SCHOOL OF CIVIL ENGINEERING

JOINT HIGHWAY RESEARCH PROJECT

JHRP-77-13

A LOW-COST MAINTENANCE
PROGRAM FOR INDIANA ROADSIDES

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PURDUE UNIVERSITY
INDIANA STATE HIGHWAY COMMISSION

Final Summary Report

A LOW-COST MAINTENANCE PROGRAM FOR INDIANA ROADSIDES

TO: J. F. McLaughlin, Director
Joint Highway Research Project

July 6, 1977

File: 9-5-6

FROM: H. L. Michael, Associate Director
Joint Highway Research Project

Project: C-36-48F

The attached Final Summary Report is on the HPR Part II Research Study titled "A Low-Cost Maintenance Program for Indiana Roadsides". The Report is presented for review, comment and acceptance by the sponsors as fulfillment of the objectives of the Study. The author has been the principal investigator on this research throughout its 5-year period.

Much of the material in the attached has already been reported in Interim Reports presented during the Study and is simply summarized herein for convenience, discussion of implementation, and evaluation of benefits from the research. This Study has produced considerable benefits to the ISHC from already implemented results. The continuous interest and cooperation of ISHC personnel has been exemplary and a major reason for the success of the Study.

Acceptance of this Final Summary Report and its publication will complete this Study.

Respectfully submitted,

Harold L. Michael
Associate Director

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by

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Project No.: C-36-48F
File No.: 9-5-6

Prepared as Part of an Investigation
Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

in cooperation with the

Indiana State Highway Commission
and the

U.S. Department of Transportation
Federal Highway Administration

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. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Purdue University
West Lafayette, Indiana
July 6, 1977

1. Report No. JHRP-77-13		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle A LOW-COST MAINTENANCE PROGRAM FOR INDIANA ROADSIDES				5. Report Date July 6, 1977	
				6. Performing Organization Code	
7. Author(s) D. James Morre				8. Performing Organization Report No. JHRP-77-13	
9. Performing Organization Name and Address Joint Highway Research Project Civil Engineering Building Purdue University West Lafayette, Indiana 47907				10. Work Unit No.	
				11. Contract or Grant No. HPR-1 (14) Part II	
12. Sponsoring Agency Name and Address Indiana State Highway Commission State Office Building 100 North Senate Avenue Indianapolis, Indiana 46204				13. Type of Report and Period Covered Final Summary Report	
				14. Sponsoring Agency Code	
15. Supplementary Notes Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration. From the Study "A Low-Cost Maintenance Program for Indiana Highways"					
16. Abstract This study was to design a minimal, low-cost maintenance program for Indiana roadsides. The principal objective was to combine mechanical and chemical methods in such a way as to maintain healthy turf at lowest possible cost to the Indiana State Highway Commission and the State of Indiana. Roadside weed surveys identified weed problems, weeds missed by conventional spraying schedules, and unnecessary maintenance operations. New herbicide combinations and techniques were developed. Laboratory, greenhouse and field studies were carried out to better understand the modes of actions of the herbicides involved, the physiological responses of the plants to be controlled, and to evaluate or verify environmental safety. The outcome was implementation of an environmentally safe, two cycle spray schedule combining late fall and early spring applications of amine formulations of 2,4-D. The elimination of unnecessary spraying cycles, reduction from 5-cycle to 3-cycle and further reduced mowing has resulted in cost savings of approximately \$800,000 per year for the 5 years of this project. Implementation of new research findings in 1977 and 1978 will further reduce mowing to 2- or even 1-cycle and increase the annual cost savings to \$1,100,000. Reduced mowing means leaving roadsides open to invasion by brush and trees. A practical alternative to 2,4,5-T, a 3-WAY MIXTURE of dicamba, 2,4-D and Silvex, was developed for chemical control of brush. In the event that 2,4-D resistant weed species increase to the point that 2,4-D spraying becomes ineffective, new and more potent herbicide mixtures were developed if and when they were needed. These mixtures give up to 6 years of control of roadside weeds including common milkweed and Canadian thistle from a single fall application.					
17. Key Words Roadside Maintenance, Herbicides, Roadside Mowing, Turf Maintenance, Vegetation Control, Weed Control, Brush Control.				18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 101	
				22. Price	

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EXECUTIVE SUMMARY

The studies of this report were to design a minimal, low-cost maintenance program for Indiana Roadsides. The principal objective was to combine mechanical and chemical methods in such a way as to maintain healthy turf at the lowest possible cost to the State of Indiana. Rights-of-ways are designed for safety and convenience. They should be kept as corridors of open turfed areas to provide the features of safety, beauty, and convenience for which they were intended. Practices of maintenance by mechanical and chemical methods developed under this project point to cost savings in excess of \$1,100,000 annually and without deterioration of existing turf.

Roadside weed surveys identified problem weeds, weeds missed by conventional spraying schedules, and unnecessary spraying cycles. Existing herbicides and application techniques were carefully examined to attempt to provide new solutions to new problems. New herbicide combinations and techniques of application were developed as alternatives to existing methods. Laboratory, greenhouse, and field studies were initiated to better understand the modes of actions of the herbicides involved and of the physiological responses of the plants to be controlled. The outcome of this approach was implementation of an environmentally-safe, two cycle-spray schedule combining early spring and late fall applications of amine formulations of 2,4-D. The elimination of unnecessary spraying cycles, reduction from 5-cycle to 3-cycle and further reduced mowing resulted in cost savings of approximately \$800,000 per year for the 5 years of this project. Implementation of new research findings in 1977 and 1978 will further reduce mowing to 2- or even 1-cycle and increase the annual cost savings to the amount of \$1,100,000 noted above. The consistency, timeliness and effectiveness of the contract applications add to the cost-saving features

of the roadside spraying program in Indiana. In the five years of the program application and inspection procedures have greatly improved but further improvements can still be made. A program of performance payment based on weed counts taken after the material has been applied is recommended.

To keep costs at a minimum, an alternative treatment of dicamba plus 2,4-D is recommended for inclusion in the contract program. The treatment is about equal to 2,4-D amine in effectiveness but is potentially less expensive. This is recommended to be mixed at the rate of 1 gal of dicamba amine plus 2 gal of 2,4-D amine in 100 gallons of water and applied at the rate of 40 gal per acre of total spray mixture. We have no evidence that higher rates of application of this mixture give sufficiently better control of resistant species to justify the extra cost.

A herbicide mixture consisting of three parts picloram (trade name Tordon) and one part 2,4-D amine plus an agent to control drift was developed as a more potent herbicide mixture for control of 2,4-D resistant species including common milkweed and Canadian thistle. In addition, the mixture controls all 2,4-D susceptible species tested as well as woody vegetation. By using the more potent herbicide mixture, we have maintained turf in a near weed-free condition for at least 3 years following a single fall application with no injury to grass, trees, or crops. Only one application every 6 years might be required. Even the spring application is eliminated. Cost saving features may outweigh the use of this more expensive material.

A new herbicide formulation was developed to replace 2,4,5-T for brush control along roadsides. In favorable situations, tests and observations showed invasion of woody species within one year in unmowed roadsides. Reduced mowing practices require combination with some form of brush control. To eliminate brush along roadsides, a 3-WAY HERBICIDE MIXTURE of 2,4-D, dicamba and Silvex was developed and proposed for use in off-road equipment on unmowed rights-of-

way. This recommendation is scheduled for implementation in the fall of 1978. Cost savings are reflected in the reduced mowing estimates.

The use of pre-emergence herbicides was explored for removal of vegetation, especially weedy annual grasses, from cracks in pavements and from stabilized shoulders. Generally, it will be less expensive and a sounder practice to fill cracks and replace shoulders as required than to try to attempt to prevent weed growth through use of herbicide treatments.

The recommendations based on findings from a 5-year mowing study completed under this project were implemented beginning with the 1977 mowing contracts. Specific recommendations were as follow: Where mowing is required, safety and/or appearance a primary consideration, three (or two) cycle mowing with exact timing based on grass height. The desirable mowing height should be increased from 12 inches to between 18 and 24 inches with a cutting height of about 5 inches. Mowing of wet grass should be prohibited to reduce "piling up". Mowing should be in combination with the Fall-Spring Spraying Program for control of broad-leaf weeds. Where mowing is not required, safety and/or appearance not a primary consideration, mowing should be eliminated entirely. Unmowed roadsides remain in good condition where brush is controlled. The Fall-Spring Spraying Program must then be modified to include a brush control agent in the spray mixture.

The need to develop chemical retardants of grass growth to further reduce or eliminate mechanical mowing was identified as one of the most pressing future objectives of roadside maintenance operations. Completed studies demonstrate the feasibility of using retardant chemicals to replace all or part of the need for mechanical mowing along Indiana roadsides. At least 5 years will be required for development and evaluation. The prognosis for a significant advance in this area is good and could result in additional savings of \$1,000,000 per year to ISHC.

INTRODUCTION

With the development of the Interstate system, the management of turfed roadsides is an increasingly important function of the Highway department. Divided lanes, median strips, and broad rights-of-way are an integral part of the modern highway, and the management of turfed roadsides is no longer a minor consideration of roadside maintenance. Healthy roadside turf prevents soil erosion, protects adjacent cropland from invading weeds, and provides features of beauty, safety, and convenience.

Rights-of-ways are designed for safety and convenience. They must be maintained if the safety and convenience features are to be preserved.

What happens when roadsides are not maintained in a turfed or semiturfed condition? Even with careful landscaping and restricted mowing, areas which are not maintained revert to native vegetation. Tall weeds and wild grass kill turf by shading only to die back during the winter to leave patches of bare soil open to erosion. In as little as one year, tree seedlings and root sprouts may become established on unmaintained rights-of-way. After a number of years, these sprouts become brush and eventually trees. Brush obscures vision to add a hazardous condition to an otherwise safe highway. If sight distances are reduced by vegetation below minimum specifications, the state is liable to litigation in the case of accidents. Trees immediately adjacent to a major highway present an obvious safety hazard. Such trees and brush must be removed at considerable expense and the turf reestablished to prevent additional erosion. The costs of tree and brush removal and

reestablishment of turf exceeds the costs of a modest annual maintenance program.

Turf stabilizes the soil and prevents erosion. Sediment from soil erosion is the major pollutant of Midwestern waterways; the problem would only increase in severity if roadside rights-of-ways were not maintained.

Along the Interstate System and major State Highways of Indiana and throughout most of the Midwest, the roadsides are already turfed, principally bluegrass and tall fescue, and mostly free of trees between the edge of the shoulder and the fence-line except for steep banks and certain scenic areas. The soil is mostly of high fertility and much of the roadside borders on cultivated agricultural land of high productivity. Of major concern in protecting both the established roadside turf and the adjacent cropland is the control of weeds and brush. The control methods must be effective, inexpensive, and not deleterious to either the environment or to adjacent crops.

This study was for research in cooperation with the Indiana State Highway Commission to design a minimal low cost maintenance program for Indiana roadsides. Mechanical and chemical methods were to be combined in such a way as to maintain healthy turf at the lowest possible cost to the State and without threat of injury to the environment.

Principal Objective

To develop a 3-year spraying rotation in combination with one cycle mowing to provide a maximum benefit, minimum cost and environmentally safe roadside maintenance program for the State of Indiana to insure that the roadsides be kept as corridors of open turfed areas.

Expansion of Research Study

In January 1977 the study was expanded to include a detailed evaluation of commercially available and a limited number of experimental grass retardants.

BACKGROUND AND SIGNIFICANCE

The planning phase of this study began in 1971 as a result of meetings with Mr. Marion Bugh, Landscape Supervisor and other officials of the Indiana State Highway Commission. The dual purposes of these meetings were to discuss implementation of information from a previous Research in Roadside Development Project and to determine how the maintenance activities of the Indiana State Highway Commission could be served best by new research activities. In addition, a series of Roadside Maintenance Seminars were held at the State Highway Commission Research and Training Center, McClure Park, Lafayette, Indiana in 1971 and 1972 to identify major problems associated with chemical weed control, problems of environmental safety, and problems unique to the spraying and mowing programs by contract. At that time liason was established with several of the principal contractors and District Landscape Supervisors. At the 1972 seminar, plans for a new minimal, low-cost maintenance program to combine both chemical and mechanical methods, were presented and discussed. The research project was formally initiated October 1, 1972.

The principles which underly this approach to research in roadside maintenance are as follow:

- 1) To identify problems where solutions to the problems will result in substantial cost savings or benefits to the State Highway Commission,
- 2) To adapt existing technology to the solution of these problems,
- 3) To develop new technology where available technology is inadequate to solve a particular problem, and
- 4) To conduct mission-related theoretical research where required to develop such new technology.

An example of how these principles have been applied is as follows. Roadside weed surveys identified problem weeds, weeds missed by conventional spraying schedules and unnecessary spraying cycles. Existing herbicides and application techniques were carefully examined to attempt to provide solutions. New herbicide combinations and techniques of application were developed as alternatives to existing methods. Laboratory, greenhouse, and field studies were initiated to better understand the modes of actions of the herbicides involved and of the physiological responses of the plants to be controlled. The outcome of this approach was implementation of an environmentally-safe, two cycle-spray schedule combining early spring and late fall applications of amine formulations of 2,4-D. The elimination of unnecessary spraying cycles, reduction from 5-cycle to 3-cycle and further reduced mowing has resulted in cost savings of more than \$1,000,000 annually. Annual cost savings of approximately \$800,000 were realized for each of the five years of this five-year project.

Much of the success of the project has derived from the fact that it combined the expertise of fundamental researchers, contract applicators, maintenance supervisors, and representatives of industry to the solution of problems where findings are translated as rapidly as possible into practice and substantial cost savings. Equally important, it does not reduce or eliminate the fundamental aspects of research which may provide a basis for new and innovative ideas. Basic to our approach are concerns for environmental safety and strict adherence to an overall program likely to yield important benefits in savings of time and money, increased safety, and better service with no decline of, more usually an improvement of, aesthetic quality.

PART I

FALL-SPRING SPRAYING ROTATION WITH 2,4-D AMINE

A 5-year study 1972-1977

FALL-SPRING SPRAYING ROTATION WITH 2,4-D AMINE--1972-1977

1. Scope and objectives: This study was to evaluate in the implementation phase, a program of alternating fall and spring applications of 2,4-D amine herbicide in the spraying-by-contract program for the State of Indiana. All phases of the program were evaluated including efficacy, method and timing of application, inspection, contractor performance and environmental safety.

2. Introduction: This portion of the study was based on findings and implementation requirements resulting from a previous project "Research in Roadside Development. Part III. Chemical Weed Control". Tests completed under the previous study indicated the overall effectiveness of fall applications of 2,4-D followed by a spring application in late April. In 1971, approximately 1,500 linear miles of highway received a fall application of 2,4-D between September 15 and October 15 under the Spraying Program by Contract. The fall application was followed by a second application in early spring.

The direct cost saving to the State of Indiana from the Herbicide Treatment Program by Contract alone was an estimated \$60,000 annually. This figure was based on the difference in cost between the standard 3 applications of herbicide in spring and mid-summer used prior to 1971 and the 3-year rotation implemented in 1971. Not included were benefits from increased weed control, safety, or reduced mowing costs.

Based on these preliminary implementation results, a State-wide program was developed, implemented and evaluated as part of the present project in close cooperation with Mr. Marion L. Bugh, Landscape Architect, Indiana State Highway Commission.

3. Method of approach: A 3-year spraying rotation was established for the entire State of Indiana. The roads were divided into three groups of about 4,000 linear miles (24,000 acres) each. Group A was the Interstate System. Groups B and C were composed of roads of the State Highway System. Roads of group A received a fall-spring 2,4-D cycle in 1972-73 and again in 1975-76. Roads of group B received a fall-spring cycle in 1973-74 and again in 1976-77. Roads of group C received a fall-spring cycle in 1974-75 and are scheduled for treatment again in 1977-78. In the fall of 1978, the third round of treatments will begin again with roads of Group A. The program is computerized to reduce administrative costs. Mr. Bugh and his staff did an excellent job in setting up the contracts so that each year approximately 1/3 of the state is sprayed with maximum efficiency for both the State and the individual contractors.

