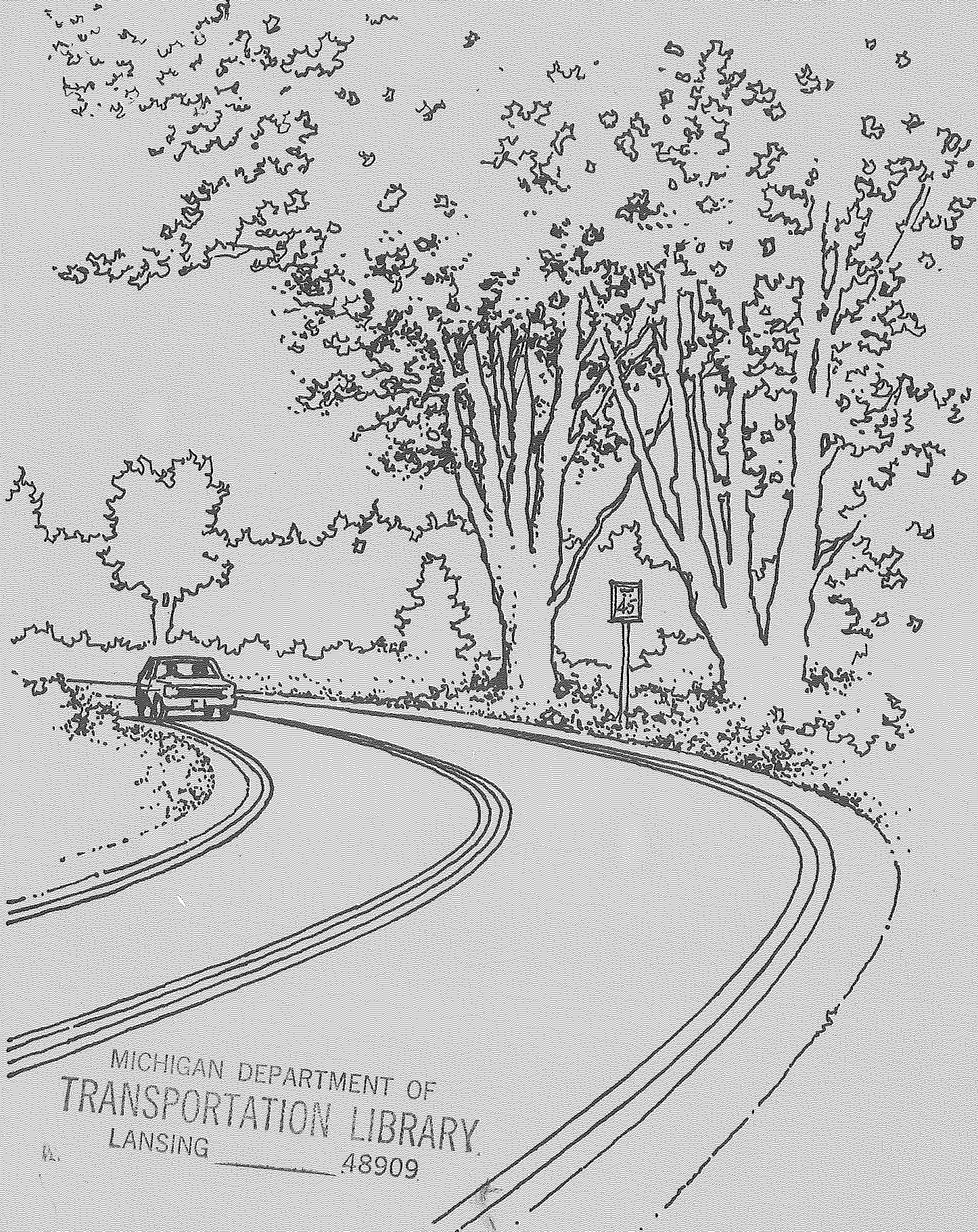

ASSESSMENT OF:

Guidelines For Removing Hazardous Trees From Highway Rights-of-Way

ASSESSMENT OF GUIDELINES FOR REMOVING HAZARDOUS TREES FROM HIGHWAY RIGHTS-OF-WAY

FOR

MICHIGAN DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

NOVEMBER, 1979

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INTRODUCTION

This assessment provides an overview of the roadside environment in Michigan and the probable environmental impacts associated with a hazardous tree removal program. Both short- and long-term, as well as statewide and regional, impacts are discussed, along with procedures that may be applied to mitigate these effects. Statewide and regional impacts of maintenance programs are also discussed. A number of alternatives to tree removal, offering on-roadway and off-roadway protection, are presented, along with a procedure for determining the appropriate site-specific treatment. References are supplied for further reading. Five appendices supplement the assessment and contain a variety of technical information. Michigan vegetation and wildlife are described; methodologies are presented and discussed for determining tree density and computing the effects of tree removal on tree/vehicle accident rates. An analysis of hazard profiles, factors common to many run-off-road accidents, is also presented.

The assessment is based on the information and step-by-step procedures outlined in <u>Guidelines for Removing Hazardous Trees from Highway Rights-of-Way: A Management Manual.</u> The manual was prepared for use by county road engineers in implementing a roadside tree risk reduction program.

The assessment is designed as a basis for preparing an environmental impact statement or negative declaration of the impacts associated with a hazardous tree removal program in Michigan.

THE ROADSIDE ENVIRONMENT IN MICHIGAN

AN HISTORICAL OVERVIEW OF NATIONAL ROADSIDE DEVELOPMENT

Interest in roadside development began in the 1890's. In 1891, a publication by Louis C. Haupt identified the elements of and the need for improving road environments (Highway Research Board, 1972). Haupt's basic premise was that good roadside development is a move toward better roads. The Parkway Concept, a standard of environmental protection, beauty, and excellence that could be applied to future highway designs, was developed in New York City in 1907. It was not widely used beyond the New York metropolitan area because of its high cost (U.S. Department of Highways, 1976). Little additional attention was given to roadside development until the early 1930's when the American Association of State Highway Officials (AASHO) and the Highway Research Board (HRB) organized their first roadside committees.

The highway systems in the United States were originally developed to enable quick movement from one place to another. Until recently, detrimental social and environmental impacts as a result of highway construction were either ignored or treated only when they became obvious or hazardous. When roadside improvements were performed they were done years after the highway was completed. An awareness of the social and environmental aspects of road building developed gradually. Separate Federal and State activities facilitated the development of tools to correct problematic situations.

Substantive financial assistance began in 1933; the National Industrial Recovery Act grants included funds for landscaping roads. The Hayden-Cartwright Act of 1934 authorized $200 million in emergency road funds and required states to use not less than 1 percent of their appropriations for improvement of roadsides. With a Federal-State partnership, roadside development tools began to include highway beautification, environmental protection, joint use of highway rights-of-way, and many other programs. Roadside development is now a recognized part of highway design and construction.

Vegetation management is a major part of roadside development. For the first 50 years, however, most of the work was directed toward erosion control. Recently, however, the Federal Highway Administration and most states have recognized other values associated with vegetation. Attention is now being directed toward the selection of proper vegetation to encourage the establishment of certain species of wildlife, and vegetation has now been recognized for its beneficial effects upon maintaining a balance between the highway and the surrounding natural environment.

In response to the National Environmental Policy Act of 1969, research has been directed toward a wide range of environmental parameters: air, noise, and water quality; social and economic effects; roadside rest areas; sewage treatment; vegetation management; aesthetics; water runoff; de-icing chemicals; spills of hazardous materials; erosion control; and wildlife. The existence of these programs cannot guarantee successful solutions to all environmental problems. They do help to assure compatibility, however, between the highway system and the total environment.

THE NATURAL ENVIRONMENT

Within 40 feet of Michigan's roadways it is estimated there are over 19.2 million trees (see Table 1 for a breakdown of the number of roadside trees by road type). Michigan's roads traverse a wide variety of vegetation cover types. These vegetational types and associated soils, drainage, and wildlife are described briefly in Appendix A. Information about unique plant species is included in Appendix B. The predominant roadside vegetation, soils, and topography of each of the 16 generic roadside environments are included in Appendix D of the Phase II Report. Tables C-1, C-2, and C-3 in Appendix C of this report give numbers of trees by distance from the road's edge for 75 sites. Common and scientific names of species mentioned in this report are included in Appendix D.

Roadside environments are products of both construction and maintenance practices. Some trees have been removed from the vast majority of Michigan's roadsides; rights-of-way in areas of past tree/vehicle accidents have been mowed to a width of about 9 feet from the road's edge (see Phase 2 report). Most freeway rights-of-way have been seeded with Kentucky bluegrass, red fescue, perennial ryegrass, and other grasses (Beard et al., 1971). Most urban roadsides have been planted with various ornamental trees and shrubs.

In many areas, particularly wetlands, naturally occurring soils have been replaced or compacted and local water tables and/or drainage patterns altered. Cutting and filling in of wetlands in Michigan have often resulted in ponding upstream and drought on the downstream sides of roads (Davis and Humphrys, 1977). Vegetation has been subsequently affected by such alterations in local hydrology; major die-offs of trees in swamps along roads have been documented (Michigan State University, 1978). Reduced tree growth and lifespan, alteration of growth forms, and other symptoms of stress related to variations in available moisture are common along roads through wetlands.

Table 1. Estimated Roadside Trees Within 40 Feet of the Roadway by Road Type*

Road Type		Total Trees
Interstate		17,500
Trunkline		685,914
Rural/Local		18,575,077
	Total for All Roads	19,278,491

* Straight and curved road sections for each road type are considered together.

In addition to such direct effects of construction and maintenance, roadside trees are subject to stresses from excess salt (used in chemical de-icing), auto emissions, and tire residues. According to Wester and Cohen (1968):

> Salt-damage injury to vegetation is serious. As observed in the Washington, D.C. area, trees, shrubbery and turf may be killed in a single season; however, the more typical reaction for shade trees is the production of chronic symptoms such as stunted growth and foliage scorch....The damage undoubtedly greatly shortens the life of affected trees, and in the process makes the trees very unattractive for ornamental purposes.

Detwyler and Marcus (1972) listed factors influencing the magnitude of salt pollution:

> The degree of plant injury depends upon numerous factors, including the inherent susceptibility of different plant species, the amount of salt applied to the road, the proximity of the plant to the road, the timing of the application with respect to snow-plowing (which piles salt and snow along the roadside), soil characteristics (including depth and duration of frost in the soil), and the amount of saltwater runoff prior to ground thaw. Low springtime precipitation helps maintain toxic levels of salt in the soil; irrigation of affected soil will leach out some of the salt and help prevent plant damage. The relative resistance of different species to road salt is not well known, but general oaks and Norway maple are more tolerant than hemlock, sugar maple and elm.

Heavy metals contaminate roadside soils (Table 2). These residues also are deposited directly on roadside plants. Toxic effects on plants of high zinc levels have been documented, and lead (from auto exhaust) has been shown to injure shallow-rooted plants such as grasses. The effects of roadside heavy metals on vegetation, however, are generally poorly understood.

There is considerable literature on the effects of gaseous auto emmissions on plants. Table 3 summarizes some of these effects; the relative sensitivity of many of Michigan's roadside plants are given in DeSanto et al. (1976). The more susceptible trees include oaks, beech, hemlock, firs, white pine, Scotch pine, and spruces; lichens are very sensitive to air pollution (Detwyler and Marcus, 1975).

Table 2. Concentrations of Cadmium, Nickel, Lead, and Zinc in Roadside Soil and Grass*

Metal	Meters from Road	Parts Per Million (Grass)	Soil Layer, cm. below Surface 0-5	5-10	10-15
			(mg. per kg. dry weight, or ppm)		
Cadmium	8	0.95	1.45	0.76	0.54
	16	0.73	0.40	0.38	0.28
	32	0.50	0.22	0.20	0.20
Nickel	8	5.0	4.7	1.0	0.81
	16	3.8	2.4	0.90	0.60
	32	2.8	2.2	0.62	0.59
Lead	8	68.2	522	460	416
	16	47.5	378	260	104
	32	26.3	164	108	69
Zinc	8	32.0	172	94	72
	16	28.5	66	48	42
	32	27.3	54	46	42

* (as a function of distance from traffic and depth in the ground. Data are averages from duplicate sampling and analysis of materials from west of Highway U.S. 1, near Plant Industry Station, Beltsville Md. Traffic density was 20,000 vehicles per day in the year of the sampling, 1966. (from Logerwerff and Specht, 1970).

Table 3. Impact of Various Air Pollutants on Vegetation, Including Sources, Symptoms, and Injury Thresholds.[1]

Pollutant	Sources	Plant Symptoms of Injury	Injury Threshold: Parts per Million (ppm)	Injury Threshold: Periods of Exposure
Sulfur dioxide (SO_2)	Combustion of coal, fuel oil, and petroleum; oil refineries	Bleached areas on leaves; yellowing of leaves; growth suppression; leaf-fall; reduction in yield	0.3 0.05	8 hours season
Nitrogen dioxide (NO_2)	High-temperature combustion of gasoline, oil, gas, and coal in internal combustion engines and power plants; manufacture of acids	Dead spots between veins and on margins of leaves	2.5 0.5	4 hours season
Hydrogen fluoride (HF)	Phosphate rock processing; aluminum refining; iron smelting; brick and ceramic works, fiberglass manufacturing	Dead tip and margin of leaves; yellowing of leaves, leaf-fall; dwarfing; lower yield	0.0001	5 weeks
Chlorine (Cl_2)	Leaks in chlorine storage tanks; hydrochloric acid mist	Bleaching between veins and dead tip and margin of leaves; defoliation	0.10	2 hours
Ethylene (CH_2)	Automobile and truck exhaust; incomplete combustion of coal, gas, and oil; chemical manufacture	Yellowing of leaves; leaf-fall; failure of flower to open; flower dropping; stimulation of lateral growth	0.05	6 hours
Ozone (O_3)	Photochemical reaction of hydrocarbons and nitrogen oxides from fuel combustion (esp. in automobiles); refuse burning; and evaporation from petroleum products and organic solvents	Flecks and bleached spots on leaves; early leaf-fall; growth suppression	0.03	4 hours
Peroxyacetyl nitrate (PAN)	Same sources as ozone	Discoloration (silvering or bronzing) on undersurface of young leaves.	0.01	6 hours

[1]After Mukammal and Others, 1968, and Hindawi, 1970.

Many roadside trees have been injured by mechanical means. Since utility lines are located in many Michigan road rights-of-way, many roadside trees have been topped or otherwise pruned to minimize interference with transmission wires. Tree/vehicle collisions and vandalism have also damaged many roadside trees.

Despite the above-mentioned stresses to which roadside trees are subjected, many have substantial ecological, social, and economic values. These functional values are described and discussed in the next section of the report.

Although no Michigan wildlife species depend solely on roadside habitats, many of the State's mammals, birds, and reptiles utilize roadsides at least seasonally. Most wildlife species that frequent roadsides are attracted by the grassy covers.

White-tailed deer (Odocoileus virginianus) frequent roadsides in early spring to feed on the green grass not yet available in the shaded woods where snow persists longer than in open areas. Ring-necked pheasants, bobwhite quail, mallards, blue-winged teal, various songbirds (e.g., meadowlarks), and small rodents (e.g., meadow voles) utilize grassy road rights-of-way for nesting and feeding.

Raptors, especially the red-tailed hawk (Buteo jamaicensis) and the kestrel (Falco spaverus), frequently use roadside trees for perches. The latter also uses utility lines. Both species were also found to favor roadsides in West Virginia because of the availability and vulnerability of prey in the grassy rights-of-way, as well as the availability of perches (Ferris, 1974).

CULTURAL RESOURCES

Cultural resources or historic properties can, in a broad sense, be considered to be those "remains" left in the ground, on the surface, or standing above the ground that represent phases of past human activity. These resources, commonly considered part of the archaeological or historical record, are unrenewable and once destroyed remain lost. They are the focus of investigation and research by archaeologists, anthropologists, historians, geographers, ecologists, environmentalists, and preservationists.

Some 12,000 years of human activity and adaptation are represented in the archaeological record of the Upper Great Lakes Region. Archaeological sites can be prehistoric or historic. Prehistoric sites represent the pre-European occupation of the North American continent by Amerind[1] people. Historic archaeological sites extend temporarily from the European contact or exploration period till the near present standing structures of historical importance and are included among these cultural resources.

The public interest in such resources is reflected both in federal and State legislation, guidelines, and regulations. The National Environmental Policy Act of 1969 elucidates general environmental policy as it regards cultural resources. The stated purpose of the Act is "to preserve important cultural and natural aspects of our national heritage, and maintain wherever possible, an environment which supports diversity and variety of individual choice." The National Historic Preservation Act of 1966, by which the National Register of Historic Places was established, provides that the head of <u>any</u> agency having indirect or direct jurisdiction over a proposed federal undertaking must take into account "any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register."

Procedures for the Protection of Historic and Cultural Properties, Title 36, VIII, 800 serve as a guideline for actions involving the above legislation and require that "at the earliest stage of planning or consideration of a proposed undertaking by an agency" identification of cultural resources be done within the project area and it be determined whether these properties would be eligible for the National Register according to criteria set forth in Code of Federal Regulations 36-800.10.

State and Regional Considerations

Cultural resources or historical properties are distributed unevenly over the land of a region. This distribution differs according to the time period and the particular technology or settlement pattern involved. Research by archaeologists, anthropologists, geographers, and historians has related cultural phenomena to environmental factors such as physiography, water systems, and climate. This is a basic step toward understanding the interaction of human technology and resources

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[1]American Indians

by which the human community survives. Recent research by archaeologists working in the Upper Great Lakes Region has produced more reliable models of the distribution of archaeological phenomena. Extrapolating from this data, areas of varying degrees of archaeological sensitivity have been projected. In a similar manner, historical research has led to a knowledge of areas of historical sensitivity dating from the 17th, 18th, and 19th centuries.

Figure 1 shows general archaeological sensitivity of the Upper and Lower peninsulas of Michigan in regard to prehistoric sites. Figure 2 is a general sensitivity map for the sites of archaeological interest. It must be emphasized that these maps are small scale and generalized. An indication of low sensitivity does not imply an absence of archaeologically valuable sites. Sites of importance can exist in areas of low sensitivity. Many areas of Michigan have not been surveyed. In each case where land-modifying activities occur, survey by a professional archaeologist is appropriate. An overview of the relationship of future tree removal and the density of archaeological and historical sites can be gained by viewing these sensitivity maps.

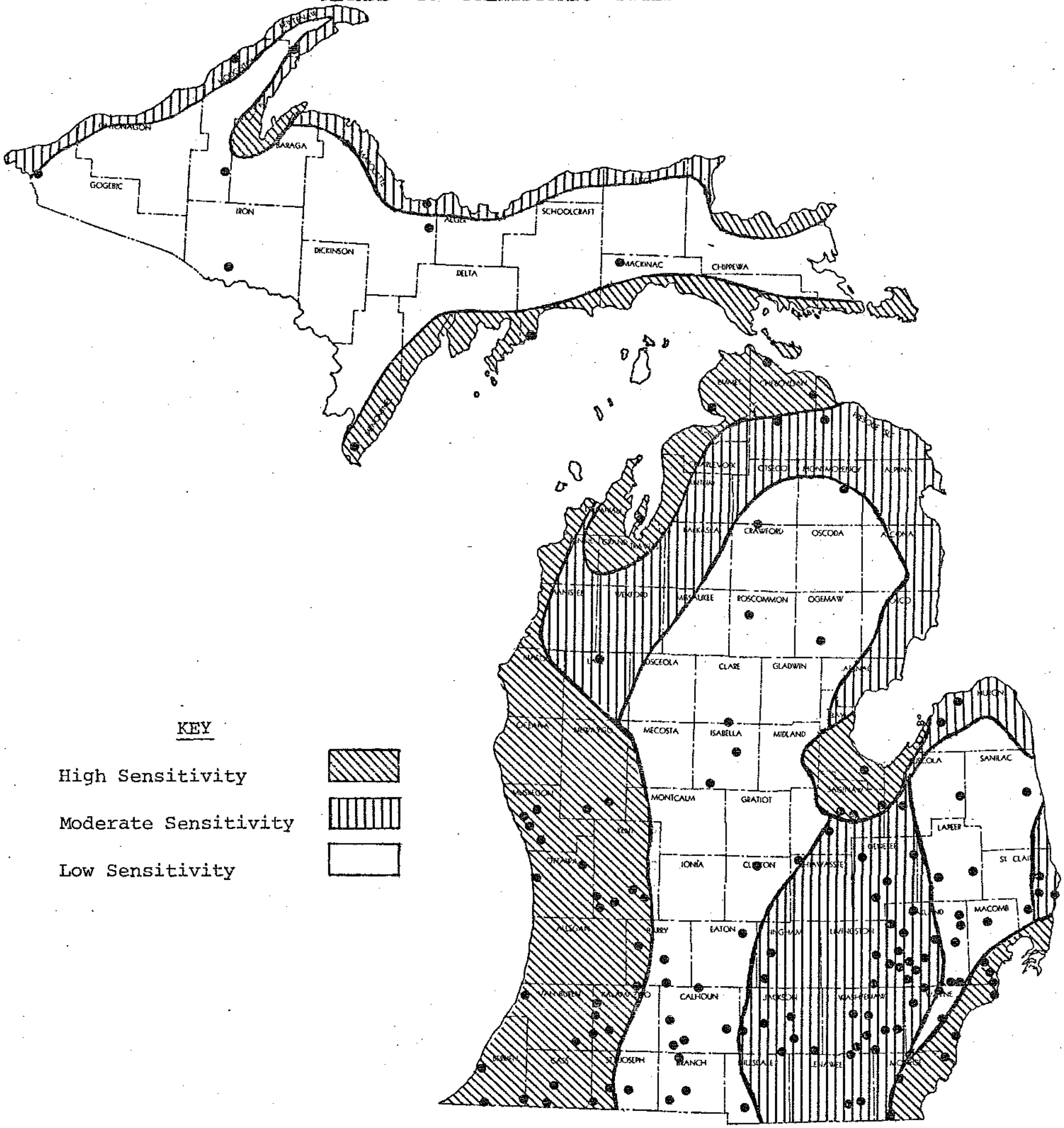
Off-Road Variables

The six specific off-road variables of land use: urban and built-up, agricultural, range land, forest, wetland, and water, each have specific cultural considerations associated with them. Agricultural areas often seem to have an abundance of archaeological sites. This is because plowing exposes sites while those in forested areas may remain hidden or be discovered by other means. Historical structures or archaeological sites of historic nature representing 19th century settlements are common in rural agricultural areas.

Forest, wetland, and water sites are important in a consideration of prehistoric or Amerind sites. Stratified sampling techniques of large survey units in the Upper Great Lakes covering disparate micro-environments show that the majority of prehistoric sites of various kinds are close to waterways, wetland, and lacustrine borders. Inland sites do exist and are of importance, representing zones of specialized procurement activities or raw materials.

FIGURE 1

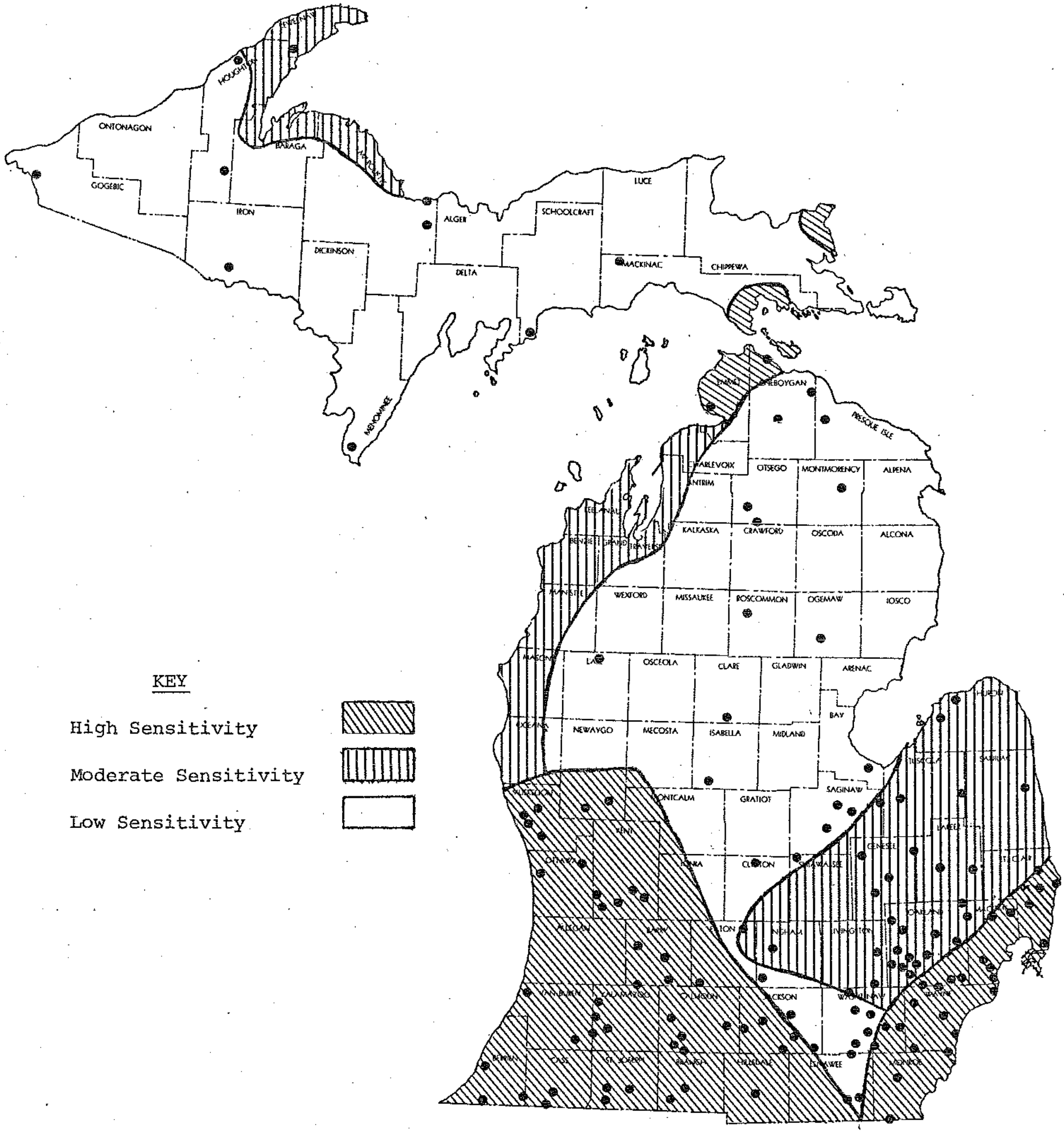
GENERAL ARCHAEOLOGICAL SENSITIVITY OF MICHIGAN WITH REGARD TO PREHISTORIC SITES



•Fatal Tree Accident Sites Which Occurred in 1976

FIGURE 2

GENERAL HISTORICAL SENSITIVITY OF MICHIGAN



●Fatal Tree Accident Sites Which Occurred In 1976

Forests are also important when considering the distribution of archaeological sites. The original citizens of the Lower Peninsula of Michigan, some 11-12,000 years ago, occupied a spruce tundra parkland environment. This forest community was followed by a coniferous forest as the climate became warmer in the post-Pleistocene era. That period was soon followed by the stabilization of the modern forest communities dominated by deciduous elements in the southern and western portions of the Lower Peninsula. The plotting of post-Pleistocene environments and the presettlement forest aides the archaeologist in considering the distribution of past haman activity. In regard to the modern forest, field investigations have determined a high correlation between prehistoric sites and the deciduous and mixed deciduous/ coniferous forest that with the purely coniferous forest. This is due to the higher carrying capacity (capacity to sustain life) of the former. Prehistoric inhabitants of the northern regions of the Great Lakes exploited a coniferous environment, but this exploitation was mitigated by the riverine or lacustrine orientation of their subsistence activities.

