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Masters degree in **Science - Forestry**

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VEGETATION MANAGEMENT ALONG TRANSMISSION RIGHTS-OF-WAY IN THE UNITED STATES AND CANADA

By

Joseph Anthony Sulak

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Forestry

2000

ABSTRACT

VEGETATION MANAGEMENT ALONG TRANSMISSION RIGHTS-OF-WAY IN THE UNITED STATES AND CANADA

By

Joseph Anthony Sulak

A survey investigating vegetation control methods along transmission rights-of-way was sent to 220 Utility Arborist Association companies. The survey contained questions regarding right-of-way characteristics, control methods used, total dollars spent on vegetation management, and priorities of the vegetation management program. The ROW area reported represented over 48% of all the investor owned ROW over 39Kv in service, throughout the United States. Over 75% of the respondents reported using herbicides on their rights-of-way. However, acres treated mechanically out-numbered those treated chemically by a margin of **2.7:1**. Garlon 3A and Garlon 4 topped all herbicides with a combined 220,574 projected gallons of the projected 549,869 gallons of herbicide applied to transmission rights-of-way in 1995. It appears that extremely low levels of active ingredient are being applied per acre. Basal, High Volume Foliar and Low Volume Foliar with a Backpack or Handgun applications accounted for approximately 75% of the acres of transmission ROW treated with herbicides.

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JOSEPH ANTHONY SULAK
2000

This thesis is dedicated to the memory of my Grandfather

Joseph Sgroi

Thanks for the inspiration and drive!

ACKNOWLEDGEMENTS

Ultimate Thanks go to:

The Michigan Forestry and Park Association
The International Society of Arboriculture/ Hyland Johns Grant Committee
The Utility Arborist Association
Dr. J. James Kielbaso for all his assistance and guidance in completing this work.
My Family and friends for their support
Juli Kerr for putting up with me
John Primus of the Dupont Corporation

Additional Thanks to:

Dr. Harvey Holt
Lynn Grayson
Kevin Eckertt
Hershall Hale
Rick Johnstone

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CHAPTER I: INTRODUCTION

In order to deliver electricity to their customers on a reliable basis, utility companies must control the vegetation growing within their rights-of-way (ROW) to prevent power outages. A significant sector of the arboriculture industry is dedicated to the development and implementation of more efficient, longer lasting and less expensive methods to control this vegetation. Despite efforts devoted to creating these methods of control, little is known about the current practices being employed by the utility industry. In an attempt to inform the public about vegetation control issues, a team of utility forestry representatives, the Vegetation Management Task Force (VMTF), in partnership with the Edison Electrical institute, developed the Environmental Stewardship Strategy for Electric Utility Rights-of-Way in August 1995. The "Strategy" was developed as a way to explain the purposes and practices of a modern right-of-way vegetation management program. The strategy states, "the long-term goal of a vegetation management program is to provide for public and worker safety and to provide reliability of service by converting right-of-way plant communities from predominantly tall growing plant species to communities dominated by low growth plant species." In general, there are two methods of vegetation control presently used to accomplish this task, namely mechanical control and herbicidal control.

Mechanical control refers to any management practice involving the use of either mechanical mowing or mechanical cutting. Mowing shears saplings at ground level and also shreds the stems. Cutting targets saplings and large trees, but the material is usually stacked or processed into wood chips (Luken 1991). Mowing or cutting of target

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vegetation perpetuates the growth of incompatible, tall-growing species because of the biological response of sprouting (VMTF 1995). As a result of carbohydrate stores located in already established root systems, multiple sprouts can grow from the severed stumps or from the roots (Johnstone 1990).

Mechanical methods are unfortunately, not completely viable techniques for inhibiting deciduous forest regeneration. The resulting stands of nearly impenetrable vegetation severely limit accessibility, and require frequent cutting of new vegetation to maintain safe distances between trees and power-lines (Luken 1991). In addition, the use of large equipment during mechanical control introduces soil heterogeneity into the corridors. This heterogeneity, created by the presence of stumps, detritus, and exposed mineral soil, provides adequate germination sites for a variety of undesirable tree species (Luken 1991).

Herbicidal control methods are the primary emphasis of the Stewardship Strategy. This is a result of their emergence as a valuable tool in the utility forester's arsenal. Unlike mechanical methods, herbicides attack both the above ground and below ground systems of the target vegetation. An economic advantage occurs since resprouting does not occur as frequently on an herbicide treated ROW as it does on one that is mechanically controlled. This results in lower maintenance costs in the future because management cycles are extended (Dow Elanco 1996). In addition to the economic benefits associated with herbicide control, a number of studies have portrayed some environmental benefits as well.

In Pennsylvania, it was shown that herbicides can be used to promote the establishment of cover-types resistant to tree seedling invasion (Bramble et.al. 1992). In

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these same right-of-way corridors, population studies on bird and small mammal populations were conducted comparing mechanically and herbicidally controlled areas. An unexpected result of the former study was the retention of a large and diverse bird population in the herbicide treated areas. The shrub cover type, developed via selective control provided cover for the birds (Bramble 1994 a). Small mammal populations were also more abundant and diverse when a combination of cover types were produced using herbicide applications (Bramble 1994 b). In both cases, the retention of vegetative cover via selective herbicide treatments, versus the total destruction of habitat via mechanical methods is what allowed wildlife populations to remain. In Canada, herbicide treatments applied to power line rights-of-way produced a plant community that contained more plant species than adjacent non-treated areas (Geier et.al. 1992). A Massachusetts study comparing the impacts of both control methods on wetland sites, showed that mechanical treatments resulted in relatively higher physical impacts to the surrounding environment than did selective herbicides. Also, chemical analysis of the soil and surface water identified petroleum residuals from mechanical equipment, whereas no herbicide residuals were found in the wetland surrounding the herbicide treated right-of-way (Nickerson 1992).

Not all aspects of herbicide application are positive. The public perception of herbicide use is not favorable. Past discoveries of detrimental side effects to non-target species, including humans, caused by chemicals has created a feeling of 'chemophobia' in the population (Worman 1991). This negative perception has resulted in increased interest in the utility industry's vegetation management practices, especially on the part of State and Federal Government agencies. In some jurisdictions, regulations have even

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been implemented to completely ban herbicide application. In addition to environmental protection, there is growing concern regarding worker safety when applying these chemicals. Current EPA regulations search to remedy these concerns by requiring herbicides be tested for their toxicity, carcinogenicity and epidemiology before they are registered for use in the United States. These test results help determine whether chemicals are classified as either general or restricted use herbicides. Each registered herbicide must contain a label detailing these results. The Occupational Safety and Health Administration (OSHA) then uses these classifications to set regulations that determine the amount of training each worker must have to use the chemical and what protective measures must be followed when applying the chemical (Worman 1991) (Lu 1991).

This thesis is one of a two-part, descriptive study of vegetation control on electric utility rights-of-way, specifically for transmission lines with an emphasis on the types and amounts of herbicides being applied. The second part will address the methods used under distribution lines.

Its intent is three fold. Primarily, it will provide an initial identification of vegetation management practices currently used by utility companies along transmission rights-of-way. Regional comparison of these methods is valuable data from which continued stewardship can be directed.

The second intent is related to public concerns of potential secondary toxicity risks associated with herbicide use. To address the concerns of herbicide risk, the Stewardship Strategy focuses on, "minimizing the amount of active ingredient of a particular product (or products) per acre rather than reducing the total volume of products

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used (VMTF 1995)." Calculating the active ingredient per acre applied for each reported herbicide will assess the current risks to the environment and the public. These calculations will provide the base line data needed to determine whether or not a further reduction in active ingredient per acre is necessary. In addition, these rates will be compared to the EPA approved, manufacturer recommended maximum rates in order to measure the compliance factor of herbicide application.

The final intent of this thesis is an investigation into possible differences of vegetation control intensity between companies in different regions of the United States. It is suspected that this intensity differs with the geographic area in which the control takes place. The focus is to compare the reported dollars spent per acre for all vegetation control, based on regional precipitation and temperature differences. Dollars per acre are not the only measure of intensity. However, in the current atmosphere of deregulation, comparisons of dollars spent per acre could be important and useful information for utility companies as competition increases. Specifically, two hypotheses were created that will be considered by these comparisons.

Ho: Precipitation differences have no influence on dollars spent per acre (vegetation management intensity)

H1: There is an influence

Ho: Temperature differences have no influence on dollars spent per acre (vegetation management intensity)

H1: There is an influence

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CHAPTER II: METHODS AND MATERIALS

SAMPLING METHOD

A survey was developed that would solicit the information needed to conduct the study (Appendix A). Respondents were to give information on various characteristics of the transmission line rights-of-way for which their companies were responsible. The survey contains five categories of questions; they are: right-of-way characteristics, control methods used, total dollars spent on vegetation management, priorities of the vegetation management program, and substation/generating station vegetation management data. The primary concern in development of the survey was ease of completion. Therefore, all questions had to be direct and readily comprehendible. This objective proved to be challenging because of the difficulty in separating mechanical and herbicide control for both transmission and distribution utility rights-of-way. Following the 5-month creation period, the survey was sent for review to various members of the vegetation management task force as a pilot study. A total of four pilot studies were done; from which, various suggestions, regarding both content and ease in completion were incorporated to create the final version.

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SAMPLING DESIGN

The study was accomplished via a census of all the companies represented by the Utility Arborist Association. A total of 220 UAA companies consisting primarily of investor owned utilities were identified. These companies represented 49 states and 4 provinces of Canada. Owing to competitive advantage concerns in the industry, it was concluded that all data acquired would be reported only as group data. Thus, all recipients were organized into one of five regions depending upon their location, and then subdivided into divisions for organization purposes. Except for Canada, these categories correspond to the U.S. Census designations, as follows:

Region 0 - Represents all Canadian respondents

Region 1 - The Northeast United States:

Division 1- Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island
Division 2- New York, New Jersey & Pennsylvania.

Region 2 - The North Central United States:

Division 3- Michigan, Ohio, Wisconsin, Illinois, Indiana,
Division 4- Missouri, North Dakota, South Dakota, Nebraska, Kansas, Minnesota and Iowa

Region 3 - The Southern United States:

Division 4- Delaware, Virginia, West Virginia, Maryland, North Carolina, South Carolina, Georgia, Florida,
Division 5- Kentucky, Tennessee, Mississippi, Alabama,
Division 6- Arkansas, Louisiana, Oklahoma & Texas.

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Region 4 - All returns in the Western United States:

Division 7- Montana, Wyoming, Utah, Idaho, Nevada, Colorado, New Mexico, Arizona,

Division 8- Washington, Oregon, California, Alaska & Hawaii.

RIGHT-OF-WAY CHARACTERISTICS

The first category, right-of-way characteristics, dealt with descriptions of the transmission line rights-of-way (ROW) that the company owned. The first question asked for the total acres or miles of ROW for which the companies were responsible. The survey was designed to solicit width of the ROW or, alternatively, the percentage of the ROW corresponding to that width if the first answer was given in miles. This information allowed conversion of miles of ROW into acres for later calculations. The next question dealt with the land type corresponding to the ROW and its percentage of the total ROW. Four options were given: percent of the ROW requiring vegetation control; percent of the ROW used as agricultural/grazing land; percent of the ROW open with no management required (lakes, roads, yards, parking lots etc.); and percent 'other', with the respondent specifying type.

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CONTROL METHODS

With the percentage of ROW requiring vegetation control established in the first category of questions, the second category of questions relate to the methods used to control that vegetation. This category is divided into two parts, herbicide control methods and mechanical control methods. Information on herbicide use was queried with the question; "do you use herbicides to control vegetation on transmission line rights-of-way?" Leading from a 'yes' answer is the Transmission Line Herbicide Report Form (Appendix A. 3). This report form requested four types of information, name of herbicide used, total acres or miles to which the herbicide was applied, the amount of herbicide applied, and the method used to apply the herbicide. Methods used were selected from six choices, all of which are accepted practices in the vegetation control industry. The six methods were: basal treatment, cut surface treatment, high volume foliar application with a hand gun, low volume foliar application with a backpack or hand sprayer, aerial spraying (including herbicide side trim), and low volume foliar broadcast (fixed boom, radiarc, etc.). An additional category of 'other' was added with the respondent specifying any other application methods not listed as a choice.

Each of the six methods can be separated into one of three management strategies: Individual Plant Treatment, Low Volume Foliar treatment and Broadcast Foliar treatment.

All individual plant treatments (IPT) apply herbicides to target vegetation following an initial brush clearing. This clearing is done either mechanically or chemically. IPT is divided into three types, Basal Bark, Cut Surface, and Soil Applied.

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With a Basal Bark treatment, herbicides are applied to the lower portion of the target plants. Generally, the herbicide penetrates the bark and is translocated to the rest of the living plant.

Cut Surface applications are basal techniques that administer herbicide to the cambium of freshly or recently cut trees. This method is the most flexible because application is possible any time of the year except during periods of heavy sap flow. The herbicide translocates to the established root system and disrupts water and stored nutrient flow, thereby reducing the potential for stump sprouting of the undesirable tree.

With Soil Applied methods of application, herbicide is administered in granular or liquid form at the base of the target plant and then transported to the roots via the soil moisture. Desired results of this method require chemicals with a moderate to high soil motility. High soil motility of chemicals increases the chances for non-target vegetation to be affected by the application. It became apparent in the pilot studies of the survey that the soil applied method was the primary one used to control vegetation at substation/generating stations where bare ground situations are preferred. Thus, it was not included as a ROW method on the report form (APP A3).

Similar to the IPT strategy of herbicide application, Low Volume Foliar methods should be used to maintain a site after it has been cleared. The term low volume refers to the amount of water that the herbicide is diluted with, not the amount of herbicide used. The best sites for this method are those with low stem density (1500-2000 stems/acre) and a low average stem height (ideally 4-7ft). The most popular of these techniques employs the use of a backpack or hand sprayer to apply the herbicide. Low volume foliar

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techniques allow the applicator to be more selective, resulting in substantially fewer off-target effects.

A second type of low volume foliar method is a broadcast method incorporating the use of a hydraulic pump to deliver the herbicide instead of a backpack. The use of long and sometimes flexible booms allows for the selectivity needed to keep low volume techniques economically feasible. This method allows applicators to use existing high-powered equipment.

The third strategy of herbicidal vegetation control is Broadcast application. Two methods fall within this category, High Volume Foliar and Aerial application. These treatments are best suited for reclamation work on rights-of-way with stem density greater than 2,500 stems/acre. High volume foliar application is a ground-based method using high-powered hydraulic pumps to deliver herbicides in a sweeping, non-selective manner; meaning, all plant life is treated regardless of species or growth form.

Aerial methods incorporate the use of a helicopter or, sometimes, fixed wing aircraft. Guidance systems are used to navigate the vehicles in order to minimize off-site damage. Aerial application methods can only be used in stable, non-inversion atmospheric conditions, with little to no wind to minimize drift of the herbicide. Both broadcast methods generally require areas where sensitive borders do not exist, so as to prevent non-target damage.