Specification of material, rate and schedule of application are summarized in Table 1. All applications were in the herbicide application program by contract. In the 1972-73, 1973-74 and 1974-75 spraying cycles, contract spraying operations were inspected regularly as part of the evaluation phase of the project. This was discontinued in the fall of 1975.

Efficacy evaluations were made in both the fall and spring as well as intervals thereafter. Test plots were selected at the discretion of the inspector. Each highway segment was designated by the number and direction, e.g. 52W. The plot location was indicated as to county and number of miles (to the nearest 0.1 miles) from a convenient landmark locatable on a district map (preferably a major road junction or county line).

TABLE 1

PROGRAM OF ALTERNATING FALL AND SPRING APPLICATIONS OF 2,4-D HERBICIDE
IMPLEMENTED IN THE SPRAYING-BY-CONTRACT PROGRAM FOR THE STATE OF INDIANA

Material: 2,4-D amine form concentrate containing at least 4 pounds of acid equivalent per gallon. Ester formulations of 2,4-D are not to be used due to possible environmental hazards.

Rate: The material was recommended to be mixed at the rate of 2 gallons of 2,4-D concentrate to 100 gallons of water. The mixture was applied at the rate of 40 gallons per acre.

Schedule of application:

- a) Fall: September 1 to first killing frost
- b) Spring: March 15 to April 30.

All broad-leaved weeds plus wild garlic were counted in an area of 10 square feet. Three different portions of the right-of-way were sampled:

- a) Adjacent to the pavement
- b) Midway between the pavement edge and the fence or fence line
- c) Approximately 6 inches back from the fence or fence line.

The first set of counts were taken on the right side of the road facing in the direction of travel. The sample zones for this series were taken every 25 feet (about 5 paces) to give a total of 10 counts for each of the three sample zones in a linear distance of about 250 feet. When the last of the 10 counts was completed, an identical procedure was repeated for the left side of the road. Also measured was the average height of the grass in inches and the approximate width of the right-of-way (pavement edge to fence line).

The procedure for sampling medians was the same except that the last series of counts was taken along the center of the median rather than along the fence or fence line.

4. Major findings: Evaluations of test plots throughout the state have shown the fall application to be extremely effective with weed control 2 months after treatment ranging from 85% to over 95% (Table II).

The fall application is followed by a second application in early spring. In a separate test in White County, the effectiveness of the spring application was checked independent of the fall spraying. Again, results showed 90% control of all species present or germinating at the time of application.

TABLE II

CONTROL OF PERENNIAL WEED SPECIES BY FALL APPLICATIONS OF 2,4-D

<u>Weed species</u>	<u>Plants/100 square feet</u>		
	<u>Control</u>	<u>2,4-D</u>	<u>% of Control</u>
Dandelion	588	71	88
Plantain	155	3	98
Wild parsnip	211	0	100
Curled dock	19	0	100

Prior to the time of spraying, counts varied from over 700,000 weed per mile (SR 27, Fort Wayne District) to less than 50,000 weeds per mile (Ind. 421, LaPorte District). Generally those roads included in a regular herbicide spraying program prior to 1971 were in the 50,000 to 100,000 weeds/mile category while those roads which were previously unsprayed averaged over 500,000 weeds per mile. An example of the late summer weed population of an unsprayed Indiana roadside is given in Table III..

The concept of a 3-year rotation stemmed from data summarized in Figure 1. These data are from the 1971 spraying program one year after spraying (data partly collected and analyzed under the present project). The lower curve represents roads which has been sprayed in previous years and contained mostly resistant species. The upper curve represents roads which had not been sprayed recently and contained mostly 2,4-D-susceptible species.

A pattern of weed control emerged as follows: The optimum weed density for maxim effectiveness was about 150,000 weeds per acre. With this weed density, control approached 90% on roads not previously sprayed. As the weed density decreased or increased from this value, effectiveness of weed control decreased. With roads having 25,000 weeds per acre or less, treatment effectiveness ranged from 0% to 30%. These roads were not "weedy" to begin with, contained mostly 2,4-D resistant species, and should never have been sprayed in the contract program.

Based on the above data and results from experimental plots, a 3-year spraying rotation was established for the State of Indiana as described under "Method of Approach". We anticipated that by the fall of 1975, roads in group A would have weed densities in the range of 75,000 to 150,000

TABLE III

WEED COUNT DATA TAKEN IN THE FALL OF 1971 PRIOR TO BEGINNING OF THE FALL-
SPRING SPRAYING ROTATION (SR 27 0.2 miles south of Jct. U.S. 224 in the
Fort Wayne District)

Weed Density	Knotweed	Lambsquarter	Red Clover	Wild Carrot	Common Ragweed
Weeds/mile	683,046	17,249	4,403	9.176	4,403
Weeds/acre	135,108	3,412	871	1,815	817
Weed Density	Dandelion	Sweet Clover	White Clover	Nodding Spurge	
Weeds/mile	47,932	21,289	12,846	2,937	
Weeds/acre	9,481	4,211	2,541	581	
Weed Density	Prostrate Spurge	Plantain	3-Seeded Mercury	Bindweed	
Weeds/mile	733	15,783	2,937	5,874	
Weeds/acre	143	3,122	581	1,162	
Weed Density	Poison Ivy	Horse Nettle	Common Milkweed	Canada Thistle	
Weeds/mile	733	1,466	367	9,545	
Weeds/acre	143	290	73	1,188	
Weed Density	Common Thistle	Other Composites	Total Weeds		
Weeds/mile	367	2,937	844,023		
Weeds/acre	73	581	166,193

Figure 1. Graph showing the relationship between weed density in thousands of plants per acre and percent total weed kill for the fall-spring 2,4-D application cycle summarized in Table I. The upper solid curve is for roads previously unsprayed and which contained mostly 2,4-D-susceptible species. The lower dotted curve is for roads which had been sprayed within the past 2 years and which contained mostly 2,4-D-resistant species. Each point represents data from a different highway within a single district. The different symbols show results from the commercial applicators (contractors A, B, and C) involved in the 1971-72 Spraying Program by Contract. Evaluations were in late August, September, and early October, 1972, one year following the fall application of herbicide in the spraying cycle.

weeds per acre so that the cycle could be justifiably repeated. These expectations were borne out by experimental findings (Table IV). Two years after spraying, the weed density was 30,000 to 50,000 per acre. At best, we could expect no more than 50% weed control to reduce the population back to 15,000 weeds per acre. By three years, however, when the weed population again reached the 75,000 to 150,000 weeds per acre level, the roads can be resprayed with the expectation of 80 to 90% effectiveness.

Summary of inspection reports by year:

1972-1973.--The 1972-1973 fall-spring spraying program by contract was restricted to the Interstate System. Approximately 700 miles of the Interstate system were driven for inspection purposes both during the year of spraying and the year following. Effectiveness was about 85% on the average. One year later control was still in excess of 80% and at 55 mph, the roads appeared weed free. These roads held up quite well and did not require respraying before 1975.

The major source of unsightly growth on the Interstates was legumes--sweet clover, red clover, alfalfa, and some white clover. Because of the legumes, some portions appeared unsightly in early June. Were it not for the legumes, no need for mowing would have been indicated at that time.

1973-1974.--The 1973 fall spraying program by contract was evaluated by a system of spot checks and weed counts taken at random throughout the state. At least one job by each of the participating contractors was evaluated. Effectiveness ranges from 85 to 98% control with the average being well over 90%, a reduction from 600,000 weeds/acre to about 2,000 weeds per acre. Weather conditions were ideal in the fall of 1973 and the contractors did an excellent job. Except for milkweed and thistle, the

TABLE IV

WEED COUNTS OF REPRESENTATIVE INTERSTATES IN MID-JULY 1975 3 YEARS
 AFTER THE FIRST FALL-SPRING SPRAYING CYCLE AND JUST PRIOR TO REENTRY
 INTO THE PROGRAM

	<u>Interstate</u>	<u>Weeds/Acre</u>
US 52	Pavement to fence	378,246
	Median	331,056
I-65	Pavement to fence	21,344
	Median	117,612
I-74	Pavement to fence	142,441
	Median	159,720
I-70	Pavement to fence	114,998
	Median	65,340
	Average	166,345

sprayed roads were essentially weed free in July following the spring application. Excellent control of wild carrot and of wild parsnip was obtained. A few weeds were encountered as "skips" where the boom was swung around to avoid a sign or where tall grass protected the weeds. Generally, however, 1973 was the best performance of the fall application of 2,4-D amine and was an elegant demonstration of the superior results possible under near-ideal conditions.

1974-1975.--Weed counts were taken in at least 3 locations in each of the separate contracts throughout the state by standard evaluation procedures. Overall results were excellent, with an average of about 7,000 weeds per acre, indicative of 90+% control. A few skips were noted especially near the fence and in the center where right-of-ways were widest. Weather was favorable for both the fall and spring applications, coverage was good, and generally, the program was nearly as successful as in 1973-1974.

1975-1976.--The 1974-1975 program marked the completion of the first cycle of the 3-year rotation. 1975-1976 marked the beginning of of the second cycle starting with roads of group A, the Interstate System. Largely due to more experienced contractors and inspectors and more reliance on unit operations, the second spraying of the interstates was more successful than the first. Most contractors were better prepared with off road equipment. Weed populations of as low as 1,000 to 2,000 weeds per acre were encountered the summer following spraying and even in July of 1977 most of the Interstates are still below the 15,000 weeds/A limit indicative of effective control of weeds.

The major problems remaining are common milkweed and Canadian thistle. These are both weeds which become unsightly in late June and are only

partially controlled by the 2,4-D amine formulation. Dandelions, buckhorn, and most of the common weeds listed in Table III have been eliminated as maintenance problem on these roads.

1976-1977.--Weed counts completed in June of 1977 were limited to about 12 spot checks in four districts and visual inspections in conjunction with evaluation of mowing operations. Weed counts varied from a low of 500 weeds/A to a maximum of 35,000 weeds per acre. The average was 4,350. Generally, there seemed to be more wild carrot than in previous years and milkweed and thistle continue to appear unsightly. Milkweed may actually be increasing. In 1972, we encountered between 50 and 100 common milkweed plants per acre. In 1977, the number was nearer 400. Some of this apparent increase may be due to reduced mowing.

Summary.--Overall through the 5 years of observation and evaluation, the fall-spring spraying rotation must be considered as a complete success. The success of the program must not be its undoing. We must continually be mindful of what happens when roadsides are not maintained in a turfed or semiturfed condition (Figs. 2 and 4). Even with careful landscaping and mowing, areas which are not maintained revert to native vegetation. Tall weeds and wild grass kill turf by shading only to die back during the winter to leave bare soil subject to erosion (Fig. 2). In as little as one year brush can invade. With the herbicide program in combination with 2 or 3 cycle mowing, roadsides have been maintained with an essentially weed-free appearance (Figs. 3 and 5).

Figure 2. Unsprayed section of I-69 near the Indiana-Michigan border. Tall weeds and grass have smothered out the turf leaving patches of bare soil subject to erosion. Photographed June 2, 1973.

Figure 3. Sprayed section of I-69 near the Indiana-Michigan border. This portion received the fall-spring 2,4-D application cycle in the 1972-73 season in the Spraying Program by Contract (Table I). The roadside is essentially weed-free. Photographed June 2, 1973.

Figure 4. Unsprayed median of I-69 near the Indiana-Michigan border. Numerous weeds are seen in the foreground. Photographed June 2, 1973.

Figure 5. Sprayed median of I-69 near the Indiana-Michigan border. This portion received the fall-spring 2,4-D application cycle in the 1972-73 season in the Spraying Program by Contract (Table I). The area is essentially weed-free. Photographed June 2, 1973.

Physiological considerations of the fall-spring spraying cycle.--

As the first killing frost approaches, hard-to-kill perennial weeds move all available materials into the underground parts of the plants.

Herbicides applied at this time reach the underground plant parts through translocation activity when these parts are most susceptible to the killing action of the herbicide. Dandelion, plantain, buckhorn, creeping charlie, dock, wild carrot, wild parsnip, thistle, and milkweeds and other roadside perennials are among the weeds susceptible to fall applications of herbicides.

Plants with a biennial growth habit are also controlled by fall applications of herbicides. Wild parsnip and wild carrot are examples of especially troublesome roadside weeds with biennial growth habits. Plants germinate in the spring and summer to overwinter as small plants with a whorl of leaves about grass height in mowed turf. The following spring, the plants produce a flowering stalk up to 5 feet high which is unsightly, obstructs vision, kills turf by shading, and produces abundant seed to ensure reinfestation. Herbicide applications in spring and summer are ineffective in killing the plants or even in preventing production of viable seed since the plants grow rapidly in early spring. They are frequently in full flower by May 15 (wild parsnip). Fall applications of herbicide give complete control of these weeds for up to 3 years while spring applications of twice the amount of herbicide may not provide even single season control.

Winter annuals are a third category of weeds controlled by fall applications of herbicides. Winter annuals germinate in the fall, enter a rosette stage in which they overwinter, and flower in early spring.

Examples include henbit, shepard's purse, yellow rocket, and most of the wild mustards. These plants are killed in the fall as they germinate through pre-emergence action of the herbicides.

The only category of plants which escapes a fall application of herbicide is the summer annuals such as pigweed, ragweed, lambsquarter, and velvet leaf. These plants are common weeds of crop lands but seldom invade healthy turf. They are encountered only infrequently along Indiana's roadsides.

Environmental safety.--An important advantage of fall applications of herbicides is that of environmental safety. In the fall, desirable plants in cropland or gardens, shrubs and flowers in lawns, golf courses or recreational areas, and in roadside plantings and forests, are dying, dead, or dormant. Trees and shrubs are losing their leaves, and unlike the plants to be controlled, escape the herbicide. Problems of drift onto soybean or tomato fields are eliminated since the growing season is over. By the following spring, soil residues are completely dissipated especially with the biodegradable herbicides such as 2,4-D.

The environmental safety of various roadside herbicides were evaluated in laboratory, greenhouse, and field investigations. The potential hazard of pure 2,4-D to fish or algae from terrestrial runoff water (concentration of 0.1 ppm or less) or direct or accidental contamination (3 lb/A applied directly to 6 inches of water) is nil. Studies with formulated materials, however, showed that 2,4-D ester derivatives are substantially more toxic than the parent acid; fish and phytoplankton kills result at the 3 lb/A rate applied directly to shallow water.

In June 1971, a recommendation was made to the Indiana State Highway Commission that only non-toxic amine and salt formulations of 2,4-D be used for roadside spraying, and that use of toxic ester formulations be discontinued.

The recommendation was accepted and beginning in the fall of 1971, use of 2,4-D has been restricted to amine formulations (Table I).

In frequent discussions with environmentalists and environmental groups, a major concern is injury to wild flowers, a point not adequately covered in prior reports from this project. We have conducted tests with spring flowers. Most are perennials from bulbs and escape injury. There is some reduction in goldenrod and asters but for the most part these species escape in the fence rows. Perhaps the only wild flower that is seriously threatened by the spraying program is wild carrot. This species is also probably our greatest problem weed along roadsides.

Timing of applications.--A survey conducted beginning March 5, 1973 revealed sufficient growth of dandelion, buckhorn plantain, curled dock, wild carrot, wild parsnip, cinquefoil and other perennials and biennials as well as winter annuals such as henbit, mustards and chickweed to have begun spraying at that time in the area south of Vincennes. The area south of Lafayette was ready to spray approximately 1 week later. By March 20, even bouncing bet and milkweed had several inches of new growth and knotweed (a summer annual) was germinating to 1" high in some regions in the Lafayette area. Tree buds were beginning to break and the entire spraying operation should have been completed by the end of March in the southern half of the state. At the rates of 2,4-D applied, the herbicide exhibits considerable pre-emergence action (up to 4 weeks additional control) on late germinating summer annuals and other weeds coming from seed. In most years, the spring application has started too late.

From the standpoint of weed control, the fall application can be started as early as the first week in August. However, the beginning is usually delayed until soybeans are "made" from environmental considerations (Table I). As a general rule, the fall spraying program should be terminated before the first killing frost. Acceptable results have been obtained as late as the first week in December but only with very favorable weather conditions.

Granting time extensions for contract spraying programs is not a wise practice, especially in the spring, and should be discouraged 1) because of possible danger to crops due to late spring applications and other aspects of the environment and 2) because of reduced treatment effectiveness both in the spring and fall.