PROBABLE ENVIRONMENTAL IMPACTS OF TREE REMOVAL

SHORT-TERM IMPACTS

All short-term impacts of tree removal are site-specific; that is, the nature and extent of the impacts are determined by the actual site of tree removal. The most serious short-term impact is a loss of aesthetic value. Measures to avoid removing unique trees and to control erosion have been considered and are outlined in Appendix 5 of the Phase 2 Report. Since disposal of slash, the vegetation that has been removed, is usually done concurrently with tree removal, the impact is of very short duration. Noise and air pollution associated with removal equipment--chain saws, trucks, etc. --are also limited.

LONG-TERM IMPACTS

The long-term impacts of tree removal are also site-specific and are associated with a loss of functional values of roadside trees. Numerous authors have described the wide variety of benefits trees and other forms of vegetation provide (Davis, 1970; Cook and Haverbeke, 1971, 1974; Federer, 1971; Robinette, 1972; Weidensaul, 1973). Grey and Deneke (1978) summarized much of the available literature on the benefits to man of trees in urban environments. They grouped the various benefits into four broad categories:

1. Climate modification
2. Engineering uses
3. Architectural uses
4. Aesthetic uses

In addition, they recognized along with other authors (Purcell, 1956; Keilbaso, 1971; Payne, 1975) that trees have economic values surpassing the more traditionally recognized lumber/firewood values.

Removing trees results in loss of some of these values, wherever and whenever removal occurs. The nature and magnitude of the associated impacts depends on numerous, interrelated, site-specific variables. It is impossible to describe all of the specific situations in which roadside tree removal may have these effects; however, the more important values, impacts, and associated variables are discussed briefly in this section.

In most cases, the primary factor in determining the magnitude of the environmental impact of loss of tree functions is whether the trees to be removed are "barrier" trees. Barrier trees separate the road from potential impact areas, such as residences, open agricultural fields, water bodies, parks, sidewalks, and aesthetically pleasing scenes. Removal of non-barrier trees is much less significant, except in situations where the non-barrier trees themselves have exceptional value (e.g., as historical resources).

Climate Modification

Trees, shrubs, and grade modify air temperatures by controlling solar radiation. In particular, tree leaves intercept, reflect, absorb, and transmit solar radiation (Grey and Deneke, 1978). The effectiveness of trees in modifying climate depends on the density of foliage, leaf shape, and branching patterns; however, there are a number of other generalizations that can be drawn from the available literature.

The most important variables affecting human comfort are air temperature, humidity, and solar radiation. Recent research has shown that single trees or small groups of trees have no significant effect on air temperature or humidity (Heisler, 1977b). Herrington and Vittum (1975), Plumley (1975) and Stark and Miller (1975) found that the cool, moist air from evapotranspiration (loss of water from the soil) is removed quickly from the vicinities of small groups of trees and dispersed by even a gentle breeze. Large groups of trees, however, can help reduce summer air temperatures and increase humidity over large areas. Kramer and Kozlowski (1960) found that a single isolated tree may transpire as much as 88 gallons of water per day if sufficient soil moisture is available. Federer (1970) compared the resultant cooling to that of five 2500 kcal/hr room air conditioners operating 20 hours per day.

Large groups of trees can cause higher night temperatures in urban areas. According to Grey and Deneke (1978):

> At night heat is lost primarily through the exchange of infrared radiation between city surfaces and the atmosphere. On cool, clear nights, city surfaces cool more rapidly, and on cloudy nights, there is less cooling. In addition, the rate of infrared heat loss varies with the type of material originally receiving heat from solar

radiation during the day. Heavy, high density materials cool slowly; thus, releasing heat that may be desirable. At night, tree canopies slow the loss of heat from city surfaces, providing a screen between the cooler night air and the warm surface materials. Thus, the night temperatures are higher under trees than in the open (Federer, 1976). In urban areas, this differential may often be as great as 10 to 15°F (5 to 8°C) (Federer, 1970).

Wind can negate cooling effects normally found under a forest canopy by replacing the cool air with warm air. Conversely, trees can interfere with the evaporative cooling process, allowing higher temperatures in protected zones. This can result in winter energy savings for homeowners (Grey and Deneke, 1978; Heisler, 1977a). Trees removed from roadsides would generally not be close enough to homes to provide insulation by creating "dead air" zones; however, some trees would likely help reduce wind chill, as discussed later in this section.

Although air temperature and relative humidity are not significantly altered by a few trees, solar radiation, the most important variable affecting human thermal comfort, can be (Heisler, 1977b). Plumley (1975) found that trees with dense canopies can reduce by 80% the solar radiation a person receives. This can be significant to home energy savings as well as to human comfort. Heisler (1977b) noted temperature differences of 16°F between unshaded and shaded white surfaces of wooden houses in New Jersey in June. The shade was from a large sugar maple (Acer saccharum). Greater temperature differences occurred with dark-colored surfaces.

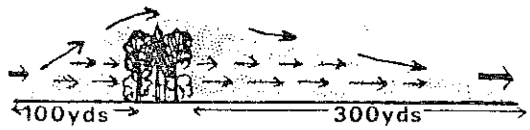
In a study in California, Deering (1956) found that dense shade from trees might reduce maximum temperatures inside houses by 20°F. When a research trailer built to simulate a typical house was beneath a group of large fig trees, the temperature inside the trailer remained above 75°F for only 5 hours in comparison to 11.5 hours above 75°F when the trailer was parked in full sun.

In Alabama, Laechelt and Williams (1974) found that mobile homes parked in tree shade had electricity bills $45-100 (in 1973) per year less than mobile homes without shade. In this study, partial shading (as low as 20%) resulted in lower air conditioning costs. Such savings, of course, could not be expected in Michigan; however, trees undoubtedly help reduce air conditioning cost somewhat.

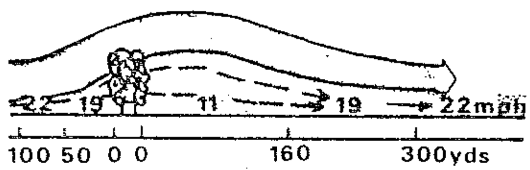
In Michigan, the most significant contribution of trees to climate modification in small, site-specific areas results from their effect on wind. Trees control wind by obstruction, guidance, deflection, and filtration (Grey and Deneke, 1978). Effects and degree of control vary with species, size, shape, foliage density and retention, and the actual location of the trees with respect to wind direction.

Wind deflection by trees has been studied extensively. Windbreaks perpendicular to prevailing winds may reduce wind in front of the barrier for a distance 2-5 times the height of the tallest trees and for distances of 30-40 times on the leeward side (Grey and Deneke, 1978). Hence, the taller the trees, the greater the protected distance. Usually, the width of a windbreak has a negligible effect in reducing wind velocity (Grey and Deneke, 1978). Dense, impenetrable windbreaks may provide more wind reduction, but the wake zone does not extend as far (Figure 3). This is because movement of air through a windbreak gives some lift to the boundary layer. Robinette (1972) found that the optimum density for a windbreak is 50-60%.

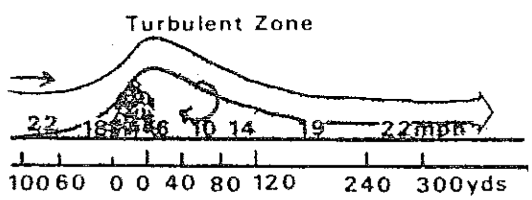
The home energy savings from windbreaks can be significant. Bates (1911) found that trees for windbreaks can reduce winter fuel consumption by 10-25%. In a study in South Dakota, Bates (1945) concluded that a 10-row deciduous windbreak resulted in a 25% savings in winter fuel. Woodruff (1954) calculated, on the basis of wind-tunnel experiments in Kansas, that a 10-row defoliated shelterbelt would provide a 15% saving in heating costs for a house located two tree heights south of the windbreak. In New Jersey, Mattingly and Petters (1975) also observed winter fuel savings up to 13% from windbreaks consisting of single rows of white pine (Pinus strobus) or Norway spruce (Picea abies). Their study suggested that windbreaks reduced heat loss by effecting a more even air pressure around the entire house, rather than simply reducing the force of air against the windward side. It follows therefore, that windbreaks may be most effective when placed quite close to buildings, even though maximum windspeed reduction takes place about five tree heights downwind of tree windbreaks (Heisler, 1977b). In another New Jersey study, Flemer (1974) found that an evergreen windbreak resulted in a 10% savings in winter fuel.



A 30ft. high shelterbelt affects wind speed for 100yds. in front of the trees and 300yds. down wind.



Effect of moderately penetrable wind-breaks on wind.



Effect of dense windbreak on wind flow. H=30ft.

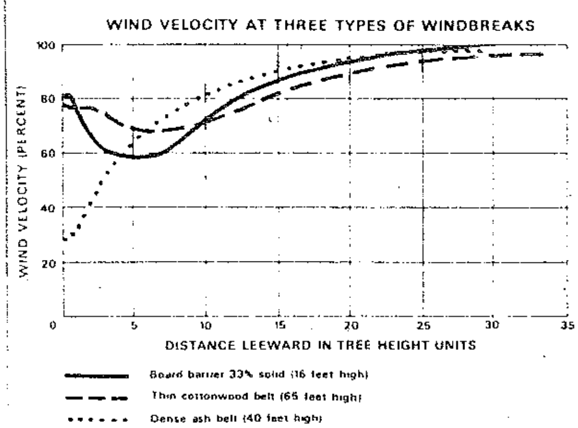


FIGURE 3 EFFECTS OF DENSITY ON THE DOWNWIND ZONES OF WINDBREAKS

Research by Jacobs and DeWalle (1976) in Pennsylvania indicated that, if a house is shaded as well as protected from the wind, some of the potential savings in winter fuel will be lost. They found, however, that for an entire season, 5% less energy was required to heat a trailer in a dense pine forest than a similar one in an open space.

Grey and Deneke (1978) noted that trees can aid traffic safety by protecting highways from cross-wind gusts. Conifers on roadside slopes can impede movement of cold air that would normally flow to low points, usually the road, thus reducing the formation of localized frost pockets.

Conversely, roadside trees can sometimes cause hazards by their effects on microclimates. Trees which shade roads often contribute to persistent icing in winter. Trees can either benefit or hinder removal of snow from roads depending on their exact location. However, low shrubs are almost always more effective than trees in preventing drifting from roads. Jensin (1954) derived the following formula for computing windbreak-caused drift patterns:

$$L = \frac{36 + 5h}{K}$$

where: L = the length of the drift in feet
h = the height of the windbreak in feet
K = the function of the windbreak density, 1.0 for 50% density and 1.28 for 70% density.

The impact of removing roadside trees on climate varies widely depending on numerous site-specific variables. In general, however, the removal of single trees or small clumps of trees affects only extremely localized areas, primarily residential. No mitigation for loss of shading values of individual trees is practical. Removal of long rows or strips of trees can result in significant secondary effects of changes in microclimate in some areas. For example, removal of a windbreak adjacent to a muck farm could cause significant wind erosion.

The removal of roadside trees will have a small positive impact on snow removal in open areas. Trees likely to be removed will be at least 30 feet in height and within 40 feet of the road. Based on the formula of Jensin (1954) and personal experience of the study team, such trees are likely to cause drifts of over 150 feet in length.

Additionally, cumulative effects of removal of large numbers of trees in urban/suburban areas could potentially affect air temperatures and humidity.

Glare and Reflection Control

Glare and reflection affect both our visual comfort and our safety. Trees can be effective in reducing both glare and reflection. As Grey and Deneke (1978) stated:

> We are surrounded by a myriad of shining surfaces--glass, steel, aluminum, concrete, and water--all capable of reflecting light. We experience discomfort when the sun's rays are reflected toward us by these surfaces. At night, we have to contend with glare from automobile headlights, streetlights, buildings, and advertising signs....
>
> ....Plants can be used to screen both primary and secondary glare. Their effectiveness depends primarily on their size and density. Sources of glare must be identified before the proper plants can be selected to control it. The degree of control is also important as it may be desirable to eliminate glare completely or to create a filtering or softening effect....
>
> ....Plants can be used along the highway to control early morning and later afternoon glare....

Removing roadside trees can result in increased glare and reflection. In general, urban/suburban areas are more sensitive to such impacts than rural areas. However, east-west oriented rural roads in Michigan are also subject to glare from the morning and evening sun throughout the year, but particularly in the spring and fall. In most cases, removal of a single tree or small clumps of trees will have minimal impact on glare and reflection.

Shrubs are sometimes effective in reducing glare under certain conditions, but trees are considerably more useful in the vast majority of situations. Hence, no mitigation for loss of the glare-reducing value of roadside trees is practical.

Air Pollution Abatement

In most roadside areas, traffic is the main source of air pollutants. The more significant automobile emissions are carbon monoxide, nitrogen oxides, and various hydrocarbons. The amounts of these pollutants in any given area depend on traffic conditions--especially volume (vehicles per unit of time), congestion (influencing the number of starts and travel speed), vehicle mix (e.g., percentage of heavy duty trucks)--and climatic variables such as wind speed, direction, and temperature. Airborne particulates, especially dust, are problems along many Michigan roads.

Many authors have expressed conflicting viewpoints about the role of trees in reducing air pollution. However, there is general agreement that under certain conditions some tree species can make significant contributions to air pollution control (Bernatsky, 1968). Trees remove air pollutants both indirectly and directly. According to Grey and Deneke (1978):

> Wind turbulence is a major factor in dispersing gaseous pollutants. Because their presence increases wind turbulence, trees can be used to aid in the dispersal of gaseous pollutants if located downwind from the source of pollution.

Conversely, trees upwind from linear sources of pollution, such as congested roads, could reduce natural dispersal.

Trees can also reduce gaseous pollutants directly through absorption. Research has shown that tall trees remove more ozone than shorter trees (Grey and Deneke, 1978). Robinette (1972) reported that a Russian study showed that a 1600 foot wide green area surrounding factories reduced sulfur dioxide concentrations by 70% and nitric oxide by 67%.

Trees can reduce particulate air pollutants by physically trapping dust, pollen, smoke and other airborne particulates, and by the phenomenon of "air washing". The latter occurs when transpiration by trees causes increased humidity which helps to settle-out particulates. Grey and Deneke (1978) also noted that the fragrance of trees (e.g., pines) often masks unpleasant odors.

To some extent, reduction of air pollution can be achieved by shrubs, grasses, flowers, and other plants as well as by trees. However, quantitative comparisons of pollution reduction by trees as opposed to other types of vegetation are lacking in the literature. The upward dispersal patterns of most air pollutants suggests that a combination of vegetation types is probably most efficient in reducing air pollutants.

DeSanto et al. (1976) summarized most of the available literature on use of greenbelts as air pollution sinks or filters. Their conclusions included the following:

1. Vegetative buffers which attain maximum height are generally more efficient in the role of sinks for air pollutants.

2. A tree that is extremely sensitive to air pollutants will be a poor sink due to irreversible damage to that particular plant. Table 4 ranks trees according to their tolerance to air pollution.

3. Multi-layerd stratification is characteristic of an efficient roadside forest for absorption of air pollutants.

4. The use of mixed plantings for reduced levels of pollution should include both coniferous and deciduous trees and shrubs. Conifers provide year-round absorption and a high surface/volume ratio, but are generally more sensitive to air pollutants. In mixed plantings, deciduous trees help protect the conifers by lowering the pollution levels in the immediate vicinity.

5. A high number of plant species with varying sizes is important for healthy, efficient greenbelts.

6. Moderate density is optimal for removal of pollutants.

7. Expanding the length and increasing the diversity of roadside forests increases their value as air pollution sinks (Figure 4).

8. Thermal chimneys within a forest aid in air circulation which causes more exposure of polluted air to the upper leaf surfaces of the canopy trees (Figure 5).

9. Trees and shrubs within 100 feet of the road play the most significant role in air pollution abatement. About 40-50% of the particulate removal occurs in the first 65-80 feet of trees. Thereafter, the efficiency with which particulates and other air pollutants are trapped or absorbed declines.

The removal of single, isolated trees or small clumps of trees along the roadside will have negligible effects on air quality. Removal of rows or strips

Table 4. Tree Species Tolerant to Air Pollution (from DeSanto et al., 1976).

DECIDUOUS *

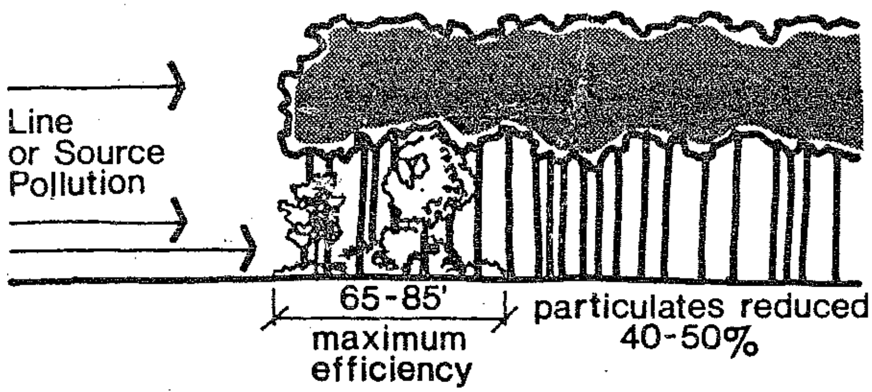
Alder *Alnus* sp.
Almond tree *Prunus amygdalus*
American Beech (Red beech) *Fagus grandifolia*
Apple *Malus* sp.
Ash *Fraxinus* sp.
Balsam poplar *Populus balsamifera*
Birch *Betula lenta*
Box-elder *Acer negundo*
Canadian poplar (Carolina poplar) *Populus canadensis*
Cherry *Prunus* sp.
Eastern poplar *Populus deltoides*
Elder *Sambucus* sp.
Elm *Ulmus* sp.
European mountain ash *Sorbus aucuparia*
Flowering dogwood *Cornus florida*
Gingko (Maidenhair tree) *Gingko biloba*
Goat willow *Salix caprea*
Hawthorn *Crataegus* sp.
Honey locust *Gleditsia triacanthos*
Japanese larch *Larix leptolepsis*
Japanese pagoda tree *Sophora japonica*
Juneberry *Amelanchier* sp.
Larch *Larix* sp.
London plane tree *Platanus acerifolia*
Oak *Quercus* sp.
Ornamental apple *Malus floribunda*
Peach *Prunus persica*
Pear *Pyrus communis*
Plum *Prunus* sp.
Poplar *Populus* sp.
Red ash *Fraxinus pennsylvanica*
Redhaw hawthorn *Crataegus mollis*
Russian olive (Oleaster) *Elaeagnus angustifolia*
Scarlet elder *Sambucus pubens*
Silve-berry *Elaeagnus commutata*
Tree of heaven *Ailanthus altissima*

CONIFEROUS *

Arborvitae *Thuja* sp.
Austrian pine *Pinus nigra*
Colorado spruce *Picea pungens*
Eastern red cedar (Cedar) *Juniperus virginiana*
Eastern white pine *Pinus strobus*
Sitka spruce *Picea sitchensis*
Western red cedar *Thuja plicata*

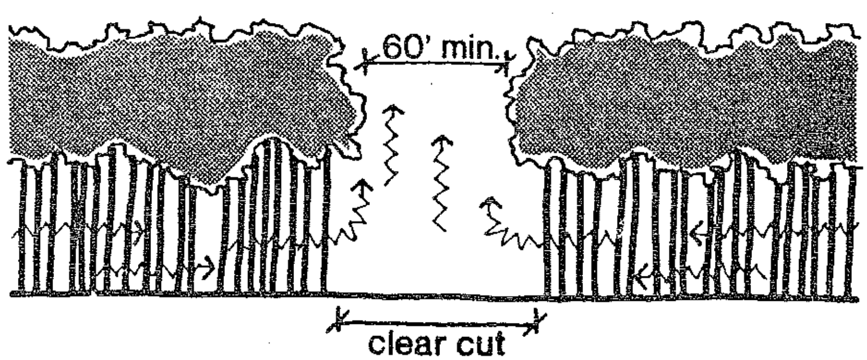
* Higher Tolerance Species Listed First

Figure 4 INCREASED DIVERSITY WITHIN EDGE CONDITION MAXIMIZES SINK POTENTIAL



(from DeSanto et. al., 1976)

Figure 5 CREATION OF THERMAL CHIMNEYS FOR VENTILATION OF FORESTS AND BUFFERS



(from DeSanto et. al., 1976)

of trees can have significant effects in some areas. In general, removal of trees along roadsides will have little impact in rural areas, except along gravel roads through open areas. Planting tall shrubs will help mitigate loss of air filtering values of trees in all areas.

Noise Abatement

Roadside trees can play a significant role in noise abatement. Road-generated noise depends on numerous factors including traffic density, speed, and vehicle mix; climatic factors, especially wind speed, temperature, and humidity; the nature of the terrain and vegetation over which the sound passes; and distance to the noise receptor. Highway noise levels are usually expressed in decibels (a unit for measuring the relative loudness of sounds). Roadside noise levels are thus characterized on the basis of repeated, "typical," sound outputs, rather than the highest noise levels which might occur; e.g., a large truck's horn blast.

Figure 6 gives typical noise levels under different traffic intensities and distances to noise receptors. Doubling the number of vehicles per hour increases noise levels by about 3 decibels (Mich. Dept. of State Highways and Transportation, 1973). Vehicle mix is important; noise levels increase with the percentage of heavy trucks (Motor Vehicle Manufacturing Association, Inc., n.d.). Doubling the distance results in an attenuation of 2-4.5 decibels in noise levels. Since decibels are expressed on a logarithmic scale, such changes are significant (Figure 7). For example, a decrease in noise from 88 to 83 decibels (dBa) is a 66% reduction in noise.

