CHAPTER 9: ROADSIDE VEGETATION MANAGEMENT

The over 17 million acres of right of way (ROW) land managed by state DOTs include some rare ecosystems and endangered species, and involve a wide range of concerns including prevention of erosion and sedimentation control and spread of noxious weeds, in addition to transportation concerns and efficient use of resources to accomplish management objectives for the right-of-way.\(^{(i)}\)

In the name of safety, improved visibility and obstacle-free roadsides, roadside vegetation managers favor grasslands. Once established, the native grasses save maintenance dollars over time, provide a self-reliant and hardy plant community, improve wildlife habitat, and protect the local character and natural heritage of a site.\(^{(ii)}\)

Integrated Vegetation Management (IVM) or the Integrated Roadside Vegetation Management (IRVM) approach encourages stable self-sustaining vegetation with limited use of mowing and herbicides. IRVM is achieved through techniques that encourage self-sustaining native plant communities to naturally discourage the establishment of unwanted plant species. IRVM starts with good soils management, planting design, and revegetation, and then recognizes proper mowing or restrictions, weeding, pruning, and thinning. Herbicide use is not ruled out, but other strategies are combined to limit its necessity. As IRVM strategies take hold over time, mature roadside plant environments lead to long-term herbicide use reductions and minimal of maintenance requirements.

9.1. THE IMPORTANCE OF VEGETATION IN THE RIGHT-OF-WAY

More than half of the United States was once covered naturally by grasslands: Palouse, prairies, Great Basin, meadows, glades, savannahs, balds, pine barrens, and others.\(^{(iii)}\) Vegetation slows or prevents erosion by intercepting raindrop impacts, retaining soil with its roots, slowing runoff velocities, and decreasing runoff volumes by increasing infiltration and transpiring water to the atmosphere.

WSDOT’s State Roadside Manual outlines some of the many functions vegetation contributes that add significant value to our environment, including: \(^{(iv)}\)

- Traffic calming
- Stress reduction
- Buffer or shade for pedestrian or park and ride facilities
- Stream bank stabilization
- Wetland mitigation

<table>
<thead>
<tr>
<th>General Environmental Practices for Vegetation Maintenance Operations in the ROW</th>
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<tbody>
<tr>
<td>After pruning, chipping, and removing vegetation, clean up your work area.</td>
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<tr>
<td>Do not leave cuttings or chips in areas where they may be easily washed into the stormwater drainage system.</td>
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<tr>
<td>Do not fuel or lubricate equipment, such as weed whackers or leaf blowers, next to drain inlets or watercourses.</td>
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<tr>
<td>Consider the potential erosion problems in an area when vegetation is disturbed.</td>
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<td>Remember to cover your load when transporting vegetation debris.</td>
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• Water quality improvement
• Water retention and smoother flows
• Air pollution mitigation
• Noise abatement
• Wildlife habitat
• Enclose, screen, expose, or blend
• Visual quality, quality of life
• Corridor continuity

Today, ROW managers must be concerned with multiple use aspects of ROW management; multiple use concerns necessitate the development of plant communities that resist the invasion of woody plants, are aesthetically pleasing, provide food and/or cover for wildlife, and can be economically established and maintained. Visual quality of the roadside is a topic of increasing interest, and several DOTs have conducted surveys to try to identify the nuances of driver preferences. The following stewardship guidelines were developed by WSDOT to maintain the visual quality of the roadside:

1. Identify opportunities to partner with adjacent land owners to preserve or reveal desirable views and roadside segments that enhance or maintain corridor continuity. (It is not WSDOT policy to remove vegetation to open up views toward commercial properties.) Balance desirable visual functions with the needs of roadway users and adjacent land owners. Coordinate with the regional or headquarters Landscape Architect. On Scenic Byways coordinate with the Heritage Corridors Program Office.
2. Enhance or retain vegetation to screen undesirable views and to meet the requirements of the Roadside Classification Plan (corridor continuity, blending with, and buffering adjacent land uses).
3. Maintain low growing vegetation or limb up trees to retain desirable views.
4. Carefully consider actions before removing vegetation to open up views. Consider whether development adjacent to the highway is likely to eliminate the view after removing vegetation. Analyze the angle of view from the driver’s perspective and minimize removal of vegetation to meet the view objective. Consider selective removal of tree limbs or removal of only the limbs on the lower one third of the tree to reveal desirable views.

NCHRP 20-5, 33-04, “Synthesis of Highway Practice: Integrated Roadside Vegetation Management” surveyed a sample of state DOTs and identified erosion control as a primary concern in management of vegetation. Indiana, Minnesota, Texas, and Washington reported that their vegetation management activities were affected by stormwater management objectives. Florida, Illinois, Indiana, Maryland, Ohio, Texas, and Washington reported control of roadside fire starts as a concern addressed by their vegetation management practices. The use of native plants in construction or restoration of roadside vegetation patterns was mandated by policy or state laws in slightly more than 40 percent of the reporting states. The dollar value assigned to benefits of
“environmentally sensitive” maintenance methods (i.e., mowing of brush versus spraying of brush) have been established by four of the responding states: Florida, Illinois, South Carolina, and Texas. The same valuation in regard to construction methods was identified by only Florida and Illinois. Connecticut, Illinois, Maine, Minnesota, Nebraska, Ohio, Pennsylvania, Texas, Utah, Washington, and West Virginia said that environmental impacts from long-term sustainability were given consideration in construction of new roadside projects.\(^{(vii)}\)

NCHRP 20-5, 33-04 recommended that an entity be created and funded as a depository for retention and distribution of IRVM BMPs.\(^{(viii)}\) It is hoped that this document, undertaken for NCHRP 25-25(04), might provide a first step in that regard.

### 9.2. INTEGRATED ROADSIDE VEGETATION MANAGEMENT AND METHODS

The Integrated Vegetation Management (IVM) or Integrated Roadside Vegetation Management (IRVM) approach encourages stable self-sustaining vegetation with limited use of mowing, herbicides, tree removal, and other methods as necessary. IVM is achieved through techniques that encourage self-sustaining native plant communities to naturally discourage the establishment of unwanted plant species. IVM starts with good soils management, planting design, and revegetation, and then recognizes proper mowing or restrictions, weeding, pruning and thinning. Manual activities, mechanical tools, and chemical applications are combined with cultural and biological methods to develop a vegetation community that requires minimal maintenance and benefits wildlife and its habitat. As IVM strategies take hold over time, mature roadside plant environments lead to long-term herbicide use reductions. According to the upcoming NCHRP 20-5, 33-04 on IRVM, on average, 58 percent of DOTs’ newly planted acreage requires no significant maintenance work on a perpetual basis; 23 percent indicted that less than 20 percent of the newly planted acreage requires significant maintenance work on a perpetual basis. Around a quarter of responding state DOTs were aiming for 90 to 100 percent of planted acreage requiring no significant maintenance work on a perpetual basis.\(^{(ix)}\)

Iowa DOT was an early leader in the implementation of IRVM, which the agency understood as simply using the most cost-effective and ecologically-sound method of management on a site by site basis. The approach was based on the following principles.\(^{(x)}\)

1. Nature does not allow bare soils to exist.
2. Bare soils are revegetated by successions of plant groups until a most-fit community of plants develops.
3. Disturbance of the vegetative cover reverses the succession of revegetation back to the bare soil starting point, and therefore allows more invasions.

The emphasis on weed eradication rather than weed prevention has led to increased mapping of vegetation, statewide planning, and new maintenance/construction practices. Within IVM, various key elements of IPM systems have only recently been developed or recognized; some examples include: \(^{(xi)}(xii)\)

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Chapter 9: Roadside Vegetation Management
• Managing a pest with integrated control measures, including prevention and an emphasis on biological control (liken to the use of low-growing plant communities to naturally control pest tree populations).
• Growing emphasis on monitoring and assessment (including refined efforts to document a pest problem).
• Decisions based on tolerance levels (of pest species/noxious weeds).
• Professional-grade prescriptions of treatments.
• Formalized efforts to determine long-term efficacy and effectiveness of treatments.

Integrated vegetation management includes the use of cultural, mechanical, biological, and chemical practices. Each location must be evaluated to determine the method to be used. One or more of the following will be used:

**Cultural control methods** introduce and manage desirable plants and covers to control noxious weeds and other undesirable plants. Many native plants are poor competitors in their early stages of growth, but once established they crowd out most other plants with minimum management. Many agencies are using native grasses to control noxious weeds, since their dense, deep root systems inhibit weed growth. Both Minnesota and Iowa DOTs have found success in controlling noxious weeds, and Canada thistle in particular in Minnesota, using native grass stands. Controlled burning is recognized as a cultural control tool for enhancing and maintaining native plant communities, but DOTs are in the early stages of exploring and defining proper burning procedures and parameters.

**Mechanical methods, usually tractor mowing,** can involve anything from complete tillage for reseeding to hand scythes, shovels, string trimmers, push mowers, pruning shears, etc. for weed control and desirable vegetation maintenance.

**Biological methods** involve the use of animals, insects, bacteria or virus to control plant growth.

**Chemical Methods** are typically selected for use based on agency guidance, label constraints, and residual effects on the environment. Chemicals are generally monitored to document their effectiveness and impacts upon target and non-target species. There are several new herbicides with very specific effects on specific plant species which can be valuable tools for controlling undesirable plants on a short-term basis.

### 9.3. DEVELOPING IVM OR IRVM PLANS

To achieve the multi-faceted goals described above, using all the tools available in an efficient and environmentally sound manner, a number of DOTs are developing Integrated Roadside Vegetation Management Plans (IRVM) or Integrated Vegetation Management Plans (IVM). A survey undertaken for NCHRP 20-5, 33-04, to be published in late 2004, reports that implementation of integrated roadside vegetation management (IRVM) programs by official policy has occurred in Florida, Maryland, Minnesota, New York, Pennsylvania, Texas, and West Virginia, and that roadside
management plans were part of the implementation program in Florida, Illinois, Maine, Maryland, Minnesota, Montana, New Mexico, Ohio, Pennsylvania, South Carolina, Texas, Utah, and the provinces of Alberta and Quebec. (xiv)

The IVM plan identifies environmental constraints and gives the vegetation manager flexibility in management methods. Properly executing integrated vegetation management practices using a combination of methods can result in the conversion of rights-of-way to a plant community requiring minimal maintenance activities in the future. Integrated vegetation management balances service reliability, environmental compliance, and customer service while lowering the cost of maintenance over time. (xv) Working with utility communities and now NYSDOT, Nowak and Ballard of the State University of New York call IVM “a sophisticated system of information gathering, planning, implementing, reviewing, and improving vegetation management treatments,” which “differs from past management approaches to managing vegetation on ROWs in its greater breadth and complexity of management considerations, and in its higher level of sophistication and effort in evaluating management choices.” (xvi) As a continuous cycle of information gathering, planning, implementing, reviewing, and improving vegetation management treatments and the related actions, IVM constitutes an Environmental Management System for roadside vegetation.

New York State’s 6-Step Approach to IVM Planning and Implementation

Integrated Vegetation Management (IVM) has been used on powerline corridors for over 20 years in New York State, where a focus on culturing desirable plant communities that minimize the presence of undesirable plants has reduced treatment needs, and reduced herbicide usage by over half during that period. (xvii) Nowak and Ballard’s work with the utility industry and NYSDOT has involved a six-step approach to IVM that provides a framework for communicating, organizing, and conducting an IVM program. (xviii) The following step-wise system is summarized and adapted from Nowak and Ballard’s work for the utility industry and EPA. (xix)

Step 1: Understand pest and ecosystem dynamics

A first step to conducting IVM is to develop a working knowledge of the organisms in the managed system and how they interact with each other and the environment, with or without vegetation management, to produce ecosystem conditions. It is important to identify and understand:

- Species life histories (reproduction, growth and longevity), plant strategies, and responses to disturbance.
- Plant succession, changes in distribution and abundance of plants through time and space.
- How plants and communities can be manipulated to control the rate and direction of plant succession via interference, grazing, and other mechanisms.
Step 2: Set management objectives and tolerance levels

Tolerance levels are specific descriptions of vegetation condition—individual plant and plant community size, abundance, and composition—that, if exceeded, trigger a need to intervene. Undesirable species are not treated unless they exceed the critical threshold. Well-defined thresholds are a critical element of IVM that can be useful in communicating management needs to various stakeholders, e.g., thresholds and tolerance levels can be used to demonstrate the cyclic nature of vegetation dynamics, which supports a need to control vegetation on a regular basis. Stakeholders include vegetation management professionals responsible for management decisions on a particular ROW, landowners of the ROW or adjacent properties, governmental regulators responsible for administering State and Federal policies and laws, and non-governmental organizations with a general concern for the environment.

Step 3: Compile treatment options

Different treatment options may be needed to match variable environmental and site conditions, concerns and interests on a ROW. Vegetation treatments can be grouped into categories, such as: mechanical, chemical, cultural, physical, biological, and ecological; however, IVM does focus on integrating biological/ecological control into all treatment schemes. Creation of stable, low-growing plant communities is the long-term objective, and biological/ecological control produces a long-term reduction in treatment efforts, and a reduction in herbicide use.

Step 4: Account for economic and environmental effects of treatments

Economic and environmental considerations factor into choice of treatment. Cost effectiveness may be used as a measure of the success of a treatment in terms of economics, plant community dynamics, and related environmental considerations. Direct costs include labor, equipment, and materials to treat ROW vegetation, while indirect costs include the loss of values or service that can result from a treatment. The latter are often associated with water quality, pollution, wildlife habitat, and aesthetics, or other ways that the environment can be degraded. Effectiveness pertains to production of desired vegetation conditions and associated benefits and values with operation and management of the transportation corridor in the public interest, taking environmental interests and values into account. Cost effectiveness timeframes may be short- or long-term, and often, efforts must be made to balance short-term savings with long-term costs. For example, it may be monetarily less costly to mow a ROW today vs. use of herbicides, but mowing may produce higher costs over the long-term because of short-term control of vegetation conditions and shorter treatment cycles than can be achieved with other treatments. IVM is used to maximize cost effectiveness of management efforts, minimizing costs while creating the desired vegetation conditions and associated positive values associated with these conditions over the long-term.

