Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
SPR-UAF-92-11		

4. Title and Subtitle	5. Reporting Date
Managing Roadside Vegetation in Alaska	August 1995
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Lawrence A. Johnson	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Institute of Northern Engineering University of Alaska Fairbanks Fairbanks, AK 99775-5900	11. Contract or Grant No.

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered.
AK Dept. of Transportation & Public Facilities Engineering & Operations Standards 3 Mile Building 3132 Channel Drive Juneau, AK 99801-7898	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report examines the problem of controlling undesirable roadside vegetation, primarily tall wood shrubs and trees, in the central and northern districts of Alaska. Other vegetation management concerns, such as reestablishing vegetation on disturbed areas following road construction and maintaining desirable, low growing species along roadsides are briefly addressed. This report does not directly examine vegetation problems in the much wetter, maritime climate of Southeast Alaska. Roadside vegetation control is a costly, recurring problem for the Alaska Department of Transportation and Public Facilities (AKDOT&PF). Mechanical cutting is the dominant means of control presently, although herbicides were widely used in the past, and these have had some recent but limited use in Southeast Alaska. To reduce most effectively the extent of undesirable woody species along the roadside, it is preferable to use multiple methods, such as mechanical cutting in conjunction with a limited basal spray (herbicide) program or with hand weeding. Such an integrated vegetation management (IVM) approach will help reduce both the number of species as well as the number of individual woody plants that might persist. On the basis of this project, I recommend that AKDOT&PF develop a long term IVM program that includes vegetation monitoring and a maintenance program to enhance desirable vegetation along roadsides.

17. Key Words	18. Distribution Statement
road maintenance, vegetation, mechanical cutting	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
unclassified	unclassified	24	

MANAGING ROADSIDE VEGETATION IN ALASKA

by

Lawrence A. Johnson, M.S.
Research Associate
Transportation Research Center
University of Alaska Fairbanks

A report on research sponsored by
Alaska Department of Transportation and Public Facilities
and Federal Highway Administration State Research Program Funding

August 1995

Report No. INE/TRC-94.27
SPR-UAF-92-11

TRANSPORTATION RESEARCH CENTER
INSTITUTE OF NORTHERN ENGINEERING
UNIVERSITY OF ALASKA FAIRBANKS
FAIRBANKS, ALASKA 99775

DISCLAIMER

The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein. This document is disseminated through the Transportation Research Center, Institute of Northern Engineering and the University of Alaska Fairbanks. This research has been funded by the Alaska Department of Transportation and Public Facilities (AKDOT&PF) and by the Federal Highway Administration through the use of the State Research Program Funding. The contents of this report do not necessarily reflect the views or policies of AKDOT&PF or any local sponsor. This work does not constitute a standard, specification, or regulation.

ABSTRACT

This report examines the problem of controlling undesirable roadside vegetation, primarily tall woody shrubs and trees, in the central and northern districts of Alaska. Other vegetation management concerns, such as reestablishing vegetation on disturbed areas following road construction and maintaining desirable, low growing species along roadsides are briefly addressed. This report does not directly examine vegetation problems in the much wetter, maritime climate of Southeast Alaska. Roadside vegetation control is a costly, recurring problem for the Alaska Department of Transportation and Public Facilities (AKDOT&PF). Mechanical cutting is the dominant means of control presently, although herbicides were widely used in the past, and these have had some recent but limited use in Southeast Alaska. To reduce most effectively the extent of undesirable woody species along the roadside, it is preferable to use multiple methods, such as mechanical cutting in conjunction with a limited basal spray (herbicide) program or with hand weeding. Such an integrated vegetation management (IVM) approach will help reduce both the number of species as well as the number of individual woody plants that might persist. On the basis of this project, I recommend that AKDOT&PF develop a long term integrated vegetation management (IVM) program that includes vegetation monitoring and a maintenance program to enhance desirable vegetation along roadsides.

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGEMENTS

The author would like to acknowledge those Alaska Department of Transportation and Public Facilities employees who graciously provided technical information and pertinent insights for this report. Several equipment operators were particularly helpful in explaining difficulties they face and maintainance and operations supervisors provided valuable background material. Finally, the author acknowledges employees from Matanuska Electric and Golden Valley Electric Associations for their input. This report was funded by AKDOT&PF, and by the Federal Highway Administration through the use of the State Research Program funding.