If herbicides were 'not' used, the respondent was directed to the next question, and asked if there were areas of the right-of-way where mechanical methods were used exclusively. Again, leading from a 'yes' answer was a report form named the Transmission Line Mechanical Brush Control Report Form (App A-4). This form

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queried a list of five mechanical vegetation control methods commonly used by utilities, with a corresponding unit of area or distance. The first two methods, mowing (i.e. Hydro Axe) and hand equipment (clearing) are used to clear all or some part of the ROW; thus they had a corresponding area unit designated in acres. The next three methods listed are variations of side trimming: side trim with use of a helicopter, side trim with use of a bucket truck and side trim using manual tools. Since side trimming is a linear procedure, all the methods listed had a corresponding distance unit designated in miles. Four additional 'other' entries were possible with the respondent specifying the other type of mechanical maintenance.

The third and fourth questions included in the Control Methods category are small but important. The third question allowed the respondents to add additional control methods that didn't fall within the herbicide or mechanical control categories. If such methods did exist, the respondents were asked to identify and explain the method. The last question in this category asked, "of all the above control methods used, which one has increased the most over the last five years (1990-1995)?"

BUDGET

The third category of questions was concerned with the budget allotted for the vegetation control program. Respondents were asked for the average expenditures for vegetation control under transmission lines over the last five years. The question contained three parts: total dollars spent, percent spent on herbicide control, and percent spent on mechanical control.

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PRIORITIES

The fourth category of questions was concerned with the priorities of vegetation management programs along transmission line rights-of-way. This question listed eight priority headings that were ranked from 1-8 in the vegetation management program (1 being most important and 8 being least important). The priorities are: Aesthetics, Biodiversity, Customer Satisfaction, Lengthen Vegetation Control Cycle, Minimize Herbicide Usage, Reduce Liabilities, Safety and Reliability of Service, and Wildlife Habitat.

SUBSTATION / GENERATING STATIONS

The last category of questions deals with substation / generating station vegetation control methods. This category was included to obtain a complete picture of herbicide use by utilities, rather than strictly herbicides used beneath transmission or distribution rights-of-way. Two questions were asked. The first being whether or not the company was responsible for vegetation control at their substations/generating stations. A response of 'yes' led to the second question; "Do you use herbicides to control vegetation at substations/generating stations?" Following a 'yes' answer to the second question was a small table asking for the following input: name of the herbicide(s) used, rate (gal/acre, lb./acre, oz/acre) at which the herbicide was applied, and the total acres to which the herbicide was applied.

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MAILING PROCEDURE

A total of five mailings were sent to the Utility Arborist Association companies. Each mailing contained a copy of the survey, a letter explaining the background and importance of the study, and a business reply envelope for returning the survey . A letter encouraging completion and prompt return of the survey from Mr. James Downey, the current president of the UAA was also included

Upon receiving the completed survey, the respondent's name was removed from the mailing list. The survey was identified and categorized as to the appropriate region, and data from the survey was entered into a computer data file.

STATISTICAL ANALYSIS

Statistical procedures and data manipulations were performed with the Anderson Bell statistical program AbStat® using a Gateway 2000 version G6-180 computer. All data were coded and entered as variables established in the program.

The analyses in this thesis are of a descriptive nature. Procedures used include cross tabulation of the several variables and the five regions, with a primary emphasis on herbicide methods, as identified in the Stewardship Strategy. An additional long-term goal of the Stewardship Strategy is to quantify the active ingredient of herbicide per acre of ROW. Therefore, calculations of active ingredient per acre (gal/acre) were performed

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dependent on the information given by the respondents. Incomplete information was regarded as missing and calculations were performed accordingly.

CHAPTER III: RESULTS

Respondent Characteristics:

A total of 81 utility companies, 37% of those solicited, representing 2,600,487 acres of transmission right-of-way, responded to the survey (Table 1). Four companies responsible for 777,414 acres of transmission ROW represent Canada. Twelve companies responsible for 211,876 acres of transmission ROW represent the Northeast United States. Twenty-two companies responsible for 627,518 acres of transmission ROW represent the North Central United States. Twenty-nine companies responsible for 824,101 acres of transmission ROW represent the Southern United States. Lastly, fourteen companies responsible for 159,578 acres of transmission ROW represent the Western United States (Table 2).

Table 1: Regional Breakdown of Population Sample

	Recipients of Survey	Number Returned	% Returned Per Region
CANADA	9	4	44
NORTHEAST	39	12	31
NORTH CENTRAL	59	22	37
SOUTH	70	29	40
WEST	43	14	30
Totals	220	81	
% Returned Overall			**37**

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ROW Characteristics

Sixty-nine percent (1,790,682 acres) of the total transmission ROW acres represented requires vegetation control. Twenty-two percent (528,793 acres) of the ROW acres are used for Agricultural/grazing purposes. Seven percent (165,450 acres) are Open land (parking lots, yards, roads, lakes) that require no management and 3% (73,167 acres) represents 'other' land use, such as submarine and subsurface cables, conductors designed with greater than 100' clearance, and a combination of agricultural and open land not requiring management (Table 2).

There are an additional 63,456 acres that were reported without the land-type designations. These acres represent approximately 4% of the total acres reported. Since their contribution to the study, in terms of land-type designation is minimal, the additional acres were left out of Table 2.

Table 2. Total Reported Transmission Line Right-of-Way Acreage, Land Type Characteristics, and Percentages for Each Region of the Population Sample

	VEGETATION CONTROL NEEDED		AGRICULTURE / GRAZING		OPEN WITH NO MNGT. NEEDED		OTHER LAND TYPES		
REGION	Acres	% of Region Total	Acres	% of Region Total	Acres	% of Region Total	Acres	% of Region Total	Total Acres in Region
CANADA	637,108	82	108,521	14	27,615	3.5	4,170	0.5	777,414
NORTH EAST	168,256	80	34,959	16	8,661	4	0	0	211,876
NORTH CENTRAL	362,383	58	208,815	33	50,126	8	6,195	1	627,518
SOUTH	571,079	69	123,666	15	75,965	10	53,391	6	824,101
WEST	51,856	32	91,911	58	15,691	10	120	0	159,578
Total Acres	**1,790,682**		**567,872**		**178,058**		**63,876**		**2,600,487**
% of Total Acres		**69**		**22**		**7**		**3**	**100**

Vegetation Management Practices:

Seventy-five percent of the responding companies stated that they used herbicides on those transmission ROW acres that required vegetation control. Furthermore, the majority of respondents in all of the regions except the Western United States, reported using herbicides on their ROW (Table 3).

Table 2: Regional Breakdown of Companies that use Herbicides on Transmission Line Rights-of-way

REGION	Use Herbicide	% Of Respondents	Do Not Use Herbicides	% Of Respondents	Total Number Of Respondents
CANADA	3	75	1	25	**4**
NORTH EAST	10	81.8	2	18.2	**12**
NORTH CENTRAL	16	70	6	30	**22**
SOUTH	25	88	3	12	**28**
WEST	5	39	8	62	**13**
Totals	**59**		**20**		**79**
% of All Respondents		**75**		**25**	**100**

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However, of those same companies, the vast majority (89%) stated there were areas of their transmission ROW where mechanical control methods were used exclusively to control vegetation (Table 4).

Table 4. Sample Population Companies that have Areas of Transmission ROW Where Mechanical Vegetation Control is used Exclusively

REGION	Exclusive Mech.		Non-Exclusive Mech.		Total Number of Respondents
	# of Responses	% of Region	# of Responses	% of Region	
CANADA	4	100	0	0	**4**
NORTH EAST	11	90.9	1	9	**12**
NORTH CENTRAL	19	85	3	15	**22**
SOUTH	25	88	3	12	**28**
WEST	12	92	1	8	**13**
TOTALS	**71**		**8**		**79**
% of All Respondents		**89**		**11**	**100**

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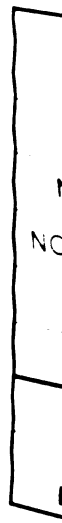

Respondents were also asked whether herbicide or mechanical control had increased the most from the period from 1990 – 1995. Six percent of the respondents chose not to answer. Of those that did respond, 35% stated there was no change; 33% stated herbicides had increased and 26% stated mechanical methods had increased (Table 5).

Table 5. Most Increased Method used to Control Vegetation along Transmission ROW From 1990-1995

REGION	No Response	Herbicide	Mechanical	Same
CANADA	0	1	2	1
NORTH EAST	0	2	4	6
NORTH CENTRAL	1	6	5	10
SOUTH	0	17	2	9
WEST	4	2	6	1
Totals	5	28	19	27
% of All Respondents	6	33	26	35

HERBICIDES

To best reflect the current trends in herbicide vegetation control used by utilities, all herbicide information has been divided into two groups. These groups are singly applied herbicides (referred to as Herbicides in tables) and herbicide mixtures (referred to as Mixtures in tables). Singly applied herbicides are those that are used by themselves to control vegetation. It should be noted that herbicide mixtures marketed under a single name are considered singly applied herbicides, and all necessary calculations were made to all ingredients. An example is Tordon 101M, which contains both Picloram and 2,4-D. Herbicide mixtures represent two or more chemicals mixed together and then applied to control vegetation. Mixtures are encouraged by most manufacturers to increase the potential of effective brush control. The number of herbicides available for use allows for a seemingly limitless number of combinations. Both groups of herbicide are reported in three different formats: 1) Herbicides Used, 2) Methods of Application, and 3) Calculated Active Ingredient of Herbicide per Acre.

Section 1: Herbicides Used

Singly Applied Herbicides

Since some returned surveys contained incomplete information regarding amounts of herbicide applied, projected total gallons of each herbicide were calculated for the top 11 herbicides and then ranked by gallons applied (Table 6).

Table 6. Most Common Herbicides Used by Respondents along Transmission Rights-of-way: 1995

Herbicide	Frequency reported	Total Gallons	# with Gallons Reported	Avg. Gallons	Projected Total Gallons
Garlon 3A	10	130,304	8	16,288	162,880
Garlon 4	19	39,475	13	3,037	57,694
Accord	14	36,383	12	3,032	42,447
Arsenal	10	19,143	10	1,914	19,143
Krenite S	9	7,829	8	979	8,807
Tordon 101M	3	6,774	3	2,258	6,774
Escort	7	3,658	7	523	3,658
Pathway	3	3,518	3	1,173	3,518
Spike	6	2,635	4	659	3,953
Tordon K	4	194	4	49	194
Pathfinder	3	53	2	27	80
Others	10	31,483			31,483
Totals	**89**	**281,449**			**340,631**

Garlon 3A was the most applied herbicide with 162,880 projected total gallons. Garlon 4 was second with 57,694 projected gallons, while Accord with 42,447 projected gallons and Arsenal with 19,143 projected gallons were third and fourth, respectively. An alphabetical listing of all singly applied herbicides reported as 'other' in Table 6, and their frequency are listed in Table 7. The 'other' category represents 7 herbicides mentioned only once or twice in the survey. These herbicides are most commonly used in agricultural situations where only broad leaf weed control is desired. Complete information on all reported chemicals is supplied in Appendix 3.

Table 7. List of 'Other' Herbicides from Table 6

HERBICIDE	FREQUENCY REPORTED
2,4 -D	2
Access	1
Banvel	2
Diuron 80 DF	1
Round up	1
Simazine	1
Weedar 64	1
Tordon 101 R	1
TOTAL	10

The Herbicide 2,4-D (2,4-dichlorophenoxy acetic acid) was reported as a singly applied herbicide by two different companies. This listing is separate from other singly applied chemicals that are sold as a mixture containing 2,4-D, such as, Pathway and Tordon 101M.

Herbicide Mixtures

Herbicide mixtures were not as frequently reported as those singly applied, totaling only 28. The mixture of Accord/Arsenal was the most common among the respondents, with 32,349 total projected mixed gallons applied (Table 8).

Table 8. Most Common Mixtures Reported along Transmission Rights-of-way: 1995

Herbicide	Frequency Reported	Total Gallons	# with Gallons Reported	Avg. Gallons	Projected Total Gallons
Accord / Arsenal	9	24,950	7	3,594	32,349
Garlon 4 / Banvel	2	8,500	1	8,500	17,000
Tordon K / Garlon 3A	3	11,118	2	5,559	16,677
Garlon 4 / Access	2	5,080	2	2,540	5,080
Others	12	6,246			6,246
Totals	**28**	**55,894**			**77,352**

As with the singly applied herbicides, those mixtures categorized as 'other' are listed in Table 9. In each case the respondents reported the mixtures only once.

Table 9. List of 'other' Mixtures from Table 8

HERBICIDE	FREQUENCY REPORTED
Accord / Arsenal / Escort	1
Accord / Escort	1
Garlon 3A / Escort	1
Garlon 3a / Tordon 101M	1
Garlon 3A / Tordon K / Arsenal	1
Garlon 4 / Arsenal	1
Garlon 4 / Weedone	1
Garlon 4 / Weedone / Escort	1
Krenite S / Arsenal	1
Krenite S / Tordon K	1
Pathway / Vanquish	1
Tordon 101 M / Vanquish	1
TOTAL	12

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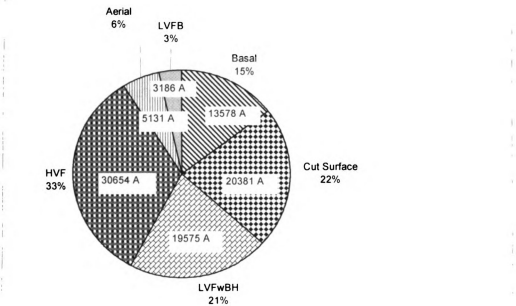
Section 2: Application Methods

The second means of herbicide analysis relates herbicides used with the methods of application. For singly applied herbicides, High Volume Foliar application was the most common, representing 33% (30,654 acres) of the total acreage to which herbicide was applied. Cut surface was second, representing 22% and a Low Volume Foliar method using a backpack or hand sprayer was third, representing 21% of the total acres (Figure 1). The acronyms **LVFwBH**, **HVF**, and **LVFB** are short for Low Volume Foliar Application using a Backpack or Hand Sprayer, High Volume Foliar Application, and Low Volume Foliar Broadcast Application, respectively.

Figure 1. Comparison of application Methods for Singly Applied Herbicides Along Transmission ROW: 1995



Two tables represent each of the 6 application methods. The first table labeled with an 'a', presents an alphabetical listing of all the herbicides applied using each method, a proportional analysis of each herbicide used, and the percent of each herbicide in relation to its total use across ALL methods. The second table, labeled with a "b", is the regional breakdown (measured in acres) of each herbicide applied using the same treatment method.

Basal Application

Only four herbicides were applied by basal application. Garlon 4 was the most frequently reported, and represented the largest area treated, with 12,240 acres (Table 10a). There were no reported basal applied herbicides in either Canada, or the Western region of the United States. The majority of Garlon 4 was applied in the North Central US (Table 10b).