5. Research implementation: Findings from this study have served as the principal basis and have given direction to the major aspects of the roadside vegetation management program of the State of Indiana. The implementation of the environmentally-safe, two cycle-spray schedule combining early spring and late fall applications of amine formulations of 2,4-D has occupied much of the effort in this part of the project over the past 5 years. The elimination of unnecessary spraying cycles, reduction from 5-cycle to 3-cycle and further reduced mowing due to improved weed control has resulted in cost savings of approximately \$800,000 annually for the 5 years of this project.

Numerous vegetation control meetings and conferences were held in 1972, 1973, 1974, and 1975 (a total of over 20) to explain the new 3-year spraying rotation for Indiana roadsides (including adoption or potential adoption by other states), to discuss mowing and brush control practices,

and to solve specific problems. Present were State, District, and University personnel from Indiana and other states, as well as County Supervisors and contractors and representatives of chemical companies. Meetings were also held with representatives of chemical companies.

On November 5-6, 1976, a Four-State Highway Vegetation Control Workshop was held at Woodstock, Illinois. Present were representatives from Universities, Highway Departments and spraying contractors from Indiana, Illinois, Michigan and Kentucky. At the meeting the Indiana Spraying Program was discussed as a model program for other states.

Close liaison with federal, state, district and contractual personnel has been maintained in planning, application, and inspection of both spring and fall applications of 2,4-D to Indiana roadsides in the spraying program by contract. Considerable time was devoted to this activity in the period 1972 to 1974.

6. Summary: The purpose of this study was to implement a minimum-cost maintenance program for vegetation control along Indiana roadsides in which mechanical and chemical methods were combined to maintain healthy turf at low cost. A 3-year (environmentally-safe) spraying rotation in combination with reduced mowing was evaluated. Environmentally-safe amine formulations of 2,4-D were applied in late fall and early spring to approximately 1/3 of the state each year. Weed control averaged nearly 90%. With the possible exception of what appears to be an increasing population of common milkweed, the program has posed no problems expected or unexpected. It has provided a maximum-benefit, low-cost maintenance program for the State of Indiana with cost savings in excess of \$800,000 annually.

7. Reports:

D. J. Morre and D. A. Werderitsh, "Chemical Weed Control", JHRP Report,
Purdue University, 1972

D. J. Morre, "A Minimum-cost, Environmentally-safe Program of Herbicide
Maintenance for Indiana Roadsides" Transportation Research Record
506: 85-93, 1975.

INSPECTION OF ROADSIDE SPRAYING OPERATIONS

1. Scope and objectives: While not a major research objective of the total project, a major implementation effort during the first three years was to evaluate the effectiveness of the system of contract applicators and state inspectors. The principle being that any chemical treatment, no matter how well conceived, is only as good as the way in which it is applied. Concerns were mainly for equipment, methods of application including adequate coverage, and inspection procedures. The role of this project was to observe and evaluate. The actual "inspection" was left to the inspectors on the job.
2. Introduction: Careful monitoring of spraying operations is necessary and should be encouraged to minimize environmental hazards and to achieve maximum treatment effectiveness. In the Indiana program, a rigorous inspection system was instituted after the first year and has continued to improve. There can be no doubt that this factor has contributed greatly to the overall effectiveness of the program although further improvements are still indicated.
3. Method of approach: The main method of approach was to be critical of the inspection system for contract spraying. During the spraying operation, crews were located, observed and, on occasion, stopped. Application rate and coverage were checked. An inspection form filled out for each crew is appended as Table V. The State inspector was frequently questioned about how the operation was going to get some appreciation of the job he was doing. Clear transgressions were corrected at the time if possible. Trends were reported to Mr. Bugh and measures were set up in succeeding years to correct obvious deficiencies.

TABLE V

INSPECTION FORM

Inspector _____ Date _____
 Contractor _____ Weather _____
 Location _____ District _____
 Crew Chief _____
 State Inspector _____

 Truck number _____ Speed before _____
 Tank height full _____ Speed during _____
 " " before _____ gallon tank
 " " after _____ Pictures taken _____
 Road width _____ Weed count _____

$$\frac{\text{height of tank at start} - \text{height of tank at finish}}{\text{height of tank full}} \times \text{tank gallonage} = \text{no. of gallons}$$

$$\frac{\text{no. of gal}}{\text{no. of A}} = \text{gal./A}$$

after _____
 gal./A during _____
 before _____

 Comments:

4. Major findings: After the second year of the program, most applications were properly made. In many instances the State Inspector was ineffective, however, expensive, and, in some instances, a definite hindrance. Clearly exceptional individuals were also encountered. Ernest Petty, a State Inspector in the Greenfield District, for example, did an excellent job, kept meaningful and detailed records, and was a definite asset to the program.

Effectiveness of contract applications was evaluated in the Greenfield District in comparisons of roads sprayed using the same herbicide mixture and at the same time of the year; one by a State Highway crew, another by a contractor. The State crew achieved 93% control of weeds from the shoulder to about 6 feet short of the fence line but only 22% control next to the fence. By contrast, the contractor achieved 100% control from the shoulder to the fence-line zone and 99% control at the fence line. The difference was a roadside that still looked weedy and a weed-free roadside. Both were properly applied from the viewpoint of the State inspector.

A concept developed from this part of the project is performance inspection. Under this concept, weed counts would be taken as outlined on page 10 two weeks to one month after application. Checks could be made both fall and spring or only in the spring. Payment would be based on the weed population remaining after treatment. For example:

15,000 weeds/A indicative of 85% control - full payment

30,000 weeds/A indicative of 70% control - half payment

50,000 weeds/A indicative of 50% control or less - no payment.

This scale could be adjusted up or down and is included only as one possibility.

The cost of performance inspection would be less than \$30,000 a year. It would probably be less expensive than present inspections that monitor only at the time of application. It would lay the burden of responsibility for a good job on the contractor and ensure that the State received what was paid for. It would serve to discourage fly-by-night operations and give the reputable contractors a well-deserved advantage.

In the first year (1972) the program was greatly hampered by lack of organization, poor weather conditions, and poorly trained inspectors. The contract awarded was too large for the amount of equipment available to the contractor. Also cited was the need for specific guidelines to be included in the contracts to aid the inspectors in job evaluation and to avoid future problems of the same sort.

A seminar on "Highway Herbicide Treatment" was held November 28 and 29, 1972 at the Highway Research and Training Center, McClure Park, West Lafayette, Indiana. A major part of the program was devoted to reports from District personnel concerning effectiveness or lack of it in the 1972 Fall Herbicide Application Program. The following points were suggested:

- 1) That a pressure gauge be available at the nozzle(s) on demand of the inspector. That a pressure gauge between the control valves and nozzle be operational at all times, visible to the operator, and calibrated to give less than 40 lbs psi at the nozzle.

- 2) That pressure be adjusted to give less than 40 psi at the nozzle to avoid drift.

- 3) That equipment be precalibrated to apply 40 gallons of water + herbicide mixture per acre. The speed at which the vehicle is to be driven to apply this amount of material must be known to the inspector and this speed must be maintained. All trucks must be equipped with functional

speedometers that record accurately in the range 5-10 mph.

4) All nozzles must be functional at all times.

5) Wind speed must be 12 mph or less (or at discretion of inspector).

If excessive drift of material onto adjacent crop land due to wind conditions is noted by inspector, the operation should be halted.

6) Spraying in rain, snow or sleet should be prohibited. If the spray runs off the vegetation, the vegetation is too wet to spray even following a rain or heavy dew.

7) Unit operation should be followed to avoid skips. Roads should be sprayed from fence to fence to the nearest 5 mile segment (On Interstates to the nearest intersection or 5 miles whichever is greater). This will avoid problems of a contractor applying the correct gallonage but spraying only the "easy" part of the road as well.

8) Median spraying should be directed by the District Engineer. Some medians do not require spraying. Other medians might be sprayed as a unit.

5. Research implementation: On August 28, 1974, a meeting was held at the Division of Materials and Tests of the State Highway Commission in Indianapolis. In attendance were State Inspectors from districts all over the state. The meeting was a briefing session for herbicide treatment contract supervisors and inspectors.

A brief outline of the recommendations adopted at that time are as follows:

1) The inspector should monitor 4 aspects of the operation

a) Mixing of the herbicide with water

b) Truck speed during spraying

c) Coverage

d) Weather conditions

2) The inspector should know:

- a) How many gallons of water are actually added at each fill
- b) How many gallons of mix to add for each 100 gallons of water
- c) Driving speed in relationship to width of right-of-way
- d) Proper pressure guage reading
- e) How to judge width of right-of-way in relationship to the correct driving speed.
- f) All rules and restrictions
 - i) Not to spray in inclement weather
 - ii) Not to spray over open water
 - iii) To shut off for residential areas
 - iv) Proper operation of warning lights on truck etc.

6. Summary: In theory, State crews could apply the fall-spring herbicide treatments as well as contractors but in practice they often do not. Equipment and technical knowhow too often are limiting. The consistency, timeliness and effectiveness of the contract applications add rather than detract from the cost-saving features of the roadside spraying program in Indiana.

In the five years of the program, application and inspection procedures have greatly improved. Awarding of smaller contracts and unit operation have eliminated many problems. On-the-truck inspection remains as a costly and inefficient method of performance inspection. A program of performance payment based on weed counts taken after the material has been applied is recommended.

7. Reports: None

COST-COMPETITIVE ALTERNATIVES TO 2,4-D AMINE FOR THE FALL-SPRING SPRAYING
PROGRAM BY CONTRACT

1. Scope and objectives: The purpose of this phase of the investigation was to identify, test and implement a herbicide mixture that was of equal effectiveness to 2,4-D amine but which might offer a pricing advantage.

2. Introduction: Beginning in 1973, the cost of 2,4-D began to increase dramatically as did the contractors' bids within the contract program. The need for an alternative herbicide or herbicide mixture to be cost competitive with 2,4-D was clearly indicated.

3. Method of approach: Based on small plot trials conducted in 1972 and 1973, a mixture of 1 lb/gal of dicamba + 2 lb/gal 2,4-D (e.g. Banvel 720) was identified as a potential cost competitive material.

In early October, a series of test plots was established along U.S. 231 north of Lafayette, Indiana east from the junction with I-65 and Ind. 43 south of Brookston. All major roadside weeds including Canada Thistle, Wild Parsnip, Wild Carrot, Common Milkweed, Whorled Milkweed, Dandelion, Plantain and Dock, were concentrated in at least one of the tests. Treatments were applied to approximately 0.5 mile plots by Chemitrol, Indianapolis, Indiana using truck mounted equipment to simulate an actual roadside spraying operation.

In early October, 1975, a second series of test plots was established on SR 28 east of the junction of I-69 and SR 28 in Delaware County. The purpose of these tests was to compare the efficacy of mixtures of dicamba and 2,4-D relative to 2,4-D alone. The mixture was tested at two rates. At one rate, the mixture and straight 2,4-D amine were compared on a pound-for-pound basis. At the other rate, the mixture and straight 2,4-D

were compared on a cost-effectiveness basis. These tests were applied in cooperation with Mr. Clyde Mason of the Greenfield District. Two treatments were applied: 1) dicamba (banvel) $\frac{1}{2}$ lb/A + 2,4-D amine 1 lb/A in 40 gal water/A and 2) dicamba (banvel) 1 lb/A + 2,4-D amine 2 lb/A in 40 gal water/A. These were compared with the standard treatment of 2,4-D amine 3.3 lb/A. Treatments were applied in 1975-1976 in the normal fall-spring spraying rotation beginning in the fall of 1975. Visual observations and weed count data were taken in late May. Clyde Mason applied several additional tests with dicamba + 2,4-D at different rates and dates in the spring of 1976 (April 4 to May 13) at approximately 12 locations in the Greenfield district.

Based on these test results, an experimental contract was planned for inclusion in one district in the 1976 fall spraying program. This experimental contract was prepared under the supervision of Mr. Marion Bugh of the Indiana State Highway Commission as appended in Table VI. The experimental contract was awarded in the Fort Wayne District to The Daltons, Warsaw, Indiana, and applied in the fall of 1976. Work was evaluated about 2 weeks following completion of the job, the following spring just after application of the spring treatment and in mid-June of 1977.

4. Major findings:

Research trials completed in the summer of 1974 show that the treatment may be as effective as 3.2 lb 2,4-D/acre (the current usage rate of 2,4-D), if not more so, and that it can cost less than 2,4-D depending on a number of factors. The material is registered with the EPA for roadside and watershed use. Extensive laboratory trials carried out under this project

TABLE VI
ADDITIONAL SPECIAL PROVISIONS
ALTERNATE BIDS

35

DICAMBA FORMULATION HERBICIDE CONCENTRATE

The Bidders attention is directed to the fact that he must submit a unit bid price for the dicamba formulation as shown on the itemized proposal (in addition to the bid on 2-4D).

The Commission at their option may award the contract on the basis of bids received on 2, 4-D Amine form weed killer concentrate or dicamba formulation herbicide concentrate.

DESCRIPTION

The work to be performed in this contract, of which these specifications form a part, consists of furnishing and applying a herbicide on both sides of the road within the limits of the right-of-way and any turfed median between pavement, in accordance with the Standard Specifications for Road and Bridge Construction and Maintenance, dated 1974. All materials, equipment and work shall conform to the requirements specified in these specifications.

The operation will require two applications of herbicide, to be placed on the dates set forth in the Schedule of Applications.

The Bidders attention is directed to the fact that the acreage of the area to be sprayed has been predetermined by the Commission. It is imperative that the Bidder examine in detail the area for which he is bidding.

LOCATION

The work location sheets contained herein shows the road sections which shall receive spray application. The attention of the Bidder is directed to the fact, the gallons shown for these sections are for one (1) application. However, two (2) applications will be applied as set out under schedule of application and further, gallons shown on the itemized proposal are totals to be applied in these two applications. The areas within the right-of-way limits to be treated are further defined as follows:

AREA "A"

Included in this category are the following portions of the right-of-way:

1. This area can be described, generally, as any median area and the area between the pavement, or paved shoulder edge, and the right-of-way line.
2. Those portions of any interchange which lie within 20 feet of a paved ramp and which can be treated while traveling with traffic.

AREA "B"

1. This area can be described, generally, as any area between the pavement, or paved shoulder edge, and the right-of-way line, which cannot be successfully reached or sprayed with the spray bar, boom or hand gun.

2. Those portions of any interchange which are not included in section 2 of Area "A".

MATERIAL

The dicamba formulation shall be a water soluble mixture of 2, 4-D and dicamba and shall be an amine formulation with a minimum of 4 pounds acid equivalent per gallon the gallon being determined at 60 F.

The mixture shall contain 1 pound ($\frac{1}{2}$ gal) dicamba acid and 2 pounds ($\frac{1}{2}$ gal) 2, 4-D acid per gallon:

All herbicide material to be used shall meet the requirements of the Indiana Herbicide Law, and shall be registered with the Indiana State Chemist located at the Purdue University Department of Biochemistry, Lafayette, Indiana.

TESTING OF MATERIAL

Tests will not be required however, A type "B" certification as outline in sec's 915.01 - 915.02 (b) of the Standard Specifications shall be provided by the Contractor.

MIXING

The dicamba formulation shall be mixed at the rate of 1.0 gallon per 100 gallon of water.

METHOD OF TREATMENT

Spray mixture shall be applied as outlined on page HT-4 of the special provisions.

BASIS OF PAYMENT

The quantity complete in place and accepted will be paid for at the contract unit price per gallon of dicamba formulation herbicide concentrate applied, which payment unless otherwise provided shall be full compensation for furnishing and applying all materials, including the water necessary for thorough mixing and for all labor, equipment, tools and incidentals necessary to complete the work specified.

in 1973 and 1974 and already reported verify that the mixture and the components of the mixture offer no hazard to the environment.

The dicamba + 2,4-D mixture is no panacea. It is less effective pound per pound than a comparable mixture of picloram + 2,4-D on thistle and milkweed but more effective than 2,4-D alone (Table VII). Very high rates are required to achieve eradication of either thistle or milkweed. This goal was not the purpose of this phase of the study.