Grey and Deneke (1978) describe the effect of temperature and wind on noise as follows:

> Excess attenuation of sound propogated along the ground is greatly affected by the presence of temperature and wind gradients. Attenuation measured upwind may exceed those (sic) measured downwind by as much as 25 to 30 decibels. In general, sounds passing downwind from a source are directed downward toward the surface, while sounds traveling upwind

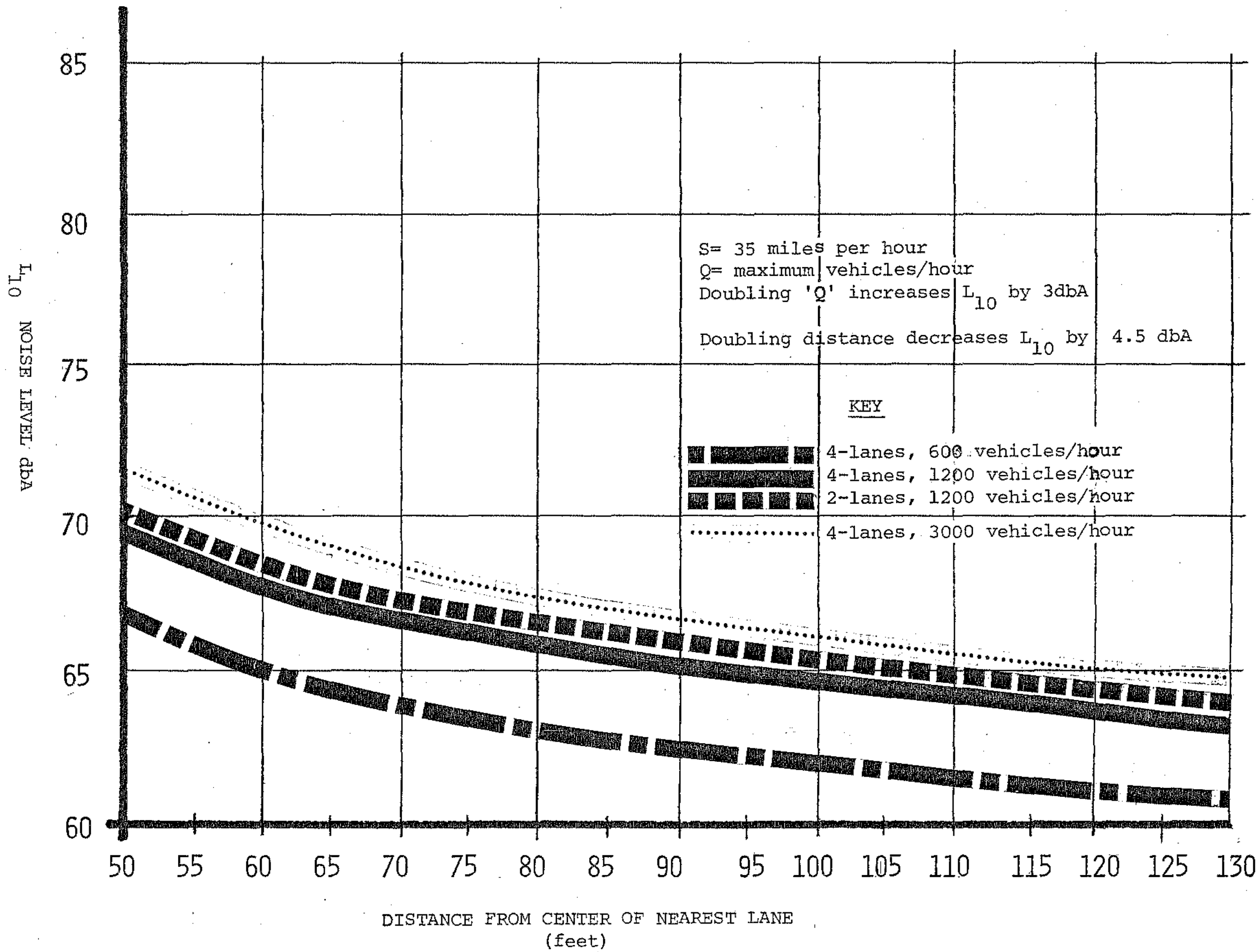


Figure 6 RELATIONSHIPS AMONG TRAFFIC FLOW, DISTANCE FROM SOUND SOURCE & NO. OF TRAFFIC LANES

(from Mich. Dept. of State Highways & Trans. 1973)

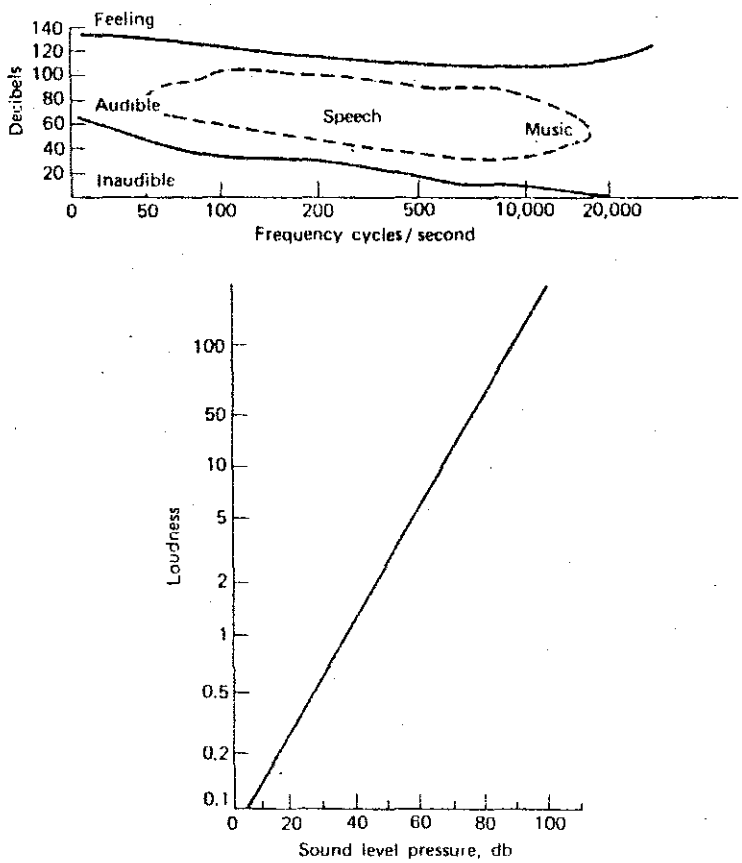


Figure 7 SOUND RELATIONSHIPS SHOWING HOW DECIBELS ARE RELATED TO SOUND FREQUENCY AND LOUDNESS (from Detwyler and Marcus, 1972)

from a source are directed upward from the surface. At night, when the atmosphere is coldest near the ground, sound will be directed away from the surface.

Trees can therefore reduce noise indirectly by blocking wind and stabilizing temperatures, as previously discussed (Weiner and Keast, 1959). Trees, like other rough-surfaced objects, can also reduce noise by absorption, deflection, reflection, and refraction. In addition, trees can reduce the perceived noise by masking, "covering" undesirable sounds with more pleasing ones, and by blocking the noise source from view. In one experiment, Aylor (1975) found that people tended to think they were hearing less noise if the source was partially screened from view. However, fully screening the source seemed to cause the opposite effect--the subjects thought the noise was louder than it actually was. Heisler (1977) and Aylor (1975) both postulated that a possible explanation for this result was that people expected a visually solid barrier to be quite effective in reducing noise. When this did not occur, the noise actually seemed louder.

Heisler (1977) provided a concise summary of the means by which trees attenuate sound:

> Trees themselves apparently do not absorb much sound. Most investigators now agree that trees are effective in reducing noise transmission primarily by reflecting and scattering sound waves (Aylor, 1975; Reethof et al., 1975). Tree bark absorbs only a small amount of sound usually less than 10 percent (Reethof et al. 1976). Foliage is also effective primarily by scattering sound rather than by absorption (Aylor 1972a, 1972b, 1975). The most effective sound absorber is the ground beneath trees (Reethof et al. 1975).

Single trees and narrow rows of trees do not significantly reduce noise (Grey and Deneke, 1978). Dense, wide clumps or strips of trees along roads can be effective; the amount of attenuation depends primarily on the species, location with respect to the noise source, noise receptors, and tree height and density. Cook and Van Haverbeke (1971, 1974, 1977) found attenuations of 5-8 dBa per

100 feet of dense, tall woods. Deciduous species, when in full leaf, did not differ greatly in ability to reduce noise. Conifers were more effective for year-round noise abatement. Embleton (1963) estimated that, on the average, forests can attenuate sound at frequencies of 1000 cycles per second or less, at the rate of 7 decibels per 100 feet of distance. Robinette (1972) and Anlor (1972a) suggested that the most effective plants for absorbing sounds are those with thick, fleshy leaves with petioles.

Heisler (1977) stated that, if major highways carrying high speed trucks pass through residential areas, tree barriers cannot reduce sound levels to a reasonable maximum within 350 feet of the highway. He noted, however, that, if only a narrow strip is available for plantings, a dense planting of shrubs backed by several rows of trees will be of some help.

Cooke and Van Haverbeke (1971) made the following recommendations for use of trees for noise reduction along roads:

1. Reduction of noise from high-speed car and truck traffic in rural areas is best achieved by tree and shrub belts 65 to 100 feet (20 to 30 m) wide with the edge of the belt within 50 to 80 feet (16 to 20 m) of the center of the nearest traffic lane. Center tree rows should be at least (14 m) tall.

2. To reduce noise from moderate--speed car traffic in urban areas, tree and shrub belts 20 to 50 feet (6 to 16 m) wide may be used effectively with the edge of the belt from 20 to 50 feet (5 to 6 m) from the center of the nearest traffic lane. Shrubs six to eight feet (2 to 2.5 m) tall should be used next to the traffic lane followed by backup rows of trees 15 to 30 feet (4.5 to 10 m) tall.

3. For optimum results, trees and shrubs should be planted close to the noise source as opposed to close to the protected area.

4. Where possible, taller varieties of trees which have dense foliage and relatively uniform vertical foliage distribution (or use combinations of shrubs and trees) should be used. Where the use of tall trees is restricted, use combinations of shorter shrubs and tall grass or similar soft ground cover, as opposed to paving, crushed rock, or gravel surfaces.

5. Trees and shrubs should be planted as close together as practical to form a continuous, dense barrier. The spacing should conform to established local practices for each species.

6. Evergreens (conifers) or deciduous species which retain their leaves should be used where year-round noise screening is desired.

7. Belts should be approximately twice as long as the distance from the noise source to the receiver, and when used as a noise screen parallel to a roadway, should extend equal distances along the roadway on both sides of the protected area.

Several authors (e.g., Simonson, 1957; Grey and Deneke, 1978; Cook and Van Haverbeke, 1974) have stated that planting of trees and other types of vegetation can be used in combination with other measures for maximum, cost-effective highway noise abatement. The effectiveness of man-made barriers can be increased by planting vines that cover the walls. This helps increase noise absorbtion while decreasing reliance on deflection for abatement. In urban areas, noise deflection often serves only to transfer noise problems from one area to another. The effectiveness of barriers increases with increasing thickness, height, and density of plantings.

Long-term impacts on noise of removing roadside trees vary greatly from one location to another. Continued exposure to high noise levels can be physically harmful, but traffic noise is primarily a nuisance rather than a health problem. Nuisance complaints are related in complex ways to numerous social as well as physical variables. Bolt, Beranek and Newman, Inc. (1969) surveyed 1200 persons at 60 sites in Boston, Detroit, and Los Angeles regarding their attitudes toward traffic noise. They found that most persons "accepted" normal passenger car noise, but objected to noise from heavy-duty trucks and "hot rodding". Most people surveyed who expressed annoyance indicated that they were home when it occurred and it was generally in the evening. Other studies have found that the number of noise-related complaints is highly correlated with income level of neighborhood residents. Some special areas generally considered as "noise sensitive" by planners, engineers, and other professionals concerned with noise control include schools, parks, hospitals, libraries, churches and rest homes.

In both urban and rural areas, removal of single trees or single rows of trees will have no significant effects on noise, except perhaps where a dense row of conifers shields a park, residence, or other "noise sensitive" area adjacent to a heavily traveled road. Mitigation by man-made barriers supplemented by plantings of vines and shrubs is possible and might be warranted in some situations (i.e., suburban and rural areas). Planting of shrubs alone will generally not replace the attenuation of sound by wide bands of trees, since the height of the stand is positively correlated with the attenuation of noise.

Soil Stabilization

Trees play a well defined role in soil stabilization. They are extremely valuable in protecting steep slopes from mass wasting (the deep-seated movement of slopes by landsliding or slumping) (Grey, 1975) and as windbreaks to protect open areas such as agricultural fields from wind erosion. However, trees are of limited value in preventing superficial erosion. In fact, by shading out more beneficial turf-building plants (e.g., grasses), trees often contribute to erosion (White and Brynildson, 1976). In some areas, thorny trees have been recommended to discourage people from hiking through areas sensitive to erosion, but shrubs are also effective for this purpose.

Thus, the removal of roadside trees will result in significant long-term loss of soil stabilization values only if trees are removed in areas subject to mass wasting or where trees are needed for windbreaks to protect soils. Wind erosion is only important on sandy and organic soils in Michigan. Specific information on soils which may be susceptible to wind erosion can be obtained from the State Soil Conservation Office. Areas highly susceptible to mass wasting are primarily road cuts through hilly areas with slopes of 18% or more. Because trees on very steep slopes are generally not hazardous, few trees valuable for prevention of mass wasting are cut. If it is necessary to cut such trees, slope failure can be prevented by "contour wattling" (Kraebel, 1936), as described in Grey (1975):

> Contour wattling consists of packing lengths of brush into continuous, thick cables partially buried at regular contour intervals across a slope and supported on the lower side by

stakes. The stakes may be made of inert material, such as split lumber, or, in the proper seasons, of living wood of species which take root readily from such cuttings.......

.....The technique has been used successfully to stabilize very high, steep slopes above and below roads constructed through National Forests in California. Contour wattling or some modification appears ideally (sic) for possible erosion control on coastal slopes along the Great Lakes.

Interrelationships with Other Plants

Except in mowed areas, roadside trees exist in association with other trees, shrubs, wild flowers, and grasses. By controlling solar radiation and affecting wind patterns, trees create site conditions which influence other plants in the immediate area.

Wherever roadside trees are removed, changes in lower vegetation will occur. These changes result in an environment of an earlier successional stage. These changes are negligible if a single isolated tree or small clump of trees are removed. If large clumps or long rows or strips of trees are removed, the diversity and interspersion of vegetation and its "edge" may be either increased or decreased. Edge refers to the structural juncture between several communities. According to Michigan State University (1978):

> If a cut is excavated through an acre of land containing a mature broadleaf forest that has no openings, the effect of the cut will be to increase interspersion and thus diversity. Shrubs and herbaceous species will eventually move into the cut, and the acre will contain two habitat types rather than one. If a cut is conducted through an acre of land in such a way that the cut moves through a broadleaf forest, removes a small conifer stand, and cuts through shrub rangeland, the overall effect will be a decrease in interspersion. With the cut eventually supporting herbaceous and shrub rangeland, the habitat types in the acre of land will be changed from three to two. A single action may have two opposite effects, in one situation beneficial, in another detrimental.....

....A cut which increases interspersion would increase edge as well. A cut producing a decrease in interspersion would produce a decrease in edge.

Reduced growth, changes in growth form, and even mortality of shade-tolerant plants can occur due to sudden exposure where taller adjacent trees are removed. However, growth rates of adjacent trees and shrubs usually increase as taller trees are removed owing to greater exposure to sun and reduction in competition for water and nutrients. Davis and Humphrys (1977) found that conifers generally showed a decrease in growth after clearing of a right-of-way (ROW) along I-75 in Roscommon County, Michigan, while hardwoods, with the exception of paper birch, showed an increase in growth rate.

Dramatic changes in adjacent vegetation can occur if trees which serve as windbreaks are removed in sensitive areas such as dunes and wooded swamps. In dunes, removal of windbreaks can slow vegetational succession and perhaps cause blowouts (Olson, 1958). In wooded swamps, removal of clumps, rows, or strips of trees can result in subsequent windthrow (felling) of adjacent shallow-rooted trees such as northern white cedar. Windthrow is at least partly a function of road orientation. Crabtree, et al. (1978) found that prevailing winds seemed to fell a greater percentage of trees in northern Michigan wooded swamps and pipeline corridors oriented north-south, rather than in those oriented east-west.

Removal of trees from roadsides can affect adjacent endangered and threatened plant species. While locations where unique species are known to exist will be left undisturbed, it is possible that other locations may also have endangered or threatened plants.

<u>Wildlife Habitat</u>

The wildlife values of Michigan's roadside environments have been the subject of few studies. Much of the literature from other states is devoted to management of shrub and herbaceous covers for small game species rather than for roadside trees (Joselyn and Tate, 1972; Montag, 1975).

Roadside trees are probably of special importance to Michigan wildlife only in open areas (e.g., agricultural lands) where other trees are scarce. In such areas they can be important to squirrels and various tree-dwelling birds for food and shelter. Rows or strips of trees in large open areas can provide important travel corridors for ground-dwelling vertebrates including deer, rabbits, pheasants, and other game species. The latter function can also be served by shrubs.

Some roadside trees may be of significant importance to wildlife because of their size, species, or condition. Snags (dead trees) are especially beneficial to cavity-nesting birds (e.g., red-headed woodpeckers, starlings) and raptors which can perch on them without limbs and leaves to obscure the birds' vision. Important factors for evaluating the wildlife values of snags include hardness, height, diameter, and bark and limb condition. Preferences of wildlife vary by species; however, snags that appear to have overall highest wildlife value are soft or rotten, about 20 feet in height and 15 inches in diameter, and have no bark or limbs (Gale, 1973).

Long rows or strips of large mast-producing trees, (fruit and nuts produced by trees that are edible to wildlife) such as oaks, also may have special wildlife values by providing supplemental fall food in the form of acorns for squirrels, deer, and other wildlife.

There is some evidence that the presence or absence of trees along roads can influence the movement of wildlife, and this is therefore related to the frequency of road kills. (Puglisi, et al. 1974; Leedy, 1975.) Most of the available literature suggests that such influences vary among wildlife species. In one study in England, more house sparrows were killed opposite gaps and openings than along stretches of road with relatively uniform forested border. Bellis and Graves (1971) found that grassy strips along Interstate 80 in Pennsylvania attracted white-tailed deer and led to numerous car/deer collisions. Grassy rights-of-way appear to encourage road crossings by small rodents adapted to open environments, for example, deer mouse (Peromyscus maniculatus) and meadow vole (Microtus pennsylvanicus). On the other hand, Oxley, Fenton and Carmody (1974) concluded:

> .....Small forest mammals such as the eastern chipmunk (Tamias striatus), and the white-footed mouse (Peromyscus leucopus) were reluctant to venture on the road surfaces where the distance between forest margins exceeded 20 m (65.6 feet).

Many authors have expressed conflicting viewpoints regarding the significance of highway-related mortality of small mammals, birds, and amphibians that have high reproductive potentials. However, there is no evidence that road kills of such animals are in any way significant when related to the total populations (Day, 1970). As Leedy (1975) stated:

> Impressive as some of the estimates of highway wildlife mortality are, it is probable that for most species, the loss is not significant, because of the relatively small proportion of the ranges of the respective wild animal species affected by highways. Leopold (1936-268) pointed out that the killing of an animal by a motor car usually is noticed by its occupants, and if the body remains on the highway, by occupants of hundreds of subsequent cars. He states that this unusual visibility gives rise to widespread alarm over the destruction, but other more important invisible factors are at work which go unnoticed.

Haugen (1944) recorded animal mortality on 124 miles of state highways in Barry County from April 1 to September 20, 1940. He found 180 farm fowl, 120 cats, 12 dogs, 3 pigs, 168 cottontail rabbits, 42 squirrels, and 90 other wild mammals and birds. However, he also concluded that the effect of highway mortality on small game, especially cottontail rabbits, was insignificant in light of the total populations.

Deer/car collisions are a significant public concern in Michigan for safety and economic, as well as for biological reasons. Deer/car collisions are a function of both traffic volume and speed, and habitat adjacent to the roads. Reilly and Green (1974) reported on highway deer mortality in a deer-wintering area in Michigan's Upper Peninsula intersected by two highways--the Mackinac Trail (formerly U.S. 2) and Interstate 75. After construction of I-75 in 1963, deer road kills in the study area increased about 500% over the average for the previous 4 years, declined slightly in 1967, and then fluctuated about an average approximately twice the pre-construction mortality rate. They urged that proposals for highways through winter deer yards be evaluated in greater detail for the potentially serious detrimental effects on deer movements and populations.

Removal of roadside trees will result in significant impacts on wildlife only in certain situations. Mitigation for loss of wildlife values of roadside trees is possible and probably warranted where large clumps or long rows or strips of trees are removed.

The three most practical mitigating measures are:

1. Planting shrubs to replace lost food sources and travel corridors.

2. Piling brush from the cut trees for shelter for small mammals and birds.

3. Constructing artificial nest boxes to replace loss of potential nesting sites in tree cavities.

Planting shrubs

There are numerous species of shrubs that have high wildlife values. Zorb (1966) reported that autumn olive (Eleaegnus umbellata) was the shrub most preferred by wildlife managers in Michigan. Allan and Sheiner (1959) found that thickets of autumn olive furnished cover and food for many species of wildlife. The berries of this shrub were particularly attractive to songbirds, bobwhite quail, ruffed grouse, and ring-necked pheasant.

Borrell (1950) recommended that Russian olive (Eleaeganus angustifolia) could provide the best food and cover of any plant in the Midwest. Edminster (1950) found that tartarian honeysuckle offered good wildlife shelter, especially for shrub-nesting birds, and summer and early fall food for many songbirds. He also stated that multiflora rose (Rosa multiflora) is one of the best shrubs for erosion control and wildlife cover. Gysel and Lemmien (1955) found that of the seven species of trees and shrubs investigated in Michigan, multiflora rose was the only species used intensively by cottontail rabbits, deer, and songbirds for both food and cover throughout most of the year. However, Scott (1955) suggested that multiflora rose is a potential pest species because of its tendency to spread easily from seed.

Gordinier (1958) recommended nine species of shrubs for southern Michigan: autumn olive, Morrow's honeysuckle, multiflora rose, intermediate lespedeza, Siberian crab, western sand cherry, silky dogwood, bicolor lespedeza, and highbush cranberry. He advocated spacing rows 6 to 8 feet apart to allow forb and grass growth between shrubs for better wildlife habitat, rather than a continuous shrubby cover.

Brush piling

Brush piling is frequently used to provide cover for wildlife, especially rabbits (Schofield, 1955; Yoakum and Dasmann, 1969; Knight, 1971). Shoman, et al. (1966) recommended piling brush to provide escape cover for wildlife and encourage burrowing by woodchucks. Woodchuck burrows are, in turn, used by a variety of mammals, amphibians, and reptiles. Yoakum and Dasmann (1969) stated that the carrying capacity of large clearings for upland game birds and cottontail rabbits can be increased by brush piles. They also noted that grasses, forbs, and vines often grow up through the brush and add density and permanence to the pile. Hamilton and Cook (1940) suggested that brush piles are important to several species of small mammals.

Several authors have suggested that size, shape, and structure of brush piles influence use by wildlife; however, no studies have verified this. Shomon, et al. (1966) recommended heaping brush over stumps or logs to prevent settling. Rusz and Bouregeois (1976) recommended scattered loose brush piles to improve winter habitat for ruffed grouse in Michigan, and denser piles for rabbits. Yoakum and Dasmann (1969) suggested that brush piles for cottontail rabbits be 25 to 50 feet long, 5 feet wide, and 4 feet high; they recommended loose piles along fence rows for pheasants. However, the aesthetics of having brush piles along roadways may be a consideration in some areas.

Artificial nest boxes

Nest boxes have been useful for wood ducks, squirrels and cavity-nesting songbirds. Basic designs for boxes and recommendations for installation are described in detail in Yoakum and Dasmann (1969), and Shomon, et al. (1966).

The removal of large clumps or wide strips of trees would result in significant changes in local wildlife values. Habitat for some species would be destroyed and new habitat for other species would be created. Whether the overall effect would be beneficial or detrimental would depend in large part on the effect of the cutting on interspersion and edge as discussed earlier (Page 33).

Removal of large numbers of trees in forested areas will usually increase edge. Development of edge habitat and the increase of edge species mitigates that loss of forest habitat and decline in forest species (Michigan State University, 1978). Edges increase the diversity of nesting and foraging sites for songbirds. Ferris et al. (1977) found that removal of forest cover in the I-95 right-of-way in Roscommon County decreased the number of birds by more than 80% during the first two years. However, the number of bird species increased and breeding pair numbers and species diversity were also higher along the edge than further from the right-of-way. Wintering and ground-nesting birds utilized forest area within 165 feet of the right-of-way more than other forested areas, suggesting that effects of right-of-way clearing extended into adjacent forest habitat.

According to Michigan State University (1978):

> Removal of forest vegetation destroys habitat for woodland species of small mammals, while development of clearings and edges in the ROW (right-of-way) creates habitat for other species. Baker (1971) reported that agricultural and suburban development destroy small rodent habitat, but that forest clearings and grassy ROWs provide new foods and create habitat for these grass eaters.
>
> Ferris et al. (1977) reported that replacement of forest cover by grass cover within ROWs shifted the relative abundances of forest and grassland species of small mammals while total abundance remained unchanged. (i.e., total number of species stay the same but number of individual species will vary).

Michigan State University (1978) also reported loss of habitat for turkey and spruce grouse after clearing of the I-75 right-of-way. Similar findings have been reported in studies of the effects of right-of-way clearing for other roads, electric transmission lines, and pipelines across the country (Foster, 1956; Arner, 1977; Tillman, 1976). Most authors suggest that clumps of shrubs and trees mixed with open grassy cover and even bare ground usually attract the most species of wildlife. To achieve maximum wildlife benefits, however, site-specific management plans based on an analysis of existing resources and limiting factors for various types of wildlife are essential (U.S. Fish and Wildlife Service, 1978).

Hydrologic Effects

Where roadside trees provide shade for streams, they can help to keep water temperatures cool in summer, in turn benefiting cold water fish (Lagler, 1952; White, 1973).

Michigan's coldwater streams receive inflow of groundwater throughout the summer, negating some of the effects of increased solar radiation. White and Brynildson (1967) recommend removal of trees from streams that received groundwater inflows to encourage growth of shade-tolerant vegetation beneficial to trout. Herrington and Heisler (1973) state that changes in stream temperatures may be one of the most important impacts of rights-of-way. Brown et al. (1971) found that the impact of removing shade from a stream may be estimated by the empirical formula:

$$T = \frac{A \times H}{D} (0.00267)$$

where: T = stream temperature in ^{o}F
A = the exposed surface area of the stream in square feet
H = the maximum heat input in BTU's/ft^2 minute
D = the stream discharge in cubic feet per second

Based on this formula, rights-of-way for highways can expose a sufficient length of a stream to cause detrimental changes in the stream's temperatures. This would be most likely to occur where a road was oriented parallel to a stream and trees were removed all along its southern bank.

Prior to removal of any trees near coldwater streams, the County Engineer must contact the Michigan Department of Natural Resources for a field assessment of possible effects. No trees are to be removed if increases in water temperature are likely to occur. It is very unlikely that such potential impacts will occur during roadside tree removal. Based on fatal tree accident analysis, a very low percentage of all generic roadside environments studied included water and wetlands.

Monetary Values

The economic values of roadside trees, particularly in urban/suburban areas, are becoming more widely recognized. In 1970, Detroit had 300,000 street trees with an estimated value of $60,000,000 (an average of $200 per tree). These dollar values were based primarily on investments in each tree by the cities. They do not reflect an attempt to place dollar values on the amenity values of urban trees (e.g., attractiveness, etc.).

Values of individual roadside trees for saw timber and firewood are easier to estimate. The City of Chicago recently began a comprehensive program for selective harvest and sale of street trees. Since any trees cut under this program would not likely be used for such purposes, these values are not relevant.

