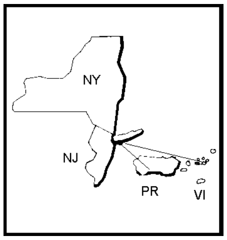

REGION II
UNIVERSITY TRANSPORTATION RESEARCH CENTER

Part 4

Developing a Cost-Effectiveness Model for Research, Development, and Application of Herbicide and Non-Herbicide Vegetation Management Treatments for Roadside Rights-of-Way

Final Report
December, 2005

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16. Abstract

Vegetation managers could use a tool to compare cost effectiveness of different non-herbicide and herbicide alternatives for treating roadside vegetation. Such a tool could be used to make informed decisions, better communicate the bases for treatment choices with various stakeholders, and direct research and development activities (focus R&D where the comparisons of different alternatives are interesting, but weak on factual information). We constructed a cost-effectiveness evaluation matrix based on expert opinion as a pilot-scale model to compare herbicide and non-herbicide alternatives for managing roadside vegetation. A Delphi process was used to rate different non-herbicide alternatives for treating roadside vegetation in comparison with conventional herbicides. The matrix was well received by the five study participants, and need not be changed for future use. Results from the pilot study indicate that a Delphi process could be used by NYSDOT to guide vegetation management choices, to better communicate with stakeholders about decision-making processes in roadside right-of-way vegetation management, and be used to guide research and development activities. Expert opinion from this pilot-scale study suggests that 1) conventional herbicide treatments are more cost effective than non-herbicide treatments, and 2) future work in non-herbicide alternatives should be focused on the use of barriers and bioherbicides in Zone 1, and the use of interference, mycoherbicides, and bioherbicides in Zone 2.

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1 EXECUTIVE SUMMARY

Overall Project: Assessing New York State DOT's Alternatives to Herbicides, Integrated Vegetation Management, and Related Research Programs

A set of five research projects on roadside right-of-way (ROW) vegetation management were conducted in 2004-2005 by the State University of New York College of Environmental Science and Forestry (SUNY-ESF) for the New York State Department of Transportation (NYSDOT).

Objectives for the research were as follows (as provided in the problem statement provided by NYSDOT):

- Objective No. 1: evaluate NYSDOT's current vegetation management program and "Alternatives to Herbicide" program
- Objective No. 2: develop recommendations for the vegetation management program and "Alternatives to Herbicide" program
- Objective No. 3: develop 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

SUNY-ESF met these objectives over the course of 2004-2005 using the following projects (all reports finalized in December 2005).

Research Project #1

A thorough search for existing information and knowledge on highway ROW vegetation management policies and techniques, and alternatives to herbicides programs and demonstrations, as applicable to New York State

Final report—PHASE 1:

Alternatives to Herbicides: Literature Review and Annotated Bibliography

Research Projects #2 and #3

Development of assessment standards (Project #2) and assessment of NYSDOT's vegetation management program (Project #3)

Final report—PHASE 2, Part 1 of 2:

Performance Standards for Assessing Vegetation Management on Rights-of-Way: Case Study of New York State DOT's Roadside Rights-of-Way Vegetation Management Program

Final report—PHASE 2, Part 2 of 2:

SUNY-ESF Right-of-Way Vegetation Management Program Assessment Report for New York State Department of Transportation, Albany, New York

Research Project #4

Development of a cost-effectiveness model for evaluating alternative vegetation management techniques for research, development, and application.

Final report—PHASE 3:

Developing a Cost-Effectiveness Model for Research, Development, and Application of Herbicide and Non-Herbicide Vegetation Management Treatments for Roadside Rights-of-Way

Research Project #5

Proposition of alternative vegetation management techniques and evaluation protocol for testing, demonstration, and operational application of those techniques.

Final report—PHASE 4:

New alternatives to herbicide techniques for treating roadside vegetation: Recommended techniques for future testing.

Phases of work were ordered according to the progression in project accomplishments, proceeding over time from Phases 1 through 4. All four phases of work and the associated five research projects were related to one or more of the other projects, as follows.

Project #1 was used to:

- collect information needed to develop the cost-effectiveness model in Project #4
- define different treatments as alternatives to herbicides as needed in Project #5

Project # 2 was used to:

- construct the performance standards needed for Project #3

Project #3 depended on results from Project #2

Project #4 depended on Project #1 and was used to

- define different treatments as alternatives to herbicides as needed in Project #5

Project # 5 depended on results from Projects #1 and 4.

All five projects together, and separately, can be viewed as foundations for future research and development work on vegetation management issues (especially those related to non-herbicide alternatives) by NYSDOT.

Project #4: Developing a Cost-Effectiveness Model for Research, Development, and Application of Herbicide and Non-Herbicide Vegetation Management Treatments for Roadside Rights-of-Way

Study Objective

Construct and apply a cost-effectiveness evaluation matrix as a pilot-scale model to compare herbicide and non-herbicide alternatives for managing roadside vegetation.

Rationale

Vegetation managers could use a tool to compare cost effectiveness of different non-herbicide and herbicide alternatives for treating roadside vegetation. Such a tool could be used to make informed decisions, better communicate the bases for treatment choices with various stakeholders, and direct research and development activities (focus R&D where the comparisons of different alternatives are interesting, but weak on factual information).

Methods

We constructed a cost-effectiveness evaluation matrix[*] based on expert opinion as a pilot-scale model to compare herbicide and non-herbicide alternatives for managing roadside vegetation. A Delphi process was used to rate different non-herbicide alternatives for treating roadside vegetation in comparison with conventional herbicides. Five experts were included in the Delphi process, representing a spectrum of experience and perspectives on the use of herbicides on roadside rights-of-way. Non-herbicide alternatives included a broad suite of physical, cultural, biological/ecological and chemical methods. Cost effectiveness was evaluated among treatment methods in terms of economics and associated changes in plant community dynamics and environmental conditions. Cost of treatments are judged to include monetary outlays for materials and labor (direct cost), but also negative effects associated with environmental externalities such as air, aesthetic, noise, and water pollution (indirect cost). Effectiveness pertains to production of desired vegetation conditions (direct benefits) and associated indirect benefits and values.

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* See attached matrices: A rating system was used to compare different treatment methods to standard herbicide methods: +, -, or O. A "+" in a matrix cell, where a cell is the defined component of cost effectiveness for a particular treatment method, indicated a positive effect or gain with that treatment, i.e., the method was better than the standard herbicide method. A "-" in a cell indicated that the method was not as valued or beneficial as the herbicide standard, and a "O" indicated no difference between the methods.

Outcome

The matrix was well received by the five study participants, and need not be changed for future use. Results from the pilot study indicate that a Delphi process could be used by NYSDOT to guide vegetation management choices and to better communicate with stakeholders about decision-making processes in roadside right-of-way vegetation management. Also, results could be used to guide research and development activities (see Phase 4).

Preliminary results from this pilot-scale study can be used to make the following conclusions.

Expert opinion suggests that:

1) Conventional herbicide treatments are more cost effective than non-herbicide treatments.
2) Future work in non-herbicide alternatives should be focused on the use of barriers and bioherbicides in Zone 1, and the use of interference, mycoherbicides, and bioherbicides in Zone 2.