In the experimental contract, the dicamba + 2,4-D combination gave 87% control of all weeds compared to 88% for standard 2,4-D (Table VIII). Dicamba + 2,4-D was less effective against wild carrot but more effective against dandelion. Canadian thistle was effectively "knocked down" by the dicamba + 2,4-D in the fall. The following spring, the pattern remained essentially unchanged (Table IX). Thistle plants showed considerable stunting, deformation and other signs of severe injury; growing points appeared to be killed. By mid-June, following the second application of both materials, control by dicamba + 2,4-D was 88% and that from the standard 2,4-D 93%. The clearest difference was greater effectiveness of the dicamba + 2,4-D against dandelion and plantain and an offsetting lack of effectiveness against wild carrot. Thistle plants no longer showed pronounced injury signs and were expected to grow normally. Somewhat more effective control of thistle was achieved but certainly nothing approaching requirements for eradication in a 3-year cycle. Also, the dicamba + 2,4-D mixture was more effective in slowing growth of milkweed in the spring but we have no evidence from this test that it was more effective than standard 2,4-D in milkweed control. Overall, the two treatments were judged to be comparable.

COMPARISONS OF DICAMBA-2,4-D MIXTURES APPLIED IN THE FALL ON CANADIAN THISTLE AND COMMON MILKWEED. Evaluations were between June 6 and June 16 the year following treatment. U.S. 231 test.

<u>Mixture</u>	<u>Rate/A</u>	<u>Canadian Thistle</u>		<u>Common Milkweed</u>	
		<u>Plants/100 ft²</u>	<u>% Cont.</u>	<u>Plants/100 ft²</u>	<u>% Cont.</u>
Check	-	50		14	
Dicamba + 2,4-D	3/4 + 1/4	25	50	16	0
	1.5 + 1/2	16	69	4	71
	3 + 1	4	92	7	50
Picloram + 2,4-D	3/4 + 1/4	30	40	3	79
	1.5 + 1/2	3	94	2	86
2,4-D	6	40	20	11	20

TABLE VIII

COMPARISON OF DICAMBA + 2,4-D and STANDARD 2,4-D IN HERBICIDE TREATMENT PROGRAM BY CONTRACT. Evaluations were on November 10, 1976 six weeks . FALL. after application of fall treatment.

Test areas for Banvel + 2,4-D were on SR 13, 14 and 15. Comparisons with 2,4-D were on SR 25.

Weeds per acre

<u>Treatment</u>	<u>Dandelion</u>	<u>Plantain</u>	<u>Wild Carrot</u>	<u>Other Weeds</u>	<u>Total</u>
Unsprayed Check	19,360	30,800	52,800	880	103,840
Dicamba + 2,4-D	434	4,836	7,750	930	14,012
Standard 2,4-D	3,100	2,108	5,580	992	12,070

<u>Treatment</u>	<u>Canadian Thistle, Plants/A in heavily infested areas</u>
Unsprayed Check	3500
Dicamba + 2,4-D	620
Standard 2,4-D	3100

TABLE IX

COMPARISON OF DICAMBA + 2,4-D AND STANDARD 2,4-D IN HERBICIDE TREATMENT

PROGRAM BY CONTRACT. SPRING EVALUATIONS.

Fall cycle applied between Sept. 14 and Sept. 28, 1977
 Spring cycle applied between April 11 and April 18, 1977
 Weed counts taken May 4, 1977

Test areas for dicamba+ 2,4-D U.S. 30 West, 1 mile west of jct. IND 15
 SR 13 south of Princeton; SR 14 W 2.5 mile east of jct. SR 13; SR 14 E
 1 mile east of South Witley; SR 114 W at jct. 105 and 114

Test area for standard 2,4-D SR 25 south of Mentone. Spring cycle not yet applied.

Ft. Wayne District

Weeds per acre

<u>Treatment</u>	<u>Dandelion</u>	<u>Plantain</u>	<u>Wild Carrot</u>	<u>Other</u>	<u>Total</u>
Unsprayed Check	32,190	29,145	67,425	13,920	142,680
Dicamba + 2,4-D	3,915	131	11,745	653	16,444
Standard 2,4-D*	5,655	2,175	2,610	1,305	11,745

<u>Treatment</u>	<u>Canadian Thistle, Plants/A in infested areas</u>
Unsprayed Check	24,360
Dicamba + 2,4-D	16,530**
Standard 2,4-D*	24,360

* Determined prior to application of spring cycle of Fall-Spring spraying cycle

**Thistle plants showing considerable stunting, deformation and other signs of severe injury; growing points appear killed.

TABLE X

COMPARISON OF DICAMBA + 2,4-D AND STANDARD 2,4-D IN HERBICIDE TREATMENT

PROGRAM BY CONTRACT. MID-SUMMER EVALUATION.

Fall cycle applied between September 14 and September 28, 1977.

Spring cycle applied between April 11 and April 18, 1977

Weed counts taken June 13, 1977

Test areas for dicamba + 2,4-D U.S. 30 east of Jct. SR 9, U.S. 30 east about 5 miles south of Columbia City, SR 205 N, 0.5 mile N of U.S. 30, SR 5 north at Jct. 325 N.

Test area for standard 2,4-D SR 25 south of Mentone.

Ft. Wayne District

Weeds per acre

<u>Treatment</u>	<u>Dandelion</u>	<u>Plantain</u>	<u>Wild Carrot</u>	<u>Curled Dock</u>	<u>Wild Parsnip</u>	<u>Milk Weed</u>	<u>Other</u>	<u>Total</u>
Unsprayed check	29,580	7,395	53,940	435	435	10,440	16,095	118,320
Dicamba + 2,4-D	0	0	8,700	0	260	2,610*	2,175	13,745
Standard 2,4-D	2,175	1,740	2,175	210	0	870	870	8,040

<u>Treatment</u>	<u>Canadian Thistle, Plants/A in heavily infested areas</u>
Unsprayed check	14,355
Dicamba + 2,4-D	5,220**
Standard 2,4-D	7,395

* Milkweed plants showed considerable stunting, deformation and other signs of injury. Control plants and plants in 2,4-D plots averaged 15 inches in height. Plants in dicamba + 2,4-D plots averaged 7 inches in height.

** Thistle plants no longer showing pronounced injury signs and are expected to grow normally.

5. Research implementation: A mixture of 2,4-D plus dicamba has been tested as a potentially more effective and less costly alternative to straight 2,4-D in the fall-spring spraying rotation. Efforts to implement these new findings in 1975 were unsuccessful. It was included as an optional treatment on an experimental basis in the 1976-1977 fall/spring spraying cycle. Based on our experience with the experimental contract, a decision was to have been made as to whether the mixture shows sufficient promise to warrant alternative status to 2,4-D in the Statewide Fall/Spring Spraying Rotation. That recommendation was forwarded to Mr. Bugh in the spring of 1977.

The following specifications are recommended:

MATERIAL

The dicamba formulation shall be a water soluble mixture of 2,4-D and dicamba appropriately labeled for industrial or non-crop use. For a tank mixture, each component shall be an amine formulation with a minimum of 4.0 pounds acid equivalent per gallon, the gallon being determined at 60 F. A premix shall be a minimum of 3.0 pounds acid equivalent per gallon containing 1 pound acid equivalent of dicamba and 2 pounds acid equivalent of 2,4-D, the gallon being determined at 60 F.

The final mixture shall consist of 1 pound dicamba acid and 2 pounds 2,4-D acid per gallon.

All herbicide material to be used shall meet the requirements of the Indiana Herbicide Law, and shall be registered with the Indiana State Chemist located at the Purdue University Department of Biochemistry, Lafayette, Indiana.

6. Summary: Dollar for dollar, Dicamba + 2,4-D seems to be as good as 2,4-D alone. This treatment was evaluated as a potential cost-saving feature of the State Spraying by Contract Program. Weed counts showed that both treatments gave about 90% control of all species. The 2,4-D amine alone was more effective against wild carrot, while the dicamba + 2,4-D combination was more effective against dandelion, plantain and appeared to be more injurious to canadian thistle and common milkweed. At present, the Banvel + 2,4-D combination is less expensive than 2,4-D amine alone. It is also slightly more effective in the control of brush (see next section of report). As a potential cost saving feature of the program, the mixture deserves consideration for future implementation.
7. Reports: None.

EVALUATIONS OF EXPERIMENTAL HERBICIDE MIXTURES GIVING CONTROL OF CANADIAN
THISTLE AND MILKWEED

1. Scope and objectives: The research undertaken was designed to explore more potent chemical mixtures in the fall cycle of the fall-spring spraying rotation by contract to achieve more effective control of 2,4-D resistant species such as Canadian Thistle and Milkweed.
2. Introduction: The only problem to arise out of the fall-spring spraying program by contract using 2,4-D amine is that of 2,4-D-resistant species. Will they eventually increase to the point that 2,4-D spraying becomes ineffective? We do not yet have the answer to that question but have explored new and more potent herbicide mixtures for use along Indiana roadsides if and when they are needed.
3. Method of approach: The herbicide mixtures were identified initially in laboratory and greenhouse studies and then tested in small plots to verify efficacy. Environmental studies were carried out in parallel to verify safety or evaluate risk. These trials were largely completed prior to 1973 and have been reported previously.

With the objective of testing the possibility of a 3-year spraying rotation in which one herbicide treatment would keep the roadside free of weeds for the entire 3-year period as well as control 2,4-D resistant species, plots were established in the falls of 1970, 1971, 1972, 1973 and 1974 to evaluate the lasting effectiveness of combination treatments, and in 1972-1974 to evaluate environmental safety. Triplicate plots were sprayed under roadside conditions to simulate actual use conditions at rates of $\frac{1}{2}$, 1, $1\frac{1}{2}$ and 2 lb/acre (up to 6 lb/acre in the environmental tests) in mid-August to early October. Evaluations were as described on page 10.

4. Major findings: A fall application of picloram (Tordon)(3 parts) plus 2,4-D (1 part) gave 90 to 100% control of all species for the first season by applications at rates of 1 lb/acre or greater (Table XI, Table XII). Evaluations one and two years later indicated lasting control for most species except a few summer annuals such as nodding spurge which germinate from seed in early summer and are not especially objectionable. For all practical purposes, the sprayed plots were still weed free at the 2 lb/acre rate 3 years after spraying. These treatments are also effective for control of canadian thistle and milkweed (Table VII, page 38). The appearance of the sprayed roadsides is illustrated in figures 6 and 7.

In the 1972 study, the environmental safety of picloram + 2,4-D mixtures was evaluated. Based on extensive laboratory, greenhouse and field testing, a 3:1 ratio of picloram plus 2,4-D was selected for initial evaluation under roadside conditions at a rate of 1 lb/A of total herbicide (3/4 lb picloram plus 1/4 lb 2,4-D amine). The application used truck-mounted equipment supplied by Chemitrol, Indianapolis, Indiana, and was in early October. The formulation, designated M-3766, was provided by Dow Chemical Company, Midland, Michigan, according to our specifications. It contained 1½ lb ai picloram plus ½ lb ai 2,4-D per gallon as the triisopropanolamine salts. Applications were at rates of ½, 1, 2 and 6 lb/acre ai. Endrift, a drift-reducing agent commercially available and manufactured by Nalco Chemical Company, was included at the rate of 1 quart per 100 gallons of spray in all applications. Drift tests showed a 40 to 50% reduction in the amount of herbicide reaching non-target areas using this material. Included in the test were roadside plantings, ornamental plantings, hardwood forest, conifers, a flowing stream, and cropland. Species composition were determined and soil and water samples were collected prior to and after

TABLE XI

EFFECTIVENESS OF A FALL APPLICATION OF PICLORAM (3 parts) PLUS 2,4-D (1 part) MIXTURES ON CONTROL OF ROADSIDE WEEDS IN THE SEASON FOLLOWING APPLICATION. The treatments were applied in mid-August 1970 and counts were taken October 7, 1971. Data are given in plants per 100 square feet.

Weed species	Check	Rate of application of total herbicide mixture			
		$\frac{1}{2}$ lb/A	1 lb/A	$1\frac{1}{2}$ lb/A	2 lb/A
Wild carrot	16	2	0	0	0
Buckhorn plantain	119	1	0	0	0
Rough cinquefoil	6	0	0	0	0
Common milkweed	3	0	0	0	0
Wild parsnip	1	0	0	0	0
Broadleaf plantain	8	0	0	0	0
Whorled milkweed	3	0	0	0	0
Black medic	12	0	0	0	0
White clover	10	0	0	0	0
Yellow woodsorrel	5	0	0	0	0
Nodding spurge	29	9	15	9	9
Composite family	6	0	0	0	0
(Golden rod, asters, etc.)					

TABLE XII

EFFECTIVENESS OF A FALL APPLICATION OF PICLORAM (3 parts) plus 2,4-D (1 part) MIXTURE ON CONTROL OF ROADSIDE WEEDS. Treatments were applied in early October 1972 with commercial truck-mounted equipment and counts were taken in May 1973.

Weed species	Untreated check	Plants/acre, May 1973		
		Picloram + 2,4-D (3:1) = M-3766 form.		
		$\frac{1}{2}$ lb/A	1 lb/A	2 lb/A
Plantain	19,575	0	0	0
Dandelion	8,260	435	210	0
Wild carrot	6,520	0	0	0
Clovers	3,480	0	0	0
Curled dock	960	0	0	0
Common thistle	1,300	135	95	0
Other composites	4,350	0	0	0
Other weeds	6,000	450	0	0

Figure 6. Portion of U.S. 421 north of Lafayette, Indiana, in White County. The right side of the road received a single fall application of an experimental formulation (M-3766) containing 3 parts picloram and 1 part 2,4-D at a rate of 2 lbs active ingredient per acre. The left side of the road was unsprayed. Photographed in the spring following application.

Figure 7. Portion of U.S. 421 north of Lafayette, Indiana in White County. The right side of the road received a single fall application of an experimental formulation (M-3766) containing 3 parts picloram and 1 part 2,4-D at a rate of 2 lbs active ingredient per acre. Photographed in early spring 3 years after initial application shown in figure 6.

spraying. At 1 lb/acre, M-3766 gave 90% control of all species including (Table XIII) Canadian thistle/and the 2 lb/acre rate gave nearly complete control of all weed species (Tables XI, XII; Figures 6 and 7).

Using sensitive biological assay procedures developed under this project, testing of water samples collected from the stream running through one of the test sites, revealed no detectable herbicide entering the water from drift (at the time of spraying). Tests of soil samples showed that the herbicide remained on the target area except for one situation at the 6 lb/acre rate where the sprayed roadside was higher than the adjacent field and where the drainage ditch channeled soil and water from approximately 1 mile of road directly onto one spot of the field. Here, herbicide entered the field and caused slight injury to soybeans. Examination of roadside plantings, native vegetation, and fruit trees in an orchard adjacent to the sprayed roadside revealed no damage to species not oversprayed directly.

A similar test, although not as extensive, was established in the spring of 1973, with M-3766 applied at a rate of 2 lb/acre. In this test, basswood trees adjacent to the sprayed roadsides were killed. Other tree species showed only minor injury symptoms including those in which root systems were directly oversprayed and all survived. In spite of heavy rains, soil movement of no more than 3 feet was experienced. However, picloram will not be recommended for use in spring or summer applications for general roadside weed control because of possible crop injury.

Picloram, which has a mode of action similar to that of 2,4-D has proven non-toxic in pure form. Laboratory tests of the formulated material are sufficient to indicate that no injury to fish or algae should result from normal use practices.

TABLE XIII

EFFECT OF PICLORAM + 2,4-D MIXTURES ON CONTROL OF CANADIAN THISTLE
AND MILKWEED COMPARING UNMOWED AND MOWED ROADSIDES.

<u>Treatment</u>	<u>Rate/A</u>	Plants/100 ft ²			
		<u>Unmowed</u>		<u>Mowed</u>	
		<u>Can. thistle</u>	<u>Milkweed</u>	<u>Can. thistle</u>	<u>Milkweed</u>
Check		30	5	36	50
Picloram + 2,4-D	3/4 + 1/4	0	0	58	8
	1.5 + 1/2	0	0	3	2

In other tests in 1973 (Table XIV) and 1974 (Table XV) the picloram + 2,4-D combination (designated M-3766) was compared to dicamba, Silvex, and a three-way mixture to be recommended for use in off-road equipment for control of brush (see Part II of this report). In each test M-3766 was superior to the alternatives and showed a consistent pattern of performance under actual roadside use conditions.