In addition to their values for saw lumber and firewood, trees can enhance property values (Kielbaso, 1971; Grey and Deneke, 1978). Payne (1975) found that trees may increase property value by as much as 20%, with average increases of 5 to 10%. Dense cover arrangements are more valuable than scattered trees on residential lots (Payne and Strom, 1975). In Michigan, real estate value of trees varies widely from county to county. Values are highest in the major population centers.

Grey and Deneke (1978) discussed the procedures for claiming income tax deductions for loss of ornamental trees. They suggested replacement costs, decreases in appraised property value, and other values as possible bases for calculating related tax deductions for collecting insurance payments.

In cases involving condemnation or civil suits and where aesthetic values of trees are of paramount importance, Grey and Deneke (1978) suggested use of the International Society of Arboriculture Shade Tree Evaluation Formula (International Society of Arboriculturists, 1975).

The evaluation procedure has been revised (International Society of Arboriculturists, 1979), and the basic revised formula for trees 8 to 40 inches in diameter is:

Tree value = basic value x species classification x condition factor x location factor

The basic value is calculated using the diameter 4.5 feet above ground to determine the cross-sectional area in square inches. The cross-sectional area is multiplied by $18 per square inch (the $18 value is based on 1979 dollars and can be adjusted due to inflation).

All other items (species classification, condition factor, and location factor) are expressed in percentages from 1 to 100. The species classification is based on local experience and varies with species and area. The condition factor combines age, growth form, and presence of disease into a single value. The location factor uses screening value, noise abatement, and climate modification to judge the architectural, engineering, climatic, and aesthetic value of trees (International Society of Arboriculturists, 1979).

The removal of roadside trees results in the loss of monetary values of trees wherever they are cut. Possibly the most practical way to dispose of lumber or firewood is by sale, because of the small number of trees cut in a single area and the high transportation costs involved.

Aesthetic Values

The myriad aesthetic values of trees are interrelated in complex ways. The primary aesthetic value of an individual tree or group of trees may be either as an object to be seen and noticed or as a frame, backdrop, or screen for a view beyond. Shrubs and herbaceous plants are also aesthetically pleasing, but in comparison with trees, have limited ability to control views or other objects or areas.

The visual elements of trees include shadows and reflections as well as color, texture, shape, growth form, condition, and movement. Such aesthetic values are described in some detail in Robinette (1972).

In open agricultural areas, trees draw attention to farmsteads, individual fields, cemetaries, streams, and other entities. In urban areas trees can emphasize and articulate design elements. As Robinette (1972) stated:

> Plants can be used as emphasizers, accentuators, and punctuators. The designer can use them to say: "This is it! This is the most important thing in the landscape."
>
> ....Plants may be used for diverting attention, for hiding, or for attracting attention in another direction...Plants used in this manner are effective on highways, where movement is fast and perception quick.

Roadside trees are very important to local and regional aesthetics because they are viewed regularly by large numbers of people. The removal of roadside trees would affect aesthetics wherever trees are cut. Straight clearing edges resulting from tree removal are potential focal points to travelers because they sharply contrast with adjacent natural vegetation in color, texture, and form. Freshly cut stumps visible to passing notorists or adjacent viewers may also draw attention to locations where trees were removed, accentuating an artificial change in the natural character of the roadside. On the other hand, many roadside trees suffer from road salting, air pollution, ponding (owing to the roadbed's interference with cross-drainage (Michigan State University, 1978), or physical damage. Removal of such trees usually benefits local aesthetics. Tree removal can also allow views of lakes, streams, and other attractive scenes.

Most roadside trees in Michigan, however, are aesthetically pleasing. Many compliment other scenery. In most areas, the most important factor influencing the aesthetic impact of tree removal is the effect on landscape diversity. Removal of trees in open areas is generally detrimental; tree removal in heavily forested areas is often beneficial in creating habitat for shrubs, showy wildflowers, and grasses. Removal of trees at specific locations, such as the outside of curves, may provide the traveler with a sequence of enclosures and openings that add variety to the driving experience, particularly in forested areas.

Significant losses of aesthetic value occur if visually pleasing trees that screen unsightly areas, such as junkyards, landfills, and industrial sites, are removed. Removal of trees from the medians of divided highways significantly reduce aesthetics by allowing views of other traffic.

Some mitigation for loss of aesthetic value of trees is practical and warranted in some areas. Shrubs can be planted to add diversity to rights-of-way in open agricultural or urban/suburban areas. However, shrubs will not be high enough to be effective in screening unpleasant scenes in many areas.

In forested areas, edges formed by clearing are in sharp contrast with surrounding vegetation and may become potential focal points to travelers; other mitigative measures may be applied. An undualting clearing edge (Figure 8) will help break up an otherwise straight line which reinforces the unnatural line of the road itself. As indicated by the Forest Service (1977), "a side benefit of the undualting edge is that of providing the traveler with a sequence of enclosures and openings which add variety to the driving experience."

Another method to reduce the aesthetic impact resulting from tree removal is by feathering clearing edges (Figure 9). This involves a reduction of vegetative density in transitional degrees (low density or number of trees per acre to higher density or number of trees per acre) as well as a gradation of tall vegetation down to low vegetation at clearing edges. Thus, an artificial line, form, color, and texture contrast made by clearing edges is faded out into a wider transitional band. With feathering techniques of large trees, their falling across or onto the highway from windthrow is less likely to occur.

Selective removal of trees to attain feathered edges provides an opportunity to cull out those trees which will be less likely to survive new conditions produced by cutting such as windthrow, sun-scald, and changes in soil moisture.

Although freshly cut stumps may be flush with the ground, if visible, particularly in urban and built-up areas, they act as an unfavorable reminder of trees which once existed there. Covering the fresh cuts with even a thin layer of dirt or painting to blend with the ground will go a long way to mitigate their impact.

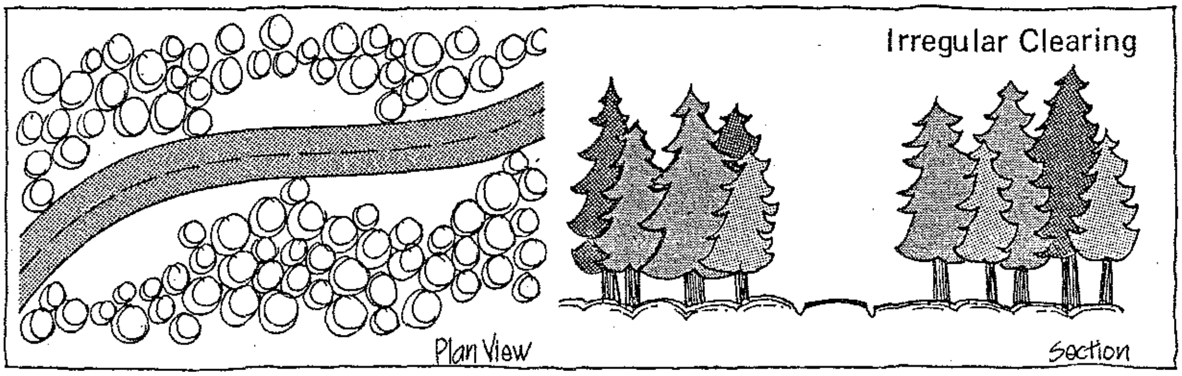


FIGURE 8 IRREGULAR CLEARING - PLAN AND SECTION VIEW

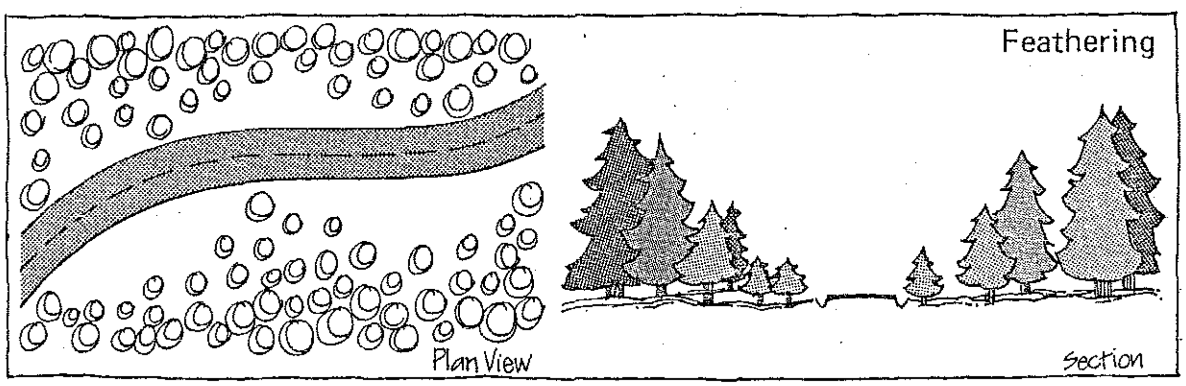


FIGURE 9 FEATHERING - PLAN AND SECTION VIEW

Cultural Resources

Impact on cultural resources is of two types: 1) direct, where land modifying activities associated with tree removal actually alter or destroy an archaeological or historical site or portions of such a site so as to render it useless to investigation, research, access, or view, and 2) indirect, where tree removal would affect the integrity or the aesthetic value of a particular historical property.

Impact of tree removal in itself is minimal if trees are removed at ground level. Most impact occurs because of presence of heavy equipment. Heavy machinery can compact and disturb the surface of sites so as to seriously alter their nature. Impact also occurs due to associated activities such as grub and hoeing or the dragging of logs over the surface of the site. An indirect impact on cultural resource structures or remains is likely when trees are removed near the site area.

Impact must also be considered from the point of view of the amount and intensity of removal. Trees can be removed as a single unit, a small or large clump, a row, or a large strip. An increase in site damage occurs if larger units of trees are removed and/or more intense land modifying activities are used. Tree density varies in different types of off-road environments. Forest density along county roads is greater than along interstate highways or trunklines. One would expect more tree removal, then, to occur along county roads than along interstates.

The land-use categories of the off-road environment have been combined with road conditions to form 16 categories of generic roadside environments (see Appendix D in Phase 2 Report). With the above in mind, these various roadside environments can be rated as to the impact on cultural resources.

For Types 1 and 2, Interstate/curve and straight, tree removal is less likely to occur. Sensitive areas include river crossings or lake or wetland borders. Any area 1/4 of a mile on each side of a river crossing should be considered highly sensitive.

Types 3 to 6, Trunkline/curve and straight, and Type 4, Trunkline/urban and built-up, contain the highest number of existing structures that may be of historical importance. Tree removal affects the integrity of such sites. Type 5, Trunkline/straight forest, contain sites in various locations. Sensitive areas include forest-prairie edges or wetland/forest areas, especially when flat benches or terraces are present bordering such areas. Various archaeological sites are randomly associated with agricultural activity. Farmhouses of historical importance to regional and local history are most often found in agricultural regions. Rangeland is randomly associated with archaeological sites. Water and wetlands are often associated with archaeological sites, and such areas can be considered extremely sensitive.

Tree removal affects Type 7-14 environments, county/straight and curve in the same ways. Sites are variously associated with agricultural and rangeland categories. Forest lands are sensitive in edgeland areas with a greater majority of sites occurring in the broadleaf forest or the mixed deciduous/coniferous forest. As mentioned above, more tree removal is postulated for county road areas because of the greater density of trees. Because of this, more impact would be expected to occur here. County road areas are also expected to contain a greater number of sites still undisturbed by urbanization. Stream crossings, lakes, and wetland border areas are considered zones of high sensitivity.

Types 15 and 16, City/straight and curve, are most apt to contain historic standing structures of importance or, in some cases, even historic districts. Archaeological sites in the urban environment are usually disturbed and under fill. But it is possible to recover these and in certain cases they yield important archaeological evidence. Rivers running through cities or villages are especially sensitive areas archaeologically and contain sites of both prehistoric and historic nature.

STATEWIDE AND REGIONAL IMPACTS OF TREE REMOVAL

Since tree removal is dependent upon site-specific conditions, a set distance for removal cannot be established and applied on a regional or statewide basis. Survey data can be used, however, to estimate the number of trees on a statewide basis that might be affected by a tree removal program.

Estimating The Number of Trees That Will Be Removed

During the study, the number of trees present at various distances from interstate, trunkline, and county roadways was estimated. These estimates are presented by generic roadside environment in Table 5. The number of trees existing along both sides of Michigan's roadways within 40 feet of the road edge totals 19,278,074. Tree densities along county roads, however, are much greater than along interstates and trunkline: 18,575,092 of the trees exist along county roads. Since most county roads lie within a 66 foot right-of-way, assuming 12 foot lanes, only about 21 feet remain from the road edge to the right-of-way boundary along these roads. Approximately 11,136,000 trees exist within this area. On interstate and state trunkline roads, because the right-of-way is wider, it is more appropriate to consider trees out to 40 feet from the road edge. There are approximately 702,982 trees in this area. The total of trees within 21 feet of county roads and 40 feet of state trunkline and interstate roads, therefore is 11,838,982. Not all of these trees will pose any safety risk at all and therefore would not be considered for treatment. Of those that are considered, treatment (removal or an alternative) would not be required in all cases.

In a significant percentage of sites, alternatives to tree cutting could be carried out. This will further reduce the number of trees considered for removal.

The Impact of Risk On Removal

Not all trees which require removal would be removed at one time or in one year. Tree removal should be carried out on a priority basis; that is, higher risk sites first, then the next higher risk sites, and so on, until the risk has been reduced to an acceptable level (as determined by an appropriate judicial or governmental authority). Until an acceptable level of run-off road tree/vehicle risk is established, a more precise estimate of the total number of trees affected can only be estimated. A method to compute the effect on tree/vehicle accident rates of tree removal and the distance within which trees might be considered for treatment along roadsides is described in Appendix E.

On a statewide cumulative basis, if analysis of the need for treatment were confined to sites (top 50%), using the fatal tree/vehicle accident survey as a basis, 97.4% of all county curves, 60% of all trunkline curves, 25.4% of all county straight roads, and 29.4% of all trunkline straight roads would be considered for tree removal (Table 6). Of the 4,962,922 trees along these roads, 2,718,719 are located within 20 feet of either side of a county road.

Table 5. Estimated Number of Existing Trees for Both Sides of Roads in Michigan by Distance from Road Edge Categorized by Generic Roadside Environment[1]

Generic Roadside Environment[2]	Estimated Miles in Michigan[3]	Estimated Number of Existing Trees by Distance from Road Edge[4]								
		0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	Totals
Interstate:										
Curve -	13.178	--	--	--	--	--	18	80	78	176
Straight -	1,304.658	--	--	--	--	--	1,744	7,932	7,620	17,326
Trunkline:										
Curve -	71.944	--	24	196	644	864	1,438	1,606	2,084	6,856
Straight -										
Urban & B-u	569.793	--	182	1,550	5,106	6,838	11,396	12,718	16,502	54,292
Forest	3,632.429	--	1,162	9,880	32,546	43,590	72,648	81,076	105,196	346,098
Other	2,920.188	--	934	7,944	26,164	35,042	58,404	65,178	84,568	278,234
County:										
Curve -										
Urban & B-u	26.696	782	2,258	2,968	2,478	1,704	1,544	1,480	1,646	14,860
Agriculture	106.784	3,126	9,030	11,874	9,910	6,818	6,176	5,920	6,586	59,440
Forest	170.187	4,984	14,392	18,924	15,794	10,864	9,844	9,436	10,498	94,736
Other	30.033	880	2,540	3,340	2,788	1,918	1,738	1,666	1,852	16,722
Straight -										
Urban & B-u	2,642.904	77,384	223,484	293,892	245,262	168,724	152,866	146,522	163,014	1,471,148
Agriculture	10,571.616	309,538	893,936	1,175,564	981,046	674,892	611,462	586,090	652,058	5,884,586
Forest	16,848.513	493,324	1,424,710	1,873,554	1,563,542	1,075,610	974,518	934,082	1,039,216	9,378,556
Other	2,973.267	87,058	251,420	330,628	275,902	189,814	171,974	164,838	183,392	1,655,044
TOTALS		977,076	2,824,072	3,730,314	3,161,200	2,216,678	2,075,800	2,018,624	2,274,310	19,278,074

[1] Estimated number of trees are based on statewide tree density sampling conducted as part of this study by Asplundh Environmental Services for Interstate, Trunkline, and County roads in Michigan. The average number of trees by road type was identified for 5-foot intervals from the road lane edge out to 40 feet for 1-mile sections.

[2] Fourteen Generic Roadside Environments (see Phase II Report) are listed above. Tree density information was not collected for Generic Roadside Environments 15 and 16, and it is therefore not presented here.

Table 5. Concluded

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[3]Miles of road are based on a personal letter to Dan Minahan, University of Michigan, Highway Safety Research Institute, Ann Arbor, MI, from John F. Woodford, Michigan Department of Transportation, April 23, 1979; and 1976 "Trunkline Vehicle Miles", Tri-Agency report, Michigan Department of State Highways and Transportation. Ninety-nine percent of the miles of road, by road type, was apportioned to straight sections and one percent to curve sections. To derive miles of road associated with Generic Types 4 through 14 (Trunkline straight, County curve, and County straight), miles of road within each road type curve or straight section groupings were apportioned based on percent occurrence of land cover/use types in Michigan (see discussion Phase II Report Appendix B, Section 1 "Distribution of Generic Roadside Environments").

[4]The estimated number of trees that exist were computed to three decimal places and then rounded to the nearest whole number. Totals presented here by Generic Roadside Environment may vary slightly from totals presented on other tables by road type curve and straight section because of this rounding off process.

Table 6. Estimated Number of Trees to be Considered for Removal in the Upper 50% of Higher Risk Vehicle/Tree Accident Locations in Michigan by Distance from Road Edge for Road Type Curve and Straight Section Groupings[1]

Road Type Curve and Straight Section	Estimated Miles in Michigan[2]	Estimated Number of Trees to be Considered for Removal by Distance from Road Edge[3]								
		0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	Totals
Trunkline Curve	43.166	--	7	59	193	259	431	482	625	2,056
Trunkline Straight	2,093.989	--	670	5,696	18,762	25,128	41,880	46,738	60,642	199,516
County Curve	325.024	4,758	13,742	18,072	15,081	10,375	9,400	9,010	10,023	90,461
County Straight	8,391.220	245,695	709,562	933,104	778,705	535,696	485,348	465,209	517,570	4,670,889
TOTALS		250,453	723,981	956,931	812,741	571,458	537,059	521,439	588,860	4,962,922

[1] Based on statewide tree density sampling conducted as part of this study by Asplundh Environmental Services for Interstate, Trunkline, and County roads in Michigan.

[2] Based on personal letter to Dan Hinahan, University of Michigan Highway Safety Research Institute, Ann Arbor, MI. From John P. Woodford, Director, Michigan Department of Transportation, April 23, 1979, and 1976 "Trunkline Vehicle Miles", Tri-Agency report, Michigan Department of State Highways and Transportation.

[3] The estimated number of trees which exist were computed to three decimal places and then rounded to the nearest whole number. Totals presented here by road type curve or straight section may vary slightly from totals presented on other tables by generic roadside environment type because of this rounding off process. Number of trees shown for all curved roads (Interstate, Trunkline, County) reflects trees on one side only. All straight road conditions reflect trees on both sides of the road.

Based on accident risk analysis completed for Phase II of this study, curved county roads carry the highest risk of tree/vehicle accidents and require priority treatment. Only 51,653 trees exist within 20 feet of curved county roads. There are 4,962,922 trees along county and trunkline roads (within 40 feet of the road edge) that can be considered in the upper 50% of the risk of vehicle/tree accidents. If all 51,653 trees on curves were cut, that would amount to about 1% of the higher risk trees. It would represent less than 1/2 of 1% of all trees within 20 feet of the edge of all county road (curved and straight) and less than 3/10 of 1% of all trees within 40 feet of the road edge of all road types.

Based on the total number of trees affected, removing the trees involved in 50% of the higher risk tree/vehicle accident sites would not have a high cumulative statewide environmental impact. Because the majority of higher risk sites occur at outside curves and these road segments account for less than 1% of the roads by mileage (based on Phase 2 Report, pages C-1 and C-2), the impact of removing affected trees on the environment in Michigan would be negligible and dispersed within the landscape.

Removal of trees in the top 50% of the higher risk sites includes 25.4% of all county straight roads. Here, removal of trees beyond 10 feet would have increasingly significant cumulative environmental impact because removal would not necessarily be dispersed, and significantly greater numbers of trees would be affected.

Removal of trees in the top 60% of the higher risk sites and beyond includes a substantially greater proportion of county straight roads and would have proportionately greater cumulative environmental impact, both in numbers and functional and aesthetic value.

Distribution of Trees

Removal of trees along higher risk road sections will not occur equally throughout the entire State. The tree/vehicle accident problem occurs with much greater frequency in the lower half of the Lower Peninsula on all types of roads--interstate, trunkline, county, and city (see Figures 1 and 2, Phase 2 Report). According to recent data on the cumulative number of fatal accidents that occurred between 1976 and 1977 (Figure 10), a higher than average number of fatal tree/vehicle crashes (4 or more) occurred on rural interstates, trunklines, and county

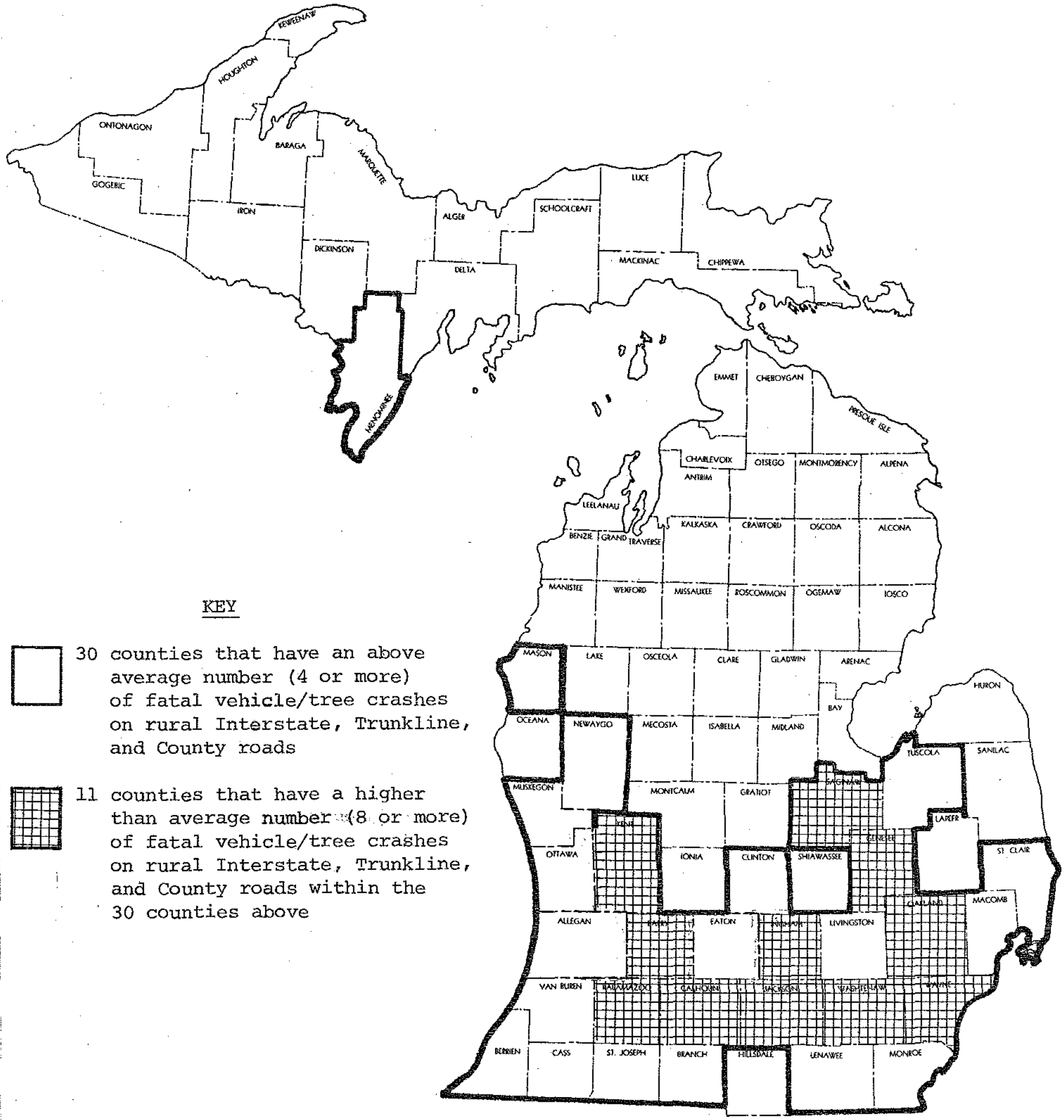

FIGURE 10 MICHIGAN COUNTIES THAT HAVE A HIGHER THAN AVERAGE NUMBER OF FATAL TREE/VEHICLE CRASHES ON RURAL INTERSTATE, TRUNKLINE, AND COUNTY ROADS (1976-1977)

roads in 30 counties. For this two-year period, 221, or 77% of the fatal tree/vehicle accidents occurred in these counties. About 46% of these accidents occurred in 11 of these counties. This data does not mean that these percentages will hold over a longer data sampling period--such as 5 to 6 years. Based on two years of data, however, the tree/vehicle accident problem seems to occur regionally.

If the distribution of fatal tree/vehicle accidents (1976-1977) is directly related to the percentage of higher risk tree/vehicle accident road sections occurring in the State, then 77% of the higher risk rural road sections (interstates, trunklines, and county roads) exist in these counties. This means that a disproportionately higher number of trees may have to be considered for removal in the lower half of the Lower Peninsual. As many as 77% of all trees considered for removal may be within higher risk sites occurring in these 30 counties. A proportionately higher number of trees may also have to be considered for removal in the 11 counties in which 46% of the fatal tree/vehicle accidents occurred during 1976-1977. Regional impact would be greater in these areas than in the rest of the State.