Future Work

To realize the full benefit of the cost-effectiveness matrix and the Delphi process of stakeholder involvement and expert opinion, NYSDOT should conduct a full-scale study of cost effectiveness of non-herbicide alternatives using the methods developed in this study.

2 INTRODUCTION

Cost effectiveness is an important measure for describing and comparing the utility of different vegetation management methods. It has been regularly used by the electric utilities over the past few decades to justify choices of treatments methods and guide research and development programs (Nowak et al. 1992, Abrahamson et al. 1995).

Cost effectiveness is used to compare the effects of a treatment in terms of its economics and associated changes in plant community dynamics and environmental conditions. Cost of treatments are judged to include monetary outlays for materials and labor (direct cost), but also negative effects associated with environmental externalities such as air, aesthetic, noise, and water pollution (indirect cost). Effectiveness pertains to production of desired vegetation conditions (direct benefits) and associated indirect benefits and values.

Vegetation managers could use a tool to compare cost effectiveness of different non-herbicide and herbicide alternatives for treating roadside vegetation. Such a tool could be used to make informed decisions, better communicate the bases for treatment choices with various stakeholders, and direct research and development activities (focus R&D where the comparisons of different alternatives are interesting, but weak on factual information).

Study Objective

Construct and apply a cost-effectiveness evaluation matrix as a pilot-scale model to compare herbicide and non-herbicide alternatives for managing roadside vegetation.

3 MATERIALS AND METHODS

An assessment matrix was developed to facilitate comparison of cost effectiveness among contemporary and emerging vegetation management techniques on electric transmission line rights-of-way (Abrahamson et al. 1995). The matrix was used to compare different herbicide methods with mechanical, biological, and ecological methods for treating powerline corridor right-of-way vegetation. Treatment methods were used to construct the columns of the matrix, and components of cost effectiveness (direct and indirect costs, and direct and indirect benefits) were used to define matrix rows. A rating system was used to compare different treatment methods to standard herbicide methods: +, -, or O. A "+" in a matrix cell, where a cell is the defined component of cost effectiveness for a particular treatment method, indicated a positive effect or gain with that treatment, i.e., the method was better than the standard herbicide method. A "-" in a cell indicated that the method was not as valued or beneficial as the herbicide standard, and a "O" indicated no difference between the methods. In this original work, a "facts only" approach was used to develop the matrix, which meant using only information from published literature or well-documented corporate experiences. While this approach removed the personal biases associated with comparing treatments, it left many unfilled cells in the matrix. This approach was useful in defining areas of research need, but it did not fully address practitioner's need for information in making management choices.

In the current study, the existing electric utility matrix was modified to include specifics uniquely associated with roadside rights-of-way vegetation management (see Appendix). Non-herbicide and herbicide treatments were compiled in consultation with New York State Department of Transportation and based on new non-herbicide treatments found in the literature. Elements of cost effectiveness were reorganized to simplify the electric utility matrix and make it more useable for roadside vegetation managers.

Non-herbicide treatments were rated against conventional herbicides for cost effectiveness using a Delphi process. The Delphi process is an expert approach to problem-solving situations where there is little or no baseline information, or "facts" (Helmer and Rescher [1960], as cited in Egan and Jones [1997]). A small set of experts are queried for opinions on a problem (in our case, a comparison of cost-effectiveness elements for various sets of vegetation management treatments) via a series of mail surveys with controlled feedback attached to each survey. The feedback is generated from the completed surveys from the previous round. Participants are given the opportunity to modify their responses from previous rounds based on feedback. The process concludes when significant convergence of opinion occurs. In summary, the Delphi approach to problem solving follows an iterative process of questions, controlled feedback, response modification, and consensus, usually executed by mail and framed by participant anonymity (Egan and Jones 1997).

Given the limited resources associated with the current project, we tested the matrix with the Delphi process using only five people: one academic/vegetation management specialist, one vegetation manager from the electric utilities, one representative vegetation/environmental manager from NYSDOT, one vegetation management scientist, and one environmentalist/ graduate student. This small pool of participants made this study into “pilot-scale”. Future development and application of this model would need a larger expert pool (n>30) and a more focused, detailed and resource-rich research and development project.

Originally, we had intended to test the matrix using only three people: one academic, one industry person, and one non-government organization (NGO)/environmental activist. At the beginning of the project, we had verbal commitment from all three individuals to participate, but after the original mailing of the matrix/Delphi system and methods for its use (see Appendix), the NGO declined to participate. In replacing this NGO person, a student at SUNY-ESF with environmental activist/anti-herbicide leanings was added to the team, along with another industrial vegetation manager and a research scientist with expertise in vegetation management.

It was the intent of the pilot project to have multiple iterations of the ratings by respondents—rating the cost effectiveness of different non-herbicide alternatives for treating roadside vegetation versus conventionally used herbicides. Multiple iterations were not required, however, because significant convergence of opinion had occurred after the first round of expert input. As a result, no feedback was provided (however, see “DISCUSSION” section for comments related to future work and the need for a feedback system).

Participants were all able to follow the directions (as presented in the Appendix). Most of the matrix cells were rated by the expert participants, with only a few missing observations (as indicated by the “?” in a cell). Two participants provided multiple ratings in many cells. For this pilot study, the lowest rating presented was used to produce a single rating from each person.

4 RESULTS

All participants' ratings were reported in sequence in each matrix cell (five ratings per cell, see Table 1 and 2).

Synthesis of results comparing non-herbicide and herbicide alternatives for treating roadside vegetation were divided into categories by component of cost effectiveness (cost–direct , cost–indirect, benefit–direct, benefit–indirect) and roadside vegetation management zones (Zones 1 or 2; see Appendix for definitions of all categories and zones).

Comparison of Cost–Direct

Zone 1:

In general, all non-herbicide alternatives were rated as having higher direct costs as compared to conventional herbicide treatments.

Physical treatments (mechanical, thermal and barrier) were rated as having higher labor and/or equipment costs. Barriers were rated as having higher materials cost. Cycle length was rated as producing a higher cost (shorter treatment cycles, more treatments necessary over a period) for all non-herbicide alternatives, except for prescribed burn and all barrier treatments (mulches, geotextiles, and solidifiers).

Bioherbicides were rated as generally having the same direct costs as conventional herbicides, except for cycle length. Apparently, the Delphi panel expects that bioherbicides will need to be applied more frequently as compared to herbicides to produce the same level of control.

Zone 2:

In general, all physical and cultural non-herbicide treatments, except for fertilization, were rated as having higher direct costs as compared to conventional herbicide treatments.

Labor and equipment costs were rated as high, and treatment cycle lengths were rated as shorter, for all mechanical and thermal methods (physical controls) as compared to conventional herbicides. Planting and grazing, as cultural tactics, were rated as more costly for labor and materials.

Mycoherbicides (biological/ecological control), bioherbicides (chemical control), and fertilization (cultural tactic) were generally rated as having the same direct costs as conventional herbicide treatments. Interference (biological/ecological control) was generally rated as having lower direct costs than conventional herbicide treatments.

Table 1. Matrix for comparing cost effectiveness of different non-herbicide vegetation management methods for Zone 1 (vegetation-free zone) of roadside rights-of-way[1].