5. Research Implementation: By using more potent herbicides, i.e. picloram + 2,4-D mixtures, we were able to maintain turf in a weed-free condition for at least 3 years and an acceptable condition for 5 years from a single application. This means that only one application every 6 years would be required. These treatments have been tested extensively in small plots and under conditions of contract application over a 5-year period. All weed species, including milkweed and Canadian Thistle were controlled as were most brush species.

Implementation was attempted in 1973-1974 but failed when an Experimental Use Permit from the Environmental Protection Agency did not materialize largely through lack of interest on the part of the manufacturers of the materials in question. New implementation activities initiated in the spring of 1977 have reopened the issue and the manufacturers appear interested in once again pursuing the use of these materials as a tank mixture within existing label restrictions.

6. Summary: A herbicide mixture consisting of three parts picloram (trade name Tordon) and one part 2,4-D plus an agent to control drift is a potent herbicide for control of a wide range of broad-leaved herbaceous and woody (see next section) roadside vegetation. Difficult to control perennial species such as common milkweed and Canadian thistle are susceptible to picloram. A significant portion of the picloram necessary for control of

TABLE XIV

COMPARISON OF PICLORAM + 2,4-D (M-3766) MIXTURES AND DICAMBA AND SILVEX
IN 1974 TESTS APPLIED IN THE GREENFIELD DISTRICT (FALL APPLICATIONS)

Plants/100 square feet								
<u>Treatment</u>	<u>Rate/A</u>	<u>Dandelion</u>	<u>Plantain</u>	<u>Wild Carrot</u>	<u>Milkweed</u>	<u>Wild Parsnip</u>	<u>Other</u>	<u>Total</u>
Check		62	50	12	12	12	10	158
M-3766	1.5	0	0	0	0	0	0	0
	2.0	0	0	0	0	0	0	0
Silvex	3	4	12	4	5	Trace	1	29
	6	1	1	2	Trace	0	0	10
Dicamba	2.25	11	1	2	5	0	0	19
	5.5	1	1	18	1	0	0	21

TABLE XV

COMPARISON OF PICLORAM + 2,4-D (M-3766) MIXTURES and A THREE-WAY MIXTURE OF DICAMBA, SILVEX AND 2,4-D AS A FALL APPLICATION APPLIED IN 1974. Ft. Wayne District. Evaluation on May 26, 1975.

Plants/100 sq. ft.									
<u>Treatment</u>	<u>Rate/A</u>	<u>Dandelion</u>	<u>Plantain</u>	<u>Wild Carrot</u>	<u>Milk Weed</u>	<u>Curl. Dock</u>	<u>Can. Thistle</u>	<u>Other</u>	<u>Total</u>
Check A		3	33	85	9	1	0	58	189
Check B		5	11	51	8	0	56	87	219
M-3766	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	7*	7
Dicamba + Silvex +	3	0	0	1	2	0	40	2	45
2,4-D	6	0	0	1	1	0	0	9*	11
Check C	1	0	0	0	6	0	14	74	95

* Mostly bouncing bet.

these species is replaced by the less-expensive phenoxy herbicide, 2,4-D, without reducing the overall effectiveness of the treatment. By using the more potent herbicide mixture, we have maintained turf in a near weed-free condition for at least 3 years following a single fall application with no injury to grass or trees. Only one application every 6 years might be required. Even the spring application is eliminated. Cost saving features may outweigh the use of this more expensive material.

7. Reports:

- S. Krawiec and D. J. Morre, "Interactions of Tordon Herbicide Applied in Combinations". Published in Down to Earth, a publication of the Dow Chemical Company, Midland, Michigan, Winter 1968
- D. J. Morre, R. D. Cheetham, S. Krawiec and R. D. Clark, "Combination Treatments for Control of Wild Garlic and Common Milkweed", JHRP Report, Purdue University, October, 1970.
- D. J. Morre, "Minimal Cost Maintenance for Indiana Roadsides", Proceedings 58th Road School, Purdue University, 1972.
- D. J. Morre and D. A. Werderitsh, "Chemical Weed Control", JHRP Report, Purdue University, 1972.
- D. J. Morre, " A Minimum-Cost, Environmentally-Safe Program of Herbicide Maintenance for Indiana Roadsides", Transportation Research Record 506: 85-93, 1975.
- D. J. Morre "Chemical Control of Brush and Environmental Safety of Roadside Vegetation Management Chemicals" JHRP Progress Report, December 1976.

PART II

CHEMICAL CONTROL OF BRUSH

and

ENVIRONMENTAL SAFETY OF ROADSIDE VEGETATION MANAGEMENT CHEMICALS

CHEMICAL CONTROL OF BRUSH AND ENVIRONMENTAL SAFETY OF ROADSIDE VEGETATION
MANAGEMENT CHEMICALS

1. Scope and objectives: With reduced mowing practices, brush is an increasing problem of roadside management. In the past, the herbicide 2,4,5-T was used extensively and effectively as a brush control agent along roadsides. However, regulatory rulings now restrict its use. The purpose of this portion of the research project was to provide a practical alternative to 2,4,5-T for the control of brush and at the same time control broad-leaf weeds. This report provides one such treatment in the form of a specific recommendation.

Since environmental safety is a major factor in the design of any vegetation management program, a large portion of the study was devoted to tests to determine or verify safety of the recommended materials to man, domestic animals, fish, aquatic food chain organisms, and non-target vegetation. Additionally, test results were obtained for picloram, a picloram + 2,4-D mixture and "Krenite" brush control agent. The latter are not yet recommended for use along the Interstate System but may find applications for this purpose or for brush control along county roads.

2. Introduction: According to the New York Department of Transportation Guide for the Determination of Moving Limits, safety overrides all other features affecting roadside maintenance. Sight distances must be maintained at intersections and on the insides of curves. Safety setbacks must be observed. Guard rails, bridge approaches, signs, and other traffic control devices must be kept open to view.

Brush is one of the major offenders in obstructing vision. Reduced mowing practices favor the growth of brush. Within two years, black locust,

willow or elm will become established in unmowed portions of roadsides. In non-prairie areas, where woody vegetation is natural to the environment and a continual invader, one must be prepared for a long fight. Brush grows up into trees which represent solid objects and present even more serious safety hazards. Trees too near traffic lanes must be removed usually at considerable expense.

Brush along county roads is a continuing problem. Sight distances on curves are reduced, approaches to intersecting roads or lanes are obscured, signs and other traffic control devices are concealed, and the situation may degenerate to the point where roadside brush becomes a threat to adjacent agricultural land.

Brush along roadsides will be controlled one way or another. It can be either as expensive removal of dangerous trees or through low-cost application of chemicals when the brush is small. Newly instituted, cost-saving practices of reduced mowing (see section III of this report) demands that some form of brush control practice be instituted. Use of chemicals is the most convenient and least expensive but which chemicals?

In the past, the herbicide 2,4,5-T was used extensively and effectively as a brush control agent along roadsides. It was most generally used in combination with 2,4-D. The herbicide combination decreased the overall cost of the materials with no significant loss or a slight gain in treatment effectiveness. However, regulatory ruling now restrict the use of 2,4,5-T. The purpose of this research project was to identify and test suitable herbicide treatment programs for use on the Interstate System in combination with reduced mowing practices that would provide a practical alternative to 2,4,5-T and at the same time control broad-leaf weeds.

3. Method of approach: Commercially available herbicides, either demonstrated or claimed to be without hazard to man or his environment, were evaluated for efficacy in control of Indiana brush species under actual or simulated conditions of field application. These studies were initiated in the fall of 1973 when the brush problem on unmowed portions of Interstates became evident, were continued in 1974 and 1975, and completed with additional studies in 1976.

Test sites were located in Boone, Kosciusko, Hancock, Tippecanoe, and White counties. Applications were with truck-mounted equipment operated by cooperating contractors (Chemitrol, Indianapolis; The Daltons, Warsaw) or industrial applicators (DuPont).

Standard industrial evaluations were used to determine the brush control efficacy and included % defoliation, % root collar resprouts, % with green stems, % dead for each species present, as well as effects on grass and other non-target vegetation. All treatments were evaluated in the second, and, if possible, third years to establish long-term efficacy. Comparisons were relative to a standard foliar application of 2,4,5-T + 2,4-D as summarized in Table XVI.

4. Major findings: A mixture of equal parts of an amine salt formulation of 2,4-D + 2,4,5-TP (Silvex) + dicamba (Banvel) was found to be suitable for inclusion in the Fall-Spring spraying rotation to be applied by off-road equipment to unmowed portions of the Interstate System (Table XVII). This same mixture or "Krenite" brush control agent (Table XVIII) are recommended as a foliar application for control of brush along county roads and other situations where hydraulic spray applications directly to stems and foliage are indicated.

Environmental safety of these herbicides to fish, fresh water organisms, and non-target vegetation was also evaluated. Similar evaluations were made

SUMMARY OF BRUSH CONTROL TREATMENTS FOR USE OTHER THAN FOR HOME GROUNDS,
RECREATIONAL AREAS, OR IN OR NEAR WATER AREAS

FOLIAGE-STEM SPRAY: 2,4,5-T or 2,4-D + 2,4,5-T amines or low volatile esters at a rate of $\frac{1}{2}$ - 1 gal (2-4 lbs) herbicide in 100 gallons water.

Wet all leaves, stems and suckers thoroughly to the groundline. Apply any time after leaves reach full size until about 3 weeks before frost. Avoid drift.

Note: If sprayed directly over water, ester formulations should not be used to avoid fish kills.

CUT STUMP: 2,4,5-T or 2,4-D + 2,4,5-T low volatile esters or oil soluble amines at a rate of 12 - 16 pounds herbicide in 100 gallons diesel or fuel oil.

To prevent stumps from sprouting, thoroughly drench each stump or cut surface with the herbicide mixture in oil. Apply any time of year as soon as possible after trees are cut.

BASAL BARK: 2,4,5-T or 2,4-D + 2,4,5-T low volatile esters or oil-soluble amines at a rate of 8-32 pounds of herbicide in 100 gallons diesel or fuel oil.

Most useful for small trees, less than 4 inches in diameter. Apply as a basal spray directed to trunk or stem from ground line up 12-20 inches. Wet root collar and stem portion thoroughly. May be used year around but is especially effective as a dormant treatment.

FRILL OR GIRDLE: 2,4,5-T or 2,4-D + 2,4,5-T low volatile esters or oil soluble amines at a rate of 12 - 16 pounds of herbicide in 100 gallons diesel or fuel oil.

Cut overlapping notches with an ax or continuous ring with chain saw. Fill the notches with as much herbicide mixture as possible or drench the cut surfaces of the saw girdle. Apply any time of year as soon as possible after cuts are made. Recommended for trees larger than 5-6 inches diameter.

INJECTION: 2,4,5-T or 2,4-D + 2,4,5-T low volatile esters at a rate of 4 lbs herbicide in 20 gallons oil.

Spaced cuts at 1-3 inch intervals are made around tree. The herbicide oil mixtures are placed in the cuts. Various mechanical devices and herbicide formulations are available for this method of treatment. Check manufacturers instructions for any particular method or product.

RESTRICTION: Do not apply 2,4,5-T on home grounds, recreational areas or in or near water areas.

3-WAY PHENOXY-DICAMBA HERBICIDE MIXTURE

CHEMICAL: A mixture of equal parts of an amine salt formulation of 2,4-D (2,4-dichlorophenoxyacetic acid) + 2,4,5-TP (Silvex = 2,4,5-trichlorophenoxypropionic acid) + dicamba (Banvel = 3,6-dichloro-o-anisic acid)

RATES are based on a tank mix of formulated products each containing 4 pounds per gallon of active material.

DIRECTIONS FOR USE

For the control of woody brush (susceptible) including:

HOW TO MIX

HOW TO APPLY

Ash	1 gallon 2,4-D amine	HYDRAULIC SPRAY APPLICATION
Basswood	+ 1 gallon Silvex	STEM-FOLIAGE-HIGH WATER VOLUME
Blackberry	+ 1 gallon dicamba plus	
Black Locust	300 gallons water	Apply after leaves are fully developed and until about three weeks before frost.
Box Elder		
Catalpa		
Cherry		
Chinquapin Oak		Treat all stems and foliage to runoff including root crown, if possible
Crab Apple		
Dogwood		
Elm; Elderberry		
Honey Locust		Use 100 to 150 gallons of spray mix per acre depending on the height and density of brush
Multiflora Rose		
Oak		
Persimmon		
Poplar	2½ gallons 2,4-D amine	AERIAL APPLICATION OR GROUND APPLICATION WITH MICROFOIL
Sassafras	+ 2½ gallons Silvex	BOOM
Sumac	+ 2½ gallons dicamba plus	
Sycamore	92.5 gallons of water	
Wild Cherry		Apply after leaves are fully developed and until about three weeks before frost
Wild Plum		
Wild Grape		
Wild Rose		
Willow		Apply at the rate of 20 gallons of spray mix per acre of brush
Witchhazel		
and similar woody plant species		

Also controlled (intermediate):

Bittersweet
Cottonwood
Hawthorne (Red Haw)
Hickory
Maple
Mulberry
Walnut

Not controlled (resistant):

Hackberry
Greenbriar

"KRENITE" BRUSH CONTROL AGENT

CHEMICAL: Krenite (ammonium ethyl carbamoylphosphonate) plus a NONIONIC SURFACTANT (Surfactant WK, Tween 20, or Triton X-100 or equivalent product)

RATES are based on a tank mix of formulated product containing 4 pounds per gallon of active material plus a surfactant.

DIRECTIONS FOR USE

For the control of woody
brush (susceptible)
including:

HOW TO MIX

HOW TO APPLY

Alianthus	1½ - 3 gallons Krenite	HYDRAULIC SPRAY APPLICATION
Aspen	+ 1 quart surfactant	STEM-FOLIAGE-HIGH WATER VOLUME
Beech	plus 100 gallons water	
Birch	(or follow manufacturer's	Apply from August 1 until
Hawthorne	label instructions)	September 15.
Hornbeam		
Locust		Treat all stems and foliage
(Black & Honey)		to runoff. Good coverage is
Multiflora Rose		critical.
Red Oak		
White Oak		Use 150 to 200 gallons of spray
Water Oak		mix per acre depending on the
Sycamore		height and density of brush.
Sumac		
Sweet Gum	2½ - 3 gallons Krenite	AERIAL APPLICATION OR GROUND
Walnut	+ ½ pint surfactant plus	APPLICATION WITH MICROFOIL BOOM
Blackberry	17 - 17½ gallons water	
and similar woody	(or follow manufacturer's	Apply from August 1 until
plant species	label instructions)	September 15

Also controlled (intermediate):

Apply at the rate of 20 gallons
of spray mix per acre of brush.

Red Alder	
White Ash	
Black Cherry	
Choke Cherry	
Pin Cherry	
Dogwood	
Elderberry	Persimmon
American Elm	Poison Ivy
Slippery Elm	Sassafras
Winged Elm	Smilax (Green Briar)
Black Gum	Virginia Creeper
Hackberry	Wild Grape
Hickory	Wild Plum
Red Maple	Willow
Mulberry	Witchhazel
Osage Orange	Yellow Poplar

Not controlled (resistant):

Box Elder
Buckeye
Buckbrush
Basswood
Eastern Red Cedar
Honeysuckle
Linden
Russian Olive
Trumpet Creeper

with picloram (Tordon) and one agent to control herbicidal drift (Nalco-trol). The three herbicides, 2,4,-D, dicamba (Banvel) and picloram (Tordon) as acid or amine salt formulations exhibited low toxicity to approximately 20 species of fresh water and marine algae even at rates approaching the maximum solubility in water. Ester formulations, including 2,4,5-T or Silvex which is formulated and sold only as an ester, were more toxic. Equivalent results were obtained with fish. For these reasons, only amine salt formulations of 2,4-D or dicamba are recommended and the Silvex content should not exceed more than 1/3 of the total herbicide mixture in the 3-way combination herbicide (Table XIX).