Additionally, because of higher than average daily traffic volumes (ADT's) and other factors, e.g., higher roadside tree densities (compared with statewide averages), these 30 counties, and especially the grouping of 11 counties, may contain a greater percentage of higher risk tree/vehicle accident locations and require priority treatment. Because of the greater frequency of higher risk tree/vehicle accident sites present in these counties compared to the entire State, impact of tree removal programs may also be greatest.

If tree removal within the above-mentioned counties is done, it will occur along rural interstate, trunkline, and county roads. As a whole, the area within the lower half of the Lower Peninsula is generally flat to gently rolling, extensively agricultural, and includes larger population centers and major metropolitan areas such as Detroit, Chicago, Grand Rapids, and Flint. Since a greater proportion of higher risk tree/vehicle accidents (relative to the extent of the total land in the State) will occur in the counties nearer the major metropolitan areas, these counties will most likely receive priority treatment. It must be remembered, however, that alternative treatments to tree removal would be considered, thus reducing the overall number of trees that will be removed.

It should also be emphasized that the number of trees that exist along roadsides is based on statewide averages and does not reflect regional differences in tree densities or numbers of trees that actually exist along roadsides.

Sensitivity of Roadside Environments

Going beyond the individual aesthetic value of trees, some areas (e.g., urban and built-up) may be more aesthetically sensitive to tree removal than others. The aesthetic value of trees combines with their functional value within the landscapes (e.g., pastoral or wilderness) to improve the quality of urban and built-up and other areas. For example, removal of trees along a roadside in a forested area may expose the road and road right-of-way to potential viewers from higher vantage points, either from nearby roads, residential areas, or recreational areas. The detrimental impact on the aesthetic quality of the surrounding landscape varies with the degree to which tree removal exposes the road. On the other hand, spot clearing may add diversity and interest to the landscape and improve aesthetic qualities. In urban and built-up areas, trees may screen harsh or unsightly conditions and clutter (utility poles, wires, concrete walls, etc.). Hence, trees add considerable aesthetic value which defines and enhances all landscapes, urban or rural. The cumulative visual impacts of removing trees is dependent on the aesthetic sensitivity of a roadside environment.

Factors considered important to road placement and construction by the U.S. Forest Service (U.S. Forest Service, 1977) are applicable to many aspects of tree removal and to determination of the sensitivity of a roadside environment. These factors include:

1. The Number of Potential Viewers

   How many people will view the roadside environment in a normal year? This would include people driving on the road, viewing the roadside, and people viewing the road right-of-way from other places.

2. Duration of View

   Will the potential viewers see either the roadway or views resulting from tree removal along the roadside and beyond for just a fleeting moment or will they view it for several hours a day?

3. Type of Potential Viewers

   Are the potential viewers concerned with the maintenance of the quality of the scene viewed, or are they people who are just in a hurry to pass through?

4. Type of Area from which the Roadway is Viewed

   Will the roadway be viewed from an aesthetically pleasing area such as a pastoral landscape or from an interstate road?

5. Number and Intensity of Focal Points that Compete with the Road for Attention

   Are there other focal points in the landscape that will draw attention away from the view?

These and other factors should be considered as they relate to the Michigan landscape, particularly where regional impact is likely to be greater.

The flat to gently sloping topography of Michigan greatly minimizes the likelihood that removal of trees at higher tree/vehicle risk locations, even at all the sites in the lower half of the Lower Peninsula, will have cumulative regional impacts. This type of terrain minimizes the viewer perception of where trees have been removed. Survey data (1976) confirmed that at 151 fatal tree/vehicle accident sites, views existed beyond 1/2 mile (to middleground or background views) only 1.3% of the time. With appropriate mitigative measures (feathering and undulating cutting lines) tree removal in areas with exceptional views may be minimized. Use of appropriate mitigative measures where the number of potential viewers increases (particularly in the lower half of the Lower Peninsula) helps minimize aesthetic impacts. These types of mitigative measures are particularly useful and necessary in areas where tourists or landscapes associated with high scenic values and concerned viewers are important. Significant cumulative aesthetic impacts may otherwise exist, especially where landmarks or high traffic volumes (exposure to larger numbers of viewers) exist.

Because the number of trees per mile to be removed in urban/suburban areas is small (removal is not broadly applied to city streets; see page 13 of the Phase 2 Report), statewide and regional impacts on climate, noise, and air pollution are minimal. The most important statewide and regional impacts of the proposed tree removal project are associated with wildlife habitats and aesthetic value. Related adverse impacts (see pages 33 to 36, and 41 to 44) are significant only if trees are removed beyond 10 feet on both sides of all straight/County roads, particularly in agricultural areas and urban and built-up areas. Agricultural areas contain a high percentage of trees to be considered for treatment, 32.3% or approximately 6,192,540 trees out to 40 feet from the road (see Table 5). Of the trees in agricultural areas, a high percentage (97%) of "barrier" trees exist adjacent to straight county roads. Although urban and built-up areas do not contain a high percentage of trees to be considered for treatment in this project (8.0% or approximately 1,532,870 trees out to 40 feet from the road), these locations may be especially sensitive because of the aesthetic and functional role "barrier" trees have. Forty-nine percent (19 out of 39) or roughly 1/2 of the "barrier" tree sites adjacent to urban and built-up areas also exist in straight county roads (Table 7).

Since most county road rights-of-way extend only about 21 feet from the edge of the road, confining tree removal and maintenance to the right-of-way significantly reduces impact on aesthetic value and wildlife. Confining tree removal along straight county roads to the right-of-way reduces the number of "barrier" trees to be removed by an even greater percentage.

Since tree removal, for legal and economic reasons, is likely to be confined to the right-of-way, the proposed program will have minimal statewide and regional impact on aesthetic value and wildlife for interstate and trunkline and county curve roads. Significant regional aesthetic impact could occur if trees are removed beyond 10 feet from county straight road edges for trees in the top 50% or 60% of the higher risk sites and beyond. A proposed statewide program may have significant positive statewide and regional impact on snow removal efforts by reducing drifting and icing of roads, and providing areas to pile snow. These benefits are of particular importance in the Upper Peninsual and northern areas of the Lower Peninsula.

Table 7. Distribution of "Barrier" Trees within 40 Feet of the Road Edge[1]

	Generic Roadside Environment	Total		Adjacent to Agriculture		Adjacent to Urban & B-u	
		Ratio[2]	%[3]	Ratio[2]	%[3]	Ratio[2]	%[3]
1 & 2	Interstate (Curve and Straight)	1/3	33				
3	Trunkline/Curve	7/10	70				
4	Trunkline/Straight/Urban & Built Up	4/8	50			4/8	50
5	Trunkline/Straight/Forest	2/6	33				
6	Trunkline/Straight/Other	3/3	100	3/3	100		
7	County/Curve/Urban & Built Up	16/18	89			16/18	89
8	County/Curve/Agriculture	8/8	100	8/8	100		
9	County/Curve/Forest	3/11	27				
10	County/Curve/Other[4]	1/1	100				
11	County/Straight/Urban & Built Up	19/20	95			19/20	95
12	County/Straight/Agriculture	20/21	95	20/21	95		
13	County/Straight/Forest	3/16	19				
14	County/Straight/Other[4]	1/1	100				
	TOTAL (Ratio, Overall %)	88/126	70	31/32	97	39/46	85

[1]Based on 1976 fatal tree accident survey data (Density Variable 183) where barrier trees include: (1) One tree, (2) One of several, (3) One of clump, (4) One of a row, and (5) Among brush. Data is based from 154 fatal accident sites that exclude missing data, unrelated data, and city streets.

[2]Number of sites with barrier trees per total number of sites.

[3]Percentages are rounded off to the nearest whole number.

[4]Limited data available.

When trees are removed, the area thus cleared may need to be maintained by mowing. Virtually all of Michigan's roadsides are maintained by regular mowing, usually at 2- to 3-year intervals. Mowing may result in the long-term loss of the functional values of roadside trees. Because the area from which trees would be clear-cut are likely to be relatively small, the increase in mowing is not likely to be great.

MOWING

Vegetation and Wildlife

Mowing reduces the diversity of both vegetation and wildlife (Leedy, 1975). Mowing does not kill woody vegetation quickly; however, repeated mowing favors fast-growing grasses and certain forbs. Hesse and Salac (1973) studied the response of 11 species of wildflowers in Nebraska to mowing on 12 different dates. They found that all species survived the mowing, but that plant vigor and the number of flowers per plant were generally reduced. Mowing creates favorable conditions for certain grasses and associated small mammals, and this undoubtedly helps such "prairie" species extend their ranges (Baker, 1971).

Schmidly and Wilkins (1977) and Ferris et al. (1977) found the total densities and species diversity of small mammals to be highest in unmowed sections of road rights-of-way. Bird species diversity also tended to be higher in unmowed sections. Mowing also often reduces habitat value for important game bird species. In Illinois, Joselyn et al. (1968) found that unmowed and seeded-unmowed roadsides contained 1.7 and 2.5 times more pheasant nests, respectively. They recommended a minimum mowing schedule for highway rights-of-way and the seeding of selected grasses and legumes to provide cover for a variety of wildlife species, such as quail, pheasants, rabbits, and some songbirds. In an area where 90% of all roadsides were so managed, the pheasant population doubled in three years.

As stated by Leedy (1975):

> Oetting and Cassel (1971) found that ducks responded quickly to cessation of mowing when alternate miles of right-of-way and half the interchange triangles were left unmowed along an interstate in North Dakota. Seventy-four percent of the ducks chose unmowed

> nesting sites....Oetting indicated that the big ducks-mallards [Anus platyrhynchos], pintails [Anus acuta], and gadwalls--were especially responsive to cessation of mowing (cover changes), whereas shovellers [Anus clypeata] and blue-winged teal [Anus discors] were not. Martz (1967) made similar observations concerning gadwalls. On the basis of their studies, Oetting and Cassell (1971) strongly recommended "....non-mowing of ditch bottoms or back slopes, minimal mowing of inslopes, and no mowing before July 20 to enhance waterfowl nesting and to reduce maintenance costs of highway rights-of-way in duck producing regions."

Mowing can directly cause significant mortality of ground-nesting game birds. Oetting and Cassel (1971) recommended no mowing before July 20 to enhance waterfowl nesting. Trautman, et al. (1959) recommended refraining from mowing roadsides until July 10 in South Dakota to avoid losses of pheasants. Joselyn and Tate (1972) and Montag (1975) suggested a July 31 first mowing date to avoid losses of pheasants in Illinois.

Refraining from mowing during the nesting season is undoubtedly the best mitigation for direct losses of wildlife. However, some reduction in bird loss can be achieved by mounting flushing devices (a bar in front of the mower which will flush birds before blades cut the grass) (Zorb, 1957).

The aesthetic impact of establishing a treeless roadside depends on numerous site-specific factors. Literature on the specific aesthetic impact of mowing, however, is very scarce and contradictory. Studies by Hesse and Salac (1973) suggest that mowing often reduces the aesthetic value of roadside wildflowers. An Illinois survey indicated that rural landowners were concerned about "weedy, shabby-looking roadsides." A survey of 738 landowners (Montag, 1975) indicated considerable public acceptance of unmowed rural roadsides:

> Among the 595 questionnaires returned, 60 percent of the landowners believed that roadsides were important to wildlife. A total of 62 percent said they would be willing to leave their roadsides undisturbed year-round, if weeds and drifting snow were not a problem. This level of cooperation would likely increase if landowners were allowed to mow after July 31, and if the effectiveness of

managing roadsides for wildlife was demonstrated...managed roadsides had a uniform appearance, acceptable both to the landowner and general public.

Oetting and Cassel (1971) found that 82% of the 182 motorists they interviewed had not noticed the alternating mowed-unmowed condition of a stretch of interstate highway in North Dakota.

In urban/suburban areas where well kept grassy areas compliment adjacent lawns and parks, mowing of roadsides can have positive aesthetic impact.

Agriculture

In general, mowing of roadsides in agricultural areas has a positive impact. Unmowed roadsides serve as a seed source for many species of undesirable weeds and were a major concern of farmers interviewed in Illinois by Montag in 1975. Since mowing tends to reduce the number of weed species, weed control in agricultural fields adjacent to mowed roadsides is often simpler and less expensive than along unmowed roadsides. Quantitative studies of such impacts, however, are lacking.

Mowing of roadsides is also an important source of hay in many rural areas of Michigan. Indeed, much of the mowing of roadsides in some rural counties is performed by farmers. If seeded with alfalfa and other desirable plants, roadside hay production per acre can approach that of other agricultural land.

Creation of Fire Breaks

Where the potential for fire and subsequent damage to valuable resources are high, road rights-of-way can have considerable value as fire breaks. The paved portions of county roads are sometimes insufficient to block the spread of wildfire if the rights-of-way are lined with woody fuel.

The value of a particular road right-of-way as a fire break depends on numerous factors, including the fire potential of adjacent lands, the right-of-way cover type and orientation, and the value of resources on adjacent lands. Choice of right-of-way cover type(s) and maintenance technique(s) is the most important factor. Herbaceous (especially short grass) plants on rights-of-way are generally more effective from a fire control point of view than other types of rights-of-way vegetation. Woody rights-of-way with dense "second growth" make particularly poor fire breaks.

MAINTENANCE ALTERNATIVES TO MOWING

There are a variety of techniques to control tree growth on road rights-of-way besides mowing. These techniques (or combinations of techniques) can also be used to provide wildlife habitat and influence the aesthetic values of roadsides.

There are two kinds of vegetation management techniques for right-of-way maintenance: broadcast (non-selective) and selective. The most commonly-used broadcast techniques are mowing (already discussed) and mechanical cutting or spraying of herbicides. Cutting and application of herbicides can also be done on a selective basis, with desirable shrubs and, perhaps, small trees retained.

The effects of mowing and other non-selective cutting depend on numerous site-related variables. The impacts of the maintenance alternatives also vary greatly from site to site. However, some general conclusions can be drawn from available literature to compare techniques to mowing.

Herbicide Application

Herbicides have been used to manipulate vegetation for several decades. Herbicide application is the most widely used technique for right-of-way maintenance. Recently, wildlife managers have also begun using herbicides to shape habitats.

Literature on the effects of herbicides on vegetation and wildlife is voluminous. Effects of specific herbicides on various plant species have been documented (deVaney, 1968; Cody, 1975). Considerable information on application methods is also available (DeVaney, 1968; Barnhardt et al., 1972; Carvell, 1973).

Herbicide application is a controversial subject among ecologists as well as the general public. Some studies have shown that herbicides can enhance habitat for certain wildlife species (Jenkins, 1955; Krefting et al., 1956, 1960; Leonard and Gain, 1961; Gysel, 1962; Krefting and Hansen, 1969); MacConnel (1968) and others have advocated their use in habitat management. In contrast, other ecologists have reported detrimental effects of herbicides on wildlife habitat (Goodrum and Reid, 1956; Tietjen et al., 1967). Johnston (1973) and Carvell (1976) studied blanket-sprayed rights-of-way in Georgia, Minnesota, West Virginia, and Virginia and selectively sprayed rights-of-way in California, Louisiana, New Hampshire, New Jersey, and Oregon. They concluded that the effect of blanket-spraying on plant communities was a smaller number of perennial herbs. However, the selectively sprayed rights-of-way were very similar to naturally occurring old field communities.

In the vast majority of cases in which the effects of blanket (broadcast) spraying and selective spraying were compared, selective spraying resulted in greater species diversity of both plants and wildlife. In addition, numerous authors (Niering and Goodwin, 1974; Bramble and Byrnes, 1969, 1976) have shown that selective use of herbicides can result in relatively stable shrub-herb-grass communities that resist tree invasion and hence are cheaper to maintain than the grassy rights-of-way that occur after broadcast spraying, mowing, or prescribed burning.

However, public criticism of herbicides has caused many industries and governmental agencies to abandon the use of both selective application as well as broadcast spraying of herbicides. Carvell (1973) stated that much of the criticism of herbicides resulted because of incidences of indiscriminate use. He further suggested that association of 2,4,5-T with the unpopular Vietnamese War may have indirectly increased public criticism of herbicide application.

The environmental and economic effects of herbicides were recently reviewed by the U.S. Environmental Protection Agency (EPA, 1974):

1. Herbicides have been used effectively in some cases to improve habitats.

2. The prime sources of herbicide pollution are drift during application and volatilization and runoff after application. After application, some herbicides vaporize rapidly and may drift and damage nontarget plants in the near vicinity.

3. Residues of the herbicides reviewed do not seem to build up in the air, water, or soil environments. Fortunately, the chemical and physical characteristics of herbicides cause most of them to degrade within about 3 months. A few herbicides bioconcentrate in aquatic organisms, but the concentration is seldom more than tenfold. Levels in warm-blooded animals are usually below detectable limits.

4. Herbicides may cause physiological changes in plants, which in turn could upset the ecological relationship between these plants and animals associated with them. Several herbicides increase toxic substances, such as potassium nitrate, produced by plants, making the plants poisonous to animals ingesting them. Also, herbicides can alter nutritive constituents of plants such as proteins and vitamins. The limited data available suggest that such changes have produced only minor problems.

5. Predicting the impact of herbicides on a particular species is difficult because organisms differ in their sensitivity to herbicides. Present data concerning the toxic effects of

herbicides on plant and animal species and ecosystems are insufficient to predict the changes that will occur in natural ecosystems. With current use patterns, most herbicides degrade rapidly, with little or no bioconcentration in the life system. Hence, on the basis of limited data, herbicide impact on natural ecosystems appears minor.

6. Little information is available concerning low-level, long-term, chronic effects on herbicides on nontarget species.

7. In some rights-of-way areas, herbicides permit selective vegetation management not otherwise possible. In extensive areas of rough terrain, the aerial application of herbicides provides the only practical method of brush control. Contamination of nontarget areas may occur because rights-of-way are only a few hundred feet wide and extend for many miles through vast wild habitats. Overall, however, the problem of pollution appears to be minor because applications are infrequent and closely regulated.

8. The costs, benefits, and risks to man and his environment in using herbicides are most comples; however, in comparison with insecticides, herbicides are generally a smaller environmental hazard.

The EPA (1974) noted that, on flat terrain, if only a grass cover is desired, mechanical means may be equally effective in right-of-way maintenance but more expensive. Along road rights-of-way in 1962, herbicide control of brush cost about $9 per mile per year, whereas mechanical control cost about $16 (McQuikling and Strickenberg, 1962). This cost-comparison, however, assumed use of the recently-banned 2,4,5-T; costs of control with other herbicides is only slightly less than right-of-way maintenance by mechanical means (EPA, 1970). Selective herbicide application has higher initial-treatment costs, but retreatments are needed much less frequently than with blanket spraying; costs are esentially equal over a period of years (Svenson, 1966; Hall and Neiring, 1959; Potomac Electric Power Co., 1964).

The literature suggests that selective use of herbicides usually has greater beneficial impact on wildlife and long-term aesthetic value than either broadcast spraying or non-selective mechanical clearing (including mowing). However, use of herbicides along Michigan roads will result in some short-term loss of aesthetic value. Applications usually are made during the growing season and will cause browning of the treated plant.

Brownouts have been a source of numerous citizen complaints to utility companies that use herbicides for transmission line maintenance. Widespread use of herbicides, particularly broadcast spraying, for road right-of-way maintenance would undoubtedly result in more citizen complaints about loss of aesthetic value than would mowing.

In recent years, there has been considerable interest concerning possible use of chemical growth retardants to reduce or replace mowing. Some studies in the Eastern United States yielded promising results. However, in 1968-69 a study was conducted by Beard et al. (1971) to observe the retardation of roadside vegetation near East Lansing, Michigan, by maleic hydrazide and other commercial growth retardants. They concluded:

> The two growth regulations studies conducted on typical Michigan roadside trufgrass (sic) communities indicate that no growth regulations commercially available provided sufficient, effective growth reduction to replace the mechanical mowing practices now being followed.

Selective Cutting

Selective cutting is becoming increasingly popular for both right-of-way maintenance and wildlife management. As in the case of selective use of herbicides, selective cutting can be used to create relatively stable shrub-forb-grass communities which resist tree invasion, require less frequent retreatment, and are generally more beneficial to most wildlife species and to roadside aesthetic value.

Besadney, et al. (1968) reported that a selective brush maintenance program for Wisconsin roadsides provided wildlife and aesthetic benefits. Desirable shrubs were cut back to permit resprouting. Low shrubs were retained, and large trees and diseased shrubs were removed. Trees that provided wildlife and aesthetic value were retained. Similar results were reported after selective cutting on a Pennsylvania utility power line right-of-way (Ulrich, 1976).

Cavanaugh, et al. (1976) compared the effects of selective cutting and clearcutting on utility rights-of-way in New Hampshire and concluded that maximum wildlife diversity after construction of a new right-of-way can be obtained by selectively removing only those trees that interfere with the transmission line. Wildlife utilization and the number of browse plants were significantly greater in selectively cut areas. They suggested that clumps of shrubs and small trees mixed with sparser vegetation, open grassy cover and bare ground should be obtained where possible by selective cutting.

Tillman (1976) found that by favoring low growing shrubs such as Vaccinum spp. and Viburnum spp., selective cutting retained valuable wildlife habitat and created a low growing plant community that required very little maintenance. Utilization of the right-of-way by white-tailed deer and rabbits increased; their browsing helped maintain low vegetation.

Perhaps the biggest drawback to widespread use of selective cutting for road right-of-way maintenance is the cost associated with training of personnel. To obtain maximum wildlife and aesthetic benefits, minimize costs, and avoid extensive future right-of-way maintenance, selective cutting should be carefully planned and based on detailed inventories of existing vegetation and other features (Goodland, 1973; Randall, 1973). Such initial training costs would also be involved in selective use of herbicides.

ALTERNATIVES TO TREE REMOVAL

The alternative treatments that can feasibly be used for each generic roadside environment, and/or hazard profile (see Appendix F) are presented below. For discussion purposes, alternative treatments are grouped by on-roadway and off-roadway protection. The feasibility and effectiveness of alternative treatments are discussed and summarized for practical use in "Guidelines for Removing Hazardous Trees from Highway Rights-of-Way: A Management Manual."

On a site-specific basis, the off-roadway area of possible environmental impact is limited for most alternative treatments. Natural factors which may be affected include soil-water relationships, vegetation, and drainage. Human factors of greatest significance are effects on adjacent land use, traffic flow, and aesthetic qualities. Generally, the extent of impact is proportional to the extent of soil disturbance. Most impacts are of short duration (during construction) and are site-specific. Road relocation, boulevard construction, and shoulder-widening, however, may have significant impacts that require impact assessment. Since alternative treatments are conducted only where they are most cost-effective, and/or where tree removal cannot be performed because of special considerations (Chapter 5, Guidelines for Removing Hazardous Trees From Highway Rights-of-Way: A Management Manual) regional and statewide impacts are limited and do appear significant.

Impacts on cultural resources (archaeological) are judged as if the land-modifying activities associated with specific alternatives occur in an archaeological site area. Prior survey determines the presence or absence of archaeological sites. Lack of evidence of cultural material in the area indicates that there would be no impact on these locations.

In assessing impact, the nature of archaeological sites must be considered. Although deeply stratified sites exist in the Great Lakes Region, the majority of archaeological phenomena occur in the top or A zone of the soil profile. It is within these few inches of the A zone that the important data resides and the interpretation of any site is made. The relationship of cultural material in a real and stratigraphic sense is critical to this interpretation by professional archaeologists. This relationship is the basic framework by which the physical, economic, and social activity which existed at an archaeological site may be judged. Artifacts may indicate the temporal position and or cultural affinities of an archaeological site, but in a disturbed state or out-of-context situation they render little else.

Short of bulldozing for grading purposes, which completely destroys the meaningful data from an archaeological site, several types of land modifying activity can disturb or destroy significant data existing in a site area. These activities include:

1. Grub and hoeing in association with tree or brush removal.
2. Use of heavy machinery, such as backhoes, dozers, pans, or drill rigs, passing back and forth over the site.
3. Excavations for foundations or posts in erecting signs or rail barriers.
4. Creation of "storage areas" for metal or wood associated with construction.
5. Creation of access roads or barrow pits.

ON-ROADWAY PROTECTION

Pavement markings-- Pavement edge and centerline marking with nighttime traffic areas are frequently inundated by fog, and sections of roadway with narrow pavement. Reflectorized edge markings serve to emphasize the curvilinear alignment of the road, thereby reducing the number of run-off-road incidents. Pavement marking can usually be done at the same time and utilizing the same equipment and material as lane marking, etc.

Pavement markings produce no significant environmental effects, but visual uniformity may be a consideration in scenic or special use areas.

Roadway delineators and signing-- Roadway delineators and advance warning signs are effective for roadways with heavy nighttime traffic and numerous curvilinear sections. Installation of reflectorized delineators and warning signs can help reduce the number of run-off-the-road incidents. Advisory speed plates used to supplement warning signs can also be used to emphasize the need for reduced speed through a higher risk road section. All traffic signs should conform in design and placement with the requirements of the Michigan Manual of Uniform Traffic Control Devices. They can be installed using equipment, material, and procedures used for the installation of standard traffic signs.

Delineators and signs produce no significant environmental effects. However, visual conflicts may occur in special cases. For example, the positioning of the signs can affect the integrity or aesthetics of structures of historical importance. Objections may come for other aesthetic reasons, but even then the impact of signs is significantly less than other alternatives. Delineators and signs may impact an archaeological site to the extent that machinery passes back and forth over the site area and some excavation is performed to install signs. They increase the difficulty in mowing; additional maintenance may be required. They can also cause vehicle damage when struck.