Effectiveness/Environmental Externalities	Physical									Chemical
	Mechanical		Thermal				Barrier			
	Mowing	Hand-cutting	Prescribed burn	Steam	Direct flame	Radiant/Infrared	Mulches	Geotextiles	Solidifiers	Bioherbicide
Cost-Direct										
Labor	- - - +0	- - - - -	- - - - -	- - - 0 -	- - - 0 -	- - - 0 -	- - - - +	- - - - +	0 - - 0+	- 0 - 00
Equipment	- - - - -	0 - - - -	- - - - +	- - - - -	0 - - - -	- - - - -	+ - - - +	+ - - 0+	0 - - - 0	00000
Materials	+++ - 0	+++00	00 - +0	+0 - - 0	00 - - 0	+0 - - 0	- - - - +	- - - - +	- - - - +	- 0 - 00
Waste disposal	+00 - -	+000 -	+00++	+0000	+0000	+0 000	+00++	0000+	0000+	00000
Cycle length	- - - - -	- - - - -	- 0 - ?0	- 0 - - -	- 0 - - -	- 0 - - -	- ++++	+++++	0++++	- 0 - - -
Cost-Indirect										
Safety	- - - - -	- - - - -	- - - - 0	- - - - 0	- - - - 0	- - - - +	++ - ++	++ - ++	0+ - 0+	00 - 00
Air Quality	0 - - - -	- - 0 - -	- - - - -	+ - - - +	0 - - - +	+ - - - +	++00+	++ - ++	0+00+	00000
Noise	- - - - -	- - + - -	+0++0	0 - - - -	00 - - -	+0 - - -	0+ - 0+	0+00+	0+000	00000
Aesthetics	0++ - 0	0+++0	- 000 -	00000	00000	00000	0++++	0+ - ++	0+0+ -	00000
Water	000 - 0	0 - + - 0	- 000 -	+000+	+000+	+000+	00 - ++	+00++	+000 -	00000
Soil	0 - +00	- 0+0+	0000 -	+0000	+000?	+000?	+0+++	+0 - ++	000+ -	00000
Wildlife	- +++ -	0++++	- 0+ - -	+0 -00	00 - - 0	+00 - 0	+00+ -	+0 - - -	000 - -	0000+
Biodiversity	++++0	++++0	+0+ - -	+0 - - 0	+0 - - 0	+00 - 0	+00+ -	00 - - -	000 - -	0000+
Benefit-Direct										
Effectiveness	- - - - -	- - - - -	- - - ?+	- - - - -	- - - - -	- - - - -	0 - - ++	0 - - ++	0 - - ++	- - - - -
Benefit-Indirect										
Aesthetics	+++ - +	+++ - +	0000 -	00000	0000	00000	++0++	0+ - ++	0+0+ -	00000
Wildlife	0++00	0++0+	- 0+0 -	0000+	- 000+	0000+	+00+ -	00 - ? -	000 - -	0000+
Biodiversity	0+++0	0++++	00+ - -	000 - +	000 - +	000 - +	000+ -	00 - - -	000 - -	0000+

[1]see "Matrix Category Definitions" in Appendix A for a description of each word or phrase in the matrix.

Table 2. Matrix for comparing cost effectiveness of different non-herbicide vegetation management methods for Zone 2 (operational zone) of roadside rights-of-way[1].

Effectiveness/Environmental Externalities	Physical						Cultural			Biological/ Ecological		Chemical
	Mechanical		Thermal									
	Mowing	Hand-cutting	Prescribed burn	Steam	Direct flame	Radiant/Infrared	Planting	Grazing	Fertilizing	Interference	Mycoherbicide	Bioherbicide
Cost-Direct												
Labor	- - - ++	- - - - 0	- - - - 0	- - - - 0	- - - - 0	- - - - 0	- - - - 0	- - - - +	0 - - 0+	- + - +0	0 - - 00	- 0 - 00
Equipment	- - - - -	0 - - - -	- - - - +	- - - - -	- - - - -	- - - - -	+ - - 00	+ - - 0+	0 - - 00	++ - ++	0 - - 00	00 - 00
Materials	+0 - - 0	+0+ - 0	00 - +?	+0 - - 0	00 - - 0	00 - - 0	- - - 0 -	- - - - -	0 - - 0?	++ - +0	00 - 00	- 0 - 00
Waste disposal	+0 - - -	+0+ - -	+00++	+0 - 0 0	+0 - 00	+0 - 00	+0 - ++	+0 - ++	00 - ++	+0 - ++	00 - 00	00 - 00
Cycle length	- - - - +	- - - - 0	- - - ++	- - - - 0	- - - - 0	- - - - 0	++ - ++	- 0 - ++	- 0 - ++	++ - ++	00 - 0+	- 0 - 00
Cost-Indirect												
Safety	- - - - 0	- - - - -	- - - - -	- - - - 0	- - - - 0	- - - - +	+0 - ++	0 - - ++	00+0+	++0++	00000	00000
Air Quality	0 - - - -	- - + - -	- - - - -	+ - - - +	0 - - - +	+ - - - +	+0+++	000++	00+++	+00++	00000	00000
Noise	- - - - -	- - + - -	00000	- 0 - - -	- 0 - - -	00 - - -	+0+++	+000+	0000+	+00++	00000	00000
Aesthetics	++++ -	++++0	- 0 - - -	000 - 0	000 - 0	000 - 0	++++ -	+0+? -	0+++ -	++0+ -	+0000	00000
Water	- 0+ - 0	- - + - 0	- 0 - - -	+00 - +	000 - +	+00 - +	+0+++	- 0 - - +	- - - - -	++0++	++00+	00000
Soil	0 - + - -	00+ 00	- 0 - - -	+00 - 0	00+ - 0	+00 - 0	+++++	- 0 - - -	0++++	++0++	+0000	00000
Wildlife	- ++ - -	00+ - 0	- 0+ - -	- 0 - - 0	- 0 - - 0	000 - 0	+++++	+ - + - ?	0++++	++0++	00000	00000
Biodiversity	- - + - -	00+ - 0	- - + - -	0 - - - 0	0 - - - 0	0 - 0 - 0	+++ - +	0 - + - ?	0++ - +	++0 - +	+0000	00000
Benefit-Direct												
Effectiveness	- - - - +	- - - - 0	- - - - -	- - - - -	- - - - +	- - - - -	- - - - +	- - - - +	- - - - +	+0 - - +	- - - - 0	- - - - 0
Benefit-Indirect												
Aesthetics	+ - ++ -	+0++0	- - 0 - -	- - 0 - 0	- - 0 - 0	- - 0 - 0	+++++	+0+? -	+++++	++0++	00000	00000
Wildlife	- - + - -	+0+ - +	- - + - -	0 - 0 - +	- - 0 - +	0 - 0 - +	+++++	+ - + - ?	+++++	++0++	00000	00000
Biodiversity	+ - + - -	+0+ - +	0 - + - -	+ - 0 - +	0 - 0 - +	+ - 0 - +	+++++	0 - + - ?	+++ - +	++0 - +	+0000	00000

[1]see "Matrix Category Definitions" in Appendix A for a description of each word or phrase in the matrix.

Comparison of Cost–Indirect

Zone 1:

Indirect costs were generally rated as being higher for all mechanical and thermal control (physical) methods as compared to conventional herbicides due to higher costs associated with safety, air quality, and noise.

In general, barrier treatments (mulches, geotextiles, and solidifiers) were rated as having lower indirect costs as compared to conventional herbicides, except for geotextiles which were rated as having negative impacts on wildlife and biodiversity.