INTRODUCTION

Vegetation control along Alaska roadways is necessary for safety, maintained integrity of the road prism, and aesthetics. Because roadside vegetation control can be very costly, it may be reduced or, at best, performed in a less than optimal manner during times of budget constraints. This study seeks to identify the present status of AKDOT&PF roadside vegetation management in the northern and central regions, to determine vegetation management practices used by Alaskan utilities or described in vegetation management literature, and, finally, to experiment with possible alternative vegetation control techniques. Southeast Alaska was outside the scope of this study due in part to its different climatic conditions.

In roadside vegetation management, there are actually two quite distinct types of problems. The first is how to establish desirable vegetation following new construction, which leaves areas of bare, unprotected, and frequently highly erodible soil. Historically, AKDOT&PF has relied upon mixes of agronomic grass seeds and fertilizers to quickly revegetate these areas. Due to the limited time and scope of this project, researchers reviewed pertinent literature for roadside revegetation, but conducted no experimental studies on these aspects.

The second and major problem AKDOT&PF faces is elimination or control of undesirable vegetation along its extensive road system. This problem has two components: (1) control of undesirable vegetation -- tall, generally woody vegetation that is perennial, and often rapid growing, limits visibility and both attracts and obscures large wildlife, especially moose,

along roadsides; and (2) encouragement and/or maintenance of low growing vegetation along roadsides, both to enhance aesthetics (primarily wildflowers), and to deter the establishment and proliferation of undesirable vegetation. This initial study focuses primarily upon the first aspect: the control of undesirable vegetation along Central and Northern Alaskan roadways.

AKDOT&PF ROADSIDE VEGETATION MANAGEMENT: A SYNOPSIS

Although current roadside vegetation management in the central and northern regions of AKDOT&PF does vary by district, there are several major similarities. First, current vegetation control is performed mainly by mechanical means, usually machine cutting. This has probably been the case since the state suspended the widespread use of herbicides in the late 1970s. Second, detailed records of long-term costs and treatment frequency for a particular site are not readily available. Finally, there are no vegetation maps of past or present roadside vegetation.

Concern for driving safety, primarily relating to sight distance, is one of the major reasons for vegetation management along roadsides. However, other reasons for management may vary with the district. Aesthetics are a concern, especially in or near urban districts, while wildlife concerns, such as prevention of moose road kills, are a priority in other areas. Vegetation control, particularly for safety, at intersections and around signs is especially important in all districts. Structural engineering considerations, such as root penetration into roadbeds, are not presently a rationale for vegetation management.

Budgetary limits are a major concern for many districts, and limited budgets impact both the type and amount of vegetation management. In addition, at least in some instances, the timing of vegetation control is determined by budgetary constraints rather than by peak effectiveness for control. Use of year-end funds limit a program to the growing season (May-August), while new monies such as deferred maintenance funds may concentrate activities in July-August. Stable funding would help to insure that vegetation management can occur throughout the snow-free season and, particularly, be concentrated during times of maximum susceptibility for vegetation damage and mortality. Timing is an important factor in optimizing the effectiveness of vegetation treatments.

Budget constraints obviously limit the total amount of vegetation control possible. Most districts presently try to maintain a two or three year cycle of vegetation control along primary roadways. However, no studies have been done to determine if this is an optimum cycle, and declining budgets may lengthen it. Finally, economics also force some districts to do 'crisis' vegetation management first and routine vegetation management only as budgetary constraints allow.

Most districts rely upon both off-road machines, primarily hydroaxes, and on-road machines, such as graders with a brush cutter mounted on an arm. Mowers are also used, primarily by urban districts. Hand vegetation management is primarily used to remove vegetation around signs and guardrails and to cut dead and/or damaged trees by chain saw. Although the scope of hand brushing varies with the specific district, it is at best limited.