Speed reduction-- A combination of excessive speed for roadway conditions and a curvilinear alignment increases the possibility of run-off-the-road incidents. In those areas where the roadside vegetation is extremely dense and there are numerous large trees adjacent to the travelled portion of the roadway a method of reducing run-off-the-road accidents has been to designate long sections, i.e., half mile and over as scenic drives. With this designation, a speed limit restriction is usually imposed and acts as a further deterrent to run-off-the-road incidents. These restrictions should only be imposed after an engineering and traffic investigation has been made in accordance with the established traffic engineering practices and the signs installed according to the Michigan Manual of Uniform Traffic Control Devices. These signs can be installed using the equipment, materials, and procedures used for standard traffic signs.

Studies have shown that speed reductions have little or no effect on 85 percent of the drivers or in the number of accidents. Additional enforcement of existing speed limits also has shown little effect.

Speed reduction creates no significant environmental effects. It may, however, reduce other types of accidents and cause minor shifts in traffic patterns and road use.

Designation of a road as a scenic drive and an associated speed reduction may eventually allow more vegetation to grow closer to the road edge. This may reduce sight distances and decrease sun filtration, increasing road icing in the winter and leading to hazardous driving conditions. However, the presence of roadside trees reduces glare.

Correcting superelevations-- In a number of areas, particularly on old country roads, an excessive crown or incorrectly shaped crown directs vehicles off the road towards existing trees. By using bituminous materials to wedge up the outside edges of the pavement, a new surface contour can be created which will steer vehicles away from contact with the roadside trees. This work is usually done by maintenance forces using road graders, spreader boxes, and steel rollers.

The primary environmental impact of this treatment is restricted traffic flow during application. Off-road use of heavy equipment, such as asphalt pavers and trucks transporting asphalt, could seriously impact an archaeological site area. Off-road use of equipment might destroy ground cover and promote local soil erosion. Generally, though, no significant environmental impact results if activities are restricted within the road shoulders.

Widening and paving shoulders-- Shoulder widening and conversion from gravel to surfaced areas can be used as spot treatments to improve the recovery potential of vehicles straying off the roadway. Shoulder widening and resurfacing generally have little environmental impact (assuming trees are not removed) because most of the activity relating to this treatment takes place on already disturbed areas immediately adjacent to the roadway. However, off-road activity of heavy equipment could seriously impact an archaeological site if it existed.

Earth moving and fill can cause significant erosion and sedimentation of adjacent water and wetland areas, particularly if no erosion control measures are taken. However, nearby water and wetland areas occur infrequently (based on generic roadway environments) on a statewide basis. Impacts, if any, would be limited to site-specific situations.

OFF-ROADWAY PROTECTION

Installing guardrail-- This treatment can prevent run-off-the-road vehicles from striking existing trees as well as other roadside obstructions. A properly designed guardrail, conforming to the standard plans developed by the Michigan Department of Transportation, can effectively dissipate the vehicle energy before contact is made with tree(s) or can channel the vehicle away from the trees. Guardrail construction can be done by maintenance crews using power augers or hand tools.

The installation of a single guardrail (spot treatment) impacts the environment minimally. It may reduce visual quality in some areas, such as near historical or aesthetically sensitive locations. Installation of guardrails may have a high impact on each archaeological site. On curves it may have the positive effect of discouraging deer crossings, which often cause run-off-the-road accidents. If grading or extensive excavation is necessary, soil erosion may occur. The temporary effects of traffic flow alterations during installation are minimal.

<u>Regrading ditches</u>-- All too frequently, roadside ditch maintenance and cleaning results in ditch lines constructed extremely close to existing trees. The result is that a vehicle which has left the travelled portion of the roadway becomes trapped in the ditch depression so that the driver cannot recover steering control and the vehicle is channelled directly into existing trees. The relocation of the ditch can eliminate this problem if there is ample room within the road right-of-way to construct a new ditch. This work is usually done with gradalls, motor patrol graders, or backhoe equipment. The work can be done as a part of a routine maintenance operation.

The amount of regrading required to redirect vehicles away from hazard trees will vary with each situation. The extent of potential impacts will also vary. No effects on drainage can be anticipated, assuming the regrading will result in equal or better water discharge. Possible negative effects, however, e.g., excessive drainage, should be considered in special situations. The primary environmental impact may be soil erosion and sedimentation during and after construction. If additional right-of-way is required, the effects on adjacent land use and drainage may be important. Again this type of alteration may have a high impact on an archaeological site if present. An archaeological site survey should definitely precede this activity. Such activity occurring near structures of historic importance could affect the integrity of such structures.

Altering slopes-- Frequently front slopes of road embankments on backslopes of ditch sections lead directly downgrade to existing trees. In some cases, it is possible to regrade the slope to direct the run-off-the-road vehicles away from the trees or provide additional space to permit the driver to regain control of his vehicle. This work can be done using graders, front end loaders, gradalls, or small earthmovers and can be included in routine roadside maintenance work.

Environmental concerns with this treatment are similar to those of ditch re-grading-- soil erosion, sedimentation, and drainage.

Planting vegetation-- Protective plantings of dense shrubs may be used where existing trees pose a hazard to run-off-the-road vehicles. Care must be taken to select shrubs which are indigenous to the area, require little continuing maintenance, and can be planted with a high degree of growth success.

The functional role of vegetation is generally associated with positive environmental effects (i.e. noise abatement, aesthetics, wildlife habitats, etc.) However, this alternative would impact archaeological sites where excavations are made to complete plantings. This activity could seriously disturb the surface pattern of cultural material.

Installing protective berms-- In roadside areas where there is sufficient room between the travelled portion of the roadway and the existing trees, a protective earth berm can be constructed to direct run-off-the-road vehicles away from the trees. These berms may be landscaped and shaped in such a way that there is no imposition on the roadside environment. This work is usually done using earth-moving equipment such as graders, front end loaders, gradalls, or small earth-movers.

Excavation of fill material on the right-of-way, and particularly off the right-of-way, may create negative environmental impacts, depending on site characteristics. Drainage of the right-of-way may be altered and affect adjacent areas and the roadway itself. Placement of fill material to construct the berm may alter soil moisture and soil aeration relationships of adjacent vegetation. Soil erosion and sedimentation may have to be controlled. Environmental impact on archaeological sites may be significant and would be similar to those discussed in above.

Road relocation or realignment-- These methods are particularly effective when existing roads are being reconstructed and improved, because it also involves heavy equipment. During the realignment of the new road, for instance, curves can be flattened and relocated to increase the isolation of the existing trees from the roadside. Road relocation entails more extensive cost and impact considerations than all previously discussed treatments. Significant short-term impacts will definitely occur. Long-term impacts will be site-specific as well as involve removal of cultural features due to road relocation. Projects which require additional rights-of-way to place the roadway further from trees will have the most environmental impact. An extended period of traffic detouring will disrupt local travel patterns and shift the associated impacts to other roads for the period of reconstruction.

Road relocation may mean direct habitat loss to vegetation and wildlife. Indirect effects may be disruption of habitat continuity and travel lanes for wildlife. An environmental assessment is required before this method can be employed. Such activity should not occur without a proper cultural resource survey of the projected impact area done under the auspices of the Michigan Department of Transportation and the State of Michigan History Division.

Boulevard construction-- This treatment is effective in areas where multiple lane pavements are planned on an existing road alignment. The construction of additional lanes frequently brings the edge of the travelled portion of the roadway extremely close to existing mature trees. By obtaining additional right-of-way behind the tree row it is possible to construct a boulevard section, divide the roadway into separate direction lanes, and increase the distance from the existing trees to the edge of the pavement. Additionally, this treatment separates oncoming traffic, and provides median space for turning lanes. Boulevard construction requires heavy equipment and is usually done as a part of the major reconstruction project.

Since boulevard construction treatment requires construction of new roadway, its design is dependent on traffic requirements and its length on the number of trees to be preserved and site-specific characteristics. The permanent surfacing of lanes and shoulders removes these areas from other uses. Adjacent land acquired for the wider right-of-way, will have limited use. The extent of environmental impact depends on site sensitivity. Large projects may require environmental impact statements, or assessments. To be considered, the impacts of the project should not be greater than the impact of removing the trees, which are the target of preservation.

DETERMINING THE SITE-SPECIFIC TREATMENT

A variety of factors must be considered to determine the correct treatment (or nontreatment) for each site. Since most treatments are costly, the size of the statewide budget will exercise a controlling influence on the number and source of treatments that can be undertaken. Ideally, treatments are selected to yield the greatest reduction in expected fatalities, within the available budget. This yield must be discounted by the amount of environmental (aesthetic and ecological) damage resulting from the treatment.

Monetary costs of a specific treatment include not only those of implementation, but also future costs. These future costs involve periodic maintenance as well as repair or replacement if necessary. For example, guardrails often must be repaired after being struck by a vehicle; small trees must be cleared or trimmed as they become large enough to constitute a danger to passing vehicles; pavement marking may deteriorate after each year and require re-marking.

Environmental effects of a given treatment further complicate selection, both on a site-specific and a statewide basis. Like other costs, environmental effects have immediate impacts, typically of an aesthetic nature, and long-term impacts. For example, the environmental damage created by removing trees that serve as wind barriers may entail future impacts in the form of increased erosion. Environmental effects could well tip the balance in favor of a slightly more expensive treatment (in monetary terms), that eliminates the need to remove trees.

Determining the precise cost of implementing a specific treatment, requires an estimate of long-term maintenance and repair costs, the dollar value of all environmental effects, both short and long-term, the effectiveness of alternative treatments in reducing serious injuries or loss of life, and the allocation of available state resources. This is the ideal case, rather than reality. Presently, lack of knowledge about many of the costs involved in applying alternative treatments is accompanied by uncertainity about their relative effectiveness. What is required, however, is an integration of available knowledge into a general set of guidelines for selecting sites and treatments. The steps for determining sites and specific treatments are:

1) Consider the road segment type. Curved/County road segments are clearly the most dangerous overall, followed by curved/trunkline, straight/county roads, and straight/trunkline.

2) Weigh the road segment type by the average daily traffic (ADT) pass the site. For example, a curved/county road segment that has almost no traffic is less likely to be the site of an accident than a straight/county road segment that is very heavily traveled. Using the relationships presented in the hazard profile analysis, (see Chapter 3 of Guidelines for Removing Hazardous Trees From Highway Rights-of-Way: A Management Manual) this procedure is not difficult. The result is a rank ordering of the more dangerous sites.

3) Determine feasible (physically possible) treatments for a specific site. For each of the technically feasible treatments, implementation costs (i.e., tree cutting, sign or barrier erection, or grading), maintenance costs (clearing, painting, brush control and the like), and replacement of protective berm) must be balanced.

4) On a site-specific basis, evaluate the suitability of each feasible treatment in terms of its effectiveness in preventing or reducing the severity of roadside accidents.

5) Add in site-specific costs. If the easement on private land must be purchased for a specific treatment (e.g., clearing trees over 20 feet from the edge of curved/trunkline segment) these costs should be added, as appropriate.

6) Consider environmental effects. A variety of such considerations are discussed in Chapter 6 of the Management Manual, Alternative

Treatments. It cannot be over-emphasized that aesthetic and ecological impacts of a given treatment must be considered along with direct, monetary costs. In certain cases, a lower cost treatment will be categorically ruled out by the environmental costs involved.

REFERENCES

Allan, P.F., and W.W. Sheiner. 1959. Autumn olive for wildlife and other conservation uses. USDA Leaflet 458. 8 pp.

American Association of State Highway and Transportation Officials. 1977. Guide for Selecting, Locating, and Designing Traffic Barriers. AASHTO, Washington, D.C.

Anonymous. n.d. Road Research - Roadside Obstacles: their effects on the frequency and severity of accidents; development and evaluation of countermeasures. Report prepared by an OECD Road Research Group.

Arner, D.H. 1977. Transmission line rights-of-way management. U.S. Dept. Interior Fish and Wildlife Serv. Rep. FWS/OBS-76/20.2. 12 pp.

Automotive Safety Foundation. 1963. Traffic Control and Roadway Elements, their relationship to highway safety. Report sponsored by Bureau of Public Roads. 124 pp.

Aylor, D. 1972a. Noise reduction by vegetation and ground. J. Acoust. Soc. Amer. 51(1) Part (2): 197-205.

Aylor, D. 1972b. Sound transmission through vegetation in relation to leaf area density, leaf width, and breadth of canopy. J. Acoust. Soc. Amer. 51(1) Part (2): 411-414.

Aylor, D. 1975. Some physical and psychological aspects of noise attenuation by vegetation. In Metropolitan Physical Environ. Conf. Proc. USDA For. Serv. Northeast For. Exp. Stn.

Baker, R.H. 1971. Nutritional strategies of myomorph rodents in North American grasslands. J. of Mammalogy. 52:800-805.

Barnhardt, J.A., S.E. Brandt, C.H. Miller. 1976. Herbicides for rights-of-way, trails, and recreation areas. Pages 128-135 in: Herbicides in Forestry; proceedings of The John S. Wright Forestry Conference, Purdue University Dept. Forestry and Nat. Resources, W. Lafayette, Indiana.

Bates, C.G. 1911. Windbreaks: their influence and value. U.S. For. Serv. Bull. 86. 100 pp.

Bates, C.G. 1954. Shelterbelt Influences II. The value of shelterbelts in househeating. J. For. 43:88-92.

Beaman, J.H. 1977. Michigan's endangered and threatened species program. The Michigan Botanist. 16:110-112.

Beard, J., J. Fisher, J. Kaufmann, and D. Martin. 1971. Improved establishment and maintenance of roadside vegetation in Michigan. Mich. Agric. Exp. Stn., Mich. St. Univ. Farm Sci. Res. Rep. 144. 66 pp.

CONTINUED

Bellis, E.D., and H.B. Graves. 1976. Highway fences as vehicle-deer collision deterrents. Inst. for Research on Land and Water Resour., Penn St. Univ.

Bernatsky, A. 1968. The importance of protective planting against air pollutants. Pages 303-395 in Air Pollution Proc. First European Congress Infor. Air Pollution, Plants, Animals, Wagenigen, Wagenigen Center for Agric. Publications and Documents, the Netherlands.

Besadny, C.D., C. Kabat, and A.J. Rusch. 1968. Practical aspects of a selective brush management program on Wisconsin roadsides. Proc. N. Amer. Wildl. Conf. 33:237-294.

Bolt, Beranek, and Newman, Inc. 1969. Motor vehicle noise identification and analysis of situations contributing to annoyance. Motor Vehicle Mfgers. Assoc. of the U.S., Inc. Variable paging.

Borrell, A.E. 1950. Personal communication. In F.C. Edminster, The use of shrubs in developing farm wildlife habitat. Trans. N. Amer. Wildl. Conf. 15:519-540.

Bramble, W.C., and W.R. Byrnes. 1969. Fifteen years of ecological research on a utility right-of-way. Proc. Northeast Weed Control Conf. 23:270-278.

Bramble, W.C., and W.R. Byrnes. 1976. Development of a stable, low plant cover on a utility right-of-way. Pages 168-176 in R. Tillman, ed., Proc. of the First Natl. Symp. on Environ. Concerns in Rights-of-Way Manage. Miss. State, Miss.

Brown, G.W., G. W. Swank, and J. Rothacher. 1971. Water temperature in the steamboat drainage. USDA Forest Serv. Res. Paper PNW-119. 17 pp.

Carvell, K.L. 1973. Environmental effects of herbicides; herbicide use on electrical utility rights-of-way: a review of recent literature on herbicides, their safety and use. Edison Elec. Inst. Publ. No. 72-903. 61 pp.

Carvell, K.L. 1976. Effects of herbicidal management of electric transmission line rights-of-way on plant communities. Pages 177-181 in R. Tillman, ed., Proc. Natl. Symp. Environ. Concerns in Rights-of-Way Manage. Miss. State Univ., Miss.

Cleveland, E.D. 1970. Traffic control and roadway elements - their relationship of highway safety. Revised. Chapter 6. Speed and speed control. University of Michigan, Department of Civil Engineering/Highway Safety Research Institute, Ann Arbor, MI. 13 pp.

Cody, J. 1975. Vegetation management on power line rights-of-way: a state-of-the-knowledge report. Applied Forestry Res. Inst. State Univ. N.Y. Res. Rep. 28. 29 pp.

Cook, D.I., and D.R. Van Haverbeke. 1971. Trees and shrubs for noise abatement. Univ. of Nebraska Agric. Exp. Stn. Res. Bull. No. 246. 77 pp.

CONTINUED

Cook, D.I., and D.F. Van Haverbeke. 1974. Tree-covered land-forms for noise control. Univ. of Nebraska Agric. Exp. Stn. Res. Bull. No. 263. 47 pp.

Cook, D.I., and D.F. Van Haverbeke. 1977. Suburban noise control with plant materials and solid barriers. Univ. of Nebraska Agric. Exp. Stn. Res. Bull. No. EM100. 74 pp.

Crabtree, A., C. Bassett, and L. Fisher. 1978. Evaluation of pipeline construction on stream and wetland environments. Mich. Pub. Serv. Comm. Lansing. 172 pp.

Davis, D.D. 1970. The role of trees in reducing air pollution. In The Role of Trees in the South's Urban Environment. A Symp. Proc., Univ. of Georgia.

Davis, P.B., and C.R. Humphrys. 1977. Ecological effects of highway construction upon Michigan woodlots and wetlands. Agric. Exp. Stn., Mich. St. Univ.

Dawson, R.F., and J.C. Oppenlnader. Traffic control and roadway elements - their relationship to highway safety. Revised. Chapter 11. General design. Vermont University, Burlington, Dept. of Civil Engineering. 1971. 14 pp. Source: Highway Users Federation for Safety and Mobility, Washington, D.C.

Day, J.M. 1970. Roads and the conservation of wildlife. J. of Inst. of Highway Engineers. July. pp 5-11.

Dearinger, J.A., and J.W. Hutchinson. 1970. Traffic control and roadway elements - their relationship to highway safety. Chapter 7. Cross section and pavement surface. Revised. University of Kentucky, Lexington, Dept. of Civil Engineering. 75 pp. Source: Highway Users Federation for Safety and Mobility, Washington, D.C.

Deering, R.B. 1956. Effect of living shade on house temperatures. J. For. 54:399-400.

DeSanto, R.S., R.A. Glaser, W.P. McMillen, K.A. MacGregor, and J.A. Miller. 1976. Open space as an air resource management measure, Vol. II: design criteria. U.S. Environ. Protection Agency Rep. EPA-450/3-76-028b. Variable paging.

Detyler, T.R. and M.G. Marcus. 1972. Urbanization and environment: physical environment of the city. Duxbury Press, Belmont, Calf. 287 pp.

DeVaney, T.E. 1968. Chemical vegetation control manual for fish and wildlife management programs. U.S. Dept. Interior, Bur. Sport Fisheries and Wildlife Res. Publ. 48. 42 pp.

Edminster, F.C. 1950. Use of shrubs in developing farm wildlife habitat. Trans. N. Amer. Wildl. Conf. 15:519-550.

Embleton, T.F.W. 1963. Sound propagation in homogenous, deciduous, and evergreen woods. J. of the Acoust. Soc. of Amer., Vol. 33.

CONTINUED

Environmental Protection Agency. 1970. Herbicide report: chemistry and analysis, environmental effects, agricultural and other applied uses. U.S. Environ. Protection Agency. Rep. EPA-SAB-74-001. 196 pp.

Environmental Protection Agency. 1974. Herbicide report: chemistry and analysis, environmental affects, agriculture and other applied uses. Hazardous Materials Advisory Comm., Sci. Advisory Broad. Washington, D.C. 196 pp.

Federer, C.A. 1971. Effects of trees in modifying urban microclimate. Pages 23-28 in Trees and Forests in an Urbanizing Environment, Univ. of Mass. Cooperative Extension Serv. Monograph No. 77.

Federer, C.A. 1976. Trees modify the urban microclimate. J. of Arboriculture 2:121-127.

Ferris, C.R., D.S. Palman, and V.B. Richens. 1977. Ecological impact of Interstate 95 on birds and mammals in northern Maine. Completion Rept., Preconstruction Phase. Variable paging.

Ferris, C.R. 1974. Effects of highways on red-tailed hawks and sparrow hawks. West Virginia University, Morgantown, West Virginia, M.S. Thesis, 60 pp., 25 tables, 2 figures.

Flemer, W. III. 1974. The role of plants in today's energy conservation. Amer. Nurseryman. 89(9):10. 39-45 pp.

Foster, C.H. 1956. Wildlife use of utility right-of-way in Michigan. M.S. Thesis, Univ. of Mich., Ann Arbor. 103 pp.

Gale, R.M. 1973. Snags, chainsaws and wildlife: one aspect of habitat management. Trans. Cal-Nev Section Wildl. Soc. 144 pp.

Goodland, R. 1973. Ecological perspectives of power transmission. Pages 1-35 in R. Goodland, ed., Power lines and the environment. Cary Arboretum, Millbrook, N.Y.

Goodrum, P.D., and V.H. Reid. 1956. Wildlife complications of hardwood and brush control. Trans. N. Amer. Wildl. Conf. 21:127-240.

Gordinier, E. 1958. Establishing shrubby cover. Mich. Dept. of Conserv. Rep. 2168. 6 pp.

Gray, D.H. 1975. The role and use of vegetation for the protection of backshore slopes in the coastal zone. Dept. of Civil Eng., Univ. Of Mich., Ann Arbor, 30 pp.

Grey, G.W., and F.J. Deneke. 1978. Urban forestry. John Wiley & Sons, N.Y. 279 pp.

Gysel, L. 1962. Vegetation and animal use of a power line right-of-way in southern Michigan. Q. Bull. Mich. Agric. Exp. Stn. 44(4):697-713.

Gysel, L.W., and W. Lemmien. 1955. The growth and wildlife use of planted shrubs and trees at the W.K. Kellogg Multiple Use Forest. Mich. St. Univ. Quarterly Bull. 38(1):139-145.

Hall, W.C., and W.A. Niering. 1959. The theory and practice of successful control of "brush" by chemicals. Proc. Northwest Weed Control Conf. 13:254-256.

CONTINUED

Hamilton, W., and D. Cook. 1940. Small mammals and the forest. J. For. 38:468-470.

Haugen, A.O. 1944. Highway mortality in southern Michigan. J. of Mammalogy 25(2):177-184.

Heese, J.F., and S.S. Salac. 1973. Effects of mowing on the vegetative and reproductive development of species of wildflowers. HPR Study 64-2. Univ. of Nebraska, Dept. of Hort. and For., Lincoln. 38 pp.

Heisler, G.M. 1977a. Discussion of ameliorization - how trees reduce energy loss in cities. Proc. Soc. Amer. For. 67-70 pp.

Heisler, G.M. 1977b. Trees modify metropolitan climate and noise. J. of Arboriculture. 3(11): 201-207.

Herrington, L.P., and G.M. Heisler. 1973. Microclimate modification due to power transmission rights-of-way. Pages 36-57 in R. Goodland, ed., Power lines and the environment. The Cary Arboretum, Millbrook, N.Y.

Herrington, L.P., and J.S. Vittum. 1975. Human thermal comfort in urban outdoor spaces. In Metropolitan Physical Environment-Conf. Proc., USDA For. Serv. Northeast For. Exp. Stn.

Hindawi, J.J. 1970. Air Pollution Injury to Vegetation. U.S. Dept. of Health, Education and Welfare, National Air Pollution Control Adm. Publication No. AP-71. Government Printing Office, Washington, D.C.

Hunter, W.H. 1977. Developing a method for roadside hazard elimination in North Carolina. UNC Highway Safety Research Center, Univ. North Carolina, Chapel Hill.

International Society of Arboriculture. 1975. A guide to the professional evaluation of landscape trees, specimen shrubs and evergreens.

Jacobs, R.E., and D.R. DeWalle. 1977. Effects of forest vegetation on energy consumption for trailer heating. Penn. St. Univ. Inst. Land and Water Resources. Final Rept. USDA grant FS-NE-22. 61 pp.

Jenkins, B.C. 1955. Wildlife habitat development with herbicides in Michigan. Proc. North Central Weed Control Conf. 12:58.

Jensen, M. 1954. Shelter effect: investigations into the aerodynamics of shelter and its effects on climate and crops. Copenhagen. 84 pp.

Johnston, P.A. 1973. Ecological effects of herbicide sprayings in shaping plant communities on transmission line rights-of-way. M.S. Thesis. W. Va. Univ., Morgantown. 196 pp.

Jorgenson, R. and Associates, Inc. 1978. Cost and safety effectiveness of highway design elements. National Cooperative Highway Research Program Report 197. Transportation Research Board, National Research Council, Washington, D.C.

CONTINUED

Joselyn G.B., and H.D. Tate. 1972. Practical aspects of managing roadside cover for nesting pheasants. J. of Wildl. Manage. 26(1): 1-11.

Joselyn, G.B., J.E. Warnock, and S.L. Etter. 1968. Manipulation of roadside cover for nesting pheasants - a preliminary report. J. of Wildl. Manage. 32(2): 217-233.

Kielbaso, J.J. 1971. Economic values of trees in the urban locale. Pages 82-94 in Symp. on the Role of Trees in the South's Urban Environment.

Kight, J. 1971. Cottontail rabbit. In How to Have Game on Your Land: Small Game. (Source unknown).

Kraebel, C.J. 1963. Erosion control on mountain roads. USDA Circ. 380. 1-44 pp.

Kramer, P.J., and T.T. Koxlowski. 1960. Physiology of trees. McGraw-Hill Co., N.Y. 642 pp.

Krefting, L.W., and H.L. Hansen. 1969. Increasing browse for deer by aerial applications of 2,4-D. J. Wildl. Manage. 33(4):784-790.

Krefting, L.W., H.L. Hansen, and M.H. Stenlund. 1956. Stimulating regrowth of mountain maple for deer browse by herbicides. J. Wildl. Manage. 20(4):434-441.

Krefting, L.W. and R.W. Hunt. 1960. Improving the browse supply for deer with aerial application of 2,4-D. Minn. Forestry Note 95. 2 pp.

Laechelt, R.L., and B. Williams. 1974. Value of tree shade to homeowners. Alab. For. Comm. Bull. 2450. 5 pp.