Bioherbicides were rated as generally having the same indirect costs as conventional herbicides.

Zone 2:

Indirect costs were generally rated as being higher for all physical control methods as compared to conventional herbicides due to higher costs associated with safety, air quality, soils (mowing and prescribed burn only), wildlife, and biodiversity. Grazing was generally rated as having higher indirect costs associated with negative impacts on water and soil.

Planting (cultural tactic), fertilization (cultural tactic), and interference (biological/ecological control) were generally rated as having lower indirect costs than conventional herbicide treatments. Mycoherbicides (biological/ecological controls) and bioherbicides (chemical control) were rated as generally having the same direct costs as conventional herbicides.

Comparison of Benefit–Direct

Zone 1:

In general, all non-herbicide alternatives were rated as producing less direct benefits (less effective—meaning that the plant communities were less controlled) than conventional herbicide treatments, except for barriers (mulches, geotextiles, and solidifiers) which had mixed ratings.

Zone 2:

In general, all non-herbicide alternatives were rated as producing less direct benefits (less effective—meaning that the plant communities were less controlled) than conventional herbicide treatments, except for interference which had a mixed rating.

Comparison of Benefit–Indirect

Zone 1:

In general, non-herbicide alternatives were all rated as having the same indirect benefits as conventional herbicides treatments, with few exceptions. Mowing and hand-cutting were rated as producing more indirect benefits, aesthetics were rated as better with barrier methods, and geotextiles were rated as reducing biodiversity.

Zone 2:

In general, physical controls (mowing, hand-cutting, prescribed burn, steam, direct flame, and radiant/infrared) as non-herbicide alternatives were all rated as reducing indirect benefits as compared to conventional herbicide treatments, except for mowing and handcutting which were rated as producing positive effects on aesthetics, wildlife and biodiversity. Planting was rated, with full agreement, as producing more indirect benefits than herbicide treatments. Fertilization and interference were rated with near full agreement as producing more indirect benefits than herbicide treatments. Mycoherbicides (biological/ecological controls) and bioherbicides (chemical control) were rated as generally having the same direct costs as conventional herbicides.

5 DISCUSSION

A series of ideas and insights were gained from the pilot work, bulleted as follows.

Comparisons on non-herbicide alternatives for treating roadside vegetation

- The cost-effectiveness matrix used to compare non-herbicide alternatives for treating roadside vegetation was well received by the participants. No comments were received on having any missing categories of either cost effectiveness or the various physical, cultural, biological/ecological or chemical controls. Participants seemed to fully use and comprehend the matrices.
- In considering all of the categories of cost effectiveness, the results of the Delphi process indicate that there are no non-herbicide alternatives that are more cost effective than conventional herbicides (Table 3); however, some non-herbicide treatments are less costly or more beneficial than herbicides in specific categories of cost effectiveness.

  In Zone 1, mulches, solidifiers, and bioherbicides were rated as producing equal or less indirect costs, and equal or more direct and indirect benefits as compared to conventional herbicides.

  In Zone 2, interference was rated as producing equal or less direct and indirect costs, and equal or more direct and indirect benefits as compared to conventional herbicides. Planting and fertilization were rated as producing equal or less direct and indirect costs, and equal or more indirect benefits as compared to conventional herbicides. It is likely that the cost effectiveness of planting and fertilization are related to interference treatment effects—planting facilitates the development of a desirable plant community that is cultured via fertilization to improve development and site occupancy. This planted/cultured desirable plant community can then produce desirable interference effects.
- Nearly all non-herbicide treatments, in both Zones 1 and 2 (except mowing and all thermal treatments in Zone 2), produced equal or greater indirect benefits—this result indicates a most critical outcome. People can be expected to desire non-herbicide alternatives because of the production of indirect benefits (aesthetics, wildlife, and diversity).

Table 3. Non-herbicide alternatives that were rated as equal to, or better than, conventional herbicides treatments, by roadside vegetation management zone and for different categories of cost effectives in treating roadside rights-of-way.

	Cost-effectiveness Categories			
Zone	**Cost–Direct**	**Cost–Indirect**	**Benefit–Direct**	**Benefit–Indirect**
Zone 1	None	Mulches, Solidifiers, Bioherbicides	Mulches, Solidifiers, Bioherbicides	All non-herbicide treatments
Zone 2	Fertilization, Interference, Mycoherbicides, Bioherbicides	Planting, Fertilization, Interference, Mycoherbicides, Bioherbicides	Interference	All non-herbicide treatments (except mowing and all thermal)

Future use of the cost-effectiveness matrix and the Delphi process

A set of "lessons learned" are presented below to aid in future use of the cost-effectiveness matrix and the Delphi process.

- Two participants provided multiple ratings for some cells in the matrices. For this study, the lowest rating presented in each cell was used for the overall analysis. In future work, these multiple ratings would need to be worked through with each participant to understand why a multiple rating was used, and whether it was possible to come to a single rating. In the process, the feedback to each participant would be shared with the group of participants to garner other reactions and feedback.
- Different than the current pilot study, a full-scale Delphi study of cost effectiveness is expected to produce important disagreement on ratings of non-herbicide alternatives in the first round. Future work with the Delphi approach and the cost-effectiveness matrix should include a post-first round workshop where all participants attend. An interactive, group reaction and feedback system would facilitate the second step in the Delphi process (redoing ratings in the matrix after learning from each other) and move the group more efficiently to consensus or agreement.
- Since two matrices were used that had some redundant categories (e.g., cost effectiveness of mowing is present as cells of both Zone 1 and Zone 2 matrices), there is an opportunity to cross-check each participant for consistency in response. Such cross-checking would provide a measure of quality of respondent efforts in rating the cost effectiveness of the different non-herbicide alternatives.
- Future work with the Delphi system would benefit from having a larger population of participants to broadly represent NYSDOT stakeholders. With a larger sample size, more rigorous statistical analysis of the ratings would be possible, producing a greater level of credibility in the study results. Note that a larger sample population would require that a different type of data summary and analysis be used, e.g., rather than report all ratings in one matrix, it will be necessary to synthesize respondent ratings.

6 SUMMARY AND CONCLUSIONS

We constructed a cost-effectiveness evaluation matrix based on expert opinion as a pilot-scale model to compare herbicide and non-herbicide alternatives for managing roadside vegetation. The matrix was well received by the five study participants of varied background, and need not be changed for future use. Results from the pilot study indicate that a Delphi process could be used by NYSDOT to guide vegetation management choices and to better communicate with stakeholders about decision-making processes in roadside right-of-way vegetation management. Also, results of a full-scale Delphi study could be used to guide research and development activities.

Preliminary results from this pilot-scale study can be used to make the following conclusions.

Expert opinion suggests that:

3) Conventional herbicide treatments are more cost effective than non-herbicide treatments.
4) Future work in non-herbicide alternatives should be focused on the use of barriers and bioherbicides in Zone 1, and the use of interference, mycoherbicides, and bioherbicides in Zone 2.

To realize the full benefit of the cost-effectiveness matrix and the Delphi process of stakeholder involvement and expert opinion, NYSDOT should conduct a full-scale study of cost effectiveness of non-herbicide alternatives using the methods developed in this study.