Step 5: Develop site-specific treatment plans

After developing a suite of treatment options (Steps 2, 3 and 4), and weighing the effects of those treatments on long-term production of vegetation conditions and associated benefits and values, a treatment is chosen by the professional vegetation manager.
Prescriptions should not be written for whole ROWs, but are instead developed for specific sections of any one ROW and the constraints therein. It is important to base treatment choices on inventory and analysis of existing site and vegetation conditions, particularly because these data will be critical in monitoring outcomes of treatments, as outlined in Step 6. Prescriptions for different areas and circumstances of vegetation management should include:

- Desired future conditions of the ROW area to be treated
- Description of the treatment as a function of current vegetation conditions, and justification of treatments, considering ecological, socioeconomic, and administrative or fiscal factors. Treatment recommendations are the crucial part of the prescription.

Step 6: Monitor outcomes and revise and adapt management plans

Adaptive management incorporates learning from experience. Monitoring of the effects and performance of various treatments may include:

- Amount of materials used in treatment
- Treatment costs
- Vegetation conditions before and after treatment (e.g. quantification of changes in noxious weed cover)

In addition to vegetative community changes, herbicide residuals with chemical treatments, water quality, and wildlife populations can also be monitored and feed into the next round of treatment planning and decisionmaking. Vegetation conditions are compared to the desired condition set during the “Management objectives and tolerance levels” step (Step 2), and described in prescriptions during the “Site-specific implementation of treatments” step (Step 5). Any disparities between “desired” and “achieved” results are investigated, and future treatment options adjusted accordingly. Monitoring assures that treatment effects are gauged, and shortfalls corrected by improving management schemes to better accomplish management objectives.

To What Extent Are You Implementing IVM: A Self-Evaluation

Nowak and Ballard pose a series of questions, which maintenance managers may use to self-evaluate their current approach to vegetation management, and identify gaps between current systems and the integrated approach presented above. Numbers correspond to the steps presented previously.

1) Do you have a detailed, basic knowledge of the managed ecosystems?
2a) Do you actively involve stakeholders in vegetation management decisions?
2b) Do you consider tolerance levels when determining the need to treat vegetation (positive approach), or do you take a rote approach and treat vegetation only routinely (negative approach)?
2c) Are you proactive in vegetation management (e.g., treat vegetation in concert with tolerance levels, with decisions based on inventory and planning), or
reactive (e.g., “hot spotting”, where vegetation is treated after thresholds are soon-to-be, or already, exceeded)

3a) Do you maintain a broad range of vegetation treatments--mechanical, chemical, cultural, and biological--in your “toolbox”, and apply a variety of treatments depending on the site and vegetation conditions?

3b) Do you foster the use of biological/ecological controls to prevent pest populations from building past economic thresholds?

4) Do you use broad considerations of cost effectiveness in selecting a treatment for a specific site?

5) Do you prescribe treatments in a site-specific manner, based on a contemporary inventory of ROW resources?

6) Do you monitor the results of treatments to compare actual conditions vs. desired future conditions, and look to improve the system based on that comparison?

Iowa DOT’s Integrated Roadside Vegetation Management Approach

Iowa DOT was one of the first DOTs in the country to encourage an integrated vegetation management approach. Iowa DOT defines Integrated Roadside Vegetation Management (IRVM) as a long term approach to vegetation management that:

• Systematically evaluates each area to be managed.
• Determines which plant communities best fit the area.
• Develops procedures that will encourage, enhance, or reestablish desirable plant communities.
• Provides self-sustaining, diversified, visually interesting vegetation.
• Keeps safety and an improved environment as priorities.
• Utilizes the most beneficial methods to prevent or correct undesirable situations caused by disturbance or less than optimum vegetative ground cover.

Iowa DOT’s IRVM plan is brief and general, allowing adaptation by counties. Iowa DOT defines the prime purpose of roadside vegetation as holding soil in place without creating hazards. At the same time, Iowa DOT hopes to address other desirable uses for roadside vegetation (aesthetic, economic, and environmental) once safety and functional requirements are met. Thus, the goals of Iowa DOT’s Integrated Roadside Management Plan are to:

• Preserve and provide safe, functional and environmentally improved corridors of travel throughout the state.
• Utilize a long-term integrated management program that promotes desirable self-sustaining plant communities. Encourage those plant communities that are native to Iowa through preservation and re-establishment whenever practical.

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• Bring about considerable reduction and possible elimination of the use of chemicals as a control method of undesirable plants.

• Enhance the scenic qualities of the roadsides and their value as wildlife habitat.

To achieve these goals, Iowa DOT outlines the following procedures, which follow a Plan-Do-Check-Act process as follows:

• Inventory the sites to be managed.

• List the existing areas of desirable vegetation as well as those that need improvement.

• Determine the appropriate management methods needed.

• Determine the best time to implement management procedures and see that they are accomplished at that time. Temporary procedures may be needed to preserve an area before permanent procedures can be utilized.

• Evaluate the results periodically.

• Take further measures if necessary.

Once an IRVM plan is developed, communication must occur. Iowa DOT’s IRVM plan committed the DOT to:

• Develop a public awareness campaign to gain support for integrated management through media, established organizations, seminars and brochures.

• Develop educational and informational material on IRVM to be presented in seminars and distributed to adjacent landowners, the general public, consultants and contractors.

• Provide guidelines and directives for contractors and others who seed, plant and maintain roadsides.

• Prepare and distribute instructions to state, county and city personnel on preservation of desirable areas and treatment of areas that need improvement.

• Gather, develop and distribute information with other jurisdictions; seek and share information with other states.

• Encourage research in all aspects of IRVM, i.e.; road design for improving IRVM, planting methods, management practices, seed sources, seeding rates, seed mixes, planting equipment, etc.

• Encourage state production of native seeds and plant materials for use in the rights of way.

Iowa DOT and the Iowa State Legislature have supported establishment of an Integrated Roadside Vegetation Management center at the University of Northern Iowa.

Mn/DOT Process for IRVM Planning

Mn/DOT’s process for IRVM planning is detailed in the Minnesota Best Practices on Roadside Vegetation Management and summarized below. (xxxiv)
Preliminary Planning, Categorization and Goals

- **A local plan adapted to fit local culture, political concerns, and climate and environmental conditions is best.** 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.

- **Plan development should be a team effort,** with input from those people having expertise in 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.

- **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, whether urban or rural, or based on zoning, high or low traffic levels, or roadway type.

- **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.
  - **Flexibility.** 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 re-establish a wetland? Once the desired outcome has been identified, a plan can be developed to achieve it.

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, management techniques should be targeted 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.

**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 a fertilizer, compost, 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.

One way to assess the health of the soil is to send a sample to your state 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.

**Soil Considerations for Herbicide Use**

- Use lower application rates for coarse-grained soils and higher rates for fine-grained soils or soils high in organic material.
- Learn the potential for herbicide runoff before using it.
- Do not spray in steep slope areas if rain is likely since steeper slopes increase runoff.

**Native Vegetation**

There are three main reasons for preserving native plants:

- **Environmental**: There are no substitutes for the original wild species of your state. Once lost, their genetic material can never be re-created. Also, native wildlife often depend on native vegetation for survival.
- **Economic**: Native plant communities are relatively stable and require little maintenance. 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.
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.

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.

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.
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.

Mn/DOT’s Best Practices for Convincing Stakeholders, Decisionmakers, and Staff to Undertake IRVM

Mn/DOT notes that convincing maintenance staff and decision makers to adopt an integrated approach to roadside vegetation management may be challenging, and full implementation of an agency-wide IRVM program may take time. To that end, Mn/DOT recommends the following best practices 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.

**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.


As part of NYSDOT’s evaluation of their current vegetation management program and the agency’s “Alternatives to Herbicide” program, NYSDOT is developing a systematic framework and research protocol for identification, evaluation, and implementation of environmentally sensitive, lower maintenance, and cost effective vegetation management techniques that can be integrated into the overall vegetation management program. (xxxvi) To assist NYSDOT in this effort the State University of New York (SUNY) developed a Draft listed in the Appendix for “Metric for Assessing Performance of
Integrated Vegetation Management on Rights-of-Way,” drawing on three sources: 1) EPA model for Environmental Management Systems (ISO14001); 2) the Forest Stewardship Council and Smartwood’s assessment standards for sustainable forest management (see www.fscoax.org, and www.smartwood.org); and 3) Nowak and Ballard’s “Framework for Applying Integrated Vegetation Management on Rights-of-Way,” key elements to IVM are presented in the metric as general Principles (total=10) and sets of associated Criteria (total number of criteria=36), which constitute stewardship practices and measures.(xxxvii)

Assessments include interdisciplinary field meetings and interviews with staff; visits to a representative sample of roadsides; and review of standard operating practices, vegetation conditions, field performances, site challenges, and vegetation management innovations. A report is developed that presents findings and recommendations associated with each principle and criteria. Each principle will have highlighted strengths and weaknesses, and sets of commendations for successes and recommendations for program improvement.

9.4. INVENTORY OF AND MANAGEMENT FOR RARE SPECIES AND SENSITIVE RESOURCES IN THE ROW

Maintenance and construction crews are making increasing use of environmental GIS data at DOTs. DOT staff in construction and maintenance already use GIS layers depicting topography (including Digital Elevation Model, Digital Line Graph, and other topographic layers), hydrology (Streams, Lakes, Wetlands), and Geology (Bedrock Geology, Soils, Land Use, Karst Aerial Photographs).(xxxviii) Inventories of species in the ROW are now being used to support IRVM planning as well.

A large number of states are undertaking efforts to map stands of invasive species and noxious weeds with Geographic Positioning Systems (GPS), which can then be used to track progress of treatment. Iowa, Kansas, Maryland, Minnesota, Oregon, Oklahoma, Missouri, New Mexico, Texas, Utah, and West Virginia are among the state DOTs that have begun such efforts.(xxxix) For example, implementation of a mapping system is an element of the IRVM Plan for Mn/DOT Maintenance Area 3B. To accomplish this, CAD maps were obtained from Mn/DOT and plat books obtained from the county. The maps that were developed included 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. Paper-based map systems are widely being converted to Geographic Information Systems (GIS). NCHRP 20-5, 33-04 reports that Maryland and Utah have connected their IRVM plan to GIS and GPS.(xli)

A number of states are beginning to identify rare plant species in the ROW and tailor ROW management to encourage native species. California, Colorado, Delaware, Iowa, Missouri, Minnesota, and Wisconsin are among the DOTs which have begun to preserve high quality roadside remnant habitats.(xlii) These initiatives typically have several common elements:

- Mapped information is combined from multiple agencies. Typically, the primary mapped data on known plant locations of rare species is obtained from the state...
Natural Heritage Program. Other potential contributing agencies may include the state DNR or Forest agency, U.S. Fish and Wildlife Service, Bureau of Land Management, U.S. Forest Service, Native Plant Societies, Department of Agriculture, knowledgeable individuals, and local counties.

- Upon completion of the initial data compilation phase, field surveys are conducted in some cases.
- Special Management Areas are set up with particular management practices.
- Maintenance forces are educated regarding the special maintenance needs of and expectations in these areas.
- Tracking of species condition and progress, in some cases.

**Caltrans Biological Management Areas**

Caltrans began a plant community preservation program in 1994. Working with conservation groups, they identified more than 20 quality natural heritage remnants on highway ROW. Each Biological Management Area is signed and has its own management plan.

**Colorado DOT Maintenance Specs and Training for Management of Rare Species in the ROW**

Roadside resource management is an important aspect of the Colorado Department of Transportation (CDOT)’s Shortgrass Prairie Initiative, a programmatic consultation and proactive avoidance, minimization, and mitigation effort covering 36 listed and non-listed species and associated habitats that could be impacted by CDOT’s maintenance and construction activities on Colorado’s eastern plains over the next 20 years. As part of the agreement, the U.S. Fish and Wildlife Service (USFWS), the State Division of Wildlife, and CDOT negotiated best management practices to be employed in the right-of-way (ROW) and developed geographic information systems (GIS) and hard copy resources/maps that can be used by regional environmental and maintenance staff. Field training is being developed as well.

Management practices were recommended as follows: (xlii)

- If target plant(s) are present, mowing will be avoided until late in the season (mid-September) if possible.
- Re-seeding of disturbed areas will be with a mix of native graminoids and forbs wherever possible. Native mixes should be specified and/or approved by the CDOT landscape architect.
- Herbicide applications will be used only if the herbicide targets monocots but not dicots. If monocot targeted herbicides are used, timing of application is not an issue.
- Where road widening results in alteration of the hydrologic regime, efforts will be made to ensure that water flow is not interrupted.
• Habitat destruction for species and decimation of the original seed source population will be avoided to the maximum extent practicable during construction/widening.

Right-of-way management practices are designed with multiple, and sometimes conflicting, species needs in mind, and with attention to the maintenance and enhancement of ecosystem processes. This builds upon CDOT’s ongoing efforts to map patches of invasive, noxious weeds and sensitive areas in the ROW via geographic positioning systems (GPS), and selectively manage plant species to promote natives. The effort has been extended statewide and will incorporate management prescriptions and proscriptions.

**North Carolina Rare Species Management**

The North Carolina Department of Transportation (NCDOT) has been protecting roadside populations of rare plants since 1989, focusing on over 90 sites with federally listed species and a number of other sites with state listed species. NCDOT’s initial efforts emphasized marking these rare plant populations in order to prevent them from being mowed. NCDOT signed a Memorandum of Understanding (MOU) with the NC Department of Environment and Natural Resources in 1990 that committed NCDOT to protect populations of threatened and endangered species that occur on NCDOT ROW, and a MOU with the NC Department of Agriculture in 1996, agreeing to work cooperatively on a variety of plant conservation issues, including protecting roadside populations of federal and state-listed endangered and threatened species. For simplicity, NCDOT has established some general [statewide management guidelines](#) for areas marked for rare species as noted in the Appendix.