Lagler, K.R. 1952. Freshwater fishery biology. W.C. Brown Co. Dubuque, Iowa. 307-316 pp.

Leedy, D.L. 1975. Highway-wildlife relationships: Vol. 1, A state-of-the-art report. Fed. Highway Admin. Rep. FHWA-RD-76-5. U.S. Dept. of Trans. Washington, D.C. 183 pp.

Leisch, J.E. and Associates, Inc. 1971. Traffic control and roadway elements - their relationship to highway safety. Revised Chapter 12: alignment. Highway University Federation for Safety and Mobility, Wash., D.C. 19 pp.

Leonard, J., and S.A. Cain. 1961. The role of herbicides in wildlife management. Pages 1422-1426 in Recent Advances in Botany. Univ. Toronto Press.

Leopold, A. 1936. Game management. Charles Scribner's Sons, N.R. 481 pp.

Little, A.D. 1966. The state-of-the-art of traffic safety: a critical review and analysis of the technical information on factors affecting traffic safety. Cambridge, Mass. 639 pp.

CONTINUED

Logerwerff, J.V., and A.W. Specht. 1970. Contamination of roadside soil and vegetation with cadmium, nickel, lead and zinc. Environmental Science and Technology. 4(7): 583-586.

MacConnell, W.P. 1968. Habitat manipulation with modern herbicides. Trans. Northeast Section Wildl. Soc. pp. 11-23.

Martz, G.F. 1967. Effects of nesting cover removal on breeding puddle ducks. J. of Wildl. Manage. 31(1): 236-245.

Mattingly, G.E., and E.F. Peters. 1975. Wind and trees - air infiltration effects on energy in housing. Princeton Univ. Center Environ. Study Rep. 20. 101 pp.

McQuilken, W.E., and L.R. Strickenberg. 1962. Conn. Arboretum Bull. 13. 3 pp.

Michigan Department of Natural Resources. 1976. Michigan land cover/use classification system. Div. of Land Resour. Prog., Lansing. 60 pp.

Michigan Department of Natural Resources. 1978. Endangered and threatened species - amendments and additions to the state list. Mich. Dept. of Nat. Resources, Lansing. 33 pp.

Michigan Department of State Highways and Transportation. 1973. Urban systems procedural guidelines for project implementation. 144 pp.

Michigan State University. 1978. Ecological effects of highway construction upon Michigan woodlots and wetlands. Agric. Exp. Stn. Res. Rep., Mich. St. Univ. 254 pp.

Mobley, H.E., R. Jackson, W. Balmer, W. Ruziska, and W. Hough. 1973. A guide for prescribed fire in southern forests. USDA For. Serv. Atlanta, Georgia. 40 pp.

Montag, D. 1975. Roadsides for wildlife. The Minnesota Volunteer. March-April. 27-32 pp.

Mukammal, E.I., C.S. Brandt, R. Neuwirth, D.H. Pack, and W.C. Swinbank. 1968. Air Pollutants Meterology and Plant Injury. Geneva World Meterological Organization Technical Note No. 96.

Niering, W.A., and R.H. Goodwin. 1974. Creation of relatively stable shrublands with herbicides: arresting"succession" on rights-of-way and pastureland. Ecology. 55:784-795.

Olson, J.S. 1958. Lake Michigan dune development: 2. Plants as agents and tools in geomorphology. J. Geology. 66(4): 345-351.

Oxley, D.J., M.B. Fenton, and G.R. Carmody. 1974. The effects of roads on populations of small mammals. J. of Applied Ecology. 11(1): 51-59.

CONTINUED

Payne, B.R. 1975. Trees could make a difference in the selling of your home. Northeast For. Exp. Stn., For. Sci. Photo Story No. 26.

Payne, B.R., and S. Strom. 1975. The contribution of trees to the appraised value of unimproved residential land. Valuation. 22(2): 36-45.

Plumley, H.J. 1975. The design of outdoor urban spaces for thermal comfort. In Metropolitan Physical Environment Conf. Proc. USDA For. Serv. Northeast For. Exp. Stn.

Potomac Electric Power Co. 1964. Specifications for basal method of spraying woody plants on PEP Co. transmission rights-of-way on a lump sum basis. Unpublished.

Puglisi, M.J., D. Lindzey, and E.D. Bellis. 1974. Factors associated with highway mortality of white-tailed deer. J. of Wildl. Manage. 38:799-807.

Purcell C. 1956. The realty value of trees. Pages 128-135 in Proc. of International Shade Tree Conf. 32:128-135.

Randall, W.E. 1973. Multiple use potential along power transmission rights-of-way. Pages 89-113 in R. Goodland, ed., Power Lines and the Environment. The Cary Arboretum, Millbrook, N.Y.

Reethof, G., O.H. McDaniel, and G.M. Heisler. 1975. Sound absorption characteristics of tree bark and forest floor. In Metropolitan Physical Environment Conf. Proc. USDA For. Serv. Northeast For. Exp. Stn.

Reethof, G., L. D. Frank, and O.H. McDaniel. 1976. Absorption of sound by tree bark. USDA For. Serv. Res. Pap. NE-341. 6 pp.

Reilly, R.E., and H.E. Green. 1974. Deer mortality on a Michigan Interstate Highway. J. of Wildl. Manage. 38:16-19.

Robinette, G.O. 1972. Plants and their environmental functions. U.S. Dept. of the Interior, Natl. Park Serv. Publications, Washington, D.C.

Rusz, P.J., and A. Bourgeois. 1976. Natural resources inventory and management plan for the Benmark property, Roscommon County, Michigan. S&R Environmental Consulting, Jenison, Mich. Unpublished. 48 pp.

Schmidly, D.R., and K.T. Wilkins. 1977. Composition of small mammal populations on highway rights-of-way in East Texas. Texas A&M Univ., Texas Trans. Inst. Res. Rep. 197-1F.

Schofield, R.D. 1955. Brushpile research and management. Mich. Dept. of Conserv. P-R Proj. Rep. W-40R-9, 3E. 1 pp.

Scott, R.F. 1965. Problems of multiflora rose spread and control. Trans. N. Amer. Wildl. & Nat. Resour. Conf. 30:360-378.

Shomon, J.J., B.L. Ashbaugh, and C.D. Tolman. 1966. Wildlife habitat improvement. Natl. Audubon Soc., N.Y. 28 pp.

CONTINUED

Simonson, W.H. 1957. Abatement of highway noise with special reference to roadside design. Highway Res. Bull. No. 110, publication No. 363, Abatement of Highway Noise and Fumes, Highway Res. Board, Natl. Res. Council.

Stark, T.F., and D.R. Miller. 1975. The effect of synthetic surfaces and vegetation in urban areas on human energy balance and comfort. In Metropolitan Physical Environ. Conf. Proc. USDA For. Serv. Northeast For. Exp. Stn.

Svenson, H.A. 1966. Vegetation management of rights-of-way, selective maintenance for improved wildlife habitats and scenic values. U.S. For. Serv. Eastern Region.

Telford, E.T., and R.J. Israel. 1952. Median Study. State of California Dept. of Public Works Division of Highways. 28 pp.

Tietjen, H.P., C.H. Halvorson, P.L. Hedgal, and A.M. Johnson. 1967. 2,4-D herbicide, vegetation and pocket gopher relationships, Black Mesa, Colorado. Ecology. 48(4): 634-643.

Tillman, R. 1976. The southern tier interconnection: a case study. Pages 221-230 in R. Tillman, ed., Proc. Natl. Symp. Environ. Concerns in Rights-of-Way Manage. Miss. State Univ., Miss. 334 pp.

Ulrich, E.S. 1976. Selective clearing and maintenance of rights-of-way. Pages 206-219 in R. Tillman, ed., Proc. Natl. Symp. Environ. Concerns in Rights-of Way Manage. Miss. State Univ., Miss. State, Miss.

U.S. Fish and Wildlife Service. 1978. Planning for wildlife in cities and suburbs. USDI Tech. Bull. FWS/OBS-77-66. 64 pp.

Weidensaul, T.C. 1973. Are trees efficient air purifers? Arborists News, Vol. 38, No. 8, pp. 85-89.

Weiner, F.M., and D.N. Keast. 1959. Sound propagation over terrain. J. of the Accoust. Soc. of Amer., Vol. 31, June.

Wester, H.V., and E.E. Cohen. 1968. Salt damage to vegetation in the Washington, D.C. area during the 1966-67 winter. Plant Disease Rep. 52(5): 350-354.

White, R.J. 1973. Stream channel suitability for coldwater fish. Proc. Soil Conserv. Soc. Amer. 28:61-79.

Wilson, T.D. 1967. Pg. 3 in: The Institution of Highway Engineers: National Conference Papers, London, England, Dec. 7-8, 1967. 47 pp.

Woodruf, N.P. 1954. Shelterbelt and surface barrier effects on wind velocities, evaporation, house heating, snowdrifting. Kansas Agric. Exp. Stn. Tech. Bull. 77 pp.

U.S. Forest Service, USDA. 1977. National Forest Landscape Management, Vol. 2, Chapter 4, Roads. U.S. Government Printing Office. 60 pp.

CONTINUED

Yoakum, J., and W.P. Dasmann. 1969. Habitat manipulation practices. Pages 173-232 in R.H. Giles, Jr., ed., Wildlife Management Techniques. The Wildl. Soc., Inc., Washington, D.C. 633 pp.

Zorb, G.L. 1966. Shrubs for wildlife habitat improvement in southern Michigan. Michigan Dept. of Conserv. R&D Rep. 81. 14 pp.

APPENDIX A

MAJOR VEGETATIVE TYPES AND ASSOCIATED SOILS, DRAINAGE, PLANTS, AND WILDLIFE IN MICHIGAN*

All major vegetational type characteristics (and associated code numbers) are directly from the Michigan Land Cover/Use Classification System (Mich. Dept. of Natural Resources, 1976). The associated unique plant species, soil and drainage characteristics, and wildlife species occurring within each vegetational type are then outlined.

3 RANGELAND

Rangeland is defined as areas supporting early stages of plant succession consisting of plant communities characterized by grasses or shrubs. In cases where there is obvious evidence of seeding, fertilizing or other cultural practices, these areas should be mapped as rotation or improved pasture (Agricultural land, 2122 and 2123).

Endangered and Threatened Plant Species: There are several endangered and threatened species associated with rangeland habitat. Endangered plants include *Baptisia leucophaea* (cream wild indigo), *Gentiana saponaria* (soapwort gentian), and *Petalostemon purpureum* (red prairie clover). Families which contain one or more threatened species in rangeland habitat are: Cyperaceae (1 species), Poaceae (4), Acanthaceae (1), Apiaceae (1), Asclepiadaceae (3), Asteaceae (10), Convolvulaceae (1), Fabaceae (1), Gentianaceae (1), Lamiaceae (1), Rosaceae (3), Schrophulariaceae (1), Violaceae (1) (Beaman, 1977). For location of endangered and threatened species by county, see TABLE B-1.

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* Modified from Mich. St. Univ. (1978).

31 HERBACEOUS RANGELAND

Herbaceous rangelands are dominated by native grasses and forbs. Such areas are often subjected to continuous disturbance such as mowing, grazing or burning to maintain the herbaceous character. Typical plant species are quackgrass, Kentucky bluegrass, upland and lowland sedges, reed canary grass, clovers, etc.

311 UPLAND HERBACEOUS RANGELAND

Soils and Water: Well drained, with channelized surface drainage patterns. Laminar drainage will occur only occasionsally over flat, uniform areas during or after heavy precipitation. High rates of infiltration. Usually little damage from erosion given abundant plant growth which increases soil stability. Groundwater may migrate horizontally toward lower elevations depending upon geological characteristics of the subsoil. Soils are predominantly mineral with well established horizons.

Wildlife: Wildlife species associated with upland herbaceous rangeland are waterfowl (nesting), marsh and shore birds, upland game birds, birds of prey, songbirds, fur and game animals, and small mammals.

312 LOWLAND HERBACEOUS RANGELAND

Soils and Water: Well drained to moderately well drained with channelized surface drainage patterns. Laminar flow may occur occasionally over flat, uniform areas during or after heavy precipitation. Usually high rates of infiltration depending upon distance to water table from soil surface. Little damage from erosion given abundant growth of vegetation. Groundwater may be near the soil surface at various times of the year but is usually found at lower elevations. Soil is predominantly mineral and organic matter and smaller particles may be leached from the A horizon.

Wildlife: Wildlife species associated with lowland herbaceous rangeland include waterfowl (nesting), upland game birds, songbirds, fur and game mammals, and small mammals.

32 SHRUB RANGELAND

Shrub rangelands are dominated by native shrubs and low woody plants. If left undisturbed, such areas are soon dominated by young tree growth. Typical shrub species include blackberry and raspberry briars, dogwood, willow, tag alder, etc.

321 UPLAND SHRUB RANGELAND

Soils and Water: Well drained with channelized surface drainage patterns. Laminar drainage will seldom occur. High rates of infiltration. Usually little damage from erosion given abundant vegetative growth, unless heavy precipitation causes splash erosion on sloping areas or runoff is sufficient to cause gulley erosion. Groundwater may migrate horizontally to lower elevations. Soils are predominantly mineral with poorly developed profiles.

Wildlife: Upland shrub rangeland provides habitat for waterfowl, upland game birds, birds of prey, songbirds, fur and game mammals, and small mammals.

4 FOREST LAND

Forest lands are lands that are at least 10 percent stocked by trees producing an influence on the climate or water regime. Forest land can generally be identified rather easily from high-altitude imagery.

Lands from which trees have been removed to less than 10 percent stocking but which have not been developed for other use are also included. For example, lands on which there is forest rotation, involving clear-cutting and block planting, are part of Forest Land. On such lands, when trees reach marketable size, which for pulpwood in the Southeastern United States may occur in two or three decades, there will be large areas that have little or no visible forest growth. The pattern can sometimes be identified by the presence of cutting operations in the midst of a large expanse of forest. Unless there is evidence of other use, such areas of little or no forest growth should be included in the Forest Land category. Lands that meet the requirements for Forest Land and also for a higher use category should be placed in the higher category. Shrub communities will be mapped under rangeland (upland) and wetland (lowland).

Endangered and Threatened Plant Species: Endangered species found in woodlands are *Arnica cordifolia* (heart-leaved arnica), *Castanea dentata* (American chestnut), *Isotria medeoloides* (smaller whorled pogonia), and *Polygonatum biflorum* var. *melleum* (Solomon-seal). Families which contain one or more threatened species in woodland habitats are Cyperaceae (1 species), Liliaceae (4), Orchidaceae (4), Araliaceae (1), Aristolochiaceae (1), Asteraceae (1), Boraginaceae (1), Caprifoliaceae (2), Ericaceae (1), Fabaceae (1), Hippocastanaceae (1), Polemoniaceae (1), and Ranunculaceae (1) (Beaman, 1977). For location of endangered and threatened species by county, see APPENDIX B.

41 BROADLEAVED FOREST (generally deciduous)

In Michigan typical species are oak, maple, beech, birch, ash, hickory, aspen, cottonwood, and yellow poplar.

411 UPLAND HARDWOODS

Soils and Water: Well drained with channelized surface drainage patterns. Generally high rates of infiltration. Usually little damage from erosion given abundant plant growth. Overstory will decrease impact of raindrops which will decrease splash erosion. Heavy runoff may cause gulley erosion. Groundwater may migrate to lower elevations, depending upon substrata characteristics. Soils are predominantly mineral. Soils in maple, elm, or beech associations are likely to be loams or sandy loams whereas in birch, oak, or cherry associations soils may be sands or sandy loams. The A horizon is generally thicker in elm, maple, or beech associations than in oak, cherry, or birch areas.

Wildlife: Wildlife species associated with upland hardwoods are upland game birds, birds of prey, songbirds, fur and game mammals, and small mammals.

412 ASPEN, WHITE BIRCH, AND ASSOCIATED SPECIES

Soils and Water: Well drained to moderately well drained with channelized drainage patterns. High rates of infiltration. Little damage from erosion given adequate ground cover. If ground cover is sparse, gully erosion may occur with heavy runoff. Groundwater may flow horizontally. Soils are predominantly mineral and sandy in texture, with poorly developed horizons.

Wildlife: Wildlife species found in aspen and white birch associations are upland game birds, birds of prey, songbirds, fur and game mammals, and small mammals.

413 LOWLAND HARDWOODS

Soils and Water: Generally well drained to moderately well drained but may be poorly drained in ash or elm associations. Channelized drainage patterns or laminar drainage depending upon the depth to the water table. Little damage from erosion given abundant plant growth. Siltation from overflow of adjacent waterways may have altered textural composition of the soil. And the soil may have a high cation exchange capacity. Soils are predominantly mineral but may have a high percentage of organic matter in the A horizon. Groundwater may migrate horizontally but generally at a very slow rate.

Wildlife: Low-land hardwoods provide habitat for birds of prey, songbirds, fur and game mammals, and small mammals.

42 CONIFEROUS FOREST

Coniferous Forests include all forested areas in which the trees are predominatly those with needle foliage. In Michigan these would include species such as pine, spruce, balsam fir, larch, hemlock, and cedar.

421 UPLAND CONIFERS

Soils and Water: Well drained land with channelized surface patterns. Little laminar drainage. Very high rates of infiltration. Little damage from erosion given abundant plant growth unless heavy runoff causes gully erosion. Groundwater may migrate horizontally towards lower elevations. Soils are mineral, usually sandy with poorly developed profiles (podosols).

Wildlife: Wildlife species associated with upland conifers include upland game birds, birds of prey, songbirds, fur and game mammals, and small mammals.

422 LOWLAND CONIFERS

Soils and Water: Moderately well drained to poorly drained in cedar and tamarack associations. Moderately well drained to well drained in balsam-fir and spruce associations. Water table may be near the soil surface where cedar and tamarack predominate whereas water table will be further below the soil surface in spruce and fir areas. Laminar drainage will occur depending upon the level of the water table and uniformity of soil elevation. Infiltration rates will depend upon the water table and organic accumulation on the soil. Generally little erosion damage unless severe flooding occurs. Groundwater may flow horizontally depending upon elevation and the rate of flow will be low. Soils may be organic mineral, or mineral with significant overburden of organic matter.

Wildlife: Wildlife species found in lowland conifers are birds of prey, upland gamebirds, songbirds, fur and game mammals, and small mammals.

43 MIXED CONIFER-BROADLEAVED FOREST

Mixed forest land includes all forested areas where both broadleaved and coniferous trees are growing.

431 UPLAND HARDWOODS AND PINE ASSOCIATIONS

Soils and Water: Well drained in specific localities to moderately well drained. Channelized drainage patterns. High to very high rates of infiltration. Infiltration rates generally higher in birch, cherry, and oak sites, and lower in maple, elm, and beech areas. Little damage from erosion unless significant splash erosion occurs on slopes, especially if drops are not intercepted by the overstory or if heavy runoff causes gully erosion. Groundwater may migrate horizontally to lower elevations. Soils are predominantly mineral. In maple, elm, or beech areas soils are likely to be loamy with well developed profile whereas in birch, oak, or cherry areas soils are likely to be sandy with poorly developed horizons.

Wildlife: Upland hardwoods and pine associations provide habitat for upland game birds, birds of prey, songbirds, fur and game mammals, and small mammals.

432 ASPEN, BIRCH, AND CONIFER ASSOCIATIONS

Soils and Water: Well drained to moderately well drained with channelized surface drainage. High rates of infiltration. Little damage from erosion given adequate ground cover. If ground cover is sparse, gully erosion may occur with heavy runoff. Groundwater may flow horizontally. Soils are predominantly mineral and sandy in texture with poorly developed horizons.

Wildlife: Birds of prey, songbirds, fur and game mammals, and small mammals are found in aspen and birch with conifer associations.

433 LOWLAND HARDWOODS WITH CEDAR, SPRUCE, TAMARACK, ETC.

Soils and Water: Moderately well drained to poorly drained. Both channelized and laminar surface drainage may occur. Rate of infiltration will depend upon depth to water table and texture at soil surface which may be altered by siltation. Little erosion damage unless flooding occurs.

Groundwater may slowly flow horizontally. Soil may be mineral, organic, or mineral with a significant organic overburden. Soils may have a high cation exchange for short periods of time.

Wildlife: Wildlife species found in lowland hardwood with cedar, spruce, tamarack, etc., associations are birds of prey, songbirds, fur and game mammals, and small mammals.

434 UPLAND CONIFERS WITH MAPLE, ELM, ASH, ASPEN, BIRCH, ETC.

Soils and Water: Generally well drained with channelized surface drainage. Very high rates of infiltration. Erosion damage with heavy runoff and sparse vegetation. Groundwater may flow horizontally. Soils are mineral, sandy textured with thin A horizons or poorly developed profile. Low in cation exchange capacity.

Wildlife: Birds of prey, songbirds, fur and game mammals, and small mammals are associated with this habitat type.

435 LOWLAND CONIFERS WITH MAPLE, ELM, ASH, ASPEN, BIRCH, ETC.

Soils and Water: Moderately well drained to poorly drained where cedar and tamarack predominate. Moderately well drained where spruce and balsam predominate. Channelized and laminar surface drainage may occur. Rates of infiltration will depend upon depth to water table and soil texture. Little erosion given abundant plant growth unless flooding occurs. Groundwater may slowly flow horizontally. Soils are mineral, organic, or mineral with a significant organic overburden.

Wildlife: Wildlife species associated with this habitat type include birds of prey, songbirds, fur and game mammals, and small mammals.

6 WETLANDS

Wetlands are those areas where the water table is at, near, or above the land surface for a significant part of most years. The hydrologic regime is such that aquatic or hydrophytic vegetation usually is established, although alluvial and tidal flats can be nonvegetated. Wetlands are frequently associated with topographic lows, even in mountainous regions. Examples of wetlands include marshes, mudflats, wooded swamps, and floating vegetation situated on the shallow margins of bays, lakes, rivers, ponds, streams, and man-made impoundments such as reservoirs. They include wet meadows or perched bogs in high mountain valleys and seasonally wet or flooded basins or potholes with no surface water outflow. Shallow water areas with submerged aquatic vegetation are classed as Water and are not included in the Wetland category.

Wetland areas drained for any purpose belong to other land use categories, whether it be Agricultural Land, Rangeland, Forest Land, or Urban and Built-up Land. When the drainage is discontinued and such use ceases, classification reverts to Wetland after characteristic vegetation is re-established. Wetlands managed for wildlife purposes may show short-term changes in vegetative type and wetness condition as different management practices are used, but are properly classified Wetland.

Two separate boundaries are important with respect to wetland discrimination: The upper wetland boundary above which practically any category of land cover may exist, and the boundary between wetland and open water beyond which the appropriate Water category should be employed.

Forested Wetland and Nonforested Wetland are the Level II categories of Wetland.

Endangered and Threatened Plant Species: Endangered species associated with wetland and water habitats are *Chelone obliqua* (purple turtlehead), *Nelumbo pentapetala* (American lotus), and *Scirpus hallii*. Families which contain one or more threatened species in wetland and water habitats include Araceae (1 species), Cyperaceae (14), Juncaceae (3), Lemnaceae (1), Liliaceae (3), Orchidaceae (4), Poaceae (10), Potamogetonaceae (5), Ruppiaceae (1), Acanthaceae (1), Apiaceae (1), Asteraceae (3), Brassicaceae (2), Convolvulaceae (3), Ericaceae (1), Gentianaceae (2), Haloragaceae (1), Lentibulariaceae (1), Malvaceae (1), Mymphaeaceae (2), Onagraceae (2), Polemoniaceae (1), Polygonaceae (1), Salicaceae (1), Sarraceniaceae (1), Scrophulariaceae (5), Valerianaceae (1), and Violaceae (1) (Beaman, 1977). For location of endangered and threatened species by county, see APPENDIX B.

61 FORESTED (WOODED) WETLANDS

Forested wetland includes seasonally flooded bottom-land hardwoods, shrub swamps, and wooded swamps including those around bogs. Because forested wetlands can be detected and mapped using seasonal (winter/summer) imagery, and because delineation of forested wetland is needed for many environmental planning activities, they are separated from other forest land. Wooded swamps and floodplains contain primarily oaks, red maple, elm, ash, alder, and willow. Bogs typically contain larch, black spruce, and heath shrubs. Shrub swamp vegetation includes alder, willow, and buttonbush.

611 WOODED SWAMPS (MAPPED UNDER FORESTRY CATEGORIES 413, 422, 433, 435)

Soils and Water: This class applied to wetlands dominated by trees. The soil surface is seasonally flooded with up to 1 foot of water. Several levels of vegetation are usually present, including trees, shrubs, and herbaceous plants. Broadleaved swamps would be placed in the forestry category 413 and 433; coniferous swamps are placed in forest category 422 and 435.

Use only types 4221 and 4351 when inventorying this condition at the fourth level of detail. Wooded bogs are placed in forest category 422 and 435; omit types 4221 and 4351 when inventorying at the fourth level.

Wildlife: Wooded swamps provide habitat for waterfowl, upland game birds, songbirds, fur and game mammals, and small mammals.

612 SHRUB SWAMPS

Soils and Water: This class applies to wetlands dominated by shrubs where the soil surface is seasonally or permanently flooded with as much as 12 inches of water. Characteristic emergent plants providing cover beneath the shrubs are the sedge and sensitive fern. Meadow or marsh emergents occupy open areas. Willow--buttonbush associations under 6125 are those aquatic shrub swamps with greater than 50 percent shrub cover and average water depth of less than 6 inches.

Wildlife: Wildlife species associated with shrub swamps include waterfowl, upland game birds, songbirds, fur and game mammals, and small mammals.

62 NON-FORESTED (NON-WOODED) WETLANDS

Non-forested wetlands are dominated by wetland herbaceous vegetation. These wetlands include inland nontidal fresh marshes, freshwater meadows, wet prairies, and open bogs. The following are examples of vegetation associated with non-forested wetland. Narrow-leaved emergents such as cordgrass and rush are dominant in coastal marshes. Both narrow-leaved emergents such as cattail, bulrush, sedges, and other grasses, and broad-leaved emergents such as water lily, pickerelweed, arrow arum, and arrowhead, are typical of fresh water locations. Mosses and sedges grow in wet meadows and bogs.