Vegetation control can be accomplished either in-house, by AKDOT&PF personnel, or by contractors. Although most districts use a mixure, at least one district relied almost exclusively upon in-house equipment and personnel. The choice of who does vegetation management may impact the program, since in-house personnel may be diverted to other, more critical areas when needed, while outside contractors may not be reliable in cutting vegetation during the optimal times of the growing season.

Public perceptions and attitudes can, and do, have a large impact upon the roadside vegetation management program of AKDOT&PF. Obviously, public attitudes and pressure have had, and continue to have, a significant impact upon state use of herbicides in Alaska. During the Hickel administration, there was very limited use of the herbicide Rodeo in local areas of Southeast Alaska, along specified mileages of roadway and solely along guardrails. Despite the strict limitation upon the areal/extent of the herbicide, public opposition has both delayed and increased the cost of this usage.

Similarly, AKDOT&PF receives pressure both to intensify their vegetation management, primarily to provide better visibility along roadsides, and to decrease the size of their cleared right-of-ways, particularly in new construction. Public attitudes about both safety and aesthetics are a concern for AKDOT&PF vegetation management.

ALASKAN UTILITIES VEGETATION MANAGEMENT

Utilities also have concerns about vegetation within their rights of way. Like AKDOT&PF, within Alaska they have eliminated or minimized herbicide use and rely primarily upon mechanical cutting, although they do use hand cutting when private landowners request it. Electric utilities require vegetation control not for driving safety, but for access to and protection of transmission lines. They are not concerned with clearing vegetation around guard rails and signs, and they tolerate vegetation that may be taller than that allowed by AKDOT&PF standards. Finally, utilities do not have the snow plowing and snow storage along road shoulders that AKDOT&PF must consider in planning for vegetation management.

Observing utility right-of-ways reveals that their mechanical and hand cutting programs do share some similar problems with those of AKDOT&PF, namely rapid regrowth of most woody species and, in addition, an increase in stem density following cutting. However, the ability of utilities to accept, or at least to function with taller vegetation allows them to cut less frequently than AKDOT&PF in the same region.

LITERATURE REVIEW SUMMARY

Roadside vegetation management is important for safety, environmental concerns such as erosion, aesthetics, and economic constraints. Vegetation management should begin during, and even before road construction begins (Teamah, 1993). Ideally, it includes stockpiling and reuse of topsoil, as well as contouring, seeding, fertilizing, and planting as appropriate.

Although seeding and planting specifications for new construction vary greatly, there has been increasing interest in the last decade for using native species of vegetation (Heine, 1990b, Anonymous, 1990; Ahern, 1988). Native species are gaining preference due to heightened environmental awareness (Johnson, 1984), and also because of aesthetic values and a desire for reducing maintenance costs. The use of native species has often been limited by the scarcity of available seed, but recent research and commercial production have begun to alleviate some of these problems. In Alaska, information on availability of native seed can be obtained from the Alaska Plant Materials Center in Palmer. Commercial seed has been produced in both the Palmer and the Delta areas, but availability fluctuates from year to year. Typically seed production in Alaska requires two or more years' notice (Johnson, 1984). Planting vegetation, although more expensive, is also widely used to increase the rate of revegetation following construction (Obenschain, 1993). Planting allows highway departments to be very selective in the size, appearance, and distribution of shrubs and trees along the roadsides. Planting or seeding of desirable low growing species in Maine has helped to suppress undesirable brush growth (Walton, 1994).

The majority of effort in roadside vegetation management goes into controlling existing vegetation along roadsides. Frequently, much of this vegetation is undesirable, either because of its excessive height (Hale 1988) or because weed species are present (Fuller, 1990). Unfortunately, many management programs do not focus upon long term control of these undesirable species, merely on limiting their size or frequency. (McLoughlin and Johnston,

1988). Such programs may rely exclusively upon mechanical cutting or nonselective application of herbicides.

With increased environmental regulations and limited funding, highway departments and other right-of-way managers have sought to diversify vegetation management methods. Techniques such as burning, (Henderson, 1993) and even use of prison labor (Heine, 1990a) have been employed to reduce costs and increase effectiveness. Perhaps most importantly, agencies have sought to use biological principals to reduce long term maintenance costs for roadside vegetation. This may start with the use of native species in seed mixes, but they employ numerous other methods as well (Tilsworth et al, 1991; Tillman, 1984; Taber and West, 1984 Hale, 1988). In a nutshell, agencies are actively seeking out desirable species of vegetation and trying to encourage their growth while using insects, pathogens, and plant competition to control undesirable species.