**Oregon DOT Special Management Areas for Rare Plants**

In 1994, the Oregon Department of Transportation introduced a voluntary Special Management Area (SMA) program designed to protect threatened and endangered (T&E) plant species occurring on its lands, drawing on information from the Oregon Natural Heritage Program and multiple agencies, individuals, and counties. The system helps ODOT apply the appropriate levels of protection within SMAs, and enables ODOT to maintain or increase population numbers and assist long-term conservation of these resources on public lands.

SMAs have special signs and activities are restricted. SMA signs installed at the edge of buffer areas for sensitive species are coded so maintenance forces understand which activities are and are not allowed. Maintenance personnel carry a “decoder card” that allows them to decipher the code on the sign. The code provides information that tells what type of maintenance activity is allowed (such as ditch cleaning, mowing, spraying, etc.) and when it is allowed (season). ODOT also developed an educational video and implemented training that was presented to ODOT maintenance crews and sign installation was initiated.
Field Signing has the benefit of giving ODOT maintenance crews information on correct management requirements for each SMA, defining the field limits of the SMAs, provides a clear optical reference so inappropriate management is not applied, and establishes continuity around the state. All SMAs in the state follow the same signing format, leading to less confusion and fewer impacts.

Thus far, 40 SMAs have been established for 14 different threatened and endangered plant species in 15 ODOT Maintenance Districts. Proactive late fall mowing has benefited two Willamette Valley species. The ODOT model is being adopted by Oregon counties and WSDOT, to manage rare species. Currently the SMA program is focused almost exclusively on flora (plants), however, other disciplines such as wetlands, fisheries, and possibly archaeology may benefit from the use of Special Management Area Signage. ODOT has noted that long-term departmental commitment and a good working relationship between Environmental Services, district maintenance crews, and state and federal regulators have been essential components in the effort’s success in protecting and enhancing populations of rare plants.

**WSDOT Threat-Specific Rare Plant Management**

During June and July of 1998 WSDOT conducted an extensive survey within 200 feet of US Highway 2 for its length of Tumwater Canyon. Biologists-botanists from WSDOT,
the Washington Department of Natural Resources’ Natural Heritage Program (WDNR-NHP), and the U.S. Forest Service participated. This survey disclosed the presence of three rare plants; one of which is proposed for federal listing as endangered and the others listed as state threatened and sensitive plants. An ortho photo with GPS points of rare plant locations was prepared and a GIS map, of much larger scale showing these same points, was prepared for the WSDOT Maintenance Office in Leavenworth and the Leavenworth Ranger District.

Actual/potential threats to rare plants were identified, highlighting ones over which WSDOT had control or influence. From that list, appropriate management practices were identified.

1. Competition and shading from native trees and shrubs
2. Competition from nonnative and/or state-listed noxious plant species
3. Wildfire and fire suppression
4. Activities associated with fire suppression
5. Plant succession in the absence of fire
6. Low seedling establishment
7. Roadside vegetation control by applying herbicides
8. Spreading of roadway anti-icers/deicers during winter months
9. Mass-wasting and soil erosion on unstable slopes
10. Motor vehicle exhaust emissions
11. Human trampling and collecting
12. Poor seed development
13. Low reproductive capacity

It was determined that WSDOT could do very little to minimize Threats numbered 3, 4, 5, 6, 10, 12, and 13. Those that WSDOT can assist to minimize (1, 2, 7, 8, 9, and 11) are covered below in the next sections.(xliii)

Minimizing competition and shading from native trees and shrubs

Rare plants can be threatened by competition and shading from native trees and shrubs. In some instances, the removal of hazard trees can help protect rare plants. At the same time, tree removal can impact rare plants if not done correctly.

WSDOT maintenance implements the following stewardship practices to reduce undesirable shading:

- Identify areas where trimming or removal of trees is desirable for maintenance.
- Contact the land manager (USFS) or regulatory oversight agency and come to agreement on the best approach, meeting on-site if needed.
- Employ identified BMPs.
Minimizing competition from non-native and/or state-listed noxious plant species

Nonnative and/or state-listed noxious plant species threaten rare plants by competition. Applying herbicides to weeds while performing roadside vegetation control can help protect rare plants. To this end, maintenance in areas with rare or endangered species involves the following stewardship practices at WSDOT:

- Inform the land manager/regulatory agency of spraying dates. Agree on best approach. Meet on site as needed. The land manager, in this case USFS, is responsible for weed control in immediately adjacent areas.
- Identify road segments where rare plants are absent and spraying can be conducted.
- Utilize selective control and hand application of herbicide when near rare plants.
- Employ BMPs for water quality, habitat, and worker protection.

Minimizing impacts to rare plants during work on ditches

To avoid adversely affecting rare plants near the highway while working on ditches, WSDOT maintenance forces employ the following stewardship practices in the vicinity of identified populations:

- Check the known locations of all rare plants.
- If rare plants occur within 2 m (6.6 ft) of the ditch and plant disturbance cannot be avoided, consult the land management/regulatory agency in advance. If another agency manages the area (such as the USFS), maintenance forces can identify work locations and ask the land manager to mark any individual rare plants on the day work will be done.
- Perform the maintenance and repair in accordance with agency procedures and stewardship practices for Water Quality and Habitat Protection.
- Remove all location markings from plants in the field.

Minimizing threats to rare plants from soil erosion on unstable slopes

To minimize rare plants being threatened by soil erosion on unstable slopes within the highway easement, WSDOT maintenance forces have committed to do the following for identified target populations:

- Check to determine if rare plants are known to exist in the unstable area.
- If within the area, mark all individual plants on the day work will be done.
- If the plant disturbance cannot be avoided, consult the land manager or regulatory agency.
- Perform the maintenance and repair in accordance with standard and agency best management practices.
- Remove all location markings from plants in the field.
Permanent solutions to chronically unstable slopes are undertaken by WSDOT’s Unstable Slope Program. In those cases, construction forces:

- Identify the areas with chronically unstable slopes.
- Consult with technicians from the Unstable Slope Program.
- Check to determine if rare plants are known to exist for each of the chronically unstable areas.
- If safety measures such as “scaling,” “bolting,” “netting,” “trim blasting,” “doweling,” “fencing,” and/or “rock buttressing” will be performed, consult the land manager and/or the regulatory agency for concurrence.
- If possible to revegetate the exposed areas, confer with the land manager or regulatory agency about using local rare plants or suitable noninvasive native plants.

**Minimizing threats from human intrusion, trampling, and unauthorized collection**

Rare plants that are threatened by human intrusion, trampling and unauthorized collection will require a conscious effort, on the part of land managers and the DOT to watch for such action or implement a monitoring program. If it is determined that such threats occur, both agencies will confer with one another to establish a contingency plan for minimizing the threat. Actions the DOT can take may include blocking newly constructed maintenance pullouts during flowering of rare plants or other measures if parking and public access become significant issues.

Annual training sessions will be conducted to assure that rare native plants, in the canyon, receive the attention required for their protection and sustainability. Field staff from both Design/Construction and Maintenance Divisions will receive training that includes discussion of the importance of the rare plants in their associated ecosystems, their natural history, and the roles each agency has agreed to play in the planned rare plant management strategies. Training should include a field review to point out individual rare plants, their specific locations, and advice as to what can and cannot be done to them. Such training should be conducted annually.

**Identifying new locations of rare plant species**

If new or additional rare plants are found, their type (common or scientific name) and specific location should be reported to DOT biologists, land management or regulatory agency biologists, and/or the state Natural Heritage Program, depending on the state DOT’s process for confirmation of plant identification. If confirmed, and depending on the location, it may be recorded as a new sighting and subsequently logged via GPS into the appropriate GIS database. The relevant state or federal agencies should be notified of the find and its location.

**TxDOT Rare Plant Management Partnership**

One of the major public landholders in Texas, a state with less than 10 percent public land, is the Department of Transportation (TxDOT). TxDOT manages over 750,000 acres of highway right-of-way. A 1989 survey of the Texas Biological
Conservation Database revealed 150 occurrences of listed or category plants on or within the immediate vicinity of highway right-of-way. To assure protection for these species, a project was undertaken between 1990 and 1994 to identify listed and non-listed rare plants occurring on highway right-of-way, collaboratively develop management agreements to protect these species, and establish monitoring plans to assess the effectiveness of the management. Of the 150 potential sites identified in the Conservation Database as possibly occurring on highway right-of-way, 57 were relocated, 15 were either not found or not found to be on highway right-of-way, and 88 were still being verified as of 1995. The management effort for species in the ROW led to establishment of 26 management/monitoring areas; monitoring/management agreements were maintained between TxDOT and the Texas Parks and Wildlife Department until the program ran out of money several years later. A total of 33 populations representing 26 species were monitored while the program was in effect, and data collected in that period indicated that about two-thirds of the species’ populations increased or remained stable under the agreed upon management regimes. Decreases were usually assignable to drought, but occasional abnormal habitat disturbances such as fiber optic cable placement contributed as well. However no decreases in either population numbers or vigor were attributable to TxDOT management. TxDOT placed “No Mow” or “Wildflower Research Area” signs were placed around some rare plant populations. In a few areas reflector posts cordoned off populations, to help keep mowers out.

Oregon DOT GIS-Based Sensitive Resource Inventory

The Oregon Department of Transportation (ODOT) has developed a geographic information system (GIS)-based inventory of sensitive resources and erosion control problem areas along nearly 6,000 miles of state highway as part of its Salmon Resources and Sensitive Area Mapping Project. The primary purpose of the project is to provide accurate resource protection maps to roadway maintenance crews so that mowing, pesticide application, and other activities do not harm listed salmon species and other sensitive resources and so that streams and banks in poor condition might begin to be addressed.

The comprehensive resource inventory was developed by using color infrared digital imagery with 2-foot resolution. Other sensitive resource features were recorded from current knowledge bases and limited roadside surveying, and from modeling of interactions between multiple resources and data layers. After distance to water, stream and bank characteristics, known threatened and endangered species locations and the overall condition of the salmon and trout habitats were identified. ODOT compared the imagery to previous data collected from other sources, such as wetland information from the National Wetland Inventory and hydrographic data from the U.S. Geological Survey to update and validate these findings.

GIS maps were tied into ODOT’s linear referencing system, which enables ODOT to identify the locations of sensitive natural resources features within a hundredth of a mile. From this GIS resource, ODOT’s Transportation Inventory and Mapping Unit and the Information Systems Branch developed a series of detailed resource maps in 0.01-mile segments, which indicate where sensitive resources are present including which side of the road. Based on the potential for environmental harm, certain restrictions were
developed for each mile of highway. This information was then placed on restricted activity zone maps. These maps were designed to alert ODOT staff to specific locations of sensitive natural resource features in order to avoid inadvertently harming wildlife or wetlands when performing routine maintenance practices, such as slope maintenance, snow removal, and vegetation management. They also served to help minimize the potential for violations of the Federal Endangered Species Act and the Clean Water Act. ODOT supplied these maps to all districts, for use by biologists, planners, and maintenance managers. Laminted Restricted Activity Zone Maps for maintenance use a simple color-coding scheme of green and red to indicate, for each major class of maintenance activity (e.g., surface and shoulder work, vegetation management, snow and ice removal, etc.), whether or not that activity should be restricted along the left or right side of a given 0.01-mile segment of highway.

For approximately the same cost as field surveys, ODOT produced better quality data that was less subject to individual interpretation, and covered over a much larger analysis area—1,000 feet from the roadway centerline, without concern for access/trespass issues. By using remote sensing techniques to collect and map data, ODOT recognized significant savings, both in cost and time. Before turning to advanced imaging technology to help implement this project, ODOT had been sending three two-person crews into the field for three and a half months to physically capture data. Once the digital imagery provided a base map to work from, the field crews were able to focus their energies on data validation instead of data capture. It also reduced the amount of time and resources needed to one two-person crew for two months, allowing for a quicker solution to the increasing problem of deteriorating wildlife habitats. Had ODOT chosen not to use digital imagery to map these sensitive areas, the results may have been significantly less accurate and outdated within a short period of time. In fact, some natural features may not have been inventoried at all as they would have been inaccessible to the field crews or too expensive to map across the entire state. The methodology developed by this project is easily adaptable for other state projects.

The library of geographic information system (GIS) data resulting from the project has given ODOT’s regional staff a detailed environmental inventory of ecological resources, facilitating consideration of sensitive natural resource features when planning and designing transportation system improvements. The maps have proven to be a reliable, desktop scoping tool. The GIS system, data layers, and existing modeling routines facilitate easy updating as new information and aerial photography becomes available. ODOT is now developing an internet-based application to enable wider desktop access to the information. Because the inventory data is digital and easily transferable between agencies, ODOT can also easily share this data and streamline communication processes with the National Marine Fisheries Service, the Oregon Department of Fish and Wildlife, the USFWS, and the U.S. Army Corps of Engineers. ODOT’s Resource and Restricted Activity Zone Maps were also key to negotiation of programmatic consultation for maintenance operation activities with the National Marine Fisheries Service (now NOAA Fisheries), under the federal Endangered Species Act (ESA). Specifically, ODOT received an exemption under 4(d) of the ESA allowing crews to perform routine road maintenance without having to consult with NOAA Fisheries on individual actions. ODOT is also exploring real-time geographic positioning system (GPS) connection to  

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maintenance vehicles, as well as herbicide application spray booms to automatically activate and deactivate applicators as needed to avoid impacting sensitive resources including streams, wetlands, or rare plant populations.

**Wisconsin DOT Characterization of the Karner Blue Butterfly Habitat in the ROW**

As part of Wisconsin’s Statewide Habitat Conservation Plan (HCP) for the Karner blue butterfly, the Wisconsin Department of Transportation (WisDOT) conducted an initial inventory of high potential corridors for the presence of lupine along state highway ROW, using soil types as a simple key indicator. Management for the Karner blue butterfly also benefits a number of other state-listed species and federal species of concern, including plants, turtles, lizards, and other butterflies.