Of the three herbicides tested, only picloram (Tordon) was persistent either in the soil or water. The hazards of this material to non-target vegetation were evaluated using several biological assay procedures developed. Potential hazards were shown to be minimal if the material was applied in the fall but more serious following a spring application. A combination herbicide of 3 parts picloram and 1 part 2,4-D had characteristics similar to picloram alone. Good control of a wide range of brush species was achieved as well as excellent control of MILKWEED and all other broad leaf species including CANADA THISTLE. Attempts to use this material in the Indiana State Highway Program under an experimental label were unsuccessful.

2,4-D alone is of limited effectiveness as a brush control agent. Fall applications of dicamba, either alone or with 2,4-D, were also ineffective in the control of brush.

Control of herbicide drift is an important aspect of any chemical program for control of brush. This is especially important for mid-summer applications to county roads where soybean fields are involved. An appropriate drift control agent or system should be used and wind conditions should be still. Dicamba (Banvel), because of possible injury to soybeans and other crops and non-target vegetation, must be applied either alone or in combination in late fall or early spring after crops have matured or before emergence.

ENVIRONMENTAL SAFETY AND SPECIAL PRECAUTIONS

3-WAY PHENOXY-DICAMBA MIXTURE: The components of this mixture all meet current regulatory requirements for use on land adjacent to and surrounding domestic water supplies, streams, lakes and ponds as well as for roadsides.

2,4-D is registered for roadside use without restriction. When amine forms 2,4-D are used, there is no danger to fish, other wildlife, domestic animals, or phytoplankton. The acute mammalian toxicity is low and 2,4-D poses no known hazards to humans. There is no danger to non-target vegetation or crops unless directly oversprayed. 2,4-D is biodegradable, with a soil-water persistence half-life of about 4 days.

Dicamba is registered for roadside use with no restrictions. It is non-toxic and also biodegradable with a soil-water persistence half-life of 25 days. It is not toxic to fish or phytoplankton or other forms of aquatic life. The acute mammalian toxicity is low and dicamba does not pose any known hazards to humans. There is some potential hazard to non-target vegetation, especially susceptible species including soybeans, from fine spray particles carried in the form of drift. Important: WHEN THE 3-WAY MIXTURE CONTAINING DICAMBA IS USED, AS A PRACTICAL MATTER DITCHES WHICH BORDER SOYBEAN FIELDS SHOULD BE SPRAYED ONLY BETWEEN AUGUST 1 and SEPTEMBER 15 (OR AFTER SOYBEANS ARE MADE) OR IN EARLY SPRING BEFORE SOYBEANS ARE UP. At other times, the dicamba in the mixture can be replaced by 2,4-D amine or by 2,4DP amine.

Silvex, unlike 2,4,5-T, can be used in roadside applications. Its toxicity properties are similar to those for 2,4-D. It is biodegradable with a soil-water persistence half-life of about 20 days. Unfortunately, Silvex is sold only as an ester formulation. Therefore, fish kills may result if rates in excess of 2 lb/A are sprayed directly over shallow water. Important: The amount of Silvex must not exceed more than 1/3 of the total herbicide in the mixture. Silvex must not be combined with ester formulations of 2,4-D ditch bank applications. The total rate of application (2,4-D amine + dicamba + Silvex) must not exceed 6 lb/A. If any of the above are violated, fish kills may result.

KRENITE BRUSH CONTROL AGENT + SURFACTANT: Krenite is labeled for use on "land adjacent to and surrounding domestic water supply reservoirs, supply streams, lakes, and ponds." There is little or no potential danger to non-target vegetation or crops unless directly oversprayed. Even with brush, unsprayed portions of larger trees normally survive. Krenite has a low mammalian toxicity, is biodegradable and poses no known hazards to humans.

The SURFACTANTS recommended for use with Krenite Brush Control Agent are not toxic to humans and generally recognized as safe. The recommended amounts should not be exceeded due to possible injury to fish.

Performance comparisons. The various materials evaluated are summarized in Table XX. Neither the 3-WAY PHENOXY-DICAMBA MIXTURE nor the KRENITE BRUSH CONTROL AGENT are as effective in the control of brush as the herbicide 2,4,5-T alone or in combination with 2,4-D (BRUSH KILLER). Both are superior to 2,4-D alone, dicamba alone, or 2,4-D in combination with dicamba. These are the only materials known to be effective for control of brush which are both commercially available (except under an experimental label) and considered to be environmentally safe.

The 3-WAY MIX is less expensive than KRENITE though both are comparable in cost. They are applied at comparable rates and both are recommended for applications in the fall. The 3-WAY MIX may give the broadest spectrum of species controlled. KRENITE has a slight edge in overall safety but has not been evaluated in terms of weed control. It is not expected to be very effective.

In summary, KRENITE BRUSH CONTROL AGENT may have considerable merit for use along county roads where the species to be controlled are susceptible to KRENITE and where emphasis is on "trimming". Where a broader spectrum of control is desired, i.e. control of both broad-leaf weeds and brush along the Interstate System, then the 3-WAY MIX is recommended for application in the fall and/or spring after crops are made or before crops are up. Because of possible injury to soybeans, the 3-WAY MIX is not recommended for use along county roads in midsummer.

TABLE XX. Performance comparisons of brush control agents based on 1973-1976 test evaluations.

Species	BRUSH KILLER* (2,4-D + 2,4,5-T) 3 lb/A	3-WAY MIXTURE (D + banvel + Silvex) 3 lb/A	6 lb/A	KRENITE BRUSH CONTROL AGENT 6 lb/A	M-3766 (4:1 rordon + 2,4-D) 1 lb/A	2 lb/A
Ash	3	3	4	3	1	2
Elm	2	5	3	4	4.5	3.5
Maple	5	2	2	3	4	5
Locust	5	5	5	5	1-5	2-5
Willow	4	3	4	4	4	5
Other Softwoods	2-5	4	4.5	3	4	4
Oak	5	2	2.5	3	insufficient	
Other Hardwoods	5	2	2.5	4	data	
Multiflora Rose	0	4	5	2	5	5
Other brambles and vines	4	1	2	2	4	4
ALL SPECIES	3.6	3.1	3.4	3.3	3.4	4.0

* Includes data from previous evaluations

TABLE XXI. Performance comparisons of brush control agents based on 1973-1976 test evaluations
Continued.

Species	SILVEX* (2,4,5-TP) 3 lb/A 6 lb/A		BANVEL (Dicamba) 2 lb/A 4.4 lb/A		BANVEL 720 (Dicamba + 2,4-D) 3 lb/A	
	0	2.5	4	4	4	4
Ash	0	2.5	4	4	4	4
Elm	4	5	2	3	2	2
Maple	1	2	0	0	0	0
Locust	5	5	variable		2	2
Willow	2	3	3	4	2	2
Other Softwoods	3	3	2	2	2	2
Oak	3	4	3	1	0	0
Other Hardwoods	3	3	3	3	0	0
Multiflora Rose	2	2	0	0	2	2
Other brambles and vines	3	3	1	1	1	1
ALL SPECIES	3.0	3.3	1.8	2.1	1.5	1.5

* Includes data from previous evaluations.

Generally sight distances were improved along county roads even under conditions where complete control of brush was not achieved, e.g. Krenite Brush Control Agent or higher rates of dicamba + 2,4-D.

Other Brush Control Tests and Evaluations

More limited tests were evaluated with the following materials.

Soil Sterilants- Hyvar X-L mixed at a rate of 1 gal/5 gal water and applied at the rate of 1 oz/2" basal diameter as a fall treatment at the crown. Good brush control was achieved; danger to adjacent crops would be expected to be minimal. The major problem with this and other soil sterilant treatments is that grass is killed (Fig. 29) leaving the soil open to erosion.

2,4-DP + 2,4,5-TP Mixtures- Evaluations were made of a ditch bordering U.S. 231 in White County. The application was by helicopter by a private contractor. Early control looked very good but regrowth was noted in subsequent years. This treatment has potential for use on county roads and plans are to begin more detailed evaluations in 1976.

Garlon- A new product of Dow Chemical Company currently available under an experimental label for non-crop uses will also be evaluated in 1976 as a possible replacement for the 3-Way Mixture on the Interstate System.

Krenite Brush Control Agent- Two additional tests with Krenite were evaluated in 1974 (Kosciusko County) (Fig. 28) and on the Interchange between I-65 and I-465 on the north side of Indianapolis). Both were applied in the fall as recommended. In the Indianapolis test, partial control of sycamore was achieved with good control of willow, black cherry, and tree-of-heaven (Ailanthus). Box elder was not controlled and partial kill was achieved for red mulberry and poison ivy.

METHODS OF APPLICATION FOR FOLIAR BRUSH CONTROL SPRAYING

Foliar applications of brush control agents is normally less expensive than dormant basal or directed applications, because less labor and time is required and water is used as the carrier. The most desirable season for foliar applications is late summer or early fall after crops are made so that dangers of injury from drift become minimal. Timing of the Krenite application is critical and must be carried out between August 1 and September 15. Timing of the 3-Way Mix application is less critical but must be between the time the brush is fully leafed out and the leaves begin turning color in the fall.

Ground application. Equipment of various types can be used with any type of off-road equipment able to traverse the area to be sprayed. Some type of boom system is most widely used. The boomless nozzle system is often criticized because of poor coverage. However, a combination of boom and boomless nozzle arrangements are very effective. Broadcast applications can be made with a handgun, and in brush applications, a straight-stream nozzle is often used. The handgun method has the advantage of being able to direct the spray to where it appears to be most needed and to reach plants not directly accessible to ground equipment. Selective treatment of brush is also possible.

The greatest problems in ground applications are to achieve adequate coverage and to avoid drift. All leaves and bark surfaces should be thoroughly wetted and the mixture even allowed to run down and puddle at the base of the trunk. If drift cannot be avoided, the applicator should stop spraying and wait for better weather conditions.

Aerial applications. Helicopters are normally used in making aerial applications but have not proven practical for most roadside uses. A truck-mounted microfoil boom can be used to simulate an aerial application with considerable success. Mixing and application rates with the microfoil boom are the same as for aerial applications. A drift-control system must be used to ensure proper application and to reduce the dangers of drift.

PROPER CONTROL OF DRIFT IS ESSENTIAL

Drift is the term used for the movement of spray particles from the time they leave the application equipment until they hit the ground. Drift damage can be avoided in the following ways:

- 1) Keep fine spray particles at a minimum
- 2) Do not spray in windy weather
- 3) Keep equipment and spray nozzles close to target
- 4) Make early or late season applications when susceptible crops are dormant or not growing
- 5) Utilize special drift reduction techniques such as invert emulsions, thickeners, gels, or foams.

Basically, drift can best be controlled by the elimination of fine particles in the spray (lower pressures and increased spray volume; use of larger nozzle tips), proper conditions for application (wind is the major factor), and the use of drift control agents. No drift control system is perfect, and none will control drift under windy conditions. DRIFT IS BOTH WASTEFUL OF CHEMICAL (It reduces treatment effectiveness since less chemical reaches the target) AND IS A HAZARD TO NON-TARGET SPECIES.

5. Research implementation: In combination with reduced mowing practices, need for chemical control of brush was indicated. In favorable situations, tests and observations showed invasion of woody species within one year in unmowed roadsides. To eliminate brush, a 3-WAY HERBICIDE MIXTURE of 2,4-D - dicamba - Silvex has been proposed for use in off-road equipment on unmowed rights-of-way. This recommendation is scheduled for implementation in the fall of 1978. Cost savings are reflected in the reduced mowing estimates.

Details of the recommendation are given in Table XXI.

6. Summary: A new herbicide formulation was developed to replace 2,4,5-T for brush control along roadsides. The new formulation consists of a 3-way mixture of 2,4-D, Silvex, and dicamba (Banvel). This material and a new material from DuPont (Krenite) were found to be sufficiently effective to warrant specific recommendations.

Testing of the various components of the herbicide formulations for safety to wildlife, fish, phytoplankton, and desirable vegetation were also carried out. The recommended materials are safe if used as directed.

7. Reports:

D. J. Morre, "Chemical Control of Brush and Environmental Safety of Roadside Vegetation Management Chemicals", JHRP Progress Report, December 1976.

RECOMMENDATION

To prevent growth of brush in unmowed portions of rights-of-way along the Interstate System, a brush control agent should be added to the Fall-Spring Spraying Rotation. For this purpose, the 3-WAY PHENOXY-DICAMBA HERBICIDE MIXTURE should be used as a general broadcast treatment at the rate of about 3 lb total active material per acre as a tank mix in all "off road" spraying equipment.

Materials:

- a) 2,4-D amine form concentrate containing 4 pounds of acid equivalent per gallon.
- b) Dicamba amine form concentrate (Banvel) containing 4 pounds of acid equivalent per gallon.
- c) 2,4,5-TP low volatile ester concentrate (Silvex) containing 4 pounds of acid equivalent per gallon. Silvex is available commercially only as an ester formulation.

Rate: The materials are to be mixed at the rate of 1 gallon of 2,4-D concentrate + 1 gallon Dicamba concentrate + 1 gallon 2,4,5-T (Silvex) concentrate in 150 gallons of water. The mixture is to be applied at the rate of 40-50 gallons per acre.

How to Apply: For best results the material should be applied as a broadcast application for control of broadleaf weeds, CANADA THISTLE, and small brush. Larger brush and thistle growth near fence line should receive, in addition, a directed spray from a hand gun to thoroughly wet leaves and stems.

Schedule of Application:

- a) Fall: August 15 to September 15 (preferred time for single application)
- b) Spring: Just after brush is leafed out until soybeans are up.
April 1 to April 30.

GRASS CONTROL IN PAVEMENT CRACKS AND STABILIZED SHOULDERS

1. Scope and objectives: To explore the use of pre-emergence herbicides for removal of vegetation, especially weedy annual grasses, from cracks in pavements and from stabilized shoulders.
2. Introduction: Weed growth in cracks and along stabilized shoulders is thought to significantly shorten the life of these road surfaces. Cost benefit calculations had suggested that if the life were extended by only one year, the cost of herbicide treatment over a 5-10 year period might be paid from cost savings.
3. Method of approach: Preliminary studies were carried out on Highway 126 in Lafayette, Indiana in the spring of 1972. Balan was applied at rates of 0.7 to 1.4 lb/A. These test results were evaluated in 1973 and 1974 and this method of treatment was continued. Various methods of reducing application costs including mixing herbicides with de-icing materials were explored.
4. Major findings: Testing the use of herbicides for removal of vegetation from expansion cracks and stabilized shoulders was initiated in 1972, evaluated intensively in 1973, continued in 1974, and terminated in 1975. A number of materials, all with a pre-emergence, soil-sterilant action, were expected to be effective but too expensive to warrant implementation at the present time.
5. Research implementation: None anticipated. The idea was never greeted with much enthusiasm by district personnel. The cost of implementing a grass control program is largely in making the application. Combining the herbicide

application with ice and snow removal in the winter where the principal cost would be the herbicide was explored but soon abandoned as being completely impractical.

6: Summary: Generally, it is a less expensive and sounder practice to fill cracks and replace stabilized shoulders as required than to try to attempt to prevent weed growth throughuse of herbicide applications.

7. Reports:

D. J. Morre and D. A. Werderitsh, "Chemical Weed Control", JHRP Report, Purdue University, 1972.

No additional reports are anticipated.

PART III

EVALUATION OF HIGHWAY MOWING PRACTICES

A 5-year study 1972-1977

EVALUATION OF HIGHWAY MOWING PRACTICES: SUMMARY AND RECOMMENDATIONS

1. Scope and objectives: This project was to evaluate mowing practices to eliminate unnecessary mowing cycles and to schedule those mowing cycles which provide the most benefit at times when they will most contribute to the effectiveness of the herbicide application program.
2. Introduction: Conservative estimates of the areas from the outside of the shoulders to the farthest boundary of the right-of-way subject to some type of vegetation management yield figures that approximately 75,000 acres of roadside in Indiana are presently included in some phase of either a contract spraying or mowing program. One mile of a typical Interstate route may have over 20 acres to maintain. Since the cost of roadside mowing normally exceeds \$25 per acre per season, even with reduced mowing due to effective weed control, the potential magnitude for cost savings in roadside mowing are considerable.

In 1970, the Indiana State Highway Department changed from a 5-cycle contract mowing program to reduce costs and to conserve energy. This reduction in the number of mowings was made possible in large measure because of effective weed control through the contract spraying program.