7 ACKNOWLEDGEMENTS

The authors acknowledge monetary and administrative support from the New York State Department of Transportation, and project management by Laura Greninger. Delphi participants are acknowledged and thanked for their time and efforts: Dr. Larry Abrahamson ("academic/ vegetation management specialist"), SUNY-ESF; Mr. Kevin McLoughlin ("vegetation manager from the electric utilities"), retired, New York Power Authority; Mr. Ed Frantz ("representative vegetation/environmental manager from NYSDOT"), NYSDOT Region 2; Mr. Ben Ballard ("vegetation management scientist"), SUNY-ESF; and Ms. Cathy Bukowski ("environmentalist/ graduate student"), SUNY-ESF.

8 LITERATURE CITED

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A APPENDIX

Documentation used in conducting the cost-effectiveness study of non-herbicide alternatives for treating roadside vegetation (all documents were sent to the Delphi participants).

1) Cover letter
2) An introductory document entitled “Assessing New York State DOT’s Alternatives to Herbicides, Integrated Vegetation Management, and related research”
3) An introductory document entitled “Developing a cost-effectiveness model for research, development, and application of herbicide and non-herbicide vegetation management treatments for roadside rights-of-way”
4) “Direction for participating in the Delphi process: Round No. 1”
5) “Defining cost effectiveness”
6) “Round-by-round description of the Delphi project”
7) Matrices (n=2) for comparing cost effectiveness of different non-herbicide vegetation management methods for both Zones 1 (vegetation-free zone) and Zone 2 (operational zone) of roadside rights-of-way.
8) “Zone definitions”
9) “Matrix category definitions”
10) “Cost-effectiveness phrases”

1) Cover letter

______, 2004

Name and address

Dear __________:

Thank you for agreeing to participate in our Delphi study of non-herbicide alternatives for New York State Department of Transportation's treatment of vegetation on roadside rights-of-way.

All of the information you will need to begin formal participation is provided via the following documents (enclosed).

1) An introductory document entitled "Assessing New York State DOT's Alternatives to Herbicides, Integrated Vegetation Management, and related research"
2) An introductory document entitled "Developing a cost-effectiveness model for research, development, and application of herbicide and non-herbicide vegetation management treatments for roadside rights-of-way"
3) "Direction for participating in the Delphi process: Round No. 1"
4) "Defining cost effectiveness"
5) "Round-by-round description of the Delphi project"
6) Matrices (n=2) for comparing cost effectiveness of different non-herbicide vegetation management methods for both Zones 1 (vegetation-free zone) and Zone 2 (operational zone) of roadside rights-of-way.
7) "Zonal definitions"
8) "Matrix category definitions"

I will serve as the Project Monitor, which means I will send you materials, receive all of your input, synthesize (or not) and share that input with the rest of the group (so that you remain anonymous), facilitate transfer of ideas so we can all learn from each other, generally administer the steps of the process, and produce a final report that documents what we have learned.

I believe that it will be helpful if you read the documents in the order presented. After reading all documents, please do not hesitate to ask me questions on clarification and intent. I think all of the information that you need is here, but I have likely missed a few things.

You are viewed as holding a special level of expertise, __________, in this arena of vegetation management on rights-of-way. As such, I expect you have much to share.

I am looking forward to working with you and the others on the Delphi team. You are one of six or so members, with the others folks coming to us from non-profit environmental organizations, universities, and the vegetation management industry.

Please contact me with questions and concerns. I will share such, along with my answers, with the whole group as warranted.

Thank you.

Sincerely,

Christopher A. Nowak, PhD, CF
Associate Professor
Faculty of Forest and Natural Resources Management

2) Assessing New York State DOT's Alternatives to Herbicides, Integrated Vegetation Management, and related research programs

The New York State Department of Transportation (NYSDOT) and the State University of New York College of Environmental Science and Forestry (SUNY-ESF) formed a partnership on November 1, 2003. The purpose of this partnership is to jointly explore ways to develop NYSDOT's "Alternatives to Herbicides" program.

NYSDOT has had a formal herbicide alternatives program for nearly 5 years. In this program, herbicides are recognized as important tools for managing vegetation on rights-of-way, but their use needs to be and continues to be refined and reduced as results of the herbicide alternatives program are progressively integrated into the overall NYSDOT program.

Further research and development on alternatives to herbicides is possible and needed. A premise for NYSDOT/SUNY-ESF partnership is that old and new alternatives to herbicides may be more effectively communicated and integrated into the NYSDOT programs using a systems approach.

Objectives

SUNY-ESF brings a team of professionals with expertise in both the scientific enterprise and vegetation management systems, specifically with rights-of-way. SUNY-ESF will assess, over the course of the year 2004, NYSDOT's herbicide alternatives program and vegetation management system performance. Objectives for the first research project from the NYSDOT/SUNY-ESF partnership are as follows:

1) *Literature Review* –conduct a thorough search for existing information and knowledge on highway ROW vegetation management policies and techniques, and alternative to herbicides programs and demonstrations, as applicable to New York State;

2) *Assessment* –assess NYSDOT's vegetation management program using an Integrated Vegetation Management / Environmental Management System model (see Figure 1, attached) that will be specifically developed for roadside ROW management;

3) *Modeling Treatment Alternatives Using a Delphi Process* –develop a cost-effectiveness model for evaluating alternative vegetation management techniques for research, development, and application; and

4) *Treatment Propositions* –propose alternative vegetation management techniques and evaluation protocol for testing, demonstration, and operational application of those techniques.

Anticipated Results

In less than 1 year's time, the partnership will produce: (1) a state-of-the knowledge review of information on herbicide alternatives for roadside rights-of-way, and recommendations for new treatment schemes for NYSDOT to research in the future; (2) an assessment metric to judge vegetation management performance, and results of the application of the metric to representative regions of NYSDOT; and (3) preliminary, pilot-scale measures of cost effectiveness developed by stakeholders via a Delphi Process. All results will be summarized and presented at the 8th International Symposium on Environmental Concerns in Rights-of-Way Management, to be held September 12-16, 2004, in Saratoga Springs, New York. A final report will be produced by December 31, 2004, with various interim reports produced throughout the year.

