes chapters on stormwater compliance, and best management practices (BMPs) and how to use them. BMPs are offered for controlling runoff, minimizing erosion, managing sediments, permanent vegetation establishment, working around water, bioengineering, site drawing, dewatering, and basin draining.

Additionally, the Local Road Research Board published "The Erosion Control Handbook for Local Roads" in 2003. This handbook offers best practices for controlling erosion during the construction of low volume roads, as well as the ongoing maintenance required for each method. It is available online at www.lrrb.org.

And, the Minnesota DNR Roadsides for Wildlife Program and Mn/DOT Office of Environmental Services are partnering to improve roadside habitat. This program promotes integrated roadside vegetation management strategies throughout the 525,000 acres of rural roadside habitat throughout Minnesota. Information regarding that program is available online at:
http://www.dnr.state.mn.us/roadsidesforwildlife/index.html

Appropriate management techniques for vegetation along a specific roadway depend on many factors, including:

- the type of vegetation desired
- the desired appearance of the roadside
- soil conditions
- roadway traffic
- roadway use and visibility
- adjacent land use
- roadway location
- topography

What is Integrated Roadside Vegetation Management?

It is a way to bring together social and cultural elements, biological concerns, mechanical treatments and pest control methods to economically manage roadsides for safety, environmental health, and visual quality.

Additional management constraints include available staff, resources, equipment, environmental constraints, and many others. When developing a plan for roadside vegetation management, all of the above need to be considered. This handbook offers suggestions for doing so, and for developing an integrated plan that optimizes available resources and desired results.

This handbook also reviews local government roadside vegetation management practices in Minnesota. It highlights some of the practices that the state, counties, and cities have found to be effective or efficient. The material should be useful to local governments that are interested in how others agencies with similar concerns manage their roadside environments.

The main conclusion from the handbook is that successful roadside vegetation management depends on an integrated approach. This includes a wide variety of best management practices to address the many issues involved. This integrated approach includes an assessment of the existing conditions and determination of the type of roadside environment desired. Other construction operations, including proper seeding techniques, selection of the correct plant in the right area, selection of salt-tolerant seed species where needed, and erosion control, will greatly affect the roadside condition. Use of integrated construction and maintenance practices is one of the most important best management practices identified in the handbook.

Introduction

Throughout Minnesota, all levels of government are concerned with the issue of maintaining their roadsides for both safety and aesthetic reasons. A healthy roadside environment reduces maintenance needs and costs, reduces erosion and improves water quality, improves water infiltration and reduces runoff, aids in preserving the roadside surface, provides safety for vehicles and travelers, limits liability for the governing agency, maintains good public relations, and improves the overall driving experience.

This handbook strives to provide assistance to local agencies in roadside vegetation management operations by sharing information obtained from the many years of experience of those working in the field, and by highlighting new technology that is improving operations. This handbook also highlights seven best management practices (BMPs) identified through research, surveys, and discussion with industry experts.

The *Best Practices Handbook for Roadside Vegetation* was originally published by the Minnesota Local Road Research Board in 2000 (manual number 2000-19). In that manual, seven best practices were identified and outlined. They are:

1. Develop an Integrated Roadside Vegetation Management Plan
2. Develop a Public Relations Plan
3. Develop a Mowing Policy and Improved Procedures
4. Establish Sustainable Vegetation
5. Control Noxious Weeds and Prevent the Establishment of New Invaders
6. Manage Living Snow Fences
7. Use Integrated Construction and Maintenance Practices

The manual provided a valuable resource to maintenance and engineering staff, and was used around the state and country. No printed manuals remain, and since the time of its publication, more information and materials have been developed, the information contained in the manual has been refined, better practices have been developed, and new noxious plants have become a problem for maintenance workers. In addition, wildlife habitat and the roadside environment emerged as an important concern for roadway maintenance.

A primary goal for the state, county, municipality, and township road authorities is to increase public safety on roadways. Good vegetation management can improve road safety. For example, living snow fences reduce ice and drifting snow. Living snowfences and other roadside habitat can also provide permanent habitat for songbirds, ducks, pheasants, and other wildlife. Deer do not live in roadsides but may browse on green roadside vegetation or lick salt along roads or cross roads to other habitats and resources. Best management practices can help reduce the likelihood of wildlife collisions while still providing essential vegetation and erosion control.

The objective of this report is to review and synthesize information from published and unpublished literature to assess the safety implications of available techniques of management of roadside vegetation and habitat in terms of wildlife use of roadsides. It also includes information regarding the frequency and timing of wildlife road-crossings.

In addition to updated information about the original seven best practices for effective roadside vegetation management, this manual includes additional best practices that can be implemented to minimize roadside use by wildlife that are hazardous to traffic while promoting the conservation and diversity of wildlife species minimally hazardous to travelers.

The manual also includes topics relevant to motorist safety including: vegetation types (including native versus non-native), species composition, and vegetation management (annual schedule of actions such as mowing, tilling, chemical treatments, and burning) specified for each lateral segment of the ditch with appropriate modifications for other roadside elements such as approaches and intersections. And there is information about the timing of wildlife traffic hazards. Also included are the benefits of management techniques of roadside habitats to less-hazardous wildlife, including pheasants, ground-nesting ducks, songbirds, gray partridge, rabbits, foxes, woodchucks, and

invertebrates such as butterflies. It also includes the safety implications and benefits of using low-maintenance, native vegetation in roadsides, and the costs and benefits of using rotational mowing, spot-treatments for weeds, burning schedules, and mowing heights for different types of vegetation.

ORIGINAL SURVEY

For the first manual, three surveys were distributed to a variety of city and county recipients in Minnesota as well as in Wisconsin, Nebraska, North Dakota, South Dakota, and Iowa to obtain information about current practices. A Technical Advisory Panel composed of industry experts evaluated the survey responses, followed up with telephone interviews, and then developed the list of seven best management practices highlighted in this handbook. The results of the survey are included in Appendix A.

The Technical Advisory Panel identified seven recommended general actions for effective roadside vegetation management, based on the findings of three surveys, discussions with practitioners, and current research. Each site is unique, possessing its own criteria, needs, and circumstances. Depending on the type of roadside environment being managed, one or all of the following management tools may apply.

HOW THIS HANDBOOK IS ORGANIZED

This handbook has nine chapters and seven appendices.

Chapters 1-8 discuss each of the eight best management practices identified by the Technical Advisory Panel and offer ways to incorporate these practices into a roadside vegetation management plan. Chapter 9 gives specific examples of where and how vegetation and roadside management techniques are being used. Appendix A presents the survey methodology, results, and responses. Appendix B gives detailed soil information. Appendix D lists use of herbicides, and Appendix E describes the eleven common Minnesota prohibited noxious weeds which must be controlled in accordance with the state weed law.

Chapter 1: Best Management Practice No. 1: Develop an Integrated Roadside Vegetation Management Plan

WHAT IS AN INTEGRATED ROADSIDE VEGETATION MANAGEMENT PLAN?

What is Integrated Roadside Vegetation Management (IRVM)? IRVM brings together many elements with social and cultural elements, biological concerns, mechanical treatments, and pest control methods to economically manage roadsides for safety, environmental health, and visual quality. Simply put, it is an overall plan for the unified management and coordination of all the many elements that go into roadside vegetation management. It can be used as a decision-making and quality management tool for maintaining roadside vegetation.

The challenges government agencies face in managing roadside vegetation drive the need for effective IRVM programs. Those challenges include

- increasing legal requirements, such as laws regarding water quality, mowing, noxious weed control, and safety
- incentives for quality improvements and cost savings
- the need for the proper use of pesticides, especially herbicides for vegetation control
- increased public demands and customer expectations
- increased liability concerns
- legislative mandates
- increasing demands for hay and cellulosic fuels

An integrated plan will greatly assist in meeting the diverse expectations and requirements listed above as well as the requirements of the Groundwater Act of 1989. This act dictates, under "State Uses of Pesticides and Nutrients," that "The state shall use integrated pest management techniques in its management of public lands, including roadside rights-of-way, parks, and forests; and shall use planting regimes that minimize the need for pesticides and added nutrients" Chapter 326, Article 5, 18B.063).

In addition to the Groundwater Act of 1989, the 1994 amendment to it (Chapter 558, Section 26) required the Commissioner of the Department of Natural Resources (DNR) to prepare a plan for the optimum use of sustainable agriculture and integrated pest management techniques on land owned by the state. A report published in March of 1996 provides the framework for the development of local IRVM plans, which are outlined in Chapter 9.

An April, 2000 article in *Erosion Control* magazine on Integrated Roadside Vegetation Management describes the basic elements of an IRVM plan, as well as a general summary of how several states approach IRVM. This article, written by Kirk Henderson, University of Northern Iowa is available online at http://www.forester.net/ec_0004_integrated.html.

Many state and local agencies have already implemented IRVM plans. Several are included as examples in Chapter 8. In 2005, The American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to conduct a study on IRVM efforts across America. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," may be of interest to local management and personnel, as well as to other professionals in both the public and private sectors. Its primary purpose is to report on the incorporation of integrated roadside vegetation management decision-making processes into highway project planning, design, construction, and maintenance, as well as to document existing research and practice.

The report contains information culled from survey responses received from transportation agencies in 21 states and 5 Canadian provinces. An overall increase in environmental knowledge and regulation has resulted in many different solutions, and some example practices are presented to supplement text references. This information is

combined with reviews of applicable literature to yield a compendium of successful practices that might have potential for success and implementation in other state DOTs. This publication, NCHRP publication synthesis 341, *Integrated Roadside Vegetation Management: A Synthesis of Highway Practice* was published in 2005, and is available online at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_341.pdf

Dr. Ian Heap and David Nelson are doing another NCHRP Best Practices Manual to be completed in 2009, entitled "National Vegetation Management Guidelines" National Cooperative Highway Research Program Project 14-16, Vegetation Guidelines.

Benefits of implementing an integrated management plan

Safety
Creation of adequate sight distances and hazard-free zones
Minimized effects of rain, blowing and drifting snow, and ice formation
Reduced hazardous conditions for maintenance staff

Economic
Increased productivity from planning work versus reacting to work problems
Economical and environmentally sustainable outcomes
Extended life of pavement
Use of optimum weed and pest control measures
Improved cost-effectiveness of construction activities
Increased small game production, e.g. pheasants, to improve hunting success and increase expenditures on hunting pursuits
Tourism is a major component of rural economies. The roadside appearance is a significant part of the visitor experience that contributes to the economic vitality of the region.

Flexibility
More efficient use of staff, time, and equipment through planning
A variety of management tools and techniques from which to choose at any given time

Environmental
Improved water quality by trapping sediment and increasing infiltration
Improved overall air quality
Protected soil
Increased biodiversity and desirable native plant communities
Reduced number of invasive plants and weeds
Improved safety for wildlife
Newly created habitat
Reduced impact of roadway projects
Increased carbon monoxide absorption
Increased carbon dioxide sequestration

Aesthetic
More healthy vegetation appropriate for the area
Creation of a diverse plant community without noxious weeds and undesirable vegetation
Use of plants for screening
Improved appearance of roadway due to native grasses and wildflowers
Pleasant experience for travelers

Public Relations
Establishment of partnerships, teamwork
Shared expertise between agencies
Increased public awareness of maintenance activities

DEVELOPING AN IRVM PLAN

In Minnesota, each Mn/DOT District/Maintenance Area is encouraged to prepare annual IRVM plans for guiding management on state roadsides. Mn/DOT's Roadside Vegetation Management Unit provides technical assistance and leadership to create and update IRVM plans as a proactive way of addressing many of Minnesota's Laws and Tribal and Federal constraints, such as:

Minnesota Noxious Weed Law Laws of Minnesota, Chapter 18, Sections 18.75-18.88 and Rules of Minnesota, Chapter 1505.0730-1505.0760.

State Mowing Law (Minnesota State Statue 160.232) This law pertains to mowing ditches outside cities, and protects nesting habitat for game birds and songbirds during critical times of the year by directing the extent and timing of mowing operations. Revised in 2005 to encourage road authorities to use native plant communities on roadsides.

Groundwater Protection Law (Minnesota State Statutes, Chapter 103H) It is the State's goal that groundwater be maintained in its natural condition, free from any degradation caused by human activities. Due to some human activities, this degradation prevention goal cannot be practicably achieved. Where it is not currently practicable, the development of methods and technology that will make prevention practicable is encouraged.

State Uses of Pesticides and Nutrients (Minnesota State Statutes, Chapter 18B, Section .063) This statute directs the state to use integrated pest management techniques in its management of public lands, including roadside rights-of-way, parks, and forests; and shall use planting regimes that minimize the need for pesticides and added nutrients.

Minnesota Invasive Species Advisory Council (MISAC)—This council was formed in response to Presidential Executive Order #13112 on invasive species that requested states to develop invasive species councils. The Minnesota Departments of Agriculture and Natural Resources are responsible for coordinating the management of invasive species in the state. Mn/DOT desires to cooperate in control efforts to minimize the spread of invasive species.

Minnesota Wetland Conservation Act (Rules of Minnesota Chapter 8420.0540 and 8420.0541)
The purpose of the Wetland Conservation Act (WCA) is to achieve a no net loss in the quantity, quality, and biological diversity of Minnesota's existing wetlands by maintaining and protecting Minnesota's wetlands and the public benefits they provide. The WCA requires anyone proposing to drain, fill or excavate a wetland first to try to avoid disturbing the wetland; second, to try to minimize any impact on the wetland; and, finally, to replace any lost wetland acres, functions, and values. An important element of developing wetland replacement sites is the establishment of "permanent, native, noninvasive vegetation," as well as the requirement for a "five-year vegetation establishment and management plan, including seeding rates, planting methods, seed and plant mixes, herbicide treatments, and control of noxious weeds and invasive or non-native species."

Tribal Lands

IRVM plans must address the requirements and constraints of Native American Tribes relative to roadside vegetation management practices. Some tribes prohibit the use of pesticides for vegetation control without permission.

Federal Lands

IRVM plans must address the requirements and constraints of federal agencies relative to roadside vegetation management practices, e.g US Forest Service lands where highways pass through such lands on easement takings. Road authorities must get concurrence to use herbicides on such lands.

When developing an IRVM plan, consider the needs of local communities and users; plant ecology and natural processes; design, construction, and maintenance processes; monitoring and evaluation procedures; government statutes and regulations; and technology. The five steps for developing a plan are:

AN ACT

160.232 MOWING DITCHES OUTSIDE CITIES.

(a) To provide enhanced roadside habitat for nesting birds and other small wildlife, road authorities may not mow or till the right-of-way of a highway located outside of a home rule charter or statutory city except as allowed in this section and section 160.23.

(b) On any highway, the first eight feet away from the road surface, or shoulder if one exists, may be mowed at any time.

(c) An entire right-of-way may be mowed after July 31. From August 31 to the following July 31, the entire right-of-way may only be mowed if necessary for safety reasons, but may not be mowed to a height of less than 12 inches.

(d) A right-of-way may be mowed as necessary to maintain sight distance for safety and may be mowed at other times under rules of the commissioner, or by ordinance of a local road authority not conflicting with the rules of the commissioner.

(e) A right-of-way may be mowed, burned, or tilled to prepare the right-of-way for the establishment of permanent vegetative cover or for prairie vegetation management.

(f) When feasible, road authorities are encouraged to utilize low maintenance, native vegetation that reduces the need to mow, provides wildlife habitat, and maintains public safety.

(g) The commissioner of natural resources shall cooperate with the commissioner of transportation to provide enhanced roadside habitat for nesting birds and other small wildlife.

History: *1985 c 127 s 2; 1986 c 398 art 27 s 1; 1989 c 179 s 1; 1Sp2005 c 1 art 2 s* An entire right-of-way may be mowed after July 31. From August 31 to the following July 31, the entire right-of way may only be mowed if necessary for safety reasons, and may not be mowed to a height of less than 12 inches.

A right-of-way may be mowed as necessary to maintain sight distance for safety and may be mowed at other times under rules of the commissioner, or by resolution of a local road authority.

A right-of-way may be mowed, burned, or tilled to prepare the right-of-way for the establishment of permanent vegetative cover or for prairie vegetation management.

Effective 5/17/85

Note: 1986 amendments are underlined.

Figure 1-1. Minnesota Mowing Law – Established in 1985 and revised in 2005.

Five Steps for IRVM Planning

1. Promoting an IRVM Philosophy and Legacy
Convincing maintenance staff and decision makers to adopt an integrated approach to roadside vegetation management may be difficult, and full implementation of an agency-wide IRVM program may take a long time. Five focus areas are given below, along with considerations for promoting an IRVM philosophy.

Public Involvement

- Educate the public on why and how roadsides are managed. This education should include the reasons for roadside vegetation management in relation to functional roadway objectives, surrounding land use, the overall ecosystem, natural processes, and applied technologies.
- Communicate an appreciation for the beauty of self-sustaining, low-maintenance roadsides.
- Communicate the cost-savings realized through lower life cycle maintenance costs, less negative environmental impact, and efficient use of tax dollars.
- Communicate the implications of mowing and haying along roadsides.

Legislative Considerations

- Communicate to the legislature that IRVM is a worthwhile investment that will result in lower maintenance life cycle costs. To do so, initial costs must be presented clearly in relation to long-term savings with innovative technologies.
- Maintenance funding must be dedicated at a reasonable base level for accomplishment of all critical maintenance and some preventive maintenance activities.

Upper Management

- Communicate the role that IRVM can play as a problem-solving tool for roadsides.
- Provide the necessary links with design and construction personnel when constructing the roadway.

Maintenance Supervisors

- Recognize that these people are the primary resources for motivation, coordination, guidance, training and follow-through on an IRVM program.
- Develop a management system that includes necessary record-keeping and cost-tracking components for measurement and evaluation.
- Require these staff members to develop and implement relevant technology and computer applications for the implementation and practice of the IRVM program.

Maintenance Staff

- Hire, train, and dedicate crews for roadside maintenance.
- Inspire crew members and motivate them to learn and continuously improve the quality of roadsides in their care.
- Recognize those individuals and crews that succeed in improving their roadside environment.
- Provide necessary field guides, schedules, and materials.

IRVM provides a way to support ongoing improvement through a continuous evaluation of how roadsides are managed. The most important factor is participation from those parties listed above.

2. Preliminary Planning
Each roadway is unique, and one plan for all roads in a jurisdiction may not be appropriate. The next step in moving towards integrated roadside vegetation management is to evaluate the roadways for which an agency is responsible, and assign them to categories for which a plan can be developed. A local plan adapted to fit local culture, political concerns, and climate and environmental conditions is best. Developing a plan requires a team effort, with input from those people having expertise in forestry, ecology, landscape architecture, maintenance, design, construction, biology, horticulture, utilities, and public relations as well as from general citizens. A steering committee responsible for developing the plan, providing guidance on how it is run, and reviewing the annual work plan and progress may also be created.

All roadsides should receive the same type of management (mowing, brushing, etc.) that results in a safe roadway for those using it. However, prior to plan development, the agency should identify the roadways they are responsible for maintaining and prioritize them according to the level of management they will receive. The amount and type of vegetative maintenance done on each roadside will depend on the category to which it is assigned.

Suggested categories include:

- Location: Urban or rural
- Zoning: Industrial, commercial, residential, and agricultural
- Level of use: High or low traffic
- Roadway type: Interstate, primary, or secondary road
- Roadways with scenic designations

While developing the plan and considering maintenance strategies, keep the following guidelines in mind:

- Timing is an important factor for all control and maintenance methods.
- Programs should be kept flexible to allow for changes as needed.
- A combination of several control methods is usually more effective than any single treatment.
- Maintenance costs are lowest when programs are planned and carried out on schedule.

Also, identify the desired outcome for a given feature. For example, is the objective to have low maintenance, return the roadside to prairie grasses, maintain golf course-like sod, or reestablish a wetland? Once you have identified the desired outcome, you can develop a plan to achieve it.

3. Assessing Existing Conditions

Assess existing conditions to assign and prioritize management strategies for an area. Three factors that will steer management techniques are soil, topography, and vegetation.

Soil

Understanding the type of soils present and their physical characteristics is important when outlining a plan for roadside vegetation management. Soil type and texture determine vegetation selection, herbicide application rates, fertilization needs, and erosion potential. Once known, target management techniques to those conditions.

The ideal surface soil is composed of 5 percent organic matter, 25 percent air, 45 percent mineral material, and 25 percent water. The organic material provides fertility and water-holding capacity and supports microbial life. Oxygen is required for all root growth. Along roadsides, soil is typically stripped of its nutrients and compacted such that little air remains in the soil, leaving a very hostile environment for vegetation to flourish. When trouble-shooting to determine causes of vegetation problems, assessing the soils in an area may explain excessive weed growth or resistance to chemical control methods.

Appendix B contains significant information about assessing soil texture, field classification of soils, soil health, and erosion/runoff potential.

Topography

Topography also affects roadside conditions. The slope of the grade, sun exposure, and configuration affect vegetation establishment and sustainability of the plants. Runoff and erosion potential are increased in areas with high topographic relief. Flat, low spots will hold water, allowing for sediment to settle and remain on site. Therefore, keep topography in mind when evaluating vegetation, erosion control needs, herbicide types, and mowing strategies.

In areas with steep slopes and rough terrain, regrading may significantly reduce erosion problems. To reduce erosion, preserve as much natural vegetation as feasible during regrading. Also, make slopes as flat as possible, with adequate rounding at the top and bottom. The degree of slope affects the roadside appearance, safety, and maintainability, with flatter slopes allowing for easier mowing, spraying, and other maintenance activities.

Some tips for reducing erosion are:

- Slow water velocity.
- Divide runoff into smaller quantities.
- Allow for water infiltration.
- Provide mechanical or structural retention methods.

A combination of adequate drainage, protective lines, and desirable vegetation offers the best means for conserving soil.

Vegetation

Native Vegetation

Native plants, and the benefits of establishing them along roadsides, have been given much attention recently. The term "native" refers to a plant species' place of origin, and in this case refers to a plant that was present in this region prior to European settlement. Native plants form naturally diverse plant communities that are well adapted to Minnesota's soils, wildlife, and extreme climate. However, a plant that is native to Minnesota may not be native to the specific area in which it is being planted. Prior to developing a plan for a roadside, consider which types of plants are native to that specific area.

In 2005, the Minnesota Legislature revised the Mowing Law (Figure 1-1) to include the following language: "When feasible, road authorities are encouraged to utilize low maintenance, native vegetation that reduces the need to mow, provides wildlife habitat, and maintains public safety."

Non-native plants have been introduced to this state from other continents by settlers, by gardeners, or by accident. They often displace native plants when their natural checks and balances do not work in the new environment. Non-native species also often form much less diverse plant communities that provide poor habitat for native wildlife. Today, Minnesota has about 1,800 species of flowering plants, of which as many as 20 percent are introduced or non-native species.

There are three main reasons for preserving native plants:

Environmental: There are no substitutes for the original wild species of Minnesota. Once lost, their genetic material can never be re-created. Also, native wildlife often depends on native vegetation for survival.

Economic: Established native plant communities are relatively stable and require less maintenance than cultivated sod. With proper care and maintenance, these natural communities provide good erosion control and are less susceptible to weed invasions.

Aesthetic: Native wildflowers and grasses provide seasonal color changes along roadsides, a natural beautification. They also screen undesirable views and objects if planted strategically.

Currently, over 120 species of plants are endangered or threatened with extinction in Minnesota. Habitat loss due to land use changes frequently threatens the existence of these rare plants. The best way to save them is to preserve their natural habitats now.

Minnesota contains four major ecological provinces, each with the following native vegetation:

- Laurentian Mixed Forest
  Extensive pine and spruce forests, peat bogs, and muskegs give the feeling of "wilderness" to the northeastern third of the state. Areas also contain members of the heath family, such as blueberry, swamp laurel, and Labrador tea, along with other forest plants such as twinflower, Canada mayflower, bunchberry, star flower, and blue-bead lily. Roadside wildflowers include fireweed, joe-pye weed, evening primrose, prickly wild rose, and wild columbine.

- Eastern Broadleaf Forest
  Ranging from oak savannas to maple-basswood forests of the "Big Woods," the eastern deciduous forests have a different variety of wildflowers. Wildflowers in these areas include trillium, jack-in-the-pulpit, hepatica, bloodroot, violets, and wild geranium.

- Prairie Parkland
  Fertile soils created by native prairie grasses originally drew the European settlers into southern and western Minnesota. Rare prairie remnants are occasionally found along railroad and highway rights-of-way and in old cemeteries, on land that was never used for agriculture. Prairie wildflowers include hoary puccoon, butterfly weed, bergamot, blazing star, and New England aster. Prairie grasses include big bluestem, little bluestem, and Indian grass.

- Tallgrass Aspen Parklands
  Historic patterns of vegetation appear mostly related to frequency and intensity of fire, which were influenced by variation in water table and moisture. The historic patchiness of fire created a complex mosaic of prairies, brushland, woodlands, and forests on upland, and wet prairies, meadows, fens and wet forests in wetlands.

Very few areas of undisturbed native vegetation remain in Minnesota. Although at one time tall grass prairies covered a third of the state, they are now very rare, covering only one percent of their original acreage. Figure 1-2 shows pre-settlement vegetation types in Minnesota. Several additional maps showing ecological classifications for Minnesota are available on the DNR web site at http://www.dnr.state.mn.us/ecs/223n/index.html.

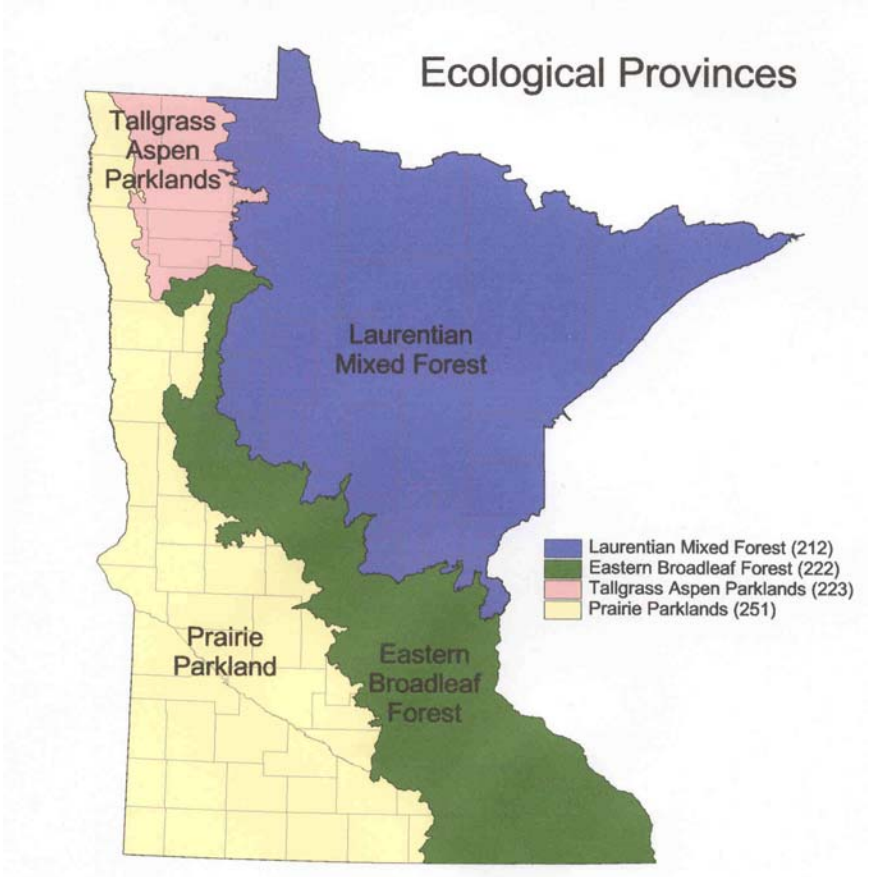


Figure 1-2. Ecological Classification System Map of Minnesota (Copyright, MDNR).

Plant Types
Plants may be grouped according to their physical characteristics or according to their life cycles (Table 1-1). Note their classification when determining a control strategy, as a plant's reaction to treatment depends on these characteristics. Understanding the life cycle of a plant will help you determine the correct timing for control methods.

Table 1-1. Plant Types

Plant Groups According to Physical Characteristics	
Grass	Have a single seed leaf; leaves are narrow and upright. Roots are fibrous and may be either a simple, shallow, annual system, or an extensive perennial system that survives winter, and spreads laterally for many feet.
Broadleaf	Have two seed leaves; generally have broad leaves with net-like vein pattern, and a coarse root system. May be winter or summer annuals, biennials, or perennials.
Woody plants	Perennial plants with woody stems, which do not die over winter. Examples are low growing brush, shrubs, perennial vines, and trees.
Plant Groups According to Life Cycle	
Annuals	Complete their life cycle in one year. **Summer** annuals germinate in spring, grow in the summer, and die in the fall. Control is most effective in the spring when they are seedlings. **Winter** annuals germinate in the fall, begin growing in the winter, and flower in early spring. Seeds are also produced in spring, and the plants die by summer. Control of these plants is most effective in the fall or early spring.
Biennials	Need two years to complete their life cycle. Produce a low-growing rosette plant in the first year, and by the second year, produce a flower stalk. The plant dies after the seeds have matured in the second year. Control is most effective during the first year of growth.
Perennials	Live indefinitely, and reproduce by seed. May also reproduce vegetatively, by rhizomes, tubers, or root sections. Difficult to control because of their extensive root systems. Control most effective by use of systemic herbicides, and when plants are seedlings. For established perennials, control methods should be adapted to the yearly life cycle of the plant. Herbicides applied to foliage during the early part of summer are not very effective because of plant characteristics. Once flowering has begun, characteristics are such that foliar applications of herbicides are most effective, during bud to flower stage, and especially just before flowering. Chemical herbicides are also effective right after plants are cut (on woody plants) and new growth occurs (on herbaceous plants.) Application in fall, prior to plants going dormant is effective since the herbicides move with natural energy flow into the roots of the perennial plants. Foliar herbicides are most effective on woody plants when applied in mid- to late summer. Treatment with dormant basal applications can be very effective from late fall through winter as well.

4. Developing a Plan
After the steering committee or appropriate personnel have been assembled and roadside areas have been categorized, the IRVM Plan may be written. Steps to writing the long-range plan are listed below.

1. Develop a vision or mission statement.
   A vision statement is a picture of your road 10 to 20 years in the future. It includes your highest aspirations for what the roadside can become and serves as a source of motivation for all those involved in the process. A mission statement is broad and outlines the ultimate reason for the program's existence.

2. Collect pertinent data, such as costs, vegetation (existing and desired), available personnel, and resources. This step includes reviewing records of current maintenance operations and taking an inventory of current roadside vegetation conditions. It is easy today to consider the use of GPS and GIS to assist in many areas

of roadside vegetation management. Commercial GPS and GIS products are on the market and in development. The systems can provide or record information, such as environmentally sensitive site locations, for use in planning or implementing IRVM programs. In addition, tracking and record-keeping systems that are linked to equipment controls make collection of data and recall/use easier.

3. Establish goals and objectives.
   When doing so, consider the following basic principles:
   - Safety for the traveling public and maintenance staff
   - Maintenance of the infrastructure and highway integrity
   - Cost-effective use of public resources
   - Environmentally sound decision-making
   - Needs and concerns of adjacent landowners and the traveling public

4. Analyze and prioritize goals and objectives.
   Identify which goals are most important. This allows problem areas to be dealt with first, making other goals and objectives easier to reach.

5. Assign duties and responsibilities for each program participant.
   With input from those staff members who will be responsible for plan implementation, assign duties and responsibilities. Set a general timeline, especially for projects that may require 2-3 years to implement.

6. Plan for budget considerations.
   Identify costs connected with implementing each plan element, as well as ways to deal with budget constraints. This may include planning for equipment purchases and staff needs and increasing the efficiency of existing operations.

7. Provide an opportunity for research and innovation.
   Note research opportunities that may result in innovations for improving quality, reducing costs, and improving working conditions for maintenance staff.

8. Provide evaluation criteria.
   This may be the most important element of the IRVM plan. It is critical that some benchmark be developed to measure program success. Meet and document short-term goals and objectives. Maintain records of implementation activities over time to evaluate overall direction and accomplishments. Periodically evaluate the plan to determine if it is advancing and if it has reasonable and attainable goals and objectives. Make changes as needed.

9. Incorporate GIS.
   Today's roadside manager has an opportunity to consider the use of GPS and GIS to assist in many areas of roadside vegetation management. Commercial GPS and GIS products are on the market and in development. The systems can provide or record information, such as environmentally sensitive site locations, for use in planning or implementing IRVM programs.

   Consider using GPS for documenting prohibited noxious weed locations and scattered locations of new species of invasive weeds; locations of prairie remnants, plant communities, or rare and endangered species; and problem erosion areas.

5. Implementing the Plan

Take the following steps to implement the IRVM plan:

1. Identify appropriate methods and application for control.
   For each maintenance activity, identify the appropriate control method. This could include mechanical methods, such as mowing and aeration; biological or natural processes; cultural methods, such as appropriate seed selection, planting and mulching, or burning; chemical methods, such as the use of herbicides and pesticides; a hands-off approach; or preservation and conservation.

2. Train.
   Train all staff responsible for implementing each element of the IRVM Plan regarding the plan components and their responsibilities. This is especially important for those staff members who will be completing the actual maintenance activities.

3. Keep records.
   Keep records of maintenance activities. This includes information about the type of control used, conditions under which it was applied, and general management information. Information about the control method includes weather, application area limits, time of application, concentration and quantity of any chemicals applied, and other information as needed. For general management purposes, hours, personnel, equipment, and costs are needed to set priorities, evaluate cost-effectiveness, and budget time and money for future activities. A complete and continuously updated location map, indicating control activities and dates of application, is recommended. This can be integrated with a Geographic Information System (GIS) to automate the record-keeping process.

4. Evaluate the program.
   Regularly evaluate in order to measure the success of an IRVM Plan. This may include tracking the number of citizen complaints received before and after plan implementation, cost reductions for certain maintenance activities, and allocation of staff time. Evaluate the effectiveness and success of plan elements and make changes as necessary. Evaluation is an ongoing process, as are changes and improvements.

ADDITIONAL RESOURCES

How to Develop and Implement an Integrated Roadside Vegetation Management Program, published by the National Roadside Vegetation Management Association and available online at www.dot.state.mn.us/environment/pdf_files/irvm_howto.pdf

NCHRP publication synthesis 341, *Integrated Roadside Vegetation Management: A Synthesis of Highway Practice* was published in 2005, and is available online at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_341.pdf

Iowa's integrated roadside vegetation management program is outlined online at http://www.uni.edu/irvm/

The April, 2000 article in *Erosion Control* magazine on Integrated Roadside Vegetation Management, written by Kirk Henderson is available online at http://www.forester.net/ec_0004_integrated.html.

Washington Department of Transportation IRVM plans are available online at http://www.wsdot.wa.gov/maintenance/vegetation/mgmt_plans.htm.

Chapter 2: Best Management Practice No. 2: Develop a Public Relations Plan

When asked to identify the most challenging aspect of roadside vegetation management, improving public relations was the issue listed most often by survey respondents. Effective public relations include dealing with a variety of audiences, such as homeowners and adjacent right-of-way owners; media relations; complaint handling; and crisis management. The most cost-effective integrated vegetation management program will include a public relations plan. Such a plan can efficiently resolve complaints and manage crises, protect the program from budget cuts by selling its advantages to the public, and increase the public's general approval of herbicide use or other management strategies. Each agency should have a plan for media relations, complaint resolution, and crisis management.

Developing and implementing a public relations plan is especially important for National Scenic Byways or other scenic routes where notification of planned roadsides management activities is a must.

Effective public relations depend on the following elements:

- *User awareness:* Users of the vegetation management plan must thoroughly understand the program, its intent, and its goals. Maintenance staff stands at the forefront when dealing with the public while conducting maintenance activities. However, all staff members, as well as other agency personnel responsible for dealing with the public, should be trained regarding the purpose of the activities and the rules and regulations considered in developing the plan. Agency staff should be cooperative and knowledgeable about the policies and procedures being implemented.

- *Public awareness*: Notify the public prior to conducting controversial roadside vegetation management activities, such as herbicide application. Coordinate control operations with adjacent property owners, whether they are homeowners, other agencies, utilities, or companies. Communicate specifics of the plan to property owners and address any concerns or oppositions prior to beginning work.

- *Media relations:* Use the media to make the public aware of spraying operations, as well as to assist in achieving public understanding and acceptance of roadside vegetation management policies, plans, and programs. Communications, whether issued before or after work is performed, should be clear, honest, and helpful.

- *Response to complaints:* Responses to complaints should be complete and professional. When a complaint is made, assign an appropriate staff person to respond to it, recording evidence with color photographs and consulting the manufacturer of a specific product if needed. Develop a standard procedure, preferably in writing, to ensure that all complaints are received and resolved in the same objective manner.

- *Crisis management:* A crisis, such as a fuel or herbicide spill is most easily managed in its early stages. Implementing a crisis plan as part of roadside vegetation management will make that quick response possible

- *Cooperation with other agencies:* This could include local governments, tribal governments, townships, state, and/or federal agencies working adjacent to, or near an area.

Effective public relations also includes working with state and federal legislators to obtain support and funding for roadside vegetation and environmental programs and maintenance. This may be handled in several ways: by government agency legislative liaisons, member or professional organizations, or by individuals.

Ideas for effectively working with policy and decision makers:

- Bring them to the area to educate them about roadside vegetation and maintenance issues. Show them the conditions and special concerns you have about safety, noxious weeds, and the environment.
- Increase communication and be pro-active about educating the policy makers in your area. If appropriate, send them information about new techniques, emphasizing the safety and environmental aspects.
- Get involved in legislation that is important to this issue. As a private citizen, you may contact your representatives when issues arise that you want to have input on.

To find out who represents you in the state House of Representatives and in the Senate, go to the general information page of the Minnesota State Legislature Web site at www.leg.state.mn.us. The legislature meets from January to May each year. Transportation issues are discussed during each legislative session. Funding appropriations are made for two years during odd-numbered years —for example, the 2007 legislature appropriates funding for FY 2008 and 2009.

Chapter 3: Best Management Practice No. 3: Develop a Mowing Policy and Improved Procedures

Since mowed areas are so visible to the public, mowing may be the single most important part of a vegetation maintenance operation. A mowing policy makes for better use of maintenance staff time, assists in the prioritization of areas to be mowed and not mowed, increases safety for the mowing staff, and improves public relations and safety to motorist as well.

Mowing roadsides is very expensive in terms of personnel hours, equipment hours, and fuel consumption. Its purpose is to provide sight distance and room for a vehicle to pull off the road, so mowing the entire roadside is unnecessary. If done improperly, mowing can cause additional maintenance problems and adverse effects to soils, roadside habitat, and nesting birds. Improper mowing height and too frequent or poorly timed mowing can reduce root mass, plant vigor, and overall plant production potential. Operating heavy equipment on roadside slopes can destroy vegetation, weakening the plant community and making roadsides more susceptible to weeds and erosion. If done at the wrong time, mowing can also help to rapidly spread undesirable weed species. Having a plan and educating staff regarding proper mowing procedures, will prevent some of these problems.

Areas that require periodic mowing to maintain safe right-of-way are intersections, bridges, sharp curves, and farm and field entrances. Everywhere else, allowing—or introducing—native grasses provides an acceptable alternative. The use of native grasses is outlined in Chapter 4.

DEVELOPING A MOWING POLICY

When developing a mowing policy, an agency should consider safe operating practices, the prioritization of mowed and unmowed areas, the use of herbicides, and the expected or required cost reductions.

A good mowing policy will identify the following:

- objective of mowing
- best practices to reduce the spread of seed and other plant off-shoots via mowing equipment, such as weed recognition and mower deck cleaning
- impacts if mowing is reduced
- a communication plan between mower operators and weed sprayer operators, including mow vs. spraying strategies; and spring, summer or fall spraying strategies
- areas that could be left unmowed with little negative effect
- ways to blend areas that are left unmowed with areas that are mowed
- treatment of those areas left unmowed
- mower operator training needs
- other maintenance activities that could be done if less time is spent on mowing
- magnitude of slopes to be mowed and not mowed
- person or persons who will determine the areas to mow and not mow
- best time to mow certain vegetation types, based on growth, time of year, or height
- alternative vegetation that could be planted that does not have to be mowed
- nesting times for local wildlife
- location of saturated soils

Obtaining input from all mowing staff will result in a mowing policy that addresses safety concerns, identifies communication issues and procedures, and establishes the criteria for which areas are to be mowed and to what extent. Agreement on these issues and inclusion in a written plan results in all staff working towards the same goal. Reducing the amount of mowing and the extent to which areas are mowed gives workers more time to complete other activities and increases the efficiency of all maintenance operations.

STATE MOWING POLICY

Currently, Mn/DOT mows approximately 45,000 acres annually, ranging in frequency from 2-3 shoulder cuts per year to 10-15 mowings in mowed portions of rest areas and building sites. In some instances, farmers are allowed to mow and hay the right-of-way by permit, which also affects the total mowed acreage.

Mn/DOT mows primarily for safety reasons. Safety reasons include shoulder and median mowing, mowing through the safety clear zone once every two to three years to prevent volunteer trees from becoming roadside hazards, mowing out brush and tall grass in order to prevent snow drift formation on the road, and mowing out sight corners at intersections. Mn/DOT also mows out new prairie plantings two to three times annually for the first two years to accelerate prairie establishment. Through precision mowing, they can mow out noxious weed patches to prevent seed formation and also to promote succulent new growth for spraying with herbicides.

Other reasons for mowing include rejuvenation mowing of shrubs, improving driver response time to deer movement, and winter mowing to restore hydraulic function of ditches. Although the mowing law does not restrict mowing within urban and suburban areas, budget cuts and the desire for more natural appearing roadsides drive the movement for less and less mowing.

The mowing policy developed by Mn/DOT is described in chapter five of the Mn/DOT Maintenance Manual (available online at http://www.dot.state.mn.us/maint/files/Maint_Manual/CH5.pdf). Their policy states that the primary purpose of maintaining vegetative cover is to prevent erosion. Roadsides are to be generally maintained in conformance with adjacent land use, and spot mowing is to be used to control noxious weeds.