WisDOT’s primary strategy for maintaining butterfly habitat is to manage ROW to provide for corridors of dispersal between larger butterfly population centers via habitat in the ROW along corridors controlled by DOT. USFWS and Wisconsin DNR see the corridors as important in creating connectivity, short-term refuge areas, and dispersal corridors. This strategy includes the following measures for areas with high potential for presence of the Karner Blue Butterfly (KBB), as determined by soil type: 1) selective mowing that avoids the growing season except immediately adjacent to travel lanes, 2) lupine seeding after construction projects in appropriate soils and locations, 3) removal of brush and trees during the non-growing season to assure continued lupine habitat (2-5 year basis for mowing), 4) mitigation for permanent take or removal, 5) monitoring KBB/lupine populations through annual surveys, and 6) public education. WisDOT corridors meeting the following criteria were included in the agreement: 1) those within high potential range of KBB, typically upland sandy soil areas in central and northwestern Wisconsin, 2) corridors that already contain significant wild lupine populations or KBB, and 3) those close to, or connected with other KBB HCP lands that have potential for similar management.

WisDOT also implemented an internal education and training program for maintenance crews and other appropriate field personnel regarding KBB and lupine identification. Herbicide use is limited to spot applications for invasive weeds and cut stumps. WisDOT shares roadside management techniques and information with counties and towns upon request.

The overall Habitat Conservation Plan brought together 26 partners, including eight counties, the WisDNR, and WisDOT. WisDOT undertook a species and habitat conservation agreement with the state DNR, which, in turn, has a statewide HCP and Incidental Take Permit with the USFWS. The implementation agreement covers approximately 4,000 acres for 10 years.

**Canadian Practices for Vegetation Preservation from Winter Maintenance**

The Transportation Association of Canada makes the following suggestions for protection of sensitive plants in the ROW from winter maintenance practices:

- In urban areas protect newly planted conifers by erecting burlap screens during the winter months;
• In urban areas consider applying anti-desiccants and anti-transpirants to the tender shoots of sensitive plants;
• Sweep salt laden grit from turf areas as soon as possible in the spring;
• Shield natural areas from salt spray by planting buffers of salt tolerant species; and
• Where feasible and cost-effective consider using snow fences (living or structural) to reduce snow accumulation on roadways or to trap salt spray and prevent it from traveling far from the roadway.

Other Cultural Control Methods

While fostering native vegetation is the most common cultural control method, goats or sheep are used for control of herbaceous weed species in a few areas. Pulling of invasive weed species is the method of choice sometimes due to environmental constraints and high leverage gripping tools have been used to pull woody plants.\textsuperscript{xlvii} The New Mexico State Highway and Transportation Department developed an experimental project for noxious weed control along a six-mile section of state highway in Taos County, using goats.\textsuperscript{xlviii}

9.5. \textbf{Reduced Mowing Policies and Other Mechanical Vegetation Stewardship Practices}

Mowing provides sight distance and room for a vehicle to pull off the road. Intersections, bridges, sharp curves, and farm and field entrances require periodic mowing to maintain a safe ROW. Mowing roadsides is a highly visible aspect of vegetation maintenance that also contributes to corridor aesthetics and public satisfaction. It is also very expensive in terms of personnel hours, equipment hours, and fuel consumption. Reduced mowing practices, which were initiated as early as the 1950s by Wisconsin DOT, expanded to many more DOTs in the 1970s, when high energy costs forced vegetation managers to mow less and spot spray, with the positive consequences such as increased wildlife habitat, enhanced natural beauty, minimized herbicide use, reduced maintenance dollars, and public acceptance.\textsuperscript{xlix} NCHRP 20-5, 33-04 indicates that state DOTs remain heavily dependent on mechanical control methods, with the bulk of states cutting over 90 percent of their ROW, a smaller set having reduced mowing to 50 to 90 percent, and only Florida and Washington indicating less than 50 percent was managed using mechanical methods.\textsuperscript{l}

In recent years, mowing policies have been tied to impacts of habitat in the right-of-way for ground-nesting birds. DOTs are in the process of converting away from traditional turf species in the ROW to those that require less maintenance. Plant growth regulators have been used on less desirable species in some cases, to reduce maintenance inputs and mowing cycles;\textsuperscript{li} however, many DOTs are now exploring policies reintroducing or allowing native grasses and restricting mowing to one mower-width along the shoulders to conserve resources, foster habitat, improve the spread of native species and move toward the displacement of noxious weeds.
In sum, reduced mowing can provide the following environmental benefits:

- Conserve staff hours spent mowing;
- Conserve fuel usage and costs;
- Conserve air quality through reduced spent fuel emissions;
- Conserve habitat for protected and declining populations of ground nesting birds
- Conserve required equipment maintenance; and
- Conserve habitats through reduced fragmentation.

**Developing a Mowing Policy**

Mowing policies help make best use of maintenance staff time, assist in the prioritization of areas to be mowed and not mowed, help achieve environmental stewardship objectives, and increase safety for mowing staff and improve public relations. Mowing policies can also reduce environmental damage that can be caused by mowing, where mowing does occur. Improper mowing can generate additional maintenance problems and adverse effects to soils, roadside habitat, and nesting birds. Improper mowing height and overly 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. Planning and following a policy with regard to mowing and educating staff regarding proper mowing procedures can help DOTs avoid some of these problems.

When developing a mowing policy, a DOT should consider the prioritization of mowed and unmowed areas, safe operating practices, noxious weeds, and expected or required cost reductions. Mowing staff will be able to provide important input 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.

The following practices will contribute to development of a good mowing policy:

- Objective of mowing
- Impacts if mowing is reduced
- A communication plan between mower operators and weed sprayer operators
- 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

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.

**Mn/DOT’s Mowing Policy and Practices**

Mn/DOT’s mowing 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.

Minnesota has a mowing law that regulates mowing outside the metro area, according to the following requirements:

- The first eight feet from the roadway surface may be mowed.
- 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.

Mn/DOT statewide requirements for mowing widths include:

- Mow all grass to a minimum height of 100 mm.
- Mow all of the shoulder.
- Mow two swaths of the mower on all in-slopes.
- Mow the entire median for those less than 17 m wide, and for medians greater than 17 m wide, mow two-swath widths.
- Develop a smooth transition when blending between mowed and unmowed areas.
- For safety reasons operators should avoid slopes greater than 3:1, be alert and slow down in high grasses, avoid traffic, and wear all approved safety equipment.
- Keep signs clear and their approaches mowed from approximately 150 m.
- Keep vegetation around guardrails controlled for approximately 0.5 m on either side to reduce the effects of trapping sand, snow, and dirt.
- Maintain sight distance at at-grade intersections, interchanges, and curves.
• Other highly recommended practices include:

• Identify noxious weeds that can and should be controlled by mowing (at least in part), identify location of patches, and thresholds when mowing should occur for these areas (such as when patch area exceeds a certain size).

• Identify noxious weeds that should not be mowed or conditions under which they should not be mowed, to avoid inadvertently spreading these weeds (e.g. leafy spurge).

• Communicate with other maintenance staff to avoid mowing areas soon after or just before spraying, and to avoid mowing areas of leafy spurge.

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.

• 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.

*Mowing to Enhance Native Species*

EPA’s Great Lakes Environmental program recommends mowing as “the primary management tool used to prevent weeds from shading prairie seedlings.”

- During the first growing season the planting may need mowing a number of times. The cutting height should be 4 to 5 inches.
- Mow each time the weed growth is 6 to 10 inches high and do not allow weeds to set seed. Do not worry about cutting the tops off or crushing the seedlings. A flail-type mower is preferable for large areas because it chops cuttings into small pieces which will filter down and serve as mulch. If a sickle-bar or rotary-type mower is used, mow more frequently so cuttings will not have become large enough to smother native seedlings.
- Try to time the last mowing so weeds can grow to about 8 inches before winter. This will help protect young seedlings from heaving frosts. During the second growing season one mowing may be helpful in late spring or early summer if weeds are thick. This should be the last mowing needed for weed control unless a serious problem occurs. Raise cutting height to 6 to 12 inches if mowing during second year.

**Nebraska Department of Roads’ Mowing Policy**

The Nebraska Department of Roads (NDOR)’s mowing policy states that limited mowing frees workers to do more important maintenance and provides benefits including a living snow fence and habitat for animals in some cases. 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 a slope indicator in them to provide additional information. NDOR mows to a minimum of 5-inch cut height. Its first mow 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.

<table>
<thead>
<tr>
<th>Type of Highway</th>
<th>Area</th>
<th>Mow width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate</td>
<td>Median</td>
<td>5-8’ if flowers present</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5-15’ if no flowers present</td>
</tr>
<tr>
<td></td>
<td>Outside</td>
<td>15’ maximum</td>
</tr>
<tr>
<td>Other highways</td>
<td>Outside</td>
<td>5-15’ with surfaced shoulders</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15’ with turfed shoulders</td>
</tr>
</tbody>
</table>

Nebraska performs a second mow 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. It 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, NDOR issued a memo of understanding with the state game and parks commission specifying frequency of mowing, mowing widths, and safety standards.
Wisconsin Department of Transportation Mowing Policy

The Wisconsin DOT adopted a Natural Roadsides philosophy in the 1950s when it became apparent that it would be fiscally impractical to mow the entire highway rights-of-way on the new 4-land divided highways that were being built. A limited mowing policy was written and is still in place today, with some modifications. WisDOT’s current mowing 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. According to WisDOT, the 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

VTrans Vegetation Mapping to Control Invasives and Reduce Mowing

The VTrans vegetation management study identifying and mapping vegetation types along Vermont’s Interstate system, utilizing survey quality GPS equipment and GIS mapping technology to create a base map of roadside vegetation. VTrans added an inventory of plants in general to their inventory, to address sustainable forest management along VTrans ROW and other VTrans owned property. Rare species had already been mapped by the State Natural Heritage Program, which VTrans then used to develop vegetation management plans. Maps generated by public agency and water supply agencies were overlayed with highway ROW to identify areas where no spray zones may be needed. The NE Plant Protection Program assisted VTrans with overlaying these maps. VTrans has allowed the Program to monitor and inventory and they come up with management plan, including how to avoid harming rare species through spraying. Paper maps have been entered into the GIS system. VTrans is also collecting rare species and seeds, based on the maps, ahead of construction activities. Invasive species identification, mowing reductions, and ongoing monitoring of these management tools are the major current emphases of the program. VTrans anticipates that future management decisions on mowing will be able to utilize data collected and mapped through the program.

Chapter 9: Roadside Vegetation Management
NCDOT Mowing Program Modifications to Encourage Wildlife Native and Rare Plant Species

NCDOT implements their mowing program with an environmental perspective to encourage wildflowers, protect rare or endangered plants and protect or create wildlife nesting areas. Currently NCDOT protects over 35 populations of rare plant species growing along its roadsides. Most of these plants are listed as federally threatened or endangered by the U.S. Fish and Wildlife Service (USFWS). Endangered species such as Smooth Coneflower, Schweinitzii’s Sunflower, Michaux’s Sumac, Rough-leaved Loosestrife and Cooley’s Meadowrue often occur along roadsides and in powerline rights-of-way, or in natural habitats that were once dominated by fire but are now mowed to mimic fire maintained ecosystems. Other species are listed as significantly rare in North Carolina. NCDOT works with USFWS, the North Carolina Natural Heritage Program and the North Carolina Plant Protection Program as well as different utility companies to protect these roadside and powerline populations of rare species. Endangered plant populations are marked with white-topped wooden stakes, an indication to mowers that the area is off limits during the growing season. These areas are managed on a site by site basis according to their individual needs. Management strategies to control invasive woody vegetation include mowing during the dormant season, hand pruning and prescribed fire. Effective communication among environmental biologists and horticulturists, environmental engineers, and roadside maintenance personnel is crucial to the success of this program. NCDOT cooperates with the North Carolina Wildlife Commission in posting and managing small game wildlife habitat areas in the ROW. Properly timed cleanup mowings enhance wildlife habitat.(liii) For more information, see and overview of NCDOT’s program in section 9.4, Inventory of and Management for Rare Species and Sensitive Resources in the ROW.

NYSDOT Stewardship Mowing Practices

General NYSDOT mowing guidelines are outlined in NYSDOT’s Mowing Limits Manual, Highway Maintenance Subdivision Operational Guidelines, and Environmental Handbook for Transportation Operations. The Mowing Limits Manual addresses safety, water quality and erosion and sedimentation control, appearance and screening, landscape plantings and woody vegetation, and natural revegetation. NYSDOT's Environmental Handbook for Operations outlines the following stewardship practices and expectations for mowing, which go beyond mowing reduction policies to address other environmental features in the ROW: (liv)

- Ditches are mowed to control vegetation rather than mechanically cleaning ditches with heavy equipment because mowing causes less erosion of exposed soil and can result in improved water quality.
- Wetland mitigation areas are not mowed. Permanent markers are installed around these areas.
- Since many federally-protected ground nesting migratory songbirds and waterfowl nest prior to July 1, mowing of large relatively flat areas located outside of built up or developed areas (such as on the interstate system) is avoided.
or limited during nesting season. In advance of mowing likely nesting areas are identified and marked.

- Areas that are managed for wildflowers are not mowed more than once a year and after the first hard frost or in the late fall.
- A minimum 3 meter (10 feet) unmowed buffer strip is left along the edge of all streams and wetlands.
- Mowing is avoided on days when ozone levels are expected to approach or exceed unhealthy levels and voluntary actions are needed to reduce emissions and formation of ozone.
- Mowing is restricted or avoided in habitats for threatened or endangered species.

In addition, NYSDOT is implementing Conservation Alternative Mowing Plans (CAMPs) that preserve safety and aesthetics while maintaining safety and aesthetic standards. CAMPs involve identification of rich landscapes as part of the maintenance planning process, threshold values for several species and suitable habitat in the landscape, species or groups of species to be used as indicators, and the barrier effect of roads. CAMPs have been successfully developed and implemented on Interstates, Expressways and Parkways at NYSDOT through a multi-disciplinary team approach, culminating in the following guidelines, using four zones that describe to the operators what management is expected in the different zones. A High Management Zone is comprised of an intensely managed area immediately adjacent to shoulder or curb; a Frequently Mowed Zone next to it is mowed multiple times per year; an Annually Mowed Zone provides a transition between the Frequently Mowed Zone and No-Mow Zone (or left to regenerate naturally); and a No-Mow Zone is left in natural state or left to regenerate naturally. The following stewardship practices are taken from NYSDOT’s draft CAMP guidelines:

- Generally, the Frequently Mowed Zone will be 30 feet in width or will be set at the back side of the drainage ditch. The limits of this zone may be reduced or extend further depending on actual site conditions.