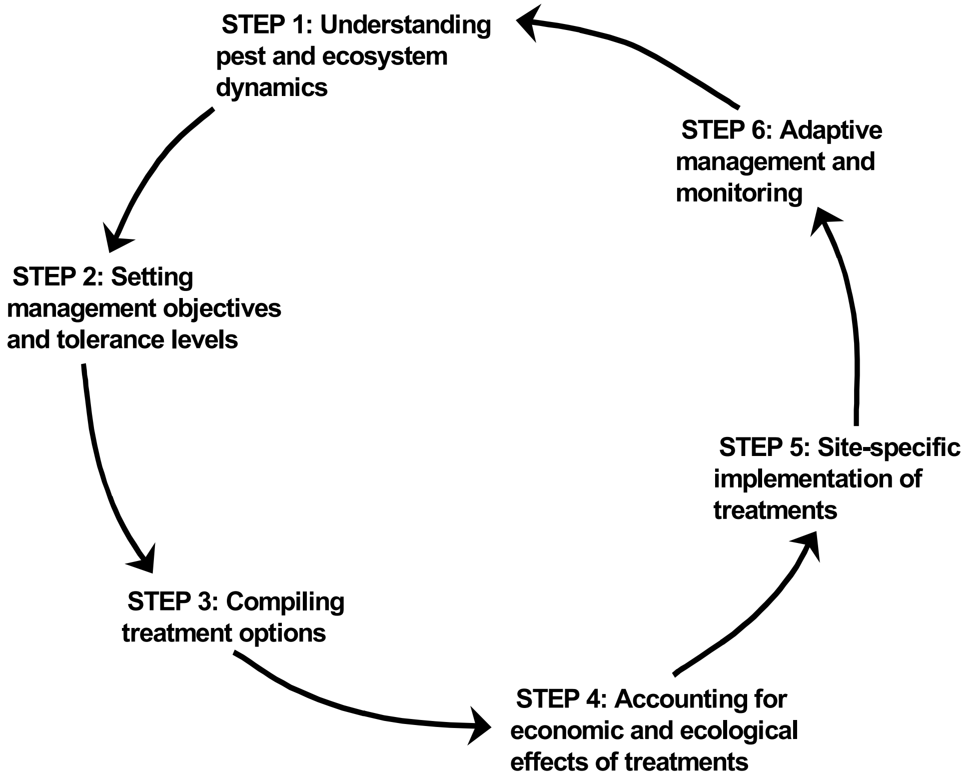

Figure 1. Component steps of Integrated Vegetation Management, a process for managing rights-of-way vegetation (adapted by Nowak and Ballard 2001, and Nowak 2002, from Witter and Stoyenoff 1996).

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Witter, J.A., and J.L. Stoyenoff. 1996. Integrated pest management in urban and rural forests. p. 151-168 In S.K. Majumdar, E.W. Miller, and F.J. Brenner (eds.) Forests-A global perspective. The Pennsylvania Academy of Science, Easton, Pennsylvania.

3) Developing a cost-effectiveness model for research, development, and application of herbicide and non-herbicide vegetation management treatments for roadside rights-of-way

By Christopher A. Nowak

Cost effectiveness is an important measure for comparing the applicability of different vegetation management methods. It has been regularly used by the electric utilities over the past few decades to justify choices of treatment methods and guide research and development programs (Nowak et al. 1992; Abrahamson et al. 1995). Cost effectiveness is used to measure success of a treatment in terms of economics, plant community dynamics, and related environmental considerations. Cost of treatments include economic costs for the materials and/or labor (direct cost), but also costs associated with externalities such as air, aesthetic, noise, and water pollution (indirect cost). Effectiveness pertains to production of desired vegetation conditions and associated benefits and values.

Early in our work with the electric utilities I helped develop an assessment matrix that allowed for a comparison of cost effectiveness among contemporary and emerging vegetation management techniques. We compared different herbicide methods with mechanical, biological, and ecological methods for treating right-of-way vegetation. Treatment methods were used to construct the columns of the matrix, and the components of cost effectiveness were used to define matrix rows. A rating system was used to compare different treatment methods to standard herbicide methods: +, -, or O. A "+" in a matrix cell, where a cell is the defined component of cost effectiveness for a particular treatment method, indicated a positive effect or gain with that treatment, i.e., the method was better than the standard herbicide method. A "-" in a cell indicated that the method was not as valued or beneficial as the herbicide standard, and a "O" indicated no difference between the methods. We used a "facts only" approach to developing the matrix, which meant we used only published literature or well-documented corporate experiences. While this approach removed the personal biases associated with comparing treatments, it left many unfilled cells in the matrix. This approach was useful in defining areas of research need, but it did not fully address a practitioner’s need for information in making management choices.

A cost-effectiveness evaluation matrix will be constructed for NYSDOT as a model to compare herbicide and non-herbicide alternatives for managing roadside vegetation. We will modify our electric utility matrix to include specifics uniquely associated with roadside rights-of-way vegetation management. We will further develop the matrix model using "facts only" (published literature discovered in Phase No. 1), but we will also test a Delphi process of expert opinion in developing and filling out the matrix.

The Delphi process is an expert approach to problem-solving situations where there is little or no baseline information, or "facts" (Helmer and Rescher [1960], as cited in Egan and Jones [1997]). A small set of experts are queried for opinions on a problem (in our case, a comparison of cost-effectiveness elements for various sets of vegetation management treatments) via a series of mail surveys with controlled feedback attached to each survey. The feedback is generated from the completed surveys from the previous round. Participants are given the opportunity to modify their responses from previous rounds based on feedback. The process concludes when significant convergence of opinion occurs. In summary, the Delphi approach to problem solving follows an iterative process of questions, controlled feedback, response modification, and consensus, usually executed by mail and framed by participant anonymity (Egan and Jones 1997).

Given the limited resources associated with the current project, we will only develop the cost-effectiveness matrix as a model. We will test the Delphi process using only six people: two or two academics, one representative from NYSDOT, one representative of the electric utility vegetation management industry, and one or two stakeholders from an environmental organization. In-depth development and application of this model would need a more focused, detailed and resource-rich research and development project. We anticipate that this could be a featured part of a subsequent study with the NYSDOT.

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Abrahamson, L. P., C. A. Nowak, P. M. Charlton, and P. G. Snyder. 1995. Cost-effectiveness of herbicide and non-herbicide vegetation management methods for electric utility rights-of-way in the Northeast: state-of-the art review. p. 27-43 In G.J. Doucet, C. Séguin, and M. Giguère (eds.) Proceedings of the 5th International Symposium on Environmental Concerns in Rights-of-Way Management, September 19-22, 1993, Montreal, Quebec, Canada.

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4) Directions for participating in the Delphi process: Round No. 1

Enclosed please find two assessment matrices for comparing cost effectiveness among contemporary and emerging non-herbicide vegetation management techniques for roadside rights-of-way. One matrix is for the shoulder area, often under guardrails (Zone 1); the other matrix is for the operational vegetation management (Zone 2) (see enclosed document entitled "Zonal Definitions"). Note that we have chosen to not exam management in Zone 3 at this time.

Please use the matrices to compare standard herbicide methods with various physical, cultural, and biological/ecological methods for treating right-of-way vegetation. Treatment methods are those non-herbicide alternatives currently being used by NYSDOT or others recently found in published sources of information. Components of cost effectiveness were used to define matrix rows, and were developed from previous right-of-way research work and our growing understanding of positive and negative environmental externalities (see "Defining Cost Effectiveness" for more information).

In this first round of our Delphi process, please compare different treatment methods to a standard herbicide method using a simple system of +, -, or O. A "+" in a matrix cell, where a cell is the defined component of cost effectiveness for a particular treatment method, will be used to indicate a positive effect or gain with that treatment, i.e., the method was better than the standard herbicide method. A "-" in a cell will be used to indicate that the method was not as valued or beneficial as the herbicide standard, and an "O" will be used to indicate no difference between the methods.

Please provide brief, written justification of your ratings, as you see fit.

The standard herbicide treatments are as follows.

> Zone 1: An Oust™ and Roundup™ mix applied as a broadcast foliar method in spring/early summer across a 3-foot wide strip along roadside edges, most often under guiderails.
>
> Zone 2: A Garlon™ and Tordon™ mix applied as a cut stump or cut stubble methods (woody plant only) in late summer to early fall.