Table 10a. Herbicides Applied Using Basal Techniques for all respondents

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
Basal	Accord	6.25	4.35	660	4.9
	Arsenal	6.25	5.88	495	3.6
	Garlon 3A	12.5	16.67	180	1.3
	Garlon 4	75	38.7	12240	90.2
Total		**100**		**13576**	**100**

Table 10b. Regional Breakdown (acres) of Basal Applied Herbicides*

	Northeast	North Central	South	Totals
Accord	0	0	660	660
Arsenal	0	0	495	495
Garlon 3A	0	40	141	181
Garlon 4	245	8676	3319	12240
Totals	**245**	**8716**	**4615**	**13576**
% of Total	**2**	**64**	**34**	**100**

* Canada and West reported no basal applications

Cut Surface Application

Seven brands of herbicides were applied by a cut surface method. Garlon 4 was again the most frequently reported, and was applied to 28.9% (5887 acres) of all the transmission ROW acres treated with this method (Table 11a). Although it was the second most frequent herbicide reported, Pathway was applied to the most acres (7781) with the majority of those acres (55%) represented in the Northeastern United States (Table 11b). Canadian companies did not report the use of a cut surface method to apply herbicides.

Table 11a. Single Herbicides Applied using a Cut Surface Method for all respondents: 1995

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
Cut Surface					
	Access	4.3	50	8	0.04
	Accord	8.7	8.7	1900	9.3
	Banvel	4.3	50	ND	
	Garlon 3A	8.7	16.67	259	1.3
	Garlon 4	52.2	38.7	5888	28.9
	Pathfinder	8.7	66.67	4545	22.3
	Pathway	13.1	100	7781	38.2
	Total	**100**		**20381**	**100**

Table 11b. Regional Breakdown (acres) of Herbicides Applied Using a Cut Surface Method*

	Northeast	North Central	South	West	Totals
Access	0	0	8	0	8
Accord	1900	0	0	0	1900
Banvel	ND	0	0	0	0
Garlon 3A	0	0	259	0	259
Garlon 4	1726	1355	670	2136	5888
Pathfinder	0	0	0	4545	4545
Pathway	7621	160	0	0	7781
Totals	11247	1515	937	6682	20381
% of Total	**55**	**7**	**5**	**33**	**100**

* Canada Reported no Cut Surface Applications

Low Volume Foliar Application with a Backpack or Hand Sprayer

Accord and Arsenal were reported with the same frequency, and a combined 52% of all herbicides applied using a Low Volume Foliar method with a backpack or hand sprayer. However, Arsenal was applied to 35% (6917 acres) of all reported transmission ROW acres treated using this method (Table 12a). All Regions of study used some form of this Low Volume Foliar method, with the significant majority being used in the Northeast, North Central and South United States regions (Table 12b).

Table 12a. Herbicides Applied Using a Low Volume Foliar with a Backpack or Hand Sprayer Method: 1995

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
LVFwBH	Access	3.7	50	392	2
	Accord	25.9	30.43	4423	22.6
	Arsenal	25.9	41.18	6918	35.3
	Escort	7.4	22.22	222	1.1
	Garlon 3A	7.4	16.67	52	0.3
	Garlon 4	7.4	6.45	1887	9.6
	Krenite S	14.9	40	5413	27.7
	Pathfinder	3.7	33.33	2	0.01
	Spike	3.7	100	265	1.4
	Total	**100**		**19574**	**100**

Table 12b. Regional Breakdown (acres) of Herbicides Applied Using a Backpack or Handsprayer Low Volume Foliar Method

	Canada	Northeast	North Central	South	West	Totals
Access	0	0	0	392	0	392
Accord	0	20	2503	1218	682	4423
Arsenal	0	20	2513	4385	0	6918
Escort	0	0	222	0	0	222
Garlon 3A	0	0	52	0	0	52
Garlon 4	247	1640	0	0	0	1887
Krenite S	0	5413	0	0	0	5413
Pathfinder	0	2	0	0	0	2
Spike	0	0	0	265	0	265
Totals	247	7095	5290	6260	682	19574
% of Total	**1**	**36**	**27**	**32**	**4**	**100**

High Volume Foliar Application

Accord was the most frequently reported singly applied herbicide using a High Volume Foliar method, but Garlon 3A was used to treat the most (7929) acres of Transmission ROW (Table 13a). High Volume foliar application was not used by Canadian respondents. The North Central and South US used a High Volume Foliar method to apply herbicides on a combined 28,563 acres, 85% of all acres reported for the method (Table 13b).

Table 13a. Herbicides Applied Using a High Volume Foliar Method: 1995

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
HVF	Accord	25	47.83	4752	15.5
	Arsenal	13.6	35.29	2288	7.5
	Banvel	2.3	50	61	0.2
	Escort	9.1	44.44	2237	7.3
	Garlon 3A	9.1	33.33	7929	25.9
	Garlon 4	9.1	12.9	820	2.7
	Krenite S	9.1	40	1009	3.3
	Tordon 101M	6.8	100	6892	22.5
	Tordon 101R	2.3	100	439	1.4
	Tordon K	6.8	75	2064	6.7
	2,4-D	4.5	100	800	2.6
	Diuron 80 DF	2.3	100	1364	4.4
	Total	**100**		**30654**	**100**

Table 13b. Regional Breakdown (acres) of Herbicides Applied using a High Volume Foliar Method*

	Northeast	North Central	South	West	Totals
Accord	110	290	2988	1364	4752
Arsenal	0	303	1985	0	2288
Banvel	0	0	61	0	61
Escort	100	0	2137	0	2237
Garlon 3A	940	6300	689	0	7929
Garlon 4	0	800	20	0	820
Krenite S	0	373	636	0	1009
Tordon 101M	240	6300	352	0	6892
Tordon 101 R	0	0	439	0	439
Tordon K	700	303	1061	0	2064
2,4-D	0	800	0	0	800
Diuron 80 DF	0	0	0	1364	1364
Totals	**2,090**	**15,469**	**10,368**	**2,728**	**30,655**
% of Total	**7**	**51**	**34**	**9**	**100**

* Method not reported from Canada

Low Volume Foliar Broadcast Application

In contrast to the 19,574 acres treated using a Low Volume Foliar Application with a Backpack or Hand Sprayer, herbicides applied using a Low Volume Foliar Broadcast method were only reported used on 3187 acres. Arsenal, Escort, and Garlon 3A were all reported with the same frequency for a combined 417 acres. Accord, although reported less frequently, was applied to more acres than either Garlon 3A or Escort. However, the herbicide Velpar topped all herbicides applied using this method with 2500 acres. Krenite S was reported as used, but any other information was not provided (Table 14a).

Ninety-six percent of all acres treated using a Low Volume Broadcast method (3054 acres) were in the Southern US. In addition, this method was not reported as used in Canada, and the Western US. Although the method was reported as used in the Northeast US, insufficient data was given (Table 14b).

Table 14a. Herbicides Applied Using a Low Volume Foliar Broadcast Method: 1995

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
LVFwB	Accord	10	4.35	204	6.4
	Arsenal	20	11.76	237	7.4
	Escort	20	22.22	106	3.3
	Garlon 3A	20	16.67	74	2.3
	Krenite S	10	10	ND	
	Tordon K	10	25	66	2.1
	Velpar	10	100	2500	78.5
	Total	**100**		**3187**	**100**

Table 14b. Regional Breakdown (acres) of Herbicides Applied using a Low Volume Foliar Broadcast Method*

	Northeast	North Central	South	Totals
Accord	0	0	204	204
Arsenal	0	33	204	237
Escort	0	33	73	106
Garlon 3A	0	0	74	74
Krenite S	ND	0	0	ND
Tordon K	0	66	0	66
Velpar	0	0	2500	2500
Totals	**0**	**132**	**3055**	**3187**
% of Total	**0**	**4**	**96**	**100**

*Canada and West reported no Low Volume Broadcast Applications

Aerial Application

All herbicides applied with an aerial method were reported with the same frequency. Arsenal was used to treat 42% (2140 acres) of all the transmission ROW controlled using this method. Incomplete information was given regarding acres treated with Garlon 4. Thus, Garlon 4 was not considered in the acre calculations even though it was reported as applied with an aerial method (Table 15a).

Table 15a. Herbicides Applied along Transmission Line Rights-of-way using an Aerial Method

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
Aerial	Accord	20	4.35	1192	23.2
	Arsenal	20	5.88	2140	41.7
	Escort	20	11.11	667	13
	Garlon 4	20	3.23	ND	
	Krenite S	20	10	1132	22.1
	Total	**100**		**5131**	**100**

Only the North Central US reported using an aerial application for herbicide vegetation control. Accord was reported in Canada, but the corresponding acre information was incomplete (Table 15b).

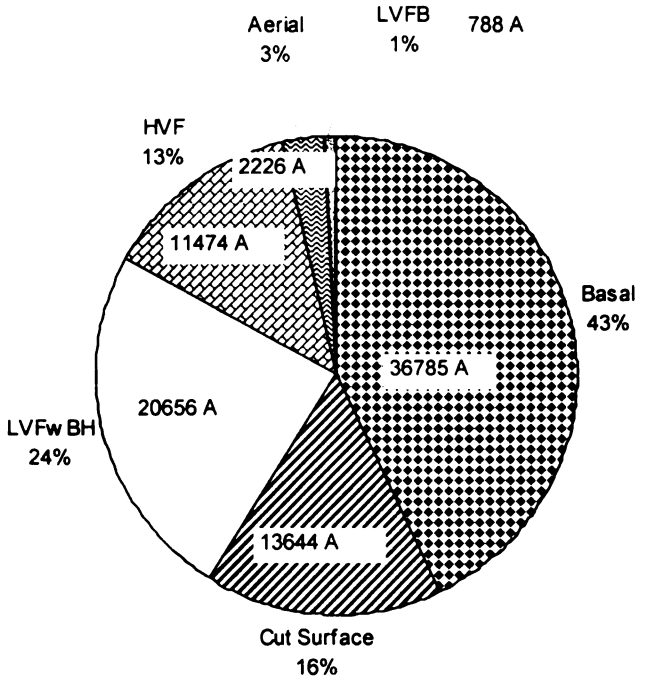
Table 15b. Regional Breakdown (acres) of Herbicides applied using an Aerial Method

	Canada	North Central	Totals
Accord	ND	0	0
Arsenal	0	1192	1192
Escort	0	2140	2140
Garlon 4	0	667	667
Krenite S	0	1132	1132
Totals	0	5131	5131
% of Total		**100**	**100**

Herbicide Mixtures

Figure 2 is a comparison of the six methods used to apply Herbicide Mixtures in terms of total acres applied by each. The acronyms **LVFwBH, HVF**, and **LVFB** are short for Low Volume Foliar Application using a Back pack or Hand Sprayer, High Volume Foliar Application, and Low Foliar Broadcast Application, respectively. The highest percentage (43%) of all acres treated with herbicide mixtures was applied using a basal method. Canadian Companies did not report using herbicide mixtures.

Figure 2. Comparison of Application Methods for Mixtures Along Transmission ROW: 1995



Basal Application

Two herbicide mixtures were applied using a basal method. The mixture of Garlon 4/Access was used on 32,523 acres (Table 16a). Only the Northeast and North Central United States reported applying herbicide mixtures using a basal method, with 99% of the total transmission ROW acres treated located within Region 1 (Table 16b).

Table 16a. Herbicide Mixtures Applied using a Basal Technique: 1995

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
Basal					
	Garlon 4 / Access	50	50	36,523	99.3
	Garlon 4 / Banvel	50	33.33	262	0.7
	Totals	**100**		**36,785**	**100**

Table 16b. Regional Breakdown (acres) of Herbicide Mixtures as Basal Applications

	NORTHEAST	NORTH CENTRAL	TOTALS
Garlon 4 / Access	36,523	0	36,523
Garlon 4 / Banvel	0	262	262
Totals	36,523	262	36,785
% of Total	**99**	**1**	**100**

Cut Surface Application

Herbicide mixtures applied using a cut surface technique were all reported with the same frequency. The mixture of Garlon 4/Banvel was applied to 94% (12,834 acres) of the total transmission ROW reported for this method (Table 17a).

Only Companies in the North Central and South United States reported using herbicide mixtures to treat ROW acres with a cut surface method. The acres reported for the South represents less than .01% of the total ROW acres reported. The mixture of Pathway/Vanquish was applied only with this method (Table 17b).

Table 17a. Herbicide Mixtures Applied using a Cut Surface Method: 1995

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
Cut Surface					
	Garlon 4 / Banvel	25	33.33	12,834	94
	Pathway / Vanquish	25	100	790	5.8
	Garlon 4 / Access	25	50	ND	
	Garlon 4 / Weedone	25	50	20	0.2
	Totals	**100**		**13,644**	**100**

17b. Regional Breakdown (acres) of Herbicide Mixtures as Cut Surface Applications*

	Northeast	North Central	South	Totals
Garlon 4 / Banvel	0	12834.4	0	12834
Pathway / Vanquish	0	790	0	790
Garlon 4 / Access	ND	0	0	0
Garlon 4 / Weedone	0	0	20	20
Totals	0	13624.4	20	13644
% of Total		**100**	**0**	**100**

* The West companies did not report using herbicide mixtures with cut surface techniques

Low Volume Foliar Application Using a Backpack or Hand Sprayer

A combination of Accord/Arsenal was the most frequent herbicide mixture applied using Low Volume Foliar. The mixture was applied to 72% (14,898 acres) of the total acres treated. The only other mixture reported more than once for this method was Tordon K/Garlon 3A (Table 18a).

Table 18a. Herbicide Mixtures Applied using a Low Volume Foliar Technique With a Backpack or Hand sprayer: 1995

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
LVFwBH					
	Accord / Arsenal	42.11	80	14,898	72.1
	Accord / Escort	5.26	100	14	0.06
	Accord / Arsenal / Escort	5.26	100	1,900	9.2
	Garlon 4 / Arsenal	5.26	50	10	0.04
	Garlon 4 / Escort	5.26	50	163	0.8
	Garlon 4 / Weedone	5.26	50	980	4.7
	Garlon 4 / Weedone / Escort	5.26	100	24	0.1
	Krenite / Arsenal	5.26	100	1,011	4.9
	Krenite / Tordon	5.26	100	661	3.2
	Tordon 101M / Vanquish	5.26	100	900	4.4
	Tordon K / Garlon 3A	10.54	40	95	0.5
	Totals	**100**		**20,656**	**100**

All of the United States regions reported applying an herbicide mixture with a LVFw/BH method. Herbicide mixtures with this method were most common in the North Central and Northeast US, representing 55% (11,312 acres) and 40% (8,154 acres) respectively, of all reported transmission ROW acres (Table 18b).

Table 18b. Regional Breakdown (acres) of Herbicide Mixtures as a Low Volume Foliar with Backpack or Hand Sprayer Application

	Northeast	North Central	South	West	Totals
Accord / Arsenal	3,520	11,192	186	0	14,898
Accord / Escort	0	0	0	14	14
Accord / Arsenal / Escort	1,900	0	0	0	1,900
Garlon 4 / Arsenal	0	0	10	0	10
Garlon 4 / Escort	162	0	0	0	163
Garlon 4 / Weedone	0	0	980	0	980
Garlon 4 / Weedone / Escort	0	24	0	0	24
Krenite S / Arsenal	1,011	0	0	0	1,011
Krenite / Tordon	661	0	0	0	661
Tordon 101M / Vanquish	900	0	0	0	900
Tordon K / Garlon 3A	0	95	0	0	95
Totals	8,154	11,312	1,176	14	20,656
% of Total	**39**	**55**	**6**	**0**	**100**

High Volume Foliar Application

High volume foliar applied herbicide mixtures were applied to 11,474 acres of transmission ROW. The herbicide mixture of Tordon K/Garlon 3A was applied to 80% (9,190 acres) of those acres. All other mixtures were reported with the same frequency. (Table 19a)

Table 19a. Herbicide Mixtures Applied using a High Volume Foliar Technique : 1995

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
HMF					
	Accord / Arsenal	14.3	10	400	3.5
	Garlon 3A / Tordon 101M	14.3	100	1,711	14.9
	Garlon 4 / Arsenal	14.3	50	24	0.2
	Garlon 4 / Banvel	14.3	33.33	41	0.4
	Garlon 4 / Escort	14.3	50	108	0.9
	Tordon K / Garlon 3A	28.5	40	9,190	80.1
	Totals	**100**		**11,474**	**100**

Utility companies in the Western United States did not report any herbicide mixtures applied using a High Volume foliar method, while companies in North Eastern United States accounted for 89% of the ROW acres treated. The only Herbicide that was reported in two different regions was Tordon K / Garlon 3A (Table 19b).