As part of the goal of controlling costs, agencies are also exploring integrated vegetation management, or IVM (Dunlap, 1991., Tilsworth et al, 1991). In this program, an agency uses multiple techniques (such as selective herbicide spraying, cutting and burning) to progressively eliminate undesirable vegetation while encouraging desirable species. By using multiple methods, some undesirable species that are otherwise able to withstand any single treatment may be entirely eliminated.

For example, a good IVM program might include mechanically cutting woody vegetation in the spring, shortly after full leaf emergence (generally in May in Alaska). This practice removes the visual barrier along roadsides posed by tall vegetation. More importantly, it removes much of the plants' food reserves, which have been stored in aboveground stems and belowground roots during the winter, and which are now low, having been used to help produce new leaves. This removal will kill some plants and weaken many others. These latter may then be killed by a subsequent burning program, using infrared burners over reemerging shoots. A final stage might be a late summer follow-up with limited herbicide application on any remaining stem sprouts. In general, a good IVM program relies upon multiple techniques; the number of undesirable species is sequentially reduced, and less effort (and cost) are required at each subsequent stage as the percentage of desirable species increases.

Finally, although they are still widely used, there is increasing opposition nationwide to the use of herbicides (Kuennen, 1990). Ground water contamination particularly has heightened concerns over herbicide use. In Alaska, there has been no widespread use of herbicides by the state since Governor Hammond issued his directive suspending state agency application of herbicides in 1978 (Tilsworth et al, 1991). Even public utilities in Alaska are reluctant to use them at present, due to the prevailing public perception (Conn, 1993).

The existing problems of roadside vegetation management are difficult at best. Recently instituted programs examining multiple treatments methods may be the best hope for long

term maintenance of our roadsides (Whitney et al, 1988; Johnston, 1984; McLoughlin and Johnston, 1988; Dunlap, 1991). However, the immediate problem will be how to maintain safety standards for vegetation along the roads until more desirable vegetation can be increased.

EXPERIMENTAL STUDY SITES: METHODS AND RESULTS

Following a road survey and discussion with AKDOT&PF personnel, researchers selected study sites in both the northern and central regions. They characterized existing vegetation at these sites, then applied experimental treatments to the undesirable tall (greater than .3m) woody species of vegetation. Treatments included cutting, girdling, multiple cutting, and hand removal. Researchers revisited these sites in early September, at the close of the growing season, to evaluate treatment effectiveness.

In addition, in both regions, researchers observed mechanical brush cutting. They collected data on the effectiveness of current control methods and the time these methods required. Additional data on existing vegetation was taken to indicate relative growth rates by species and by region. Since AKDOT&PF must deal with wide climatic variation as well as numerous types of equipment, it is important that information from multiple sources be available for study.

The data gathered at the Fairbanks and Palmer AKDOT&PF study sites reveals that both regions have a high percentage of desirable, low stature vegetation, but this is overtopped by

varied amounts of undesirable, tall, woody shrubs and young trees. The Palmer site averaged 67% desirable vegetation cover and 27% undesirable vegetation cover prior to treatment, while the Fairbanks site averaged 45% desirable cover and 72% of undesirable vegetation cover. The annual growth rate at Palmer averaged 86 cm for balsam poplar and almost 115 cm for feltleaf willow. At the Fairbanks site, annual growth rates were lower, averaging 50 cm for alder, 79 cm for feltleaf willow, 62 cm for balsam poplar, and 55 cm for paper birch.

The higher growth rates of the central region may affect an agency's treatment choice as well as treatment efficacy. Both sites showed regrowth from cutting, and researchers also observed regrowth in other AKDOT&PF treated areas (machine cut). Also, researchers noted that only 69% of the woody stems were in fact cut by one operator in Palmer. The rate, and hence the cost, of mechanical cutting varies with the type and density of the vegetation, as well as with the prevalence of such obstacles as traffic signs, guardrails and leaning trees. One operator using a modified road grader with a sidearm can usually cut from five to seven highway miles per day. Stem density varies by species and by geographic region. The northern site averaged 28 woody stems exceeding one meter in height per square meter. The most numerous species were willows, averaging 20 stems/m^2. The maximum height was 1.65cm. The central region experimental site had a much lower stem density, just 15 stems/m^2, with willows, at 6 stems/m^2, the most frequent. The maximum stem height was approximately 1.5m.