You are not the only person filling out the matrix. We have others of varied backgrounds filling out the matrices who bring similar, or different, expertise and backgrounds to the problem. The results of their efforts will be anonymously shared with you, as will yours with them, throughout the next few months as we weave through the process. We expect it will take about 3 months to complete this process (see enclosed document entitled "Round by round description of the Delphi project"), though your time should not total more than 10 to 20 hours. A full report will be shared with you at project's end.

Please return completed matrices and accompanying notes to the project monitor by June 15th, 2004.

5) Defining cost effectiveness

Cost effectiveness is a measure of the success of a treatment in terms of economics, plant community dynamics, and related environmental considerations. It can be defined by its two component parts: cost and effectiveness. Cost for right-of-way vegetation management can be viewed as including direct costs and indirect costs. Direct costs pertain to the actual outlay of money made to treat right-of-way vegetation. Labor, equipment, and materials are commonly reported as direct costs. Indirect costs are the loss or non-production of values or service that can result from a treatment. These are often associated with water quality, wildlife habitat, and aesthetics, or other ways that the environment can be degraded. They are sometimes referred to as "environmental externalities", though environmental externalities can be either positive or negative, depending on whether they are a benefit or a cost. Other indirect costs are associated with risk of treatment to human health, and related pollution of soil, air, and sound (noise). Actual dollar amounts are difficult to ascribe to indirect costs.

Effectiveness pertains to production of desired vegetation conditions and associated benefits and values, including safe and reliable transmission of electricity, promotion of diverse plant and animal communities, protection of riparian areas and water quality, creation of visual attributes fashioned to minimize negative impacts to aesthetic appeal or quality, and enhancement of opportunities for recreational endeavors.

Time-frames for consideration of cost effectiveness can be short- or long-term. Since vegetation management and the Integrated Vegetation Management process is a long-term affair, efforts must be made to balance short-term savings with long-term costs. For example, it may be monetarily less costly to mow a right-of-way 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.

Vegetation managers need to select the most cost-effective treatment for each right-of-way management scenario. Since no two situations are alike, different treatments are often needed to maximize cost effectiveness. In general, we expect that treatments will lead to a reduction in the pest organism (plants in the wrong place at the wrong time) and will minimize (prevent) further development of a problem, which will lead to a reduction in management inputs, and a reduction in both direct and indirect costs. Integrated Vegetation Management equates to using treatments that are least costly in terms of dollars, produce minimal risks for human health and the environment, and create the desired vegetation conditions and associated positive values or externalities associated with these conditions over the long-term. Said differently and more simply, Integrated Vegetation Management is used to maximize cost effectiveness of management efforts.

6) Round-by-round description of the Delphi project

Our Delphi Process is being used to gather information, address concerns, and structure communication about roadside vegetation management and alternatives to herbicide use.

The entire process will develop through subsequent rounds of participant interaction (through mail) over about three months.

Round 1

Dates: June 1-15

Participants receive/are asked:

- A packet explaining the purpose of the project and process
- Matrices with definitions; fill out along with brief justifications on ratings

Time allowed: approximately 2 weeks

Round 2

Dates: July 1-15

Participants receive/are asked:

- A summarization of the filled out matrices compiled from all participants
- A compilation of justifications, concerns and questions from Round 1; participants are asked to review and comment on these
- Another empty matrix, same as the first; asked to fill out again

Time allowed: approximately 2 weeks

Round 3

Dates: August 1-15

Participants receive/are asked:

- A summarization of the results from Round 2 using a new matrix with revisions based on the synthesis of justifications, questions and concerns decided on after Round 2
- Participants fill out a new matrix, this time justifying their decisions and explaining how the Delphi process did or did not affect a change or lack of change on filling out the matrix and evaluating the different treatments.

Time allowed: 2 weeks

Round 4

Dates: September 1-15

Participants receive/are asked:

- Provide a newly compiled matrix based on the preceding rounds
- Participants do not need to refill a new matrix, but just comment on whether they find it acceptable in covering everything that has been discussed, etc.

Time allowed: 2 weeks

Final Report

Date: October 15th, 2004

A final report will be provided to the participants that documents what was learned with this pilot Delphi process.

7) Matrices for comparing cost effectiveness of different non-herbicide vegetation management methods for both Zones 1 (vegetation-free zone) and Zone 2 (operational zone) of roadside rights-of-way.

Matrix for Comparing Cost Effectiveness of Different Non-Herbicide Vegetation Management Methods for Zone 1 (Vegetation-Free Zone) of Roadside Rights-of-Way[1]

		Physical									Chemical
		Mechanical		Thermal				Barrier			
		Mowing	Hand-cutting	Prescribed burn	Steam	Direct flame	Radiant/Infrared	Mulches	Geotextiles	Solidifiers	Natural herbicides
	Cost-Direct										
	Labor										
	Equipment										
	Materials										
	Waste disposal										
	Cycle length										
Effectiveness/ Environmental Externalities	**Cost-Indirect**										
	Safety										
	Air Quality										
	Noise										
	Aesthetics										
	Water										
	Soil										
	Wildlife										
	Biodiversity										
	Benefit-Direct										
	Effectiveness										
	Benefit-Indirect										
	Aesthetics										
	Wildlife										
	Biodiversity										

[1] see "Matrix Category Definitions" for description of each word or phrase in the matrix

Management Methods for Zone 2 (Operational Zone) of Roadside Rights-of-Way[1]

Effectiveness/ Environmental Externalities

	Physical: Mechanical: Mowing	Physical: Mechanical: Hand-cutting	Physical: Thermal: Prescribed burn	Physical: Thermal: Steam	Physical: Thermal: Direct flame	Physical: Thermal: Radiant/Infrared	Cultural: Planting	Cultural: Grazing	Cultural: Fertilizing	Biological/ Ecological: Interference	Biological/ Ecological: Mycoherbicide	Chemical: Natural herbicides
Cost-Direct												
Labor												
Equipment												
Materials												
Waste disposal												
Cycle length												
Cost-Indirect												
Safety												
Air Quality												
Noise												
Aesthetics												
Water												
Soil												
Wildlife												
Biodiversity												
Benefit-Direct												
Effectiveness												
Benefit-Indirect												
Aesthetics												
Wildlife												
Biodiversity												

[1] see "Matrix Category Definitions" for description of each word or phrase in the matrix

8) Zone definitions

Zone 1

Vegetation Free Zone

Typically a narrow zone that extends from the edge of the road for a distance of approximately 3 feet and often includes guiderails. The zone should be essentially free of vegetation to prevent pavement breakup, avoid sod collection that can interfere with drainage, and maintain visibility.

Zone 2

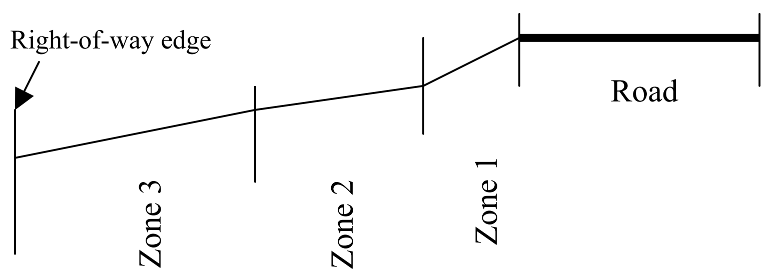
Operational Zone

A hazard-free (of deadly objects, such as trees) area that extends past Zone 1 on either side of a road and is maintained for the safety of errant vehicles needing to regain control as well as visibility of traffic signs or the intersecting of other roadways. A grass turf is typically maintained for protection against soil erosion. Woody and herbaceous species, especially trees, are not desirable.