Table 19b. Regional Breakdown (acres) of Herbicide Mixtures as High Volume Foliar Applications

	Northeast	North Central	South	Totals
Accord / Arsenal	0	0	400	400
Garlon 3A / Tordon 101M	1,711	0	0	1,711
Garlon 4 / Arsenal	0	0	24	24
Garlon 4 / Banvel	0	41	0	41
Garlon 4 / Escort	108	0	0	108
Tordon K / Garlon 3A	8,331	859	0	9,190
Totals	10,150	900	424	11,474
% of Total	**89**	**8**	**4**	**100**

Low Volume Foliar Broadcast Application

The only herbicide mixture reported applied with a Low Volume Foliar broadcast method was the combination of Accord/Arsenal (Table 20). The mixture was only applied to 788 acres in the Southern United States.

Table 20. Herbicide Mixture applied using a Low Volume Foliar Broadcast Method, all in the Southern U.S.: 1995

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
LVFwB					
	Accord / Arsenal	100	10	788	100

Aerial Application

Tordon K/Garlon 3A was the only herbicide mixture reported that was applied using an aerial method (Table 21). All of the treated acres (2,226) are located in the North Central United States.

Table 21. Herbicide Mixture applied using an Aerial Method, all in the North Central U. S.: 1995

Method	Herbicide	% of Method	% of Total Herbicide Use	Acres	% of Total Acres
Aerial					
	Tordon K / Garlon 3A	100	20	2226	100

Section 3: Active Ingredient Per Acre

The third examination of data is in direct response to the use risk reduction strategy noted in the Stewardship Strategy for Electric Utility Rights-of-way. The minimization of the amount of active ingredient per acre applied, rather than total volume of products used, is the primary focus. To assist in the analysis of risk, the average active ingredient per acre for each herbicide reported was calculated and listed in the following tables. Dilution rates of herbicides prior to application differ for each method used; therefore, the results are separated by method for all the sample regions. The main purpose of these tables is to list the calculation results. They are not comparison tables. Comparisons between different chemicals applied by the same method are not valuable since each chemical is mutually exclusive. Tables 22-27 present the singly applied herbicides used and the calculated average Active Ingredient per Acre. Tables 28-33 present the same information, but for the herbicide mixtures. Each entry in the tables is the average of all reported uses for that herbicide.

The calculations were executed using the following steps. Gallons of product applied were multiplied by the suggested percent dilution rate and then by the percent of active ingredient contained in the product; for herbicide mixtures, the percentage mix rate of each herbicide ingredient was also multiplied by the total gallons. The result was then divided by the acres treated to obtain the final average.

Table 22. Average Active Ingredient Per Acre (Gal/Acre) for Singly Applied Herbicides Using a Basal Method: 1995

BASAL	ACTIVE INGREDIENT	NORTH EAST	NORTH CENTRAL	SOUTH	Avg Gal / Acre
ACCORD	Glyphosate			0.08788	0.0879
ARSENAL	Imazapyr			0.27556	0.2756
GARLON 3A	Triclopyr		22.2*	0.27143	0.2714
GARLON 4	Triclopyr	0.03673	0.0418	0.06087	0.0465

* The calculated amount for Garlon 3A in the North Central region, was not included in the final average calculation, because the value was so high it was considered an outlying value.

Table 23. Average Active Ingredient per Acre (gal/acre) for Singly Applied Herbicides Using a Cut Surface Method: 1995

CUT SURFACE	ACTIVE INGREDIENT	NORTH EAST	NORTH CENTRAL	SOUTH	WEST	Avg Gal / Acre
ACCORD	Glyphosate	0.0916				**0.1200**
BANVEL	Dicamba	ND				
GARLON 3A	Triclopyr			2.7751		**2.7800**
GARLON 4	Triclopyr	0.0349	0.0419	0.0879	0.0151	**0.0449**
PATHFINDER	Triclopyr				ND	
ACCESS	Picloram & Triclopyr			0.0428 / 0.0813		**0.0428 / 0.0813**
PATHWAY	Picloram & 2,4-D	0.0103 / 0.0403	0.69375 / 2.675			**0.3520 / 1.3576**

Table 24. Average Active Ingredient Per Acre (gal /acre) for Singly Applied Herbicides Using A Low Volume Foliar Technique with a Backpack or Hand Sprayer: 1995

LVFwBH	Active Ingredient	Canada	North East	North Central	South	West	AVG. GAL / ACRE
ACCORD	Glyphosate		0.25000	0.01466	0.18418	0.02287	**0.1179**
ARSENAL	Imazapyr		0.06000	0.00119	0.02166		**0.0276**
ESCORT	Methyl-2*			0.00002			**0.0000**
GARLON 3A	Triclopyr			1.74875			**1.7488**
GARLON 4	Triclopyr	0.08097					**0.0810**
KRENITE S	Fosamine		0.02518				**0.0252**
PATHFINDER	Triclopyr		3.5000				**3.5000**
SPIKE	Tebuthiuron				0.37736		**0.3774**
ACCESS	Picloram & Triclopyr				0.0510 / 0.0969		**0.0510/ 0.0969**

*Abbreviation for: Metsulfuron methyl {Methyl2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) amino]-carbonyl]-amino]sulfonyl]benzoate}

Table 25. Average Active Ingredient Per Acre (gal/acre) for Singly Applied Herbicides Using a High Volume Foliar Method: 1995

HVF	ACTIVE INGREDIENT	NORTH EAST	NORTH CENTRAL	SOUTH	AVG GAL/ACRE
ACCORD	Glyphosate	0.00982	0.01084	0.0843	**0.0350**
ARSENAL	Imazapyr	ND	0.00017	0.0044	**0.0023**
BANVEL	Dicamba			0.3115	**0.3115**
ESCORT	Methyl-2'	0.00001		0.00058	**0.0003**
GARLON 3A	Triclopyr	0.00166	0.00167	0.03996	**0.0144**
GARLON 4	Triclopyr		0.17325		**0.1733**
KRENITE S	Fosamine	ND	0.12377	0.00098	**0.0624**
TORDON K	Picloram	0.00023	0.00013	0.00002	**0.0001**
TORDON 101M	Picloram & 2,4-D	0.0005 / 0.002	0.00102 / 0.00396	0.00102 / 0.00395	**0.0008 / 0.0033**
2,4-D	2,4-D		37.5		**38**

Table 26. Average Active Ingredient Per Acre (gal/acre) for Singly Applied Herbicides Using a Low Volume Foliar Broadcast Method: 1995

LVFB	ACTIVE INGREDIENT	NORTH CENTRAL	SOUTH	**Avg Gal / Acre**
ACCORD	Glyphosate		0.031250	**0.0313**
ARSENAL	Imazapyr	0.000900	0.000539	**0.0007**
ESCORT	Methyl-2'	0.000420	0.000003	**0.0002**
GARLON 3A	Triclopyr		0.012162	**0.0122**
TORDON K	Picloram	0.000378		**0.0004**
VELPAR	Hexazinone		1.400000	**1.4000**

Table 27: Average Active ingredient per Acre (gal/acre) for singly applied herbicides using an Aerial Method: 1995

AERIAL	ACTIVE INGREDIENT	NORTH CENTRAL AVG. GAL / ACRE
ACCORD	Glyphosate	**0.0167**
ARSENAL	Imazapyr	**0.0013**
ESCORT	Methyl-2'	**0.0001**
KRENITE S	Fosamine	**0.1026**

Herbicide Mixtures

The following tables are the calculated active ingredients per acre for the herbicide mixtures given in the survey. As with the singly applied herbicides, the figures are not to be compared between herbicides. Instead, the tables are provided for organization of the chemicals used. The only valid comparison would be between values of different application techniques for the SAME herbicide.

Table 28. Active ingredient per Acre (gal/acre) for Herbicides Mixture Applied Using a Basal Method, in the Northeast United States

BASAL	REGION	NORTHEAST	
	ACTIVE INGREDIENT	1	2
Garlon 4 / Access	Triclopyr & Access*	**0.01426**	**0.001 / 0.002**

Access is a discontinued herbicide produced by DowElanco that contains formulations of both Picloram and Triclopyr.

Table 29. Average Active ingredient per Acre (gal/acre) for Herbicides Mixture Applied using a Cut Surface Method, in the North Central United States.

CUT SURFACE	REGION	NORTH CENTRAL	
	ACTIVE INGREDIENT	1	2
Pathway / Vanquish	Picloram / 2,4-D & 3.6-Dicloro-o-anisic acid	**0.0386 / 0.1505**	**0.40622**

Table 30. Average Active Ingredient Per Acre (gal/acre) for Herbicide Mixtures Applied Using a Low Volume Foliar Method with a Backpack or Hand Sprayer

	REGION	NORTHEAST		NORTH CENTRAL		SOUTH		WEST		AVG GAL / ACRE	
LVFwBH	ACTIVE INGREDIENT	1	2	1	2	1	2	1	2	1	2
Krenite / Tordon K	Fosamine & Picloram	0.00919	0.00064							**0.009**	**0.0006**
Krenite / Arsenal	Fosamine & Imazapyr	000181.	0.00012							**0.002**	**0.0001**
Tordon 101M / Vanquish	Picloram / 2,4-D & Vanquish	0.01384 / 0.05375	0.07710							**0.014 / 0.054**	**0.077**
Garlon 4 / Escort	Triclopyr & Methyl-2'	0.00052	0.00001							**0.001**	**0.00001**
Accord / Arsenal	Glyphosate & Imazapyr			0.1149	0.00795	0.0931	0.0006			**0.104**	**0.004**
Tordon K / Garlon 4	Picloram & Triclopyr			0.366	2.435					**0.366**	**2.435**
Accord / Escort	Glyphosate & Methyl-2'							0.14821	0.03202	**0.148**	**0.032**

Table 31. Average Active Ingredient per Acre (gal/acre) for Herbicide Mixtures Applied using a High Volume Foliar Method.

HVF	REGION	NORTH EAST		NORTH CENTRAL		SOUTH		AVG GAL / ACRE	
	ACTIVE INGREDIENT	1	2	1	2	1	2	1	2
Tordon K / Garlon 4	Picloram & Triclopyr	0.3660	0.9240	0.3660	0.9240			**0.3660**	**0.9240**
Garlon 3A / Tordon 101 M	Triclopyr & Picloram / 2,4-D	0.00312	0.000535 / 0.00208					**0.0031**	**0.0005 / 0.0021**
Garlon 4 / Escort	Triclopyr & Methyl-2'	0.0053	0.00001					**0.0005**	**0.00001**
Garlon 4 / Banvel	Triclopyr & Dicamba			0.1207	0.0125			**0.1207**	**0.0125**
Accord / Arsenal	Glyphosate &Imazapyr					0.01017	0.0007	**0.0102**	**0.0007**

Table 32. Average Active ingredient per Acre (gal/acre) for an Herbicides Mixture Applied using a Low Volume Foliar Broadcast Method in The Southern United States

LVFB		SOUTH	
	ACTIVE INGREDIENT	1	2
Accord / Arsenal	Glyphosate & Imazapyr	**0.0001**	**0.00001**

Table 33. Average Active Ingredient per Acre (gal/acre) for Herbicides Mixture Applied using an Aerial Method, in the North Central United States

AERIAL		NORTH CENTRAL	
	ACTIVE INGREDIENT	1	2
Tordon K / Garlon 4	Picloram & Triclopyr	**0.3657**	**0.9236**

Comparison of Calculated Active Ingredient Per Acre with the Maximum Recommended Rates of Application

The Environmental Stewardship Strategy for Electric Utility Rights-of-way stated that the pesticide use/ risk reduction strategy for United States utilities is aimed at "minimizing the amount of active ingredient of a particular product (or products) per acre rather than reducing the total volume of products used." Simply calculating the active ingredient per acre only provides half of the information required to evaluate if reduction is necessary. Comparison of the active ingredient per acre for the most common herbicides with the maximum recommended application rates will reveal if there is indeed a potential exposure risk to humans and the environment. As with the preceding calculations, the different dilution rates for each herbicide affect the rates for each application method. The herbicide labels provide a range of values for the application rate, the applicator decides on a rate depending on the situation. The maximum rates were used for comparison because it is easier to ascertain compliance. Basal and Cut Surface comparisons are excluded because the rates of application are based on a per tree or per stump basis and not 'per acre.' Herbicide mixtures are also excluded because the variability in mixture possibilities eliminates a standard from which comparison can be made. The maximum rates of application in terms of gallons of active ingredient per acre were calculated as follows.

1) The mean of the recommended dilution from the label was calculated as percent of product contained in the final herbicide solution.

2) This number was then multiplied by the maximum recommended gallons per acre given on the label.

3) The calculated product amount per acre was multiplied by the percentage of active ingredient contained in the product to obtain the values in Table 34. An example is located in Figure 3.

Figure 3. Sample Calculation of Maximum Recommended Application Rate for Garlon 3A Using a LVFwBH Method.

1) 4-5 gal / 100 gal H_2O = 4.5% = **0.045 of product**

2) Recommended rate = 10-20 gal / acre,

THUS, .045 * 20 = **0.9 gallons of Garlon 3A / acre**

3) Garlon 3a contains 44.4% of Triclopyr

THUS, .444 * 0.9 = **0.3996 gallons of Triclopyr / acre**

Table 34. Recommended Maximum Limits of Active Ingredient Per Acre (gal/acre) for The Most Commonly-used ROW Herbicides

HERBICIDE	METHOD OF APPLICATION			
	LVFwBH	HVF	LVFB	Aerial
Garlon 3A	0.3996	1.332	1.332	1.332
Garlon 4	0.4928	1.232	1.478	1.232
Accord	1.038	1.038	1.038	1.038
Arsenal	0.215	0.215	0.215	0.215
Krenite S	1.66	1.66	1.66	1.245
Escort	0.00703	0.01875	0.00703	0.0035
Tordon K	-	0.122	0.122	-
Tordon 101M	-	0.204 / 0.792	-	-

The ratio comparisons were calculated using the average active ingredient per acre calculations from the previous section and the above maximum recommended rates (Table 35).