The amount of stem left following mechanical cutting may influence both rate of regrowth and mortality. This varies with the microtopography as well as the operator's expertise. At one Fairbanks site, cut stems averaged 17.2 cm above ground, while they averaged only 12.1cm at a Palmer Site. Also, the particular species of woody vegetation can influence both the difficulty of cutting and the height at which it can be cut. One equipment operator commented that willows are the hardest species to mechanically cut in the northern region.

Both single and multiple cuts are effective short term treatments for reducing roadside vegetation. However, many species such as willow and balsam poplar readily resprout, frequently increasing stem density (stems per unit area) following cutting. Unfortunately, in a short term (one season) study such as this the long term effects of cutting upon vegetation growth cannot be determined. Nevertheless, the cover of desirable, low growing vegetation, such as clover, yarrow, foxtail, prickly rose, and bluejoint reedgrass in the central district increased from 67% to 72%, and, in the northern district, fireweed, clover, raspberry, yarrow, dandelion, and bluejoint reedgrass, increased slightly from an average of 45% to an average of 52%, following cutting or multiple cutting.

The results of girdling were mixed. After one growing season, 80% of the girdled willows and alders at both the northern and central sites had only dead foliage, whereas only 40% of the girdled balsam poplar at the central site had dead foliage at the end of the first season. An experimental treatment at the central site, whereby stems received only a single cut girdling the stem (instead of a double parallel cut with removal of a strip of bark and

cambium) did not significantly damage the plants. However, we cannot ascertain the longer term effects of girdling from this initial year of data.

The hand removal treatment appears to work only on young, relatively small stems. Aspen and birch under 1 meter in height could be effectively uprooted and permanently removed, while balsam poplar and alder were difficult to uproot at 1 meter and virtually impossible to uproot once they were established. The feasibility of uprooting is directly related to both plant size and the particular species. For example, balsam poplar is notorious for spreading by means of its roots, which grow outward and then upward to form new plants. Thus, a clone of more than 100 plants may be interconnected. The multiple stems of alder, particularly once they have been cut and have regrown, cannot be manually eliminated. Soil type also affects the difficulty of hand removal. The gravel, typically utilized for roadbeds, increases the ease of removal while silts and clays increase the difficulty.

At virtually all roadside areas observed, there existed some cover of so-called desirable species. These are defined as all herbaceous species or woody species where maximum height is less than .3m (approximately 1 foot). These included highly visible wildflowers such as fireweed (Epilobium angustifolum), dandelion (Taraxacum cerataphorum), clover (Trifolium repens), butter and eggs (Linaria vulgaris), yarrow (Achillea borealis), grasses such as bluejoint reedgrass (Calamagrostis canadensis), foxtail (Alopecuras pratensis), and other species such as horsetails (Equisetum spp.), raspberry (Rubus idaeus) and blueberry

Table 1: Selected Vegetation Control Methods

Methods	Advantages	Disadvantages
1) Broadcast Multiple Herbicide Sprayings.	Kills high percentage of most vegetation.	Public opposition may slow project, increase cost. Potential environmental problems such as groundwater contamination may be costly. Woody stems remain. May kill desirable species.
2) Mechanical Cutting	May be able to use in-house equipment and labor. Removes woody stems.	Potential danger to workers. Difficult along guardrails and around signs. Will not kill most vegetation unless repeated. Most effective only if done shortly after leaf out. Non selective.
3) Girdling	Selective in removing unwanted woody species. High safety.	Labor intensive-prohibitively expensive for high densities of stems. Woody stems remain.
4) Hand pulling	Selective in removing unwanted stems. Safe.	Not feasible for well established shrubs with widespread roots. Expensive for high densities. Labor intensive.
5) Selective Herbicide Spraying (e.g., basal stem spraying)	Decreased danger of environmental problems. Selective removal of individual plants	Labor intensive. May still encounter public opposition. Woody stems remain.
6) Heat (steam, infrared..)	Kills all aboveground vegetation.	Energy intensive. Limited to relatively low vegetation. Single application won't kill most plants. Woody stems remain. Requires specialized equipment.