Zone 3

Transitional Zone

When present, this zone is a variable area between the more important operational zone (Zone 2) and the edge of the right-of-way. Vegetation management is typically not necessary or kept at a minimum. There are multiple reasons to maintain the transition zone such as maintaining sight distance on curves and intersections, planting for aesthetics, preservation of existing vegetation, maintaining views or planned natural regeneration of vegetation, etc. If maintaining sight distance, trees and brush should not be greater than 36 inches in height.



9) Matrix category definitions

Treatments:

Physical– Treatment of vegetation through force using principles more associated with physics than biochemistry, physiology or ecology.

Mechanical– Treatments that alter vegetation communities by physically removing or otherwise disturbing portions of plants so as to kill them, or at the least, reduce their vigor and chances for success.

- Mowing– The use of machinery specifically designed to non-selectively cut vegetation at a desired height. Some machines can be used to cut very small patches of vegetation and therefore be somewhat selective, e.g., Micro-Mower™ or Polecat™ mowers.
- Hand-cutting– The use of machinery specifically designed to selectively cut vegetation by hand and allows only problem vegetation to be removed or controlled, e.g., chainsaw on woody stems or trimmers/brushcutters for grasses and other herbs.

Thermal– Intense heat is created and directed towards a target plant causing cells to break open by disrupting cell walls. Essentially, the water or sap in cell walls boils or expands and bursts the cells.

- Prescribed burn– A planned and managed fire is used to control undesirable plant communities and to achieve specific management objectives within a predefined area.
- Direct Flame– Uses propane gas to create a flame directed at weeds.
- Radiant/Infrared– Propane gas flame heats a ceramic element or steel plate to extremely high temperatures, with radiant heat directed at weeds. (Eliminates danger of an open flame)
- Steam– Water is heated to extremely high temperatures and sprayed onto plants. Care must be taken that heat is not lost to the air during spray time.

Barrier– Material applied to the soil surface to prevent or suppress weed growth.

- Mulches– Can be made from recycled products such as newspapers, plastics, or tires or from natural sources such as wood chips. Applied to the soil surface in a thick enough amount to block out light for plant growth.
- Geotextiles– Permeable landscape fabric that can be laid beneath mulches or used alone to effectively block sunlight from reaching the soil and to help stabilize slopes.
- Solidifiers– A polymer substance applied to the bare soil surface that binds soil creating a solid surface that is impenetrable by weeds.

Cultural– Treatments that add new elements to the managed plant ecosystem (e.g. plants, nutrients, or herbivores) to control the rate and direction of plant succession.

- Planting– Desired vegetation is planted and maintained in order to successfully out-compete or suppress undesirable vegetation. Plantings may also provide positive visuals.
- Grazing– Grazing animals are allowed to feed in a controlled area for enough time to effectively remove or reduce undesirable vegetation.
- Fertilizing– Applying enough nutrients to a particular site in order to promote the growth of certain vegetation and cause undesirable vegetation to die through competition for resources, mainly light.

Biological/Ecological– Treatments or combination of treatments that introduce or culture the natural "enemy" of the pest plant; usually the "enemy" is another plant and death is often caused through interference; could also be various insects or pathogens introduced to the system.

- Interference– Use of desirable plants to interfere with the growth of undesirables, either through competition of resources or through allelopathy to create stable, low-growing, desirable plant communities that lead to a reduction in undesirable vegetation types and produces a long-term reduction in treatment efforts and herbicide use.
- Mycoherbicide– A pathogenic fungus applied to vegetation, in order to infect a specific host plant and slow or stop its growth.

Chemical– Treatment of vegetation through alterations of biochemical and physiological modes of action; typically meaning the use of herbicides. Synthetic herbicides commonly used are Garlon™, Tordon™, and an Oust™/Roundup™ mixture.

- Natural herbicides– Products derived from non-synthetic sources to be used in the same application techniques developed for synthetic chemicals. A few examples of natural herbicides include Finale™, Scythe™, Phosphinothricin™, Burn-Out™, and corn gluten.

Depending on the zone and the maintenance needs, herbicides can be either used in spot-treatments (plant specific or selective application) or broadcast applications (applied to all vegetation or non-selective).

10) Cost-effectiveness phrases

Costs– Outlay or expenditure made to achieve a vegetation management objective.

- Direct– Outlay of money made to treat vegetation.
  - Labor– Number of employees (plus their salary) and hours needed to perform a treatment.
  - Equipment– The cost of the machinery needed for the treatment as well as its maintenance costs.
  - Materials– The cost of most anything else (other than labor and equipment) needed to perform a treatment such as fuel, quantity of herbicide, electrical fencing to contain grazing animals, safety clothing for workers, signs, etc.
  - Waste disposal– Waste created on-site from equipment or materials such as oil filters, packaging, etc., that needs to be properly disposed. Accidental spills of chemicals, fuel or oil must be cleaned up at a cost.
  - Cycle length– The amount of time that elapses after a treatment has been successfully performed and before it must be performed again to keep vegetation at desired levels.

Effectiveness– Measure of accomplishment of a desired result or the fulfillment of a purpose or intent; non-accomplishment or non-fulfillment can be considered a cost (indirect); positive and negative results of treatment that are not quantifiable via monetary measure are considered as "environmental externalities".

Environmental Externalities– Indirect costs (negative effects) or benefits (positive effects) that are difficult to monetarily quantify due to their intrinsic nature.

- Indirect– Losses or non-production of values and services that can result from a treatment, generally not quantifiable on a monetary basis.
  - Safety–Possible injury costs related to mechanical equipment, flame, or chemicals; may be a direct cost; injuries can occur to applicators, or to other right-of-way users, including passers-by.
  - Air quality– Pollution resulting from fossil fuel combustion related to mechanical equipment or chemical spraying.
  - Noise– Working equipment may create substantial noise that affects local stakeholders.
  - Aesthetics– Particular treatments may produce results that are not visually appealing for periods of time, which may not be acceptable to the public.
  - Water– Pollution of nearby water sources or ground water may occur from the treatment, such as erosion and sedimentation or misuse of chemicals.

  - Soil– Soil erosion and stream sedimentation are possible. Certain treatments may adversely affect soil by increasing compaction and surface run-off.
  - Wildlife–The removal of certain elements of habitat that may negatively affect local wildlife.
  - Biodiversity– Reduction in the richness and abundance of wildlife, including plants, and associated habitat and environs, ecosystem processes that occur at local sites, and larger-scale landscape, such as, nutrient cycling, water dynamics, and energy flow.

Benefits– Something profitable, useful or desirable that directly or indirectly results from vegetation management activities.

- Direct– Measurable effect definitely stemming from a vegetation management activity
- Indirect– Addition/production of values and services resulting from a vegetation management activity that are not directly measurable.
  - Aesthetics– Enhanced view, visual appeal and “feel” for an area created by a particular treatment.
  - Wildlife– The addition of certain elements of habitat that may positively affect local wildlife.
  - Biodiversity– Increase in, or maintenance of, the richness and abundance of wildlife, including plants, and associated habitat and environs, including ecosystem processes that occur at local sites and larger-scale landscape, such as, nutrient cycling, water dynamics, and energy flow.