- The limits of the Frequently Mowed Zone may require adjustment to preclude the development of annually mowed areas that are too narrow (less than 60 feet wide), too small (less than 2 acres), or too linear. Annually Mowed Zones will not be mowed until after August 1st. Annually mowed zones should be mowed no more than once per year, however to further increase the conservation benefits, these areas may be mowed less frequently but with due consideration of the desire to limit establishment of woody plants within periodically mowed zones.

- The decision to include an annually mowed zone should consider many factors including, the adjacent land use and the width and length of the area. Since the annually mowed zone is important for ground nesting birds, these areas should be at least 60 feet in width and greater than 2 acre in size to reduce nest predation and allow a large enough nesting territory. Annually mowed areas will be most effective when located adjacent to or in close proximity to existing grassy fields and in these situations should extend to the limits of the ROW. When the
adjacent land use is mature forest, the annually mowed zone should not be included or should be combined with a no-mow zone, as appropriate.

- For consistency, Mowing Limit Markers should only be placed at the transition between the Annually Mowed Zone and the No-Mow Zone (the markers can be placed to create a natural appearing, meandering boundary.) Markers should be standard wooden or fiberglass stakes. Over time, the need for these markers should diminish as the demarcation of the zones becomes well established. These zones should also be captured electronically using GPS. Mowing Limit Markers should be placed with due consideration of sight distance. This is especially important at entrance/exit ramps. The No-Mow Zone shall not encroach into the sight distance cone and restrict visibility.

- The No-Mow Zone can be left to regenerate naturally. This process is termed succession. The final stage of succession is a self perpetuating, sustainable, and interdependent community of plant and animal life. The establishment of No-Mow zones is intended, in part, to permanently reduce the amount of mowed area and to reduce the negative environmental effects of habitat fragmentation.

- On narrow medians (less than 120 feet between the High Management Zones), new No-Mow zones may be established between the 30 foot minimum Frequently Mowed Zones with due consideration for maintenance structures such as drainage ditches, deer reflectors, living snowfences, etc.

- New woody plantings can be included to the No-Mow Zone. The purpose of these plantings should be to increase diversity of the plant community.

- Careful consideration should be given to any new planting of trees and/or shrubs in the Annually Mowed Zone. In addition, new plantings should be grouped in such a manner as to preclude the necessity of maintenance personnel to mow around individual plants. Supplemental (new) plantings can be included to correct existing conditions by “filling in” the spaces between the existing plants where mowing is difficult or not possible. Living snowfences, wildflowers or deer reflectors may also be included in this zone. All new planting in this zone should be carefully coordinated with NYSDOT Maintenance to insure that it can be maintained without undue effort. Any exceptions to this rule must be agreed to by NYSDOT Maintenance.

- Any dead and/or dying trees should be carefully reviewed for potential hazard. If it is determined that the tree would not cause a hazard if it falls, consideration should be made to leave the tree standing. Dead trees provide cover, nesting cavities and perches for birds and small animals.

- Vegetation management practices may be modified depending on the characteristics of the land use adjacent to the corridor (urban, suburban, and rural). Urban corridors may be expected to have a greater proportion of High Management and Frequently Mowed vs. Annually and No-Mow Zones. Additionally, Parkways and Expressways may require different management due to the nature of the different roads.
VTrans Characterization of Roadside Vegetation to Reduce Mowing and Manage Invasives

VTrans has been characterizing vegetation along the interstate, in the hope that mowing can be limited in certain areas where it is not needed for the maintenance of safety zones. The project is identifying and mapping vegetation types along Vermont’s Interstate system using survey quality GPS equipment and GIS mapping technology to create a base map of the vegetation along these roadways. An emphasis of this project is the identification of invasive species, as the mapping and future updates will be used as a monitoring tool to monitor the spread of invasive species along Vermont roadways.

Mowing Management in Southern Quebec, Canada

According to a study commissioned by the Ministère des Transports du Québec, traditional methods of controlling vegetation along the agency’s 2000 km of highway corridors in southern Quebec (Canada) “result in a boring landscape, deteriorate the various wildlife habitats and impoverish wild plant life while generating high maintenance costs.” Recently, the agency has pursued develop new maintenance methods, including elimination of multiple annual mowings, to improve the safety of the highway system’s users, satisfy neighboring residents, beautify the landscape and consider the plant life and wildlife present along the highways. The new approach eliminates multiple mowings except on the first two meters from the pavement, which will be mowed more frequently to ensure highway safety (visibility) and better control of the allergen, ragweed. The agency and its researchers have also been monitoring the slowly increasing biodiversity in the unmowed area since 1998.\(^{(lvii)}\)

Oregon DOT’s Mowing and Brush Removal Practices

Oregon DOT’s mowing, trimming, removal of brush and cleanup practices are designed to restore sight distance, reduce ice (due to shading), and to control/prevent slope failure.\(^{(lviii)}\)

- Local Integrated Vegetation Management Plans identify mowing areas, and are designed to minimize impact to receiving waters while still maintaining grassed areas.
- ODOT Maintenance actions will limit mowing to no more than 8 feet off edge of pavement in significant resource areas, unless needed to maintain proper functioning of highway features (e.g. drainage).
- Cut brush, in riparian areas, will be left in place where doing so does not interfere with sight distance, create safety issues, cause fire hazards, involve noxious weeds or the proper functioning of highway features (e.g. drainage).
- ODOT Maintenance will maintain shade trees along streams and rivers, unless those trees are danger trees (as determined by ODOT Forester and/or appropriate resource agency), could potentially impact bridge structures, or could impact line of sight. If trees provide shade or bank stabilization within 50 feet of...
streams and are determined to be danger trees that must be removed, tree removal will be coordinated with ODFW or other regulatory agency.

- Only brush within 20 feet (on either side) of and under all bridge structures will be removed. All other brush not within ODOT’s clearzones will be left in its current condition, unless the brush interferes with sight distance, shades the structure, or the brush is a noxious weed (e.g. scotch broom). Mapping of sensitive resource areas may lead to additional areas not being brushed.

- On culverts 6 feet or greater, ODOT Maintenance will remove 10 feet of brush on both sides of the culvert, on the upstream end of the culvert and 10 feet on both ends on the downstream side, unless the brush around the culvert is a noxious weed. If other brushing needs are identified, ODOT will coordinate with ODFW. When removing mature trees (over 12-inch (30cm) diameter at breast height (dbh)) in riparian areas, ODOT will replant two seedling/cuttings for every tree removed. ODOT will coordinate with ODFW on species and location of trees to be replanted within the same watershed. ODOT will ensure that the replanted trees will not pose a future threat to ODOT structures.

**Other DOTs with Brush Control BMPs**

NCHRP 20-5, 33-04 reported that Arkansas, Connecticut, Illinois, Maryland, Pennsylvania, Texas, and West Virginia have identified BMPs for mowing brush/small trees on their roadsides. (lx) Illinois, Nebraska, New York, and Texas had BMPs for other horticultural activities including best management practices for controlling trees that are or may be roadside obstructions and tree trimming by contract, in addition to general brush control guidelines. (lx) Alaska, Connecticut, Illinois, Maryland, Nebraska, New York, Pennsylvania, Texas, and Utah indicated they have best management practices for controlling trees that are or may be roadside obstructions. (lxii) The author is aware of brush control BMPs in use in Delaware, Kentucky, and Oregon, some of which are summarized in the previous section.

**9.6. CONTROLLED BURNING**

Controlled burning or prescribed fire is a carefully planned and controlled fire conducted to manage natural areas such as prairie, oak savanna, wetlands and oak woodlands. Prescribed or controlled burns have been used by land managers for over 25 years in modern history and for over hundreds of years by Native American tribes. Fire kills the above ground parts of shrubs and small trees. Prairie plants grow more vigorously when built-up plant materials and shade are removed. Spring fire uncovers the soil, so it warms sooner, thus extending the growing season. Roadside areas across the United States are the site of important remnant native grassland habitats, many of which can be enhanced by management by fire. Controlled burning offers the following benefits: (lxii)

- Control weeds and woody invaders
- Stimulate the growth of many native prairie plants
- Remove thatch
- Recycle nutrients
- Warm the soil and give warm-season plants an earlier start.

After two growing seasons, planted prairies need to be burned annually for the next several years to become well established (mature prairies with no serious weed problems may need burning only once every two to four years).\(^{(lxiii)}\)

- Always use caution when burning.
- Check local fire regulations and obtain permits.
- Try to burn or mow only one-third of the prairie area each year to preserve overwintering insects, their eggs and pupae.
- Always plan fire safety into plantings, even if you are not going to use burn management. Prairie fires intentionally or accidentally set during fall or spring dormancy can burn very rapidly.
  - Use any existing features such as roads, driveways, streams, lakes, or mowed lawns as fire breaks.
  - In addition to paths through a prairie, also include a wide path around the perimeter.
  - A mowed lawn buffer 20 feet in width between buildings and prairie is advised.
- An alternative to burning is to mow in late fall after seeds set or preferably in early spring (late March to mid-April). Sites that are too wet in spring need fall mowing when soil is dry.
- If burning does not occur periodically, cuttings need to be removed to avoid a thatch layer buildup.
- Do not cut and then burn large quantities of plant material (creating thick piles) or you will sterilize the soil beneath.

Before undertaking a controlled burn, staff must be properly trained and plans developed. Planning considerations should include:

- Traffic safety. Any burning plan must include smoke management provisions for safety purposes.
- Weather conditions.
- Equipment.
- Staffing.
- Timing. Burning is most beneficial from mid-April to early May for warm-season grasses. As with spraying growing weeds, burning earlier is better for wildflowers, and waiting does more harm than good.
Controlled burning is practically explained by Wayne Pauley in his *How to Manage Small Prairie Fires.* The Missouri Department of Conservation recommends the following practices for controlled burns, drawing on Pauley’s work:

While fire management requires training and knowledgeable individuals, it takes “as little as a few hundred dollars in equipment, including drip torches, rakes, and safety clothing…Roadside prescribed burns are easy. The road is one fire break and the others can be a mowed field of harvested hay or lawns.” Staff undertaking burns should be forewarned that corn stubble and older fence posts smolder.

Additional information regarding proper burning procedures can be obtained from the Fire Management and Research Program at The Nature Conservancy (850-668-0827) or your state resource agency. The Texas Parks and Wildlife Department (TPWD) uses an on-line burn plan form for controlled burns on state property and provides a [Sample Burn Plan](#).

**Controlled Burning or Hay Removal as Roadside Grassland Management Alternatives to Mowing**

Mn/DOT and the University of Minnesota have been exploring whether mowing can be as effective as yearly burning at encouraging native prairie grasses and discouraging botanical invaders. A research team investigated the impacts of burning and mowing on three separate test areas, examining above-ground vegetation and below-ground fungal communities, as well as measuring changes in various soil parameters. Findings and recommendations were as follows: (lxvi)

- Prescribed burning has the strongest effects on plant community composition and was the most effective method to increase aboveground plant biomass in a restored tallgrass prairie. Burning especially favors warm season grasses and legume species, though it also favors certain annual species. Also, when immediate grass cover is desired, burning is the best maintenance technique available to increase grassland productivity.

- When burning is not an option, haying may be the next best alternative. The addition of lime may be important to consider on restorations of former agricultural lands.

- Adding lime to hayed prairie may help benefit the cool-season plants, native and exotic.

- Spring haying is an acceptable alternative to spring burning, though its effects are less dramatic than the burn. In particular, haying does not favor warm season grasses as extensively and may not damage cool-season species as thoroughly as burning. Spring haying did not control exotic species.

- Burning and haying provided the greatest increase in arbuscular mycorrhizal fungal structures, which may correspond to the increases in plant growth on these treatments. In prairie restoration, addition of arbuscular mycorrhizal inoculum appears to provide long-term benefits.
• Mowing the prairie in the spring has a similar affect on the plant community as no management. It is only useful for the control of woody species. Mowing may decrease nitrogen mineralization rates temporarily. This may help to prevent invasive species but is not likely to do so if mowed annually.

• Frequent burning or haying should be performed in order to prevent the accumulation of inorganic soil nitrogen, which may favor many weedy species. If haying is used instead of burning, soil pH should be tested periodically to detect acidic soil. Although this did not become apparent on this experiment, it may occur on long-term hayed grasslands. Acidification may lead to decreases in certain plant populations or losses in productivity.

• The process of removing litter seems to be the most important cause of the ecosystem response to prescribed burning. Hayed plots are the most similar to burned plots in terms of soil moisture, temperature, and litter quantity. Hence, litter removal by haying will likely be a sufficient practice to replace prescribed burning at many sites.

Controlled Burning for Noxious Weed Management

Five acres of highway ROW were targeted to learn more about prescribed burns as a management tool in California. The Bear Creek Botanical Management Area, one of the last examples of Upland Wildflower Fields in California, contained a plant community remnant with more than 200 native California plant species. After careful planning, Caltrans District 3 forces coordinated the safe passage of vehicles and the California Department of Forestry and Fire Protection (CDF) conducted the burn. The key target was yellow star thistle which had invaded half the site within a short time. Observations following the fire have shown the prescribed burn to be more effective than the preceding years of mowing, spot spraying, and hand pulling of star thistle.\(lxvii\)

9.7. MANAGEMENT OF WOODY VEGETATION

Trees and shrubs are pruned to preserve their health, remove dead branches, protect utilities, maintain sight distances, preserve aesthetics and prevent property damage. In the name of safety, improved visibility and obstacle-free roadsides, roadside vegetation managers favor grasslands. Management of woody vegetation comprises a significant expense for many DOTs. For example, 60 percent of PENNDOT’s roadside maintenance budget goes to brush removal, approximately $26 million annually for maintenance of approximately 250,000 acres of ROW land statewide; reducing encroachment of the roadway is a major focus and main roads receive brush control annually.\(lxviii\) A 1994 New Jersey study implied that mowing once every 4-5 years would be enough to discourage forest invasion into the roadside recovery zone.\(lxix\)

Brush Control Guidelines

Brush control is designed to restore sight distance, control noxious weeds, prevent snow drifting, reduce ice (due to shading) and to control/prevent slope failure. These actions involve mechanical mowing, trimming, removal of brush and cleanup. This includes vegetation management around existing bridges. The primary purpose of bridge
vegetation management is to maintain sight distance. Bridge vegetation management must also maintain access to the bridge structure for maintenance, fire safety and to maintain the integrity of the structure.