In 1972 studies were initiated to evaluate these reduced mowing practices. The objectives of the study were as follow:

- 1) To identify unnecessary mowing cycles so that additional cycles might be eliminated.
- 2) To schedule those mowing cycles which provide the most benefit at times when they most contribute to the effectiveness of the Fall-Spring Roadside Spraying Program.
- 3) To evaluate reduced or limited mowing practices, including unmowed areas, to determine deleterious effects on turf or other undesirable features.
- 4) To inspect actual mowing operations to determine how mowing practices might be improved to enhance appearance and efficiency, to minimize mowing acreage, and optimize the production of a healthy turfed roadside.

2. Method of procedure:

Mowing evaluations were based on uniform test plots established as part of this research project, regular unscheduled inspections of contract mowing state-wide, roadside areas for which accurate mowing histories were available, and information from other states and countries.

Uniform test plots.--Uniform test plots were established in the spring of 1973 on I-74, in the Crawfordsville Subdistrict along the west-bound lane approximately one mile west of Crawfordsville, on State Road 28, in the Veedersburg Subdistrict on the southside of the road approximately 3/4 mile from the junction with State Road 25 and along State Road 126 in Tippecanoe County. Each 1 mile long test area was divided into four sub-plots (Table XXIII).

- 1) SECTION I, DO NOT MOW (unmowed)
- 2) SECTION II, 1 CYCLE (summer mowing only)
- 3) SECTION III, 2 CYCLE (spring and fall mowing only)
- 4) SECTION IV, 3 CYCLE (spring, summer and fall mowing).

Mowing dates selected were:

SPRING: June 20 to July 8

SUMMER: August 4 to August 18

FALL: September 22 to October 8

The sections in the test plots were mowed to the fence rather than to the ditch plus 5 feet. All mowing operations were by district personnel. At the state level, Melvin Calvert and Marion Bugh of the Landscape Division Indiana State Highway Department assisted with administrative affairs. At the district level, Kelsey McDaniel, Ed Kirkpatrick, and Don Bickel of Crawfordsville and Kelley Little of Veedersburg assisted in establishing and maintaining the test plots.

Don Bickel, and especially Ed Kirkpatrick, were most helpful in contacting maintenance crews at the proper times. Personnel with the maintenance crews were also very helpful.

SAMPLE UNIFORM MOWING TEST PLOT

Location: Crawfordsville Sub-district, along the west-bound lane of Interstate-74 approximately one mile west of the I-74 and U.S. 231 interchange.

Description: There are four (4), mowing test plots in this experiment which are labeled as follows:

- 1) SECTION I, DO NOT MOW
- 2) SECTION II, cycle 1
- 3) SECTION III, cycle 2
- 4) SECTION IV, cycle 3

Schedule: Mow section III and section IV in late June, early July (June 20 to July 8).
Mow section II and section IV in early August (August 4 to 18).
Mow section III and section IV in late September or early October (September 22 to October 8)

Notes: In each section the area to be mowed is from the roadside to the fence row.

Inspections of contract mowing.--Biweekly inspections of contract mowing operations were made each summer beginning in 1972 at various locations throughout the state. The following observations were made (Table XXIV).

Average grass height

Date and grass height at time of mowing

Overall appearance

Evidence of scalping, piling up or skips

Weather conditions especially at time of mowing

Photographs were taken to document major observations.

Evaluations of roadside areas where accurate mowing histories were available.

Areas in interchanges on various Interstate Systems were utilized heavily to evaluate effects of reduced mowing on turf. Some of these areas are now entering their 6th and 7th years of non-maintenance except for chemical weed control. Clyde Mason of the Greenfield Subdistrict was especially helpful in bringing such areas to our attention and in providing accurate mowing histories.

Information from other states and countries.--Based on published mowing practices and limited inspections, comparisons on the Indiana mowing program were made with those in Illinois, Michigan, Ohio, Missouri and New York. Additionally, evaluations of mowing practices in Central Europe were made in 1975 while the project director was on sabbatical leave from Purdue University. These latter comparisons were especially helpful since limited mowing is rather generally practiced in most parts of Europe.

TABLE XXIV

MOWING INSPECTION REPORT

Joint Highway Research Project, Purdue University

Date of inspection _____ Inspector (name) _____

Day Month Year
Road _____ Direction (E)(W)(N)(S) From _____ To _____

Predominant grass species _____

MOWED PORTION: (Unmowed)(to ditch)(to ditch plus 5 ft)(to fence)(other)

Explain _____

Height in inches _____ Range: _____ to _____ % with seed heads _____

UNMOWED PORTION: Ht _____ Range: _____ to _____ % with seed heads _____

Weather at time of inspection: Temp ($^{\circ}$ F) _____ Moisture (raining)(wet)
(moderately wet)(average)(moderately dry)(dry)(very dry)

Highway safety:

Approximate sight distance at
intersections (feet) _____Weed information: Species visible at
normal driving speeds and height above
grass (in inches)Approximate sight distance on
inside of curves (feet) _____Guard rails, signs and other traffic
control devices open to view (Yes)(NO)
Explain: _____Evidence of:

Skips (Yes)(No) Comments: _____

Piling up (Yes)(No) Comments: _____

Scalping (Yes)(No) Comments: _____

Overall appearance:

MOWED PORTION (attractive)(good)(fair)(poor)(very poor) Explain:

UNMOWED PORTION (distracting)(not objectionable)(attractive) Explain:

Brush: (No./100 ft) _____ Ave Height (feet) _____ Species

present: _____

Mowing in progress at time of inspection (Yes)(No) Comments _____
Condition of grass (raining)(grass wet)(grass dry)

Name of contractor _____ Chief operator _____

With whom did you speak (name)? _____

Comments including equipment and personnel (use reverse side if necessary):

4. Major findings:

Uniform Mowing Tests: Other than appearance during the growing season, we have yet to observe any differences due to 1-, 2- or 3-cycle mowing on the Interstate System. In all three types of maintenance, grass remains healthy. Here the predominant grass species is smooth brome which tends not to pile up or be smothered by results of late mowing unless grass is wet when mowed .

Where bluegrass was the dominant species, yellow foxtail was sometimes abundant late in the season. Since the foxtail is very succulent (contains much water), it tends to cause piling up when mowed short (4 inches) even if the grass surface is dry.

Generally, it was found that mowing could be started much later than is generally done. Especially on Interstates, roads were inspected in mid-June when grass is between 18 and 24 inches tall. The roads are not yet unsightly, sight distances are maintained at intersections and on the insides of curves, and guard, rails, signs, and other traffic control devices are still visible. This is especially true for roads where bluegrass is the dominant species. An example was the Veedersburg test plot on July 31 along SR 28. This is very near the optimum timing. In 1973, it was especially evident that 1-cycle mowing, the first week of August, would have been adequate.

A major objective of this study was to evaluate what, if any, harmful results would come from not mowing. In none of our tests did we note any harmful effects of not mowing on grass where weed control was adequate, e.g. along Interstates. In fact, no mowing was superior to 1- or 2-cycle mowing done poorly. The only serious drawback to not mowing is brush. In the uniform test plots, unmowed test plots contain willow, black locust, and other species, 1-3 feet tall by the end of the second year on non-maintenance. Other, plots, including those mowed only once or only once in 2 years, did not contain brush.

Inspections of contract mowing.--Major findings from uniform test plots were verified from inspections of contract mowing. Generally, mowing could be delayed much longer than indicated from State mowing policy (Table XXV), with no harmful effects. If anything, grass was being mowed too early and too short.

In general, the mowing program was good. I-65 received good maintenance, whereas I-74 was not as well maintained in some years, e.g. 1974. Most problems can be traced to weather, inadequate equipment, or contract difficulties. One serious problem arose when a contractor was awarded three contracts with only enough equipment to handle one.

Some specific problems noted with contract mowing of Interstates include:

1) Piling up. The phenomenon of piling up occurs most frequently when the grass is either too heavy or too wet. Wetness is the greatest contributor. An otherwise good mowing job can be bad if the mowing was done right after a heavy rain so that unnecessary piling up was the result. It is also evident that weedy grasses that contain much water, such as yellow foxtail, also contribute to piling up very often. The piles tend to smother out the underlying turf and leave bare spots open to erosion and weeds.

Piling up can be avoided by mowing only when the surface of the grass is dry.

2) Scalping. Scalping occurs when the mower blade cuts into the crown of the grass at the soil surface. Grass that has been scalped is either very slow to recover or killed. Scalping is largely a design problem, e.g. ridges in the right-of-way that are straddled by the mower, but is aggravated by cutting the grass too short. A maximum mowing height of 6 inches avoids much scalping, tends to reduce piling up, and produces a presentable roadside.

3) Skips. Skips are the result of careless mowing. Strips left between mowing swaths are inexcusable and contractors who allow this practice should be penalized. Generally trimming around poles, signs, guard rails, etc. has been sporadic to poor. This is not a technical problem but rather a problem of enforcement. A practical solution is the use of growth retardant chemicals to prevent grass growth in

TABLE XXV

January 24, 1974

INDIANA STATE HIGHWAY COMMISSION

Mowing Policy

A. GENERAL

1. Where mowing is required, maintain height of vegetation between a 4" minimum and a 12" maximum.
2. Slopes steeper than 3:1 shall not be mowed.
3. Mow from the edge of the pavement, or the edge of the paved shoulder, to a point 5' beyond the ditch line in cut sections and 5' beyond the shoulder break in fill sections.
4. Mow any area that is necessary to provide satisfactory sight distance for the traveling public.

B. ROADSIDES

1. At locations where developed areas are adjacent to the right-of-way mow to the right-of-way line.

C. MEDIANS

1. The entire area of medians which are 60' or less in width shall be mowed.
2. The entire area of medians which are wider than 60' but which have only one center ditch shall be mowed.
3. Variable width medians with a ditch serving each pavement shall be mowed the same as Items 2 and 3 under A General.

D. INTERCHANGES

1. Additional mowing may be required in interchange areas to provide a satisfactory appearance. Such mowing shall be by methods and at intervals as directed by the Engineer.

these difficult-to-mow areas. Careful cost-benefit studies should be carried out with State Highway Officials to determine if use of growth retardants (not soil sterilants) around poles, signs, guard rails, etc. might actually result in substantial cost savings.

Evaluations of roadside areas where accurate mowing histories were available.

A considerable number of such areas were examined. Except for growth of brush in unmowed areas, no deleterious effects of reduced maintenance along Interstates were noted. The practice of mowing to the ditch or to the ditch plus 5 feet provides an attractive roadside and is sound:

- 1) As long as adequate sight distances are maintained and
- 2) Brush is controlled.

Brush control (either chemical or mechanical) must be considered as an integral part of the maintenance of unmowed rights-of-way.

A few test areas were encountered where unmowed roadsides had persisted for as long as 7 years without deleterious effects. These sites were located in a true prairie environment where brush invasion is somewhat less prevalent. Even here, however, introduced species such as black locust will become established. In other non-prairie sites, the woody vegetation is more natural to the environment and is a continual invader. One must either accept woody vegetation (brush and trees) in the unmowed areas or be prepared for a continuing fight.

Weed count data on areas that were both unmowed and unsprayed are limited. However, weed counts taken 2 years after spraying show consistent reduction of the "lawn type" annual weed species from unmowed roadsides (Table XXVI). The eliminated species include dandelion, buckhorn plantain, and knotweed. Other species such as Canada thistle, wild parsnip and milkweed are less affected, perhaps favored, in unmowed areas.

TABLE XXVI

Weed populations comparing mowed and unmowed portions of interchanges in the Greenfield subdistrict 3 years after spraying with 2, 4-D amine. The unmowed portions were unmowed for about 5 years.

<u>Weed species</u>	<u>Plants/acre</u>	
	<u>Mowed</u>	<u>Unmowed</u>
Plantain	12,610	430
Dandelion	1,740	380
Clovers	3,450	1,225
Common thistle	1,300	1,400
Black medic	5,227	4,800
Common milkweed	650	780
Wild carrot	6,969	3,500
Knotweed	17,400	4,800
Composite family	2,600	2,750
Yellow woodsorrel	2,200	2,600
Other weeds	<u>6,000</u>	<u>5,450</u>
Total weeds	60,146	28,115

Legumes and need for early mowing.--A consistent observation in all of our studies is that roadsides seeded to legumes, especially red clover, appear unsightly early in the season and seem to require mowing not because of the grass but because of the legumes. This was not as much due to the height differential but due to color and distribution of foliage. The legumes are only 1-3 inches taller than the grass in most instances. The legumes are a much darker green than the grass. The legumes have the greatest leaf density toward the top while the grasses have the greatest leaf density at the bottom. Visually, the legumes appear to be nearly twice as tall as the grass and to require mowing. Actual measurements show that this is not so. In any event, the roadsides appear unsightly.

The conflict between landscapers and weed controllers in the seeding of legumes is sometimes wasteful. The legumes may increase maintenance costs by perhaps as much as one mowing per season. As soon as the area is sprayed in the contract program, much of the legume population is killed. That which remains creates the kind of problem discussed above. Application of slow release nitrogen fertilizer might prove less expensive than legume seeding if one mowing is saved when legumes are not present.

Information from other states. Based on observations of mowing practices in other states, the impression is that Indiana overmows. This is especially noticeable on roads under State maintenance. A most successful application of reduced mowing practices was encountered in central Europe when fuel is much more expensive than in the United States. Here nearly all roadsides received only a single mowing cycle late in the season (mid July to mid August). The effects are the continued maintenance of healthy turf, moderate regrowth before winter, control of brush species, a slightly "ragged" appearance in late June and early July, but a substantial cost saving relative to the Indiana program.

Features to consider in determining highway mowing practices.--According to the New York State Department of Transportation Guide for the Determination of Mowing Limits, there are four categories of features which must be taken into consideration. These are highway safety, topography, adjacent land use and vegetation and existing vegetation within the right-of-way.

Highway safety.--According to the New York Guide "Highway safety overrides all other features affecting mowing practices. Sight distance at intersections and on the inside of curves must be maintained. Safety setbacks for major trees must be observed and guide rails, signs and other traffic control devices kept open to view." Obviously, maintenance of appropriate sight distances is the most important single reason that makes both mowing and weed control a required feature of roadside maintenance.

Topography.--Obviously the physical ability to machine mow will determine mowing limits. Ditches and other drainageways, e.g. those in medians, should be mowed to maintain water-carrying capacity. Slopes 1 or 2 or steeper are normally would not require mowing much beyond the ditch.

Adjacent land use and vegetation.--Whenever highway right-of-way borders on agricultural land of high productivity, mowing is justified to keep down weeds and brush, to prevent shading, and for good public relations. It is my experience that State roads bordering farms of high productivity are mowed regularly one way or another, if not by State crews then by the farmers themselves. One uniform mowing test was abandoned because the farmer whose soybean field bordered the test plots mowed the roadside despite personal pleas and the signs saying "DO NOT MOW."

Existing Vegetation within the right-of-way. It is often possible to mow around large masses of landscape plantings without mowing around individual plants. Pure stands of smooth brome or bluegrass may be easier to maintain than mixed stands. Certainly weeds and legumes are a factor. When weeds are controlled, less mowing is required.

RECOMMENDATIONS

1. WHERE MOWING IS REQUIRED: Safety and/or appearance a primary consideration.

Three (or two) cycle mowing with exact timing based on grass height. The desirable mowing height should be increased from 12 inches to between 18 and 24 inches with a minimum height for cut grass of 5 inches. Mowing of wet grass should be prohibited to reduce "piling up". Mowing should be in combination with the Fall-Spring Spraying Program for control of broad-leaf weeds.

2. WHERE MOWING IS NOT REQUIRED: Safety and/or appearance not a primary consideration.

Eliminate mowing entirely.

Fall-Spring Spraying Program for control of broad-leaf weeds must then be modified to include a brush control agent in the spray mixture.

OR

One cycle mowing in late July and early August in combination with the Fall-Spring Spraying Program for control of broad-leaf weeds.

5. Research implementation: Considerable time was spent during the first quarter of 1977 in initiation of implementation of mowing practices. Discussions with M. L. Bugh, Landscape Architect, Indiana State Highway Commission and Mr. K. Mellinger, ISHC, in January, 1977, emphasized evaluation of mowing practices to eliminate unnecessary mowing cycles and to schedule those mowing cycles which provide the most benefit at times when they will contribute most to the effectiveness of herbicide applications.