To protect pheasants and other ground nesting birds, Minnesota state law limits the time period for mowing the entire right-of-way by road authorities to between July 31 and August 31. The exceptions to that rule are when mowing the entire right-of-way is done for safety reasons, prairie establishment, or to spot mow for noxious weeds. The Minnesota mowing law regulates mowing outside the metro area. This law lists the following requirements:

The first eight feet from the roadway surface may be mowed at anytime. The entire right-of-way may be mowed from **July 31 to August 31** for any reason. **The rest of the year, the entire right-of-way may be mowed only for safety reasons, and only to a minimum height of 12 inches.**

The entire right-of-way may be mowed to maintain sight distance. The entire right-of-way may be mowed, burned, or tilled for establishment of permanent vegetative cover or for prairie vegetation management.

Permissible grass heights, from Chapter Five of the Mn/DOT Maintenance Manual, are listed in Table 3-1.

Table 3-1. Permissible Grass Heights

	Urban Height (Inches)		Rural Height (Inches)	
Shoulder	Minimum	Maximum	Minimum	Maximum
Sod	4	6	4	12
Gravel or Paved	Vegetation growing on gravel shoulders will be controlled by blading. Vegetation growing in cracks in bituminous shoulders should be destroyed by herbicides, soil sterilants, or other acceptable methods.			
Shoulder Inslope Top 2 mower swaths	4	12	4	18
Ditches and Back Slopes Below top 2 mower swaths	4	12	Terminal	Terminal
Steep Slopes Steeper than 1:3	Terminal	Terminal	Terminal	Terminal
Medians				
Less than 55 ft	4	12	4	4
Greater than 55 ft	4	12	Terminal	Terminal
Interchanges	4	12	4	18

The Mn/DOT Seeding Manual outlines a prescription for mowing frequency on each seed mixture. That manual is available online at http://www.dot.state.mn.us/environment/pdf_files/seedingmanual.pdf

Mn/DOT Requirements for All Mowing Widths
Mow all grass according to the state mowing law. You should mow:

- all of the shoulder (the first 8 feet)
- two swaths of the mower on all inslopes (first 8 feet)
- all of the median for those less than 55 feet wide, and for medians greater than 55 feet wide, mow two-swath widths
- a smooth transition when blending between mowed and unmowed areas

For safety reasons, Mn/DOT mowing policy recommends that operators avoid slopes greater than 1:3, be alert and slow down in high grasses, avoid traffic, and wear all approved safety equipment.

To control noxious weeds, Mn/DOT mowing policy requires operators to mow heavily infested patches of Canada thistle when the patch area exceeds 50 square feet, to communicate with other maintenance staff to avoid mowing areas soon after or just before spraying, and to avoid mowing areas of leafy spurge.

Other Guidelines from the Mn/DOT Policy

- Keep signs clear and their approaches mowed from approximately 500 feet.
- Keep vegetation around guardrails controlled for approximately 2 feet on either side to reduce the effects of trapping sand, snow, and dirt.
- Maintain sight distance at at-grade intersections, interchanges, and curves.

The Mn/DOT Maintenance Manual also notes the primary purpose for planting and maintaining a vegetative cover on roadside areas is to prevent erosion of the soil. And, it is desirable to manage the vegetative growth in a manner that will maintain a healthy roadside ecosystem, create a safe and appealing roadside for the motorist and provide protection for nesting wildlife.

Also, roadsides are generally maintained in conformance with adjacent land use. The entire right-of-way may be mowed if the adjacent land is a manicured park, cemetery, church, roadside business, home or farmstead. Maintenance staff are instructed to blend full-width mowing into the roadside by mowing to a natural geographical feature or a maximum distance of 500 feet from the park, cemetery, etc.

Maintaining the Clear Zone
The roadside clear zone as defined in the Mn/DOT Road Design Manual as "the distance from the edge of the travel lane which should be free of any non-traversable hazard such as steep slopes or fixed objects." Clear Zone widths are targeted towards allowing approximately 80 to 85 percent of all run-off-the-road vehicles to recover or come to a safe stop. The width of the clear zone along a horizontal alignment is dependent on roadside geometry, design speed, radius of horizontal curvature and ADT.

Maintenance of the clear zone can be related to sight distance which provides that a vehicle operator must be able to see ahead a sufficient distance to perform a variety of vehicle maneuvers as may be needed. For field maintenance, a sufficiently wide roadside clear zone should be available in areas of known wildlife habitat to provide adequate stopping sight distance in the event an animal intrudes or is about to intrude onto the roadway. Similarly, the roadside clear zone should be maintained sufficiently wide where possible to provide adequate intersection sight distance at at-grade intersections or private driveways where vehicles may be entering or leaving the traveled roadway.

Determination of adequate clear zone width is a function of vehicle speed, degree of road curvature, location on a cut or fill section and slope of the roadway inslope. A procedure for determining the clear zone width at any given location and conditions noted above is available in the Mn/DOT Road Design Manual, section 4-6.04, located online at http://www.dot.state.mn.us/tecsup/rdm/english/4e.pdf.

Equipment Cleaning After Mowing

The control of invasive weeds is outlined in Chapter 5. It is inevitable that weeds will be encountered during mowing operations. According to the Summer 2005 Edition of the Native Warm-season Grass Newsletter published by the Missouri Conservation Department, "the greatest vector for spreading weed seed is rotary mower decks". Figure 3-1 illustrates a good example of this. In both photos, the cuttings are completely covering the mower deck. Figure 3-2 shows seeds lodged in a vehicle's headlight, illustrating the ease with which invasive seeds can travel through normal maintenance activities.

Figure 3-1. Mowing clippings completely covering mower decks

The DVD entitled, "Dangerous Travelers: Controlling Invasive Plants Along America's Roadways" outlines the problem of weeds migrating across the country. Weeds and seeds get carried by cars and maintenance equipment, and are spread through the arteries that roads provide. This DVD is published by the USDA Forest Service, and is available for downloading online at http://www.fs.fed.us/invasivespecies/prevention/dangeroustravelers.shtml

Several ways to combat this problem are:

1. Thoroughly clean maintenance equipment after working in infested areas. This includes mowers or blading equipment. Cleaning should include power washing.
2. Stockpile any cuttings removed from infested areas. Dispose of this material; do not reuse it where weeds could spread.
3. When working in a weed-infested area, control traffic if possible. Traffic traveling through the area can easily pick up and transport weed fragments and seeds.
4. Insist that all equipment brought on site is clean and weed-free.
5. Frequently inspect equipment storage areas for weeds. Remove any weeds that are present.

Figure 3-2. Seeds lodged in vehicle light reservoir

Chapter 4: Best Management Practice No. 4: Establish Sustainable Vegetation

Planting and establishing sustainable vegetation along roadsides is very important, since trying to establish plants and trees that are not suited to an area or condition is a waste of time and resources. Sustainable vegetation requires less maintenance and thrives where it is planted. The keys to a sustainable roadside environment include:

1. Using native grasses and wildflowers
2. Using salt tolerant species
3. Staging planting
4. Controlling erosion
5. Selecting appropriate shrubs and trees for a given area
6. Strategically managing woody vegetation and trees

USING NATIVE GRASSES AND WILDFLOWERS

Two primary objectives of roadside maintenance, weed prevention and erosion control, can be accomplished through the use of native grasses and wildflowers. The establishment of native plants in an area results in a diverse and strong plant community adapted to local conditions — including a wide range of soil types, moisture levels, and climactic conditions. Most prairie grasses and wildflowers grow best during hot, dry summer months, thus they provide excellent erosion control all year. Deep roots also prevent the invasion of noxious weeds and reduce the number of undesirable and competing shrubs and trees. Additionally, including wildflowers with native grasses creates a more stable and colorful environment throughout the growing season and adds color, texture, and beauty to the roadside.

Other benefits of using native grasses and wildflowers include:

- Potential for less money spent on herbicides, fertilizers, and maintenance. Because native plants are self-sustaining, they require less maintenance, and their dense roots force out competing plants, so the area typically requires less herbicide use.
- More effective application of herbicide through better use of equipment and spot spraying only the weeds. Using the best products at the right time optimizes chemical use.
- Soil stabilization through the use of native prairie grasses. The dense and deep root systems (typically 6 feet and deeper) for these grasses prevent erosion and slope failure.
- Roadside beautification and enhanced wildlife habitat (such as food and nesting cover for birds) through restoration of a piece of Minnesota's natural heritage.
- Improved traffic safety, as vegetation screens headlight glare in curved median areas and delineates the roadway for drivers.
- Creation of an inexpensive and low-maintenance snow fence.
- The ecological benefits of a more diverse, self-sustaining planting with a possible reduction in mowing and spraying needs fewer chemical applications or mowing.
- Aesthetic improvements to the road and travel experience, which can help reduce driver fatigue and boredom.
- Reduced environmental impacts from maintenance operations.
- Improved water and air quality.

These benefits can be achieved by integrating several management techniques into a system that encourages desirable vegetation and prevents undesirable vegetation from establishing.

A partial list of native grasses that can be grown in western Minnesota include:

- blue-joint grass
- big and little bluestem
- fringed brome
- Kalm's brome

- Buffalo grass
- prairie cord grass
- prairie dropseed
- sand dropseed
- tall dropseed
- blue and hairy grama
- Indian grass
- June grass
- Sand lovegrass
- Green needle grass
- switchgrass
- slender wheatgrass
- Western wheatgrass
- Canadian wild rye

A complete list of Minnesota-hardy grasses, as well as appropriate wildflowers and their substitutes, is on the Mn/DOT Office of Environmental Services Web site at www.dot.state.mn.us/environment. The information is listed under the section for **Erosion Control,** in the seeding manual. Wildflowers are listed for each of four areas in Minnesota, as well as for wetland areas.

Seed should be purchased on the basis of Pure Live Seed (PLS) rather than bulk weight, and this should be based on a current seed test. Buying seed in this way ensures that the desired amount of viable seed is obtained. All wild-type native grass and forb seed shall have a source of origin within Minnesota, eastern North or South Dakota, northern Iowa, or western Wisconsin. To ensure that plants are locally adapted, native grass and wildflower seed should be purchased as "yellow tag" seed, which is wild-type seed that has been source-identified by the Minnesota Crop Improvement Association. Wild-type seed is defined as that which is derived directly from native wild stock, including seed that was collected in the wild and placed into production or that which has been harvested directly from native stands regional or local ecotypes that have not undergone a selection process. Wild-type refers to all native seed referred to as "common" in the industry.

A Survey of Existing Native Plants
To identify existing native plant stands in your jurisdiction, conduct a preliminary survey. Once existing native plants are identified, develop and implement appropriate management guidelines. The survey should include:

- Identifying road segments contiguous with federal, state, county natural areas so that roadside prairies may receive prescribed burning or augment seeding at the same time such treatments are being done on the adjacent lands. This requires communication and synchronization with the adjacent natural area landowners.
- Specialized management techniques, such as prescribed burns, reduced mowing, and reduced herbicide/pesticide spraying, which are required for high-quality native plant communities.
- The location of rare plants, so that spraying, construction, and other disturbances can be avoided.
- Potential sources for native seed for future roadside plantings.
- Management guidelines for different areas.
- A plan to contact railroad companies and utilities to coordinate appropriate maintenance practices.
- Identification of areas for future research opportunities on the use of tall grasses for snow-drift control.
- Identification of areas for future research opportunities on roadside wildlife preservation. Coordination and communication with the DNR and National Rails to Trails Conservancy (RTC) concerning potential recreational/educational uses of abandoned railroad rights-of-way.
- Identification of problem weeds and locations so that appropriate maintenance practices can be outlined and priorities for brush control set.
- Determination of whether opportunities exist for National Prairie Passage enhancement projects on the National Transportation system, or related secondary or prairie remnant routes. More information on Minnesota's Prairie Passage Route can be found at http://www.fhwa.dot.gov/environment/greenerroadsides/sum03p5.htm

Seed Sources and Harvesting
Native grass and wildflower seed is expensive, costing approximately $50-100 more per acre than varietal turf grass seed. Some agencies have chosen to harvest seed from stands of established native grasses. Harvest the seed in the fall, either by hand, perhaps using volunteer organizations, or with farming equipment. Some weedwhipper-style equipment is effective; combines, seed strippers, and flail vacs are practical for larger areas.

Several books provide information on harvesting dates, seed storage, and propagation. It is important to obtain permission before collecting seed on state and county reserves, private land, and state right-of-way and to leave at least 80 percent of the seed for regeneration.

Use seed that has adapted to local climate and environmental conditions. Through natural selection, genetic variants within species have developed to adapt to local conditions. These variants, known as ecotypes, are suited to local climate, soil type, diseases, and pests. To date, the Midwest has relied heavily on western varieties for prairie plantings. These varieties, typically selected from a limited gene pool, were developed as vigorous forage plants and can overtake less aggressive local populations. In addition, due to their limited gene pool, these western varieties may also lack resistance to local diseases, pests, and weather, making them short-lived.

They may also bring in new diseases that threaten local populations.

A list of sources to obtain local ecotype seed is on the Mn/DOT Office of Environmental Services Web site at www.dot.state.mn.us/environment under the link labeled "Erosion Control".

Originally, most of the effort by seed producers had been put towards producing native prairie seed. Seed for natives from other vegetative zones, such as woodland edges and wetlands is now being produced as well and its availability is increasing.

The Minnesota Native Wildflower and Grass Producers Association can offer assistance in selecting appropriate seeds, and in propagating a healthy native environment. Their web site can be accessed at: http://www.mnnwgpa.org/MNNWGPA%20Brochure.pdf

How to Start a Prairie Planting

When planting prairie plants, use hardy drought-resistant wildflowers and grasses indigenous to the area. To determine what types of plants will grow in an area, visit local natural areas that have similar topography. Match plants to sun or shade and drainage needs.

STEPS TO A PRAIRIE PLANTING

- Visualize what the planting is to accomplish, whether providing erosion control, wildlife habitat, beautification, or reduced maintenance.

- Survey the site and consider drainage requirements, soil type, existing vegetation, sun and wind exposure, and adjacent land uses and management impacts.

- Clear the existing vegetation by using a broad-spectrum herbicide, such as glyphosate (Roundup™). Allow a week for the herbicide to work effectively, then mow or burn to remove the dead plant material. After that, drill or rake seed into the stubble.

- If timing permits, an alternative to using herbicides is cultivation, or sequences of till, fallow, and till. Plow or harrow the soil several times prior to planting to destroy existing vegetation and eliminate germinating weeds. The last two cultivations before seeding should be just deep enough to remove any remaining weed seedlings. While avoiding the use of herbicides, this technique does increase the likelihood of erosion and may not be suitable for use on slopes.

- Plant a native mix that includes fast cover and permanent establishment species, using as many species as are affordable (plantings with many species are more resistant to invasion by weeds, more tolerant of harsh weather extremes, and add to the beauty and diversity of the roadside). Achieving good seed-to-soil contact is the best insurance for successful establishment. For larger areas, use a native grass drill if available, and if seeding over heavier soils, such as loams and clays. Broadcasting seed is preferred on sandy soils because the drill generally sinks into the soil, planting seeds to deep for healthy germination.
- It is usually not recommended to add nitrogen fertilizer for native plantings. Many native species are very efficient users of nitrogen and excess nitrogen tends to increase weed competition.

- Unchecked weeds can shade out prairie seedlings during the first year. To prevent this, mow weeds at a height of 4 inches the first year, on approximately June 1, July 15, and September 1. The second year, mow at a height of 7 inches in May and 12 inches in June, if needed. These mowing heights will help prevent damage to emerging prairie plants. Additional spot mowing or hand weeding may also help control invasive weeds.

- Spot-spraying of more persistent weeds may be necessary while native vegetation is getting established. If large patches are sprayed, the resulting bare soil may need to be re-seeded to prevent the weeds from returning.

- Burn as soon as enough leaf litter accumulates to carry a fire (usually the second or third year after planting). This helps destroy weedy species and stimulate prairie vegetation. Burning every three to five years should be sufficient. If woody vegetation becomes a problem, burn more often. Burn in sections and at different times of the year to reduce adverse effects to any one prairie species. If burning is not possible, remove plant litter by some other means, such as raking or mowing. Note that most of the growth in the first two years occurs below ground, and it may be three to four years before the growth above ground is well established.

How to Plant Prairie Grasses and Wildflowers in your own Ditch:

1. Start small. Keep the size manageable by only planting a few patches.
2. Inventory your plantings.
3. Plant in late fall (November) or by mid-June in the spring.
4. Order seed from a local supplier.
5. Spray the area with a broad-spectrum herbicide (such as glyphosate) prior to burning or cutting to reduce competition.
6. Burn off the existing vegetation or cut it as low as possible with a mower or weedwhipper.
7. Avoid deep tillage, which invites erosion and weeds. Rake lightly to loosen the soil and improve establishment.
8. Scatter the seed by hand. Mix seed with sand to allow more even distribution.
9. Work the seed into the soil by raking the area to a depth of 1/4 inch.
10. Firm the seedbed.
11. Post a sign so that the area is not sprayed.
12. When weeds reach a height of 10 inches, mow to a height of about 5 inches several times during the first growing season. This stimulates warm season plant growth.

Maintenance Needs

Burning and haying are the two primary management techniques for use with prairie vegetation. Burning offers the following benefits:

- stimulate the growth of many native prairie plants
- control weeds and woody invaders
- remove thatch
- recycle nutrients
- warm the soil and give warm-season plants an earlier start

Consider traffic safety, weather conditions, equipment, and staffing before burning. Timing is important and depends on the vegetation management objectives. Burning is most beneficial from mid-April to early May for warm-season grasses. Any burning plan must include smoke management provisions for safety purposes.

Burning permits may be required; inquire at the local sheriff's office or fire department. Burning should be conducted by trained crews with proper safety and fire suppression equipment. Certification requirements vary with different agencies and organizations. More information can be found by contacting The Nature Conservancy, MDNR, Mn/DOT Environmental Services, and the County Fire Marshall for specific requirements in your local area.

USING SALT-RESISTANT VEGETATION

Road salt and deicers can greatly damage roadside vegetation. Although these damaging effects are most severe within 50 feet of the pavement, they may extend hundreds of feet depending on the volume and speed of traffic traveling on, and wind direction near, a particular road. Accumulated salt in a soil can also affect its drainage capabilities. Because anti-icing and de-icing salt use on pavement is required for safe winter travel in Minnesota, the use of salt-resistant vegetation is vital for sustaining vegetation along the road.

A 1989 study conducted by the Wisconsin Department of Transportation found that local geology affects the impact of a roadway deicer. The relative impact is related to the chemical load of the surface and ground water. Traffic volumes and local topography also affect the deicer impact; a deicer is diffused further from the roadway in high traffic and in high fill sections. The amount of salt that a soil retains is related to its clay content. In addition, the study found that chlorine accumulates in both deciduous and coniferous trees at a rate of 40 to 100 times the amount retained in the soil.

To alleviate the effects of roadway salt on adjacent soil and vegetation, treat the soil with gypsum, which reverses the effects of sodium (Na) and chloride (CL) accumulation, and plant salt-resistant grasses and wildflowers. Approximately 1 pound of gypsum per 5 square feet of soil may be used.

The following natives or wildflowers can also be used with success in areas where salt is an issue:

Native grasses:	Canadian wild rye, Indian grass, little bluestem, blue grama, side oats grama
Wildflowers:	Black-eyed Susan, purple prairie clover, yarrow, bush clover

A report titled *Establishment, Protection, and Reestablishment of Urban Roadside Vegetation Against Salt and Ice* is available through Mn/DOT Office of Research Services. The report outlines many maintenance and construction activities to use in Minnesota. It is available online at the Minnesota Local Road Research Board website at http://www.lrrb.org. Search the title of the report, and it can be downloaded.

Also, a best practice is outlined in Chapter 9 for salt alleviation. It involves placing a 2-6 foot wide strip of leaf and grass compost adjacent to the roadway's shoulder edge. This creates a barrier to the salt-laden soil and may discourage deer from licking it.

STAGED PLANTING

Staged planting involves planning for the continuous maintenance and improvement of roadside areas. This could include:

- replacement of trees and vegetation that dies out
- addition of vegetation as funds become available
- filling in gaps from killed noxious weeds
- temporary seeding during construction
- seeding in stages during construction, as each area is completed
- special projects and experimentation

CONTROLLING AND PREVENTING EROSION

Since this manual was originally published, the Minnesota Pollution Control Association has significantly changed requirements for the control of sediment and stormwater runoff. Mn/DOT has published a new Erosion Control Handbook (number II), which is available through the Office of Environmental Services at (651) 366-3600.

This updated handbook includes chapters on stormwater compliance, and best management practices (BMPs) and how to use them. BMPs are offered for controlling runoff, minimizing erosion, managing sediments, permanent vegetation establishment, working around water, bioengineering, site drawing, dewatering, and basin draining.

Additionally, the Local Road Research Board published "The Erosion Control Handbook for Local Roads" in 2003. This handbook offers best practices for controlling erosion during the construction of low volume roads, as well as the ongoing maintenance required for each method. It is available online at www.lrrb.org.

Erosion control is required to maintain a healthy roadside environment, since the structure and contents of soil must be preserved if vegetation is to thrive. Actions that help control erosion include:

- incorporating good design methods that reduce flow velocity
- using effective cover crops when seeding areas are slow to establish native plant communities
- using structural methods, such as sediment basins and check dams
- using vegetative methods, such as blankets and mulches

Mulching protects the soil, reduces flow velocity, and retains moisture. Straw (either wheat or oats) makes good mulch material. All mulch should be free of weeds. Use hay where new weeds will not be a problem. Wood chips make for good mulch around trees.

Mulch slopes as shown in Table 4-1. During construction, temporarily seed stockpiles. Seed all completed and final-graded areas as soon as possible.

Table 4-1. Mulching Recommendations for Slope Steepness

Slope	Mulching Recommendations
1:3 or steeper that drain to special waters	3 days
1:3 or steeper	7 days
1:4 to 1:10	14 days
Flatter than 1:10	21 days

CHOOSING THE RIGHT TREE OR SHRUB FOR A GIVEN AREA

As with plants and grasses, placing a tree or bush in an area where it will not thrive causes maintenance problems that could have easily been avoided. When selecting a specific type of vegetation, consider the vegetative zone of the area, local soils, temperatures, precipitation and runoff, slope, and sunlight exposure to better the chances for survival.

Trees and shrubs listed in Table 4-2 are suitable for use in Minnesota. Consult with a Mn/DOT or DNR forester to determine species and quantities.

Table 4-2. Trees and Shrubs in Minnesota

Trees	Shrubs
Statewide Upland	
American elm	American elder
American linden	American plum
Big tooth aspen	Common chokecherry
Box elder	Downy arrowwood
Bur oak	Gray dogwood
Common hackberry	Nannyberry
Eastern cottonwood	Red-berried elder
Green ash	Smooth sumac
Ironwood	Smooth wild rose
Northern pin oak	Oldfield juniper (*Juniperus communis*)
Statewide Lowland	
American elm	Highbush cranberry
Black ash	Pussy willow
Eastern cottonwood	Red-osier dogwood
Green ash	Sandbar willow
	Tamarack (except SW)

Tree and Shrub Seedling Mixes

In past years, Mn/DOT relied heavily on using red pine along roadways. In some cases, it was planted outside of its native range and in areas not suited to the requirements of the tree. A better practice is to note native plant communities in the area and then select a suitable tree or shrub. Table 4-3 outlines appropriate selections for Minnesota planting zones (see Figure 4-1). A 50-50 mix of trees and shrubs planted at an average spacing of five feet apart will provide a diverse and adaptable plant community.

Five to 20 plant species will also ensure plant diversity, but in some cases, planting all of the same species may be desirable.

Table 4-3. Trees and Shrubs for Minnesota Zones

Species	**Minnesota Planting Zone**					
	1	2	3	4	5	6
Trees						
Mixed conifer/hardwoods						
Bur oak	X	X	X	X	X	X
Northern pin oak	X	X	X	X		
Northern red oak	X	X	X	X		
Red maple	X	X	X			
White pine	X	X	X			
White spruce	X	X	X			
Mixed conifer						
Red pine	X	X	X			
Jack pine	X	X	X			
White pine	X	X	X			
White spruce	X	X	X			
Balsam fir	X	X	X			
Other						
Kentucky coffee tree	X					X
Northern red oak	X	X	X			X
Red maple	X	X	X			
River birch	X					
Showy mountain ash	X	X	X			
Silver maple	X	X	X			X
Sugar maple	X	X	X			
White ash	X	X				
Yellow birch	X	X	X			
Shrubs						
American hazelnut	X	X	X	X	X	
Beaked hazelnut	X	X	X	X	X	
Dwarf bush honeysuckle	X	X	X	X		
Staghorn sumac			X	X	X	
Winterberry (winter holly)	X	X	X	X		

Note: All species listed are appropriate in upland areas. The River birch and Silver maple are also appropriate in lowland areas.

Note that white pine may be used in zones 1,2 and 3,but deserves special consideration due to the low percentage (approximately 1 percent) of Minnesota land covered by this tree. Since white pine tolerates some shade, it can be planted in the understory of deteriorating stands of pioneer hardwoods like aspen and birch. The tree should not be planted in areas with high average daily traffic (ADT) and considerable amounts of de-icing salts are used.

Consult a Mn/DOT forester or other specialist to determine species and quantities. Another good resource, Mn/DOT *Woody and Herbaceous Plants for Minnesota Landscapes and Roadsides* expert system for plant selection, online at http://plantselector.dot.state.mn.us.

Site Preparation
Minimizing competition from grasses and weeds requires site preparation. The amount of preparation depends on the soil type: loamy sands require little or no preparation, whereas heavier sandy loam to clay loam areas require more preparation. Appropriate levels of site preparation are listed in Table 4-4.

Seedling Storage and Handling
Store plants in a cool place at 35 - 45° F and plant within three to five days. Keep the root system cool and moist and protected from the drying effects of the sun and wind. Prior to planting hardwoods, you may choose to soak roots for one hour, but inspect the roots first to ensure they are disease-free, as soaking may spread the disease. Do not soak evergreens.

Planting Dates
The optimal planting time is in the spring, from frost to May 15.

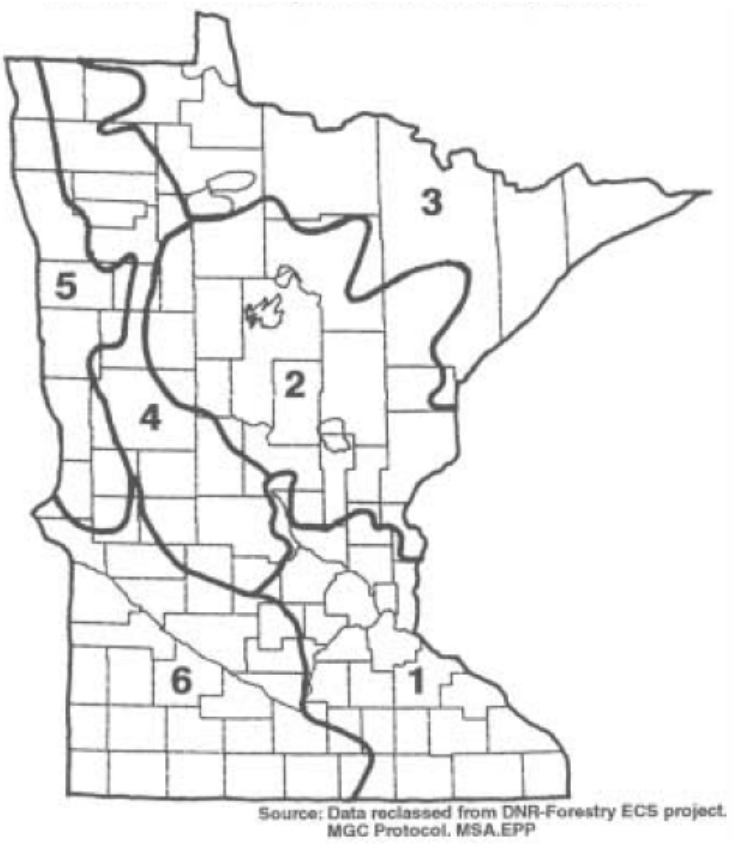


Figure 4-1. Minnesota Plant Species Suitability Zones

Table 4-4. Levels of Site Preparation

Area	Site Preparation Required
Areas traversable with tractor and tree planter	1. Spray the planting area with glyphosate, preferably during late summer prior to spring planting. Till with a spading machine, machine plant, and mass mulch the area with wood chip mulch. Prior soil loosening can be eliminated if "Whitfield Planter" is used when planting through sod. 2. Spray the planting area with glyphosate, preferably during late summer prior to spring planting. Machine plant into killed area, and apply surflan for control of germinating weeds. 3. In light soils plant into existing vegetation without site preparation.
Steep slopes not traversable with mechanized equipment	1. Spray 3' diameter areas with glyphosate for each plant, hand plant, and apply weed fabric and/or wood chip mulch to the sprayed area. 2. In light soils, plant into existing vegetation without site preparation. Applying a 3' diameter circle of wood chip mulch will reduce evaporation and evapotranspiration.
Another option	Dramatic results and accelerated growth have been documented in Ottawa roadside reforestation trials by tilling in compost and planting through perforated black poly. The poly is cut and pulled out after 3-4 years, assuming crown closure and full leaf litter are achieved to control competition.

Seedling Installation
When installing by machine, drive the tractor slowly to ensure that seedlings are planted straight and to prevent J-root formation. Hold the seedling's root flare with index finger and thumb, and make sure the root flare is even with the groundline when placing the plant in the planting trench. Walk behind the tree planter and perform a "tug test" to ensure that soil is firmly packed around the root system. Seedlings should not give or pull out when they are gently pulled at their base.

Planting machines are available from Mn/DOT, the DNR, and the Soil and Water Conservation Districts. Mn/DOT's machines, designed to plant through a sod layer, are available at Duluth District 1A and Mankato District 7A. The Soil and Water Conservation District's machines, most suited to planting in tilled planting sites, are available for a minimal fee on a first-come, first-served basis. A seed/acorn planter is available in the Metro District. The DNR has over 200 machines throughout the state available for loan or rental.

Seedling Sources
The DNR has a good selection of native trees and shrubs from local seed sources. They may be contacted at:

General Andrews Nursery
Box 95
Willow River, MN 55795
Phone: 218-372-3183 or 1-800-657-3767
Fax: 218-372-3091

If purchasing from a private nursery, make sure seedlings have been grown from Midwest-or Minnesota-origin seed, or from other propagation material such as softwood cuttings. The Minnesota Crop Improvement Association (MCIA) should certify the source of plants or seed.

The proof of certification, usually in the form of a tag affixed to the box or other shipping container, indicates where the product was collected.

Direct Seeding
Several tree and shrub species may be established from seed. Those that are good candidates are listed below:

Trees	Box elder, green ash, American elm, hackberry, silver maple, black walnut, bur oak, red oak, northern pin oak, Kentucky coffee tree
Shrubs	Red-osier dogwood, gray dogwood, American plum, red-berried elder, and staghorn and smooth sumac. (Note: both types of sumac require pretreatment, which consists of placing the seeds in boiling water, turning off the heat, and letting them soak in this same water for 24 hours. Sumac seed treated this way must be planted in the spring.)

*Site Preparatio*n: Spray existing vegetation with glyphosate, preferably in late summer for fall or spring seeding. Apply 1-2 inches of wood chip mulch over either tilled or untilled ground after planting the woody plants. Tilling prior to seed scattering provides a better seedbed for woody seeds; however, more weeds will emerge from tilled soil.

Timing: The best time for seeding most species is in the fall (September 15 – November 1), which gives the seeds a period to winter and naturally stratify in preparation for spring germination and eliminates the need to store seeds over winter in refrigerators. If storing seeds in refrigerators, put them in closed containers to prevent drying out. Some seeds will take one to two growing seasons to germinate, in spite of fall seeding. A 1-to 2-inch layer of wood chip mulch or straw layer over the seeds will reduce rodent and bird predation and provide some weed control and moisture retention.

Rates: Allow 3-to 10-foot spacing between surviving trees and shrubs. Direct seeding rates for tree and shrub propagation are listed in Table 4-5.Seeding associations determine the total seeds necessary to achieve this spacing, assuming an average 7.5 percent survival rate, based on information in the table.

Table 4-5. Direct seeding rates for tree and shrub propagation

Species	Average no. of seeds/pound	Pounds per acre*	
		Monoculture*	Association*
Trees			
Box elder	13,400	0.5-1	0.2
Green ash	17,260	0.4-1	0.2
American elm	70,900	0.2-0.5	0.1
Hackberry	43,000	0.3-0.5	0.1
Bur oak	75	100-150	30
Red oak	125	50-100	20
Northern pin oak	245	25-50	10
Kentucky coffee tree	230	25-50	10
Shrubs			
Red-berried elder	286,000	NA	0.01-0.1
Gray dogwood	13,000	NA	0.5-1.0
Red-osier dogwood	18,500	NA	0.5-1.0

*Monoculture refers to planting only one species and Association, to planting two or more species.

MANAGING WOODY VEGETATION AND TREES

According to the Iowa IRVM, maintaining a safe travel environment requires a sustained, adequately funded effort employing a variety of practices, including:

- Chainsaw crews, brush chippers and cut stump treatments
- Foliar herbicide applications
- Basal bark herbicide treatments
- Use of boom mowers
- Tree shear and other heavy equipment

To manage woody vegetation along a roadway, it may be necessary to divide the right-of-way into zones, as shown in Figure 4-2, and assign a management strategy to each. For example:

Zone 1 – shoulders, shorter turf
Zone 2 - clear zone, prairie vegetation or small shrubs
Zone 3 – brush, woodland or prairie vegetation

GENERAL BEST MANAGEMENT PRACTICES FOR WOODY VEGETATION

Brush Control Guidelines

- Don't spray big brush; rather, cut it down, and chemically treat stumps. The extreme color change from spraying may cause public concern.
- The best way to kill brush is to clear cut (with a mower or brush hog) and treat foliage when it resprouts to 3-5 feet tall. This will lead to a 7-10 year treatment cycle. Low profile stubble or stump treatments will shorten the treatment cycle to five years due to misses.
- Spray when trees and shrubs are small (less than six feet tall).
- Mow smaller brush before spraying and let it resprout to 3-5 feet height.
- In sensitive areas, consider spraying in the fall, because the color of the dead foliage will look like natural fall color. Brush spraying in the fall typically is not as effective as spraying in the summer, due to resistance to treatments. And, chemicals used at that time may accidentally kill other species like grasses and forbs.

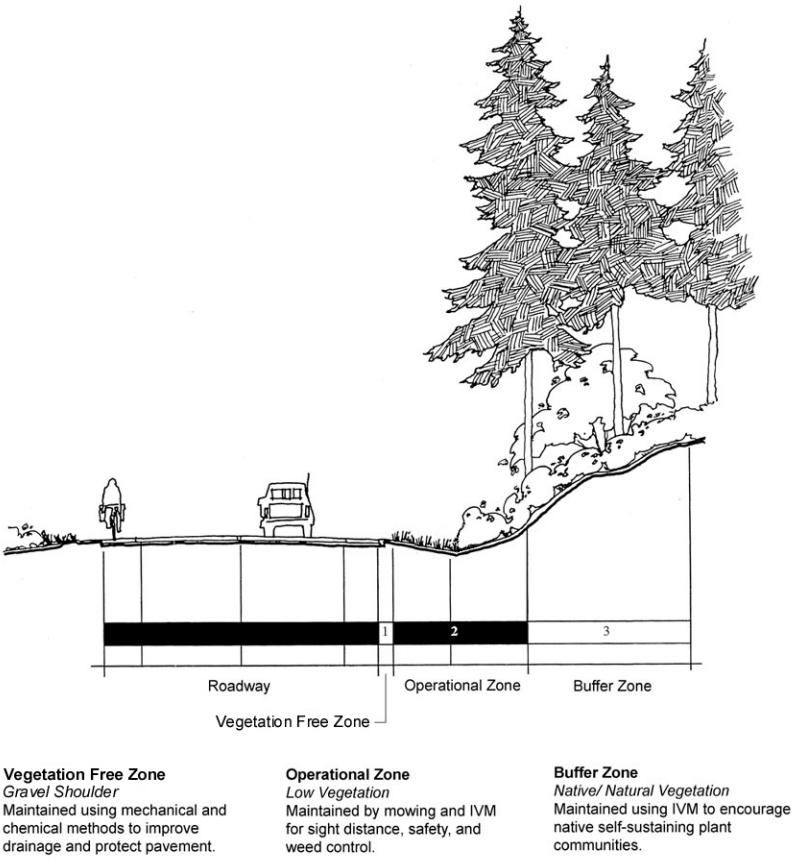


Figure 4-2. Typical Roadway Vegetation Management Zones **(Ray Willard, Washington DOT).**

Tree Care and Pruning Guidelines

- Remove trees greater than 4 inches in diameter from zone 2.
- When spraying, keep an adequate distance from desirable woody plants.
- Prune every two years on young trees and every five years on trees in intensively managed areas.
- Don't ignore the mid-size tree. Removal of dead wood reduces the risk of ice-storm and wind-storm breakage at a time when these trees are providing many environmental benefits.
- Follow safety and OSHA standards.
- Do not work within 10' of overhead power lines.

Pruning

Trees are pruned along the roadside primarily for:

Safety: Removing branches that could fall and cause injury or damage property, trimming branches that interfere with the sight lines, and removing branches that grow into utility lines. Selecting species that will not grow beyond the available space and have strength and form characteristics appropriate for use along roadsides can reduce the need for safety pruning.

Health: Removing diseased or insect-infested wood, thinning the crown to increase airflow and reduce pest problems, and removing crossing and rubbing branches. Pruning can be used to direct trees to develop a strong structure and reduce the likelihood of damage during severe weather. Removing broken or damaged limbs encourages wound closure. Removal of dead wood in mid-size to mature trees reduces the risk of ice-storm and wind-storm branch breakage.

Aesthetics: Enhancing the natural form and character of trees or stimulating flower production. Pruning for form is especially important on open-grown trees that do very little self-pruning.

The emphasis when pruning young trees should be on producing strong structure. As trees grow, shift the emphasis to maintaining the tree structure, form, health, and appearance.

The common types of pruning are:

Crown thinning: The selective removal of branches to increase light penetration and air movement throughout the tree crown. The intent is to maintain or develop a tree's structure and form. No more than one-quarter of the living crown should be removed at a time. This technique is primarily used on hardwoods.

Branches with strong U-shaped angles of attachment should be retained. Branches with narrow, V-shaped angles often form included bark, and should be removed. Included bark forms when two branches grow at sharply acute angles to another, producing a wedge of inward-rolled bark between them. This prevents strong attachment of branches and may cause a crack at the point below where the branches meet. Co-dominant stems that are about the same size and that arise from the same position often form included bark, so remove some of the lateral branches from a co-dominant stem. When possible, reduce the co-dominant branch over a several year period by practicing subordination pruning to reduce growth of the unwanted branch.

Crown raising: The practice of removing branches from the bottom of the crown of a tree to provide clearance for vehicles or line of sight. After pruning, the ratio of living crown to total tree height should be at least two-thirds. On young trees, temporary branches may be retained along the stem to encourage taper and protect trees from vandalism and sunscald. Less vigorous shoots, about 6 to 8 inches apart along the stem, should be selected as temporary branches. Prune these annually to slow their growth, eventually removing them altogether.

Crown reduction: Also called drop crotch pruning; used most often when a tree has grown too large for its permitted space (such as beneath a utility line). This method is preferable to topping because it results in a more natural appearance, increases the time between prunings, and minimizes stress to the tree. However, this technique often results in large stem wounds that may lead to decay; it should never be used on a tree with a pyramidal growth form. A better long-term solution is to remove the tree and replace it with one that will not grow beyond its available space.

The importance of proper tree pruning is illustrated in Figures 4-3 and 4-4. At planting, tree B was pruned correctly. Both the broken branch and the competing branch were removed close to the trunk. Another branch, swollen from an insect laying eggs, was also removed. After three or four years, all root suckers and sprouts in the crown and excessive branches were removed to reduce competition for light, water, and nutrients. A co-dominant leader branch was removed as well, as were several of the lowest limbs.

At five to seven years, the lower limbs were pruned off to raise the bottom of the crown out of the way of human heads. The lowest limbs will now be the permanent lowest limbs. Note that branches do not move upward as a tree grows taller. The center of a branch at 5 feet will always be at 5 feet.