Minnesota DOT provides the following environmental stewardship practices for brush control in the ROW: (lxx)

- Don’t spray big brush; rather, chop it down. The extreme color change from spraying may cause public concern.
- Spray when trees and shrubs are small (less than 6 feet tall), and preferably in the fall
- Mow smaller brush before spraying.

The Montana Department of Transportation (MDT) employs the following guidance to avoid and minimize environmental impacts from brush control. (lxix)

- Leave cut brush in place in riparian areas, where doing so does not interfere with sight distance, create safety issues, cause fire hazards, involve noxious weeds or the proper functioning of highway features (e.g. drainage).
- Limit mowing to no more than 8 to 10 feet off edge of pavement in significant resource areas defined by DEQ as state water quality impaired segments, unless needed to maintain proper functioning of highway features (e.g. drainage or snow drift control).
- Maintain shade trees along streams and rivers, unless those trees are danger trees, could potentially impact bridge structures, constitute a probable clear zone hazard, or could impact line of sight. If trees provide shade or bank stabilization within 50 feet of streams and are determined to be danger trees that must be removed, tree removal should be coordinated through the DOT botanist or other regulatory agency.
- Only remove brush necessary to perform the activity.
- Only remove the brush within 20 feet (on either side) of and under all bridge structures for access and repair to the structure. (In some instances, road access under or adjacent to the structure will be outside the 20 foot buffer.) All other brush not within the DOT’s clear zones should be left in its current condition, unless the brush interferes with sight distance, shades the structure, shades the highway, or the brush is a noxious weed. Mapping of sensitive resource areas such as listed state water quality impaired water bodies may lead to additional areas not being brushed.
- On culverts that convey live streams, only remove 10 feet of brush on both sides of the culvert on the upstream end of the culvert and 10 feet on both sides on the downstream end, unless the brush around the culvert is a noxious weed.
- When removing mature trees (over 12-inch (30cm) diameter at breast height (dbh)) in riparian areas, coordinate with the DOT MDT Maintenance will coordinate with the MDT Botanist or District Biologist to determine appropriateness of replanting two seedling/cuttings for every tree removed. Coordinate on species and location of trees to be replanted within the same

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watershed and to ensure that the replanted trees will not pose a future threat to
MDT structures.

Removal of Danger Trees
Maintenance identifies and removes “danger trees,” often in coordination with the DOT
botanist or environmental staff and/or the appropriate resource agencies. Trees may be
removed from forested areas which are weighting unstable slide areas, or where the trees
or slide have the potential to reach the highway. Maintenance also occasionally removes
trees that threaten to fall and uproot large portions of bank area. The Montana
Department of Transportation (MDT) utilizes the following practices for removal of
danger trees.\textit{(lxxii)}

- Where possible, attempt to maintain buffer strips along riparian areas: 100 feet in
  width for large rivers, 70 feet in width for medium rivers and no less than 50 feet
  in width for most streams (first-second order tributaries).
- Maintain shade trees along streams or rivers unless those trees are “danger trees”
  as described above. If trees provide shade or bank stabilization, are within 50 feet
  of streams, and are determined to be danger trees that must be removed, tree
  removal should be performed in consultation with DOT environmental staff.
  Develop a replanting and erosion control plan for removal of many trees from
  streamside areas. Significant consideration will be given to retaining trees, which
  provide stream shading (e.g. within 50 feet of the active channel). When
  removing mature trees (over 12-inch (30cm) dbh) in riparian areas, coordinate
  with the DOT Botanist or District Biologist to determine the appropriateness of
  replanting two seedling/cuttings for every tree removed.
- Pursue permanent solutions to chronically unstable areas will be pursued through
  the project development process. Solutions could include artificial hillside
  drainage or permanent shoring.

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.
  - 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.

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o Keep tools sharp. One-hand bypass or scissors cut (not anvil-type) pruning shears with curved blades work best on young trees.

o 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.

o 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.

o 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.

- Don’t ignore the mid-size tree.
- Follow safety and OSHA standards.

**Further information on correct pruning methods** can be found online.

**Compost and Shredded Brush on ROWs**

Compost consists of mixtures of peat moss, bark, processed wood chips, lawn grass chippings, manure, and other materials which interact to produce a healthy growing ecosystem, using debris that might normally be landfilled or burned. Over 50 percent of municipal solid waste compost is recycled.\(lxxiii\) An important trend in tree, brush, and wood waste management is the fact that in most states, this material can no longer be burned or buried. As a result, more and more material is being processed on site or is being recycled in central locations as compost. Chippers and grinders are a cost-effective way to recycle wood waste into useable mulch.\(lxxiv\)

**9.8. Noxious Weed Management**

Plants designated as noxious weeds include invasive plants that compromise agriculture, harm humans, or degrade natural areas. Invasive, non-native species can cause significant disruptions to ecosystems as well as cause economic harm to farmers and other land managers who are responsible for controlling these species. According to a recent Cornell study, invasive plants spread into another 4600 acres daily, impacting our nation environmentally as well as economically at a cost of $23 billion annually from problems such as the following: \(lxxv\)

- Contamination or competition with crops.
- Decrease in forage value of rangeland and pastures.
- Displacement of valuable wildlife habitat.
• Elimination of waterfowl migration stops.
• Reduction in property values and ability to acquire loans.
• Alteration ground water reserves.
• Change in aesthetics of the landscape and degradation of natural heritage and educational value.
• Increased fire threats.
• Compromise of roadside visibility and safety.
• Attraction wildlife to roadside.
• Addition costs of roadside maintenance.

Construction projects, transportation systems, spraying and mowing operations, use of forage mulches that have not been certified weed-free mulches and other erosion control products can facilitate the spread of plant and animal species outside their natural range, exacerbating the costs imposed by invasive species. In the past erosion control has involved the planting of many species that are now controlled as invasives, including aggressive sweet clovers, alfalfa, smooth brome, trefoil, and perennial rye. Importation of topsoils to projects often increases ragweeds, thistles, and sweet clovers. Ill-timed maintenance disturbances like blading, mowing, ditch dredging, and bare-grounding have been known to increase weeds such as kochia, foxtails, thistles, and milkweeds. Movement of construction equipment from a weedy site to a non weedy site can transport undesirable seeds.\(^{(lxxvi)}\)

Most states develop and maintain noxious weed lists particular to issues and species of concern in their state. A Federal Weed Seed list addresses the transfer of certain weed seed of agricultural concern. State DOT efforts with regard to noxious weed management have taken on renewed urgency since FHWA issued guidance on invasive species in August 1999,\(^{(lxxvii)}\) following Executive Order 13112 calling on agencies to work to prevent and control the introduction and spread of invasive species. It encouraged state DOTs to join interagency partnerships and to increase funding of maintenance efforts, research, and training.

The guidance specified that federal funds cannot be used for construction, revegetation, or landscaping activities that purposely include the use of known invasive plant species as listed by states or the National Invasive Species Council. Subsequent NEPA analyses required determinations of the likelihood of introducing or spreading invasive species and a description of measures being taken to minimize their potential harm. With regard to construction and maintenance, Federal-aid funds can be used for new and expanded invasive species control efforts under each state DOTs’ roadside vegetation management program. Recommended prevention and eradication measures included:

• Statewide, right-of-way inventories of vegetation that map existing invasive plant infestations.
• Inspection and cleaning of construction equipment.
• Commitments to ensure the use of invasive-free mulches, topsoils and seed mixes.
• Eradication strategies to be deployed should an invasion occur.

A number of on-line resources are available to assist in the identification and development of management strategies for particular noxious weeds.

• Fact sheets available for invasive exotic species are available on-line at Penn State University.

• The University of Davis and The Nature Conservancy maintain national control information on specific invasive species, detailed methods, tools, and techniques for weed control, as well as an inventory of photographs, and lists of species resources.

Among the variety of ways of containing weeds are biological, cultural, physical, and chemical control methods. Cultural control of weeds includes planting native grasses or competing plant species to force out noxious weeds. Physical control of noxious weeds includes tilling, mowing, and burning areas to control weeds. Chemical control of noxious weeds has been the most common to date, and will be discussed in the section on herbicide usage. Biological weed control includes the use of insects or pathogens.

Mechanical methods can be used as part of a control strategy for many species of noxious weeds. Mechanical methods are discussed in detail under the section on “Reduced Mowing and Other Mechanical Vegetation Management Stewardship Practices.” Such mechanical methods are often used in conjunction with cultural control methods to foster revegetation with native species, discussed below.

All equipment used for invasive species control, whether hand tools or power driven, must be cleaned prior to entering a new site and prior to leaving the site, in order to reduce transport of plant propagules and reduce the potential for new invasive introductions.

Revegetation and Noxious Weed Control by Fostering Native Species

As part of their commitments to reduce noxious weeds and to develop attractive and sustainable roadside environments which are better for native species and DOT budgets, many DOTs are turning to native revegetation projects and plans. Revegetation with native species is strongly encouraged federally as well. Federal agencies are directed or strongly encouraged to use native species by various Executive and Administrative Orders. These orders do not, as yet, specify sources; however, species collected near a disturbance tend to be more biologically suited for revegetating the site. Perhaps surprisingly, NCHRP 20-5, 33-04, reports that DOTs are averaging only 45 percent of use of native grasses for revegetation on projects, though this ranges to a high of 90-100 percent in a few states.\(^{(lxxviii)}\)

Revegetation with native species provides the following advantages:

• They are better adapted and appear more natural than introduced species.

• Introduced species have the potential to escape into the natural environment.
DelDOT-Livable Delaware Program to Revegetate with Natives

DelDOT’s Roadside Environment program has undertaken to improve the appearance of Delaware roadsides by using landscape enhancements that include native plants that are adapted to the region, displace invasive species that are highly competitive and detrimental to most plant species, and to do so in a manner that is cost effective and does not result in more maintenance but will require the same level of maintenance or will reduce the frequency of maintenance operations.

While DelDOT made a commitment to improve the aesthetics of the roadsides of Delaware under the leadership of their former Secretary of Transportation and Roadside Environmental Administrator, DelDOT discovered that colorful mass plantings of annual wildflowers can be costly for labor and soil preparation and are sometimes lost due to highly competitive weed situations. As a result, DelDOT undertook a study, “Enhancing Delaware Highways” which recommended roadside trials of native plants to evaluate aesthetics, compatibility with existing vegetation, costs associated with installation and maintenance. DelDOT funded a 5-year initiative through 2006 with the University of Delaware Transportation Institute to determine how native vegetation alone and in combination with existing plant communities on DelDOT rights-of-way can provide aesthetically pleasing surroundings in a cost effective manner for motorists traveling the highways of the First State.

The effort is unique among DOTs in the extent to which it is examining use of trees and tree preservation within the right-of-way, to supplement the use of native grasses, wildflowers, and shrubs. The cost of maintenance is being estimated for any landscape enhancement proposed by the project team for large-scale implementation, along with a determination whether those costs will be offset by lower frequency of maintenance over a five-year period.

Iowa DOT Revegetation Program Controls Noxious Weeds

Iowa DOT and many Iowa counties have shifted from traditional roadside maintenance of a monoculture of exotic grass in favor management regimes which restore native vegetation and reduce the use of herbicides and mowing. Iowa DOT 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 conditions. Most prairie grasses and wildflowers grow best during hot, dry summer months, providing excellent erosion control during the fall and spring.

Iowa DOT recently extended their landmark IRVM program to revegetate approximately 5,200 acres of roadside annually with native grasses and forbs. Forty percent of that acreage is restoration unrelated to construction. The program is documenting species diversity and wildlife benefits as well. Twelve roadside areas were surveyed for abundance and species richness of disturbance-tolerant and habitat-sensitive butterflies and compared with nearby roadside dominated by primarily nonnative legumes and/or grasses; species richness of habitat-sensitive butterflies showed a two-fold increase on restored roadsides compared with grassy and weedy roadsides. Abundance increased
five-fold for native grass and forb habitat over nonnative. Tracking studies found butterflies were less likely to exit the restored roadides, indicating mortality rates may be lower and offering preliminary evidence that roadsides have the potential to be used as corridors.\(^{(lxx)}\)

Iowa DOT recently released a roadside management guide containing collections of plant profiles, characteristics, requirements, and how these species are used in roadside management.

**Illinois DOT Enhancement and Maintenance Projects Restore Prairie, Native Wildflowers**

Illinois DOT established the “Wildflowers of Illinois” program utilizing existing roadside enhancement and maintenance funding to plant native wildflowers and prairie plants in place of manicured turf along roadsides. Plant materials and labor will be contributed to the program by the Illinois Department of Natural Resources and the Illinois Department of Corrections. Illinois and other vendors will supply the balance of materials needed for successful planting and establishment of the gateways, which will be funded by existing roadside maintenance budgets. As part of the Governor’s overall environmental emphasis and with support from the state’s first lady, Illinois DOT anticipates that the program will foster economic development and tourism, promote responsible stewardship, encourage environmental understanding and reduce roadside maintenance costs.