(Vaccinium uligonosum). If the taller, undesirable woody vegetation can be removed, these species of vegetation may significantly increase their cover and hence their visibility.

DISCUSSION

No single method can effectively eliminate all undesirable vegetation. For example, even a broadcast application of multiple herbicides along a railroad in Alaska did not kill all vegetation (Tilsworth, et al., 1991). Similarly, the cost, as well as the effectiveness, of vegetation control methods may vary according to the size, density, and species composition of the vegetation. Each method will have advantages and disadvantages that user agencies must consider (see Table 1). A long term vegetation management plan should utilize multiple methods, both to maximize the effectiveness of each treatment and to minimize the likelihood that an undesirable species will survive or increase in cover.

In order to reduce costs, a vegetation control program should evaluate both short and long term costs. For example, a single mechanical cutting will be much cheaper than girdling followed by a cutting program. But a girdling/cutting combination will provide control for a much longer period than will a single cutting.

Treatment costs are affected by immediate costs such as labor, equipment rental, and material as well as by the efficiency of the treatment (that is, percent mortality) and the lifetime of the treatment (one or more years). Long term costs, such as liability and environmental cleanup must also be considered. For example, in an Alaska Railroad study, with a treatment life of

one year for all treatments, broadcast herbicide spraying was the least expensive, but potential liability costs were excluded (Tilsworth et al., 1991). However, it is impossible to determine the costs of such yearly applications without knowing the actual effectiveness and life of each alternative treatment. Further, especially with herbicides, unforseen environmental costs may significantly shift relative costs.

CONCLUSIONS AND RECOMMENDATIONS

The existing AKDOT&PF roadside vegetation management is hampered both by funding constraints and by the lack of a long term plan. Both the northern and central regions currently rely almost exclusively upon mechanical cutting, the effectiveness of which is hampered by the amount and the type of available funding.

Much of the recent efforts outside Alaska for roadside vegetation management have focused upon developing alternatives to mechanical cutting and to herbicide use alone. However, in most cases, these roadways are much more intensively managed, as they are in the more urban areas of Alaska, such as the municipalities of Anchorage and Fairbanks.

Results of experimental studies indicate that the effectiveness of mechanical cutting for vegetation control may be increased by altering the time of cutting and by increasing its frequency in a growing season. The maximum effectiveness of cutting occurs when it is done within 2-3 weeks of full leaf emergence. Repeated cuttings should also be done within 2-3 weeks of leaf reemergence. Therefore, machine cutting should be concentrated in May and

June to be most effective. But single cutting alone will not eliminate undesirable, tall woody species, which both decrease roadside visibility and attract large wildlife (primarily moose) to roadsides. In contrast, girdling and/or hand removal (if completed while stems are scattered and small) may permanently remove unwanted woody species.

A longer term study could also begin to address strategies to maintain and increase the cover of desirable vegetation. A periodic fertilization program combined with preventative measures such as hand removal of woody species or basal spraying of herbicides may reduce roadside vegetation management costs by utilizing desirable species to out-compete the undesirables, reducing the need for costly engineering measures to control taller woody species (see Table 2).

Table 2: Example of a Long Term IVM

1) Complete vegetation survey to determine species composition and woody stem density.

2) If density of woody deciduous species exceeds 10 stems/m^2, cut stems in spring after full leave emergence.

3) Cut stems a second time after leaves reemerge from regrown shoots.

4) Either girdle any regrowing stems or treat regrowth with a basal stem spray of herbicide.

5) Monitor area in subsequent years to remove any undesirable woody species. Depending upon species and stem density, this may be done by hand removal, basal stem spray, or girdling.

6) Once desirable vegetation has increased to 80-90% cover, fertilize as needed to promote continued competitive exclusion of taller woody species.