Table 35. Ratio Comparisons of Actual to Recommended Active Ingredient Per Acre for All Respondents

HERBICIDE	METHOD OF APPLICATION			
	LVFwBH Actual : Recom	HVF Actual : Recom	LVFB Actual : Recom	Aerial Actual : Recom
Garlon 3A	4 : 1	1 : 93	**1 : 109**	-
Garlon 4	1 : 6	1 : 7	-	-
Accord	1 : 9	1 : 29	1 : 33	1 : 62
Arsenal	1 : 8	**1 : 93**	**1 : 307**	**1 : 165**
Krenite S	1 : 65	1 : 26	-	1 : 12
Escort	1 : 35	1 : 63	1 : 35	1 : 35
Tordon K	-	1 : 2	**1 : 305**	-

Only Garlon 3A had a higher ratio to the recommended rate, all other resulted in ratios far below the recommended. Tordon 101 M was not included in the table but its ratios are: **Picloram** - 1 actual : 255 recommended and **2,4-D** – 1 actual : 240 recommended.

Mechanical Methods

Mechanical Methods were divided into two categories, treated ROW acreage and linear side trim of ROW. Treated acreage is represented by two methods: mowed acres and hand treated acres (Table 36a). Mowed acres represents 80% (394,997 acres) of all mechanically treated ROW. There were a considerable amount of respondents in all regions that neither mowed nor used hand equipment to treat transmission line ROW. Companies in Canada and the Southern United States reported 94% of all ROW acres treated mechanically. Fifty-six percent of all reported mechanically treated acres were located in the southern United States (Table 36b).

Table 36a. Regional Breakdown of ROW Acres Treated with Mowing and Hand Equipment: 1995

	MOWING			HAND EQUIPMENT		
REGION	**Acres**	**% of Total acres**	**% that Do not Mow**	**Acres**	**% of Total acres**	**% that Do not Mow**
Canada	135,000	43.8	75	46,500	65	50
Northeast	1,386	0.5	46	4,152	6	27.2
North Central	6,202	2	55	11,004	15	70
South	249,253	52.7	24	22,505	10	60
West	3,156	1	50	2,610	4	42
Totals	**394,997**			**86,771**		
% of Total		**82**			**18**	

Table 36b. Regional Breakdown of Total Acres Treated Mechanically: 1995

Region	Total Acres Mechanically Treated	% Of Total Acres
Canada	181,500	**38**
Northeast	5,538	**1**
North Central	17,206	**4**
South	271,758	**56**
West	5,766	**1**
Totals	**481,768**	**100**

The second type of mechanical control is a linear method known as a Side Trim. Typically, side trim methods fall into three categories, side trim with a bucket truck, side trim manual, and side trim with a helicopter. Side Trim with a bucket truck, was used on 50% of the reported side trim miles, interestingly, this method was not used by any of the Canadian respondents (Table 37a). A total of 16,773 miles of transmission line ROW was treated using a side trim method (Table 37b).

Table 37a. Regional Breakdown of Side Trim Methods used and the Percentage of Respondents that do not use each Method

	BUCKET TRUCK			MANUAL			HELICOPTER		
	Miles	**% of Total Miles**	**% Do Not Use Method**	**Miles**	**% of Total Miles**	**% Do Not Use Method**	**Miles**	**% of Total Miles**	**% Do Not Use Method**
Canada	0	0	100	30	0.4	75	600	38	75
Northeast	171	2	64	3346	49	36	120	8	91
North Central	1414	17	65	2110	31	55	167	11	90
South	6385	77	40	1196	17	56	535	34	92
West	370	5	67	173	3	58	150	10	92
Totals	8335	50		6855	41		1572	9	

Table 37 b. Regional Breakdown of Total ROW miles Side Trimmed

	Total ROW Miles Side Trimmed	% of Total Miles
Canada	630	4
Northeast	3637	22
North Central	3703	22
South	8110	48
West	693	4
Totals	**16773**	**100**

Four additional mechanical control methods were given in an 'other' category in the survey. Three of these methods, Shearblade, Brontosaurus, and Mowing Kershaw, were used to control 8550 acres of transmission ROW. The fourth method is a Side Trim method using a machine known as a Jaraff, totaling 486 treated miles treated (Table 38).

Table 38. Individual Mechanical Methods Reported as 'Other' and the Relative Miles Or Acres Treated

Method	Canada	Northeast	North Central	South
Shearblade	350 Acres			
Brontosaurus		4900 Acres		
Mowing Kershaw			3300 Acres	
Side Trim Jaraff				486 Miles

Public Perception and Characteristics of brush were the two most frequently used reasons given to explain the use of mechanical control methods instead of herbicide methods. In the North Central United States, the cheaper cost of mechanical control methods as compared to herbicide methods was the second most popular reason for mechanical preference (Table 39). The numbers in Table 39 are tabulations of the reasons given and are ranked according to the number of times the response was given. For example, sites being protected or sensitive was given as a reason a total of 18 times.

Table 39. Ranking of Reasons given as to why Mechanical Methods of Vegetation Control were used Rather than Herbicide Methods

		Number of Responses				
REASON	Canada	Northeast	North Central	South	West	Totals
Public Perception	3	8	8	12	5	**36**
Characteristics of Brush	2	4	7	3	3	**19**
Protected and/or Sensitive Site*	2	7	6	3		**18**
ROW Agreement Restricts Herbicides		4	5	3	1	**13**
Cheaper		1	1	6	2	**10**
Customer Safety		2		2		**4**
Liability Concerns			1	2		**3**
Aesthetic Concerns			1	1	1	**3**
Work Done in the Winter	1		1		1	**3**
Terrain					3	**3**
Young Program				2		**2**
Environmental Concerns			1	1		**2**
Reluctance to Change				2		**2**
Zoning Restrictions				2		**2**
Job Creation	1					**1**
Wildlife				1		**1**

* This category includes environmental Regulations set by the EPA

These responses do not represent all the respondents. In fact, there were a number of responses that did not contain a response to this query.

Vegetation Management Budget

A total of $ 81,636,098 dollars was spent among all respondents for their vegetation management program. Sixty-six percent of this amount was allotted to mechanical control, while 34% was allotted towards herbicide control. Canadian dollars were converted to United States currency with an exchange rate of $.75 Canadian: $1 American (Table 35).

Table 40. Regional breakdown of the Average Budget Allotted for Vegetation Control From 1990-1995

Region	Herbicide Dollars	% of Total Region Dollars	Mechanical Dollars	% of Total region Dollars	Total Dollars	% of Total Dollars
Canada	2,405,625	34	4,625,625	66	7,031,250	13
Northeast	7,395,490	57	5,431,510	43	12,827,000	17
North Central	9,126,802	29	17,805,546	71	26,932,348	31
South	8,039,400	31	22,846,100	69	30,885,500	34
West	381,920	10	3,578,080	90	3,960,000	5
Total Dollars	**27,349,237**		**54,286,861**		**81,636,098**	
% of Total Dollars		**34**		**66**		**100**

Climatic Comparisons between United States Divisions

As stated in the Introduction, two hypotheses have been developed to investigate possible differences of vegetation control intensity (based on dollars spent per acre) in different regions of the United States. The first hypothesis deals with precipitation differences.

Ho: Precipitation differences have no influence on dollars spent per acre (vegetation management intensity)

H1: There is an influence

The theory is that areas with low annual rainfall averages (<25") would require *less* dollars spent per acre for vegetation control, since these ecozones have climax vegetation with a maximum height and density that is compatible to a ROW environment. Conversely, areas with high annual rainfall averages (>40") would require more dollars spent per acre to control the vegetation, since the climax vegetation becomes a potential outage threat in a shorter time span.

The second hypothesis is concerned with temperature differences between different areas of the United States.

Ho: Temperature differences have no influence on dollars spent per acre (vegetation management intensity)

H1: There is an influence

The theory is that as the mean temperature increases, meaning a longer growing season, the potential for outage threats increases. With a longer growing season the intensity to control the vegetation would seem to increase. An increase in intensity is reflected in more dollars spent per acre. However, an alternate scenario is possible; the longer growing season also increases the management season. Therefore, an area with access year round could allow for a control program that can be paced over a twelve-month period, thereby saving money.

The comparisons between United States divisions are also based on the precipitation – effectiveness index. The precipitation-effectiveness index is an aridity index measurement computed as ten times the sum of the monthly precipitation to evaporation ratio at a given location (Fairbridge 1987). Aridity is a function of the interplay between rainfall, temperature and evaporation. This index categorizes the different ecozones of the United States so growth pattern and vegetation types can be predicted (Little 1971).

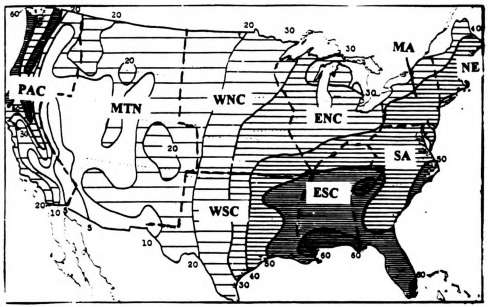
To keep with the format of the study, the United States census **divisions** are used for comparisons. These Divisions are,

***Division 1*- New England (NE)**	Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island
***Division 2*- Mid-Atlantic (MA)**	New York, New Jersey & Pennsylvania.
***Division 3*- East North Central (ENC)**	Michigan, Ohio, Wisconsin, Illinois, Indiana
***Division 4*- West North Central (WNC)**	Missouri, North Dakota, South Dakota, Nebraska & Kansas Minnesota, Iowa

***Division 5*- South Atlantic (SA)**	Delaware, Virginia, West Virginia, Maryland, North Carolina, South Carolina, Georgia, Florida
***Division 6*- East South Central (ESC)**	Kentucky, Tennessee, Mississippi, Alabama
***Division 7*- West South Central (WSC)**	Arkansas, Louisiana, Oklahoma & Texas
***Division 8*- Mountain (MNT)**	Montana, Wyoming, Utah, Idaho, Nevada, Colorado, New Mexico, Arizona
***Division 9*- Pacific (PAC)**	Washington, Oregon, California, Alaska & Hawaii.

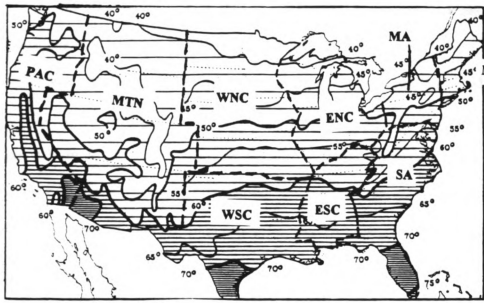
Three rainfall categories were developed. They are 1) areas averaging less than 25 in/ year, 2) areas averaging between 25-45 in/year and 3) areas averaging over 45in/ year. For the states east of the Mississippi River, correlation of the divisions and amount of precipitation was relatively easy, but for the states west of the Mississippi, precipitation levels depend not only on the geographical location of the area, but on elevation of the area, as well. Therefore, certain divisions include two or three different precipitation categories. Figure 4 contains a map of the normal precipitation levels and the normal temperature levels of the United States; the geographical divisions are listed in Table 41 with their corresponding precipitation category and precipitation-effectiveness index rating.

Figures 4a & 4b. Normal Annual Precipitation and Temperature Delineations of the United States, with Thesis Geographic Divisions Superposed.



4a

Normal annual precipitation (in.).



4b

Normal annual temperature (°F).

Maps reproduced from the *Climatic Atlas of the United States* (Visher 1954).

Table 41. Precipitation categories for the geographic divisions of the United States Based on annual Rainfall

Division	Average Precipitation Range	Precipitation Category	Precipitation - Effectiveness Rating
NE	25-45"	2	Humid
MA	25-45"	2	Humid
ENC	25-45"	2	Humid
WNC	<25"	1	Humid
SA	>45"	3	Humid
ESC	>45"	3	Humid/ subhumid
WSC	20-45	2 & 3	Humid/ subhumid
MTN	<20" with exceptions	1 & 2	Semiarid / subhumid
PAC	20-60+"	1, 2 & 3	Super humid overall

The west south central states (Division 7) can be divided into two sections. Louisiana and Arkansas are humid regions receiving over 45" of rain annually. Oklahoma and Texas, on the other hand, are part of the plains states where the annual rainfall is less, ranging 15" on the western front to between 35-40 inches of rainfall, on the eastern front. In the western states, it is hard to separate entire divisions into respective rainfall categories. The Rocky and Cascade Mountains have a dramatic effect on the patterns of rainfall. In general, the mountain states receive less than 20" of rain annually. However, the Rocky Mountain areas of Idaho, Montana, Wyoming and Colorado receive between 25-45 inches annually. The Pacific states are highly affected by the Cascade and Rocky Mountain ranges to the north and the Sierra Nevada and Rocky Mountain ranges to the south. Meteorological dynamics of weather behavior,

dictates that the western face of these mountains average over 60 inches and the eastern face average less than 25 inches. The valleys between the mountain ranges average about 30" per year.

Overall dollars per acre were calculated in two steps. First the dollars spent per acre for each company in a given geographic division was calculated; then the mean for all the company-calculated values was obtained. It is that mean value which is reported in Table 42. The percentage of dollars spent on either herbicide or mechanical methods is provided for comparison.

Table 42. Divisional Breakdown of Dollars Spent Per Acre To Control Vegetation on Transmission Rights-Of-Way

Division	Average Expenditure	Vegetative Acres	Dollars/ Acre	Percent of $ Herbicide	Percent of $ Mechanical
1 - NE	$ 4,150,000	96,923	**61**	64	36
2 - MA	$ 8,667,00	71,332	**137**	55	45
3 - ENC	$ 19,927,247	25,677	**44**	39	61
4 - WNC	$ 7,005,100	56,796	**76**	18	82
5 - SA	$ 14,597,000	220,163	**188**	29	71
6 - ESC	$ 5,720,000	68,928	**236**	15	85
7 - WSC	$ 10,650,000	269,762	**50**	27	73
8 - MTN	$ 551,000	39,630	**35**	37	63
9 - PAC	$ 3,559,000	53,256	**114***	5	95

* $ 3,832.75 is excluded

Companies in the NE and MA states reported that the majority of vegetation control dollars were spent on herbicide methods, whereas, those in the ENC states were the opposite with the majority of dollars being spent on mechanical methods. Companies in the West North Central states averaged $76 dollars per acre for vegetation control. The vast majority (82%) of their vegetation management budget was spent on mechanical control. For companies in the SA and ESC states, the average dollar per acre spent annually were $188 and $236, respectively. The respondents in both divisions reported that the majority of their dollars were being used for mechanical control. All companies located in the West South Central states (Division 7), averaged $50 per acre spent to control vegetation. The companies in Division 7 also reported that the majority of the vegetation control dollars were spent on mechanical methods.

Three fourths of the respondents in the Mountain States (Division 8) failed to report ROW widths when they reported the amount of ROW miles their company maintained. Therefore, the vegetation miles in this division were multiplied by the average ROW width for the western United States (85.29ft), to convert the miles to acres. The three responding companies located within this Division averaged $35 per acre. With only three companies providing information for the MTN states, the confidence level of this amount is low. Further comparisons based on annual precipitation were not performed so as to prevent company identification. California member companies did not respond to the survey. Thus, any comparisons made of Pacific States include only Washington, Oregon, Alaska, and Hawaii. The average dollars spent per acre to control vegetation was $579. This figure is heavily influenced by a company whose average cost

per acre for vegetation control was approximately $3,800. With this number removed from the analysis, the average cost / acre for the remaining companies in the division averaged $114 per acre. The vast majority (95%) of the vegetation control budget in the Pacific States was spent on mechanical methods. Of all 81 respondents, 10 companies did not know or care to divulge their average expenditures.