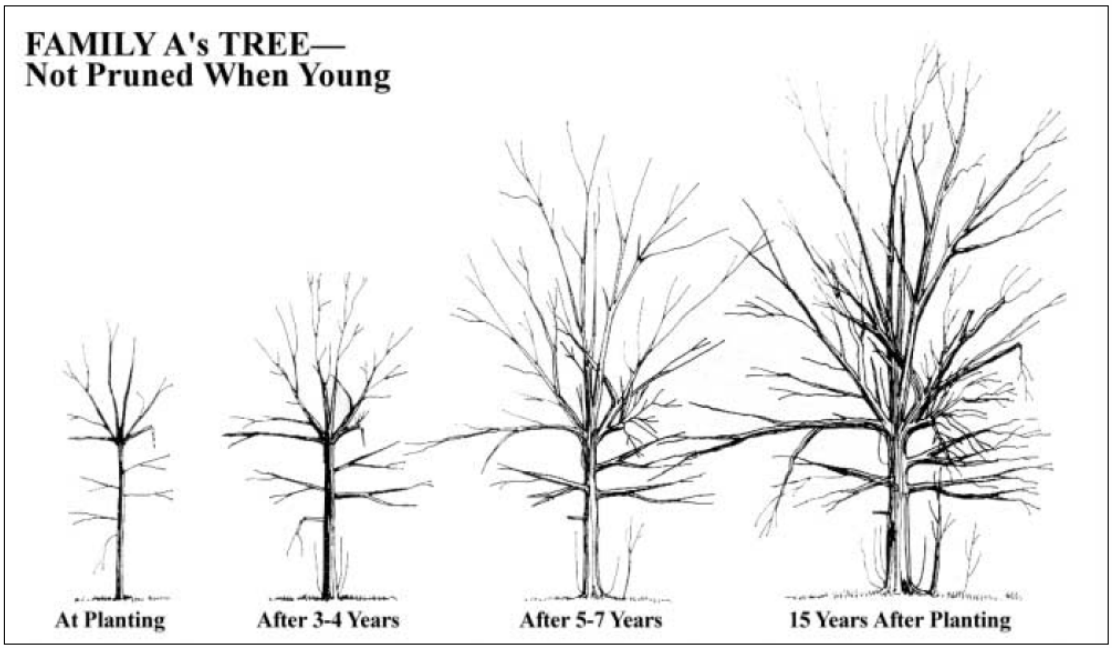


Figure 4-3. Improper Pruning Technique- Source: How to Prune Young Shade Trees, Tree City USA Bulletin No. 1

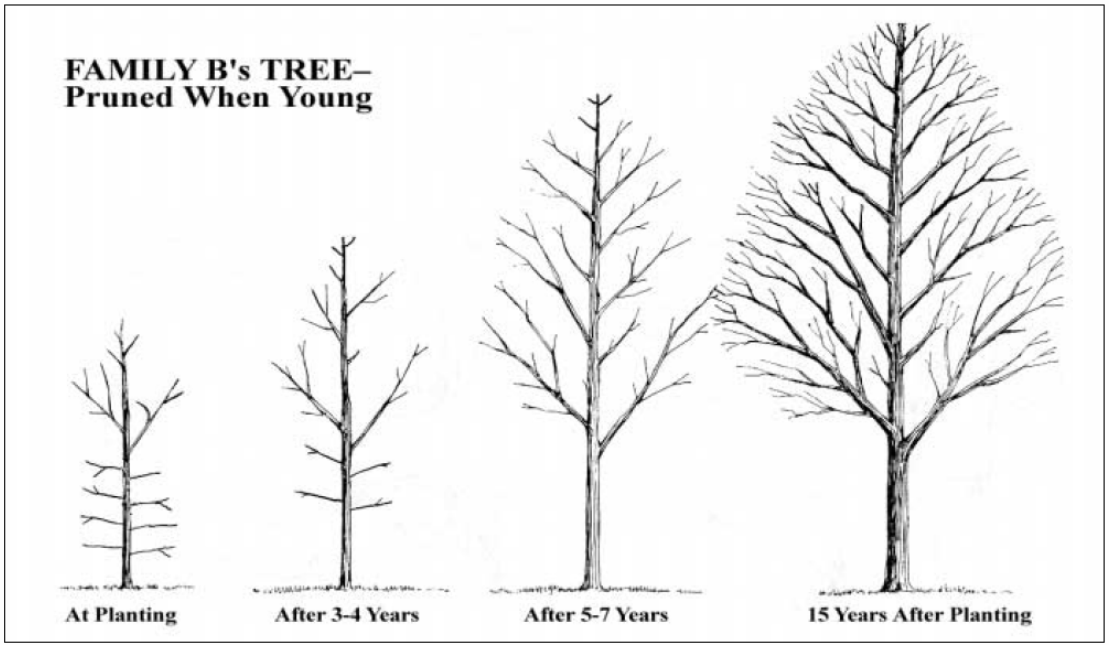


Figure 4-4. Proper Pruning Techniques- Source: How to Prune Young Shade Trees, Tree City USA Bulletin No. 1

Keys to Good Pruning

- Prune early in a tree's life so that pruning wounds are small and growth occurs at the best location.
- Begin with a visual inspection at the top of the tree and work downward.
- Identify the best leader and lateral branches before pruning, and remove defective parts before pruning for form.

- Aside from protecting against oak wilt, pruning cuts need not be protected if they are done properly. For aesthetics, you may feel better painting larger wounds with neutral color tree paint, but evidence shows that it does not prevent or reduce decay.
- Keep tools sharp. One-hand bypass or scissors cut (not anvil-type) pruning shears with curved blades work best on young trees.
- Make safety a number one priority. For high branches, use a pole pruner. Some, like the one shown in Figure 4-5, have both a saw and a shears on the same tool.
- When you prune back to the trunk for a larger limb, branches too small to have formed a collar (the swollen area at the base)should be cut close.(Note in the figure of the pruning shears that the cutting blade is cutting upward for less effort and a close cut.) Otherwise, follow the rules of good pruning of larger limbs by cutting just outside the branch ridge and collar, at a slight down and outward angle, so as not to injure the collar. Do not leave a protruding stub.
- When simply shortening a small branch, make the cut at a lateral bud or another lateral branch. Favor a bud that will produce a branch that will grow in a desired direction (usually outward). The cut should be sharp and clean, and made at a slight angle, about 1/4 inch beyond the bud.

The optimal time to prune depends on the reason for pruning. Light pruning and the removal of dead wood, with the exception of oaks, can be done at any time in dry conditions. Some guidelines are given below.

Bad pruning results in too many co-dominant branches.

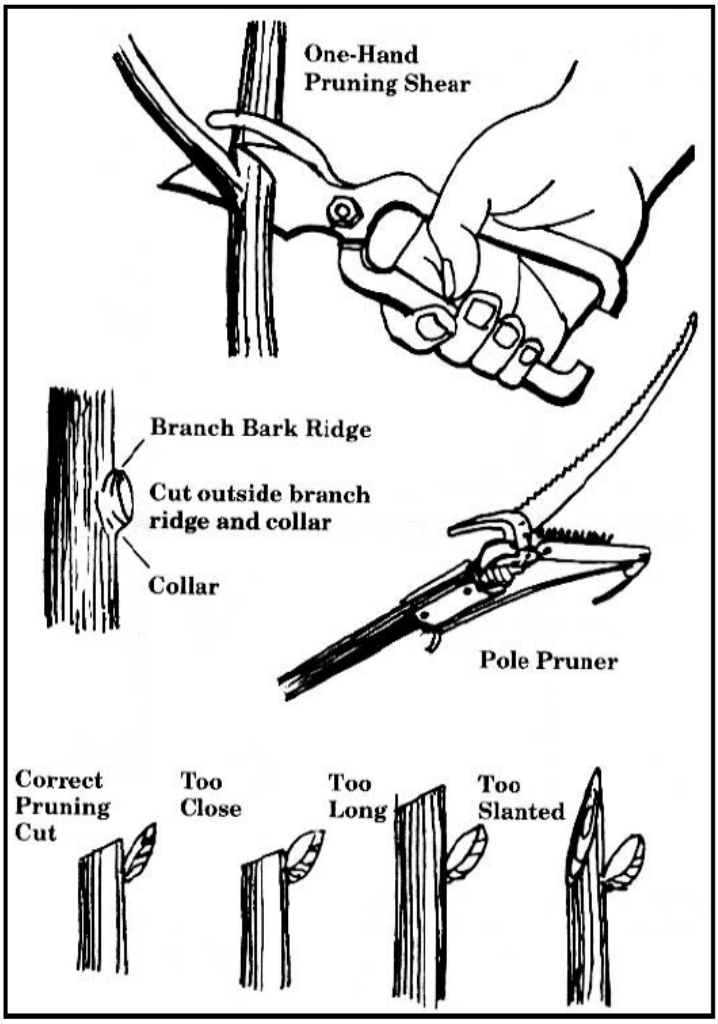
Winter: Pruning during dormancy is the most common practice. This results in a vigorous burst of new growth in the spring, so use this method if that is the desired effect. Preferably, wait until the coldest part of winter has passed.

Summer: To direct growth by slowing unwanted branches, or to slow or dwarf the development of a tree or branch, pruning soon after seasonal growth is complete. The slowing effect results from the reduction of total leaf surface, which thereby reduces the amount of food manufactured and sent to the roots for their development and next year's growth of the crown. Pruning in the summer can also be done for corrective purposes, since defective limbs, or limbs that hang down too far under the weight of leaves, can be seen more easily.

Fall: Because decay fungi spread their spores profusely and cut wounds heal more slowly in the fall, this is a good time to leave your pruning tools in storage.

Flowering Trees: If the purpose for pruning is to enhance flowering:

- For trees that bloom in the summer or the fall on current year's growth, prune in the winter.
- For trees that bloom in the spring from buds on one-year-old wood, prune when the flowers fade.



Source: *Tree Care: A Manual for Public Trees*, City of Chesterton, Ind.
Figure 4-5. Keys to Good Pruning

Urban foresters and arborists suggest including the following tips into a tree maintenance program:

- Prune minimally immediately after transplanting; within three years, prune for strength and form; every three years thereafter, prune to lift the canopy of street trees.
- Provide initial training and annual refresher training for pruning crews.
- Stress tool sharpness and disinfection methods if necessary.
- Develop an up-to-date inventory of all maintenance operations, including pruning, and note future needs.
- Monitor on an annual basis.

Additional Pruning Guidelines for Trees

- Remove all dead branches as well as branches that cross or rub.
- To prevent the spread of infectious diseases, disinfect all pruning tools before using them on a new tree.
- Prune all large, established lower branches as needed for traffic or pedestrian clearance under the tree. For street clearance, allow 15 feet and for sidewalk clearance, allow 8 feet.
- Use proper pruning techniques (listed below). Make all cuts with a sharp saw or pruner and only at the nodes or crotches.
- Avoid using wound dressings except on oak pruning wounds made during the growing season, especially during April, May, June, and July when the risk of oak wilt fungus spread is greatest.

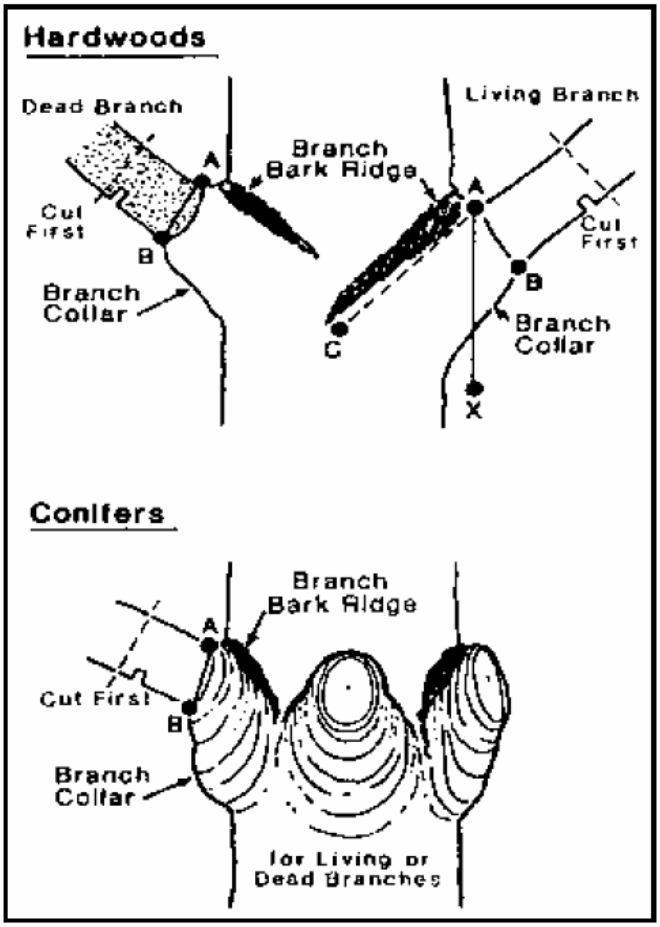


Figure 4-6. Proper Pruning Principles

Natural Target Pruning

1. Locate the branch bark ridge (BBR).
2. Find target A - outside BBR.
3. Find target B - where branch meets the collar.
4. If B cannot be found, drop an imaginary line at AX. Angle XAC equals CAB.
5. Stub cut the branch.
6. Make final cut at line AB. (With power saws, make final cut on upstroke.)
7. Proper cuts leave the branch collar but **no** stub to hang your hat on!

Do not:

- Make flush cuts behind the BBR.
- Leave living or dead stubs.
- Injure or remove the branch collar.
- Paint cuts.

Pruning Practices that Harm Trees

Topping: Pruning large upright branches between nodes, sometimes done to reduce the height of a tree.

Tipping: Cutting lateral branches between nodes to reduce crown width. Both tipping and topping result in the development of epicormic sprouts, or in the death of the cut branch back to the next lateral branch below. The epicormic sprouts are weakly attached to the stem and eventually will be supported by a decaying branch.

Stub cutting: An action that delays wound closure and possibly provides entry to canker fungi that kill the cambium, which delays or prevents woundwood formation.

Tree Removals

Safety along a roadside is the main issue when determining which trees should be removed. All trees and branches that endanger the public should be removed as soon as possible. Where possible, remove the stumps of trees to a depth of at least 6 inches below ground level, fill the cavity with soil, and level it off. If stump grinding is not possible, cut the stump to a maximum of 3" above ground.

Factors to consider when dealing with problem trees are:

- Contribution of the tree to the land use character, the roadway, and the surrounding area.
- Functional classification of the roadway now and in the future.
- Traffic volume and speed, road geometry, and how that affects the clear zone requirements. See the Mn/DOT Road Design Manual, section 4-6.04 at http://www.dot.state.mn.us/tecsup/rdm/english/4e.pdf for guidance in this area.
- Roadway geometrics, such as horizontal and vertical alignment, width, and cross-section.
- Effects of the tree on the environment: Does it reduce sight distance, or block signals or signs?
- Effects of the roots on underground utilities and pavement integrity.

Young tree in need of pruning. Note multiple leaders.

ADDITIONAL RESOURCES

Establishment Protection and Reestablishment of Boulevard Turf Against Salt and Ice (MnDOT report 2000-33, November 2000) is available through the Minnesota Local Road Research Board. Contact the Mn/DOT Office of Research Services at 651-366-3780 or download at http://www.lrrb.org.

For information on proper prescribed burning procedures, contact the Fire Management and Research Program at The Nature Conservancy (850-668-0827), the DNR Division of Forestry, or the County Fire Marshall.

For extensive information about best management practices for erosion control and soil preservation, see Chapter 6 of the publication *Best Management Practices for Erosion Control*, published by the Minnesota Pollution Control Agency.

Remove trees that are hazardous roadside obstacles (in safety clear zone) when they are small.

For information on plant selection, see Mn/DOT's *Woody and Herbaceous Plants for Minnesota Landscapes and Roadsides* expert system for plant selection, available online at http://plantselector.dot.state.mn.us/Description1.html.

The DNR has a good selection of native trees and shrubs from local seed sources. Contact General Andrews Nursery, Box 95,Willow River, MN 55795.Phone: 218-372-3183 (or 1-800-657-3767); fax: 218-372-3091.

The 2007 Mn/DOT Seeding Manual is available online at
http://www.dot.state.mn.us/environment/pdf_files/seedingmanual.pdf

Mn/DOT's Erosion Control Handbook (number II), is available through the Office of Environmental Services at (651) 366-3600.

The Local Road Research Board's publication "The Erosion Control Handbook for Local Roads" in 2003 is available online at www.lrrb.org.

The Minnesota Native Wildflower/Grass Producers web site can be accessed at:
http://www.mnnwgpa.org/MNNWGPA%20Brochure.pdf

Chapter 5: Best Management Practice No. 5: Controlling Prohibited and Restricted Noxious Weeds

According to Minnesota's Noxious Weed Law (Minnesota Statutes, sections 18.75 to 18.88 and Minnesota Rules, parts 1505.0730 to 1505.0760), all agencies shall control prohibited noxious weeds on the roadside or right-of-way at a time and in a manner ordered by the Commissioner of Agriculture or local weed inspector. It is unlawful to neglect, fail, or refuse to comply with a notice to control noxious weeds. Plants identified as "noxious", either by the state of Minnesota or by individual counties, are listed in Table 5-1. Note that the list of noxious weeds changes periodically, so obtain a current list for control purposes.

Note that counties may elevate secondary noxious weeds to prohibited noxious weed status.

Current prohibited and restricted noxious weeds can be found online at the Minnesota Department of Agriculture's web site at: www.mda.state.mn.us/news/publications/pestsplants/badplants/noxiousplantsminnesota.pdf

Table 5-1. Undesirable Plants

Type of Plant	Description	Examples
Prohibited noxious weeds	Plants that have been characterized as injurious to the public health, the environment, public roads, lifestock, and property by legislation, and whose control is mandated by law.	Field bindweed, hemp, purple loosestrife, poison ivy, leafy spurge, perennial sowthistle, bull thistle, Canada thistle, musk thistle, plumeless thistle, and garlic mustard. **These eleven weeds are on the statewide list.**
Restricted noxious weeds	Plants whose only feasible means of control is to prohibit the importation, sale, and transportation of them or their propagating parts in the state.	Common or European buckthorn, Glossy buckthorn, including all cultivars **These two weeds are the only statewide restricted noxious weeds.**
Secondary weeds	Plants that may be added by county petition to the level of prohibited noxious weed status.	Hoary alyssum, Jerusalem artichoke, wild buckwheat, buffalobur, burdock, tall buttercup, bracken, wild carrot, nightflowering catchfly, white cockle, common cocklebur, oxeye daisy, curly dock, flixweed, giant foxtail, gumweed, narrowleaf, hawkweed, Russian thistle, and spotted knapweed.
Offensive weeds	Undesirable for reasons that are insufficient to result in their classification as noxious, but warrant control for other reasons.	Poisonous plants such as stinging nettle. Prickly weeds: sandbur, cocklebur, wild parsnip Allergy producing plants: ragweed Messy plants Herbicide resistant weeds

CONTROLLING WEEDS

Participate in Weed Management Areas (WMA) Collaborations

WMAs are local organizations that bring together landowners and managers (private, city, county, State, and Federal) in a county, multi-county, or other geographical area to coordinate efforts and expertise against common invasive weed species. The WMA functions under the authority of a mutually developed memorandum of understanding and is subject to statutory and regulatory weed control requirements. A WMA may be voluntarily governed by a chairperson or a steering committee. WMAs develop printed weed I.D./control brochures, organized weed education events, written and obtained grants, coordinated demonstration plots, and institute joint eradication, mapping, outreach, and other effective weed management projects.

Information about one specific organization, the Northwoods Cooperative Weed Management Area is available on their web site at http://www.northwoodscwma.org

The National Fish and Wildlife Foundation (NFWF) provides one source of funding for WMAs. The Minnesota Board of Water and Soil Resources (BWSR) also administers a WMA program. Their web site is http://www.bwsr.state.mn.us.

Conduct Weed Surveys and Inventories
Mn/DOT Research Services publication entitled "Management Practices for Weed Control in Roadway Rights of Way (MN/RC 2007-42) provides methodology for surveying weed extent and distribution in roadsides. Appendix B. Contains a "User Guide for GPS/GIS Roadside Weed Management Systems. The publication may be accessed online at www.research.dot.state.mn.us/results.asp .

Practice Early Detection and Rapid Response on New Invaders and an Integrated Approach to Prevent Spread via Maintenance Vehicles and Equipment
Effective weed management will depend on early detection, and rapid response for new invaders. Developing a weed inventory, either formally or informally, will assist maintenance staff to know what weeds are present in an area, how much they have spread or been contained, and when new weed species emerge.

Also, it is important that maintenance staff not inadvertently contribute to the spread of weeds along a roadway corridor. The DVD entitled, "Dangerous Travelers: Controlling Invasive Plants Along America's Roadways" outlines the problem of weeds migrating across the country. Weeds and seeds get carried by cars and maintenance equipment, and are spread through the arteries that roads provide.

Several ways to combat this problem are:

1. Thoroughly clean maintenance equipment after working in infested areas. This includes mowers or blading equipment. Cleaning should include power washing, and all runoff water should be contained and disposed of.
2. Stockpile any materials or cuttings removed from infested areas. Dispose of this material; do not reuse it.
3. Make sure that all materials brought on site are certified weed free. This includes seed and aggregate materials. If there is not a certification program in your local area, create one.
4. When working in a weed-infested area, control traffic if possible. Traffic traveling through the area can easily pick up and transport weed fragments and seeds.
5. Insist that all equipment brought on site is clean and weed-free.
6. **Remove the minimum native cover when working in an area**. If you encounter a weed infestation, remove the area using hand tools, if practical. Minimize disturbance to native cover. Dispose of infested materials so as to not infect additional areas.
7. Frequently inspect equipment storage areas for weeds. Remove any weeds that are present.

This DVD is published by the USDA Forest Service, and is available for downloading online at http://www.fs.fed.us/invasivespecies/prevention/dangeroustravelers.shtml

Among the variety of ways of containing weeds are biological, cultural, physical, and chemical control methods.

According to Iowa's IVRM web site, the best practices for weed control are:

- Spraying only the weeds
- Spraying at the right times
- Spraying with the most effective herbicides
- Spraying with the latest technology
- Spraying with better trained personnel
- Prioritizing and spraying proactively
- Planting self-sustaining vegetation
- Reducing disturbances to healthy vegetation

Biological Weed Control
Biological weed control includes the use of insects or pathogens. The U.S. Department of Agriculture (USDA), in cooperation with the Minnesota Department of Agriculture is conducting a major biological control program that involves importing, propagating, and distributing weeds natural enemies. These feeding insects inhibit the growth and reproduction of weeds, reducing their ability to compete with desirable native range plants.

In general, these insects are best used in areas of large infestation. Smaller infestations are better treated with herbicides. Several beetles are also available for use with leafy spurge. *Aphthona flava* feeds on the leaves and flowers, which reduces photosynthesis. Others feed on the stems and roots of the plants.

A leaf-eating beetle is also available for use on purple loosestrife. Spotted and diffuse knapweeds can be controlled using one of 12 insect species cleared by the USDA for use in the United States. These insects are either root-borers (*Agapeta zoegana,Cyphocleaonus achates, Pterolonche inspersa,Sphenoptera jugoslavica)*or seedhead agents *(Metzneria paucipunctella, Bengasternus fausti,Chaetorellia acrolophi,Larinus minutus,Larinus Obtusus,Terellia virens, Urophora affinis,Urophora quadrifasciata*).

For Minnesota Department of Agriculture and Mn/DOT Bio-control contacts, see Table 5-2.

Cultural Control of Noxious Weeds
Cultural control of weeds includes planting native grasses or competing plant species to force out noxious weeds. This information is included in the section on Use of Native Grasses in Chapter 4.

Physical Control of Noxious Weeds
This includes tilling, mowing, and burning areas to control weeds. Mowing policies are described in Chapter 3.

Chemical Control of Noxious Weeds
Chemical weed control includes the use of herbicides, outlined in the following section and Table 5.2.

Mowing Canada thistle at the wrong time will distribute seed and spread weed infestation.

APPLYING HERBICIDES

Minnesota law requires that herbicides be applied in accordance with the product label and in a manner that will not cause unreasonable adverse effects on the environment, endanger humans, or damage agricultural products, food, livestock, fish, or wildlife. Herbicides may not be applied onto property beyond the boundaries of the target site, nor directly on a human by overspray. Workers in an immediately adjacent property may not be exposed. Spray drift should be minimized; most herbicide labels indicate methods for reducing spray. The treated area must be posted if the labels indicate a specific time delay before safe human reentry or if the area is treated through irrigation systems.

Proper coverage is important for effective control, especially when using systemic herbicides.

The following tips will help ensure good coverage.

- Use the correct amount of oil or water as carrier. Too much water will cause the mixture to drip off the plants and will render the remaining solution too diluted to be effective. Too little water will result in incomplete coverage.
- Spray the undersides of leaves whenever possible to improve penetration.
- Since leaves with hairs or bristles prevent absorption, use a wetting agent to improve effectiveness when spraying weeds and brush.

Spot spraying minimizes drift.

Three Things to Remember When Using Herbicides

1. Spot Spraying

Herbicides should be spot sprayed, rather than blanket sprayed over an entire area, since blanket spraying may cover desirable plants and may weaken existing vegetation (thus increasing weed infestation). Blanket spraying may be used to kill existing turf and weeds in preparation for native prairie seeding. Applying herbicides using appropriate nozzles and low pressure will reduce drift. Also, certain additives will increase droplet size.

2. Appropriate Timing

Table D-2 in Appendix D outlines the appropriate time to spray a specific weed in order for spraying to be most effective. Herbicides work better when used at higher temperatures. However, some formulations (e.g. ester formulations) should not be used when temperatures exceed 85^{o}. Foliar herbicides must be applied during a rain-free

period to be effective, and herbicides that are absorbed through the roots need rain directly after application to work best. Under all circumstances, herbicides should be sprayed when it is not windy in order to minimize drift.

3. Knowing How Herbicides Work

Tables 5-2 and 5-3 provide information for better understanding herbicide formulations and applications. Knowing the appropriate herbicide to use for a given situation will optimize its use.

Maintain adequate separation between desirable vegetation and weeds when spraying. Roots of trees or shrubs may extend into an area treated with a soil-active herbicide causing injury or death.

Table 5-2. Partial List of Pest Situations and Possible Pesticide/Control Products

Situation or Weed	Possible Products/Activities	Comments
Pavement Cracks	Glyphosate (Roundup Pro™*, etc.)	Kills emerged vegetation.
	Glyphosate (Roundup Pro™*, etc.) + Oryzalin (Oryzalin 4 Pro™)	Kills emerged vegetation and prevents annual weeds for one (1) growing season.
	Glyphosate (Roundup Pro™*), etc.) + Pendimethalin (Pendulum™)	Kills emerged vegetation and prevents annual weeds for one (1) growing season.
	Imazapic + Glyphosate = (Journey™)	Glyphosate kills emerged vegetation and Imazapic provides pre-emergent activity. Soft residual that is easy on most trees—read label for sensitive trees and shrubs.
	Glyphosate (Roundup Pro™*, etc.) + Prodiamine (Endurance™)	Kills emerged vegetation and prevents annual weeds for one (1) season, very effective/safe mixture, non-staining.
	'Patchen Weed Seeker'	Sprayer attachment that detects chlorophyll in plants thereby triggering precision spraying of plants only in cracks or gravel shoulders – reduces herbicide use. Metro District has machine.
Guardrails	Glyphosate (Roundup Pro™, etc.) + Prodiamine (Endurance™)	Kills emerged vegetation and prevents annual weeds for one (1) season, very effective/safe mixture, non-staining.
	Glyphosate (Roundup Pro™,etc). + Oryzalin (Oryzalin 4 Pro™)	Kills emerged vegetation and prevents annual weeds for one (1) growing season.
	Glyphosate (Roundup Pro™, etc.) + Pendimethalin (Pendulum™ Aqua Cap)	Kills emerged vegetation and prevents annual weeds for one (1) season.
	Glyphosate (Roundup Pro™, etc.) + Simazine (Simazine™)	Less expensive, lasts one (1) to two (2) seasons.
	Imazapyr (Arsenal™) or equivalent Imazapyr (Polaris™)	Do not use this product in pavement or sidewalk cracks fencelines or guardrails where desirable tree and shrub roots may take up the chemical and be killed. Lighter rates in lighter soils, otherwise you can expect runoff. Heavier soils tie-up more chemical reducing chemical runoff or leaching.
	Imazapyr (Arsenal™) + Diuron = (Sahara DG™)	Use with caution, watch for runoff into landscaping, more movement risk under severe rainfall conditions. Also use same pre-cautions listed above for Arsenal™
	Sulfentrazone (Portfolio™)	New label, trial use.
	Typar Biobarrier	Geotextile impregnated with Trifluralin (Treflan™), also has application in landscape beds and around state entrance markers.
	Impervious Mats	Labor intensive, some states doing trials, Mn/DOT has a trial on T.H. 61 near Lake City using Weed Ender ™
	Plant Growth Regulators (PGR's)	Stunts grass growth, less problems with herbicide resistant weeds taking over. Many state DOTs use low rates of Imazapic (Plateau ™) to reduce shoulder mowing cycles.
Cattails in Drainage-ways—also Giant Phragmites and Reed Canary Grass	Imazapyr (Habitat™)	Trial use in drainage-ways where maintaining water flow is critical. Aquatic label with same active ingredient as Arsenal™. DO NOT USE where roots of desirable woody plants may extend into the treated drainageway. **Commercial applicators must hold an aquatic license when applying this product.**

Situation or Weed	Possible Products/Activities	Comments
Canada Thistle	Clopyralid (Transline™)	Very effective, general use, good for sensitive landscape areas. Do not use near desired honey locust trees or other woody legumes such as caragana or Kentucky coffeetree.
	Clopyralid (Transline™) combined with Chlorsulfuron (Telar™) or Dicamba + Diflufenzopyr (Overdrive™--trial use)	Extend the window of control into bloom stage with the addition of Chlorsulfuron (Telar™). Do not use Chlorsulfuron (Telar™) in sensitive landscape areas.
	Aminopyralid (Milestone™)	**Trial use during 2006 application season and increased use in 2007 showed good results. Impacts to woody landscaping not known!**
	Pseudomonas Syringae Tagetis (Bacteria)	Mow infested Canada thistle plants when moist in order to promote spread of this natural bacterium. Still under research with U of M to determine field conditions conducive to spread.
	Brown Brush Monitor (BBM) & Diamond Wet Blade (DWB)	Mows and applies herbicide at the same time—Mn/DOT District 8-Willmar has a "BBM"—Mn/DOT Met District has a "DWB"
	Mowing	If the patches cannot be sprayed before seed set (just before bloom) then mow if at all possible to stimulate re-growth which then can be sprayed in late Fall season when re-growth is at least 6" tall.
Leafy Spurge	Picloram + 2,4-D (Tordon 101™)	**Restricted use herbicide,** do not use near landscaping (min. 10' from drip line) or within the root zone of susceptible non-target plants. Use on small scattered patches. **Mn/DOT is limiting the use of Picloram (Tordon K™ & 101™) and recommends its use only on scattered patches of leafy spurge.**
	Picloram (Tordon K™) **Reduce Picloram rates by combining with Dicamba + Diflufenzopyr (Overdrive™)**	**Restricted use herbicide,** do not use near landscaping (min. 10' from drip line) or within the root zone of susceptible non-target plants. Use on small scattered patches. Can be used in invert system. **Mn/DOT is limiting the use of Picloram (Tordon K™ & 101™) and recommends its use only on scattered patches of leafy spurge.**
	Imazapic (Plateau™)	Fall use only, easier on adjacent landscape plantings--read the label on impacts to various woody plants, use with methylated seed oil (1.5-2 pints/acre).
	Fosamine-ammonium (Krenite S™)	Effective when spurge in bloom, especially following prescribed burns, use in sensitive areas.
	Flea Beetles	Use in large patches, 2000-5000 flea beetles per release site, effective but takes time for flea beetle populations to build up, long-term solution. **Mn/DOT Bio-Control contact is Tina Markeson (651-366-3619) tina.markeson@dot.state.mn.us Contact your County Ag Inspector www.mda.state.mn.us/appd/weeds/cailist.html or Monika Chandler, Mn Dept. of Ag. 651/201-6468**

Purple Loosestrife	Triclopyr (Garlon 3A™ or Renovate™)	Now has **aquatic label** for use on purple loosestrife, brush, etc.; in and around standing water; such as marshes, wetlands, and banks of ponds and lakes.
	Glyphosate (Rodeo™)	**Aquatic label**, nonselective.
	2,4-D (DMA4 IVM™)	**Aquatic label**, Dimethylamine salt of 2,4-D.
	Parasitic Insects/Beetles	500-1000 insects per release site, preferred alternative in extensive, heavily infested areas. **Contact Luke Skinner, DNR** 651/259-5140 **for details on how to obtain and raise leaf-eating beetles.**
Spotted Knapweed	Clopyralid (Transline™) combined with Metsulfuron methyl (Escort™) or Dicamba + Diflufenzopyr (Overdrive™-trial use)	Highly effective treatment in fall or spring/early summer. No restrictions on haying/grazing! **However, manure from livestock feeding on roadside hay treated with clopyralid may cause damage to soybeans or other sensitive plants such as tomatoes for up to 18 months.**
	Clopyralid (Transline™)	Best as fall or early summer treatment.
	Aminopyralid (Milestone™)	**Trial use during 2006 application season showed good results. Impacts to woody landscaping not known!**
	Bio-Control (Insects)	**Mn/DOT Bio-Control contact is Tina Markeson (651-366-3619) tina.markeson@dot.state.mn.us Contact your County Ag Inspector or Monika Chandler, Mn Dept. of Ag. 651/201-6468**
Wild Parsnip	Metsulfuron methyl (Escort™)	Treat fall or spring/early summer. 0.75 oz/acre recommended.
	Glyphosate (Roundup Pro™, etc.)	1-2% in early spring, preferably when few if any other plants are actively growing.
Garlic Mustard	2,4-D (DMA4 IVM™) Amine + Metsulfuron methyl (Escort™)	Treat early to mid-summer when actively growing.
	Glyphosate (Roundup Pro™, etc.)	In late fall after hard frost or in late winter and early spring when mustard rosettes are active and desirable plants are dormant.
Grecian Foxglove	Metsulfuron methyl (Escort™)	0.5 grams/3 gals --Mix ratio for backpack which equates to ½ oz Metsulfuron methyl (Escort™) per acre assuming 100 gallons of mix applied per acre , very effective in trials and subsequent follow-up work. Mid-June applications before seed set and fall applications to 1st year and second year rosettes is very effective.
Scouring Rush	Chlorsulfuron (Telar™) & 2,4-D (DMA4 IVM™)	Also known as field horsetail [either common scouring rush (Equisetum hyemale L.) or smooth scouring rush (Equisetum laevigatum A. Br.)]--increasing in guardrails especially in southern Minnesota. Telar™ at 3 oz/acre rate along with 2,4-D at 2 qts/acre is reported to be effective.
Landscape Plantings Pre-emergent		
Mulch Beds	Dichlobenil (Dyclomec™)	Overdose kills or injures woody plants—not much room for error.
Bareground or Rock Mulch	Oryzalin (Oryzalin 4 Pro™)	Good safety factor, questionable in wood chip mulch beds.
	Oxyfluorfen (Goal™)	Can injure leafed-out deciduous plants, poor on grasses.
	Oxadiazon (Ronstar™)	Reported to be effective before mulch placement or on top of wood chip mulch.

	Pendimethalin (Pendulum™ Aqua Cap.)	Soft-residual treatment
	Prodiamine (Endurance™)	Longest residual of the pre-emergents, requires tank agitation.
	Isoxaben (Gallery™)	North Carolina DOT reports good results with Gallery™ in landscape beds.
Landscape Plantings Post-emergent		
Before bed prep	Clopyralid (Transline™)	Spot spray thistle patches with Clopyralid prior to broadcast spraying Glyphosate (Roundup Pro™).
Before bed prep	Glyphosate (Roundup Pro™, etc.)	Broadcast spray over proposed planting/seeding area. Rates for bluegrass = 1-2 qts/acre, rates for bromegrass = 3-4 qts/acre. May till up and plant in 5 days.
Weeds in beds	Glyphosate (Roundup Pro™, etc.)	Wiper or wick applicator, absorbing woody roots in mulch can take up Glyphosate (Roundup Pro™) if sprayed on mulch.
Grass in beds	Fluazifop (Fusilade™, Ornamec™)	Can injure juniper and potentilla when sprayed over the top. Timing is critical.
Site Prep–Planted Prairies	Clopyralid (Transline™)	Broadcast spray in fall to clean up thistle, birds foot trefoil and crown vetch, wait til spring to prepare and seed site.
	Glyphosate (Roundup Pro™, etc.)	Site prep treatment in spring, can interseed in 5 days.
	Imazapic (Plateau™)	Labeled for and effective as a site prep or release application for warm season planted prairie grasses and several forbs.
Thistles in Wildflowers	Clopyralid (Transline™)	Spot spray only, backpack rate=1 oz per 3 gallons water, spray to wet only.
	Glyphosate (Roundup Pro™, etc.)	Wick applicator--20% Roundup Pro™, 80% Water.
	Pseudomonas Syringae Tagetis (Bacteria)	Effective for long term control of thistles and ragweed, etc. in high density wildflower plantings. Not commercially available, spread enhanced by damaging thistle when wet.
Dandelions and other weeds in Turf	2,4-D (DMA4 IVM™)	Amine formulation to prevent volatilization. For non-crop turf areas, including parks, roadsides, and vacant lots
	Triclopyr + Clopyralid (Confront™)	Use with caution, this is a mix of Triclopyr (Garlon™) and Clopyralid (Transline™), causes severe leaf curl on basswood and other lindens, no damage to most other woodies. **Cannot be used on residential lawns!**
	2,4-D, 2-(2-m-4-c) propionic acid, & dicamba (Trimec™)	Dicamba can injure broadleaf trees and shrubs via root uptake.
Poison Ivy	Triclopyr (Garlon 4™)	Volatility can be a problem when temps exceed 80°F.
	Triclopyr (Garlon 3A™)	Amine, low risk to adjacent plants. Use when temps above 80°F.
	2,4-D + Dicamba (BK 800™)	Ester, volatility can be a problem when temps exceed 80°F.
	Triclopyr + 2,4-D (Crossbow™)	
Pocket Gopher	Strychnine	Restricted use.
	Anticoagulants	Restricted use.
	Prairie seeding	Poor habitat for gophers.

	Cultural	Eliminate/reduce legumes from site or seed mixes.
	Fenceline woody plantings	Encourages predators like kestrel, other hawks, badgers.
Yellow-headed spruce sawfly	Carbaryl (Sevin ™)	Spray sawfly larvae when in 1st through 3rd instars (less than ½ inch in length), spraying later instars kills beneficial predatory insects (like wasps that parasitize the sawfly larvae), **notify beekeepers if spraying extensive areas.**
	Safer Insecticidal Soap	Easier on beneficial insects.
Adjuvants	Activator 90	Surfactant, less expensive.
	Silco VM	Highly effective wetting agent and penetrant, improves rain-fastness.
	Nu-Film IR	Surfactant, increases effectiveness of applications, improves rainfastness, touted for preventing/minimizing movement of herbicides applied around guardrails.
	Choice	Water conditioner! Hard water can reduce the effectiveness of herbicides. Water hardness readings vary greatly, e.g. the City of Minneapolis takes water from the Mississippi River--4.5 grains of hardness--would not need a water conditioner. City of Robbinsdale uses well water-24.5 grains of hardness--this water should be conditioned when mixing herbicides.
	Liberate	Combined surfactant and drift reduction all in one product.
	Windbrake	Drift control mixes easier in low agitation.

Notes:
1. There are many new formulations of glyphosate (Roundup™, etc.) now that the patent ran out for Monsanto—pay attention to percent active ingredient. This is true of many other products where knowledge of the common name becomes more important.
2. Mention of trade names does not constitute endorsement.
3. Mn/DOT is limiting the use of Picloram (eg. Tordon K™ and Tordon 101™) and is recommending its use only on scattered patches of leafy spurge and brush control in non-sensitive areas.

Caution—Always Read, Understand and Follow the Label! Rates vary with weed/brush species and growth stage, time of year, weather, application techniques, active ingredient percent, etc. Boom and boomless sprayers are usually calibrated to put out 25 gallons per acre, whereas applications with handguns and backpacks result in 50-100 gallons per acre (about 50 gallons per acre with herbaceous plants and up to 100 gallons per acre with brush). Rates for spraying seedlings and pre-bloom stage are usually lower than rates for more mature plants including bloom stage. Make sure you do not exceed the labeled high rate for the chemical!

Always use an integrated approach that results in actions that fit the site and considers long term consequences. All too often we forget about the "Power of Seed." or adding desirable vegetation to our weed control measures. If you have questions, contact Paul Walvatne at paul.walvatne@dot.state.mn.us or phone 651-366-3632 or Mn/DOT Bio-Control Coordinator, Tina Markeson at tina.markeson@dot.state.mn.us or phone 651-366-3619.

Other recommended practices include:

Adhere to Mn/DOT Herbicide Policy & Guidelines
http://www.dot.state.mn.us/environment/forestry/veg_mgmt/herbicide.html

Look for the least toxic and economical methods and options before selecting a treatment. Always use an integrated approach that considers cultural, biological, mechanical and chemical methods that result in actions that fit the site and consider long term consequences.

Mn/DOT's goal is low profile and precision treatments that take out target weeds and do not harm desirable trees (see Figure 5-1), shrubs, wildflowers, other desirable vegetation, plant stabilized slopes (see Figure 5-2) and the waters of our state. Know where native prairie remnants, rare plants and other habitats of concern are located on right of ways. If you have questions on locations of rare plants contact Tina Markeson, Mn/DOT Forester at (651) 366-3619 or e-mail: **tina.markeson@dot.state.mn.us**, or Ken Graeve, Mn/DOT Botanist at (651) 366-3613 or e-mail: **kenneth.graeve@dot.state.mn.us**

Adhere to Minnesota Department of Agriculture Voluntary Best Management Practices (BMP's)
http://www.mda.state.mn.us/appd/bmps/bmps.htm#finalbmps

Caution – Always, read, understand and follow the Label. Rates vary with weed species, time of year (growth stage), soil texture, organic matter, weather conditions, application technique, active ingredient percent, etc. Roots of trees and shrubs often extend 2-4 times the distance from the tree trunk to the drip-line! (Figure 5-1)

Maximize fall spraying activity on hard to kill perennial weeds like Canada thistle and leafy spurge because herbicides follow the seasonal flow of energy deeper into the roots of the weeds in the fall.

Note: Mention of trade names does not constitute endorsement.

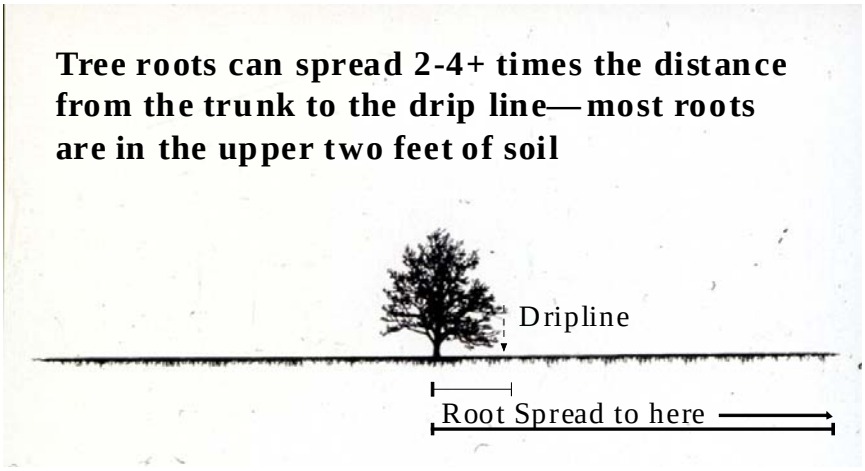


Figure 5-1. Tree root extent and depth—adhere to label precautions regarding applying herbicides where roots of desirable plants may extend.

BEST PRACTICES FOR BRUSH CONTROL

1. Have a legitimate reason for controlling the brush, e.g., in sightlines or safety clear zone, causes snow drifts on road, security. Is the brush a resource or a detriment?
2. Make sure brush is less than **6 feet tall when spraying in full leaf** to minimize unsightliness—actually 3' height would be better.
3. Do not cut stems treated during the dormant season until at least mid-summer. This allows the chemical to move systemically through the root system. This is not a problem visually since plants do leaf out (although leaves are tiny and soon die).
4. Leave desirable low growing shrubs/brush whenever possible to take advantage of the canopy cover that will to some extent limit the invasion of trees into safety clear zones or vistas.
5. If situations require **mechanical or manual control only**, such cutting should be timed for early to Mid-June when plants are in full leaf and are at their lowest reserves. Even then brush will sprout back quite vigorously unless treated with an approved herbicide.
6. Monitor results, and make adjustments to refine methods.