Finally, a basic vegetation inventory along Alaskan roadsides combined with a long term plan (five to ten years) for vegetation management should be implemented. Such a project will help move AKDOT&PF from crisis management to a sustainable vegetation control program. Presentation of a specific long term plan might also help in stabilizing funding so that vegetation management can be done in a timely, effective manner.

Unfortunately, a study such as this, which only observes treated sites for a single growing season, cannot accurately assess long term results. Follow-up studies of experimental sites would help to determine both the regrowth rates and mortality of treated species, the long term changes in cover of desirable species such as wildflowers, and the effectiveness of combining treatments such as mechanical cutting with application of herbicides to cut stems. Experimental sections should be established in each region to determine the effective lifetime of each treatment, to evaluate treatment cost, and to determine which treatment combination is most effective.

Finally, once methods are developed to replace undesirable tall woody vegetation, there should be increased emphasis upon enhancing and maintaining cover by undesirable species. Maintenance programs that evaluate the cost and effectiveness of fertilization, hand weeding, and basal stem spraying should be established on 1, 2, and 3 year frequencies.

REFERENCES

Ahern, J. 1988. The establishment and maintenance of wildflowers and native plants in highway landscape. In Proceedings of Fourth Symposium on Environmental Concerns in Right-of-Way Management (EROW): 99-104.

Anonymous. 1990. Roadside planting that reduces costs. Better Roads. May: 33-35.

Conn, J. 1993 USDA Personal Communication.

Dunlap, D. 1991. The Lane County Experience. In Eighth Annual National Roadside Vegetation Management Association Meeting Proceedings: 49-52.

Fuller, M. 1990. Weed control blossoms into revegetation program. Roads and Bridges 28 (2): 32-33.

Hale, A.M. 1988. Low maintenance vegetation potential for rights-of-way management. In Proceedings of Fourth EROW: 142-148.

Heine, M. 1990 a. Herbicide program, skill and Missouri maintenance. Roads and Bridges 28 (2): 32-33.

Heine, M. 1990 b. Prairie motif saves on maintenance costs. Roads and Bridges 28 (2): 34-35.

Henderson, K. 1993. Setting Fire to Roadsides. Land and Water 37 (March/April): 28-31.

Johnson, L.A. 1984. Revegetation along pipeline rights-of-way in Alaska. In Proceedings of 3rd EROW: 254-264.

Johnston P.A. 1984. Cost comparison of rights-of-way treatment methods. In Proceedings of 3rd EROW: 320-323.

Kuennen, T. 1990. Will 90's kill herbicides? Roads and Bridges 28 (2): 11.

McLoughlin, K. and P.A. Johnston. 1988. Rights-of-Way treatment cycles. In Proceedings of Fourth EROW: 121-122.

Nage, C.J. 1989. Landscaping and environmental design. In Sixth Annual National Roadside Vegetation Management Association Meeting Proceedings: 24-26.

Obenschain, K. 1993. Roadside Planting Basics. Land and Water 37 (March/April):27.

Ropp, and J. Hett, 1988. Comparative aspects of three experimental vegetation management programs along rights-of-way in Western Washington. In Proceedings of Fourth EROW: 60-72.

Taber, R.D. and S.D. West 1984. Biological processes in the control of risk tree species on rights-of-way in forested mountains: Pacific Northwest. In Proceedings of Third EROW 410-415.

Teamah, J.A. 1993 Texas Department of Transportation studies effectiveness of temporary sediment conferences for construction prospects. Land and Water (May/June) 37: 27-29.

Tillman, R.E. 1984. Potential role of allopathy in Row vegetation management. In Proceedings of Third EROW p.416-420.

Tilsworth T., L.A. Johnson, J.D. Dust, J.S. Chouinard, D.F. Mulkey, A.H. Owen and T.L. Preston 1991. Final report to Alaska Railroad integrated vegetation management research project.

Walton, C. 1994. Using sustainable vegetation management on Maine roads. Better Roads (July): 21-22.

Whitney, P.H., S.D. West M. Vaughn, f. Shon, J. Ropp, and J. Hett, 1988. Comparative aspects of three experimental vegetation management programs along rights-of-way in Western Washington. In Proceedings of Fourth EROW, pp. 69-72.