Substation/Generating Stations:

Substation queries were specifically designed to solicit herbicide information. The majority (60%) of the respondents stated that they were responsible for vegetation control at substation/generating stations, 37% stated they were not and 5 respondents (3%) gave no response to the question (Table 43). Of the 60% who are responsible, 98% use herbicides to control the vegetation (Table 44).

Table 43. Company Responsibility for Vegetation Control at Substation/Generating Stations, by Region

REGION	Responsible	% of Respondents	Not Responsible	% of Respondents	Totals
CANADA	4	100	0	0	4
NORTHEAST	9	73	3	27	12
NORTHCENTRAL	11	50	11	50	22
SOUTH	17	60	11	40	28
WEST	7	54	4	31	13
Totals	**48**		**29**		**79**
% of Total		**60**		**37**	**100**

Table 44. Herbicide Use at Substation / Generating Stations for Companies with Vegetation Control Responsibilities, by Region

Region	Use Herbicides	% of Respondents	Don't use Herbicides	% of Respondents	Totals
Canada	4	100	0	0	4
Northeast	8	88	1	13	9
North Central	11	100	0	0	11
South	17	100	0	0	17
West	7	100	0	0	7
Totals	**47**		**1**		**48**
% of Total		**98**		**2**	**100**

As with the ROW analysis, herbicides used at substation/generating stations are divided into singly applied and herbicide mixtures.

Singly Applied

The seven most common singly applied herbicides used at substations are listed in Table 45. Oust was the most frequently used, representing 21.7% of the herbicides reported, Roundup was second representing 17.4% , Karmex represented 15.2%, and Arsenal and Diuron 80DF tied with 6.5%.

Table 45. Most common Herbicides used at Substation / Generating Stations

Herbicide	Count	% of Total
Oust	10	21.7
Round up	8	17.4
Karmex	7	15.2
Arsenal	3	6.5
Diuron 80DF	3	6.5
Accord	2	4.4
Krovar I	2	4.4
All Others	11	23.9
Totals	**46**	**100**

Herbicides are applied to substations to maintain a bare ground environment. The most common methods used to establish this objective are, soil applied techniques and broadcast techniques. A total of 7,592 acres of Substation / Generating station vegetation were controlled. In terms of acres treated, Dycleer, Roundup, and Karmex topped all other herbicides. Dycleer was only reported by the Canadian companies surveyed. Table 46 is the regional breakdown of each herbicide used at substation/generating stations and the amount of acres to which each was applied.

Table 46. Regional Breakdown (acres) of Herbicides applied to Substation / Generating Stations

Herbicide	Canada	North East	North Central	South	West	Total Acres	% of Total
Accord		30	35			65	0.9
Arsenal	127		675	47		849	11.2
Casoron 4G					70	70	0.9
Diuron 80DF				300	2	302	4
Dycleer	1856					1856	24.4
Escort		30				30	0.4
Garlon 3A				47		47	0.6
Karmex		30	1045	186		1261	16.6
Krovar I			128			128	1.7
Krovar II			ND			ND	
Oust		60	200	486	7	753	9.9
Pramitol			3			3	0.04
Predict			35			35	0.5
Princep					10	10	0.1
Rodeo					10	10	0.1
Round up	1393		369	84	2	1848	24.3
Surflan				25		25	0.3
Weedar 64				300		300	4
Totals	**3376**	**150**	**2490**	**1475**	**101**	**7592**	**100**
% of Total	**45**	**2**	**33**	**19**	**1**		

Mixtures

Karmex/Oust was the most frequently reported herbicide mixture used at substation/generating stations (Table 47). The mixture was applied to 78% (2,050 acres) of the total substation acres. Although Accord/Pendulum 3.3 is listed as an herbicide utilized, the appropriate acreage data was incomplete; thus, it was not used in the acre calculations located in Table 48. Companies in the western United States did not report using mixtures at their substation/ generating stations.

Table 47. Herbicide Mixtures Reported Applied at Substation/ Generating Stations: 1995

Herbicide	Times Reported	% of Total
Accord / Pendulum 3.3	1	16.7
Hyvar / Pendulum 3.3	1	16.7
Karmex / Oust	2	33.3
Karmex / Oust / Roundup	1	16.7
Oust / Diuron	1	16.7
Totals	**6**	**100**

Table 48. Regional Breakdown (acres) of Herbicide Mixtures Used at Substation / Generating Stations

Mixture	North East	North Central	South	Total Acres	% of Total Acres
Accord/Pendulum 3.3		ND		ND	0
Hyvar/Pendulum 3.3			11	11	0.4
Karmex/Oust	450	1600		2050	78.2
Karmex/Oust/Roundup	120			120	4.6
Oust / Diuron			440	440	16.8
Totals	570	1600	451	2621	100

Vegetation Management Program Priorities:

Not unexpectedly, safety and reliability of service was ranked the highest in terms of vegetation management priorities among all respondents, with customer service ranked second in importance. These rankings are a result of multiplying the value of a ranking (1-8) by the frequency of the ranking. The results are listed in Table 49.

Table 49. Vegetation management program Priorities for 1995, by Region, based on a Scale of 1-8

Priority Ranking	All Respondents	Canada	Northeast	North Central	South	West
1	**S&R**	S&R	S&R	S&R	S&R	S&R
2	**Cust Sat**	Cust Sat	Red Liab	L Veg	Cust Sat	Red Liab
3	**L Veg**	Red Liab	L Veg	Cust Sat	L Veg	Cust Sat
4	**Red Liab**	L Veg	Cust Sat	Red Liab	Red Liab	L Veg
5	**Aest**	Min Herb	Aest	Aest	Aest	Aest
6	**Wildlife**	Aest	Min Herb	Min Herb	Wildlife	Wildlife
7	**Min Herb**	Biod	Wildlife	Wildlife	Biod	Min Herb
8	**Biod**	Wildlife	Biod	Biod	Min Herb	Biod

S&R= Safety and Reliability of Service
Cust Sat = Customer Satisfaction
Lveg = Lengthen Vegetation Control Cycle
Red Liab = Reduce Liabilities
Wildlife = Wildlife habitat
Min Herb= Minimize Herbicide Use
Biod= Biodiversity
Aesth = Aesthetics

CHAPTER IV: DISCUSSION

PROJECTION TO THE UNIVERSE

The Edison Electric Institute estimated that there were 672,177 miles of Electric Transmission line of 22 KV and above in service, throughout the United States in 1995 (Statistical Yearbook of Electric Utilities:1995). In order to determine the amount of this total represented by the sample, a number of steps are necessary. First, the 2,600,487 acres listed in Table 2 must be converted to miles, so that both sources are comparable. This is done using the mean ROW widths calculated for each region to attain the linear units. In most cases, the voltage of the utility line directly influences ROW width; in other cases, width is dependent on legalities involved with original ROW agreements and easement rights. Table 50 lists the mean ROW width used to convert acres to miles for each sample region and the corresponding mile values. In addition, the number of miles reported without ROW widths are listed. The sum of the converted miles and these additional miles represents the total miles reported in the study. For example, a company in the Northeast reported being responsible for 1400 miles of transmission ROW, which was then added to the 13,656 converted miles (from acreage) to obtain the 15,056 miles of transmission ROW located in the Northeast region.

Table 50. Mile Conversions of Total Sample Acres Reported for each Region of the United States

REGION	Total Acres	Average Width	Converted Miles	Miles w/o Width	TOTAL MILES
Northeast	211,876	128 ft	13,656	1,400	15,056
North Central	653,196	93.97 ft	57,347	1,300	58,647
South	859,879	90.72 ft	78,197	5,200	83,397
West	161,578	85.29 ft	15,629	14,950	30,579
TOTALS	**1,886,529**		**164,829**	**22,850**	**187,679**

The converted miles above represent 28% of the estimated EEI miles for all utility companies. However, this is not an accurate representation of the study sample. The majority of member companies in the Utility Arborist Association, the sample universe for this study, are investor owned. A separate listing, provided by EEI, estimates that there were 541,022 miles of investor owned transmission electric line of 22 KV and above, in service in 1995 (Appendix 6). An additional adjustment to this figure was needed because fewer than 2% of the transmission ROW reported contained information from lines with less than 40 KV of power. Therefore, in order to increase the accuracy of the sample representation, the amount of investor owned miles with less than 40 KV (152,436 miles) were subtracted from the total, resulting in 388,587 miles. With these corrections, the 187,679 sample miles are compared with the total miles of investor owned transmission line above 40Kv, resulting in a 48% sample representation. Extrapolation of land type characteristics for the 388,587 investor owned miles are calculated using the United States adjusted percentages from Table 2, and are listed in

Table 51. Canadian companies were excluded from the extrapolations because the Edison Electrical Institute only reports United States ROW miles.

Table 51. Estimated Land-type Characteristics of the 338,587 miles of Investor Owned Utility Transmission Line with Voltage Greater than 40KV

REGION	VEG CONTROL	AG / GRAZING	OPEN	OTHER	Total Miles
United States Land-type Percentages	64 %	25%	8%	3%	100%
Northeast	37,304	7,772	1,865	0	46,941
North Central	77,095	43,716	10,259	1,166	132,235
South	124,348	26,230	15,854	10,376	176,808
West	9,948	19,429	3,109	117	32,603
TOTALS	**248,695**	**97,147**	**31,087**	**11,658**	**338,587**

To better comprehend the area of land encompassed by the 248,695 miles of investor owned transmission ROW requiring vegetation control; the miles are converted back to acres. Again, the mean ROW widths for each region are used for the conversions and the resulting acres are listed in Table 52.

Table 52. Investor owned ROW land-types converted to acres from miles in Table 51

REGION	VEG CONTROL	AG / GRAZING	OPEN	OTHER
Northeast	578,777	120,583	28,936	0
North Central	878,135	497,938	116,853	13,281
South	1,367,376	288,435	174,336	114,098
West	102,844	200,861	32,141	1,210
TOTALS	2,927,132	1,107,817	352,266	128,589

With an estimated 2,927,132 acres of investor owned transmission ROW requiring vegetation control, a better understanding of the techniques employed becomes increasingly important.

The remainder of this chapter is composed of three sections, each corresponding to the intents mentioned in the introduction. These sections will try to identify certain trends in the vegetation management strategies. The first section is an analysis of the results listed in Chapter 3. The second section addresses the concern of risk reduction by analyzing the results of the active ingredient per acre calculations and the comparisons of those figures with the maximum recommended application rates obtained from the manufacturer labels. The third part has an ecological focus and will attempt to relate the intensity of vegetation control (cost/acre) with ecological land type based on temperature and precipitation variation within the United States.

ANALYSIS OF RESULTS

Vegetation Management Practices

The field of ROW vegetation control has become inundated with information and products praising the effectiveness and economic savings associated with herbicide application. At the same time, mechanical techniques are noted as causing a proliferation of undesirable target vegetation, which creates higher management costs because of shorter cutting cycles, decreased access, and increased labor intensity

Preliminary analysis of Table 3 would suggest that, with 69% of the respondents reporting herbicide use, the above stated philosophies do indeed influence management behavior. However, closer examination of the results provides insight into the actual condition of United States utility transmission rights-of-way. Recall that according to the 'Stewardship Strategy', a utility company has three objectives in terms of vegetation control:

-To provide safe and reliable service

-To minimize interruptions by trees and other vegetation

-To maintain a harmonious relationship with varied land uses and the environment (VMTF 1996).

The compliance of management practices to these objectives is revealed through three areas of investigation. These areas are: the most common herbicides used by

utilities; the most common methods of herbicide application; and the influence of mechanical methods in the process of vegetation control.

Herbicides Used

Information in this section is taken from the required labels and MSDS forms that accompany all herbicide sales.

Garlon 3A and Garlon 4 were the most common herbicides (in terms of frequency reported and total projected gallons) used for ROW vegetation control. Garlon 3A has a precautionary statement of Danger; its active ingredient, Triclopyr as the triethyl amine salt, has been shown to cause irreversible eye damage in laboratory test situations when undiluted (DowElanco 1994). Garlon 4 has a precautionary statement of Caution; its active ingredient is Triclopyr as a butoxyethyl ester formulation, which is toxic to fish (DowElanco 1995). Although possible, both of these consequences can be avoided if a knowledgeable applicator takes the proper precautions prior to, and during application. Besides the toxicity to fish, the environmental impact of Triclopyr is small since it has high soil affinity and is decomposed quickly by resident microorganisms; both of these characteristics reduce the potential of off-target damage. However, in most cases, these herbicides are diluted with a petroleum-based product. Petroleum based carriers increase the probability of penetration into the target plants. If these carriers are contaminated or are improperly applied, they can cause serious environmental damage by leaching into water sources and sterilizing the surrounding soil.

Accord and the mixture of Accord/Arsenal were the third and fourth most commonly applied herbicides. Both herbicides, separately and as a mixture, are diluted in a water-based solution prior to application. Glyphosate, the active ingredient in Accord, has a high soil affinity, a short half-life, and is listed as slightly toxic to a variety of organisms (Monsanto 1996). The active ingredient in Arsenal, Isopropylamine salt of Imazapyr, also has high soil affinity, a short half-life and is listed as slightly toxic (Cyanamid 1994). Both Glyphosate and Imazapyr have a precautionary statement of Caution and are effective at low rates of application if applied properly. Chemicals in the 'Slightly Toxic' classification have an oral and/or dermal LD_{50} in the range of 500-5000mg/kg (Lu 1991). Krenite S is the fifth ranked chemical in terms of projected gallons. It has a precautionary statement of Caution; its active ingredient, fosamine ammonium, has high soil affinity, a very short half life (less than 1 – 5 days), and is listed as practically non-toxic with an oral LD_{50} greater than 5,000 mg/kg (DuPont 1996). Tordon 101M was the next most applied herbicide. It is a restricted use pesticide since one of its active ingredients, Picloram, has rapid soil motility. This motility can result in serious off-target damage to adjacent vegetation, if poorly applied. Tordon 101M also contains the herbicide 2,4-D, which broadens the spectrum of species controlled. The herbicide carries a precautionary statement of Warning; the mixture of active ingredients is considered 'slightly toxic' with an oral LD_{50} in rats at 2598 mg/kg (DowElanco 1994).

The risk of these chemicals to humans is relatively low. Each herbicide is required to undergo US Environmental Protection Agency analysis and approval in order to become registered for public use. The low toxicity of these herbicides results from the mode of action of the active ingredients. The majority of herbicides mentioned inhibit

enzymes found only in plants; therefore, organisms without these enzymes (i.e. animals) are not adversely affected. An example is the herbicide Arsenal. Imazapyr inhibits the enzyme AHAS (acetohydroxyacid synthase). The enzyme is used for amino acid synthesis without which the plant will die (Cyanamid 1994). Unless they are improperly applied and/or proper precautions are not taken, these herbicide formulations pose little threat to workers and those living adjacent to the ROW.