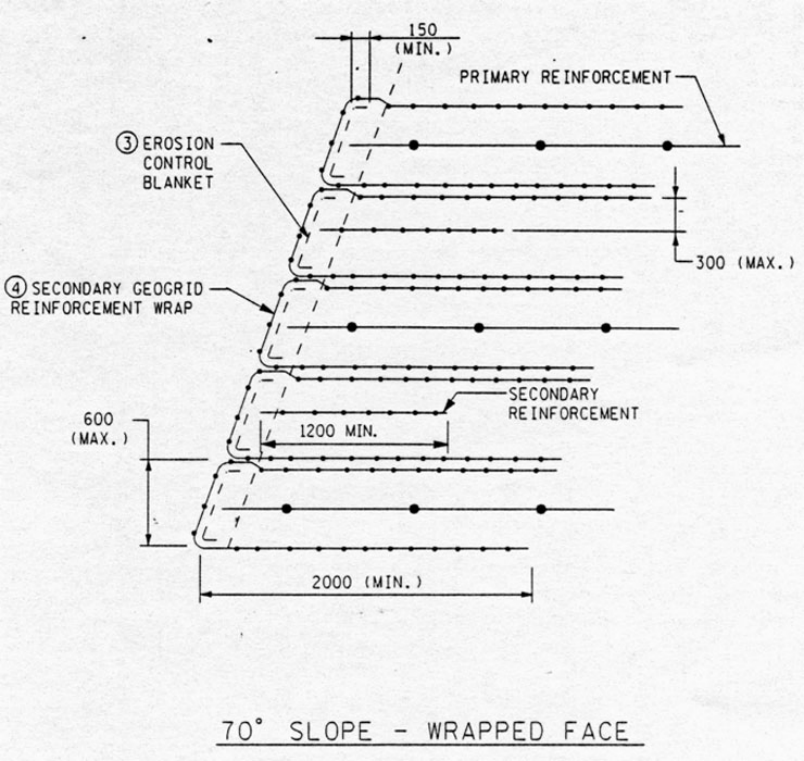


Figure 5-2. Reinforced Soil Slope—do not use glyphosate or soil sterilants on guardrails above these engineered living slopes where spray trajectory, spray drift or runoff will kill grasses and groundcovers.

PRECAUTIONS FOR ALL HERBICIDE APPLICATIONS (Table 5-3)

1. Always follow label directions. Use lowest rates that give optimum control. Know the points of rate adjustment. Dry/wet weather, target plant maturity, season treatment timing, etc.

2. Make ***every*** possible effort to avoid off target plants, **especially crops and homeowner property**. If in doubt do not treat near areas in question.

3. When choosing a herbicide, make sure the choice is compatible with the environment you are working in. Be fully aware of waterways and geography type. If unsure, ask for help. Industry suppliers, Mn/DOT Roadside Vegetation Management Unit. They **all** enjoy helping you make the right choices.

4. Always take public concerns into account when choosing products. Most products are very safe when handled properly. Answer their questions using product Q & A sheets designed for answering concerns. Do not just hand out labels and Material Safety Data Sheets (MSDS) alone to the public. They do not explain products in layman terms.

5. Do everything possible to set up your equipment properly. Use high volumes of water and low pressures to reduce risk of fines and off target particle drift.

6. Do not “push the window” with regard to wind speed. If the wind speed exceeds 10 mph don’t treat or find sheltered locations.

7. Always use drift control agents when operating conventional spray systems.

Above all, use the highest degree of safety principles for yourself, your co-workers and the public at large.

Table 5-3. Brush Control Situations, Partial List of Chemicals & Tools for Roadsides

Situation	Possible Products	Per Acre Rate	Comments
Foliar Brush Upland Sites-- Ideal time for high volume foliar applications is leaf out until July 15th—after that it is best to add a surfactant for increased efficacy. After August 15th switch to other methods like basal	Triclopyr (Garlon 4™) or (Garlon 4 Ultra™)	Follow Label	Garlon 4 is an ester formulation that can move off site during high temperatures. Use at temperatures below 85 degrees Fahrenheit
	Triclopyr (Garlon 3A™)	Follow Label	Use Garlon 3A (Amine Formulation) when temperature above 85 degrees Fahrenheit
	Krenite	Follow Label	**NO BROWN OUT!** Mid to late summer for sensitive areas, plants go into normal fall coloration, **can weaken or kill grass**
	Triclopyr (Garlon 4™) + Picloram (Tordon K ™)	Garlon-2 quarts + Tordon K-1 quart	***Tordon K™ is "restricted use"**--use with caution around coarse sandy sites, sites with high water tables or karst topography (See MnDNR Ecological Subsection Map, Figure 5-3). Most effective selective mixture for killing woody species and leaving green grass. Use when temps below 80 deg F.
	Triclopyr (Garlon 4™) or Garlon 4 Ultra™) + 2-4,D & Dicamba (BK 800™)	Garlon-2 quarts + BK 800- ? qt.	See Garlon comments above. BK 800 contains **dicamba which can also move off site at high temperatures.** Almost as effective as Garlon 4™ + Tordon K™
	Triclopyr (Garlon 4™) + Metsulfuron methyl (Escort™)	Garlon-2 quarts + Escort-2 ounces	Works fairly well on most species although may cause some grass kill. See Garlon comments above.
	Triclopyr (Garlon 3A™) + 2-4,D (DMA-4™) + Imazapyr (Arsenal™)	Garlon-2 quarts + DMA4-2 quarts + Arsenal 4 oz.	New mixture deploying Arsenal™. Works very well like Tordon K™ and in higher doses can kill trees and shrubs off target. **Do not exceed 4 oz of Arsenal™ per acre.**
	Picloram (Tordon K™) + Metsulfuron methyl (Escort™) + Imazapyr (Arsenal™)	Tordon K-1 quart + Escort-2 oz. + Arsenal-4 oz.	This is called the "hot mix" and is very effective but you need to watch the cautions on the label. **Tordon K is "restricted use"!** (See MnDNR Ecological Map). **Do not exceed 4 oz. of Arsenal™ per acre.**
Foliar Brush Lowland or Wetland Sites	Triclopyr (Garlon 3A™) + 2,4-D (DMA4 IVM™)	Garlon 3A-2 quarts + DMA4- 2 quarts	**Good mixture for brush in wetlands or wet ditches on rights of ways—Aquatic labels.** The combo provides broader spectrum control, however it is weak on conifers.
Basal Brush	Garlon 4/Bark Oil Blue	20%/80% **Backpack**	Low profile dormant stem treatment, good kill on stems up to 6 inches in diameter, treat the lower 12" to 18" on stems >4" & lower 6" to 12" on stems <4". Bark Oil Blue LT (Low Temp) formulation can be used in cold weather.

	Garlon 4/Bark Oil Blue	25%/75% **Stain Pad**	Treat 6 inch band on both sides of stem
Cut Stumps	Pathway (Tordon RTU)	Ready to Use Product	Not restricted use, do not use in landscape beds or within the dripline of desirable trees or shrubs, **DO NOT USE this product on buckthorn stems under forest canopies.**
	Pathfinder II (Garlon)	Ready to Use product	Labeled for floodplains. Must be used at temperatures above freezing.
	Garlon 3A & Water or environmentally friendly anti-freeze (Sierra, etc.)	50%/50% **Pipe Dauber**	Three Rivers Parks (formerly Hennepin Parks) uses for buckthorn control—on cut surface only (immediately following cut)
	Garlon 4/Bark Oil Blue	20%/80% **Backpack**	Spray top of stump, collar and root flare
	Chontrol™ Paste	Ready to Use in one-liter squeeze bottles	Trial use only, biological herbicide for inhibiting resprouting of alders, aspen and other hardwoods

***Note about use of the "restricted use" herbicide picloram (Tordon K™ or Tordon 101™).** Please note precautions against use in coarse sandy sites, in the vicinity of Karst topography (sink holes) and around high water tables. Ecological sub-sections (see Figure 5-3) in the un-glaciated southeast part of Minnesota including the "Blufflands" (222Lc) and the Rochester Plateau (222Lf) are most likely to contain sink holes characteristic of Karst topography. Coarse sandy sites may be located throughout the state, however, the Anoka Sand Plain (222Mc) and the Pine Moraines and Outwash Plains (212Nc)are large sub-section areas characterized by coarse sand soils. Other sub-sections containing large areas of course sandy sites include the St. Croix Moraine (212Jd), the St. Louis Moraines (212Nb), the St. Paul Baldwin Plains and Moraines (222Md) the Hardwood Hills (222Ma).

Additional information on herbicide formulations and uses of herbicides for noxious weed control is included in Appendix D.

Handling Herbicides

Safety is the most important factor in herbicide use. It's important not only to protect workers, but also to protect the environment. All herbicides have a warning label that contains one of the signal words DANGER, WARNING, or CAUTION - that denotes the toxicity level of the product. Materials with the word DANGER on their label are at least 10 times more toxic than those with the word WARNING and 100 times more toxic than those with the word CAUTION.

The hazard potential of a herbicide depends on two primary variables: toxicity and exposure. Toxicity is the capacity of a substance to produce injury or death; exposure refers to the contact with the untargeted species. Therefore, a product may be extremely toxic but present little hazard to the applicator or others when used:

- in a very diluted formulation;
- in a formulation not readily absorbed through the skin or readily inhaled;
- only occasionally and under conditions to which humans are not exposed; and
- only by experienced applicators that are properly equipped to handle the material safely.

On the other hand, a product may have relatively low toxicity but present a hazard if used in concentrated form, which is readily absorbed or inhaled.

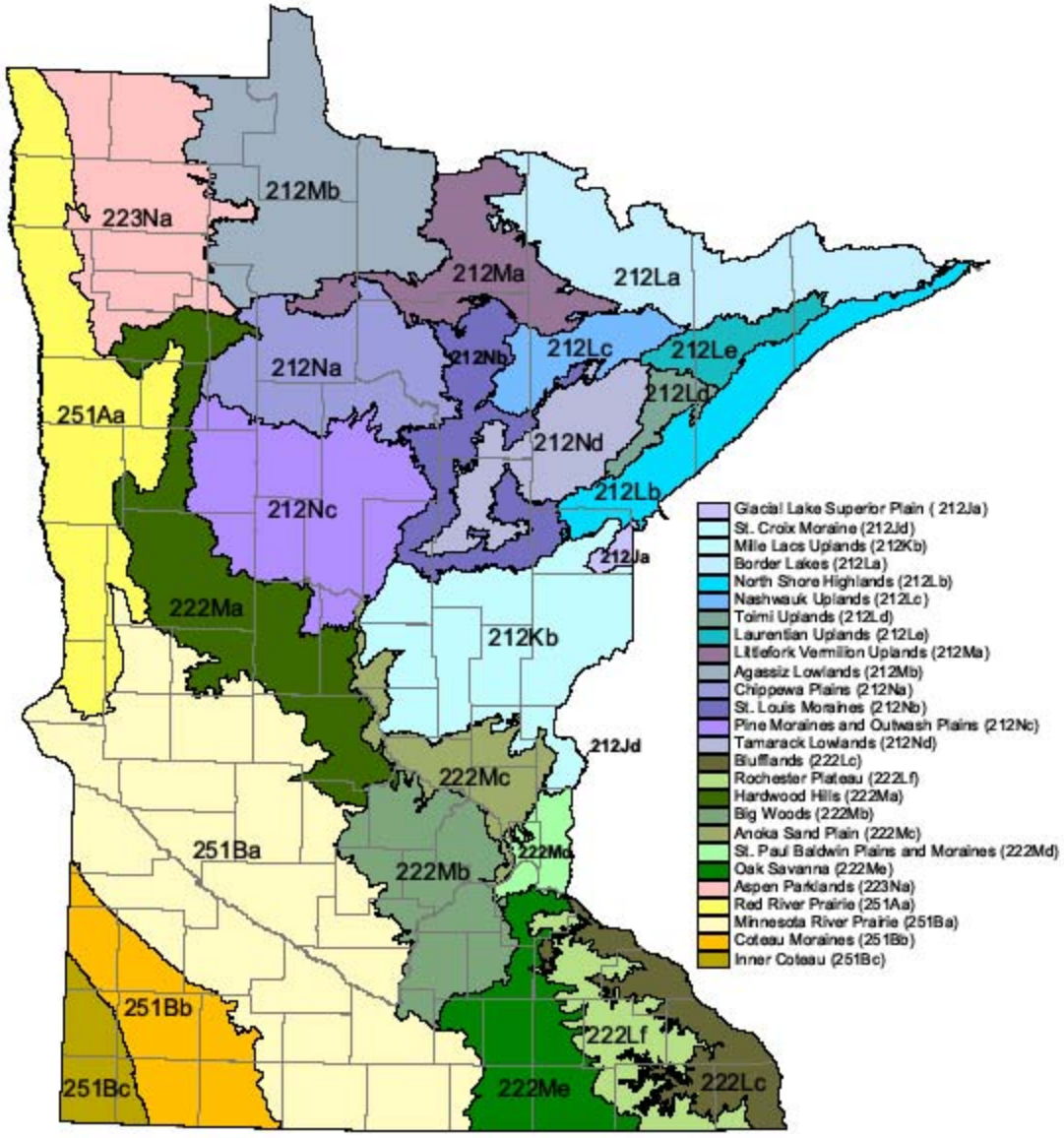


Figure 5-3. Ecological Subsections of Minnesota (Copyright MDNR). See www.dnr.state.mn.us

To reduce the human hazards posed by the application of herbicides, always:

- Read, study, and follow the labeling instructions and precautions.
- Avoid spilling the material on human skin and clothing, and wear adequate protective clothing as indicated on the label. If a spill occurs, wash immediately with soap and water.
- DO NOT SMOKE while mixing or using.
- Wash thoroughly and change clothes after spraying.
- Store herbicides in original containers only.
- Prevent drift by slowing down, reducing pressure, or adding adjuvants.
- Be alert and keep your mind on the job.
- Get medical attention quickly if you or a coworker experience any unusual or unexplained symptoms while applying herbicides.
- Have an **Incident Response Plan** ready and available where pesticides are stored and handled. **Failure to produce an Incident Response Plan during a Minnesota Department of Agriculture facility inspection may result in a considerable fine.**

Herbicide Spills

A herbicide spill is potentially hazardous and should be cleaned immediately. Exercise extreme care when using materials and read and follow all labeling information.

To prevent possible spills:

- Prevent bags and cardboard containers from getting wet.
- Prevent or correct leaks in herbicide containers and application equipment.
- Keep drift to a minimum by the proper use of spray adjuvants, nozzle selection, pressure, and sprayer speed.
- Avoid volatilization by using only amine formulations. Ester formulations may be used with caution for dormant stem treatments.
- Properly dispose of all empty containers as required by law.
- When transporting herbicides, tie down or secure the containers in order to prevent them falling off the vehicle. Follow all state requirements for transporting.

If a spill occurs:

- Rinse all skin that has been exposed to the material and remove all contaminated clothing.
- Contain the spill as well as possible. Do not spread the spill by washing it down. Prevent the spill from contaminating any water sources.
- Contact the State Duty Officer for the Minnesota Department of Agriculture. The duty officer is available 24 hours a day to receive your spill notification at 1-800-422-0798 (greater Minnesota) or 651-649-5451 (Twin Cities Metropolitan area). More information on Agricultural Chemical Emergency Response can be obtained from their website at www.mda.state.mn.us/chemicals/spills/incidentresponse/emergresponse.htm
- Clean the spill by removing the contaminated soil or by neutralizing the chemical with an application of activated charcoal, or both.
- Wash spills off sprayer and dispose of the contaminated rinse water in accordance with state regulations.

Herbicide Records

Commercial applicators must maintain a record of herbicides used on each site for a minimum of five years. Records must include the following information:

- Application date number of units treated
- Name/address of customer completion time
- Brand name Name/signature of applicator
- Site location US/EPA registration number
- License number of applicator wind speed/direction
- Dosage of herbicide used name/address of applicator company
- Temperature
- Wind speed and direction

- Number of units treated/acre or square foot
- Completion date
- Name and signature of applicator
- Name and address of applicator company

Although non-commercial applicators are only required to keep daily application records on "restricted use" pesticides, we recommend they keep records on all applications including the application of non-restricted use pesticides. Accurate application records are good insurance against crop and landscape damage claims.

ADDITIONAL RESOURCES

Mn/DOT Herbicide Policy & Guidelines, available online at
http://www.dot.state.mn.us/environment/forestry/veg_mgmt/herbicide.html

Herbicide Labels & Material Safety Data Sheets (msds), available online at www.greenbook.net and www.cdms.net

Pesticide Registration accessed at www.kellysolutions.com/mn/

MnDNR website at www.dnr.state.mn.us/invasives/terrestrialplants/herbicides.html

Chapter 6: Best Management Practice No. 6: Manage Living Snow Fences

Since this manual was first published, much has been done in the way of standardizing living snow fence design and implementing their use across the state. Road authorities spend millions of dollars on snowplowing each winter. Many problems with drifting snow occur in the same place year after year, creating huge snow removal costs. Fortunately, living snow fences have emerged as a low-cost and relatively easy-to-implement solution.

Living snow fences are designed plantings of trees, shrubs, and/or native grasses located short distances upwind of roads, ditches, homes, farmsteads, communities, or other important facilities. When correctly located, these living barriers trap and control blowing and drifting snow to keep the roads open to traffic.

A guidebook titled *Catch the Snow with Living Snow Fences* was published in 1999 to help practitioners effectively design living snow fences. It is available through Mn/DOT's Office of Research Services, or online at http://www.extension.umn.edu/distribution/naturalresources/DD7311.html

The introduction to the guidebook provides the background for using living snow fences, and the benefits that can be realized with their use. The following is taken from that manual:

> A 10-year study on Interstate 80 in Wyoming showed that structural snow fences reduced snow removal costs by one-third to one-half. Just the savings in property damage due to reduced accidents could amortize the initial cost of fences in 15 years. Benefit-to-cost ratios for structural snow fences, based only on reduced snow removal costs, typically range from 10:1 to 35:1. Living snow fences are even more cost-effective than structural fences because the cost of installing and maintaining them is about one-third that of structural fences and they last longer.
>
> Analysis of several living snow fences proposed by five Mn/DOT district offices and for Soil and Water Conservation Districts in northwestern, western, and southern Minnesota yielded benefit/cost ratios ranging from 2:1 to 36:1, with an average of 17:1. These analyses used conservative assumptions, including average winter conditions (32" of snowfall) and $1/ton for snow removal costs (severe storms can cost up to $3/ton for snow removal). Only benefits related to snow removal costs were included in the evaluations. Results would be even more favorable if economic benefits from avoiding road closures and reducing accidents were included. Benefits would further increase greatly if all the above factors were evaluated for severe winters.
>
> In addition to reducing snow removal costs, living snow fences have these benefits:
>
> - improving driver visibility and safety, reducing accidents
> - preventing drifts on farmyards and communities
> - enhancing the appearance of roadsides and communities
> - providing wildlife habitat
> - reducing energy costs for heating and feed costs for livestock
> - increasing crop yields for crops growing in areas protected from wind by 10 percent or more, especially in dry years
> - reducing maintenance costs through less fuel and salt use
> - sequestering carbon to help reduce atmospheric CO_2
> - reducing spring-time flooding and improving water quality
> - trapping top soil wind erosion before it settles in road ditches

GUIDELINES FOR SNOW FENCE PLACEMENT AND DESIGN

Living snow fences are designed plantings of trees and/or shrubs and native grasses located along roads or around communities and farmsteads. Standing corn rows are 12 to 18 rows of standing corn set back approximately 200 feet from the edge of the highway right of way. When properly designed and placed, these living barriers trap snow as it blows across fields, piling it up before it reaches a road, waterway, farmstead or community.

Mn/DOT has developed and maintains a comprehensive web site containing information on the design and use of living snow fences. Complete design guidelines are available online at www.dot.state.mn.us/environment/livingsnowfence. Select the "Design" heading for more information.

The design of the living snow fence incorporates the ditch as well as the plantings. Ditches designed correctly can catch snow before blowing across roads. General rules for designing drift-free roads are as follows:

1. Minimum distance from the edge of pavement to the toe of the backslope should be 46 feet
2. Ditches should be at least 4 feet deep
3. Distance from the edge of pavement to the top of the backslope should be based on the equation:

$$W_{top} = 95+(\sin \alpha)5.8H$$

Where: W_{top} is the distance from the PI of road to top of backslope
α is the attack angle of prevailing winds
H is the height of cut

There are four types of living snow fences: twin shrub row, community shelterbelt, deciduous tree windbreak, and standing corn rows.

Twin Shrub Row

Shrubs are smaller than trees and can tolerate the drier conditions of western Minnesota, and they can trap lots of snow (Figure 6-1). Also, they do not displace grassland nesting birds. In most locations, use of the twin shrub row design will enhance wildlife habitat. Twin shrub rows are typically planted using a geotextile fabric and pea rock as a weed barrier.

Note that to enhance grassland nesting bird habitat, seed native grasses within the downwind snow storage area and beyond. The grass component should be a minimum width of 150 feet. If the strip is too narrow (less than 100 feet), roosting birds may be buried by the snow.

Figure 6-1. Twin Shrub Row Snow Fence

Community Shelterbelt

The community shelterbelt is a multi-row design (Figure 6-2). It works with a combination of shrubs, hardwood trees and evergreens that decreases the wind speed and causes the blowing snow to accumulate in front of and within the shelterbelt in a manner that prevents huge snow drifts from inundating homes, businesses, and roads.

Deciduous Trees Windbreak

This design uniformly distributes the snow across the field to replace soil moisture without delaying springtime planting, and also helps to control topsoil wind erosion

Standing Corn Rows

Mn/DOT annually purchases standing corn rows, to serve as snow fences, from area farmers adjacent to sections of highways that have a history associated with blowing and drifting snow (Figure 6-3). Corn must be planted parallel to the road to serve as a fence. A typical stand corn row snow fence is one-quarter-mile long and 16 rows wide covering an average of 1.2 acres. The fence is set back 120 to 240 feet from the highway right-of-way.

Based upon estimated corn yield per acre, Mn/DOT pays farmers an additional $1.50 per bushel above local elevator price for corn. More information about enrolling in the standing corn row program with Mn/DOT is available on the snow fence web site.

Figure 6-2. Community Shelterbelt

Figure 6-3. Standing Corn Row Snow Fences

Design Methods

An online tool for using road design and snow fences to control snow on roadways is available online at http://climate.umn.edu/snow_fence/Components/Design/introduction.htm

The tool guides participants through the process of designing a living snow fence. The Mn/DOT Plant Selector referenced in chapter 4 and available online at http://plantselector.dot.state.mn.us/Description1.html. can also be used to select appropriate plants for snow control.

MAINTENANCE ACTIVITIES

A separate two-page resource document is available that outlines the recommended maintenance on living snowfences. This document, entitled "Growing and Maintaining Living Snowfences" was published by Mn/DOT and is available online at www.dot.state.mn.us/environment/livingsnowfence/pdf_files/lsf_growandmaint.pdf

A yearly activity schedule is provided in Table 6-1 and regular maintenance activities include:

- Watering: proper watering should match a 1-inch rainfall, which required applying 2 gallons of water in an 18-inch radius around each new seedling.

- Mowing: For the first two growing seasons, mow the turf to a height of 6-10 inches. Mowing also maintains firebreaks and keeps brush from spreading into the grassland buffer strip.

- Re-anchoring landscape fabric: Make sure the staples secure the fabric tightly to the ground, which prevents the wind from picking up the fabric and blowing it away. Landscape fabric serves as a weed barrier, moderates soil temperatures, and conserves moisture.

- Controlling weeds: Control all noxious weeds, using non-chemical methods first. Don't use weed control methods that injure or damage the plants in the snow fence.

- Pruning: Prune when the plant is dormant.

- Replanting: Replace dead seedlings and fill gaps.

- Scouting: Routinely assess the condition of the snow fence. Check for damage, and notify your living snow fence primary contact person if there appears to be adverse plant health changes.

Table 6-1. Yearly Activity Schedule for Living Snow fences

Activity	**Frequency**	**Schedule**
Watering	Immediately after planting and as needed	April – November
Re-anchoring landscape fabric	As needed	
Mowing	2 times (per year for the first two growing seasons)	July – Sept. 15
Weed control	As needed	April – November
Pruning	As needed	November – March
Replanting	As needed	April – May 31st
Scouting	Continual	Year round
Visit Mn/DOT's web site at www.livingsnowfence.dot.state.mn.us		

Source: Growing and Maintaining Living Snow Fences, Mn/DOT

USE IN MINNESOTA

In Minnesota, living snow fences have been used since the 1930s, when Mn/DOT planted 12 million trees and shrubs along 600 miles of highway to control snow. These rows of trees were installed 75 feet from the highway centerline, which has since been proven too close, actually making the problem worse. In the winter of 1996-1997,Mn/DOT hired an international snow control consultant to review 18 problem drifting areas in the southern part of the state. Based on estimates of snow transport during an average winter and maximizing the benefit/cost ratio, the consultant concluded that a 10-foot tall fence is required to provide adequate storage over an average winter. Using more conservative guidelines, a 12-foot fence would provide sufficient capacity 95 years out of 100.

Springfield, Minnesota

In Springfield, Minnesota, an 8-foot tall structural fence installed 275 feet back from the centerline held 11,424 tons of snow during the winter of 1996-1997 (Figure 6-4). This resulted in an estimated savings of $34,272 based on a typical removal cost of $3/ton of snow.

Figure 6-4. Structural Snow Fence

Chapter 7: Best Management Practice No. 7: Use Integrated Construction and Maintenance Practices

A Mn/DOT study showed that five major items, listed below, are significant in the establishment of good vegetative cover.

- Control of water flow
- Preparation of slope and topsoil
- Seeding and fertilizing
- Use of mulch and erosion control products
- Mowing

Of those five items, three are affected during construction. The goal of the turf establishment process is the quick establishment of self-perpetuating plants that stabilize the soil, protect road structure, and enhance the value of the road.

Sediment created by erosion is the single greatest pollutant by volume in our waters. It creates an unhealthy environment for fish, destroys the balanced biological conditions required for a healthy aquatic environment, increases flood crest, and decreases the capacity of drainage channels. Minimizing erosion controls sediment.

During construction, the disturbed soil is especially subject to erosion. Conservation of the soil, and the need for soil of adequate depth with the required nutrients for establishing vegetative cover, is extremely important. Make efforts to retain the soil on site to establish a good vegetative cover later, since poor soils or inadequate soil depth will allow for the establishment of undesirable vegetation.

When designing and specifying requirements for a project, consider roadside vegetation through provisions for soil conservation, erosion control, topography, and aesthetics. Specify required soil type and depths, which will greatly influence the health of the roadside environment. Implement a control plan for controlling erosion and sediment that incorporates the use of silt fences, sediment basins, and temporary seeding and mulching prior to beginning the earthwork. Unless elements of roadside vegetation management are considered in design, maintenance staff will encounter difficulties in implementing the plan, especially as it relates to erosion control and the establishment of desirable vegetation.

INTEGRATED CONSTRUCTION AND MAINTENANCE PRACTICES

Erosion Control

The following techniques can help to reduce or control erosion during construction:

1. Minimize the area exposed at any one time, as well as the duration of the exposure. Develop a staging plan that specifies temporary seeding as an area of construction is completed.
2. Minimize the area disturbed for the project. Clear only within the construction limits or as required for safety or clear zones.
3. Apply erosion control practices throughout construction. For example, keep soil covered, roughen the slope on the contour, and track the area with a cleaned dozer.
4. Use perimeter control practices, such as dikes, filters, and sediment basins.
5. Keep runoff velocity low, and retain runoff on-site by flattening, reducing slopes, and preserving the natural vegetative cover.
6. Place gravel-based materials immediately after completing the subcut.
7. Strip existing topsoil and store for use later. Seed stockpiles while waiting to reuse.
8. Follow up work with periodic inspections.

Topsoil Placement and Grading Operations
Place topsoil on subsoil that is loose, scarified, or bulldozer-tracked perpendicular to slope contours (bulldozer operating up and down the slope) so that a bond occurs, thus preventing slippage during rain. Use mulch to establish vegetation by stabilizing the soil surface, protect against wind and water, hold the seeds in place, protect seeds from rapid changes in temperature, and reduce evaporation. In most cases, do not finely grade slopes. Moderately rough surfaces help trap seeds and moisture, and so will result in more successful vegetation establishment.

Temporary Seeding
Use temporary seeding to prevent disturbed soil from lying unprotected until the entire project is completed. If one area of a project is completed, seed it as soon as possible. Stockpiles and temporary structures can also be seeded temporarily. Be sure to properly prepare the seedbed to a depth of at least three inches and use quality seed. Fast-growing annual seed, such as recommended in section 3876 of the Mn/DOT Standard Specifications for Construction, provides temporary cover quickly.

Only fertilize if needed. Apply seed evenly to 1-1/2-inch maximum depth for grain and less than 1/2-inch depth for grasses. Complete with a mulch cover.

Permanent Seeding
Select an appropriate seed mixture based on the area, soil, and climate. The appropriate fertilizer and application rate is also important. As with temporary seeding, soil should be prepared to a depth of at least three inches. Apply mulch uniformly to a depth of 1/4 to 1/2 inch to protect the seed and minimize soil erosion. Note the seeding dates as listed in the Mn/DOT Standard Specifications: do not seed between September 1 and October 15 in northern Minnesota or between September 15 and November 1 in southern Minnesota.

Tom Tri, St. Louis County Environmental Project Manager, recommends seeding Northeast Minnesota roadsides (following construction activity) to introduced turf grasses that form a dense sod cover that deters woody seed germination and establishment for approximately 10-14 years. Ideally, roadsides should be chemically treated on a 7-10 year cycle.

Tree Protection
Trees are subject to damage and destruction during construction and must be protected. Table 7-1 outlines some ways to do this.

Mn/DOT Standard Specification 2572,Protection and Restoration of Vegetation, is included in Chapter 9. This specification, describing the protection and preservation of vegetation from damage and the corrective action to use when damage occurs, should be followed during construction. Vegetation in this respect includes but is not limited to trees, brush, roots, woody vines, and perennial forbs and grasses.

Table 7-1. Tree Protection during Design and Construction and Maintenance Phases

Impact to Tree	Construction Activity	Methods/Treatments to Minimize Damage
Branch and trunk damage	Injury from equipment	Fence trees to enclose low branches and protect trunk. Report all damage promptly so an arborist can treat appropriately.
	Pruning for vertical clearance for building, traffic and construction equipment	Prune to minimum height required prior to construction. Consider minimum height requirements of construction equipment and emergency vehicles over roads. A trained person should perform all pruning.
	Felling trees in construction area	Require that trees being removed be felled away from tree protection zones.
Root damage or loss	Stripping site of organic surface soil	Restrict stripping of topsoil around trees. Any woody vegetation to be removed adjacent to trees to remain should be cut at ground level by hand and not pulled out by equipment, or root injury to remaining trees will result.
	Digging into topsoil layer and killing roots while loading piles of soil, sand, gravel	Store outside fenced protection zones and away from root zones. Place plastic tarp, straw, plywood or geotextile material beneath pile.
	Lowering grade, scarifying, preparing subgrade for fills, structures	Use retaining walls with discontinuous footings to maintain natural grade as far as possible from trees. Excavate to finished grade and cut exposed roots with a saw to avoid root wrenching and shattering by equipment, or cut with root pruning equipment. Soil below cut face can be removed by equipment sitting outside the drip line of the tree.
	Subgrade preparation for pavement	Use paving materials requiring minimum amount of excavation. Design traffic patterns to avoid heavy loads adjacent to trees (heavy loads require thicker pavement structures). Specify minimum subgrade compaction under pavement within root zone. Install aeration pipes if necessary.
	Excavation for footings, walls, foundations	Design walls and structures with discontinuous foots and pier foundations. Excavate by hand near major roots. Avoid slab foundations, use post-and-beam footings.
	Trenching for utilities, drainage	Coordinate utility trench locations with installation contractors. Consolidate utility trenches and try to have them placed next to driveways and walks. Excavate trenches by hand in areas with roots larger than one-inch diameter. Tunnel under woody roots rather than cutting them. Curve trenches rather than using straight lines.
	Fill dirt over roots	Avoid adding soil over root zone. If unavoidable, insert aeration pipes.

Unfavorable conditions for root growth; chronic stress from reduced root systems	Compacted soils	Fence trees to keep traffic and storage out of root area. In areas of engineered fills, specify minimum compaction if fill will not support a structure. Provide storage yard and traffic areas for construction activity well away from trees. Protect soil surface from traffic compaction with 6" to 8" of wood chip mulch. Following construction, vertical mulch compacted areas, install aeration vents.
	Spills, waste disposal (e.g. paint, oil, fuel)	Post notices on fences prohibiting dumping and disposal of waste around trees. Require immediate cleanup of accidental spills.
	Concrete wash-out and waste dumping	Designate wash-out areas. Dig pit and remove after construction, if necessary.
	Soil sterilants (herbicides) applied under pavement	Use herbicides safe for use around existing vegetation and follow label directions.
	Impervious surface over soil surface	Utilize pervious pavement material where possible. Install aeration vents in impervious paving.
Inadequate soil moisture	Re-channelization of stream flow; redirecting runoff; lowering water table; lower grade	In some cases, it may be possible to design systems to allow low flows through normal stream alignments and provide bypass into storm drains for peak flow conditions. Provide supplemental irrigation in similar volumes and seasonal distribution as would normally occur.
Excess soil moisture	Underground flow backup; raising water table	Fills placed across drainage courses must have culverts placed at the bottom of the low flow so that water is not backed up before rising to the elevation of the culvert. Study the geotechnical report for ground water characteristics to see that walls and fills will not intercept underground flow.
	Lack of surface drainage away from tree	Where surface grades are to be modified, make sure that water will flow away from the trunk, i.e. that the trunk is not at the lowest point. If the tree is placed in a well, drainage must be provided from the bottom of the well.
	Irrigation of exotic landscapes	Some species cannot tolerate frequent irrigation required to maintain lawns, flowers, and other shallow-rooted plants. Use free form mulch areas or avoid landscaping under those trees, or utilize plants that do not require irrigation.
Increased exposure	Thinning stands, removal of undergrowth	Save groups or clusters of trees when working with species that perform poorly in the open or as single trees. Maintain the natural undergrowth.
	Excessive pruning	Prune sparingly, especially in stands of shade-tolerant species. Leaves manufacture the food needed for root growth and recovery from shock.

Source: Tree City USA Bulletin No. 20, The National Arbor Day Foundation

Chapter 8: Best Management Practice No. 8: Managing Roadside Vegetation for Wildlife and Vehicle Safety

John D. Krenz, Department of Biological Sciences, Minnesota State University, Mankato MN 56001

The purpose of the chapter is to summarize concepts and techniques relating to enhancing roadsides for wildlife as well as promoting vehicle safety (reducing deer-vehicle collisions; DVCs).

PREMISES

1. A primary purpose of roadsides is to provide drainage away from the roadway, to store snow, and to provide a clear zone for the safety of passengers in vehicles that leave the road. The primary purpose of roadside vegetation is to minimize soil erosion on the roadside.
2. Roadsides can provide relatively unique and permanent strips of critical habitat, particularly in agricultural and forested landscapes, valuable as wildlife cover for reproduction, feeding, and predator avoidance, and as connections between isolated habitat patches.
3. Although roadside habitats are almost completely unnatural patches with engineered topographies and shapes, anthropogenic soils, and contrived plant communities, the more natural the patch, the better: We should promote assemblages of native plant species accompanied by natural disturbances.
4. Roadside management is a political optimization of vehicle safety, aesthetic preferences of the public, management costs, and alternative (potentially competing) public land-uses such as wildlife production versus hay production.
5. Success of roadside vegetation management depends on the integration of government groups (such as the US Forest Service and state agencies such as Mn/DOT and MDNR, and local governments), cultural groups, and other organizations such as Minnesota Deer Hunters Association, Pheasants Forever, Minnesota Waterfowl Association, and Ducks Unlimited), and private landowners and farmers.

VALUE OF WILDLIFE

Roadsides provide benefits to travelers and non-travelers alike. Much of the wildlife harvested - especially ground-nesting species in the agricultural region - originate either in habitats created as conservation lands enrolled in government programs such as the Conservation Reserve Program (CRP), lands protected by conservation agencies and organizations, or in roadside habitats. Restoring grassy patches to the landscape increases biological diversity and wildlife abundance, providing critical but rare habitats used for feeding, reproduction, and cover by wildlife (invertebrates and vertebrates, game and non-game) including a variety of pollinating insects and predators of crop-pests that benefit farmers. There is aesthetic value in viewing the wildlife diversity provided by roadsides, especially in regions with low biological diversity such as agricultural landscapes or the coniferous forest. Roadside habitats often provide biological diversity for the viewing pleasure of not only those in vehicles but also bikers and walkers.

The economic impact of hunting in Minnesota is very significant and well-documented elsewhere (USFWS and USCB, 2001). Furthermore, non-consumptive uses of wildlife have grown significantly: in 2001, over 2 million people spent $531 million observing, feeding and photographing wildlife in Minnesota, generating 12,730 jobs with wages and salaries of $296.3 million (USFWS, 2003). Those jobs generated $32 million in state sales and income taxes.

Many governmental units in the state have established scenic highways to promote tourism; management of roadside vegetation for wildflowers and wildlife contributes to the attraction. For example, the state has many Scenic Drives and Scenic Byways, with most of the advertisements for these routes touting the opportunity to view wildlife. National Scenic Roads and Highways - such as the Great River Road that follows the Mississippi River and the Prairie Passage Route - also exist in Minnesota and the opportunity to view wildlife attracts travelers.

In Minnesota, 2,860 miles of state and local roads have been designated as State or National Scenic Byways. National, state and local advertising promotes the positive experience of driving these scenic routes along with

recreational opportunities in communities, parks and other byway designations. The appearance of the roadside contributes to the overall visitor experience which contributes to the vitality of local economies.

Nearly all Scenic Byways have local organizations that are committed to the marketing and stewardship of their byway. These groups may serve as advocates for effective IRVM practices as well as participants in vegetation management planning activities with local landowners and local government agencies. For more information, visit the America's Byways website at www.byways.org and the Explore Minnesota Tourism website at www.byways.exploreminnesota.com/home.html.

ECOLOGY OF ROADSIDES

1. Biogeographical concepts important to wildlife

Edge habitats

Landscapes can be considered to consist of a mosaic of habitat patches with edges that may be definite or more diffuse. Some species of wildlife prefer and/or require large and relatively homogeneous patches of habitat (Samson 1980). Examples of such "interior" grassland species in Minnesota - those not likely to benefit from roadside habitats because of their narrow shape - include Sharp-tailed grouse, Henslow's sparrow, and Baird's sparrow (MDNR, 2006).

Roadsides are artificial narrow strips of habitat usually dominated by herbaceous vegetation, bounded by definite edges, having high edge-to-area ratios, and lacking 'core areas' (See Figure 8-1); they are essentially edge habitats that often feature higher biological diversity but may also be detrimental to some species of wildlife because edges are often successfully used by predators and parasites such as the obligate nest parasite, the Brown-headed cowbird (Andren & Anglestam, 1988). However, some wildlife thrive in such strips (See Figure 8-2) with high edge-to-area ratios (Bryan and Best, 1991; Reeder et al., 2005); roadside habitats can be of great value as a remnant habitat for species that otherwise would not persist in the region (Bennett 1990).

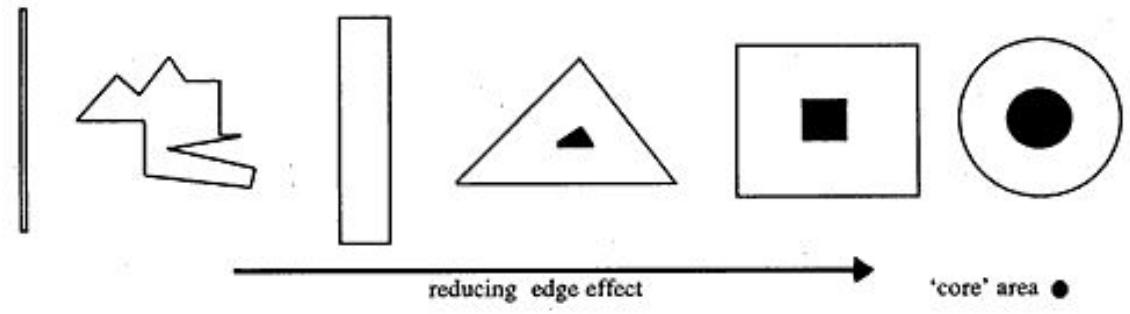


Figure 8-1. Habitat Patches - especially artificial patches such as agricultural fields, silvicultural stands, and roadsides - may be defined by abrupt ecological transitions (edge). Factors extrinsic to the patch may affect species living in the patch, extending part way into the patch (edge effect) leaving a smaller core area. Some wildlife species appear to be adapted to either edges or core areas. For most wildlife species, roadsides can be considered to be represented by the shape on the far left, a narrow strip consisting entirely of edge habitat. Figure from Rowley et al., 1993.

Corridors

Roadsides can be used by wildlife as 'conservation corridors,' not necessarily as conduits for individuals to travel on a daily or seasonal basis, but as connections between larger habitat patches that serve to mix otherwise isolated gene pools by occasional exchanges of individuals over generations or longer periods of time and to thereby increase the viability of sub-populations (Simberloff and Cox, 1987). Grasslands and other natural vegetation along highways and other routes such as railways are important to wildlife in providing cover and resources needed in corridors. Conversely, corridor habitats (roadsides), while often touted as providing valuable connections between habitat fragments, have also been identified in some studies as posing a threat to some species of wildlife because mortality in such strip-habitats exceeds reproduction, creating a "sink population." This sink effect may be especially true for artificial (as opposed to natural) strip habitats such as power-line right-of-ways and roadsides (Simberloff and Cox, 1987).

Figure 8-2. Kestrels are Roadside Specialists - often seen hovering while hunting for mice in roadsides.

2. Principles of the effects of vegetative characteristics on wildlife

Wildlife species richness (number of species) has been correlated with habitat (vegetative) diversity in terms of both vegetative species composition and vegetative structural diversity (Wiens 1969). This general principle - that vegetative diversity is good - can be accomplished in several ways.