Wildflowers for Communities will involve various communities throughout Illinois in 2004 and beyond. After signing an agreement with the department to participate in the program, each community will select locations along state highways within their communities, and develop a plan for the establishment of the wildflowers with the assistance and approval of department Landscape Architects. The communities will then install the plantings with contractors, their own employees, or community volunteers such as Master Gardeners. Watering, weeding and other similar cultural needs will be arranged by the communities, usually employing similar resources. The agreement provides for an initial grant from the department of up to $35,000 with a $5,000 local match per community. The local portion may be a cash outlay or in-kind services. The agreements provide for two years maintenance by the communities with a reimbursement of $5,000 per year for that work.\(^{(lxxi)}\)

**TxDOT Pilot on Context Sensitive and Natural Landscape Design in the Highway Right-of-Way**

The purpose of TxDOT’s pilot on context sensitive and natural landscape design in the highway right-of-way was to recreate the visual character of the regional native landscape and develop self-sustaining vegetation community groups that recycle nutrients, conserve soil moisture, regenerate themselves, and provide habitat for nesting birds. Their process included 1) identifying the environmental impacts of the highway on this site, 2) identifying the appropriate natural systems processes most suitable to solving these problems, and 3) gaining input and support from the community in developing design alternatives. Management needs placed a heavy emphasis on the reduction of maintenance while developing a publicly acceptable landscape aesthetic, and interviews
with maintenance personnel provided the basis for the design program. Maintenance staff identified three problem areas:

- A large amount of hand maintenance was required around the guardrails, bridge columns and areas that equipment could not access.
- Steep slopes in parts of the project were difficult to mow without causing damage that would lead to erosion.
- Grass and weeds in the detention ponds were considered to be difficult to mow due to moist conditions in the ponds.

Based on these observations, the first three goals of the design plan were established as:

- Eliminate need for hand maintenance wherever possible, especially near travel lanes;
- Prevent erosion on slopes; and
- Improve the appearance and maintainability of the detention ponds.

This approach offered a design solution meeting specific goals regarding water quality and habitat in an urban area and while demonstrating visual acceptance by the public. The project elevated habitat, native plants, water quality, erosion control, reduced herbicide usage, and reduced mowing in TxDOT’s design approach for roadside improvement projects.\(\text{(lxxii)}\)

**TxDOT and Houston Green Ribbon Program**

In the past four years the Houston District has improved and removed from TxDOT maintenance more than 100 acres of right-of-way through agreements with partners or landscape planting. Approximately 200,000 trees, shrubs, and vines have been installed on state right-of-way in the same period without increasing maintenance activities, as part of implementation of Houston’s *Green Ribbon Project Corridor Aesthetics and Landscape Master Plan*, released in December 1999. Proudly Called the Bayou City, Houston is naturally laced with attractive green belts and waterways now obscured by highway overpasses. The goals of the Green Ribbon Project are to:

- Establish a higher level of visual appeal along the corridors through landscape and architectural improvements (aesthetics);
- Promote and enhance highway safety and maintain traffic flows (mobility);
- Promote fiscal responsibility in capital investments and reduce maintenance costs by the use of sustainable plantings, including the use of native trees, shrubs and grasses (sustainability);
- Reduce implementation and maintenance costs through the design of sustainable landscapes (sensibility);
- Promote public/private partnerships for implementation and maintenance of improvements (partnerships);
• Develop unifying themes through the use of art and neighborhood gateway markers to express the cultural uniqueness of adjacent neighborhoods (expression);
• Develop functional and innovative design solutions for architectural elements, including bridge components, walls, railings, barriers, sign supports, and lighting (innovation); and
• Integrate civic art of any material or medium that is permanent in nature and integral to the environment in which it is placed (artistic expression).

Since the establishment of the GRP, the impact to the freeways has been dramatic. The Green Ribbon Project routinely oversees the planting of literally thousands of native trees in intersections, hundreds of oleanders, crepe myrtles, and palm trees, as well as, the installation of irrigation systems. Over 1200 plants were installed at one freeway intersection, including some 80 palm trees, to emphasize the freeways Gulf connections. The Houston District has moved to a 100 percent naturally derived non-chemical landscape development and is currently working to reduce our chemical usage for herbicide control, as well.

In 2001, the Texas Legislature added Rider 57 to TxDOT’s appropriation, requiring TxDOT to expand concepts from the successful program to other areas of the state. The guiding concepts or principles for the program are:

Five design principles guide the Green Ribbon Project. These are: —

• **Green First**—make new plantings or the preservation of existing plantings the first priority in recommended improvements;
• **Integration**—consider all improvements in context with each other and design solutions to emphasize the visual, as well as the physical, integration of all components;
• **Continuity**—design all improvements to create a continuous appearance;
• **Freeways are Public Space**—the freeway rights-of-way belong to the public and should provide a visually pleasing experience; and
• **Maintenance**—the planning and implementation of all improvements should include long-term maintenance costs with respect to plantings, structures, surface treatment and other materials along roadways.

TxDOT and the state legislature tied GRP improvements to air quality and CMAQ funds when measures when funding for landscaping and other enhancement activities occur in districts that are non-attainment and near non-attainment counties for air quality degradation. TxDOT’s Design Division (DES) - Landscape Design Section now oversees the Green Ribbon Landscape Improvement Program so the GRP will continue to make a positive impact on TxDOT. The GRP program manager has facilitated integration of GRP principles into the project development process. TxDOT would not have the financial resources to implement all of the proposed design concepts and in response, the GRP manager has facilitated successful public/private partnerships with local governments in the six-county area – in Baytown, La Porte, Clute, Freeport.
In 1999, the project was recognized with the Highest Honor Award, the American Planners Association, Houston District, for its strategic planning effort. The Texas Forest Service gave the Texas Community Forestry Award of Merit to the project in 1999. The Park People, a Houston civic group, awarded the project its Visionary Award for 2000. Trees for Houston, another civic group, awarded the project its Arbor Day 2000 Award and the American Society of Landscape Architects-Texas Chapter honored the project with its Merit Award for 2000. In 2001, the Green Ribbon Project won the National Arbor Day Foundation’s Lady Bird Johnson Award. It is awarded by the Foundation for individuals and organizations whose work sets a worthy example for others to follow in roadside beautification. (lxxxi

Chemical Control of Noxious Weeds

IVM stresses the need for selectivity, restraint and proper training and protections whenever herbicides must be used. On the shoulder and in other zones, too, noxious weeds must be controlled to protect against undesirable succession of plant communities, not only for the sake of the roadside zone itself, but also to prevent the roadside from becoming a refuge for invasive species and source of further spreading. Chemical vegetation controls are used to protect preferred vegetation, to provide fire protection and to improve roadside appearance.

Chemical Spraying consists of spraying chemicals to control the growth and spread of noxious weeds or brush. Herbicides used include broad-based foliar-active herbicides and soil residual herbicides. The primary subtasks include support equipment operation, mixing and loading chemicals and chemical application. Leaks, spills and improper application are possible pollutant sources that can result in release of: pesticides, fuel, hydraulic fluid, oil and sediment. Water used for chemical mixing or in application must be controlled to prevent unpermitted non-stormwater discharges.

Mn/DOT Position Statement on the Use of Herbicides

Mn/DOT’s Position Statement on the Use of Herbicides states the agency’s commitment to “using the least toxic, efficacious pesticides available for controlling identified pest species. Herbicides selection and use should be based upon scientific information, including but not limited to, efficacy on targets to be controlled, environmental fate, and toxicity. Selection and use of herbicides is further governed by state and federal laws and regulations. Herbicides selected and used are to be applied by licensed applicators except as allowed in the herbicide policy guidelines adopted here under. All applications should be in accordance with applicable laws, regulations, and label instructions.”

Practices and Guidelines for Environmentally Sensitive Herbicide Use

In support of the policy Mn/DOT’s Guidelines to Ensure Appropriate Herbicide Use calls for the following environmental stewardship practices (lxxiv). Related and additional practices used by Caltrans (lxxv), NYSDOT (lxxvi), Montana DT (lxxvii), and Oregon DOT (lxxviii) are included.

- Herbicides should be considered only part of a more comprehensive and integrated roadside maintenance program.
• Alternatives that can control vegetation without using synthetic herbicides are investigated in an ongoing fashion.

• The use of herbicides should be based on target plants to be controlled, extent of the problem and site considerations. Herbicides will be used for roadside weed and brush control, but only to the extent necessary for effectiveness results.

• NYSDOT’s policy is to restrict herbicide use to locations that cannot be mowed by conventional means, such as around guiderail and sign posts. (lxxix) Caltrans’ states that chemical vegetative control measures will not be used on vegetated treatment BMPs except where Caltrans is directed by the California Department of Food and Agriculture to treat the BMPs for invasive weeds. Under Caltrans’ goal is to reduce chemical usage, the agency follows an approved list of chemicals developed by Maintenance Headquarters that is generally more restrictive than herbicide use options available to other agencies and the public. (xc) Oregon DOT Maintenance does not use any restricted-use chemicals to control vegetation; herbicides used include broad-based foliar-active herbicides and soil residual herbicides. (xci)

• Inspect the route ahead of time and “flag” all cross culverts, streams and wetlands so that the sprayer can be shut off 20-30 feet before entering the sensitive area and its required buffer area. Identify these locations with permanent identification markers.

• Use chemicals approved for use near aquatic resources, or as directed by regulators.

• Herbicides are not applied within 30 meters (legally 100 feet) of a wetland without a wetland permit and an approved Integrated Vegetation Management Plan.

• Eliminate spray activities on structures located over streams or adjacent to wetlands. Within riparian areas, necessary spraying around structures that require vegetation control is done by hand.

• Within 25 feet of riparian areas, boom spraying occurs no further than eight feet from the edge of pavement, and within 25 feet of an active, flowing stream, all boom spraying is prohibited.

• Herbicides should be used in accordance to EPA labels.

• Herbicides applications are avoided within 30 meters (legally 100 feet) of a dwelling, public building, or public park.

• Proper application techniques will be used to ensure that herbicides are not applied to non-target or sensitive areas.

• Follow an Integrated Vegetation Management program with mapped locations of sensitive natural resources and identifies areas where spraying does not occur. ODOT’s IVM Plans include protection of sensitive fish species via modification of spray times and modifications of spray widths to protect riparian areas. Further minimization/avoidance measures are developed on a site-specific basis. (xcii)
• Herbicides should be mixed, handled and applied strictly in accordance with the product labeling. 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.

• Only herbicides properly labeled for use on right-of-way and registered by the EPA, and the state Department of Agriculture will be purchased and used. In the event of conflict between the various regulations, the more restrictive requirements will apply.

• Herbicides should not be stored for more than 18 months. When storage is necessary, they will be stored inside and in accordance with Department of Agriculture guidelines.

• Spills of any herbicides are cleaned up as quickly as possible.

• When herbicides spill into a water body, environmental staff are notified.

• The spot spray application technique should be used to selectively treat areas infested with weeds, brush, or other harmful pests. Ideally 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).

• Calibrate the spray rig to ensure accurate application of herbicides.

• Use precision application technology.

• Do not spray chemicals when rainfall causing runoff is forecast within 12 hours.

• Spray drift should be minimized; most herbicide labels indicate methods for reducing spray. Apply herbicides using nozzles and low pressure to reduce drift. Also, certain additives will increase droplet size. Drift retardant can be used, and staff should avoid using herbicides that drift the most. Staff should watch the wind—if above 15 miles/hour stop or go to side of road so that drift occurs over already sprayed area.

• 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. Except for those herbicides that are cleared for use in aquatic environments, herbicides must be introduced into the application equipment after it is filled with water.

• Herbicides should be applied at the proper time when weeds and/or brush are susceptible so that the minimum concentration is required. Areas where brush is undesirable should be identified and the brush controlled at an early stage. Undesirable brush should be controlled at a height less than six feet. In the event that undesirable brush is more than six feet in height, it will be cut and the regrowth treated if necessary. Herbicides work better when used at higher temperatures. 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.

- Weeds should be sprayed during the seedling stage and prior to flowering. To ensure that herbicides are applied at the proper time, modified work schedules and overtime for crews may be authorized.

- Spraying should not be attempted when noxious weeds or brush become too mature or tall for satisfactorily results. In the event that the noxious weeds are too mature, the infested area will be mowed as soon as possible and the regrowth treated with herbicide, if necessary.

- Avoid using overhead irrigation for as long as the chemical manufacturer recommends after applying herbicides.

- Herbicides will be applied by licensed applicators or trained non-licensed applicators. Applicators should be aware of integrated approaches to weed and brush control. Trained, non-licensed applicators may apply general use herbicides only such as glyphosate, pre-emergent herbicides, Ready To Use (RTU) stump treatments, and plant growth regulators to kill or suppress unwanted vegetation in rest area/travel information centers, headquarter sites, truck stations, storage yards, communication towers and around guardrails.

- Records should be kept of all herbicide applications. These records shall include, but not be limited to: the date of treatment, temperature, wind direction and velocity, units treated and dosage used, location, brand name of pesticide, EPA registration number, company name and license number of applicator, and signature of operator. Records should be retained in a location designated by the Maintenance Area for at least five years.

- Each District or Maintenance area shall develop and maintain a plan that describes its pesticide storage, handling, and disposal practices in accordance with existing laws and regulations.

- Drums, cans, and containers should be properly disposed of. When possible, drums and/or containers will be returned to the vendor or recycled.

- Herbicide application equipment or empty containers are not washed in ditches, streams, ponds or wetlands, nor is the wash water allowed to flow into any surface waters, including wetlands.

- Where computer-assisted spray trucks are owned, they will be utilized. Computer assisted spray trucks can manipulate the mixture and rate sprayed, and can stop and start spray activities to avoid impacting individual creeks.

**New Equipment to Focus and Minimize Herbicide Application**

Herbicides have conventionally allowed the effective and seemingly inexpensive achievement of these goals. Crews now have the computerized equipment and knowledge to be able to target weeds, use less product per acre, and document all
conditions and location of the job. Nevertheless, citizens are still concerned about herbicide use in many places and some DOTs have taken up the goal of reducing herbicide usage.