The environmental impacts of these chemicals are also small if proper application procedures are followed. Effects on the surrounding environment play just as important a role in herbicide classification as human risk from exposure. An example is Tordon herbicides, which are categorized as restricted because of their high soil motility and potential off-target effects, not because of their toxicity to humans. The biggest threat of environmental damage is from the oil-based carriers of some herbicides and not the chemicals themselves. The widespread use of water based herbicides such as, Accord, Arsenal, Tordon 101M and Krenite, suggests that a shift from oil based carriers is occurring. Water based chemicals allow selective control of target species, while having little effect on the surrounding soil, which in turn, helps establish a low growing, tree invasion resistant community.

Acres of Treated Right-of-way

Although toxicity concerns should be paramount when discussing herbicide use, product information alone does not provide adequate insight into the current vegetation management trends. To better reflect these trends, an additional investigation into the

amount of acres treated either herbicidally or mechanically was completed. Recall that 1,790,682 acres of transmission ROW required vegetation control. However, the results show that only 566,117 (32%) acres were represented by a specific treatment. Herbicide techniques accounted for 10% of the total and mechanical control for 22%. The remaining 68% were not accounted for even though vegetation control was required.

There are two possible explanations for this discrepancy. The first is that the survey results misrepresent the sample population. This is feasible since reporting herbicide and/or mechanical techniques was difficult for a number of companies. This became apparent when a number of respondents supplied incomplete information regarding the amounts of ROW treated.

A second explanation may relate to the concept of a vegetation control cycle. Although a company is responsible for vegetation control on all the reported area, only a percentage can actually be treated per year. Most companies incorporate a rotation cycle, usually from 3-5 years, at the end of which the entire ROW area is treated. Since this survey only requested 1995 information, it is likely that only a percentage of the total acres reported were treated. Thus, the entire ROW would not be represented. Unfortunately, questions regarding rotation cycles were not included in the survey. Therefore, an average management cycle cannot be calculated. However, with almost 33% of the total ROW requiring vegetation control represented, it could be assumed that a 3-year rotation cycle is the norm. In addition to the acres given, an additional 17,110 miles were reported treated without a ROW width. In all actuality, it is most likely a combination of both scenarios that caused the discrepancy. With this in mind, the following observations are made.

Methods used.

In general, there are two types of herbicide application techniques, selective and non-selective (Table 53). Each of the methods used in the survey fall into one or both types. Selective techniques, such as Basal and Low Volume Foliar methods, target only the undesirable vegetation, leaving behind herbaceous and low growing woody plants to establish shrub dominated communities resistant to tree seedling invasion (Niering 1974) (Bramble 1991). Cut surface techniques can be either selective or non-selective depending on the situation, since a mechanical cutting of brush is required. Non-selective techniques, such as High Volume Foliar and Aerial methods, are used to reestablish control of the right-of-way vegetation. These broad sweeping techniques, used in areas containing over 2,000 stems/acre, generally kill all vegetation within a given ROW area creating a 'clean slate' where desirable vegetation can become established. In most cases, a period of intensive maintenance following non-selective techniques is required in order to achieve the desired results. If the maintenance is not performed, the ROW will revert back to its original problem state. Except in the case of aerial application, most non-selective techniques require the use of heavy equipment. This, coupled with eradication of most vegetation, actually produces soil conditions that can benefit the establishment of the undesirable vegetation. However, these effects are not exclusive to non-selective herbicide techniques; they also exist following a mechanical clearing of brush (Luken 1991).

Selective techniques can only be used effectively on areas where stem densities are low and tree size is small (DowElanco 1994)(DuPont 1996). These are typically

areas of the transmission ROW that are in transition to, or exist as, a stable low growing plant community. This situation exists as a result of previous maintenance or the climatic conditions of the area.

Notice in Table 53, that at least 53% of herbicide methods reported were selective. Since it can be assumed that most companies would not employ techniques that are ineffective, a good proportion of the transmission ROW acres treated contain utility line compatible vegetation. However, the presence of non-selective techniques also suggests that a substantial amount of acres do not contain stable, low growing communities and, in fact, require some sort of reclamation technique in order for control of the vegetation to be reestablished. This is also evident in the following section on mechanical control. Despite the disadvantages of non-selective treatments, high volume foliar methods were the most common, after basal treatments. In fact, if the one case of 36,523 acres treated with a basal method is removed from the analysis; the most common application method would be high volume foliar.

Table 53. Herbicide Application Methods, and Their Selectivity, ranked by Total Acres Treated

METHOD	TYPE	ACRES	% OF TOTAL
Basal	Selective	50,363	28
High Volume Foliar	Non-Selective	42,128	24
Low Volume Foliar with a Backpack or Hand Sprayer	Selective	40,231	23
Cut Surface	Non-selective/ Selective	34,025	19
Aerial	Non-selective	7,357	4
Low Volume Foliar Broadcast	Selective	3,974	2
Totals		178,078	100

Low Volume Foliar applications are relatively new techniques. The most common is Low Volume Foliar with a Backpack or Hand Sprayer. The major advantage of this method is the increased selectivity and accessibility. However, to ensure correct target plant identification and safe and effective herbicide application, both time and money must be invested.

Low Volume Broadcast techniques are less common. The equipment involved can pose problems in terms of cost, inaccessibility, and site impacts that can expose mineral soil which favors seed germination and establishment of some tree species (Smith 1986).

Aerial techniques are less likely to be used because of the threat of damage to adjacent areas due to drift.

Cut surface methods are unique because they require a combination of mechanical and herbicidal techniques. In terms of selectivity, the variable is the type of mechanical control used. Mowing is non-selective, whereas, cutting can be very selective. The most popular method of cut surface application is cut stump or cut stubble. These methods require a clearing of vegetation before the herbicides are applied to the cut stems, which complete the kill.

The continued use of non-selective methods can be viewed from two different perspectives. The first is from the perspective of cost. Non-selective techniques initially cost less than selective techniques. While the short-term total vegetation control solution is inexpensive, the high intensity maintenance required to establish the desired vegetation dynamics is expensive (DowElanco 1994). Therefore, long term management should be the goal; not short-term savings. The repeated use of non-selective methods creates a situation where vegetation control is only possible if the same techniques are repeated. For example, transmission ROW treated periodically with a High Volume foliar technique will continually produce undesirable plants, since the efforts to establish compatible vegetation cover resistant to tree seedling invasion are not attempted.

The second point of view is from the perspective of nostalgia. High Volume foliar techniques were the industry standard for a number of years. The shift in methods takes time since some companies may be reluctant to give up old methods that are effective.

The issue of costs cannot be ignored when herbicides are used. In a heavily wooded area, initial investments for the conversion of ROW will be high regardless of the methods used (Abrahamson et.al. 1991). However, the need for intensive, selective techniques decrease as the desired communities are established; thus, costs decrease. Non-selective techniques are still popular and are irreplaceable for certain situations. The presence of selective techniques such as basal and low volume foliar with backpack or hand sprayer would suggest that serious efforts are being made to establish utility compatible vegetation communities that have the probability of cost savings in the future.

Influence of Mechanical Methods

As mentioned earlier, mechanical cutting of hardwood stumps, either with equipment or by hand, can perpetuate the undesirable species in the ROW via the process of stump sprouting in deciduous hardwoods. However, 89% of the companies that responded, stated there were areas of their ROW where mechanical methods were used exclusively. In fact, the amount of acres treated mechanically was 2.3 times greater than the total acres treated chemically. This data would suggest that despite the current pro herbicide philosophy, utility companies are continuing to rely on mechanical techniques to maintain vegetation. A number of reasons exist as to why the mechanical methods are preferred.

The most common reason given regarding mechanical, instead of chemical, control was public perception. This refers not only to the individuals who reside adjacent to the rights-of-way but the general public as well. Herbicides carry such a powerful

stigma that some companies are unwilling to take on the challenges of educating their customers to the benefits. This perception has influenced every facet of herbicide application procedure, from customer notification, to government regulations regarding permit acquisitions. These added procedures and specifications also increase the cost of herbicide programs.

The next reason for mechanical methods being preferred over chemical control was the characteristics of the brush being treated. Most herbicide techniques are relatively ineffective on extremely dense or tall brush. The non-selective nature of mechanical treatment eliminates all brush, but creates an ideal stump-sprouting hardwood environment that dictates more frequent cutting. In most cases the very dense vegetation, treatable only by mechanical techniques, is the result of the continual cutting back of the ROW area.

The higher cost of herbicide control compared with mechanical was another reason given. This reason seems to focus on the short term costs of the treatment, while the benefits and long term control of selective herbicide applications are not considered. As mentioned earlier, the initial investments and treatments can be expensive. (Abrahamson et.al. 1991). Capital is needed to purchase new equipment and facilitate worker hiring and training. Most companies that do use herbicides contract out the spraying to specialized firms to try to save capital. The negative public perception of herbicides has increased costs by creating an environment of government regulations that dictate funds be allocated for legal assistance. Also, the creation of support crews is necessary to inspect and monitor the spray program, inform customers and obtain consent to spray from individuals adjacent to the ROW being treated. If the perspective is long-

term, then the benefits of a stable shrub community resistant to tree invasion, outweigh the costs. Additionally, as the vegetative communities become more resistant, less intense maintenance is required, which results in less costs and higher profits in the future.

Another reason given for mechanical control preference was that herbicide use was forbidden on certain lands. These restrictions are for protected or sensitive sites and pertain mainly to the Western United States where the majority of utility transmission rights-of-way are located on either Bureau of Land Management or USDA Forest Service land. These agencies prohibit any pesticide or herbicide use; therefore, companies have no choice but to mechanically manage the areas.

None of the above reasons are mutually exclusive. In most cases, they influence or create each other. The biggest problem facing herbicide use is the current public perception. A shift in attitudes, based on legitimate research, can create a situation where minimal amounts of control, either mechanical or herbicidal, are needed.

Active Ingredient per Acre Comparisons

The analysis of the previous section indicates that the most common herbicides used are relatively non-toxic to humans and are environmentally safe, assuming they are applied at the recommended rates. Ratio comparisons between actual and maximum recommended active ingredient per acre (Table 35) were contrary to what was expected. The original concern was that the calculations would reveal an over-application of herbicides on transmission ROWs. Instead, these herbicides were applied below the maximum recommended rate. In some cases, these ratios were two orders of magnitude less. Only Garlon 3A, applied using a low volume foliar technique with a backpack or hand sprayer exceeded the recommended maximum active ingredient per acre. Before progressing any further, it should be remembered that a number of respondents failed to provide the information necessary to completely represent all reported herbicides applied using a specific method. Therefore, the ratios should be viewed as possible trends in application, and not absolute for all areas.

Depending on the effectiveness of the herbicide control program, these low ratios can be assessed in one of two ways. If the programs are effective, then the increased acceptance of herbicide application as a viable vegetation management technique is possible. Examples of effective programs with low application rates dispel the need for herbicide reduction since the risk factors are low. In turn, a small potential risk will reduce the negative perception of herbicides, currently held by the public. The fact that some herbicides are applied below the recommended maximum rates, with desired results, can only improve upon the current negative image.

If the herbicide programs are ineffective, then the perceived cost of herbicide control is altered. Recall that the higher cost of herbicide programs was a common reason some utility companies preferred mechanical methods. Low application rates may cause decline symptoms on the targets without administering a lethal dose. Poor control of target species requires reapplication, which results in additional cost. Some utility companies try to pass these additional costs on to the contractor by implementing a 100% control policy. In most cases, these policies require a visual inspection of areas for missed targets. Those individual plants that display symptoms of decline are not retreated. Future problems arise when these targets recover from the application and reestablish themselves as outage threats. The contractors incur all costs if a ROW area needs to be treated again. These added costs are reflected in the next bid to treat new areas. Thus, ineffective herbicide programs result in target retreatment either after the initial spraying or after a number of years, creating a double payment for the same target. These higher costs, due to herbicide program inefficiency, could explain the dissatisfaction of some members of the industry regarding herbicide vegetation control.

A possible explanation for these low ratios is that the information given regarding herbicide application was purposely unrepresentative. The motive for this type of action is most likely the possibility of company policy being revealed publicly. As the industry becomes more competitive, this could be perceived as giving other companies an edge. Although the possibility of false information is mentioned here, the hope is that professional integrity was used during completion of the survey.

Climatic Comparisons between United States Geographic Divisions

Overall, the budgets allotted for vegetation management were primarily spent on mechanical control; only two, of the nine geographic divisions, included companies where the majority of vegetation control dollars was spent on herbicide techniques. These divisions are located in the Northeast United States. This budget allotment seems contrary to the notion mentioned earlier, of mechanical methods being preferred because they are less costly than herbicides. However, these numbers should be expected, since total acres treated mechanically were in excess of twice the amount of acres treated chemically.

Comparison of the dollars spent per acre for certain geographic divisions based on precipitation and temperature will provide insight into the influence that climate has on vegetation management intensity. The first hypothesis investigates differences in dollars spent per acre for divisions within the same temperature range but different precipitation category. The first comparison is between the East North Central states (Division 3) which average 25-35" of rainfall annually and the West North Central states (Division 4) which average 15-25" of rainfall per year. Both divisions have a precipitation – effectiveness index rating of humid. The companies in Division 3 spend an average $44 per acre with 61% of the budget spent on mechanical methods. In contrast, companies in Division 4 spend an average $76 per acre with 83% of the budget being spent on mechanical control. A similar comparison can be made between the East South Central states (Division 6) and the West South Central states (Division 7). Division 6 is a humid area averaging over 45" of precipitation annually and, Division 7 is a humid – subhumid area averaging 25-45" annually in Louisiana and Arkansas, to less than 25" of

precipitation annually at the western front of Texas and Oklahoma. Analysis of the companies in Division 6 & 7 reveal the opposite scenario than the former comparison. Division 7 spends on average $50 per acre for vegetation control, with 73% of their budget allotted to mechanical control, while Division 6 spends $236 per acre, with 85% of the vegetation control budget also allotted to mechanical control (Table 37). Identifying possible trends of control intensity (dollars/acre) based on precipitation differences proved difficult; since the above investigations have revealed both an increase and a decrease in dollars spent per acre as the mean rainfall levels decrease.

The second hypothesis investigates differences in dollars spent per acre for areas within the same precipitation category but different temperature ranges. The West North Central states (Division 4) and The West South Central states (Division 7) receive approximately the same average annual precipitation ranging from 15-30" annually. Division 7 has a normal annual temperature 10-15 °F warmer than Division 4. Division 4 spends on average $76 per acre, while Division 7 spends $50 per acre. A comparison between the mid-Atlantic States (Division 2) and the South Atlantic States (Division 5) is equally insightful. The majority of both divisions are humid areas averaging 40-50" of precipitation annually. The normal annual temperature in Division 5 is 25-30 °F warmer than Division 2. The companies in the Mid-Atlantic States reported spending on average 137 dollars per acre for vegetation control, whereas the South Atlantic states spent 188 dollars per acre on average. As with the precipitation comparisons above, identification of possible trends in control intensity (dollars/acre) based on temperature differences proved difficult; since the investigations have shown both an increase and decrease in dollars spent per acre as the temperature increased.