- First, exotic species should be eliminated and avoided in areas of seeding and planting because exotics such as smooth brome tend to form dominant monocultures, reducing plant and animal diversity (see Figure 8-3).
- Diverse vegetation attracts a diversity of insects which in turn supports insectivorous birds such as pheasants and meadowlarks.

- Second, intermediate levels of disturbance have also been shown to result in maximal diversity. For roadsides, this means occasional mowing (or burning); a disturbance of the vegetation once every 3 to 5 years would likely maximize plant species diversity.

- Third, structural diversity can be achieved by mixing plants of different growth forms (herbaceous, shrubs, and trees mixed to achieve vertical stratification). For example, the inclusion of shrub habitats on roadsides resulted in greater numbers of birds and

Figure 8-3. Biological Diversity - results from native seedings in Clinton County, Iowa. (Photograph: Clinton County, Iowa, IRVM)

rabbits (Roach and Kirkpatrick, 1985). However, mixing of plant growth forms generally favors more-common habitat generalists which are already abundant. Furthermore, because of the need for clear zones in the right-of-way and the link between the elimination of low-level woody vegetation and reducing DVCs, this third method of enhancing structural diversity can compromise vehicle safety (see Figure 8-4). In high-DVC areas, structural diversity can be enhanced with a variety of heights of grasses and forbs.

In roadsides sufficiently wide such that the right-of-way exceeds the clear zone, trees (or standing dead trees known as snags) beyond the clear zone may be desired in naturally forested regions to provide wildlife with nesting cavities, structural diversity, and perches so long as the trees do not pose a safety risk by retarding ice-melt or by falling onto the roadway. Local managers may strike a balance between the benefit to wildlife of the presence of (structurally diverse) woody vegetation beyond the clear zone and the safety implications to travelers.

Figure 8-4. Woody Vegetation in Roadsides - provides cover for deer and increases the risk of deer-vehicle collisions ***(Photograph: BASF Professional Vegetation Management.)***

A second habitat characteristic that affects wildlife is habitat abundance. Population size of many grassland bird species is limited by the amount of grassland habitat available to them. Although roadsides comprise <2% of the land area in most landscapes, they can provide the only grassland habitat available in intensively cultivated or otherwise developed areas.

SIGNIFICANCE OF ROADSIDE HABITAT FOR WILDLIFE

Minnesota can be partitioned into biologically meaningful zones based on the Minnesota Ecological Classification System: Laurentian Mixed Forest, Eastern Broadleaf Forest, Tallgrass Aspen Parklands, and Prairie Parkland (see Figure 1-2). Because vehicle safety requires wide clear zones, the habitat provided by roadsides usually consists of herbaceous vegetation, potentially a mix of grasses and forbs, similar in physical structure to prairie. Roadsides are relatively novel habitats in the forested regions of the state and can be considered as surrogate grasslands in the prairie zone, a region now largely converted to row-crop agriculture. As native prairie habitat was increasingly eliminated and fragmented, many wildlife species - particularly grassland birds - have declined in abundance (Sauer and Droege, 1992: Zaletel and Dinsmore, 1985).

Throughout the state, roadsides can offer herbaceous cover needed by a wide array of wildlife for reproduction, feeding, and protection (Table 8-1). Although government land programs such as Re-Invest in Minnesota (RIM), Conservation Reserve Program (CRP), and the Conservation Reserve Enhancement Program (CREP) have allocated land to non-agricultural uses that benefit wildlife, roadsides remain an important permanent source of wildlife habitat (see Figure 8-5).

The greatest potential benefit to roadside wildlife is in southern and western Minnesota, a landscape in which row-crop agricultural has replaced most of the prairies and wetlands. Of the state's pre-settlement wetlands (about 20 million ac), about half have been lost, mostly in the agricultural zone (MDNR 1997). Presently, about 2 million ac potential wildlife habitat in Minnesota resides in lands enrolled in government-subsidized conservation programs: 90% of the acreage in the Conservation Reserve Program (CRP) and 10% in the Conservation Reserve Enhancement Program (CREP, initiated in 1985) and the Reinvest in Minnesota Program (RIM; initiated in 1986; Unpubl. data, T. Hoek, Minnesota Board of Water and Soil Resources, August, 2007). Although roadside area in southern and western Minnesota covers less than 1% of the landscape (estimated as 500,000 ac by Varland (1985b)), it can provide rare wildlife habitat in the form of permanent grassland strips potentially connecting other natural

fragments. In addition, well-managed roadsides can inspire interest and appreciation for grasslands and wildlife from neighboring landowners, potentially leading to additional grassland restoration projects.

Varland (1985a) estimated up to one half of successful ring-necked pheasant nests, and most gray partridge nests, occur in roadsides in Minnesota. With the increase in lands enrolled in programs such as CREP, the proportion of such nests on roadsides declined, but was still significant: Clark et al. (1999) examined grassland patches and roadsides in Iowa and estimated that about 59% of successful nests occurred in blocks of grasslands like those protected by CREP and 14% of successful nests were in roadsides.

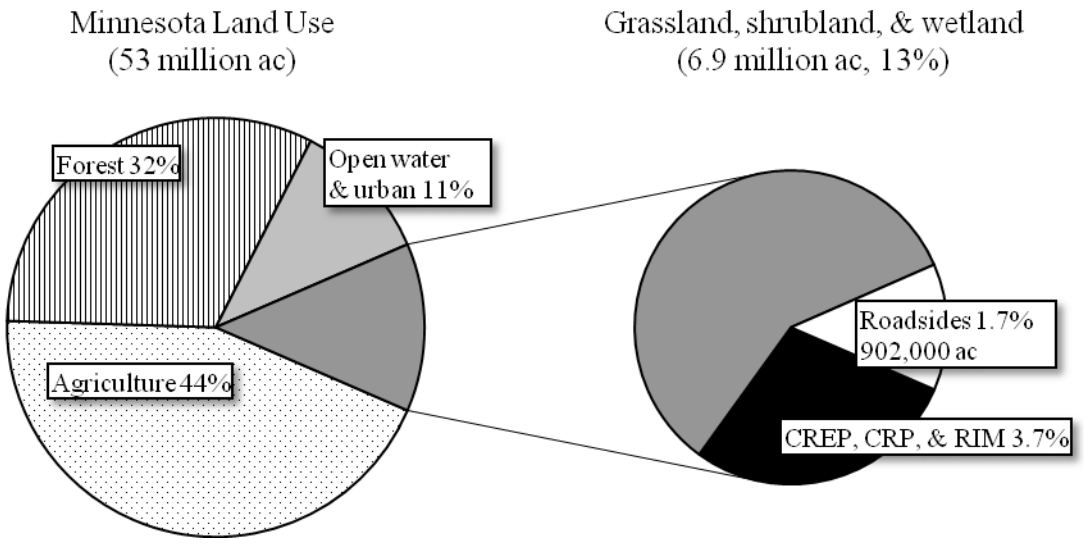


Figure 8-5. Land Area in Minnesota by Land-use Type

EFFECTS OF ROADSIDE ENCROACHMENT AND DISTURBANCE ON WILDLIFE

Encroachment is the destruction, disturbance, or taking of (public) roadsides or roadside resources for private use. Undisturbed grassy roadsides provide critical nesting cover for many species of mammals and birds such as ring-necked pheasants, meadowlarks, and waterfowl such as mallards and northern pintails. Encroachment on roadsides - harmful to wildlife and illegal at certain times of the year – includes the following:

- Over-cropping
- Over-spraying
- Operation of all-terrain vehicles (ATVs)
- Haying
- Mowing

Killing or injuring plants and wildlife by over-spraying of herbicides and/or pesticides across field boundaries onto roadsides either accidentally or by negligence is encroachment. Pesticides kill insects needed by bird chicks and other wildlife. Herbicides kill plants, reducing wildlife habitat and indirectly eliminating insects. This effect is tempered by the use of selective herbicides; for example, herbicides that kill thistle, reed canary grass, or other species selectively may allow a diversity of native plants to flourish. Encroachment by the operation of vehicles such as all-terrain vehicles (ATVs) for recreation or farm-work injures or destroys vegetation and increases soil erosion. The expansion of crop fields onto public roadsides eliminates habitat and reduces the width of roadside strips, exaggerating edge effects (see Figure 8-1). Other disturbances such as haying and mowing reduces wildlife productivity especially if they occur during the nesting season. Haying and mowing prior to August 1st destroys active nests and can kill females and offspring.

Table 8-1. Wildlife Species (birds, mammals, and reptiles) - reported to reproduce in (shaded) or use (unshaded) roadsides in Midwestern states by one or more of the noted references

Birds	
American Bittern	*Botaurus lentiginosus*
American Goldfinch	*Carduelis tristis*
Bobolink	*Dolichonyx oryzivorus*
Brown-headed cowbird	*Molothrus ater*
Blue-winged Teal	*Anas discors*
Common yellowthroat	*Geothlypis trichas*
Dickcissel	*Spiza americana*
Eastern meadowlark	*Sturnella magna*
Eastern wild turkey	*Meleagris gallopavo*
Field Sparrow	*Spizella pusilla*
Gadwall	*Anas strepera*
Grasshopper Sparrow	*Ammodramus savannarum*
Gray Partridge	*Perdix perdix*
Greater prairie chicken	*Tympanuchus cupido*
Killdeer	*Charadrius vociferus*
Lesser scaup	*Aythya affinis*
Mallard	*Anas platyrhynchos*
Mourning dove	*Zenaida macroura*
Northern pintail	*Anas acuta*
Northern shoveler	*Anas clypeata*
Red-winged blackbird	*Agelaius phoeniceus*
Ring-necked pheasant	*Phasianus colchicus*
Sharp-tailed grouse	*Tympanuchus phasianellus*
Song sparrow	*Melospiza melodia*
Upland sandpiper	*Bartramia longicauda*
Vesper sparrow	*Pooecetes gramineus*
Western meadowlark	*Sturnella neglecta*
Brown thrasher	*Toxostoma rufum*
Horned lark	*Eremophila alpestris*
Northern harrier	*Circus cyaneus*
Red-headed woodpecker	*Melanerpes erythrocephalus*
Savannah sparrow	*Passerculus sandwichensis*
Mammals	
Eastern cottontail	*Sylvilagus floridanus*
Eastern spotted skunk	*Spilogale putorius*
Northern pocket gopher	*Thomomys talpoides*
Prairie vole	*Microtus ochrogaster*
Richardson's ground squirrel	*Spermophilus richardsonii*
White-tailed jackrabbit	*Lepus townsendii*
American badger	*Taxidea taxus*
Eastern mole	*Scalopus aquaticus*
Franklin's ground squirrel	*Spermophilus franklinii*
Long-tailed weasel	*Mustela frenata*

Meadow jumping mouse	*Zapus hudsonicus*
Meadow vole	*Microtus pennsylvanicus*
Red fox	*Vulpes vulpes*
Short-tailed shrew	*Blarina brevicauda*
Striped skunk	*Mephitis mephitis*
Thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*
Western harvest mouse	*Reithrodontomys megalotis*
White-footed mouse	*Peromyscus leucopus*
Woodchuck	*Marmota monax*

Below: Additional species of "Greatest Conservation Need" that use habitats similar to roadsides.

Birds		
Baird's sparrow	*Ammodramus bairdii*	*Prairie*
Bell's vireo	*Vireo bellii*	*Shrub/Woodland-Upland*
Chestnut-collared longspur	*Calcarius ornatus*	*Prairie*
Golden-winged warbler	*Vermivora chrysoptera*	*Lowland shrub*
Henslow's sparrow	*Ammodramus henslowii*	*Surrogate grasslands*
Sprague's pipit	*Anthus spragueii*	*Prairie*
Swamp sparrow	*Melospiza georgiana*	*Lowland shrub*
Mammals		
Plains pocket mouse	*Perognathus flavescens*	*Surrogate grasslands*
Reptiles		
Eastern hognose snake	*Heterodon platirhinos*	*Shrub/Woodland-Upland*
Eastern racer	*Coluber constrictor*	*Shrub/Woodland-Upland*
Five-lined skink	*Eumeces fasciatus*	*Shrub/Woodland-Upland*
Milk snake	*Lampropeltis triangulum*	*Shrub/Woodland-Upland*
Six-lined racerunner	*Cnemidophorus sexlineatus*	*Shrub/Woodland-Upland*
Western hognose snake	*Heterodon nasicus*	*Shrub/Woodland-Upland*

Table References: Camp & Best 1993, Fouchi 1993, Hergenrader 1962, C. Nelson, MDNR unpub. data, Oetting & Cassel 1971, Svedarsky 1977, Varland 1985a, and Varland 1985b. **Table Notes:** This is likely an incomplete list of the species that use Minnesota roadsides for reproduction, feeding, or cover; uses by many other species wildlife probably occur but are unreported. For detailed information on the roadside resources used by particular species of wildlife, contact the MDNR Roadsides for Wildlife Coordinator. Listed separately (as "Additional Species") are species not reported to use roadsides specifically but have been identified as "species of greatest conservation need" (SCGNs) by MDNR (2006) as using Prairies. Lowland Shrub, Shrub/Woodland-Upland, or Surrogate Grassland habitats. Species that are not listed but are reported to use edges between woody and grassy (roadside) habitats include Common Grackle, Eastern Kingbird, American Robin, Eastern Bluebird, American Kestrel, and Brown Thrasher.

RECOMMENDED BEST PRACTICES

A summary of recommended practices to enhance roadsides for wildlife is provided in Table 8- 2. These are conclusions based on the review of principles of roadside ecology and the factors affecting deer-vehicle collisions (DVCs) as discussed below.

The use of prescribed burns in the prairie/agricultural zone rather than mowing or spraying to maintain roadside vegetation is a better way to favor native species because it is a natural form of disturbance and because it is more economically more efficient when used on a large scale (K. Graeve, Mn/DOT Plant Ecologist, personal communication). Efforts to establish and maintain native prairie plantings may fail without the periodic use of fire.

Table 8-2. Best Management Practices - to promote vehicle safety while enhancing roadsides for wildlife as a supplement to the recommendations presented in preceding chapters of this handbook. These treatments are constrained by existing guidelines such the Mn/DOT Maintenance Manual and the State of Minnesota mowing law (MS 160.23) which requires that road authorities delay mowing until August 1st except for safety reasons (first 8 feet of roadside and near intersections) and for precise weed-control.

Treatment	Best Management Practice	Ecological rationale or outcome
1. Prescribed burning.	1-1. Prescribed burns are preferable to other forms of disturbance (mowing or chemical treatments) wherever feasible. Burning may not be feasible in the Northern Coniferous Forest.	Disturbance by prescribed burning simulates natural wildfire and will favor native rather than exotic species.
2. Mowing.	2-1. Mow (or hay or burn) beyond the first swath only once every 3 to 5 yrs in late summer (early August). Prescriptions must fall within the State Mowing Law.	Control invasion of woody vegetation and rejuvenate herbaceous growth. This timing allows birds and other wildlife to complete the reproductive season. Forage value of warm-season grasses is highest in late-summer, making haying a viable option which also reduces Mn/DOT maintenance costs.
	2-2. If mowing (or burning) beyond the first swath, use a 3 to 5-yr rotation.	Creates vegetative diversity within short distances along the road, and increases wildlife population abundance.
	2-3. Vegetation should be 10 to 12" high by the end of the growing season.	Protects plants from damage over winter. Provides winter cover and spring nesting cover for birds.
3.Encroachment	3-1. Prevent encroachment by private parties. Prevent illegal encroachment (such as cropping and over-spraying, or use of recreational vehicles, except on snow cover). Post right-of-ways and property lines to deter encroachment.	Reduces habitat loss, soil erosion, and maintenance costs.
	3-2. Prevent untimely disturbance. Restrict timing of maintenance activities (mowing, spraying, use of recreational vehicles) to the period outside of the nesting season.	Reduces disturbance to nesting wildlife.
	3-3. Use of recreational vehicles. Restrict timing to the period outside the nesting season and restrict frequency.	Reduces disturbance to nesting wildlife and reduces habitat loss. This will also protect roadsides from rutting and soil erosion that results from over-use.

4. Spraying.	4-1. Spot-spray rather than broadcast when sufficient for eliminating noxious weeds or other targets.	Reduces disturbance to nesting wildlife. Preserves prairie vegetation and protects local genotypes. Reduces the costs of materials, equipment, and labor, and reduces off-target damage and unnecessary pesticide addition to the environment.
	4-2. Use water-based sprays when spraying during bird nesting seasons (prior to August 1).	Petroleum carriers may coat and seal eggs, inhibiting gas exchange and killing bird embryos.
5. Seeding.	5-1. Use native seed mixes, and where possible use local ecotypic species. In high-DVC areas, avoid mixes including non-native species such as red clover and alfalfa or other species that provide palatable forage for ruminants. Maintenance of natives will often require the use of fire.	Increases biological plant diversity which leads to biological diversity, including insects and other invertebrates. Because native plants and animals are co-evolved, exclusion of exotics leads to diverse and stable communities.
	5-2. Avoid mast-producing species such as bur oak, red oak, and northern pin oak.	Avoids the attraction of deer to the roadside, reducing DVCs.
6. Managing woody vegetation.	6-1. Removal of woody vegetation that inhibits driver sight-lines. Extend clear zone into Zone 3 (backslope) as indicated in Figure 4-2, especially around low-lying areas or where forest patches exist adjacent to the ROW. Exceptions include individual trees (and low-density stands of trees) with no foliage low enough to provide deer cover or to inhibit driver sightlines, including snags (see next line).	Woody cover attracts deer and diminishes driver sightlines resulting in increased DVCs. Trees with no foliage in sight-lines provide wildlife habitat without a significant safety risk.
	6-2. Do not remove standing snags on the backslope.	Snags provide nesting cavities, perches and foraging sites for wildlife.
7. Cleaning equipment.	Clean equipment such as tractors and mowers that may transport seeds or plant parts from one site to another.	Unintended transport and introduction of species between locations may accelerate the spread of noxious or exotic species.
8. Managing living snow fences.	8-1. Avoid mast-producing species such as bur oak, red oak, and northern pin oak.	Avoids the attraction of deer to the roadside, reducing DVCs.
	8-2. Make grass strip as wide as possible.	Nest success of grassland birds increases with increasing patch width.

PRACTICES TO REDUCE DEER-VEHICLE COLLISIONS (DVC's)

1. Economic and safety costs of DVCs.

DVCs are a world-wide problem. Putman (1997) reviewed management options to reduce DVCs in Europe, noting that more than 50,000 deer are killed annually in Sweden and about 12,000 in Germany. In the US, about 200,000 deer were killed in 1980 (Williamson, 1980). Recent estimates of the annual mortality in the US are between 500,000 and 750,000 per year (Conover et al., 1995; Romin and Bissonette, 1996). Deer kills in Minnesota increased 42% from 1982 to 1991 (11,471 to 16,280). The economic value for individual deer - primarily because of the economic impact of hunting expenditures - was estimated as $1313 in 1992 by Romin and Bissonette (1996) and the MDNR assigns a value of $500. However, DVC deer mortality does not threaten the viability of deer populations and the cost of losing deer is small; it is the human safety risk and property damage that are usually of concern.

Property losses are significant: Over a 10-yr period in Vermont, over 23,000 DVCs caused $31 million in losses (Romin and Bissonette, 1996). Annual property losses in the US were estimated as $280 million for 1993 (Fehlberg, 1994) and as over $1 billion per year in 2007 (R. Weinholzer, Pers. Comm.) The combined cost of property loss and human injury was estimated as $1.2 billion annually in the US (Cook and Daggett, 1995). In the 1980s, approximately 5% of DVCs resulted in human injury (Hansen, 1983; Stoll et al., 1985). About a million DVCs occur in the US annually, resulting in about 200 human deaths (R. Weinholzer, Pers. Comm.). Data from the Minnesota Department of Public Safety, Office of Traffic Safety, as reported at www.deercrash.com, shows about 90,000 to 100,000 DVCs in Minnesota since 1993, resulting in 400 to 500 human injuries and several (< 10) fatalities each year. The insurance industry estimates that 35,000 DVCs occur each year in Minnesota.

2. Vegetation management to reduce DVCs.
Techniques that rely on managing conditions other than vegetation are outside the scope of this handbook, but they are noteworthy because of the importance of DVC reduction and because some involve vegetation. Danielson and Hubbard (1998) provided a comprehensive review of DVC reduction techniques. Common efforts include warning signs, reduced speed limits, highway lighting, fencing, underpasses and overpasses, reflectors that reflect car lights toward deer on the roadside, more-sophisticated systems such as deer-detection systems (Gordon et al. 2004), and others. Most DVC reduction techniques that have been put in place have never been rigorously tested for their effect (Putman, 1997; Romin and Bissonette, 1996; Danielson and Hubbard, 1998). The only widely acknowledged methods of reducing DVCs are the reduction of deer density by harvest and the use of fencing (Knapp, 2006).

Fencing ($\geq$ 2.4 m or 7.5 ft height) although expensive can be effective (Bashore et al., 1985; Ludwig and Bremicker, 1983) but only if it is maintained in good condition because deer will often crawl under erosion gaps or go through small openings in fences. A negative effect of fencing is that deer between the road and the fence may be trapped there. One-way exit gates can be built into fences but these are often ineffective; Lehnert and Bissonette (1997) recommended earthen ramps instead. In conjunction with fencing, the reduction of palatable forage between the road and fence is advised where practical.

Underpasses for wildlife are less likely than overpasses to be used by wildlife to cross roads, but they are more common and cheaper than the latter. Underpasses already exist in some locations where deer naturally travel: where roads cross rivers, streams, and low-lying areas that typically have greater amounts of vegetative cover than the rest of the roadside. Wildlife will be more likely to use an underpass if there are greater amounts of vegetation in and around the underpass, if there is an earthen floor, and if the underpass is short and more open, having a height and width of at least 15 feet (Reed, 1981; Putman 1997; see Figure 8-6). MnDOT has recently begun an alternative design for underpasses with rocky slopes (riprap) that includes a level pathway for animal crossings (passage bench) under bridges and along watercourses (P. Leete, personal communication).

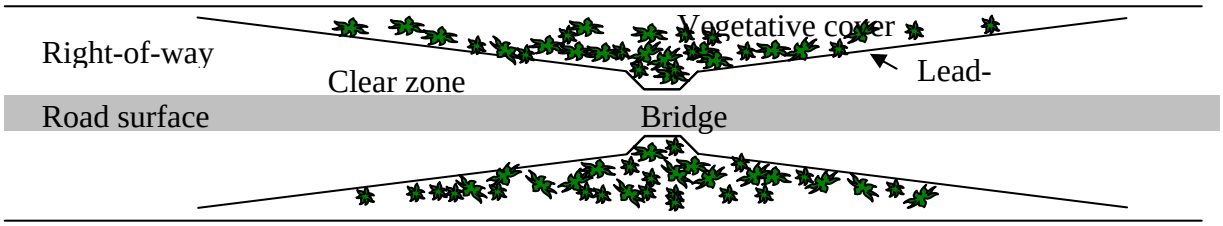


Figure 8-6. Overhead View of Road Underpass with Lead-fencing. Wildlife are less likely to cross on the road and more likely to use a road underpass or overpass if there are lead fences that funnel deer toward the passage. Longer lead fences reduce the likelihood of end-runs. Fences should be splayed slightly to form a broad funnel if possible. Greater vegetative cover near the passage and along fences will encourage wildlife, but the area between the road and the fence should be devoid of palatable forage or any resource that may attract wildlife.

Lead-fences extending away from underpasses and along the road can funnel wildlife toward the underpass, especially when coupled with visual cover provided by vegetation located near the underpass and along the fences but not located between the road and the fence (Putman, 1997; Foster and Humphrey, 1995; see Figure 8-6). However, lead-fences can also trap deer between the road and the fence as mentioned above. The use of long leads will reduce the likelihood of deer traveling around the fence and onto the roadside.

Human behavior

Lower speeds would be the most effective way to reduce DVCs (Pojar et al., 1975) but warning signs usually have little effect on speed. Visibility of deer to the driver may be enhanced with highway lighting and by removing or lowering vegetation in the clear zone (see Figure 8-6). However, highway lighting was found to have no effect on the frequency of DVCs by Reed (1981). It is possible that with more light, a larger clear zone, and/or less vegetation, drivers will increase speed until they reach an acceptable level, or perception, of risk. Hubbard et al. (2000) and Bashore et al. (1985) suggest that drivers may adjust their driving behavior - seemingly to maintain a constant level of risk - by driving slowly on curves and more-vegetated sections of road with shorter sightlines, but increasing speed on straight roads and roads with larger clear zones, resulting in a tendency toward equalizing the risk of DVCs among road types.

Figure 8-7. Attraction of Deer to Roadsides - Deer may be attracted to roadsides for resources such as forage (especially in forested regions in spring) and salt that accumulates on roadsides in spring. (photo: Defenders of Wildlife, Habitat and Highways Campaign.)

This theory that drivers behave according to an acceptable level of risk implies that the creation of clear zones and other safety measures may have a limited effect on the likelihood of DVCs. However, using vegetation management to avoid abrupt changes in DVC risk along the road is probably beneficial. The most effective way to reduce DVCs is for drivers to adjust their level of risk by slowing down.

Deer behavior

Deer occur on roadsides for primarily one of two reasons: either they are attracted to a resource on the roadside (such as salt or forage; Figure 8-7), or they are simply crossing the road as they travel from one resource to another. The annual and daily timing of DVCs are illustrated in Figures 8-8 and 8-9.

Disturbances such as blading and frequent or low-height mowing may increase the abundance of new vegetative growth in roadsides making them more attractive for deer as sources of forage. This is particularly true for forested regions where springtime roadsides receive more sunlight and may offer new herbaceous growth while the shady forest floor offers little (Feldhamer et al., 1986) and this is less true for agricultural regions where other foods such as waste corn is abundantly available away from the roadsides.

Species composition of roadside vegetation may influence the attraction of deer. A Mn/DOT internet site (http://plantselector.dot.state.mn.us) provides a Plant Selector Program that identifies species of plants that deer may be attracted or averse to. There are many such lists of plant species divided by deer preference available online. For the purpose of DVC reduction, seeding mixes may be selected that provide the potential for shorter, less-dense, or less palatable vegetation (grasses such as little bluestem and sand dropseed) which allows greater visibility of deer by drivers. Seed-mix selection may need to be tailored to meet local soil and climate conditions.

Deer may be attracted to salt applied to road surfaces which then accumulates on the roadside during spring (Bruinderink and Hazebroek, 1996). Ice treatments without salt can be used especially in high-DVC areas (Feldhamer et al., 1986).

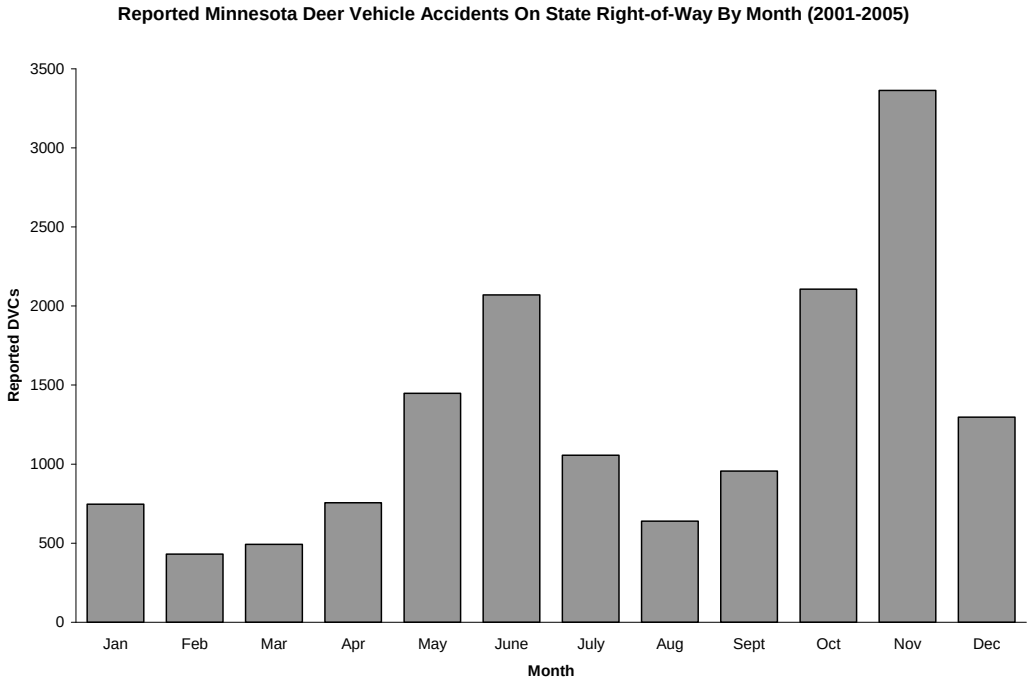


Figure 8-8. Number of Reported Deer-Vehicle Accidents by Month in Minnesota. The peak in June is probably caused by increased movements of females and juvenile dispersal. The peak in November is caused by increased movements during the mating season.

With regard to deer movements across roads (without attraction to the road *per se*), only one vegetation management technique has reduced DVCs (by 50% in one Utah study) and it is known as Intercept Feeding (Wood and Wolfe, 1988), wherein food sources are created between deer bedding areas and roadsides. However, such food sources (plantings or other) would occur in (private) areas outside the ROW and such actions would probably provide only a temporary reduction in DVC frequency. There seems to be an absence of studies that relate vegetation management on roadsides to DVC frequency involving deer whose travel routes cross roads rather than deer that may be attracted to roadside resources.

Individual deer range over a large area encompassing patches of habitat used for feeding, resting, or other functions. They develop daily travel lanes within their home range, and may cross roads habitually. A study of the association of landscape features with DVCs in Iowa found more DVCs occurring in places with greater woody patches and grass patches as well as near bridges (Hubbard et al 2000). The correlation with bridges is probably caused simply because greater deer densities and/or movements occur in areas where bridges are placed, areas like stream-courses that may be low-lying and having more vegetative cover which may serve deer as natural travel routes. The positive correlation does not mean that bridges cause more DVCs. To encourage deer to use underpasses, Ng et al. (2003) recommended that woody vegetation and greater vegetation structure be allowed to develop near the underpasses. In addition, flanking fences (or leads) have been recommended to funnel deer toward underpasses (Hubbard et al., 2000; Ng et al., 2003). Ironically, in these areas, the use of greater vegetative cover - rather than less vegetative cover - might reduce DVCs, but only if lead-fences are used.

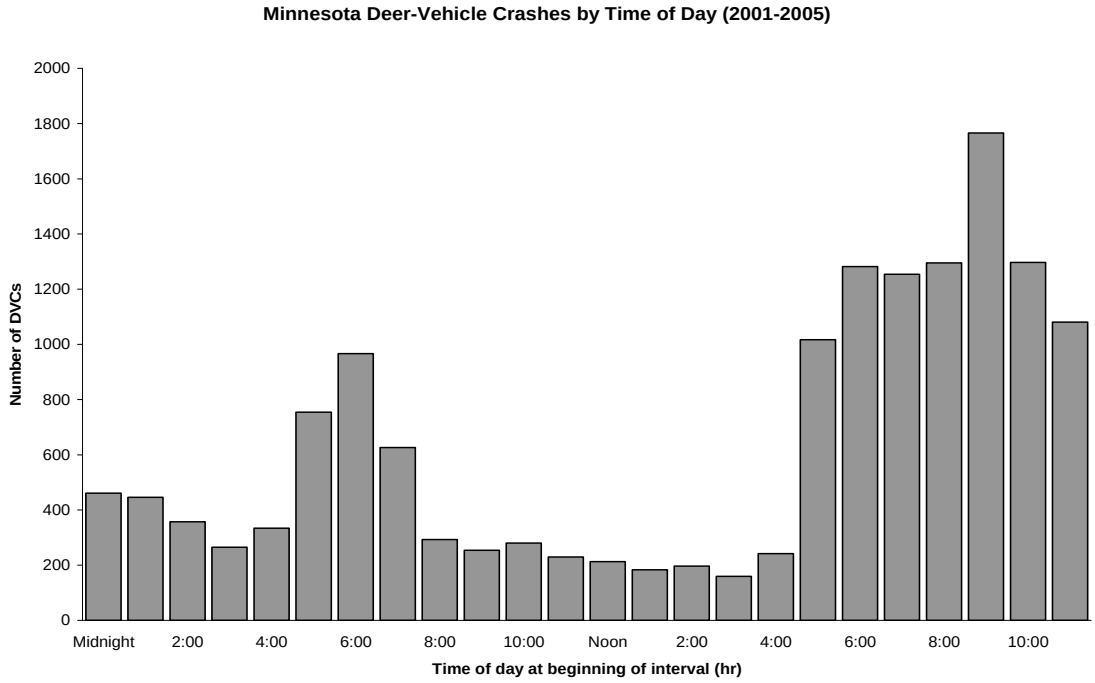


Figure 8-9. Number of Reported Deer-Vehicle Accidents by Time Of Day. The peaks at dawn and dusk are thought to be caused by increases in deer movements and by decreased driver visibility. Haikonen and Summala (2001) studied DVCs in North America and Europe and found the greatest peak 1 hr after sunset.

LITERATURE CITED & BIBLIOGRAPHY

Abraham, J. 2003. "Big lakes, empty skies." *Minnesota Volunteer*. Sept.

Anderson, L.D. 1996. *Guidelines for Roadside Revegetation to Create Wildlife Habitat in Northern Utah.* MLA Thesis, Utah State University. Logan, Utah.

Anderson, S.H., K. Mann, and H.H. Shugart. 1977. "The effect of transmission-line corridors on bird populations." *American Midland Naturalist* 97: 216-221.

Andren, H., and P. Anglestam. 1988. "Elevated predation rates as an edge effect in habitat islands: experimental evidence." *Ecology* 69:544-547.

Bashore, T.L., W.M. Tzilkowski, and E.D. Bellis. 1985. "Analysis of deer-vehicle collision sites in Pennsylvania." *Journal Wildlife Management* 49:769-774.

Beier, P., S. Loe. 1992. "A checklist for evaluating impacts to wildlife movement corridors." *Wildlife Society Bulletin* 20:434-440.

Bennett, A.F., 1990. "Habitat corridors and the conservation of small mammals in a fragmented forest environment." *Landscape Ecology* 4, 109-22.

Berner, A. 1984. *Management of roadsides for wildlife.* Ann. Rep., MDNR Farmland Wildlife Populations Research Group. Minnesota Department of Natural Resources. Madelia, Minnesota.

Bryan, G.G., and L.B. Best. 1991. "Bird abundance and species richness in grassed waterways in Iowa row-crop fields." *American Midland Naturalist* 126:90-102.

Bruinderink, G.W.T.A., and E. Hazebroek. 1996. "Ungulate traffic collisions in Europe." *Conservation Biology* 10:1059-1067.

Camp, M., and L.B. Best. 1993. "Bird abundance and species richness in roadsides adjacent to Iowa rowcrop fields." *Wildlife Society Bulletin* 21: 315-325.

Chesness, R.A., M.M. Nelson, and W.H. Longley. 1968. "The effect of predator removal on pheasant reproductive success." *Journal of Wildlife Management* 32:683-697.

Clark, W.D., and J.R. Karr. 1979. "Effects of highways on red-winged blackbird and horned lark populations." *Wilson Bulletin* 91:143-145.

Clark, W.R., R.A. Schmitz, and T.R. Bogenschutz. 1999. "Site selection and nest success of ring-necked pheasants as a function of location in Iowa landscapes." *Journal of Wildlife Management* 63:976-989.

Clevenger, A.P., B. Chruszcz, and K. Gunson. 2001. "Drainage culverts as habitat linkages and factors affecting passage by mammals." *Journal of Applied Ecology* 38:1340-1349.

Conover, M.R., W.C. Pitt, K.K. Kessler, T.J. DuBow, and W.A. Sanborn. 1995. "Review of human injuries, illnesses, and economic losses caused by wildlife in the United States." *Wildlife Society Bulletin* 23:407-414.

Cook, K.E., and P.M. Daggett. 1995. *Highway roadkill; Associated issues of safety and impacts on highway ecotones.* Task Force on Natural Resources, Transportation Research Board, Natural Research Council. Washington, D.C., USA.

Crossley, A., and T. Peterson. 1990. *Wildlife and roadsides: A review of the literature.* Wisconsin Department of Natural Resources, Madison, Wisconsin.

Danielson, B.J., and M.W. Hubbard. 1998. *A literature review for assessing the status of current methods of reducing deer-vehicle collisions.* Report to the Iowa Departments of Transportation and Natural Resources. Iowa State University, Ames, Iowa.

Falk, N.W., H.B. Graves, and E.D. Bellis. 1978. "Highway right-of-way fences as deer deterrents." *Journal of Wildlife Management* 42:646-650.

Feldhamer, G.A., J.E. Gates, D.M. Harman, A.J. Loranger, and K.R. Dixon. 1986. "Effects of interstate highway fencing on white-tailed deer activity." *Journal of Wildlife Management* 50:497-503.

Foster, M.L., and S.R. Humphrey. 1995. "Use of underpasses by Florida panthers and other wildlife." *Wildlife Society Bulletin* 23:95-100.

Fouchi, C.M. 1993. *Roadsides for wildlife program, a plan for action, 1994-1999.* Minnesota Department of Natural Resources. St. Paul, Minnesota.

Gordon K.M, M.C. McKinstry, and S.H. Anderson. 2004. "Motorist response to a deer-sensing warning system." *Wildlife Society Bulletin* 32:565-573.

Grimm, J.W., and R.H. Yahner. 1987. "Small mammal responses to roadside habitat management in South Central Minnesota." *Journal of the Minnesota Academy of Science* 53:16-21.

Haikonen, H., and H. Summala. 2001. "Deer-vehicle crashes: Extensive peak at 1 hour after sunset." *American Journal of Preventive Medicine* 21:209-213

Hansen, C.S. 1983. "Costs of deer-vehicle accidents in Michigan." *Wildlife Society Bulletin* 11:161-164.

Hergenrader, G.L. 1962. "The incidence of nest parasitism by the Brown Headed Cowbird (*Molothrus ater*) on roadside nesting birds in Nebraska." *The Auk* 79: 85-88.

Horton, T. 2005. "The weed eaters: Experts in the field talk about integrated vegetation management." *Roads and Bridges* (March): 56-57.

Hubbard, M.W., B.J. Danielson, and R.A. Schmitz. 2000. "Factors influencing the location of deer-vehicle accidents in Iowa." *Journal of Wildlife Management* 64: 707-713.

IRVM. 1992. *Integrated roadside vegetation management technical manual.* University of Northern Iowa, Cedar Falls, Iowa.

Johnson, C.W., L. Anderson. 1997. *Utah's rural roadsides for wildlife program: A technical manual.* Utah St. University. Logan, Utah.

Joselyn, G.B., J.E. Warnock, and S.L. Etter. 1968. "Manipulation of roadside cover for nesting pheasants-a preliminary report." *Journal of Wildlife Management* 32: 217-233.

Knapp, K.K. 2006. "Reduction factors for d*eer-vehicle* crash countermeasures: State of the knowledge and suggested safety research needs." *Journal of the Transportation Research Board* 1908:172-179.

Kuennen, T. 2006. "Critter crossings, sensors keep wildlife, motorists apart." *Better Roads* (Nov) 28-38.

Laursen, AU. 1981. "Birds on roadside verges and the effect of mowing on frequency and distribution." *Biological Conservation* 20:59-68.

Lavsund, S., and F. Sandegren. 1991. "Moose-vehicle relations in Sweden: A review." *Alces* 27:118-126.

Lehnert, M.E., and J.A. Bissonette. 1997. "Effectiveness of highway crosswalk structures at reducing deer-vehicle collisions." *Wildlife Society Bulletin* 25:809-818.

Levy, A. 2005. "Where the wildlife meets the road." *Public Roads* (May/June) 2-9.

Ludwig J., and T. Bremicker. 1983. "Evaluation of 2.4-m fences and one-way gates for reducing deer-vehicle collisions in Minnesota." *Transportation Research Record* 913:19-22.

Mann, C.C., and M.L. Plummer. 1995. "Are wildlife corridors the right path?" *Science* 270:1428-1430.

Manville, R.H. 1966. "Roadside abundance of woodchucks." *American Midland Naturalist* 75: 537-538.

Michael, E.D. 1980. *Use of different roadside cover plantings by wildlife.* West Virginia Dept. Highways. West Virginia University Report 77-247, Charleston, WV.

Minnesota Department of Natural Resources. 1997. *Minnesota wetlands conservation plan.* St. Paul, Minnesota.

Minnesota Department of Natural Resources. 2006. *Tomorrow's habitat for the wild and rare: An action plan for Minnesota wildlife, comprehensive wildlife conservation strategy.* Division of Ecological Services. St. Paul, Minnesota.

Mitchell, R.B., R.A. Masters, S.S. Waller, K.J. Moore, and L.J. Young. 1996. "Tallgrass prairie vegetation response to spring burning dates, fertilizer, and atrazine." *Journal of Range Management* 49: 131-136.

Montag, D. 1981. "A condition and management survey of roadsides in Minnesota's agricultural area." *Minnesota Wildlife Research Quarterly* 41:41-70.

Nationwide Insurance. 1993. "Deer and moose collisions: No laughing matter." *Nationwider* Summer 1993, Portland, Oregon.

Ng, S.J., J.W. Dole, R.M. Sauvajot, S.P.D. Riley, and T.J. Valone. 2003. "Use of highway undercrossings by wildlife in southern California." *Biological Conservation* 115:499-507.

Oetting, R.B., and F. Cassel. 1971. "Waterfowl nesting on interstate highway right-of-way in North Dakota." *Journal of Wildlife Management* 35:774-785.

Oxley, D.J., M.B. Fenton, and G.R. Carmody. 1974. "The effects of roads on populations of small mammals." *Journal of Applied Ecology* 11:51-59.

Pojar, T.M., R.A. Prosence, D.F. Reed, and R.H. Woodward. 1975. "Effectiveness of a lighted, animated deer crossing sign." *Journal of Wildlife Management* 39:87-91.

Putman, R.J. 1997. "Deer and road traffic accidents: Options for management." *Journal of Environmental Management* 51:43-57.

Reed, D.F. 1981. "Effectiveness of highway lighting in reducing deer-vehicle collisions." *Journal of Wildlife Management* 45:721-726.

Reed, D.F., T.D. Beck, and T.N. Woodard. 1982. "Methods of reducing deer-vehicle accidents: Benefit-cost analysis." *Wildlife Society Bulletin* 10:349-354.