State DOT efforts include the following:

- Caltrans and UC-Davis are undertaking research to develop an improved Intelligent Herbicide Application System (IHAS) to assist the Caltrans in reducing the amount of herbicide applied for roadside vegetation management. The system selectively applies post-emergent herbicide to weeds at the edge of the roadway and not to bare soil, reducing the amount of herbicide required for weed control. (xciii)

- The New Mexico State Highway and Transportation Department has undertaken internal research to minimize the use of herbicides while successfully controlling noxious weeds. As part of the study NMSHTD is conducting a review of methods or combinations of methods that are available for the control of noxious weeds and it finds existing policies and procedures in other states for minimizing the use of herbicides. (xciv)

- The Alabama DOT has implemented herbicide delivery systems that will ensure better control of herbicides ordered for application on state roadways, not only cutting purchase cost, but greatly reducing disposal cost for hazardous herbicides. (xcv)

NCHRP 20-5, 33-04 on Integrated Vegetation Management reviews some of the equipment on the market today to focus and reduce herbicide applications. (xcvi)

- Commercial GPS/GIS systems can provide or record information, such as environmentally sensitive site locations, for use in planning or implementing integrated vegetation management programs. Tracking and record keeping systems that are linked to today’s compatible high tech injection sprayers or roadside mowers are being marketed.

- Computer controlled spray equipment is on the market today. Injection type sprayers that measure and inject multiple ingredients used in herbicide applications make it possible for equipment operators to use computers to change materials and/or rates of materials as they move along the right-of-way. The total volume of mixed spray is controlled, allowing the equipment operators to vary their travel speed and area of coverage while moving. Onboard computers can generate the required pesticide application record information for downloading or storage in databases. Today’s injection systems can be coupled with the use of packaged pesticide concentrates that are totally ‘closed’, minimizing the potential for spills and/or operator exposure associated with traditional material transfer from packaged materials to spray tanks.

- Nozzles and materials that reduce the potential for off-target drift of sprayed materials are available. Nozzles that reduce or eliminate the generation of spray particles that are under 200 microns in size reduce the potential for significant off-target movement of liquid applied herbicides. Nozzles have been developed which enable applications to be made to targets at the outside edge of many
right-of-ways, improving the efficiency of roadside vegetation management applications without increasing the risk of off-target placement.

- Spray mix additives and/or special mixing equipment have led to roadside invert-emulsion spray equipment that can deliver large droplet, oil-rich, herbicide applications to target plants with minimal risks of drift, and with improved herbicide absorption by the target plant. This invert emulsion technology and equipment has been around for several decades but has recently been reintroduced to roadside vegetation management programs. A roadside vegetation management research report by the Commonwealth of Pennsylvania and Pennsylvania State University (xcvii) contains information about invert emulsion sprays, and other roadside vegetation management items.
- Recent research and development work by Purdue University has led to commercial production of an equipment system (xcviii), which can electronically identify individual weeds within its path and deliver a prescribed targeted application of herbicide, in a single pass over the roadside. This innovation has the potential to reduce the amount of herbicide needed to treat an acre of roadside, reducing costs, and minimize the amount of herbicide introduced into the roadside environment.
- Mowing equipment with herbicide application nozzles incorporated within the cutting head cowling has helped produce little or no ‘brownout’ beyond that associated with the mowing operation.

**Stewardship Practices Prior to Herbicide Use**

IRVM-Related steps before use of herbicides include: (xcix)

- Evaluating each site to determine if weeds really present a problem.
- Spot mowing to prevent annual weed seed production.
- Removing a [non-native species] and allowing desirable species to reclaim the area.
- Prescribing burning of prairie communities to promote healthy vegetation.
- Using biological controls as alternatives.
- Frequent roadside management equipment cleaning to help reduce seed transfer.

**Performance Indicators for Mowing and Herbicide Use**

MoDOT Mowing and Herbicide Costs are included in the DOT’s Dashboard Annual Report of high level indicators, under the strategic goal of improving maintenance of the state’s highway system. MoDOT’s has determined that herbicide use is more efficient than mowing and thus has designed a system to show reduced mowing costs and stable or increasing herbicide costs as a positive indicator, in the effort to reduce mowing. The agency acknowledges that the maximum amount of herbicide expense vs. mowing expense needed to reach the highest level of cost efficiency on roadside maintenance is unknown at the time the measure was drafted, but will be revised as the agency moves.
forward. In contrast, WSDOT is aiming for and tracking reduction in herbicide usage, as part of its IRVM program, though usage has increased in various years as noxious weed treatments have increased.

**Biological Control of Noxious Weeds**

Biological weed control includes the use of insects or pathogens. Biocontrols are a relatively inexpensive and safe alternative to chemical or mechanical control. The U.S. Department of Agriculture (USDA) 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, insects are best used in areas of large infestation. Smaller infestations are better treated with herbicides. (c)

Canada thistle was among the first 19 weed species selected as targets for biological control when the USDA Rome Laboratory was established in 1959 (Schroeder, 1980). However, most host specificity testing of agents for Canada thistle was conducted from 1961 to 1984 by staff of Agriculture Canada or by the International Institute of Biological Control (now CABI Bioscience) working with Canadian funding. The agents released in the United States have been those that became available as a result of the Canadian program, the results of which were reviewed in 2001. (ci) Most releases in the eastern United States were made by USDA, ARS staff at the Beltsville Agricultural Research Center; some studies were carried out by staff of the Maryland Department of Agriculture. (cii)  MDSHA now includes reduction of acres of Canada Thistle in the ROW as one of its key environmental indicators. “Thistle Yellows” are one effective method that can be used against Canada thistle infestations.

Several DOTs have become very active in use of biological controls. The upcoming NCHRP 20-5, 33-04 on IRVM reports that biological control practices using predator organisms such as beetles and seed flies are in use on ½ to 2 percent of the ROW in Florida, Illinois, Kentucky, Maryland, Utah, and Washington. (ciii)

- Caltrans has research underway on biological controls for Yellow Star thistle and Tumbleweed (Russian Thistle). (civ)
- In 1995, Mn/DOT launched their first school partnership in beetle rearing for roadside use, an educational and public awareness success story, after two beetle species released at a site in southern Ontario effectively reduced purple loosestrife infestation by over 90 percent over five years, allowing native plant populations to extend their reach. (cv) The Mn/DOT Office of Environmental Services uses beetles to control leafy spurge. (cvi)
- Between 1997 and 1999, NHDOT and the Department of Agriculture (NHDA) monitored a beetle release at a mitigation site infested with purple loosestrife; by 2000 all loosestrife within and adjacent to the site was either dead or extremely stressed and dying and none of the remaining live plants appeared to develop flowers and therefore seed. Self-sustaining populations of beetles still were found among the remaining loosestrife plants. Indigenous vegetation, likely from seed in
the existing soil bank, filled the void and restored diversity. NHDOT and NHDA released beetles at 12 additional sites the following year.\textsuperscript{cvii)}

- The Michigan State University’s lab produces 150,000 beetles per year, which MDNR has been releasing on state game areas infested with purple loosestrife since 1994. The lab has trained local groups around the State to rear the beetles, release and monitor their affect, leading to an expected 80 percent reduction in density in 10-20 years.

- The Vermont Agency of Natural Resources and VTrans have mapped purple loosestrife populations and VTrans is testing three approaches: 1) release of beetles without mowing or spraying; 2) mowing right after flowering begins for easy identification yet not be mature enough to disperse seed; and 3) spraying.\textsuperscript{cviii)}

- Rive beetles are available for use with leafy spurge. A leaf-eating beetle is 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. In Tennessee, the DOT was able to reduce musk thistle infestations by 95 percent with one such biocontrol beetle.\textsuperscript{cix)}

**State DOT Partnerships to Manage Noxious Weeds**

The imperative to control the spread of invasive species and noxious weeds has led to a variety of comprehensive DOT noxious weed control efforts and innovative partnerships.

**NYSDOT’s 10-Point Invasive Species Management Plan**

NYSDOT’s 10-point invasive transportation vegetation management plan consists of the following components: 1) Developing a prioritized list of threatening flora or fauna based upon regional environments, 2) Field and GIS mapping of existing invasive populations, 3) Integration of invasive species identification and analysis as part of the department’s normal NEPA /SEQR processing, 4) Evaluation of potential impacts caused by construction or maintenance activities, 5) Development of preventive best management practices, 6) Testing, execution and evaluation of eradication measures, 7) Annual reviews and updates of the vegetation management plans, 8) Progression of innovative design solutions to reduce the opportunities for the introduction or spread of invasive species, 9) Promote a climate of interagency cooperation and sharing of coordinated research with public and private sectors, 10) Increase employee and public knowledge through outreach training of the effects of invasive species to the users.\textsuperscript{cx)}

In the environmentally sensitive Adirondack Park, NYSDOT regional maintenance staff, the Adirondack Park Agency and the Adirondack Chapter of The Nature Conservancy have jointly initiated a demonstration knotweed control program. The pilot demonstration project involves hand cutting individual knotweed plants, properly disposing of the harvested plants and using NYSDOT-certified herbicide applicators to swab the residual cut knotweed stems with “Rodeo.” This project incorporates a training component by inviting local Department of Public Works (DPW) maintenance workers and resource agency staff to observe and participate.
Wyoming DOT MOU with Ag Department and County Weed and Pest Districts

By 2001, Wyoming DOT had inspected 95 percent of all State and federal centerlane miles for noxious weeds, the result of an effort begun in 1985 as a Memorandum of Understanding (MOU) with the State Agriculture Department and County Weed and Pest Districts to control weeds in public rights-of-way. The inspection and tracking effort resulted in the spraying of 4,600 rights-of-way acres and the use of native, competitive plants for revegetation since 1991. WYDOT has required certified mulches on construction projects since 1986, a proactive approach which has saved significant state dollars. (cxι)

Coordinated Weed Management Areas in New Mexico

In 2001, New Mexico Highway and Transportation Department (NMHTD) and 32 other groups signed a Memorandum of Understanding (MOU) drawing together all levels of land managers to participate and support Coordinated Weed Management Areas (CWMAs) covering the state. The signatories of the agreement jointly inventory, manage, prevent, and eradicate whenever possible, plants designated as noxious pursuant to the New Mexico Noxious Weed Management Act of 1978, using the New Mexico Strategic Plan for Managing Noxious Weeds, as a basis for coordination. New Mexico built on the experience of Idaho, Montana, Wyoming and the Dakotas. NMHTD implements Noxious Weed Management Plans for individual projects and is reviewing maintenance strategies to further improve its weed reduction efforts.

On-line Resources for Noxious Weed Control

FHWA and others have compiled on-line resources for control of noxious weeds: (cxii)

- **Federal Interagency Committee for the Management of Noxious and Exotic Weeds** is home of the (FICMNEW), an interagency partnership to pull together all stake holders since 1994.

- **National Invasive Species Council** (NISC).is the gateway to the federal effort based on EO 131112: There you can find a copy of the national invasive management plan and related information.

- The information for Cornell’s program in **Biological Control** of non-indigenous plants is online.

- **Natural Resources Conservation Service** contains the view of federal and state weed law, Invasive Plants including the federal noxious weed list as well as the noxious weed laws of most States.

- TNC’s **Wildland Invasive Species Program** offers decision-makers years of land management experience form The Nature Conservancy (TNC) regarding problem plants, control methods, a power point presentation you can use, a press release template, and ways to utilize volunteers.

- **Center for Aquatic and Invasive Plants** is a site that contains images and information for 383 native and non-native species found in Florida plus.
• The **Prairie Region** website targets weeds. It includes the Heibert ranking assessment.

• **INVADERS Database System** is the website from the University of Montana. It contains the INVADERS Database System provided by the Agricultural research Service (ARS), USDA. The site includes the U.S. and Canadian noxious weed lists.

• The **New England Wild Flower Society** addresses invasive plants in New England.

• **Southwest Exotic Plant Information Clearinghouse** serves the southwest. This site is filled with practical information for this region.

• **Center for Invasive Plant Management** is home to an in-depth western weed clearinghouse of information. The information comes to us from Bozeman, Montana. It is made up of seed science professionals in the western U.S. and Canada.

*Tracking Progress in Control of Noxious Weeds with GIS and GPS*

Many DOTs are using their noxious weed inventory effort as part of a continual process for tracking and improving management of noxious weeds. Partnerships with 4-H, The Nature Conservancy, other volunteer citizen groups, Natural Heritage Programs, and county organizations have supplemented the tracking efforts of DOT maintenance forces in some states.

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xxvii. Personal communication, Laura Greninger, NYSDOT, June 1, 2004.

xxviii. Christopher Nowak and Benjamin Ballard, State University of New York, First Interim Report for the project “Assessing New York State DOT’s Alternatives to Herbicides, Integrated Vegetation Management, and Related Research Programs” (RF Project No. 1036966; Award No. 31103), for the period November 1, 2003 to April 30th, 2004.

xxix. Personal communication, Janice Osadczuk and David Isley, Indiana DOT (April 28, 2004).

xxv. Venner, 2002 survey.


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xli. North Carolina Department of Transportation: Research and Analysis “Application Placement Technologies for Vegetation Management on North Carolina Roadsides:” http://www.ncdot.org/planning/development/research/2003-08.html. Contact: Kadibhai, Mustansir A Phone: (919) 715-2467, Email: mkadibhai@dot.state.nc.us.
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http://tti.tamu.edu/enviro_mgmt/projects/mopac.

lxxxiii. TxDOT 2003 AASHTO Environmental Excellence Award Application,

Mn/DOT Policy Guideline (February, 2003).


lxxxvi. New York State Department of Transportation Environmental Analysis Bureau, “Environmental Handbook for Transportation Operations” (July 2001) 44 pp., p. 3.1.9.


lxxxix. New York State Department of Transportation Environmental Analysis Bureau, “Environmental Handbook for Transportation Operations” (July 2001) 44 pp., p. 3.1.9.


xciii. California Department of Transportation, “Intelligent Herbicide Application System (IHAS II) for Reduced Herbicide Vegetation Control Phase II - Commercialization and Injection Research Study, started in 2002.

xciv. Personal communication, David Albright, Phone: (505) 246-6421
Email: david.albright@nmshtd.state.nm.us.

xcv. Personal communication, John Lorentson, Maintenance Manager, Alabama DOT (March, 2005).


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cv. Personal communication, Luke Skinner, Minnesota DNR Coordinator, Purple Loosestrife Program