However, an overall examination of all the divisions reveals that those divisions receiving 40" of rainfall or more a year, Divisions 2,5 & 6, spend more on vegetation control per acre than the other divisions analyzed. The higher amounts of rainfall promote the establishment of forest vegetation that, by nature, requires a more intensive management scheme than areas that receive moderate of low levels of rain. The exceptions are the Northeast division, which averages $64 per acre and the West South Central states (Division 7), which average $50 per acre. Whether or not the smaller cost in the Northeast is due to herbicide use can only be speculated. The difference in Division 7 is most likely due to the variation in precipitation levels from east to west. However, to accurately decipher the cause, an in depth economic analysis of costs is needed, which is beyond the scope of this study.

Another point of interest is the original average dollars spent per acre in the Pacific states (Division 9). An initial average of $579 per acre, although large, is not surprising. This division includes terrain that is inaccessible and requires large amounts of time or expensive equipment to maintain.

It should be remembered that these trends are not statistically significant and are based on generalizations of figures calculated from a sample of the entire Utility Industry population in the United States. More respondents and more precise information are needed before a clear understanding of the effects that climate variation has on vegetation control can be achieved. In reality, the variability in climate and terrain create vegetative control situations unique to each division. Grouping of the divisions by climate is not representative of the macro and microenvironments each utility company must face, in order to maintain a service it is required to provide.

Substation/Generating Stations

The nature of herbicide vegetation control for a substation is completely different than a ROW. The desired effect is a bare-ground situation, meaning that no vegetation is allowed to grow inside and adjacent to the area. The high voltage located in these areas dictates that they be restricted. Safety and accessibility for employees are the driving forces behind this strategy. The presence of any animate or inanimate material within the areas can create an electrical hazard. The majority of the herbicides used are pre-emergent herbicides registered for controlling broad leaf weeds. Woody plant control is not as common because most tress never become established.

The most common method of post-emergent and pre-emergent herbicide application is the soil-applied technique. Pre-emergent herbicides are applied to the soil and prevent the germination of weed seeds. Post-emergent herbicides are applied to the ground surrounding the target plants, usually at higher concentrations than on ROWs. The herbicides are translocated through the roots and affect the tree systemically. Soil motility and product persistence should be the major considerations when selecting herbicides for substations.

The herbicide Oust has a precautionary statement of Caution; its active ingredient, Sulfometuron methyl, has a half-life from 15-30 days depending on the pH, moisture and temperature of the soil. It has an oral LD_{50} level of greater than 5,000 mg/kg putting it in the 'Almost Nontoxic' class (DuPont 1996). The herbicide Roundup also has a precautionary statement of Caution; its active ingredient, Glyphosate as the isopropylamine salt, has a high soil affinity, a short half-life, and is listed as slightly toxic

to a variety of organisms. However, a surfactant included in the Roundup formulation (modified tallow amine) is more toxic to fish than many common surfactants (EXTONET 1994). The herbicide Karmex was applied to the most substation acres and has a precautionary statement of Warning; its active ingredient, Diuron, has an oral LD_{50} level of 1017 mg/kg putting it in the 'Moderately toxic' class. The soil affinity of Karmex increases in soils with a high composition of clay and organic matter (DuPont 1996).

Negative public opinion towards substation herbicide programs is less than Rights-of-way for a number of reasons. The risk factors of the most popular herbicides used are low, and since most of them are pre-emergent, damages to off target plants are diminished. The perimeters of substation/generating stations are landscaped with utility compatible and showy vegetation to focus attention away from the bare ground characteristics. The most important reason is that a high potential for electric shock discourages frequent visits by humans; therefore, less attention is drawn to the area.

CONCLUSIONS

A survey to seek information about the 1995 transmission ROW vegetation control programs, was sent to 220 Utility Arborist Association companies. The survey contained questions regarding right-of-way characteristics, control methods used, total dollars spent on vegetation management, priorities of the vegetation management program, and substation / generating station vegetation management data. The project focus was three fold. As a contrast to the majority of research in this area, its primary purpose was to describe the current vegetation control techniques used by utility companies. Its second objective was to quantify the active ingredient per acre of herbicides used to assess possible secondary exposure (post dilution) risks incurred by applicators and the environment. The third purpose of this study was to compare the climatic regions of the United States to investigate if management intensity (in terms of dollars spent per acre) varied with either precipitation or temperature differences. Data from the survey, represented 37% of the sample universe. However, the ROW area reported, represented over 48% of all the investor owned ROW over 40Kv in service, throughout the United States. Over all, an extrapolated 2,927,132 acres of ROW require some form of vegetation control annually.

Vegetation management generally falls into two categories, mechanical and chemical control. Acres treated mechanically out-numbered those treated chemically by a margin of **2.7:1**. A total of 481,768 acres were treated mechanically, with an additional 16,773 miles of ROW mechanically side trimmed. An overwhelming majority (82%) of these acres was mowed. A total of 178,078 acres were treated with herbicides.

Mechanical techniques (especially mowing) have been shown to cause a proliferation of undesirable vegetation via the phenomenon of stump sprouting. Increased stem density and decreased accessibility are the result, both of which are characteristics not conducive to herbicidal techniques. Therefore, continual mowing of areas creates a situation where only mechanical techniques can be employed.

The majority of respondents stating mechanical control reported negative public perception as the most common reason for the preference. This perception can be remedied through a two step initiative. The first step is the creation of educational programs targeted at explaining utility company policies and the benefits of herbicide techniques. The Vegetation Management Task Force and The Edison Electric Institute, with the publication of the Environmental Stewardship Strategy for Electric Utility Rights-of-Way, have initiated this step. Utility companies can use the information provided to develop literature and programs that can ease any anxiety that residents have regarding herbicide application.

The second step involves increasing the public's confidence in the safety and effectiveness of herbicide programs. That concern may be partially resolved by the results of this study. However, the study results are only as strong as the information received. The most startling fact regarding this project was the lack of knowledge some respondents had in regards to their respective transmission ROW vegetation control programs. This lack of knowledge (in the form of incomplete answers), was evident in all five categories of questions. Despite some missing information, a number of observations, concerning herbicide use, were obtained from the data.

The two most common herbicides in use, Garlon 3A and Garlon 4 pose little

threat to human or environmental well being if proper precautions are taken and application is done according to the label. The biggest threat comes from the petroleum-based carriers used to dilute these herbicides, which can cause substantial environmental damage. Other herbicides reported such as Accord, Arsenal, Escort, and Krenite are water-soluble and thus, are not as big an environmental threat. The majority of herbicides used today target specific plant enzymes required for proper metabolism. Therefore, organisms not having these enzymes (i.e. animals) are unaffected by these chemicals. All herbicides used in the United States must undergo Environmental Protection Agency scrutiny prior to their approval for use. In most cases, adverse effects from these herbicides would only occur with an extremely large exposure amount (2,000-2,500 mg/kg).

To determine whether the reported application rates posed any risks to applicants and the public at large, comparisons of active ingredient per acre applied and the maximum recommended application rates were performed. Contrary to what was expected, the comparisons have resulted in extremely low levels of active ingredient being applied. The preliminary deductions of these comparisons is that there is no need to reduce the active ingredient applied per acre, since there is currently, no threat of over exposure. However, two points of interest should be considered before any conclusions are made. First, the effectiveness of these programs is not known. Effective programs would only solidify the safety and reliability of herbicide programs, whereas, ineffective programs would reveal over inflated costs and further deflate the public's confidence in herbicide techniques. The second point of interest is that the numbers used to create these comparisons are averages of information provided by the respondents. some of

which was incomplete. Therefore, they are meant to provide a foundation from which future research can be built.

A recurring theme throughout this thesis is the concept of cost. As investor owned companies, most utilities have an obligation to create a profit. Unfortunately, to meet this goal, some vegetation control programs are based solely on the cheapest methods available. These methods involve either mechanical or chemical non-selective techniques that clear all vegetation from the rights-of-way. Although these methods may provide profits, they do not provide adequate control because incompatible vegetation becomes reestablished. The prominence of non-selective techniques in the results supports this argument. However, evidence of selective control programs does exist. Selective herbicide techniques allow companies to establish low growing, tree seedling-resistant vegetation that requires less frequent maintenance, thereby saving money in the long run.

No specific patterns emerged from comparisons between precipitation and temperature delineation and dollars spent per acre. However, those companies in areas with a mean rainfall in excess of 40 inches per year do show evidence of having spent more dollars per acre than the other divisions included. More respondents and more precise information are needed before a clear understanding of the effects that climate variation has on vegetation control can be achieved. In reality, the variability in climate and terrain create vegetative control situations unique to each division.

Research Recommendations:

The main purpose of this thesis was to provide a descriptive analysis of the current practices and possible philosophies of the 1995 electric utility vegetation control programs along transmission rights-of-way. This study has provided a foundation for additional research to be built upon. During the analysis, it became apparent that certain areas of focus should be pursued further.

The first area is a follow up survey, similar to the first, but one that can obtain more accurate information. The biggest problem of the previous study was incomplete information. The next study will need to be easier in its completion and more accessible to a larger number of respondents. This has already been undertaken by the Michigan State University Forestry Department with the help of the Hyland Johns' Grant provided by the International Society of Arboriculture. The survey tool is being transformed from a paper to an electronic document. A web-site is being constructed to allow a respondent to send all relevant information to a database located at Michigan State University. In addition to the increased ease in completion and accessibility to respondents, the site will facilitate faster analysis of the data. The ultimate goal of this web-site is to quantify vegetation management techniques for all Rights-of-Way, Utility, Railroad, Pipeline, and Highway, in the United States and Canada.

Unfortunately, two areas of investigation were not included in the current study, both of which would have helped in the analysis of the data. These areas are the vegetation control cycles employed by utilities and the relative effectiveness of herbicide

programs. Each of these areas has been explored on a regional basis but not on a national level. The new survey form can solicit information regarding both of these concerns. The effectiveness of herbicide programs becomes even more important with the knowledge that the possibility of under application exists. Also, investigation into whether the active ingredient in Garlon 3A and Garlon 4, Triclopyr, or their petroleum-based carrier has more of an impact on vegetation, would be useful.

A third area of investigation could focus on the adjuvants associated with the herbicide application. A number of emulsifying, wetting, sticking, and drift control agents are added to formulations to improve some aspect of the herbicide's performance. They can be added to the product either at the time of formulation by the producer or mixed with the herbicide by the applicator prior to application. As with the case of Roundup, a surfactant proved to be more toxic to fish than Glyphosate, the active ingredient. Quantification of adjuvant use will provide an even clearer picture of what is being applied to the nation's rights-of-way to control vegetation.

The most important concern for future research is the lack of knowledge and/or unwillingness to share information, on the part of the respondents. These actions only complicate matters because they increase the distrust of utilities by the public. Initiatives like the Stewardship Strategy, focused at educating the public and reducing the negative image of herbicide techniques, will create sustainable, stable, low growth communities, which will reduce power outages and in turn, lower the costs to both electric producers and consumers.

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APPENDIX

HERBICIDE USE ON TRANSMISSION LINE RIGHTS-OF-WAY

1. When reporting about transmission lines is it easier to report in ACRES or MILES? [circle one]

USE THE CIRCLED UNIT (CHOSEN IN #1) THROUGHOUT THE SURVEY.

2. How many acres or line/pole miles of transmission line ROW is your company responsible for?

_____acres _____ line/pole miles

3. If line/pole miles is given in question #2, please record the kV of the transmission line, the width corresponding to that voltage and the % of the total ROW miles.

kV	Width	% Miles

4. What % of the ROW given in question #2 requires vegetation control? _____

5. Do you use herbicide to control vegetation on transmission line ROW? YES NO
[If YES, complete the "Transmission Line Herbicide Control Report Form"]
[If NO, continue with question #6]

6. Are there areas of your transmission line ROW where only mechanical means of control are used?
[If YES, complete the "Transmission Line Mechanical Control Report Form"]
[If NO, continue with question #7] YES NO

7. Are you responsible for vegetation control at substations and/or generating stations? YES NO
[If YES, continue with question #8]
[If NO, continue with to question #9]

8. Do you use herbicide to control vegetation at substations and/or generating stations? **YES** **NO**
[If YES, complete the table below]

HERBICIDE	RATE	ACRES
A	B	C

DIRECTIONS:
Column A - Name herbicide used.
Column B - Give the rate (i.e. gal / acre) at which herbicide in [A] was applied.
Column C - Give the total amount of acres that the herbicide was applied.

9. Are there any methods used that aren't mentioned in questions #5 and #6? **YES** **NO**
[If YES, please explain]

10. Of the above control methods which one has increased the most over the last 5 years?

11. What is your average expenditures for vegetation control over the last 5 years?

Total _____

% Herbicide _____

% Mechanical _____

12. What is the goal of your vegetation management program?

13. Do you feel your program is successful/efficient? Why or why not?

TRANSMISSION LINE HERBICIDE REPORT FORM

NAME:

TITLE:

COMPANY:

ADDRESS:

PHONE:

FAX:

	NAME	ACRES OR MILES	AMOUNT	METHOD APPLIED (100% TOTAL)						
				BASAL TREATMENT	CUT STUMP TREATMENT	HIGH VOLUME FOLIAR WITH HAND GUN	LOW VOLUME FOLIAR WITH BACK PACK OR HAND SPRAYER	AERIAL SPRAYING (INCLUDING HERBICIDE SIDE TRIM)	LOW VOLUME FOLIAR BROADCAST, FIXED BOOM, RADIARC, ETC.	OTHER (SPECIFY)
	A	B	C	D						
1	ACCORD									
2	ARSENAL									
3	ESCORT									
4	GARLON 3A									
5	KRENITE									
6	TORDON 101M									
7	TORDON 101R									
8	Other									
9	Other									
10	Other									

Partial List of Other Herbicides

Access
Banvel
Karmex
Krovar
Pathway
Pramitol
Rodeo
Roundup
Spike
Transline
Velpar
Weedone
2, 4-D
Accord & Arsenal
Arsenal & Escort
Tordon & Garlon

DIRECTIONS:

Column A - Identify the herbicide(s) used in 1995 in column A. Specify which "other" used in lines 7-10, along with formulation.

Column B - Fill in the # acres, or pole/line miles, for each chemical that was applied in 1995 in column B.

Column C - Record how much of each chemical was used in 1995 in column C (specify whether gallons or pounds) and formulation if there can be any doubt.

Column D - List method(s) you used to apply each herbicide under transmission lines in column D by recording the percentage of each method used. The total for each chemical should equal 100%.

MSUFOR396

TRANSMISSION LINE MECHANICAL BRUSH CONTROL REPORT FORM

	METHOD	ACRES OR MILES CONTROLLED
	A	B
1	MECHANICAL (i.e. HYDRO-AXE)	acres
2	HAND EQUIPMENT (CLEARING)	acres
3	SIDE TRIM WITH HELICOPTER	miles
4	SIDE TRIM (i.e. BUCKET TRUCK)	miles
5	SIDE TRIM MANUAL	miles
6	other	
7	other	
8	other	
9	other	

DIRECTIONS:
Column A - Identify the mechanical means you used in 1995 in column A.
Specify which "other" used in lines 6-9.
Column B - List the amount of transmission line ROW on which these methods were used.

Please indicate the two or three most important reasons why mechanical methods are used for brush control, rather than chemical.

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