Reeder, K., D.M. Debinski, and B.J. Danielson. 2005. "Factors affecting butterfly use of filter strips in midwestern USA." *Agriculture, Ecosystems, and Environment* 109:40-47.

Reeve, A.F., and S.H. Anderson. 1993. "In effectiveness of Swareflex reflectors at reducing deer-vehicle collisions." *Wildlife Society Bulletin* 21:127-132.

Roach, G.L, and R.D. Kirkpatrick. 1985. "Wildlife use of roadside woody plantings in Indiana." *Transportation Research Record* 1016:11-15.

Romin, L.A., and J.A. Bissonette. 1996. "Deer-vehicle collisions: status of state monitoring activities and mitigation efforts." *Wildlife Society Bulletin* 24: 276-283.

Rost, G.R., and J.A. Bailey. 1979. "Distribution of mule deer and elk in relation to roads." *Journal of Wildlife Management* 43: 634-641.

Rowley, L., R. Edwards, and P. Kelly. 1993. *Edges: Their effect on vegetation and wildlife.* Land for Wildlife Notes. State of Victoria, Department of Natural Resources and Environment.

Rusch, A.J., D.R. Thompson, and C. Kabat. 1980. *Management of roadside vegetative cover by selective control of undesirable vegetation.* Wisconsin Department of Natural Resources Technical Bulletin No. 117

Samson, F.B. 1980. "Island biogeography and the conservation of nongame birds." *Transactions of the North American Wildlife Natural Resources Conference* 45:245-251.

Sauer, J.R., and S. Droege. 1992. "Geographic patterns in population trends of neotropical migrants in North America." Pp. 26-42 in: J.M. Hagan & D.W. Johnston, eds., *Ecology and Conservation of Neotropical Migrant Landbirds*. Smithsonian Inst. Press., Washington D.C.

Schad, D. 1984. *Status of Minnesota's pheasant range in roadsides, 1983, and changes since 1973.* Minnesota Department of Natural Resources. St. Paul, Minnesota.

Simberloff, D., and J. Cox. 1987. "Consequences and costs of conservation corridors." *Conservation Biology* 1:63-71.

Singer, F.J., and J.L. Doherty. "Managing mountain goats at a highway crossing." *Wildlife Society Bulletin* 13:469-477

Smith, D.S., P.C. Hellmund, and R.T. Forman. 1993. *Ecology of Greenways.* University of Minnesota Press. Minneapolis, Minnesota.

Soule, M.E. 1991. "Land use planning and wildlife maintenance." *Journal of the American Planning Association* 57: 313-324.

Stout, R.J, R.C. Stedman, D.J. Decker, and B.A. Knuth. 1993. "Perceptions of risk from deer-related vehicle accidents: Implications for public preferences for deer herd size." *Wildlife Society Bulletin* 21:237-249.

Svedarsky, W.D. 1977. "Roadside nesting by prairie grouse in northwest Minnesota." *Prairie Naturalist* 9:41-42.

Thurber, J.M., R.O. Peterson, T.D. Drummer, and S.A. Thomasma. 1994. "Gray wolf response to refuge boundaries and roads in Alaska." *Wildlife Society Bulletin* 22:61-68.

U.S. Department of Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau. 2001. *2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Minnesota.*

Varland, K. 1985a. *Roadsides for wildlife.* Minnesota Department of Natural Resources and Minnesota Department of Transportation.

Varland, K. 1985b. "Why roadsides for wildlife?" *The Minnesota Volunteer*. March-April

Viles, R.L., and D.J. Rosier. 2001. "How to use roads in the creation of greenways: Case studies in three New Zealand landscapes." *Landscape and Urban Planning* 55:15-27.

Voorhees, L.D., and J.F. Cassel. 1980. "Highway right-of-way: Mowing versus succession as related to duck nesting." *Journal of Wildlife Management* 44: 155-163.

Ward, A.L. 1982. "Mule deer behavior in relation to fencing and underpasses on Interstate 80 in Wyoming." *Transportation Research Record* 859:8-13.

Waring, G.H., J.L. Griffis, and M.E. Vaughn. 1991. "White-tailed deer roadside behavior, wildlife warning reflectors and highway mortality." *Applied Animal Behaviour* 29:215-223.

Warner, R.E., L.M. David, S.L. Etter, and G.B. Joselyn. 1992. "Costs and benefits of roadside management for ring-necked pheasants in Illinois." *Wildlife Society Bulletin* 44:155-163.

Wegner, J.F., and G. Merriam. 1979. "Movements by birds and small mammals between a wood and adjoining farmland habitats." *The Journal of Applied Ecology* 16: 349-357.

Wiens, J.A. 1969. "An approach to the study of ecological relationships among grassland birds." *Ornithological Monographs* 8:1-93.

Williamson, L. 1980. "Reflectors reduce deer-auto collisions." *Outdoor News Bulletin* 34:2.

Wood, P. 1986. *Intercept feeding as a means of reducing deer-vehicle collisions.* MS Thesis, Utah St. Univ., Logan, Utah.

Wood, P., and M.L. Wolfe. 1988. "Intercept feeding as a means of reducing deer-vehicle collisions." *Wildlife Society Bulletin* 16:376-380.

Zaletel, L.R.F., and J.J Dinsmore. 1985. "Breeding bird populations in Iowa, 1968-1980." *Proceedings of the Iowa Academy of Science* 92:85-94.

Chapter 9: Examples of Best Management Practices

This chapter highlights examples of cities, counties, state districts, and neighboring states that are using the best management practices identified in this handbook.

BMP #1: DEVELOP AN INTEGRATED ROADSIDE VEGETATION MANAGEMENT PLAN

Examples of Integrated Roadside Vegetation Management Plans from the following agencies are highlighted below:

- Iowa Roadside Vegetation Management Program
- Mn/DOT Maintenance Area 3B IRVM Plan
- Mn/DOT Metro Division IRVM Plan
- Washington State DOT
- Visual Quality Best Management Practices for Forest Management in Minnesota

Table 9-1 outlines a summary of the first three plans.

Table 9-1. Elements of Roadside Vegetation Management Plans

Best Management Practice	Iowa RVMP	Mn/DOT Area 3B	Mn/DOT Metro
Establishing Sustainable Vegetation	Control topsoil erosion from surface runoff and wind. Use of conservation tillage.	Use of appropriate vegetation type to control erosion.	Use of interseeding in areas where turf is sparse or weed-infested.
Mowing Operations	Reduced mowing; only in areas to improve safety sight distance.	Reduced mowing. Mowing based on type of roadway. Many areas left unmowed.	Reduced mowing. Many areas left unmowed.
Control of Noxious Weeds	Use of native grasses and wildflowers. Use of herbicides as a second choice.	Use of cultural (native grasses) and biological (insects) control. Spot spraying with herbicides.	Spot spraying. Use of biological control.
Woody Vegetation and Brush Control	Conduct these operations during winter when staff is available.	Spray brush less than 6 feet high. Remove other brush and hazard trees. Allow naturalization of brush beyond the ditch lines.	Spray brush less than 6 feet high. Remove other brush and hazard trees. Allow naturalization of brush beyond the ditch lines. Control Dutch Elm and Oak Wilt diseases.
Native Grasses	Strongly urge use of native grasses to control noxious weeds, and to create a more diverse landscape.	Use of prescribed burning, where safety and traffic permit. Harvesting native grass seed from existing stands.	Use of controlled burning; attempt to coordinate with burning of adjacent land. Establish stands of prairie grasses.

Iowa Roadside Vegetation Management Program

The Office for Integrated Roadside Vegetation Management at the University of Northern Iowa has published its roadside vegetation management plan in *The Roadside Almanac IRVM*, elements of which are outlined below. Additional information can be found online at http://www.iowalivingroadway.com/IRVM.asp

ESTABLISHING SUSTAINABLE VEGETATION
One plan objective is to control topsoil erosion from water runoff and wind blowing across bare fields. Adjacent farmers are encouraged to employ conservation tillage that lets crop residue protect the soil surface and reduces soil movement. Since eroded soil from adjacent lands can bury roadside vegetation and increase maintenance work, road authorities find ways to prevent it through cooperative efforts between adjacent landowners and the local soil and water conservation districts.

CONTROL OF NOXIOUS WEEDS THROUGH USE OF NATIVE GRASSES
Iowa controls annual and biennial weeds through the use of native grasses and wildflowers. Its IRVM plan recognizes that most of the plants growing on the roadside are harmless and may be native wildflowers. A diverse plant community will result in a continuous bloom of flowers throughout the growing season.

Iowa has identified maintaining a healthy stand of native grasses as the best way to control invasive weeds. These grasses have extensive roots that offer the toughest competition to Canada thistle. In addition, plant diversity along the roadsides creates a strong plant community. Prairie plants can adapt to a wide range of soil types, moisture levels, and climactic condition. Most prairie grasses and wildflowers grow best during hot, dry summer months, providing excellent erosion control during the fall and spring. Deep roots also prevent the invasion of noxious weeds and reduce the numbers of shrubs and trees.

If natives are not used, Iowa's second choice for controlling noxious weeds is herbicides. Spot spraying is recommended, as blanket spraying applies herbicide on the entire roadside plant community, weakening existing vegetation, killing wildflowers, and allowing more weed invasion.

Annual and biennial weeds typically produce many seeds and complete their life cycle in one or two years. The top layer of soil is loaded with weed seed, and with heavy rainfall, seeds germinate, establish roots, and grow. The question of whether to mow or spray these weeds is important. These weeds die after flowering, and it may take a year or two of average rainfall for a group of small weed patches to be established. If prairie plants are nearby, in time they will eventually reclaim the disturbed area. In order to determine the correct response (if any) for managing individual weeds, one must understand their life cycle.

MOWING PRACTICES
Mowing roadsides is very expensive in terms of personnel hours, equipment hours, and fuel consumption. If the purpose of mowing is to provide sight distance and room for a vehicle to pull off the road, mowing the entire roadside is unnecessary. Improper mowing height and too frequent or poorly timed mowing can reduce root mass, plant vigor, and overall production potential. Operating heavy equipment on roadside slopes can tear up vegetation, weakening the plant community and making the roadside more susceptible to weeds and erosion. Because of this, Iowa's plan calls for reduced mowing, and the mowing of only those areas where it is needed for sight distance and safety.

Some areas do require periodic mowing to maintain a safe right-of-way. They include:

- Intersections
- Bridges
- Sharp curves
- Farm and field entrances

Everywhere else, Iowa is learning to appreciate the flowing beauty of the tall grasses that do not require mowing.

WINTER PLANNING AND ROADSIDE MAINTENANCE ACTIVITIES
During winter months, equipment is maintained, seed and herbicide supplies are inventoried, and plans are made for the warmer months' roadside vegetation management activities. Other winter activities include:

- Renewing landowner contacts
- Controlling brush (on milder days)
- Removing trees and brush to provide a safe recovery area for vehicles

- Removing trees from foreslope ditch bottoms growing in fencelines or at the base of noisewalls and drainage structures
- Treating stumps to prevent resprouting
- Removing brush and trees on the backslope as required by local practices
- Pruning landscape trees and shrubs and applying wood chip mulch for weed control

Integrated Roadside Vegetation Management Plan for Mn/DOT Maintenance Area 3B – St. Cloud
Mn/DOT's Maintenance Area 3B developed its integrated roadside vegetation management (IRVM) plan as a proactive way to address roadside management and respond to the following legislation:

- Groundwater Act of 1989 (Chapter 326,Article 5,Section 18B.063) under STATE USES OF PESTICIDES AND NUTRIENTS: The state shall use integrated pest management techniques in its management of public lands, including roadside rights-of-way, parks, and forests; and shall use planting regimes that minimize the need for pesticides and added nutrients.

- 1994 Amendment to the Groundwater Act of 1989 (Chapter 558, Section 26). The legislature required the Commissioner of the Department of Natural Resources (DNR) to prepare a plan for the optimum use of sustainable agriculture and integrated pest management techniques on land owned by the state. A report published in March of 1996, *Sustainable Agriculture and Integrated Pest Management Plan for State-Owned Lands*, provides the framework for the development of local plans such as the 3B effort.

Mn/DOT's plan represents planning at the local effort, with a core committee composed of Mn/DOT maintenance and technical advisory personnel, Minnesota Department of Agriculture regulatory personnel, and county agricultural inspectors. The plan supplements the roadside section of the Maintenance Operations Manual, as well as pertinent sections of Mn/DOT's design manual and the "vegetation height control" and "noxious weed control" standards developed as part of the Mn/DOT area maintenance engineer's planning process.

The plan includes the general elements that follow.

MISSION STATEMENT
Manage roadsides with environmental stewardship, using economical methods, for public safety and visual quality.

PRINCIPLES
1. Promote a safe environment for the traveling public, services employees, and wildlife.
2. Protect, respect, and encourage the natural, native environment.
3. Be receptive and respectful of inputs from other entities.
4. Set a respectable example for all that use, benefit from, maintain, or adjoin the right-of-way.
5. Search for and/or develop methods that will reduce operating costs.

GOALS
1. Reduce roadside hazards.
2. Reduce state and county listed noxious weeds.
3. Reduce mowing.
4. Improve the catalog and record-keeping system.
5. Increase and preserve native vegetation.
6. Increase public awareness and enhance Mn/DOT's image.

Specific objectives are listed for each sub-area to meet the above goals. For example, some of the objectives for one sub-area are listed below:

1. Inventory and remove 50% of hazard trees on two-lane roads and 100 percent on I-94, with 100% removal in five years.
2. Maintain 100% of all sight corners to appropriate safety standards.
3. Control 75% of noxious weeds and encroaching brush with a 15% reduction of herbicide use per year for the next three years; increase control to 90% in five years.

4. Further reduce mowing by timely and appropriate use of herbicides and staying with "top cut" only in all appropriate areas.
5. Maintain areas of native prairie with controlled burning of 20% of burnable sites every year.

General requirements for the IRVM Program are also listed. Components of the IRVM plan include:

- Mowing
- Brush control
- Herbicide application
- Biological control methods
- Prescribed burning
- Planting
- Tree trimming and cutting
- Rodent and insect control
- Mulching and fertilizing
- Erosion control
- Native seed harvesting

Each of these operations will be conducted as an integral part of an overall program, so that personnel performing each activity will know that they are part of this overall goal-oriented program. In addition, customers (such as the public) will be informed that there is a program with goals in place.

The plan also outlines a strategy for categorizing roadsides. Roadsides in Area 3B fall into three different types based on the management practices needed to keep them safe and aesthetically pleasing. The three types are listed below.

Type	Description	Examples
1	Minimal mowing, no full width mowing, natural vegetation height, shoulder cuts only	TH 94/10 TH 65 Bypass
2	50/50 mowing, areas next to at grade businesses and homes mowed, many areas left unmowed	TH 15 in St. Cloud
3	High frequency mowing, parkways, boulevards, bluegrass turf, many areas left unmowed also	TH 15 St. Cloud Business

The plan includes a mapping and communication plan that states that roadsides of each type will be indicated on maps so that all maintenance personnel and the public are informed. The roadside category will dictate the amount and type of each of the IRVM practices conducted and will form the basis for the long-term goals for each of the roadside types. The maps will also include current-year noxious weed control, landscape partnership projects, ongoing vegetation research projects, and prairie restoration projects. IRVM guidelines are included in the plan. The roadside is divided into several roadside management zones, as shown in Figure 9-1.

These guidelines include:

- Following a mowing effort that allows mature vegetation height where appropriate and also addresses safety and aesthetic issues. Mowing will also be used to control annual weeds and to knock down perennial weeds prior to spraying. Quality, not quantity, is the goal.
- Using brush control where needed and where brush is taller than 6 feet. Control brush in accordance with Figure 9-1. Allow naturalization of woody plants beyond the ditch line (except where the clear zone goes beyond the ditch line).
- Following a herbicide application effort that controls noxious weeds. Unwanted brush less than 6 feet in height may also be sprayed in accordance with Figure 9-1.
- Working with other agencies on attempting biological control of noxious weed and insect pests in selected areas. Areas will be located on maps.
- Working with prescribed burning of native vegetation for enhancement and weed control, where safety and traffic permit.
- Incorporating a planting effort for visual aesthetics, and in places where the turf is sparse and/or in weed-infested areas.

- Trimming and/or cutting hazard trees (defective trees with a target such as people, cars, and other property)in rest areas and other roadside areas.
- Using appropriate methods of rodent/insect control when infestations become a problem.
- Mulching/fertilizing specifically in landscape plantings, higher visibility and maintenance areas such as rest areas, etc.
- Integrating the use of appropriate types of vegetation by seeding or planting in areas where erosion control is needed.
- Continuing to expand the native seed harvesting of existing stands of native prairie in order to make future new seeding in the area more economical.

Ongoing program requirements include:

- budgeting
- conducting resource inventories
- establishing lines of authority
- providing employee training
- encouraging employee input
- interacting with technical experts
- reviewing and determining equipment needs
- determining how state resources are to be used
- reviewing and evaluating the program

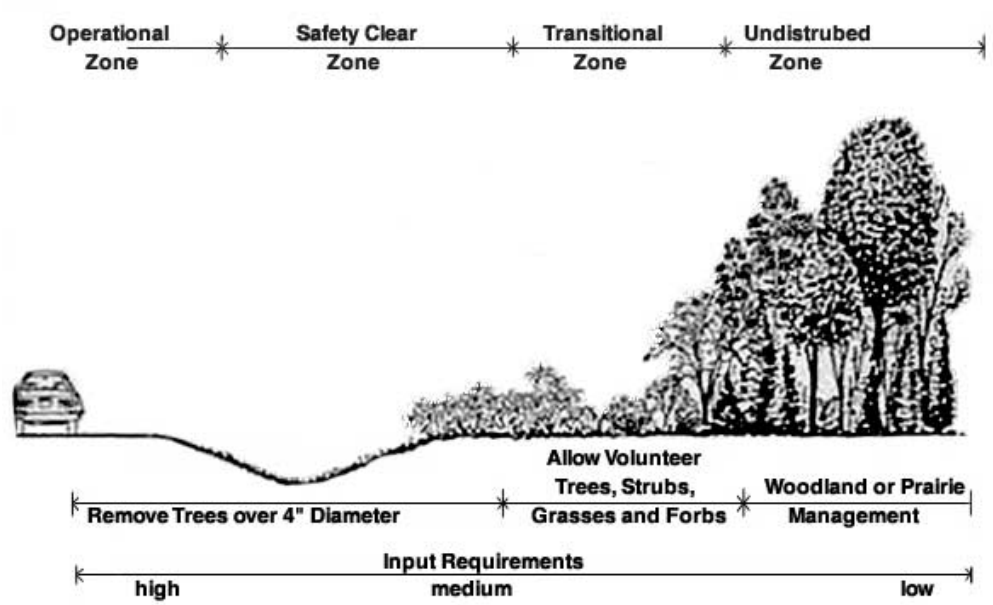


Figure 9-1. Roadway Management Zones

RESPONSIBILITY FOR THE PLAN

The plan also outlines who is responsible for the IRVM program. A core committee is identified whose responsibility is to provide direction and guidance on how the program is run. The committee comprises maintenance personnel as well as vegetation management experts. The committee is to meet yearly and develop goals for the upcoming season, as well as develop a summarized activity report for the year. In addition, the plan lists resource experts who are responsible for the various plan elements.

IMPLEMENTATION SUMMARY

Reduction of Roadside Hazards
Prior to plan implementation, there was confusion as to what constitutes a roadside hazard, especially because of the concept of reduced mowing together with the idea of leaving naturally growing vegetation on the backslopes. The plan includes specific documentation regarding clear recovery zones and sight safety corner requirements, along with a copy of indicators for vegetation height control and a speed chart for sight intersections. Roadside hazards, especially at sight corners, were always a priority for the area, but now with the appropriate uniform information for all workers, these issues are addressed much more confidently and efficiently.

Efficiently Reducing Mowing
In the first year of plan implementation, right-of-way mowing was reduced by an average of 30 percent. The policy states that areas are to be "mowed top cut only, with exceptions." Exceptions for the year included the center median of Interstate 94,which was mowed at the request of the State Patrol to improve the effectiveness of radar equipment. Other exceptions were made to provide sight distances, clear thistles and deer crossing areas, help prevent drifting snow, and improve aesthetics within some city limits. Experimenting with different rental tractor and mower setups helped identify much faster and more efficient ways to mow top cut throughout an entire area. A successful spring training and information meeting on reduced mowing was held, but more information will be provided to workers in the future. Mowing can and should be further reduced.

Reduction of Noxious Weeds with Herbicides
Maintenance workers who were licensed pesticide applicators were given the title of Intermittent Supervisor and allowed to work on vegetation management full time during the season. Since they could purchase needed herbicides and equipment, they could apply herbicides on a timely basis without interference. Meanwhile, part-time summer help was hired to fill in for those workers. In the first year of the program implementation, noxious weed spraying increased overall by 50 to 75 percent, but this was due to decreased mowing, which was previously used to control weeds. Noxious weed populations and herbicide use are both expected to drop in the future.

Burning Native Prairie Areas
Maintenance Area 3B incorporated burning into its maintenance program in order to restore native prairies and control weeds. During the first year, almost 30 acres of prairie were burned, but most of the focus of the program was on training and acquiring equipment. Significant gains were made in training; after one year, the area had a full complement of trained workers, experienced, equipped, and prepared for burning on a larger scale. Additional burns have been successfully completed since.

Implementation of a Uniform Maintenance Area Mapping System
Implementation of a mapping system is an element of the IRVM Plan for Maintenance Area 3B. To accomplish this, computer generated maps were obtained from Mn/DOT and plat books obtained from the county. The maps that were developed include established areas of noxious weed infestations, hazard trees, native seeding, and other important elements of the management plan. These maps are updated and assist in program planning, record keeping, and assessment.

Increase Areas of Native Vegetation
The IRVM Plan notes that increasing native vegetation will lead to better weed control, reduced mowing, and protection of the environment. One problem that Maintenance Area 3B encountered was the high cost and short supply of native seed. To make seed more available, it initiated a program to harvest existing stands of native seed within the maintenance area. In 1995,Mn/DOT and the DNR together harvested 400 pounds of native grass seed, which was shared between the two departments. Maintenance used the seed for 40 acres of right-of-way. In addition, a large construction project was planted with native species, from which additional seed can be harvested.

Integrated Roadside Vegetation Management Plan for Mn/DOT Metro Division
Mn/DOT's Metro Division developed its integrated roadside vegetation management (IRVM) plan as a proactive way to address roadside management and as a response to the same legislation as referenced in Maintenance Area 3B's plan. The Metro Division's plan includes the general elements that follow.

The May 2006 version of the Metro IRVM plan is available online at
http://www.dot.state.mn.us/metro/maintenance/IRVM2006.pdf

MISSION STATEMENT
We are committed to managing Metro Division roadsides to ensure the safety, well being, and enjoyment of travelers and adjacent neighbors while using cost-effective and environmentally appropriate vegetation management methods.

GOALS
In conjunction with the plan, goals for the 2006 season were identified for the following areas:

- Update color-coded IRVM maps.
- Collect data for partnership map and beetle release map
- Continue removal of Dutch Elm infected trees
- Conduct Hazard reviews of all Class I Rest Areas. Develop an inventory using GPS.
- Continue releases of biological control insects in heavily infested leafy spurge, purple loose strife and spotted nap weed areas in the Twin City Metro area.
- Monitor selected sites for progress.
- Bi-annually, conduct Training in Noxious Weed identification, Mowing and Herbicide application. Next training, 2008.
- IRVM will meet and comply with MS4 requirements.
- Get back to a reasonable level of care for the 35E Parkway after minimal maintenance.
- Remove dead stock from median area
- Apply pre-emergent to median area – Mid April
- 7th street bed filled with weeds, reshape ditch
- Continued diligence on controlling/eradicating Grecian Foxglove and giant phragmites in the Metro District.
- Plant steep slope where Canada Thistle was sprayed and we have collateral damage to the Crown Vetch. Need to plant sumac, plum, chokecherry, etc.
- Track acres and areas where sprayed.
- Cooperation between the Department of Ag in controlling infestations of invasive weeds, insects and other pests.
- Cooperation with the Department of Ag in defining herbicide materials and methods.
- ICWC crews to treat stumps of diseased elm trees.

CHARACTERIZATION OF MANAGEMENT PRACTICES
Roadsides are categorized based on management practices needed to keep them safe and aesthetically pleasing. They range from high-maintenance turf and landscaped areas requiring frequent mowing and fertilizing to low-maintenance areas where a natural or wild appearance is acceptable and desired. The three categories for the plan are the same as those identified in the plan for Maintenance Area 3B.

MAPPING/COMMUNICATION
Roadsides of each type are indicated on maps so that the public and all maintenance personnel are informed. The roadside category dictates the amount and type of maintenance performed and forms the basis for the long-term goals of each roadside type. The maps will also include current-year landscape partnership projects and programmed landscape projects, ongoing vegetation research projects, and prairie restoration projects.

IRVM PROGRAM COMPONENTS
- Mowing
- Brush mowing and cutting
- Spraying chemicals and biologicals
- Planting and interseeding
- Biological control
- Care of landscaping

- Fertilizing
- Mulching
- Hazard tree control
- Dutch elm and oak wilt control
- Washout repair
- Prescribed burning

Each operation is conducted as though it is an integral part of an overall program. By doing so, personnel performing roadside maintenance activities will be aware that there is a program in place and that they are working within an overall program. In addition, the public and others will be aware that a program with goals is in place.

IRVM GUIDELINES

Guidelines for the Metro Plan are given below. Note the similarities with the program for Maintenance Area 3B. Both groups were given similar objectives but each developed different guidelines.

1. Follow a mowing effort that allows mature vegetation height where appropriate and also addresses safety and aesthetic issues. Mow to control annual weeds and to knock down perennial weeds prior to spraying. Quality, not quantity, is the goal.
2. Use brush mowing and cutting where brush needs to be controlled and is over 6 feet in height. Mow from the edge of the shoulder to just beyond the bottom of the ditch on a four-year cycle to control brush and to reveal washouts in this zone. Contact the herbicide coordinator for follow-up herbicide treatments on brush regrowth following mowing. Control brush in accordance with Figure 9-1 (see Maintenance Area 3B).Allow naturalization of woody plants beyond the ditch line (except where the clear zone goes beyond the ditch line).
3. Follow a spot spraying effort that controls noxious weeds. Unwanted brush less than 6 feet in height may also be sprayed in accordance with Figure 9-1.
4. Work with other agencies on attempting biological control of noxious weed and insect pests in selected areas. Areas will be located on the map.
5. On an initial limited basis, work with controlled burning of native vegetation where safety and traffic permit. Where possible, use controlled burns in conjunction with adjacent burns.
6. Fertilize areas where the turf may be weak or depleted, especially in the highly maintained type 3 roadsides, such as the I-35E Parkway and the Mall of America.
7. Incorporate interseeding efforts in places where the turf is sparse and/or in weed-infested areas.
8. Identify and treat hazard trees (defective trees with a target such as people, cars, and other property)in rest areas and other roadside areas.
9. Control Dutch elm and oak wilt disease along state roadsides in communities with active control programs.
10. Integrate reforestation and prairie establishment efforts in appropriate areas.

ONGOING PROGRAM REQUIREMENTS

Like the Maintenance Area 3B Program, the Metro IRVM Plan identified several ongoing requirements that must be met to conduct a successful program. They are:

- Budgeting
- Having established line of authority
- Providing employee training
- Encouraging employee input
- Communicating
- Interacting with technical experts
- Reviewing and determining equipment needs
- Determining ratios of, type, and amount of contract work
- Reviewing and evaluating the program
- Determining how state forces are to be used

Many of the above requirements were already in place prior to the plan's development. Yearly goals were established for each of the above to ensure continuation.

STEERING COMMITTEE
A steering committee was assembled to provide input to the process and ongoing program requirements. It provides for input from employees and other agencies. At a minimum, the steering committee will be made up of six members, five from Mn/DOT and one from the Minnesota Department of Agriculture. Mn/DOT members must include management, front-line workers, and central office technical experts.

Yearly goals will be established by the steering committee based on a review of the previous year's accomplishments. The yearly goals will be established by February 15 and will form the basis for the upcoming season. Each year the steering committee will develop a report of accomplishments. This report, to be completed by January 15 of each year, will be distributed to maintenance workers as well as staff.

RESPONSIBILITY, REPORTABILITY, NETWORK OF TECHNICAL EXPERTISE
The plan assigns one person with overall responsibility for implementation. In addition, technical experts are identified to assist in plan implementation. They include representatives from Mn/DOT Environmental Services, the Minnesota Department of Agriculture, and county ag inspectors.

Visual Quality Best Management Practices for Forest Management in Minnesota
This handbook, developed in May 1994 and recently updated, is a cooperative project involving many government and industry agencies. The best management practices guidelines were designed to provide forest managers and loggers with the tools to voluntarily implement visual quality BMPs into an overall integrated resource management approach to forest management operations. The handbook is divided into the following five parts:

- Part I "Laying the Groundwork" explains the concerns and the process that led to the cooperative development of these practices.
- Part II "Visual Management Planning" describes the concept of visual management planning.
- Part III "Classifying Sensitive Visual Management Areas" outlines the factors used in determining classifications, the three classifications themselves, and the classification process.
- Part IV "Recommended Visual Quality BMPs for Forest Management" describes 11 forest management activities and offers recommendations for enhancing visual quality for each of the three sensitivity levels.
- Part V "Training, Implementation, and Monitoring" explains the factors that will determine the long-term success of this effort.

This small, spiral-bound handbook, designed for use in the field, contains many photos along with explanations of best management practices. Copies can be obtained from the MN DNR, or by going online to http://www.dnr.state.mn.us/forestry/visual_sensitivity/index.html.

Washington Dot IRVM Plans
All of the districts in the Washington state DOT have developed IRVM plans that are posted online, at http://www.wsdot.wa.gov/maintenance/vegetation/mgmt_plans.htm.

Their website states the following:

> Area maintenance crews use roadside vegetation management plans to determine the most appropriate tools, techniques and timing, for accomplishing prioritized roadside maintenance activities. These plans, once developed, become the basis of an ongoing process of refinement and crew training, using annually documented experience of each area's proven success and lessons learned. This is an open process and WSDOT encourages input at any time from the general public, its neighbors, and/or any other statewide or local interests.
>
> The plans include geographic inventories of routine maintenance activities, weed infestations, sensitive areas, and other relevant information. They also include a record-keeping system and database to document, evaluate and reference site-specific treatments, various situations and types of vegetation.
>
> Roadside vegetation management plans have been developed and implemented throughout much of the state, individual plans may be accessed from the active links below. All remaining areas will be completed

by the spring of spring of 2007. Earlier versions of area plans vary slightly in format and content. Beginning in 2007 WSDOT will institute a process whereby each area plan will be reviewed and updated on an annual basis.

Aesthetic Initiative Measurement System (AIMS) Study
Another example of an integrated approach to roadside vegetation management is the development of a tool known as the Aesthetic Initiative Measurement System (AIMS) that offers project managers and engineers an easy-to-implement method for gaining feedback from roadway users. Mn/DOT funded the project as a way to understand and document how travelers perceive the attractiveness of Minnesota's highway corridors. The study also showed how travelers prioritize many roadside features.

The results of this research project may assist designers in understanding public preferences. For the first part of this project, researchers developed a method for collecting data, and then they trained facilitators to use the method. After that, the facilitators and a total of 63 Minnesota citizens who volunteered to participate in the research took to the road. The volunteers split into three groups. Each group traveled in vans along one of three selected routes in Rochester, the Twin Cities, and Duluth.

While driving the routes, facilitators asked the volunteers to call out any views along the way that attracted their attention. They assigned a "view note" number and a corresponding mileage location. At regular intervals, facilitators stopped and encouraged discussion about each recorded view, asking the participants who noted the view what made it attractive or unattractive and asking others to comment and rate the view's attractiveness.

As part of the project, researchers also trained Mn/DOT staff on the use of the tool. "We wanted to look at the corridor from the customer's perspective," says David Larson from the Office of Environmental Services who provided technical guidance to the project. "The AIMS tool offers an efficient way to learn what the public thinks and values along Minnesota highways. Such information up front makes it easier–and ultimately more cost-effective–to determine ways to meet customer needs."

What researchers learned from the tool's testing and implementation also offers useful information to transportation project managers and engineers. Volunteers who participated in the project indicated the following priorities for roadside elements:

Good Maintenance
Participants saw good maintenance as important in attractive landscapes as well as less attractive landscapes. While maintenance alone does not create the perception of an attractive landscape, poor maintenance can make an otherwise attractive landscape look less attractive, and good maintenance can add value to a landscape that might otherwise be ordinary or unattractive.

Perception of Nature
Viewers mentioned "wildlife, green, environmental, natural" to explain what they thought made a very attractive landscape.

Good Design Elements
Good design elements within the right-of-way accounted for much of what viewers rated as attractive in the entire range of landscape attractiveness. Elements noted by the participants included planting design and design of architectural details, such as railings, walls, and bridge materials. Good design also created attractive aspects of less attractive landscapes.

Good Highway Design within an Attractive Landscape Context
Overall, the study found that the most attractive aspects of the highway experience related to highway design that took advantage of vistas and emphasized the natural features of the surrounding landscape, such as ecology, hills, and forests.

In *Perceptions of the View from the Road. AIMS II: A Statewide Web Survey*, J. Nassauer, E. Dayrell, and Z. Wang (2006) of the University of Michigan have provided some key findings that can be summarized as follows (Daniel

Gullickson, personal communication). These findings are based on surveying over 1,000 Minnesota licensed drivers and reflect what is perceived as being safe, attractive and natural.

1. "While an entirely mown turf right-of-way without any other planting is seen as unattractive and unnatural everywhere, and brome grass without any other planting is seen as unattractive and unnatural in urban settings, virtually all other planting designs have positive effect on public perception. This suggests that mowing the entire right-of-way for aesthetic reasons is unnecessary."

2. "Overall, the mowing treatment that was most preferred in both rural and urban contexts was a single mown swath along the roadway. While a curved mowing pattern was preferred over an entirely mown right-of-way, it was less preferred than a single, straight mown swath in nearly every setting. This suggests that the least cost mowing alternative has the greatest aesthetic benefit."

3. "Prairie flower vegetation is the only vegetation treatment that has a powerful positive effect on attractiveness, naturalness, maintenance, and safety in all contexts. This suggests that the prairie flower roadside plantings could be widely used for predictably positive aesthetic effects."

4. "Consider widely adopting a flowery mix of native herbaceous plants or a dense naturalized mixed species woodland. Both are perceived as very attractive and very natural in many landscape contexts. The flowery mix of native herbaceous plants also tends to be perceived as well-maintained and safe. Both vegetation compositions would probably be relatively inexpensive to maintain once they were established, and they would be likely to provide greater biodiversity benefits than other compositions."

5. "Avoid using only mown turf or only brome grass with no other vegetation in the right-of-way. Both tend to be perceived as unattractive in any setting."

6. "Consider adopting mowing regimes that limit mowing to a single swath along the roadside. This pattern is generally perceived as most attractive and natural, and as well as adequately maintained and safe. It also would seem to require less fuel and staff time to implement compared to other, less attractive alternatives."

AIMS offers a tool that transportation project managers and engineers can use to achieve valid results. “From the research, we know we can replicate the process in a consistent way that produces reliable information,” says Larson. AIMS also fits well with Mn/DOT’s commitment to context sensitive design practices, which strives to integrate projects into the context or setting through careful planning, consideration of different perspectives, and tailoring designs to project circumstances. Mn/DOT will use this tool in training initiatives and bring it to design engineers and other professionals for consideration.

Research reports offer more detail about the project. To receive a copy, contact Mn/DOT’s Office of Research Services at 651/366-3780 and ask for Report #2001-04. For information about the project or to talk about training opportunities, contact David Larson at 651/366-4637, or david.larson@dot.state.mn.us.

BMP #2: DEVELOP A PUBLIC RELATIONS PLAN

Figure 9-2 gives an example of a letter Wright County staff sent to all adjacent property owners to indicate that work would be done near their property. Property owners are allowed the option of maintaining the right-of-way between their land and the roadway, but must indicate to the county that they are choosing to do so. They must sign a notice stating their choice and post signs telling the maintenance crews not to spray. If property owners do not eliminate noxious weeds by the date indicated on the form, the county will remove the weeds without the property owner's consent. Figure 9-3 gives an example of the statement property owners must sign.

Mn/DOT District I Plan for North Shore Drive

The T.H. 61 Vegetation Management plan was developed in response to public concerns after Mn/DOT and a utility company cooperatively cleared the roadside tree and shrub community between the highway and the utility corridor during the winter of 2007. Local citizens demanded Mn/DOT treat future vegetation management efforts with greater sensitivity. The plan serves as an excellent example of addressing public concerns along this unique corridor which is one of only a handful of roads with two national designations: "All American Road" and "National Scenic Byway."

The plan was reviewed by the North Shore Scenic Drive Council, Lake County Board and Cook County Board prior to implementation. It identifies the types of vegetation control work that will be performed by Mn/DOT field personnel, and also outlines items that need special consideration due to the scenic nature of the corridor, adjacent landowner concerns and environmental concerns. The plan also describes the public involvement process to be followed before major roadside vegetation management work begins.

The vegetation management plan was to serve as a guide for the Mn/DOT maintenance field personnel for managing with vegetation issues along the T.H. 61 Corridor from Duluth to the International Border Crossing at Pigeon River. It addresses work supervised by Mn/DOT field maintenance personnel either as work performed by Mn/DOT employees or by contractors, and included mowing, herbicide application, brush and tree removal.

As an example, the plan uses vegetation control guidelines outlined in the Mn/DOT Maintenance Manual. It covers specific practices for mowing, weed control, and brush and tree removal as shown below:

> Mowing
> Mn/DOT mowing policies and practices will be followed as noted in the Mn/DOT Maintenance Manual. Mowing beyond the top cut is not always possible on this corridor due to terrain.
>
> Weed Control
> Weed control will be performed in accordance with practices described in the Mn/DOT Maintenance Manual.
>
> Brush and Tree Removal
> Brush and tree removal will be performed to remove hazard trees on the right of way, maintain clear zone at least to the ditch bottom in areas with steep inslopes, maintain sight corners, reduce shading of the roadway and maintain scenic vistas of Lake Superior. Priority will be given to safety related clearing. There are also clearing activities on Mn/DOT right of way that are permitted to adjacent landowners and utility companies that are legally allowed to use the highway right of way for their infrastructure. These clearing activities are related to overhead power line and telephone line clearing and clearing for visibility of on-site advertising.

The plan states that mowing, weed control, removal of hazard trees, maintenance of sight corners and clear zone are considered the highest priority work along the corridor. Vegetation removal to reduce shading may also be high priority work based on accident analysis to determine locations where shading has affected winter related traffic accidents. Maintenance of scenic vistas would be a lower priority for use of Mn/DOT's maintenance funds.

And, special considerations were outlined. The plan noted the following:

- The environment along this corridor is considered scenic and unique. There are several plant species that are rare and unique to this corridor, steps must be taken to identity and avoid impacts to rare and unique plant species.
- There are special considerations that need to be made for landowners along the corridor.
- The scenic nature of the drive must be considered when tree clearing and brushing operations are undertaken.
- Most importantly, the public must be informed as to our planned work prior to implementing.

The plan also outlines expectations for public involvement through the corridor. It states that mowing and weed control are annual routine maintenance activities that should be expected along the highway right of way. No public notification will be made prior to undertaking this type of work. The plan also states that hazard tree removal can also be expected along the corridor in spot locations. Efforts should be made to contact adjacent landowners prior to undertaking this work.

Maintenance of sight corners, maintenance of clear zone and removal of vegetation to reduce shading that result in brush and tree removal are likely subject of higher public scrutiny. Prior to undertaking work of this nature, some effort of public notice should be made in the form of newspaper ads or press releases. The notification should include indicating the reasons for the brush and tree removal, location, timeframe and contact information for the maintenance supervisor for citizens to provide input. All input should be addressed prior to performing this work. Additionally, the plan indicates that contacts should be made with affected adjacent landowners. The planned removal limits should be marked with ribbon prior to making public notice.

Permits that allow brush and tree removal for utility corridor maintenance or advertising device visibility should also contain requirements for the public notice process identified above.

Beginning in May, the Wright County Highway Department, as part of its vegetation management program, will be scheduling some roadside vegetation work along all Wright County Highways. The unwanted brush will be cut and/or treated with herbicide. We're notifying you about this work since your land may be adjacent to the roadside scheduled for treatment.

Our goals are to eliminate the brush and to promote grass cover along the roadside. Brush along the road reduces driving visibility, obstructs road signs and reduces driver reaction time to crossing wildlife. Brush presents maintenance problems by retaining water along the roadbed, obstructing ditches and damaging equipment.

To meet these goals, we use selective herbicides that control the brush and noxious weeds but allow the grasses to grow, unharmed. All herbicides we use have been fully tested and are approved by the US Environmental Protection Agency and the Minnesota Department of Agriculture.

During the spraying operation, we'll take care to avoid sensitive areas adjacent to the right-of-way such as tree plantations, ornamental plantings, crops, gardens, front yards, lakes and streams.

If you would like to maintain the right-of-way adjacent to your land in some other fashion, such as mowing, please follow these instructions:

1. Stop by (prior to May 1, 1999) at the Wright County Public Works Building (located along State Highway 25 at the Jct. Of CR. 138 on the north side of Buffalo) and fill out the proper form including the property description.
2. Post the "DO NOT SPRAY" signs that you will be given.
3. Remove the brush and/or noxious weeds within that site by May 15, and continue to maintain it. If the brush and/or noxious weeds are not removed, then we must treat the area as part of our vegetation management program.

If you have any questions please call the Wright County Highway Dept. at 1-800-362-3667, extension 7383 or 682-7383.

Figure 9-2. Example of a Letter to Property Owners from Wright County Highway Department

SPRAYING FORM

I _____ being the owner or occupant of the following described land do hereby state that I do not wish to have weed or brush spraying done adjacent to my property on Wright County Highway number _____ and I further agree that I will control the weeds and brush along this area of road right-of-way prior to May 15, 1999.

I understand that if the weeds/brush are not cut or sprayed by this date that the County will spray these areas, even if the signs are in place.

Property Description: _____
(address) _____

Township: _____

_____
Owner/Occupant Signature

_____
Highway Dept. Witness

Figure 9-3. Example of a Spraying Form used by Wright County Highway Department

The Mn/DOT web site also contains a sample news release for communicating with adjacent landowners.