By rescheduling so that the first cycle mowing is begun when grass is 18-24 inches tall and approximately 12 inches of growth is left going into the fall, we are hopeful to eliminate one mowing cycle and possibly go to 1-cycle mowing in some areas depending on the season. Where mowing is not required for motorist safety or for aesthetic purposes in urbanized areas, no mowing is recommended in combination with chemical control of brush. Even with the added cost of chemical brush control (about \$60,000 annually), cost savings of about \$300,000 annually are anticipated.

The findings from the 5-year mowing study completed under this project were scheduled for implementation beginning with the 1977 mowing contracts in the form of new ROADSIDE MOWING GUIDELINES appended as Table XXVII. This list of recommendations was presented and discussed on March 10 at the Maintenance Session of Road School, Purdue University, Lafayette, Indiana by Mr. Bugh, Mr. Mellinger and Morre.

In the second quarter of 1977, the operation of the new mowing guidelines was evaluated. More than 50 locations throughout the state were checked. In most locations, especially in the Vincennes and Seymour districts, the fescue was 3 to 4 ft high and turning brown at the time of mowing during the first

TABLE XXVII

ROADSIDE MOWING GUIDELINES

Mowing is to be accomplished in such a manner as to preserve the turf, maintain traffic safety, and enhance appearance of the roadsides. Mowing will begin when the height of vegetation is approximately 18" and be completed before the height reaches 24".

Mowing limits are, in general, identified by the following conditions:

1. Mowing shall be from the edge of pavement or paved shoulder to a point 5' beyond the ditch line in cut sections or 5' beyond the shoulder break in fill sections.
2. Total median areas shall be mowed only when the median width is 60' or less or where there is a single median ditch.
3. Full width mowing may be required adjacent to developed or urban areas.
4. No mowing shall be permitted on slopes steeper than 3:1.
5. Hand trimming is required in conjunction with machine mowing and includes trimming around objects such as guardrail, delineator post, signs, shrubs, headwalls or other fixtures within the machine mowing limits. Trimming applies only to the perimeter of shrub beds and not the individual shrubs within the shrub bed. Hand mowing of areas not accessible to the tractor mowers will be required only where necessary to maintain adequate sight distance.
6. Ramps and connecting roads at interchanges will be treated as separate roadways in accordance with above.
7. Additional mowing may be required in some areas to provide adequate sight distance.

8. Mowing shall be performed with rotary mowers, sickle bar mowers, or other approved equipment. All mowing equipment must have protective shields to prevent foreign objects from being thrown from the cutting unit enclosures. All equipment shall be maintained in a sharp good cutting condition. All machine mowers shall be adjusted to cut at a height of 5" and shall be operated in such a manner so as to prevent scalping, rutting or other damage to the turf. Under no conditions should mowing height be less than 3".

weeks of June. This was most noticable during the first week of June when conditions were especially dry.

Up through the first week of June, sight distances were maintained on all roads checked. With some roads, e.g. U.S. 52 north from Lafayette and U.S. 41 north from Terre Haute, it is doubtful if mowing was really necessary at all. Largely due to the excellent job of weed control, roadsides of primary routes for the most part did not appear unsightly. The major (in some roads, the only) weed problem is milkweed which was starting to show through the grass about mid-June. We received no complaints concerning the modified mowing policy. Of approximately 50 motorists questioned specifically, none found the appearance of the roadsides objectionable prior to mowing. Most were unaware that mowing has been delayed.

With these late mowed roads, there were less problems with piling up of heavy grass than was anticipated. This was due probably in part to the dry conditions of the grass at the time of mowing. Following the rains about June 9, the grass seemed to recover well in spite of the fact that mowing had been delayed much, much longer on a height basis than was recommended in our progress report.

The main problem with the late mowed roads was a ragged appearance due to grass in wheel tracks not being mowed and some skips. Most contractors are not well equipped to mow grass as tall as was encountered during the first week of June this season. It is important to note, however, that the few stalks of grass which remained did not constitute a safety hazard in any way. Trimming operations were also complicated by the new mowing limits and the earliness of the growing season. Work was especially slow and tedious for contractors using small "lawn-type" rotary mowers to trim around guard rails and sign posts.

The policy of mowing from the edge of the pavement or paved shoulder to a point 5 feet beyond the ditch line in cut sections or 5 feet beyond the shoulder in fill sections is working quite well with the new mowing limits. These areas do not look ragged and may not require even a second mowing during the 1977 season depending on weather conditions.

The problem is with medians. Full width medians look ragged. Medians which were mowed approximately 5 feet or so short of the ditch line look much better. It may be advisable to alter the recommendations somewhat so that less mowing for medians is required in general. With reduced mowing, the overall appearance of the highways under conditions of reduced mowing would be much improved.

6. Summary: A 5-year evaluation of roadside mowing practices in the State of Indiana was completed. Findings show that the first mowing cycle is the most critical. This mowing if done too early is wasted because the most rapid grass growth occurs early in spring. If carried out too late or when the grass is wet, it becomes injurious to turf due to piling up of grass and smothering. The optimum height for the first mowing cycle is between 18 and 24 inches. To prevent scalping and to avoid piling up and smothering of grass, the minimum height should be increased to 5 or 6 inches depending on the number of cycles. The second cycle of 3-cycle mowing is less critical and could be eliminated most seasons if the first cycle were delayed. The last cycle should be delayed so that no more than about 12 inches of growth occurs before winter. This leaves the roads with a well maintained appearance during the winter months and with enough growth to protect the grass from winter killing but not so much growth that the fall-spring spraying for control of broad-leaf weeds is interfered with.

Unmowed roadsides remained in good condition over the 5-year observation period. A major problem is that brush begins to take over in many areas. Addition of a brush control agent to the fall-spring spraying rotation for these areas is indicated or 1-cycle mowing (mid-July to mid-August) at least every other year.

Major findings were implemented by ISH personnel for the 1977 season for both contract operations and mowing by State crews.

7. Reports:

D. J. Morre and J. Eberle, "A 5-Year Evaluation of Highway Mowing Practices: Summary and Recommendations", JHRP Interim Report, December, 1976.

EVALUATION OF COMMERCIALY AVAILABLE CHEMICAL RETARDANTS OF GRASS GROWTH

1. Scope and objectives: This portion of the project constitutes an expansion of the original project outline to carry out feasibility studies of use of chemicals to retard growth of grass (chemical mowing). No development of new materials was attempted under this project. For the most part testing was limited to compounds available commercially, obtained through industrial cooperators, or where synthesis and testing was carried out under an independent project.

2. Introduction: The need for chemical growth retardants, "chemical mowing" was identified under this project as one of the most pressing future needs in roadside maintenance. As energy and labor costs rise, mechanical mowing of roadsides will become increasingly prohibitive. Of the approximately 30 mowing contracts advertised by the State of Indiana in the spring of 1974, only a fraction were within the engineer's estimates. This situation has gradually worsened and is likely to increase in severity in future years. Once chemical mowing is realized, additional cost savings are projected to be considerably in excess of \$1,000,000 annually to the State of Indiana.

3. Method of approach: Laboratory, greenhouse, and field tests were initiated in 1975 to screen commercially available retardants of grass growth for possible use to reduce or eliminate roadside mowing. A more extensive series of field trials was established in the spring of 1977. Among the criteria evaluated were degree of growth retardation, degree of seed head suppression, effects on color, reduction or enhancement of vigor, effects on underground plant parts (stolons, rhizomes, roots) and mode of action.

4. Major findings: About 20 commercially available retardants were screened in laboratory, greenhouse and field tests. One compound, Sustar 2-S, a product of the 3-M Corporation, was found to be effective as a bluegrass retardant without obvious injury to turf. However, cost and availability of the material turned out to be a factor which would probably limit its use as a general grass retardant for roadside use.

MH-40, CIPC, EPTAM, STAM and several other commercially available growth retardants of the "carbamate" type were also evaluated. Careful examination of the treated grass revealed weakened root systems and an overall unhealthy appearance including discoloration. Field experience with these materials also indicated a strong tendency toward weakening of the root system and stand reduction of established turf. Clearly such materials could not be recommended for use in a long-term chemical mowing program.

As part of this study, a long-term test with MH-40 established by Clyde Mason of the Greenfield district was also evaluated. Again, examination of the treated grass revealed weakened root systems, stand reduction, and an unhealthy appearance. The findings emphasize the need for long-term evaluations in the field over a period of several years before making recommendations concerning the general use of any retardant material.

In 1977, studies of chemical growth retardants for bluegrass height reduction were expanded to approximately 60 different compounds or mixtures with and without 2,4-D at 3 locations. Tests on tall fescue were at 2 locations with 30 materials under roadside conditions. At least 3 different materials or combinations of materials compatible with 2,4-D (the latter to give control of broadleaf weeds) were found to eliminate the need for mowing on bluegrass and to reduce fescue growth sufficient to permit at least one cycle mowing. Seed heads were reduced or eliminated, early growth was slowed,

and seed head height was reduced 50 to 70%. With all three retardant materials, grass is expected to go into the winter within the new mowing specifications for Indiana roadsides without ever being mowed. In general the appearance is uniform and with at least one material rate of application can be varied by a factor of two without affecting the results.

5. Research implementation: None pending further study. A continuing evaluation of these and other retardant materials is the primary objective of a new HPR Part II Study titled "Chemical Mowing: A New Maintenance Concept for Indiana Roadsides". At least 5 years will be required to realize the objectives of this project but the prognosis for success is good. The potential for actual direct cost savings to the State of Indiana in one year exceeds by a factor of 10 or more the total projected costs of the new research project.

6. Summary: Studies were completed which demonstrate the feasibility of using newly identified retardant chemicals to replace all or part of the need for mechanical mowing along Indiana Roadsides. At least 5 years will be required for development and evaluation of the products. The prognosis for success is good and could result in additional savings of \$1,000,000 per year to ISHC.

7. Reports :

None pending further study.

CONCLUSIONS

1) Tests to evaluate the effectiveness of the fall applications of 2,4-D were completed in 1972. This treatment was evaluated at approximately 60 locations in all five districts of Indiana and was found to give 85-90% control of weeds reducing weed populations to an acceptable level of about 15,000 per acre.

2) Beginning in the fall of 1972, evaluations were conducted of a 2-cycle (fall-spring) 3-year spraying rotation. More than ample evidence was collected over the 5-year period to verify cost-effectiveness of this practice. Final evaluations included in this report recommend a performance payment system of inspection based on efficacy determined by weed counts.

3) Tests were initiated in which the 2,4-D in the fall spray program might be replaced by varying rates of more potent or equally effective but less costly herbicides or herbicide combinations. By using more potent herbicides we were able to maintain turf in a near weed-free condition for 3-5 years from a single application. This means that only one application every 6 years would be required. These treatments were tested in small plots and under conditions of contract application. Implementation was attempted in 1973-1974 but failed when an Experimental Use Permit from the Environmental Protection Agency failed to materialize largely through lack of interest on the part of the manufacturer of one of the materials in question. Implementation of a cost competitive material as an alternative for Fall-Spring spraying was implemented on an experimental contract basis in the fall of 1976. Evaluations completed in the spring of 1977 show the material to be effective, more so than straight 2,4-D amine on thistle, less so on wild carrot, and of approximately equivalent cost to 2,4-D depending on the season.

4) The dicamba + 2,4-D mixture is recommended not to replace 2,4-D amine but as a cost competitive alternate. It is recommended to be mixed at the rate of 1 gal of dicamba amine plus 2 gal of 2,4-D amine in 100 gallons of water and applied at the rate of 40 gal per acre of total spray mixture.

5) We have no evidence that higher rates of application of the dicamba + 2,4-D mixture give sufficiently better control of 2,4-D resistant species to justify the extra cost. Higher rates of application that exceed label recommendations over the sum of two applications are not recommended.

6) Mowing practices were evaluated to eliminate unnecessary mowing cycles and to schedule those mowing cycles which provide the most benefit at times when they will most contribute to the effectiveness of the herbicide application. These studies were completed in the fall of 1976 and implementation discussions were completed in January 1977. The findings were implemented beginning with the 1977 mowing contracts. By rescheduling so that first cycle mowing is begun when grass is 18-24 inches tall and approximately 12 inches of growth is left going in the fall, we are hopeful to eliminate at least one mowing cycle and possibly go to 1-cycle mowing in some areas depending on the season. Where mowing is not required for motorist safety or for aesthetic purposes in urbanized areas, no mowing is recommended in combination with chemical control of brush. Even with the added cost of chemical brush control (about \$60,000 annually), cost savings of about \$300,000 per year to ISHC are anticipated.

7) Herbicides were tested for control of vegetation in expansion cracks and on stabilized shoulders. The possibility of making these applications in conjunction with snow and ice removal was examined as a means of reducing application costs and increasing benefits. This work was initiated in 1971

and completed in 1973. Filling of cracks was found to be a more economical and desirable method of circumventing this problem. Use of chemicals to extend the life of stabilized shoulders proved to be uneconomical. No implementation is recommended or expected.

8) Several herbicides and herbicide combinations were considered for possible application under new asphalt surfaces as a preventative weed control practice to reduce the possibility of the life of the surface being shortened by unwanted vegetation. Costs of effective treatment outweighed expected benefits sufficiently so that work on this study area was abandoned in 1973. No implementation is recommended or expected.

9) In combination with reduced mowing practices, need for chemical control of brush was indicated. In favorable situations, tests and observations showed invasion of woody species within one year in unmowed roadsides. For this purpose, a 3-WAY MIXTURE of 2,4-D-dicamba-Silvex was developed for use in off-road equipment on unmowed rights-of-way. This recommendation is scheduled for implementation in 1978. Cost savings are reflected in the reduced mowing estimates of 6).

10) To guarantee state-wide 1-cycle mowing or to eliminate mechanical mowing entirely from large segments of the highway system, it became apparent during the course of this project that use of chemical retardants of grass growth (chemical mowing) was needed. A few commercially-available materials were evaluated during 1976 and again in 1977. Completed studies demonstrate the feasibility of using retardant materials to replace all or part of the need for mechanical mowing. At least 5 years will be required to develop and evaluate the experimental materials giving best results. The prognosis for a significant advance is good and the result might be an additional saving of \$1,000,000 per year to ISHC.

11) Long term test plots were established throughout the state to compare different maintenance treatments. These will be continued.

12) Environmental safety checks employed tests with aquatic ecosystems including fish, evaluation of effects on non-target species, and specific biological assays. Extent of degradability were considered and soil residue analyses were supplemented where required by biological indicators to evaluate new compounds entering the testing program. All materials recommended for inclusion into the Low-Cost Minimal Maintenance Program for Indiana Roadsides have been verified to offer no deleterious threat to man or his environment.

SUMMARY OF IMPLEMENTATION ACTIVITIES AND POTENTIAL COST SAVINGS

A LOW-COST MAINTENANCE PROGRAM FOR INDIANA ROADSIDES

Project: C-36-48 F File: 9-5-6 Date Started: October 1, 1972

<u>Study Objectives</u>	<u>% Effort</u>	<u>Recommendations</u>	<u>Estimated Annual Cost Savings</u>	<u>Implementation Date</u>
1. Implementation of Fall-Spring Spraying Rotation with 2,4-D Amine	10	No major changes in program as implemented Change to performance inspection	\$200,000 30,000	1970 ?
2. Search for cost competitive material as alternative for Fall-Spring Spraying Program	5	Dicamba - 2,4-D amine mixture. Cheaper depending on price of 2,4-D. Controls Canada Thistle	5,000	1976
3. Reduced mechanical mowing	20	Two-cycle mowing where required. No mowing + chemical control of brush elsewhere. More growth between cycles.	\$300,000	1977
4. Chemical control of brush on unmowed roadsides	15	3-WAY PHENOXY-DICAMBA mixture in Fall-Spring Rotation once every 3 years. Treat brush in fenced portions growing in the fence line	Included in Item 3	1978
5. Environmental studies	15	All recommended chemicals are safe.	No estimate-- could be considerable for \$7.00/foot to replace 1977 fence \$0.06/foot to spray.	will try - -
6. Control of thistle & milkweed	20	-	-	-
7. Chemical mowing (chemical retardants of grass growth)	15	Potential cost savings indicate new area for major emphasis	\$1,000,000	est 1982

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