News Release

April 3, 2006

Farmers are reminded that a permit is required for mowing and haying on state right-of-way

ST. CLOUD, Minn. - The Minnesota Department of Transportation reminds farmers that mowing and haying is only allowable by permit on state highway right-of-way.

Mn/DOT mows primarily for safety reasons. Safety reasons include shoulder and median mowing. Permit locations for mowing and putting up hay are on a first come, first serve basis. A $100 deposit is required when applying for a permit, which will be returned to the applicant after work completed meets permit requirements.

Obtaining a permit is required, according to Mark Renn, Road Regulations. Mowing is prohibited in wildflower areas as well as those harboring noxious weeds, such as leafy spurge, which spreads rapidly when cut.

More information on mowing and haying permits may be obtained by contacting
Mark Renn, Road Regulations, St. Cloud, at (320) 255-4176; or Ken Larson, Road Regulations, Baxter, at (218) 828-2469.

For updated statewide traffic, construction, weather, and travel information visit www.511mn.org.

In Work Zones: Pay Attention or Pay the Price.

Author's Note: Do not issue a permit for mowing before August 1st if an agency owns the right-of-way in fee.

BMP #3: DEVELOP A MOWING POLICY AND IMPROVED PROCEDURES

Nebraska Department of Roads
The Nebraska Department of Roads' mowing policy states that limited mowing frees workers to do more important maintenance. They recognize the benefits of allowing vegetation along the roadside to grow tall, since it provides a home for animals and serves as a living snow fence.

Nebraska's policy allows for mowing only those slopes less than 3:1. Areas with slopes greater than 3:1 are marked with a sign, and all mowers have built in slope indicators to provide additional information. Mowing steeper slopes is not safe. Also, the state mows to a minimum of 5-inch cut height. Its first mowing is by Memorial Day. The width of the mowed area depends on the type of highway, whether the area is a median or shoulder, and whether or not decorative flowers are present.

Type of Highway	Area	Mow width
Interstate	Median	5-8' if flowers present 5-15' if no flowers present
	Outside	15' maximum
Other highways	Outside	5-15' w/surfaced shoulders 15' w/turfed shoulders

Nebraska performs a second mowing sometime during the summer to provide sight distance. The final mowing is done after Labor Day, as needed to provide snow control and to finish total mowing. Nebraska does not use

mowing to control brush, which is controlled with chemical application. To ensure that agencies have an equal understanding of its mowing policy, the Nebraska Department of Roads issued a memo of understanding with the state game and parks commission. This memo specifies frequency of mowing, mowing widths, and safety standards.

Wisconsin Department of Transportation
The Wisconsin Department of Transportation's policy is to maintain a clear zone, free of woody vegetation within 25-30 feet of the roadway edge. Mowing in the clear zone beyond the shoulder cut is permitted every two to three years, and is only allowed from mid-July to the end of March to allow nesting birds to hatch. The grass is mowed to a minimum height of 6 inches and a width of 15 feet on the outside of the road and 5 feet on the inside. For safety reasons, no mowing is allowed where the slope is greater than 3:1.Mowing is allowed in the first few years after construction to control weeds.

This policy has resulted in:

- More attractive roadsides
- Clear vision at intersections
- Safe pull-off areas
- Clear recovery zones
- Lower maintenance costs
- Smooth visual transition from roadway to vegetation beyond
- Preserved native vegetation
- Natural regrowth
- Improved wildlife habitat

Mn/DOT Metro District Mowing Policy
The Metro Area mows with an emphasis on quality, not quantity, and follows these principles:

MOWING FOR SAFETY

- Sight corners at same grade intersections of township, county, and state highways.
  Vegetation that obstructs the vision above a 30-inch sight line to crossing traffic should be mowed or cut within the boundaries of the right-of-way markers.
- Sight lines at interchange entrance ramps.
  Vegetation that obstructs the vision above a 30-inch sight line to mainline traffic should be mowed out within 300 feet of where the mainline and the merging lane join.
- One-to two-swath perimeter mowing.
  Vegetation not to exceed 18 inches, and optimally 12 inches.

MOWING FOR NOXIOUS WEED CONTROL

- Mow heavily infested thistle patches over 50 square feet before the plants go to seed. Minimize scattered mowing patterns.
- Communication between mower operators and Mn/DOT or contract herbicide applicators is extremely important to prevent mowing right after spraying or mowing out areas to be sprayed in the future.
- Do not mow leafy spurge.

AESTHETIC CONSIDERATIONS WHEN MOWING

- Make attractive flowing mow lines that blend with features such as guardrails, delineator posts, traffic signs, light standards, retaining walls, etc.
- When a one-to two-swath cut results in mowing out over half the width of a narrow right- of-way strip, mow the entire strip to the retaining wall, noise wall, or other feature.
- Mow to the break in the slope on fill slopes even if it means mowing less than the capacity of the mower. It may even take mowing one instead of two swaths.
- When mowing out noxious weed paths, drive to the patch with the mower off and raised up unless a blending cut makes sense off the one-to two-swath cut.
- Conduct fall mowing/cleanup mowing before winter.

The Posi-Track offers excellent mobility for mowing and brush control.

BMP #4: ESTABLISH SUSTAINABLE VEGETATION

Use of Native Grasses

WRIGHT COUNTY PILOT HARVEST PROJECT
Wright County instituted a pilot project to harvest seed from stands of native grasses in county parklands. Partnering with the Minnesota Department of Transportation, the county used Mn/DOT's equipment to harvest the seed, then returned half of the seed harvested to Mn/DOT. After seed has been harvested, it is sifted manually and prepared for storage and later use.

IOWA NATIVE GRASS SEED HARVESTING
Some Iowa counties plant locally harvested seed in nursery plots, establishing a seed source for future years.

TH56–MOWER COUNTY NATIVE GRASS STANDS
Trunk Highway 56 in Mower County runs parallel to an abandoned railroad line and contains prairie remnants that have not been disturbed since the railroad was built. Mn/DOT determined that this site was important for the preservation of prairie grasses and added the right-of way from LeRoy to about two miles northwest of Rose Creek to the Mn/DNR Natural Heritage Registry in 1982.Mn/DOT also developed a resource management plan for the site, based on a plan initiated by Kathy Bolin, then employed by Mn/DOT. The plan incorporated planned burning on TH56.

Prairie Restoration Project on Interstate 90

PRESCRIBED BURNS FOR NATIVE GRASS MANAGEMENT IN SHERBURNE NATIONAL WILDLIFE REFUGE

Sherburne National Wildlife Refuge conducts a series of prescribed burns every year as part of its habitat management program. Refuge staff trained and certified in fire fighting conducts these burns, but local fire departments, law enforcement agencies, and state natural resource offices are informed of the burn and remain on stand-by.

The prescribed burn is a managed fire conducted under a special set of guidelines for weather and safety. Most burning is done in April and May, but can also be done in the fall, on days when conditions meet the required set of guidelines. Factors considered are humidity level, wind speed, and wind direction.

Every year, several areas on the refuge are selected for burning. Each unit is bordered by plowed breaks, waterways, or roads that allow the fire to be contained. In 1998, 12,281 acres were burned during four burn days. The burn area is ignited by hand using a drip torch, and refuge fire engines with trained firefighters are on-site to ensure that the fire remains under control.

Burning helps restore and maintain many plant habitats by removing dry, dead plant matter that has built up over the years, opening up space for new plant growth and providing better cover and food for wildlife. The burn allows nutrients locked-up in dried plants to be returned to the soil for use by new plants. Burning also enables the restoration of the ecosystem that existed in the area prior to European settlement. The plans and wildlife are adapted to fire and depend on periodic burning for their continued existence. Their deep root system allows them to resprout quickly after a fire passes.

Use of the Right Plants in the Right Areas

MN/DOT INTERACTIVE PROGRAMS

A challenging element of roadway design and maintenance is selecting the appropriate vegetation to plant in the project right-of-way. The wrong selection can lead to expensive removal and replacement of dead plants. Mn/DOT's Office of Environmental Services has recognized the need to provide assistance in making these selections and has developed an excellent tool in response, an interactive, easy-to-use program titled *Woody & Herbaceous Plants for Minnesota Landscapes & Roadsides.* Its purpose is to improve the quality of roadside plant selection and management in Minnesota by offering expert assistance in selection, thereby increasing the likelihood that plants will be placed in locations and under conditions in which they are likely to survive, if not flourish.

For a given area, the user is provided a list of existing growing conditions. The program then quickly and accurately determines the most appropriate plant(s), based on the location, site conditions, and expected functions for landscape design, restoration, and management. This program has been used by district maintenance staff, external agency staff, consultants, and community landscaping professionals to select appropriate herbaceous grasses, sedges, ferns, perennial flowers, trees, shrubs, groundcovers, and vines for any combinations of desired characteristics and existing site conditions. It is totally comprehensive and applicable for all vegetation types and conditions applicable to transportation and general landscape development, restoration, and management in Minnesota. This program can be easily downloaded on line at http://plantselector.dot.state.mn.us/Description1.html. Mn/DOT is updating and enhancing the capabilities of the program. The project will be completed in 2008.

Salt Alleviation

Salt accumulation along roadsides attracts deer who lick the soil. To alleviate the accumulation of salt in the soil, Dwayne Stenlund of Mn/DOT Office of Environmental Services suggests placing a 2-inch layer of leaf and grass compost in a 2-6 foot strip adjacent to the roadway shoulder edge. The compost can be spread with a manure spreader equipped with side discharge.

This treatment enhances the roadside in two ways:

1. It reduces the salt accumulation that attracts deer, thereby reducing the number of deer present.
2. It enhances the growing environment for the vegetation along the shoulder.

Additional information can be obtained by contacting Dwayne at Dwayne.Stenlund@dot.state.mn.us.

Erosion Control and Use of Roadsides by ATVs
The use of the roadsides by ATVs can significantly increase erosion and drainage problems. Note that ATVs may not be operated within the right-of-way (ditch) of a state or county road from April 1st to August 1st in Minnesota's agricultural zone. This does not apply to Class 1 ATVs registered and used exclusively for agricultural purposes. Class 2 ATVs cannot be operated on ditches ever.

The MN Agricultural zone is the area lying south and west of a line of a line formed by the following rights of way: starting at the North Dakota border, the line goes east along state highway 10 to state highway 25, then follows highway 23 east to state highway 95 to the Wisconsin border. The agricultural zone does not include the rights-of-way of these boundary highways, and applies only to class 1 ATV use.

Effective ways to deal with ATV damage are listed below:

1. Develop a collaborative relationship and work with local ATV clubs to reduce damage, and to encourage them to maintain the trails, and repair any damage caused by their use.
2. Increase enforcement during April 1st and August 1st for areas in the Agricultural zone described above. Work with your local Sheriff and law enforcement.
3. The DNR Trails and Waterways Office can assist with damage caused by ATV and Off Highway Vehicle damage. To make a claim, the damage must be caused by the unpermitted use of off-highway vehicles, the damage must have happened after August 1, 2003, and reasonable efforts must be taken to identify the responsible party and obtain payment from that individual. In addition, reasonable efforts must be made to prevent the reoccurrence of damage. The DNR requires supporting documentation for each condition. The claim form is available online at http://files.dnr.state.mn.us/assistance/grants/ohvdamage/claimform.pdf.

BMP #5: CONTROL NOXIOUS WEEDS

Cultural Control
Many agencies are using native grasses to control noxious weeds, since their dense, deep root systems inhibit weed growth. Both Wright County and Mn/DOT Maintenance Area 3B have found success in controlling noxious weeds, specifically Canada thistle, using native grass stands.

Biological Control
The Mn/DOT Office of Environmental Services and participating Mn/DOT Districts use beetles to control noxious weeds, such as leafy spurge, in several Districts around the state. Beetle use can also effectively control purple loosestrife. For example, in June 1993, two beetle species were released at a site in southern Ontario that was covered with purple loosestrife. Over the last ten years, the insect populations there have exploded, completely suppressing seed output and reducing the purple loosestrife infestation by over 90 percent, while native plants such as cattails were flourishing. Purple loosestrife is severely damaged through the entire area, and beetles have spread for miles from the site. The reductions in purple loosestrife over large areas and the return of native cattails show the potential of biological weed control as a management tool.

Since this manual was originally published, significant advances have been made in the biological control of weeds. According to the DNR website, nearly one million insects were released in Minnesota last summer to devour purple loosestrife. During the summer and fall, the DNR and the University of Minnesota (U of M) helped agricultural inspectors in 30 counties, and the Minnesota Department of Agriculture (MDA) field staff raise leaf-eating beetles that prey on purple loosestrife. That specific weed infests wetlands and lakeshores. Using insect-rearing starter kits, each county agent raised 20,000 to 40,000 beetles and released them at infestations within their own county. By putting insect-rearing kits into the hands of county agents, the DNR hopes to significantly increase the number of loosestrife bugs released. Since 1992, DNR and U of M staff members have raised and released 300,000 beetles at 80 infestation sites across the state.

The Biological Control Laboratory at the University of Guelph in southern Ontario conducted another biocontrol study. In 1993, two thousand loosestrife-eating bugs were released at a large wetland infested with loosestrife. Over the next three years, the insect numbers dramatically increased, while the loosestrife biomass was reduced by more than 90 percent. According to Jim Corrigon, a research scientist at the laboratory, the insects moved

elsewhere once they ran out of loosestrife. "Their response to a lack of loosestrife isn't to chew on something else, but to find more loosestrife," he says. If the loosestrife returns, so do the bugs.

Although the Ontario experiment may actually exceed the Minnesota DNR's expectations for the beetles in Minnesota, they have seen great results here as well. Other experiments have shown that it takes five to seven years before enough insects exist in a site to significantly reduce the abundance of loosestrife. And it may take more than 20 years before enough insects are released and then reproduce in the wild to take a significant bite out of the state's purple loosestrife population.

For more information on this project, contact:

Luke Skinner
Coordinator, Purple Loosestrife Program
Minnesota DNR
DNR Building Box 25
500 Lafayette Road
St. Paul, MN 55155-4025
Phone:651-259-5140
E-mail: luke.skinnner@dnr.state.mn.us

The U.S. Department of Agriculture (USDA) has a similar program to eliminate spotted knapweed infestations through the release of beetles. Twelve beneficial insect species from Europe have been cleared by the USDA for release in the United States, and most of them attack both species of knapweed. The insects work together by feeding on the seeds or in the roots of the weeds. Each attack reduces the knapweeds' defenses by inhibiting seed production, either from direct destruction of seeds or by stunting overall growth and strength of the plant. In some cases, when the insect larvae burrow into the root, they allow naturally occurring soil components such as fungi and bacteria to enter the plant's system, further weakening the plant. For more information, contact your local ag inspector or Tina Markeson at the Mn/DOT Office of Environmental Services.

Spot Spraying Techniques

Herbicides may be applied more effectively through better use of equipment and by spot spraying only the weeds. Using the best products at the right time ensures optimal chemical efficiency.

Appendix D contains information about correct timing for herbicide applications. The figures below show the correct timing for control of one noxious weed, Canada thistle. Figure 9-4 shows Canada thistle just after mowing. After mowing, it is best to wait for at least 6" of new growth to appear before spraying with herbicides. Figure 9-5 shows another time to spray Canada thistle, which is just prior to seed release. This is the worst time to mow, as mowing will aid in seed distribution. Figure 9-6 shows Canada thistle after it has been sprayed.

Figure 9-4. Canada Thistle After Mowing and the Emergence of a Minimum of 6" of Regrowth. Fall Spraying is Best In Order to Capitalize On Movement of Energy from Growing Tips to the Root System.

Figure 9-5. Canada Thistle Just Prior to Seed Release When Reserves in the Weed Are Low.

It is also important to maintain adequate distance between desirable and undesirable vegetation. Figure 9-7 shows spraying too close to the vines on the fence. This killed the vines as well as the targeted weeds. Adequate distance depends on wind, herbicide used, and other conditions Note that some vegetation, such as milkweed, is desirable and should not be sprayed. Since milkweed is often mistaken for an undesirable weed, refer to Figure 9-8 for help in identifying this plant.

Use of Cooperative Weed Management Areas

As noted in chapter 4 of this manual, Cooperative Weed Management Areas can also be used to successfully battle weed infestations. The Northwoods Cooperative Weed Management Area (NCWMA) is a cooperative relationship for effective management, coordination and implementation of invasive terrestrial and aquatic plant species in northern Wisconsin. As noted earlier, invasive non-native plants can have devastating impacts on native plant communities, fish and wildlife habitat, agricultural yields, recreational and subsistence opportunities, and ultimately, local economies.

Because these plants disperse widely across the landscape and administrative boundaries, it is advantageous to work cooperatively towards management and control objectives. In addition, the number of new exotics being introduced into local ecosystems continues to out-pace control activities, and is too much for any one agency to manage alone.

Figure 9-6. Canada Thistle after Spraying

Figure 9-7. Spraying too Close Killed Vines on Fence - Soil active herbicides can kill desirable plants containing roots in the treated zone.

Figure 9-8. Milkweed is Desirable - along roadsides and should not be sprayed. The presence of Milkweed plants are absolutely necessary for Monarch butterflies to live in an area.

The Northwoods Cooperative Weed Management Area provides a forum to share information, collaborate on planning and cooperate on management activities in northern Wisconsin. Many best practices are outlined on the Northwoods CWMA web site at www.northwoodscwma.org.

With funding from the Pulling Together Initiative and the National Fish and Wildlife Foundation (a consortium of funding from six federal agencies), Clay county started the first CWMA in Minnesota in 2005. Becker county followed suit in 2007 using the same funding sources..

In Spring, 2008, the BWSR awarded grants to 19 counties through funding from the Minnesota Legislature. For a complete listing of the grants and amounts, go to: www.bwsr.state.mn.us/grantscostshare/cwma2008.xls.

For more information, please contact:
Leah Gibala
Bad River Band of Lake Superior Chippewa
Odanah, WI
(715) 682-7123
wetlands@badriver.com

For more information, please contact:
Dan Shaw
Vegetation Specialist/Landscape Ecologist
Minnesota Board of Water and Soil Resources
520 Lafayette Road North
St. Paul, MN 55155
Phone: (651) 296-3767
Online:www.bwsr.state.mn.us/

BMP #6: MANAGE LIVING SNOW FENCES

Use in Minnesota

In Minnesota, living snow fences have been used since the 1930s, when Mn/DOT planted 12 million trees and shrubs along 600 miles of highway to control snow (Figure 9-9). These rows of trees were installed 75 feet from the highway centerline, which has since been proven too close, actually making the problem worse. In the winter of 1996-1997, Mn/DOT hired an international snow-control consultant to review 18 problem drifting areas in the southern part of the state. Based on estimates of snow transport during an average winter and maximizing the benefit/cost ratio, the consultant concluded that a 10-foot tall fence is required to provide adequate storage over an average winter. Using more conservative guidelines, a 12-foot fence would provide sufficient capacity 95 years out of 100.

Figure 9-9. Snow Drift on Rural Roadways can be Dangerous

BMP #7: USE INTEGRATED CONSTRUCTION AND MAINTENANCE PRACTICES

Contract Enforcement

One way to enforce the requirements of the seeding contract is to withhold funds for an incomplete grading operation on a per acre level. Mn/DOT allows for funds to be withheld from the contract when grading and turf establishment requirements are not met.

Specifications

Another way to ensure that trees, brush, flowers, and grasses are not damaged during construction is to enforce the requirements of Specification 2572, Protection and Restoration of Vegetation. This specification promotes the protection and preservation of vegetation from damage and the use of corrective action when damage does occur (Figure 9-10). Vegetation includes, but it not limited to, trees, brush, roots, woody vines, and perennial forbs and grasses.

Elements of section 2572.3

Figure 9-10. Scarifying the Soil - during construction significantly improves the chances of any vegetation establishment.

CONSTRUCTION REQUIREMENTS:

A. Protecting and Preserving

The Contractor shall protect and preserve:
(1) Specimen trees.
(2) Threatened and endangered plants, as listed on the federal and state threatened and endangered species list.
(3) Vegetation designated in the Contract to be preserved.
(4) Trees, brush, and natural scenic elements within the right-of-way and outside the actual limits of clearing and grubbing consistent with section 2101.3.
(5) Other vegetation the Engineer identifies for protection and preservation.

The Contractor shall not place temporary structures, store material, or conduct unnecessary construction activities within a distance of 25 feet outside of the dripline of trees designated to be preserved without approval from the Engineer.

The Contractor shall not place temporary structures or store material (including common borrow and topsoil) outside of the construction limits in areas designated in the Contract to be preserved.

A1 Temporary Fence

The Contractor shall place temporary fences to protect vegetation before starting construction (Figures 9-11 and 9-12). The Contractor shall place temporary fence at the construction limits and at other locations adjacent to vegetation designated to be preserved when specified in the Contract, directed by the Engineer, or allowed by the Engineer. The Contractor shall not remove the fence until all work is completed or until removal is allowed by the Engineer. The fence shall prevent traffic movement and the placement of temporary facilities, equipment, stockpiles, and supplies from harming the vegetation.

Figure 9-11. Using Temporary Tree Protection Fencing or Silt Fence - keeps equipment and construction activities off the tree root systems and trunks.

A2 Clean Root Cutting

The Contractor shall cleanly cut all tree roots at the construction limits when specified in the Contract or directed by the Engineer. The Contractor shall immediately and cleanly cut damaged and exposed roots of trees designated for protection back to sound healthy tissue and shall immediately place topsoil over the exposed roots. The Contractor shall limit cutting to a minimum depth necessary for construction and shall use a vibratory plow or other approved root cutter prior to excavation. The Contractor shall immediately cover root ends that are exposed by excavation activities to within 6 inches of topsoil as measured outward from root ends.

A3 Destroyed or Disfigured Vegetation

If the Contractor destroys or disfigures vegetation designated to be preserved, the Contractor shall, at no expense to the Department, restore the damaged vegetation to a condition equal to what existed before the damage was done. The Engineer may assess damages against the Contractor on vegetation where an equal level of restoration is not accomplished. The Engineer will assess damages to trees and landscaping at not less than the appraisal damages as

determined by the International Society of Arboriculture appraisal guide. The Engineer will determine and assess damages to other vegetation.

A4 Other Vegetation Protection Measures

The Contractor shall provide other vegetation protection measures, including root system bridging, compaction reduction, aeration, and retaining walls, as specified in the Contract or as directed by the Engineer.

Figure 9-12. Protecting Trees during Construction

Appendix A: Survey Methodology and Results

SURVEY METHODOLOGY

As part of this study, three surveys were distributed to a variety of audiences. The first survey, sent to all cities with populations over 5,000 and all counties in Minnesota, consisted of a short questionnaire asking recipients to provide general program information and to rate their agency's roadside vegetation program. Those who indicated that they had some sort of roadside vegetation management program in place were sent a second, more detailed survey. This second survey was also given to state agencies in Wisconsin, Nebraska, North Dakota, South Dakota, and Iowa, as well as to people attending a maintenance workshop sponsored by the Minnesota Technology Transfer/Local Technical Assistance Program (T2/LTAP). The third survey was distributed to attendees of the Vegetation Management Association of Minnesota conference in July of 1998.

FIRST SURVEY

The first survey consisted of a brief questionnaire requesting general information about the roadside vegetation management program in each jurisdiction. The survey attempted to identify those cities and counties that have developed formal roadside vegetation management programs or that are working to create best management practices for managing their roadsides.

Respondents were asked to indicate areas of interest relating to roadside vegetation management. The questionnaire also asked respondents for information about new seeding methods (seed application and staged seeding, seed certification and interseeding, native seed harvesting), pesticide use, mowing operations, and equipment.

This first survey was sent to 200 agency engineers, and 49 (24.5 percent) responded. Respondents were first asked to rate the roadside vegetation management plan for their jurisdiction on a scale of 1 to 5, with 1 the lowest, indicating that they have no management plan, and 5 the highest, indicating that their plan is totally integrated. **The survey results indicated that most agencies do not have a formal roadside vegetation management plan.**

Respondents gave a variety of brief descriptions for the roadside vegetation management plan for their jurisdiction, some of which are summarized below. Several agencies have a formal or informal rotation system in place to mow or spray a given portion of their area each year. Most agencies concentrate their efforts on mowing (either all or designated portions of their roadsides), noxious weed control, and brush control. Noxious weeds and brush are controlled most often by spraying. A few respondents indicated that they were beginning to use native grasses and wildflowers.

Respondents noted the following as areas of interest in plan development:

- economic factors, including maintenance costs
- planting sustainable vegetation
- the use of native grasses
- the use of seeds and trees adapted to roadside soils
- protection and better use of topsoil
- construction issues relating to erosion control and monitoring of topsoil

The questionnaire also requested information about new seeding methods, including seed application and staged seeding, seed certification, and interseeding and native seed harvesting. Information on the use of pesticides, mowing operations, and equipment was also requested. Those cities and counties responding that they are implementing some element of roadside vegetation management were asked to identify a contact person for their jurisdiction. A more detailed survey was then sent to that person, asking for much more relevant information. Survey responses are listed below.

Survey Responses

Surveys were sent to 200 agency engineers; 49 (24.5 percent) responded.

1. Please rate the roadside vegetation management plan for your jurisdiction, with 1 being the lowest rating, indicating that you have no management plan, and 5 being the highest rating, indicating that your plan is totally integrated.

Rating:

no rating: 3 (6.2 percent)
1: 9 (18.3 percent)
2: 12 (24.5 percent)
3: 17 (34.7 percent)
4: 6 (12.2 percent)
5: 2 (4.0 percent)

2. Briefly describe the roadside vegetation management plan for your jurisdiction.

Examples of roadside vegetation program activities identified by the first survey respondents:

Mowing

- "At present, we make two shoulder cuts and full ditch cuts on one-quarter of the county right-of-way. We spot spray various weeds, and saw cut brush that gets too large for the mowers to remove. The highway department does have some native plantings in place."
- "We have a combination mechanical/chemical program, and are trying to move to a full chemical application program. We have worked from a 100 percent contract writing program to currently a 50 percent contract/50 percent county forces program."
- "At this time, our management plan is mostly mechanical cutting and mowing. The maintenance forces complete the roadside mowing and cut small/light trees and brush. We typically let a contract to cut the larger trees. Spraying is done as needed to control noxious weeds."
- "We mow medians and some boulevards along undeveloped property. We do some weed spray mixed with a growth retardant—primarily in medians. Mowing is only about two times a year, except in high visibility median areas 'downtown,' then approximately four times per year."
- "Our department mows roadside ditches after [July 31] to allow wildlife nesting to hatch. After this, we try to mow the approximately 12 miles of ditches/roadsides once a month until September."

Brush and Tree Control

- "Boulevard tree trimming program was started seven–eight years ago, and includes trimming and shaping one-fifth of the boulevard trees every winter. We also have a small program for mowing the boulevard and right-of-way (ROW) ditches, which includes 20 miles: mow three–four times a summer."
- "Our maintenance crews spray brush to ensure sight distances and to alleviate potential problems. We contract mow all CSAH and county road ROW from the shoulder to the backslopes. Noxious weeds are also controlled by spraying."

Noxious Weed Control

- "We spot spray noxious weeds May 15 to July 1. Brush control this same period plus full application approximately two weeks. Mow one-third of county road right-of-way complete each year."
- "Mowing two SHCO cuts twice a year, spot spraying ROW springs, summer, and fall. Brushing winter and brush hog fall and winter. Also growth regulator, guardrail treatment."
- "We mow and brush cut the entire right-of-way on a three-year rotation. We spray for Canada thistle and leafy spurge wherever and whenever we find it."

Other

- "Roadside vegetation management is a very minor activity for our city. We do have a very strong landscape maintenance and flower garden program with a newly instituted integrated pest management (IPM) plan."
- "Spot spray two-thirds of the county and continuous spray one-third; rotate every year."

- "In rural areas (non-developments) seeding is allowed. In urban areas (new development) seeding is allowed until new home is constructed, then sodding boulevard is required along with the construction of existing roads: We generally resod boulevard where needed, and repair isolated areas. We generally topsoil and reseed."
- "Scheduled mowing, noxious weed control, brush/tree removal."
- "We mow yearly, combined with noxious weed spraying. Mowing is done at least three times during the summer (top cut only). Complete ROW mowing done about once every five years. No wildflower and controlled burning done."
- "Shoulder mowing twice/year; herbicide applied to thistles and trees as needed."
- "We spot spray for weeds and mow the entire ROW every other year."
- "We spot spray for weeds; top cut all county roads; mow entire ROW every four years (one quarter of county each year)."
- "Top cut mowing June, July, August; spray noxious weeds as required; when possible during September, October, November, and December we cut brush and trees and treat them with chemical treatment; we are trying to start three-year burn cycle with private groups and forest service; some native grass seeding by contract."
- "Beginning to experiment with salt-resistant seed along roadsides. Standard erosion control implemented on construction projects. Maintenance includes mowing schedule, trimming, weed management."
- "All miles driven, and we spray as required. A minimal second pass is sprayed on trouble spots. All miles top cut, 50 percent ROW to ROW every year minimal, then sprayed and covered. We also spray with Telar and HiDep, mow, and conduct brush control."
- "Hennepin County's roadside vegetation management plan consists of controlling noxious weeds by weed spraying and roadside mowing. Contracted roadside mowing was done in the western MTCE district. This was our first attempt at contracted roadside mowing and it worked well for us."
- "Brushcutting, clearing, spraying on an annual basis; mowing on an annual basis."
- "New road construction has defined criteria to follow regarding establishment of turf, and erosion protection of all slopes, ditches, etc. For maintenance, roadside mowing and brushing is done seasonally."
- "It is addressed primarily through road reconstruction when turf is established. On the opposite end of the spectrum, we are starting a pilot program for roadside spraying to control excessive brush."
- "Biweekly mowing of nonresidential boulevards by staff; contractual mowing of rural sections."
- "We do a fall spray using Tordon K, Garlon 4, SEE 2, 4-D. Lately we are on a four-year rotation mowing to fence line on all county roads, which has had a big impact on our brush problem. Also have planted some native grasses on new construction."
- "We do some spot spraying, we also do some roadside mowing, but we need to implement a better plan for the future."

SECOND SURVEY

Those cities and counties that indicated on the first survey that they were implementing some element of roadside vegetation management were asked to identify a contact person for their jurisdiction. The second, more detailed survey was then sent to that contact person. Because so few respondents from the first survey indicated that they had a vegetation plan in place, only 21 follow-up surveys were sent out; of those, 14 were returned (66.7 percent). This second survey was also sent to state agencies in Wisconsin, Nebraska, Iowa, North Dakota, and South Dakota. Some of the information returned in the state agency survey is highlighted in Chapter 8, under specific examples of Best Management Practices. This survey asked much more detailed questions about a variety of topics, including equipment, herbicides, mowing, seeding, and erosion control. Best Management Practices identified in those areas are as follows:

Seeding

- interseeding with native grasses
- staged seeding during construction
- use of hydromulches and other mulches

Erosion Control

- use of silt fence and fabric
- use of mulch, ditch blocks, blankets
- use of crown vetch and tree planting
- staked netting or bales used with sodding and riprap

Mowing

- full cut every three years on a three-year rotation, beginning August 1
- mow 6–12 feet width twice yearly; spot spray for noxious weeds
- spray medians and sidewalks in high visibility areas once a year
- mow top cut 100 percent of system, and mow to right-of-way over 50 percent of system each year
- mow as much roadside as possible, but not on steep slopes; first cut ASAP, cut to right-of way to control brush; avoid use of chemicals

Biggest Challenges

- getting the work done with weather and time constraints
- getting out public information on herbicides, and overcoming controversy (mentioned by four)
- noxious weed and tree and brush control (mentioned by two)
- satisfying conflicting public expectations regarding weed control, mowing, and expenditures
- controlling leafy spurge and purple loosestrife
- keeping farmers happy
- getting contractors to take the time it takes to do a good and timely job of turf establishment and erosion control

Innovative Practices

- establishment of native grass stands
- management of roadsides using natives and wildflowers
- fall spraying, change from mowing to spraying
- biological and weed control using insects

THIRD SURVEY

One more survey was distributed, this one at the Vegetation Management Association of Minnesota (VMAM) annual meeting in July of 1998. At the time this survey was conducted, the TAP had identified most of the best management practices. However, this conference was attended by a wide variety of vegetation and environmental industry representatives and their perspective and input was sought. The attendees at the VMAM were asked to identify best and worst management practices. In addition, they were asked to give specific examples of where the best management practices already identified by the TAP were being used.

Perhaps the most important piece of information obtained from performing all three surveys was that there were few best practices being implemented locally in Minnesota. So the TAP looked to successful programs in other states and results of current research to identify Best Management Practices for roadside vegetation. In addition, individual responses for all surveys were evaluated, and follow-up phone calls were made to those respondents who had identified an innovative or cost-saving practice in their jurisdiction.

BEST MANAGEMENT PRACTICES SELECTED BY SURVEY RESPONDENTS

The wide variety of responses obtained from the three surveys is summarized below. Note that "best management practices" identified by survey respondents are not necessarily the same practices that this manual's Advisory Panel would select.

General

- effective partnerships with adjacent landowners to fully accomplish BMP objectives
- the development of partnerships with other agencies for roadside management
- an integrated approach to roadside vegetation management
- practices that encourage diversity along the roadside environment
- biological control of invasive species
- prescribed burning
- use of living snow fences
- elimination of the use of invasive (but not noxious) non-native species, such as crown vetch, birdsfoot trefoil, and reed canary grass
- fall spraying after most farmers have cut ditches and some regrowth has taken place, which greatly reduces the risk of damage to adjacent crops, especially soybeans

Seeding

- interseeding with native grasses
- staged seeding during construction
- use of hydromulches and other mulches
- use of quality seed, with good seed-to-soil contact
- seed drilling

Erosion Control

- use of silt fence and fabric
- use of mulch, ditch blocks, blankets
- use of staked netting or bales with sodding and riprap
- use of staged grading during construction and establishing vegetative cover early
- early coordination with the DNR on construction projects
- requirement of an erosion control plan in all grading contracts
- contractor responsibility for implementing the erosion control plan during construction
- establishment of vegetation early; use of mulch, erosion control blankets, hydromulches, bales, silt fences, rock check dams, and sediment basins during and after construction, and conducting these activities as soon as possible after grading is completed

Mowing

- reduced mowing
- interagency coordination for mowing
- full cutting every three years on a three-year rotation, beginning August 1
- twice-yearly mowing of a 6- to 12-foot width and a spot spraying for noxious weeds
- spraying of medians and sidewalks in high visibility areas once a year top cutting of 100 percent of system and mowing to right-of-way over 50 percent of system each year
- mowing of as much roadside as possible, but not on steep slopes; a first cut ASAP to right-of-way to control brush; avoidance of chemical use

- mowing after the general plant height in the area reaches 12 inches, with that mowing to a minimum height of 6 inches
- rotational mowing

Worst Management Practices Identified by Survey Respondents

- broadcast herbicide spraying
- mowing entire right-of-way
- inadequate erosion control
- excessive salt use
- planting high maintenance vegetation
- mowing during nesting season
- mowing when the ground is wet, causing ruts and tearing up slopes

Greatest Challenges

- completing work with weather and time constraints
- communicating to the public about on herbicides, and overcoming controversy
- controlling noxious weeds
- satisfying conflicting public expectations regarding weed control, mowing, and expenditures
- controlling leafy spurge and purple loosestrife
- keeping farmers happy
- getting contractors to do a good and timely job of turf establishment and erosion control
- obtaining adequate funding, given competing department needs
- accomplishing goals with limited staff and funding
- establishing vegetation after construction
- maintaining quality vegetation without adequate water
- establishing native grasses and wildflowers
- educating maintenance personnel about management policies
- practicing tree and brush control
- dealing with the effects of salt, sand, and ice
- controlling erosion
- carrying out public relations
- ensuring the safety of workers
- accomplishing the work without enough time and funding

Innovative Practices

- establishing native grass stands
- managing roadsides using native grasses and wildflowers
- spraying in the fall
- changing focus from mowing to spraying
- controlling weeds using insects (biocontrols)
- integrating planning, design, and construction into construction plans
- bidding items in order to pay contractors for each care cycle they perform satisfactorily (expecting a minimum of two years on plantings)
- following policies and paying attention to stand establishment
- allowing farmers to plant alfalfa in ditches, which eliminates the need for weed control and reduces the amount of wildlife living along roadsides
- allowing roadsides to return to the natural environment and be maintained only for safety and drainage
- using living snow fences
- spot spraying for noxious weeds and brush

Appendix B: Soils Information

BASIC SOILS INFORMATION

Weathering

A soil's characteristics depend on the material from which it evolved, called the parent material, and the method by which it formed. Soil results from the weathering of rock or the decomposition of organic materials. Weathering can be achieved mechanically, by temperature changes, frost action, rain, wind, ice or other physical means, or chemically, from the reaction of rock minerals with oxygen, water, acids, or salts. The type of soil produced by rock weathering depends on the rock type. Granites weather to form silty sand or sandy silts. Basalt weathers into clayey soils, and sandstone weathers into sandy soils.

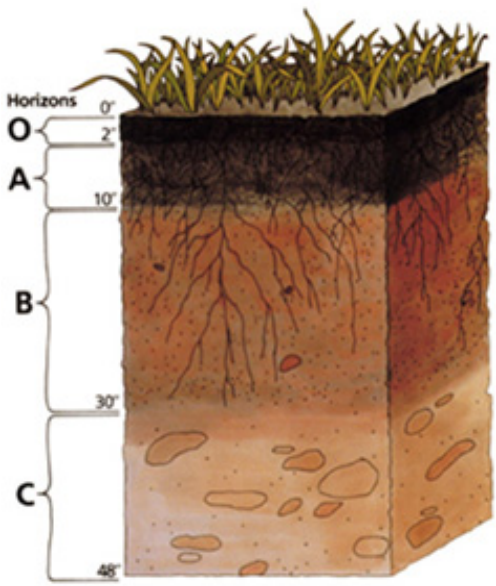
Soils produced by weathering are categorized by their location relative to the parent rock. Soils that remain over the rock from which they came are called residual soils, and those soils that are transported from their place of origin and deposited elsewhere are called transported soils.

The particle size, shapes, and composition of residual soils may vary widely, depending on the amount and type of weathering. The depth of a residual soil layer depends on the rate at which the rock weathering occurred. Transported soils are commonly moved by gravity, water, glaciers, and wind. Gravity deposits, typically located close to the parent material, are generally loosely compacted. Soils moved by water, or alluvial deposits, are often found in the vicinity of moving water. They tend to be loose and compressible soils. Glacial deposits are made up of soil and rock mixed together. Wind deposits may be fine or coarse in texture.

Soil Profile

The soil profile is a natural succession of zones below the ground surface and represents the alterations to the original soil brought about by the weathering process. In general, there are four distinct zones in a natural soil profile:

O horizon Leaves, vegetation, and organic debris
A horizon Sometimes called the topsoil layer, the layer rich in humus and organic plant material, frequently darker in color than the underlying soils due to the accumulation of organic matter
B horizon The subsoil immediately below the topsoil layer; often contains more clay soils
C horizon The soil beneath the A and B horizons from which they were derived; also known as the parent material



An example of a soil profile

Soil Texture

The soil texture refers to the relative size of the mineral particles. It is an important characteristic, as it limits and defines the soil's uses. Most natural soil types are composed of a combination of many particle sizes, the distribution of which gives the soil a distinctive appearance. This appearance—texture—is the term most often used to identify a soil.

There are three main textural classes: coarse- or light-grained, medium-grained, and fine- or heavy-textured soils. These may also be characterized as gravels, sands, and silts or clays. According to the Mn/DOT Grading and Base Manual, grain size ranges for these soil sizes are as shown in Table B-1.

Table B-1. *Grain Size Distribution Ranges*

		Corresponding US Standard Sieve Sizes	
Particle Size	Diameter (mm)	Passing	Retained On
Gravel	76 (3") to 2.0	3"	No. 10
Coarse Sand	2.0 to 0.42	No. 10	No. 40
Fine Sand	0.42 to 0.074	No. 40	No. 200
Silt	0.074 to 0.002	Cannot be separated by sieving.	
Clay	< 0.002	Determined by settling velocity in soil-water suspension.	
*Colloidal Clay	< 0.001		

*Colloidal Clay is usually included in the clay size of fraction and is the smallest size clay particle. In addition to their physical characteristics, colloidal clay particles possess marked chemical factors and frequently have electrical charges present on their surface.

Laboratory Determination of Soil Texture

To separate the soil particles by size, conduct a gradation analysis in which the soil sample is run through a series of sieves. The portion passing or retained on each sieve is measured and expressed as a percentage. The percentages of smaller size particles that pass the No. 200 sieve are determined by hydrometer analysis, which determines the soil size based on its settling velocity.

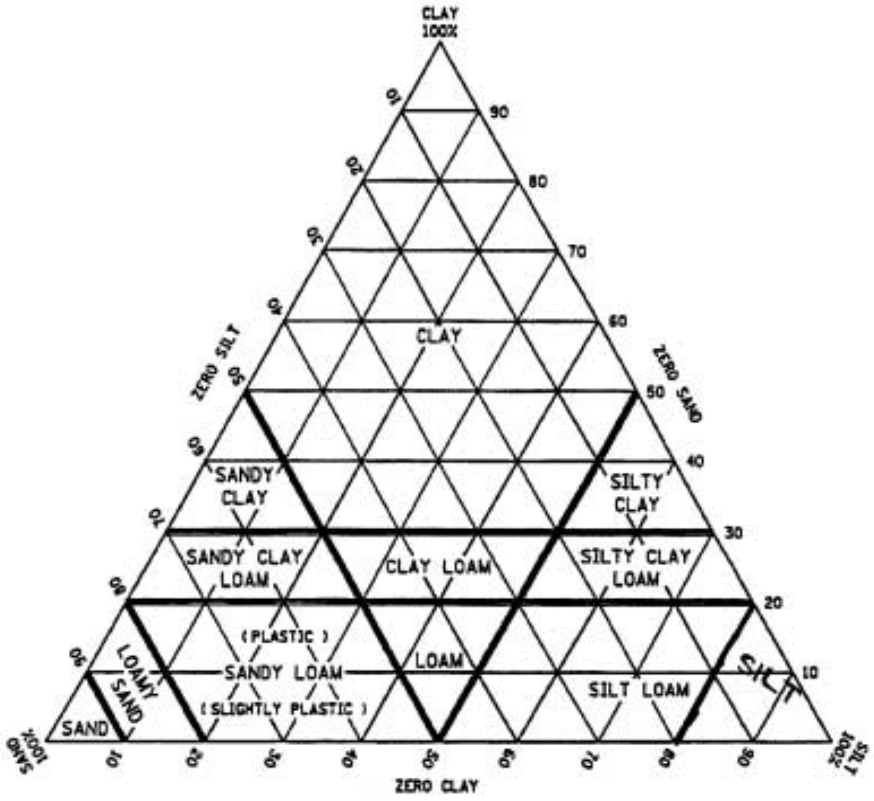


Figure B-1. *Soil Classification*

Once the percentage of each particle size in the sample is known, the soil can be assigned a definite textural classification dependent upon the amounts of sand, clay, and silt present. Use the triaxial chart shown in Figure B-1 to classify a soil. Stone and gravel particles larger than the sand size (No. 10 sieve) do not have much effect on the

basic soil classification. Soils containing more than 25 percent gravel particles are generally termed gravelly or stony soils.

The textural names of the soils obtained from the chart are designed to tell as much as possible about the soil in one to three words. Once the textural classification is known, approximations and estimates of many soil properties can be made, such as its strength, water-holding capacity, frost heave potential, maximum dry density, and optimum moisture content.

The triaxial chart places soil textures into three main groups based on clay content. Those three groups are then subdivided further, as follows:

Soils containing less than 20 percent clay:
- Sand
- Loamy sand
- Sandy loam
- Loam
- Silt loam

Soils containing 20–30 percent clay:
- Sandy clay loam
- Clay loam
- Silty clay loam

Soils containing more than 30 percent clay:
- Sandy clay
- Clay
- Silty clay

Table B-2, from the Mn/DOT Grading and Base Manual, lists soil textures with their gradation limits determined by laboratory mechanical analysis

Table B-2. Gradation Limit of Textural Soils Groups

Soil Class	% Gravel	% Coarse Sand	% Fine Sand	% Silt and Clay	% Silt	% Clay
Group 1						
Gravel	90–100			0–10		0–10
Sand and Gravel	25–90			0–10		0–10
Coarse Sand	0–25	50–100		0–10		0–10
Sand	0–25	0–50	0–50	0–10		0–10
Fine Sand	0–25		50–100	0–10		0–10
Loamy Sand and Gravel	25–50	0–50	0–50	10–20		0–20
Loamy Coarse Sand	0–25	50–90		10–20		0–20
Loamy Sand	0–25	0–50	0–50	10–20		0–20
Loamy Fine Sand	0–25		50–90	10–20		0–20
Gravelly Sandy Loam	25–50	25–50	0–50	20–50		0–20
Coarse Sandy Loam	0–25	50–80		20–50		0–20
Sandy Loam	0–25	0–50	0–50	20–50		0–20
Fine Sandy Loam	0–25		50–80	20–50		0–20
Gravelly Loam	25–50			50–70	30–50	0–20
Loam	0–25	0–50	0–50	50–70	30–50	0–20
Silt Loam			0–50	50–100	50–100	0–20
Group 2						
Gravelly Sandy Clay Loam	25–80	0–80	0–80	20–50	0–30	20–30
Gravelly Clay Loam	25–50	0–50	0–50	50–80	20–50	20–30
Sandy Clay Loam	0–25	0–80	0–80	20–50	0–30	20–30
Clay Loam	0–25	0–50	0–50	50–80	20–50	20–30
Silty Clay Loam	0–25	0–30	0–30	70–100	50–80	20–30
Group 3						
Sandy Clay	0–25	0–70	0–70	30–50	0–20	30–50
Clay			0–50	50–100	0–50	30–100
Silty Clay			0–20	80–100	50–70	30–50

Field Determination of Soil Texture

Conducting laboratory tests to determine soil texture and type is not always practical or possible, so it is useful to have methods of classifying soil in the field. You can do this by feeling the soil and by making judgments based on its appearance.

To make a field determination, break the soil in your hand. How easily it breaks is one indicator of the soil type. For example, silt loam will produce clods that are easily crumbled.

Next, moisten the soil and form it into a cast. Press or rub the moist sample between your thumb and index finger to create a thin ribbon until it breaks. You will be able to "ribbon" the soil if it is moist enough to be worked with the fingers but provides some resistance. Ribbons of soil should be about 1/2-inch wide and about 1/8-inch thick for best results. For example, a sandy loam can be pressed into a ribbon, but a sandy soil cannot. Classifying soils using

these methods may prove difficult at times, but with practice and experience, it is possible to become reasonably proficient.

The descriptions of the soil classes in Table B-3 are for field use. The main soil classes are described as well as likely variations. Figure 1-1 shows the Triaxial Chart that is used in the Mn/DOT Grading and Base Manual.

Appendix B contains additional detailed information about soil weathering, formation, and texture.

Table B-3. Field Classification of Soils

Soil Classification	**Description**
Gravel (G)	A combination of soil particles between 2 mm and 3 inches in size. Fine gravel has a predominance of particles between 2 mm and 3/8 inch. Gravel is easily identified by visual inspection.
Sand (S)	100% of particles are smaller than 2mm (No. 10 sieve). Contains less than 10% silt and clay. Appearance is loose and granular, and the individual particles can be readily seen and felt. It is non-plastic, and therefore can't be pressed into soil ribbons. If squeezed into a cast in the hand when dry, it will fall apart when the pressure is released. Squeezed when moist, it will form a cast that holds its shape when the pressure is released, but will crumble when touched. Coarse sand (Cr S) - main particle size is 425 µm (No. 40) - 2 mm (No. 10) Fine sand (FS) - main particle size is 75 µm (No. 200) - 425 µm (No. 40) Very fine sand (VFS) - almost all particles are close to 75 µm (No. 200 sieve). It may be difficult to distinguish between very fine sand and silt. Sand (S) – applied when the sample is well graded, and contains approximately the same amount of coarse and fine sand.
Sand and Gravel (S & G)	A mixture of sand and gravel. Very well graded, identified by visual inspection. Variations may include: Sand and Fine Gravel (S & FG) Coarse Sand and Gravel (Cr. S & G) Coarse Sand and Fine Gravel (Cr. S & FG)
Loamy Sand (LS)	All material is smaller than 2 mm (No. 10 sieve). Contains 10-20% fine-grained silt and clay combined. Soil is loose and granular, and the individual soil particles may be easily seen and felt. It appears dirty when compared to the sand, due to the higher silt and clay content. Loamy sand is non-plastic and therefore can't be pressed into soil ribbons. If squeezed into a cast in the hand when moist, it will form a cast that holds its shape when the pressure is released. The cast will withstand careful handling and some jarring without crumbling. This stability differentiates loamy sand from clean sand. Loamy Sand can be further classified as coarse, fine, or very fine, depending on the proportions of different sizes of sand particles present. The term Loamy Sand (LS) is used when the material is well graded, containing approximately equal proportions of coarse and fine sand.

Sandy Loam (SL)	Contains 20-50% silt and clay combined, but less than 20% clay. May contain 0-50% silt and 0-20% clay, but must always contain at least 50% sand grains. This soil is plastic, and when moist it can be pressed into thin ribbons between the thumb and index finger. Individual sand grains can be seen and felt. Other soils fitting into this category include: Slightly plastic Sandy Loam (sl pl SL) Plastic Sandy Loam (pl SL) slightly plastic Coarse Sandy Loam (sl pl Cr SL) plastic Fine Sandy Loam (pl FSL) plastic Very Fine Sandy Loam (pl VFSL)
Loam (L)	The term "loam" generally means a combination of sand, silt and clay, and contains more than 50% silt and clay combined. It contains 30-50% sand, 30-50% silt, and 0-20% clay. It is somewhat gritty, but feels smoother than sandy loam. When moist, it will form a ribbon ¼-1 inch in length, but somewhat thinner and stronger than can be formed with sandy loam. The word loam is commonly used in agricultural fields to describe topsoil, which contains black organic material.
Silt Loam (L)	Contains 50-100% silt, 0-50% sand and 0-20% clay, and must always contain at least 50% silt particles. When dry, silt loam may appear cloddy, but the lumps can be easily broken. When pulverized, it feels soft and fluffy. When moist and pressed between the thumb and index finger, it offers little resistance to pressure and feels smooth or slippery. Pure silt is nonplastic and will not press into a continuous ribbon, but rather into shorter, crumbly, dull sections. It sticks together when moist because of its fine grained structure in a manner similar to flour when water is added. In its natural state in the ground, silt loam may be very wet, due to the capillary affinity for water.
Clay Loam (CL)	Contains 20-30% clay, 20-50% silt, and 20-50% sand. It is fine textured and will form a ribbon 1-2" long before breaking. Does not offer as much resistance to pressure as clay loam and has a dull appearance, but it is slippery.
Silty Clay Loam (SiCL)	Contains 20-30% clay, 50-80% silt, and 0-30% sand. A fine textured soil, which will form a 1-2" ribbon without breaking. It does not offer much resistance to pressure as clay loam and has a dull appearance, but it is slippery.
Sandy Clay Loam (SCL)	Contains 20-30% clay, 50-80% sand, and 0-30% silt. It has a gritty feel compared to the more slippery feel of clay loam, and will form a 1-2" ribbon.
Clay (C)	Contains 30-100% clay, 50% silt, and 0-50% sand. It is smooth and shiny and will form a long, thin flexible ribbon 2 inches or more in length.
Silty Clay (SiC)	Contains 30-50% clay, 50-70% silt, and 0-20% sand. It is very plastic, but feels smooth and slippery ("buttery") and will form a ribbon 2 inches or more in length.
Sandy Clay (SC)	Contains 30-50% clay, 50-70% sand, and 0-20% silt. It is very plastic, but feels gritty. It will form a long, thin ribbon 2 inches or more in length.

Soil Health

Healthy soil is a critical element for establishing a healthy roadside environment. Even the most appropriate and useful tools for managing roadside vegetation may not work if the soil lacks enough nutrients to support the targeted vegetation. To improve unhealthy soil, try measures such as the use of aeration, or deep scarification to incorporate oxygen into the soil. If improving soil health is not possible, choose appropriate vegetation (that does not need high nutrient soils to flourish) for establishment in that area.

An excellent way to assess the health of the soil is to send a sample to the University of Minnesota Extension Service Office. For a small fee, the service will analyze the nutrient content of the soil sample and recommend the

appropriate type and application rate for any necessary fertilizer. Minnesota's Extension Office web site is available at: http://www.extension.umn.edu/

Soil Considerations for Herbicide Use

Herbicide application rates vary according to soil type. When determining a method to control weeds, evaluating the soil type may explain a specific weed growth or resistance to treatment in an area.

Guidelines for Herbicide Application

1. Use lower application rates for coarse-grained soils and higher rates for fine-grained soils or soils high in organic material. Follow label recommendations.
2. Evaluate the local topography and assess the potential for herbicide runoff before spraying. Do not spray in steep areas if rain is likely.
3. Follow precautions on herbicide labels, especially regarding use on well drained sandy soils.

Soils can be categorized as coarse or light, medium- or fine-grained, with the following properties and resulting considerations for herbicide application (Table B-4).

Table B-4. Soil Types and Properties

Grain Size	Description	Properties	Herbicide Considerations
Coarse or light	Dry: breaks easily, crumbles into loose soil Moist: feels gritty, forms ribbons ≤1/2" long	Contains more than 50% sand, and is well drained. Doesn't hold nutrients well, or cause chemicals to break down quickly.	Low rates of application needed for sandy soils. Follow label directions.
Medium	Dry: resists moderate pressure before breaking. With high silt content, soil will pop apart suddenly in a burst of floury soil; soil feels soft and floury with some grit. Moist: forms 1" ribbon, and leaves dull fingerprint marks.	Loamy soils have low sand clay content, but high silt. They are chemically inactive, and do not absorb or tie up chemicals.	Normal application rates. Follow label directions.
Fine or heavy	Dry: hard to break clods of soil. Moist: makes very firm casts, forms ribbons > 1" long, and leaves shiny fingerprint marks.	Chemically active particles have surfaces that attract and hold onto water, minerals, and chemical herbicide particles.	Higher rates of application are needed. Follow label directions.

Erosion/Runoff Potential

Erosion and runoff can be a serious problem along roadsides, both during and after construction. Erosion is caused when the land surface is washed away by wind or water; sediment is the byproduct (Figure B-2). In addition to the loss of valuable soil resources, erosion results in an unhealthy environment for growing vegetation, waterways polluted with sediment, and costly maintenance activities to repair damage. Damage at the site may include rilled and gullied slopes, washed-out ditches, damage to pavements and drainage structures, clogged pipes, and flooding. Water bodies are damaged when they become filled with polluting sediment, making them susceptible to flooding and stream bank erosion.

Vegetation retards erosion. A recent study showed that, in a given rainfall episode, an acre of bare soil can lose up to 100 pounds of sediment, mulched soil loses up to 20 pounds, and well-vegetated soil loses only up to one pound. The presence of well-established vegetation, or even a mulch cover, will preserve the soil and reduce the effects of erosion in an area. The five types of erosion are listed in Table B-5.

Figure B-2. Significant erosion problems can occur during construction before new turf is established

Table B-5. Types of Erosion

Type of erosion	Description	Minimization Technique
Raindrop splash	The impact of the raindrop dislodges soil, causing bare soil to be splashed into the air. The effect of the splash also increases compaction and destroys open soil structure.	Stabilize the soil to prevent erosion
Sheet erosion	Transporting mechanism of soil loosened by raindrop splash, removal of soil from sloping land in thin layers. A function of soil type, depth and velocity of flow.	Minimize by diverting flow away from the slope.
Rill erosion	Occurs where sheetflow becomes concentrated in small, defined channels a few centimeters deep. Form of erosion in which most rainfall erosion occurs.	Prevent by slope stabilization and diverting flow. Repair immediately with disking or tilling.
Gully erosion	Concentrated flow in unrepaired rills.	Requires extensive repair.
Channel erosion	Occurs at bends and in constrictive areas.	Smooth bends, add riprap.

Sandy or gravelly soils may be excessively drained, and are typically light brown with a red or orange tint. Herbicides applied to these soils may leach through quickly when their application is followed by a heavy rain, potentially polluting the groundwater layer. Herbicides may also be transported laterally underground, affecting non-targeted regions.

According to the Natural Resource Conservation Services, there are four major soil groups, based on infiltration rate.

Type A: Sands and gravels, with low runoff potential and high infiltration rates.
Type B: Average to medium coarse-textured soils, with average runoff potential and moderate infiltration rates.
Type C: Moderate- to fine-grained soils, with high runoff potential and slow infiltration rates.
Type D: Clay soils, with very high runoff potential and very low infiltration rates.

Generally, the permeability and water-holding capacity of a soil increases with its organic content, soil structure, and fertility.

Appendix C: Conducting Educational Workshops For Managing Roadsides For Wildlife

Essential elements of wildlife workshops directed at those administering and carrying out roadside management. Adapted from Johnson (1997; see citation in Chapter 8).

1) Coordination of governmental and non-governmental units.
    1.1 Identification of roles and positions of government agencies, non-governmental groups, and citizen's groups.
    1.2 Setting priorities and objectives. Balancing the promotion of wildlife habitat with the protection of traveler safety.
2. Ecology: Concepts of habitat edge, habitat fragmentation, corridors.
3. Wildlife value: Aesthetic and Economic values.
4. Wildlife identification and nesting schedules.
5. Plant identification: Estimation, mapping, and reporting of existing roadside conditions.
6. Establishing roadside habitat.
    6.1 Planning.
    6.2 Planting.
    6.3 Seeding.
    6.4 Erosion control.
    6.5 Continuing maintenance in years 1 to 3.
7. Treatments of existing vegetation.
    7.1 Burning.
    7.2 Mowing.
    7.3 Chemical applications.
8. Workshop evaluation by attendees (an assessment process).

Appendix D: Minnesota Prohibited Noxious Weeds

All eleven noxious weeds for Minnesota are described and illustrated below. Source: Mn/DOT Office of Environmental Services. Each year, the University of Minnesota publishes a document titled *Cultural and Chemical Weed Control in Field Crops*, which includes control strategies for many of the noxious weeds listed below. The publication is available online at www.appliedweeds.coafes.umn.edu. Note that these weeds all must be controlled statewide in accordance with the Minnesota State Weed Law.

HEMP (MARIJUANA)

Description: An annual plant with a branched taproot that reproduces only by seed. It grows 2–10 feet tall, has coarse, somewhat grooved, rough, hairy stems. Plants will become large and bushy unless crowded. Hairs on the upper parts of the plant exude a sticky resin with a characteristic odor. Leaves are alternate or opposite, petiolate, and divided into 5–11 hairy leaflets with notched edges. Male and female flowers are on separate plants. The male flower is green without petals. The male plant, which produces the pollen, turns yellow and dies soon after pollen is shed. The female plant produces flowers in the axil of the upper leaves and remains green and vigorous until frost. Flowering occurs from July to September and seed production, from August until frost. Seeds are yellowish-tan to mottled brown, 1/8-inch long, and oval-shaped.

Distribution: Hemp prefers rich, low, wet areas, but can be found in waste areas near farm fields and buildings. Hemp is found throughout the southern half of Minnesota.

Hemp *Cannabis sativa*

BULL THISTLE

Description: Bull thistle grows most often as a biennial, reproducing only by seed. During the first year of growth, a large basal rosette with a large taproot is formed. During the second year of growth, an erect flowering stem grows 2–4 feet tall. The stem is large, branched, and covered with dense hair. Leaf bases extend down the stem, giving it a winged appearance. The leaves are alternate, dark green, and coarsely lobed, with 3–4 points per lobe, each ending in a long sharp spine. The upper surface of the leaf is covered with short, stiff hairs and spines, and the underside of the leaf is covered with dense, woolly, gray hair. The flower heads are compact, 1–2 inches in diameter, and spine-tipped bracts surround each reddish-purple flower. Flowering occurs from late June through August and the seed matures from July through September. Seeds are 1/8-inch long, oblong, flattened and curved, and light brown with dark brown stripes.

Distribution: Bull thistle is primarily found in pastures, waste areas, and along roadsides throughout Minnesota in a variety of soil types.

Bull Thistle *Cirisium vulgare*

GARLIC MUSTARD

Description: This plant grows three to four feet in height. Lower leaves are heart or kidney shaped, while upper leaves are toothed, and triangular in shape. Flowers are white and clustered on the top of the stem. Young plants smell like garlic.

Distribution: Garlic mustard is found in the forest understory, at the edges of wooded areas near trails, roadsides, and areas where trees have been removed.

Garlic mustard *Alliaria petiolata*

MUSK THISTLE

Description: This plant, also called nodding thistle, reproduces only by seed and grows most often as a biennial, although it can occasionally grow as a winter annual or annual. During the first year of growth, a large basal rosette with a large taproot is formed. During the second year of growth, an erect flowering stem grows to a height of 3–6 feet. The stem is branched with spiny leaves extending down the stem to give it a winged appearance. The wings are lobed and wavy with each lobe ending in a spine. The leaves are bluish-green with light green midribs and a white margin. They are alternate, smooth, coarsely lobed with 3–5 points per lobe, and slightly wavy. Each lobe ends in a prominent hair on either surface. The flower heads are large—up to 2 inches across—and frequently droop on the ends of long spineless stems. The flowers are deep rose to violet in color and are surrounded by large spiny bracts. Flowering occurs from late June through August, and the seed matures from July through September. The seeds are yellowish-brown, oblong, and 3/16-inch long with a protrusion at the place where they were attached to the pappus.

Distribution: Musk thistle is primarily found in pastures, waste areas, and along roadsides throughout southern Minnesota, with the most severe infestations in southeastern Minnesota. Prefers moist alluvial soils, but can grow elsewhere.

Musk Thistle *Carduus nutans*

PLUMELESS THISTLE

Description: Plumeless thistle reproduces only by seed, growing most often as a biennial, but occasionally as a winter annual or annual. During the first year of growth, it forms a large basal rosette with a large taproot. During the second year, it grows an erect, branched flowering stem 3–6 feet tall with spiny wings. The leaves are alternate, narrow, and deeply lobed with scattered hair on the upper leaf surface and dense white hair on the lower surface, especially along the midrib. Lobes on the leaves and stem end in white to yellowish spines. The flower heads are globe-shaped, erect, and single or loosely clustered with spiny bracts at the base of each. Flowers are reddish-purple and 1/2–1 inch in diameter. Flowering occurs from June through August, with seeds maturing 5–12 days after full bloom. The seeds are straw-colored with brown striations to the collar where the pappus is attached, 1/16-inch long, and usually linear but occasionally curved.

Distribution: Plumeless thistle is primarily found in pastures, waste areas, and along roadsides throughout Minnesota. It prefers sandy, well-drained soils.

Plumeless Thistle *Carduus acanthoides*

CANADA THISTLE

Description: Canada thistle is a perennial that reproduces by seeds and underground roots. Roots extend several feet deep and some distance horizontally, often forming dense patches. The mature plant reaches a height of 2–5 feet. Upright stems are grooved, branched at the top, and slightly hairy when young and increasingly hairy as they mature. The leaves are alternate and somewhat lobed, with crinkled edges and spiny margins. The flower heads are numerous, compact, and 3/4-inch or less in diameter. Flowers are reddish-purple to purple and are surrounded by bracts with spiny tips. Male and female flowers are usually borne on separate plants. Flowering occurs from June through September, with seeds maturing 8–12 days after full bloom. Seeds are gray to brown, smooth, slightly tapered, and 3/16-inch long with a ridge around the blossom end.

Distribution: Canada thistle can be found in all crops, pastures, waste areas, and along roadsides throughout Minnesota. It is the most prevalent and persistent broadleaf weed in the state.

Canada Thistle *Cirsium arvense*

FIELD BINDWEED

Description: Field bindweed, also called creeping Jenny or morning glory, is a perennial that reproduces by seeds and underground roots. The root system is very extensive and may penetrate the soil to a depth of 20–30 feet. The plant grows prostrate or climbs on any nearby object. The spreading stems are smooth, slender, usually twining, and 2–7 feet long on a mature plant. The arrow-shaped leaves are alternate with smooth margins and two basal lobes. The flowers are white to pink, approximately 1 inch in diameter, funnel shaped, and borne singly on long stalks in the axil of the leaf. The flower stalk has two bracts located 1/2–2 inches below the flower, which helps distinguish this weed from hedge bindweed. Flowering occurs from May to September. Seeds are borne in egg-shaped seedpods, each containing four seeds. The dark brownish-gray seeds are 1/8-inch long with a rough surface and one rounded and two flattened sides.

Distribution: Field bindweed will grow in most cultivated fields, gardens, lawns, waste areas, and along roadsides throughout Minnesota, with the heaviest infestations found in the western half of the state.

Field Bindweed *Convolvulus arvensis*

LEAFY SPURGE

Description: Leafy spurge is a perennial that reproduces from both seeds and underground roots. The root system is extensive and consists of numerous coarse and fine roots that occupy a large volume of soil. Roots are most abundant in the upper foot of soil; however, some roots can extend to a depth of 15 feet or more. The mature plant will reach a height of 2–3 feet. Stems are smooth, branched at the top, and filled with a milky juice. The linear-shaped leaves are alternate, bluish-green, and narrow (1/4-inch wide) with smooth margins. Leafy spurge produces a flat-topped cluster of yellowish-green flower-like structures, called bracts, on which the true flowers are produced. Flowering occurs from June through August and seeds are produced from July to September. Seeds are borne in three-lobed pods that contain three seeds each. The smooth, 1/8-inch long seeds are gray-white to gray-brown, usually mottled or flecked with brown, and marked on one side by a faint dark seam running the length of the seed.

Distribution: Leafy spurge grows primarily in pastures, waste areas, and along roadsides throughout Minnesota. The heaviest infestations are found in the western half of the state and along most of the roadsides in Minnesota's metropolitan areas, especially in the western suburbs f the Twin Cities metropolitan area.

Leafy Spurge *Euphorbia esula*

PERENNIAL SOW THISTLE

Description: Perennial sow thistle is a perennial that reproduces by seed and underground roots. Roots can penetrate the soil to a depth of several feet. Mature plants reach a height of 3–7 feet. The smooth upright stems, either with or without hair, contain a milky juice. Leaves are variable in shape and size. Basal leaves are narrow and deeply lobed, and leaves along the stem are 4–8 inches long, alternate, attached directly to the stem, irregularly toothed, and lobed with spiny edges. Flower heads are approximately 1-1/2 inches in diameter, produced in bright yellow clusters, and attached to terminal branches at the top of the plant. Flowering occurs from June through August and seeds mature July through September. The reddish-brown seeds with small cross wrinkles are 1/8-inch long, slightly flattened, and longitudinally ribbed with 5–7 ribs.

Distribution: Sow thistle will grow in cultivated fields, pastures, waste areas, and along roadsides throughout Minnesota, with the heaviest infestations found in the western and northern half of the state.

Perennial Sow Thistle *Sonchus Arvensis*

POISON IVY

Description: Poison ivy is a native perennial woody species that reproduces by both seeds and underground roots. It primarily grows as a woody vine; however, when growing in full sunlight it may become a shrub up to several feet tall. As a vine, poison ivy will climb fence posts, shrubs, and trees. Older vines may exceed 2 inches in diameter and reach 75 feet in length. Leaves are alternate and consist of three leaflets that can vary greatly in shape. Most often, leaflets are 2–4 inches long, pointed at the tip, and shiny with notched or smooth edges. Leaves are petiolate, and often the terminal leaflet has the longest stem. Leaves usually contain three leaflets, resulting in the phrase "leaves of three, leave them be" to help people avoid touching these poisonous plants.

The small, five-petaled flowers are yellowish-green and borne in a cluster 1–3 inches long. Flowering occurs from August through September, although not all plants will flower or bear fruit. Seeds are produced inside a fruit that grows in clusters on slender stems in the axil of the leaves. The fruit is grayish-white to yellow, 3/16-inch in diameter, and marked with distinct lines on the outer surface, somewhat like a peeled orange. Seeds are grayish striped and approximately 1/8-inch in diameter. All parts of this plant contain a poisonous material that causes blistering of the skin. The fall leaf coloration is a beautiful, shiny red.

Distribution: Poison ivy grows along stream banks and the edges of paths, roadsides, and fences, in woodlands, and in other non-cultivated areas throughout Minnesota. The heaviest infestations are found in wooded areas of the state. It prefers moist, shaded locations.

Poison Ivy *Rhus radicans* or *Toxicodendron radicans*

PURPLE LOOSESTRIFE

Description: This is an aquatic perennial that reproduces by seed or underground roots and can spread by sprouting from pieces broken off the plant. It has a woody taproot and a fibrous root system that forms a dense mat. The erect stems of a mature plant can reach 7 feet in height. The branched stems are somewhat square and covered with fine hairs. The leaves are opposite or whorled, linear-shaped with smooth edges, hairy, and attached directly to the stem. Purple or magenta flowers form in dense terminal spikes at the top of the plant with 5–7 petals. Flowering begins in June and continues through early September.

Distribution: Purple loosestrife is an aquatic plant that grows in moist soils in wet meadows, pasture wetlands, cattail marshes, streams and riverbanks, lakeshores, and ditches. Infestations are increasing in the state, with more than 75 percent of Minnesota counties infested.

Purple Loosestrife *Lythum salicaria* or *virgatum*

Appendix E: Practices of an Integrated Roadside Wildlife Plan

Adapted from the Utah and Minnesota programs, broad objectives are categorized as directed at people (managers and the public) or directed at roadside vegetation; both elements are essential for a successful roadside program.

Table E-1. Practices of an Integrated Roadside Wildlife Plan

	Utah's Rural Roadsides for Wildlife Program (adapted from Johnson 1997)	Adapted from the MDNR's Roadsides for Wildlife Program
Managing people.	- Educate and involve public in making policy. - Discourage illegal encroachments by private parties. - Foster cooperation among governmental agencies, private groups, and landowners.	- Conduct organizational events involving citizens and local road authorities to plan management priorities and methods. - Explain the benefits of a diverse and undisturbed roadside environment. - Encourage landowners to support and practice management techniques for wildlife. - Provide free "Roadsides for Wildlife" Signs. - Provide cost-sharing for local road authorities and private landowners to purchase native prairie seed.
Managing vegetation.	- Mow shoulders annually (12" minimum) and remainder once every 3 to 5 yrs, but only after August 1. - Chemical use limited to spot treatments for noxious weeds or safety concerns. - Seed native species.	- Delay roadside mowing of the ditch bottom and back slope until after August 1st. - Roadsides mowed after September 1st should mowed high. - Use spot treatment to manage sites for noxious weed control, safety, and snow drifting. - Incorporate native prairie species in roadside plantings.

Appendix F: Glossary of Terms

Absorption:	Entrance of pesticide into plant, animal, or soil.
Activate:	To cause a herbicide to have a toxic effect on plants, usually by moving the herbicide into contact with the roots.
Active ingredient:	The portion of a pesticide that works toward killing or controlling a pest. Expressed as a percentage (dry materials) or pounds per gallon (liquids).
Adjuvant:	A product added to sprayed materials to improve their ability to contact or penetrate the plant.
Adsorption:	The attraction of particles of one substance to the surface of a solid.
Adventitious roots:	Roots that originate from an unusual location on a plant such as along the stem.
Aerial application:	Application by helicopter or airplane.
Aerosol:	A very fine mist of solid or liquid particles suspended in air.
Agitation:	Constantly stirring or mixing spray material in the tank.
Amine salt:	An organic (carbon-based) compound containing hydrogen derived from ammonia. A water soluble herbicide formulation with low volatility.
Annual:	A plant that completes its life cycle, from seed to flowering and seed production, in one year, then dies.
Antagonism:	Loss of chemical activity of a herbicide by exposure to another chemical. A situation in which the mixing of two herbicides results in the reduced effectiveness of both.
Antidote:	A treatment administered to nullify or reverse the effect of a poisonous material taken internally.
Aquatic:	A plant or animal that grows and lives in water.
Aqueous:	A solution that contains water.
Aromatics:	Chemical compounds derived from hydrocarbon benzene.
Aspect:	The direction from which sunlight strikes a slope.
Backslope:	The side of the ditch furthest from the road.
Band application:	Placing a chemical herbicide in strips on the ground.
Bare ground treatment:	Herbicide application with the objective of keeping soil clear of all vegetation.
Bark:	The woody tissue outside of the vascular cambium layer of a woody plant.
Basal treatment:	Applying a herbicide to stems at ground line, root collar, and exposed roots.
Biennial:	A herbaceous plant that completes its life cycle in two years by germinating during one growing season, overwintering, then producing flowers and seeds during the second growing season before dying.
Biological diversity:	Refers to the variety and variability of living organisms (plants or animals) in a given area.
Biological integrity:	A state of being in which an area contains only those species that are native to the area, unpolluted by the introduction of undesirable or alien species.
Overall treatment:	A chemical applied uniformly over an entire area.
Boot stage:	The growth stage of grass when the seed head has formed but has not yet emerged from the sheath.
Broadleaf weeds:	Dicotyledonous plants that are not grasslike, but rather have broad net-veined leaves.
Broadcast application:	Spreading a spray or dust over an entire area.
Brush:	Woody plants.
Bunchgrass:	A grass that produces many side shoots and thus grows in a clump.
Carrier:	Liquid or solid material to which a chemical is added to facilitate application.
Chemical:	A synthetic compound that, when applied properly to target vegetation or other pests, will kill any part of that pest.
Chemical trimming:	The use of contact herbicides to selectively control encroaching plant growth.
Chlorinated hydrocarbon:	A synthetic organic pesticide compound containing chlorine, hydrogen, and carbon.
Companion crop:	Often necessary for plantings on highly erodible sites. It usually consists of oats planted at the rate of 1/2 or 1-1/2 bushels per acre to hold the soil until the permanent seeding gets established.
Compatibility:	When two or more materials can be successfully mixed and used together, they are said to be compatible.

Concentration:	The amount of active ingredient in a given volume of liquid or dry material.
Conifer:	A tree, usually an evergreen, that produces its seeds in cones and has needle-like leaves.
Contact herbicide:	A herbicide that kills only the part of a plant that it touches directly rather than by translocation.
Contaminate:	To pollute.
Cool season:	Plants, mostly grasses, that grow during the fall and spring and are more or less dormant during the summer.
Corrosion:	To wear away by chemical means.
Crown:	That part of the plant where stem and roots join.
Cuticle:	A waxy layer that forms on the outer surface of plant foliage.
Deciduous:	A plant that loses its leaves seasonally.
Decreaser:	Range plants that decrease under heavy grazing. Some plants can be decreasers or increasers depending on soil and moisture conditions.
Degradation:	The process by which a chemical is broken down into simpler forms.
Delayed action:	Herbicidal activity that does not show effects immediately after application, but whose response occurs after a time.
Desiccant:	A material or herbicide that causes plant tissues to become dehydrated.
Diluent:	Any material, liquid or dry, that dilutes or carries an active ingredient.
Directed application:	Applying a pesticide to a specific area of a plant rather than as an overall broadcast application (spot spraying).
Dormancy:	A necessary period of rest that most perennial plants undergo during which visible growth is temporarily suspended. May result from the season or from stress.
Dormant seeding:	Seeding made in late fall just prior to freezing. Use the regular seeding rate if the seed is incorporated into the soil.
Dormant spray:	Applied to woody plants during their dormant period.
Dosage:	The amount of active ingredient applied per acre.
Drift:	Small particles of spray solution that are carried off target by air.
Ecosystem:	An ecological community together with its physical environment; considered as a unit.
Ecosystem-based management:	An approach that considers the whole system, not just the parts, and brings people together to work for the health of the land and the communities it supports
Ecotype:	In a species having a wide geographical distribution, a subgroup that has developed specific adaptations to local conditions such as temperature, light, and humidity.
Emergence:	The time during the growth of a plant when the seedling shoot first breaks through the soil.
Emulsifiable:	A formulation in which the active ingredient is dissolved in an organic solvent. The concentrate then can be diluted in water or oil for application.
Emulsifier:	A chemical that facilitates the suspension of one liquid in another. An additive that improves the mixing properties of two liquids.
Encroachment:	Practices on land adjacent to roadsides resulting in negative impacts to roadside vegetation.
Erosion:	The physical removal of surface material, either rock or soil, by water or wind.
Ester:	A relatively volatile formulation in which an inorganic acid such as 2,4-D is mixed with alcohol.
Fertilizer:	Any material added to soil to supply nutrients for plant growth.
Fibrous root system:	A root system in which all roots are about the same length and diameter.
Field border:	A narrow strip of grass planted between field and roadside that protects roadside vegetation from cropland activities and runoff.
Foliage:	The leaves of a plant.
Foliar application:	Herbicide applied to leaves or needles of a plant.
Foreslope:	The side of the ditch closest to the road. May also be called the “inslope”.

Formulation:	The physical form in which a herbicide is used. It may be 1) water solution, 2) oil solution, 3) liquid emulsions, 4) suspensions, or 5) dry (granules, dusts, or pellets).
Frilling:	Cutting slits through tree bark and filling them with chemicals.
Frost seeding:	A seeding made in late February or March on seedbeds prepared in the fall. Seed is sown on the surface that has been made friable by freezing and thawing. The soil surface is usually honeycombed with small cracks.
Germination:	The beginning of growth from a seed.
GPA:	Gallons per acre.
GPM:	Gallons per minute.
Granules:	Pesticide formulation in which small particles of clay or organic matter are impregnated with the active ingredient.
Grasses:	Monocotyledonous plants that have narrow leaves, parallel venation, and leaves composed of blade, sheath and liqule.
Ground application:	Spray application made by equipment carried by hand or mounted on trucks or other ground equipment.
Ground cover:	Any low-growing vegetation that protects soil from erosion.
Growing season:	The period of time between the last killing frost in spring until the first killing frost in fall, and during which time plants are actively growing.
Growth regulator:	A hormone-like chemical, either natural or synthetic, that speeds up or slows down the growth rate of plants. Commonly used to slow down the growth of grasses.
Herbaceous:	Non-woody vegetation.
Herbicide:	Chemical materials, natural or artificial, used to kill or control plants.
Hormone:	A synthetic or naturally existing plant growth regulator.
Humidity:	The amount of moisture air is holding at a certain temperature. Herbicides are more effective under conditions of moderate humidity.
Impermeable:	Cannot be penetrated.
Increaser:	Range plants that increase in number as the decreaser plants are weakened and die.
Inhibit:	To slow down or stop an activity.
Introduced:	Plants that have been brought in from outside North America and are not in the original vegetation.
Invert emulsion:	A mixture in which water is dispersed in oil.
Kg/ha:	Kilograms per hectare.
Label:	Printed material attached to a pesticide container. The label is a legal document providing explicit instructions for use.
Lateral encroachment:	Vegetation that grows and extends into areas where it is not wanted.
Lb/A:	Pounds per acre.
Leaching:	Downward movement of material through soil while dissolved or suspended in water.
Miscible:	Two or more liquids that can be mixed together and remain mixed.
Mission statement:	Answers the question "why do we exist?" from a customer's perspective. It usually describes products, services, and the customers who use them.
Monocotyledon:	A plant that has a single leaf; includes grasses.
Mulch:	A layer of material placed on the ground to retain moisture, to control soil temperature, or to inhibit the growth of weeds.
Native:	Plants that are native to the North American continent.
Native plant:	A plant species that occurs naturally in a particular area without human cause or influence. Known to exist in an area prior to European settlement.
Native Plant Community:	A diverse group of native plants that grow together in the same general place and have mutual interactions.
Native seed:	Seed from a plant species that occurs naturally in a particular area without human cause or influence.
Nonselective herbicide:	A chemical formulation that destroys any type of plant.

Noxious weed:	A weed defined by law as being objectionable enough to warrant a law requiring its control.
Orifice:	The opening of a spray nozzle through which the liquid is sprayed.
Pelleted:	A type of herbicide formulated for dry application in which the active ingredient is carried by particles of inert material or formed into small pellets.
Perennial:	A plant that normally lives three or more years.
Pesticide:	A chemical used to kill or inhibit a pest, whether vegetation, insect, animals, or fungus.
Phloem:	The living conductive tissue in plants that carries food manufactured by the leaves down into the plant roots.
Photodecomposition:	Destroyed or broken down by light.
Photosynthesis:	A process by which green plants manufacture their own food by combining carbon dioxide and water in the presence of light.
Phytotoxic:	Damaging to plant leaves.
Pollutant:	Contamination of water, soil, or air by harmful substances.
Postemergence:	Herbicide applied after weeds have begun active growth.
Pre-emergence:	Herbicide applied to soil to prevent successful germination.
Prevention control:	Preventing the initial establishment of weeds.
Pure live seed (PLS):	The percent of seed germination times the percent of seed purity of each species.
Rate of application:	The amount of chemical material applied per acre.
Regrowth:	Sprouts from roots or suckers from stumps of partially killed plants.
Residual:	The length of time that a pesticide remains active, usually in soil.
Resistance:	The ability of an organism to avoid damaging effects of a material by some internal mechanism.
Rhizome:	A perennial underground stem that can produce new plants.
Root collar:	The portion of a woody plant where the stem meets the root.
Root kill:	Root system completely dead, usually by application of systemic herbicide to a perennial plant.
Root suckering:	Sprouts that arise from roots that are still alive although the top of the plant may be dead.
Seed source:	The locality where a seedlot was collected. If the stand from which collections were made was exotic, the place where its seed originated.
Sensitive:	The inability to withstand injury from a herbicide.
Soil persistence:	The length of time that a soil-applied chemical remains phytotoxic in soil.
Soluble:	A material made by dissolving a material in a liquid, usually water. A true solution tends to remain stable, whereas emulsions and suspensions tend to settle out.
Solvent:	A liquid that will dissolve a substance.
Species:	In the system of binomial classification of plants and animal, a species is a subdivision of a genus.
Spot treatment:	Herbicide application limited to a small area or to individual plants.
Spreader:	A chemical additive that increases the ability of a herbicide spray to adhere to the surface of the target plant. Often used with wettable powder formulations.
Stolon:	The above ground horizontal stem of a perennial plant. Capable of developing roots, thereby spreading the plant by vegetative reproduction.
Suckering:	Sprouts arising from roots or underground stems.
Summer annual:	A plant that grows from seed, produces flowers, and dies within a single year.
Surfactant:	A surface active agent added to a herbicide mix to improve contact with the plant.
Susceptible:	Capable of being affected or injured, as when a plant is susceptible to the effects of a particular herbicide.
Suspension:	A mixture in which very fine particles of a solid are suspended in a liquid, rather than dissolved.
Sward:	Portion of ground that is covered with grass.
Synergism:	Cooperative action between two pesticides where the results are greater than the sum effect of both pesticides used alone.

Systemic:	A pesticide that is applied to one part of a plant, absorbed, and translocated throughout the plant.
Taproot:	A main root that grows downward and has only a few fibrous lateral roots.
Tolerance:	The ability to resist injury from pesticides or other adverse condition, or the amount of pesticide allowable in or on form products at the time of sale.
Top kill:	When leaves and stems are killed to the ground line.
Toxicity:	The degree to which a material is poisonous.
Translocation:	To be moved from one part of a plant to another by the plant's own vascular system.
Transpiration:	Evaporation of water from within a plant through its foliage. Turf: A mat formed on soil surface by grass, including root system.
Vapor drift:	The movement of herbicide vapor through the air away from the area of application.
Vapor pressure:	A chemical property that causes liquids to evaporate. The lower the vapor pressure, the faster a liquid evaporates.
Vines:	Woody or succulent plants that climb by tendrils or by twining, or that trail along the ground.
Viscosity:	The resistance of a liquid to flow readily. Viscosity usually decreases as temperature increases.
Volatile:	A substance that evaporates or vaporizes at ordinary temperature when exposed to air.
Warm season:	Grasses that reach their peak growth in midsummer. They have deep roots that allow them to have lush, green growth during July and August when cool season grasses are dying out.
Weed:	Any plant growing where it is not wanted.
Wettable powder:	A powder applied as a spray by mixing with water, forming a suspension rather than a solution.
Wetting agent:	A chemical added to a liquid spray mix to improve contact when the liquid is applied to plants.
Wildflower route:	A highway or system of highways that has been identified as having significant native or planted population of wildflowers available for viewing by travelers.
Winter annual:	A plant that germinates in fall, over winters as a rosette, and produces seed during the second growing season.
Woody plants:	Plants that develop woody tissue above ground.
Xylem:	Plant tissue that primarily conducts water upward within the plant. In woody plants, the xylem in the sapwood (more recent growth rings) conducts a majority of water movement upward in the plant.

From *Roadside Almanac; Roadside Vegetation Management Manual, Penn*DOT*; Mn/*DOT *Standard Specifications for Construction,* and *How to Develop and Implement an Integrated Roadside Vegetation Management Plan*