621 MARSHLAND MEADOW

Soils and Water: This class applies to wetlands dominated by meadow emergents, with up to 6 inches of surface water in the late fall, winter and early spring.

During the growing season, the soil is saturated and the surface exposed, except in shallow depressions and drainage ditches. Meadows occur most commonly on agricultural land where periodic grazing or mowing keeps shrubs from growing. Grazed meadows will be mapped under permanent pasture 2123. Ungrazed meadows will be mapped under lowland herbaceous rangeland 312.

Wildlife: Marshland meadow provides habitat for marsh and shore birds, upland game birds, birds of prey, songbirds, fur and game mammals, and small mammals.

622 MUDFLATS

Soils and Water: Land areas supporting little or no vegetation exposed during periods of low water.

Wildlife: Mudflats are important to waterfowl and songbirds, particularly for feeding.

633 SHALLOW MARSHES

Soils and Water: This class applies to wetlands dominated by robust or marsh emergents, with an average water depth less than 6 inches during the growing season. Surface water may be present throughout the year or absent during the late summer and abnormally dry periods. Floating leaved plants and submergents are usually present in open areas. Duckweed is often abundant in quiet water. Submergents are primarily shallow-water species like coontail, bladderwort, and waterweed. Cover plants generally occupy 50 percent of the marsh area.

Wildlife: Shallow marshes provide habitat for waterfowl, marsh and shore birds, birds of prey, songbirds, fur and game mammals, and small mammals.

624 DEEP MARSHES

Soils and Water: This class applies to wetlands with an average water depth between 6 inches and 3 feet during the growing season. Emergent marsh vegetation is usually dominant, with surface and submergent plants present in open areas. Cover plants generally occupy less than 50 percent of the marsh area.

Wildlife: Deep marshes are important feeding areas for waterfowl.

Wetlands by definition are poorly drained lands where water table is at, near, or above the land surface for a significant part of most years. Laminar and channelized drainage will occur. Peak flows of adjacent waterways or severe flooding may cause erosion. Predominantly organic or sedimentary soils. Erosion may be greater on mudflats (622) and shallow marshes (623) than in shrub swamps (612) or wooded swamps (611).

APPENDIX B

UNIQUE PLANT SPECIES ON RIGHTS-OF-WAY OR ADJACENT LANDS IN MICHIGAN

There are 16 endangered and 196 proposed threatened plant species in Michigan (Mich. Dept. of Natural Resources, 1978). Most have always been uncommon in Michigan (Beaman, 1977). The areas with the highest number of endangered and threatened species are the southwest corner of the State, and the northern tip of the Lower Peninsula (Table B-1). The central areas of the State have fewer unique species. However, this apparent concentration pattern may be, at least in part, an artifact of collecting efforts. Table B-2 gives the numbers of endangered and threatened plant species by habitat type.

Table B-1. Michigan counties with large numbers of threatened, endangered, and probably extinct plants.

	Threatened	Endangered	Probably extinct	Total
Kalamazoo	48	1	1	50
Isle Royale (Keweenaw)	40	-	1	41
Keweenaw (mainland)	30	2	5	37
Berrien	28	2	1	30
Washtenaw	24	1	1	26
Cass	22	-	2	24
Kent	23	-	1	24
Van Buren	18	2	3	23
St. Clair	19	1	2	22
Monroe	18	2	1	21
Wayne	19	-	2	21
Emmet	16	-	1	17
St. Joseph	15	-	2	17
Cheboygan	16	-	-	16

From Beaman, 1977

Table B-2. Habitats of probably extinct, endangered, and threatened plants in Michigan

	Probably extinct	En-dangered	Threatened				Total
			Pterido-phytes	Monocots	Dicots	All threatened	
Aquatic and wetlands	9	3	1	45	33	79	91
Prairies, open areas, fields	9	3	-	6	24	30	42
Rock outcrops, bluffs	3	6	6	8	13	27	36
Woodlands	2	4	2	10	13	25	31
Dunes and other sandy areas	-	-	-	11	3	14	14
Unclassified	2	-	3	5	14	22	24
Total	25	16	12	85	100	197	238

From Beaman, 1977

APPENDIX C

METHODOLOGY USED TO DETERMINE TREE DENSITY

Selection of Study Sites: To select the actual sites to be studied for each road type (Interstate, Trunkline, County Road) a list of random numbers was generated for each type. Every other random number on the list was chosen which idenfified what county the site would be in. This was done until 25 different sites for each road type had been selected.

Once the counties and the number of road sections that happened to fall in that county were known, the specific road section had to be selected. A dot grid with each dot numbered differently was laid over a map of a chosen county. For each road type to be sampled in that county, a random number was chosen to identify a dot on the map. From that dot, the closest one mile section of the appropriate road type was chosen unless it fell wholly or partially in city limits. If it did, the next closest one mile section outside city limits was used.

Field Forms: Prior to going into the field, each site's location was recorded on a form. To insure randomness, a coin was flipped to determine which side of the road would be sampled.

Five foot intervals up to 40' were used to count trees $\geq$ 4" (Diameter at Breast Height). The 40' maximum was chosen because 95% of all 1976 fatal run-off-road accidents and a sampling of the non-fatal accidents occurred within 40' of the road edge.

The form also divides tree counts into tenths of a mile. This was done simply for seeing spatial distribution that occurred along the one mile stretch and to facilitate counting of trees.

Field Surveys: A two-person crew visited each site. The driver of the car drove along the edge of the road and counted off the tenths of a mile on the odometer. The passenger counted the trees in each 5' interval using either a 100' tape or range finder to verify distances. Photographs were also taken usually at the beginning of the section and at the halfway point.

Tree numbers were tallied by 5' intervals and for the entire one-mile stretch. Totals and averages for all sites surveyed are presented in Tables C-1, C-2, and C-3.

To get an estimate of the number of trees by road type in the entire state, the average number of trees by road type can be multiplied by the number of miles of that road type in the state. This figure should then be multiplied by 2 to get the number of trees represented on both sides of the road.

Table C-1. Sampling of Trees 4 inch DBH or above, by Distance from Roadway (pavement) Edge of Interstate Highways for the State of Michigan

Sites	0-5'	6-10'	11-15'	16-20'	21-25'	26-30'	31-35'	36-40'	Totals
1	-	-	-	-	-	-	-	10	10
2	-	-	-	-	-	-	-	-	0
3	-	-	-	-	-	-	-	-	0
4	-	-	-	-	-	-	-	-	0
5	-	-	-	-	-	-	-	-	0
6	-	-	-	-	-	2	10	12	24
7	-	-	-	-	-	-	-	-	0
8	-	-	-	-	-	-	-	4	4
9	-	-	-	-	-	-	-	2	2
10	-	-	-	-	-	-	-	-	0
11	-	-	-	-	-	-	-	4	4
12	-	-	-	-	-	-	-	26	26
13	-	-	-	-	-	-	-	-	0
14	-	-	-	-	-	-	-	-	0
15	-	-	-	-	-	30	88	64	182
16	-	-	-	-	-	-	4	6	10
17	-	-	-	-	-	-	-	-	0
18	-	-	-	-	-	-	-	-	0
19	-	-	-	-	-	-	-	-	0
20	-	-	-	-	-	-	2	-	2
21	-	-	-	-	-	-	-	-	0
22	-	-	-	-	-	-	10	12	22
23	-	-	-	-	-	2	28	2	32
24	-	-	-	-	-	-	-	2	2
25	-	-	-	-	-	-	10	2	12
Totals	0	0	0	0	0	34	152	146	332
Avg. Trees Per 1 mile Interval	0	0	0	0	0	0.68	3.04	2.92	6.64

Table C-2. Sampling of Trees 4 Inches DBH or above, by Distance from Roadway (pavement) Edge on Trunkline Roads in Michigan

Sites	0-5'	6-10'	11-15'	16-20'	20-25'	26'30'	31-35'	36-40'	Totals
1	-	-	-	10	12	20	12	16	70
2	-	-	12	54	54	36	20	50	226
3	-	-	4	30	18	22	28	42	144
4	-	-	-	-	-	12	14	34	60
5	-	-	-	-	-	-	12	18	30
6	-	-	-	4	30	62	68	48	212
7	-	-	-	6	4	-	-	22	32
8	-	-	-	-	-	-	-	6	6
9	-	-	6	18	10	14	2	8	58
10	-	-	-	2	6	6	12	2	28
11	-	4	10	32	12	22	48	62	190
12	-	-	-	6	-	6	4	8	24
13	-	-	-	-	-	-	2	14	16
14	-	-	-	-	-	-	6	48	54
15	-	-	-	-	-	-	-	-	0
16	-	-	4	6	8	10	2	2	32
17	-	-	-	18	4	38	8	92	160
18	-	-	-	-	2	4	18	20	44
19	-	-	22	24	42	32	12	2	134
20	-	-	-	-	-	-	-	2	2
21	-	4	10	4	8	18	28	14	86
22	-	-	-	8	12	62	130	136	346
23	-	-	-	-	-	-	2	2	4
24	-	-	-	-	-	-	-	-	0
25	-	-	-	2	78	136	130	76	422
Totals	0	8	68	224	300	500	558	724	1,382
Avg. Trees Per 1 Mile Interval	0	.16	1.36	4.48	6.00	10.00	11.16	14.48	47.67

Table C-3. Sampling of Trees 4 Inches DBH or above, by Distance from Roadway (pavement) Edge on Rural/Local Roads in Michigan

Sites	0-5'	6-10'	11-15'	16-20'	21-25'	26-30'	31-35'	36-40'	Totals
1	8	68	276	194	32	8	6	6	598
2	14	70	186	106	114	116	118	138	862
3	112	180	168	184	70	40	24	28	806
4	264	330	250	194	220	178	190	270	1,896
5	-	-	14	78	152	192	192	220	848
6	124	166	172	236	230	214	308	314	1,764
7	2	6	60	120	144	118	83	76	612
8	40	118	182	110	116	148	134	164	1,012
9	-	-	-	-	-	2	4	-	6
10	2	38	12	50	10	-	8	2	122
11	6	342	650	422	78	78	54	48	1,678
12	6	164	78	60	54	30	34	26	452
13	52	270	226	156	100	70	72	54	1,000
14	-	-	-	4	16	28	10	20	78
15	8	70	34	12	2	6	8	10	156
16	-	-	8	16	14	10	20	24	92
17	6	2	12	6	-	4	-	2	32
18	-	-	20	10	24	34	36	16	140
19	-	-	2	6	-	-	-	-	8
20	-	-	-	-	-	4	6	12	22
21	48	92	46	24	26	18	8	18	280
22	6	54	82	130	90	38	16	10	426
23	32	106	150	80	72	76	36	64	616
24	2	34	122	78	6	6	6	4	258
25	-	4	30	44	26	28	10	10	152
Totals	732	2,114	2,780	2,320	1,596	1,446	1,386	1,542	13,916
Avg. Trees Per 1 Mile Interval	14.64	42.28	55.60	46.40	31.92	28.92	27.72	30.84	278.32

APPENDIX D

COMMON AND SCIENTIFIC NAMES OF SPECIES MENTIONED IN THIS REPORT

WILDLIFE

Common Name	Scientific Name
Chipmunk, eastern	*Tamias striatus*
Deer, white-tailed	*Odocoileus virginianus*
Gadwall	*Anas strepara*
Grouse, ruffed	*Bonasa umbellus*
Hawk, red-tailed	*Buteo jamaicensis*
Kestrel, American	*Falco sparverius*
Mallard	*Anas platyrhynchos*
Meadowlark, eastern	*Sturnella magna*
Mouse, deer	*Peromyscus maniculatus*
Mouse, white-footed	*Peromyscus leucopus*
Pheasant, ring-necked	*Phasianus colchicus*
Pintail	*Anas acuta*
Quail, bobwhite	*Colinus virginianus*
Rabbit, eastern cottontail	*Sylvilagus floridanus*
Shoveler, northern	*Anas clypeata*
Squirrels	*Sciurus* spp.
Starling	*Sturnus vulgaris*
Teal, blue-winged	*Anas discors*
Vole, meadow	*Microtus pennsylvanicus*
Woodchuck	*Marmota monax*
Woodpecker, red-headed	*Melanerpes erythrocephalus*

PLANTS

Common Name	Scientific Name
Alder	*Alnus* spp.
Alder, tag	*Alnus rugosa*
Alfalfa	*Medicago sativa*
Arnica, heart-leafed	*Arnica cordifolia*

Plants

Common Name	Scientific Name
Arrow arum	*Peltrandra* spp.
Arrowhead	*Sagittaria* spp.
Ash	*Fraxinus* spp.
Aspen	*Populus* spp.
Beech	*Fagus grandifolia*
Birch	*Betula* spp.
Blackberry	*Rubus allegheniensis*
Bluegrass, Kentucky	*Poa pratensis*
Bulrush	*Scirpus* spp.
Buttonbush	*Cephalanthus occidentalis*
Cattail	*Typhus* spp.
Cedar, northern white	*Thuja occidentalis*
Cherry	*Prunus* spp.
Cherry, western sand	*Prunus besseyi*
Chestunut, American	*Castanea dentata*
Clover, red prairie	*Petalostemon purpureum*
Cottonwood	*Populus deltoides*
Crab, Siberian	*Malus baccata*
Cranberrry, highbush	*Viburnum trilobum*
Dogwood	*Cornus* spp.
Dogwood, silky	*Cornus amomum*
Duckweed	*Lemna* spp.
Elm	*Ulmus* spp.
Fescue, red	*Festuca* spp.
Fir	*Abies* spp.
Fir, balsam	*Abies balsamea*
Gentian, soapwort	*Gentiana saponaria*
Grass, reed canary	*Phalacis arundinacea*
Hemlock	*Tsuga canadensis*
Hickory	*Carya* spp.
Honeysuckle, Morrow's	*Lonicera morrowi*
Indigo, cream wild	*Baptisia leucophaea*
Larch	*Larix larcina*
Lespedeza, bicolor	*Lespedeza bicolor*
Lespedeza, intermediate	*Lespedeza* spp.
Lotus, American	*Nelumbo pentapetala*

Plants

Common Name	Scientific Name
Maple, Norway	*Acer platanoides*
Maple, red	*Acer rubrum*
Maple, sugar	*Acer saccharum*
Oak	*Quercus* spp.
Olive, autumn	*Elaeagnus umbellata*
Pickerelweed	*Pontederia* spp.
Pine, Scotch	*Pinus sylvestris*
Pine, white	*Pinus strobus*
Pogonia, smaller whorled	*Isotria medeoloides*
Poplar, yellow	*Liriodendron tulipifera*
Quackgrass	*Agropyron repens*
Raspberry	*Rubus occidentalis*
Rose, multiflora	*Rosa multiflora*
Ryegrass	*Lolium perenne*
Sedges	*Carex* spp.
Sensitive-fern	*Onoclea sensibilis*
Solomon's-seal	*Polygonatum bilforum*
Spruce	*Picea* spp.
Spruce, black	*Picea mariana*
Turtlehead, purple	*Chelone obliqua*
Water lily	*Nymphaea* spp., *Nuphar* spp.
Willow	*Salix* spp.

APPENDIX E

COMPUTING THE EFFECTS OF TREE REMOVAL ON TREE/VEHICLE ACCIDENT RATES

This appendix describes the procedure used to produce estimates from the combination of accident and environmental data relative to run-off-road and tree crashes in Michigan. Specifically discussed will be:

1. An estimate of the number of trees along county roads in Michigan.
2. An estimate of the annual number of tree accidents per tree at various distances from the roadway.
3. An estimate of the annual number of run-off-road events at various distances from the roadway.
4. An estimate of the accident reduction effect of removing one or more trees at various distances from the roadway.

The accuracy of an estimate depends on a number of assumptions made necessary by limitations in the data. In the following computation, where these assumptions affect absolute accuracy the likely effect will be noted.

In Michigan there are approximately 12,0000 reported tree/vehicle crashes each year, most of which occur along county roads. While the number varies from one year to another, an estimate of 10,000 county road tree/vehicle crashes is used for these computations.

In the detailed examination of fatal and non-fatal tree accidents done in an earlier part of this study, a measurement was made of the distance of the accident tree from the road edge. Most trees involved in tree/vehicle accidents occur within 20 feet of the roadway (see Figure E-1). The mode of this distribution lies at about 10 feet; approximately 35% of the crashes occur at distances less than 30 feet. While the distribution is half composed of fatal crash data, there is little difference between the fatal and non-fatal portion. Multiplying this distribution point-by-point with the 10,000 accidents per year computes the expected number of accidents in each 5 foot zone (column 2, Table E-1).

Tree density along roads has been determined by a survey of roadsides in a random sample of Michigan roads. The average number of trees per mile (for county roads) is shown in the fifth column of Table E-1.

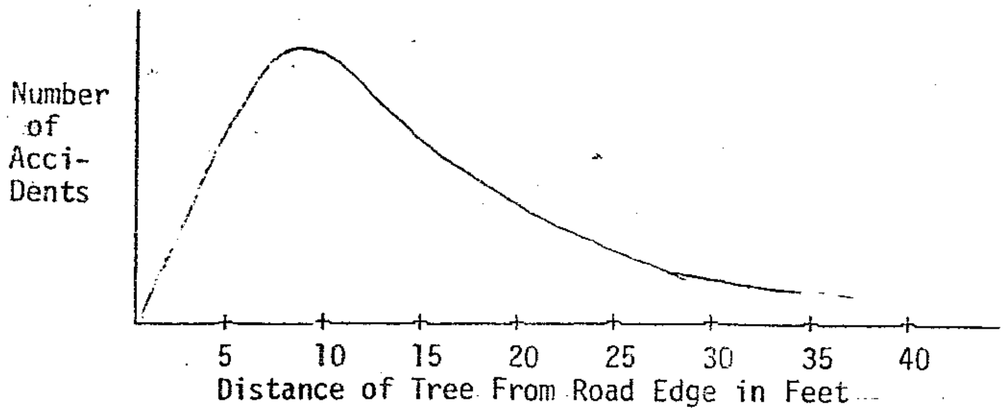

Figure E-1

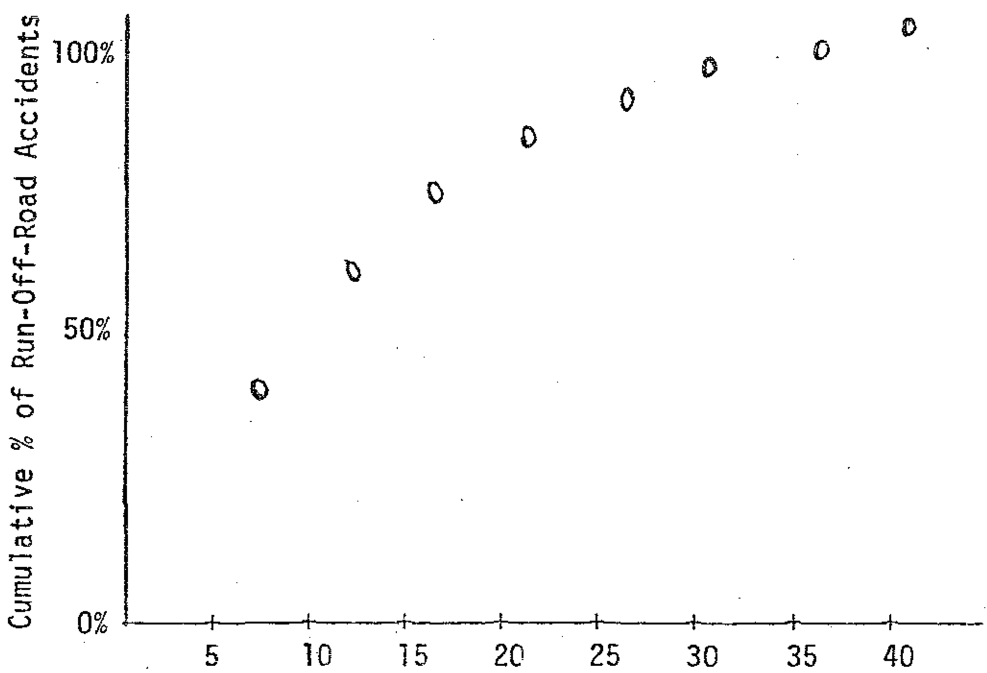

Figure E-2

TABLE E-1 Expected Number of Accidents Per 5 Foot Zone

REGION (DISTANCE FROM ROAD)	# TREE ACCIDENTS	ACCIDENTS PER TREE	TREES PER ACCIDENT	# TREES PER MILE	# OF TREES IN 33,000 MILES OF COUNTY RD.	FRACTION OF TREE ACCI. PER MILE	TOTAL NO. OF RUN-OFF-ROAD	CUMULATIVE RUN-OFF-ROAD
0-5 Feet	1180	.00122	818.8	14.64	966,240	.0693	17.027	17,027 (27.7%)
5-10 Feet	2440	.00088	1143.6	42.28	2,790,480	.2002	12,188	29,215 (47.7%)
11-15 Feet	2760	.00075	1329.6	55.60	3,699,600	.2633	10,482	39,697 (64.5%)
16-20 Feet	1340	.00431	2320.2	46.40	3,062,400	.2200	6,091	45,788 (74.4%)
21-25 Feet	1180	.00056	1785.4	31.92	2,106,720	.1151	7,809	53,597 (87.0%)
26-30 Feet	710	.000372	2688	28.92	1,908,720	.1369	5,186	58,783 (95.5%)
31-35 Feet	160	.000088	11434	27.72	1,829,520	.1313	1,128	60,001 (97.4%)
36-40 Feet	230	.000115	8854	30.84	2,035,440	.1460	1,575	61,576 (100%)
TOTAL	10,000			278.32	18,369,120		61,576	

At this point it may be useful to estimate the number of run-off-road tree/vehicle accidents from the available data. For any traffic volume on any road type it is possible to estimate the probability of run-off-road events. Knowing the tree density at any given site or road segment, it is possible to estimate the probability that any run-off-road event will result in a tree/vehicle accident. For example assume that, in effect, a tree represents a 25-foot long object pointed at a vehicle or vice versa. Within 0-5 foot of the road, then, there will be 366 "feet" of trees (14.64 x 25) per mile of highway. A run-off-road event, therefore, has a probability of 266/5230 or 0.069% chance of resulting in a tree/vehicle accident within 0-5 feet of the road.

A simple method for computing the expected effect of removing a single tree involves the data in the third column, "Accidents per Tree." Assuming that removing a tree in the first zone (0-5 foot) prevents the computed fraction of the accidents, i.e., a vehicle will not hit a tree farther from the road in the second or third zone, and that this computation is valid only for an average tree, then removal of one tree in the 0-5 foot zone along a county road should, on the average, reduce the number of tree accidents in Michigan by 0.00244 accidents per year, on a road with average ADT and on an "average site" (considering curved and tangent sections together).

There is probably no truly average situation. Thus, one would wish to compute the value of a specific tree removal using knowledge of the specific site.

The technique for estimating the impact of tree removal upon accident reduction would be based on this equation:

$$\text{Accident value reduction} = \left(\begin{matrix}\text{Distance}\\ \text{Factor}\end{matrix}\right) \times \left(\frac{\text{ADT}}{\text{Avg. ADT}}\right)^{.7} \times \left(\begin{matrix}\text{Curve}\\ \text{Factor}\end{matrix}\right)$$

where:

Distance Factor is selected from column 3 of Table 1

ADT/Avg. ADT is the actual ADT of that road section divided by the average ADT for that road class (500 in the example above)

Curve Factor is a multiplier derived from the previous data to take into acount the higher probability of running off the road at a curve.

This model provides an estimate of the accident effect of removing one or more trees at various distances from county roadsides. It should be emphasized that the probability of hitting a tree (accidents per tree) varies with the distance from the road, but overall, is generally less at greater distances from the road edge.

Although pursuit of this specific approach appears promising, practical application as part of a tree removal management plan to determine distance trees should be removed for all rural roads in Michigan requires considerable data on tree/vehicle crash distances on trunklines and county roads not currently available, and beyond the scope of this project. A practical approach to identify the distance trees should be considered for removal from the road edge based on data currently available, is discussed in Chapter 4, "Higher Risk Roadside Tree Environments", of Guidelines for Removing Hazardous Trees from Highway Rights-of-Way: A Management Manual.

APPENDIX F

ANALYSIS OF HAZARD PROFILES

Improving roadside safety represents a complex problem in resource allocation. Sufficient resources do not exist to remove all hazards in the roadside environment. A need thus exists to identify sites where the danger of a serious accident involving a tree is particularly great. To do this one must determine what features make a site dangerous. In this analysis the sites of all fatal accidents involving trees within Michigan during 1976 will be examined to identify critical factors--physical attributes which are frequently present, and hazard profiles--combinations of these critical factors. Other sites across the state where similar profiles are present thus become prime candidates for danger-mitigating treatments--either removal of trees that are hazardous to passing motorists or some type of barrier that prevents contact with these trees.

FATAL ACCIDENT SITE DATA

The data used in this analysis were obtained from the 1976 Michigan State Police files* and subsequent field investigation of 1976 fatal tree/vehicle accident sites. For each fatal accident site a wide variety of attributes were recorded. These attributes relate to environmental, geographical, and driver/vehicle factors most closely associated with tree crashes. In all, 154 fatalities involving tree crashes were recorded, of which 126 occurred in nonurbanized areas. Since this study is concerned with State roads and highways, the 18 urban accidents are not included in the analysis to follow.

Road Segment Types

Within the State Police files road segments along which fatal tree crash occurred are divided into six types: interstate curve, interstate straight, state trunkline curve, state trunkline straight, county curve, and county

*The data used are discussed in the Phase 2 Report.

straight. The number of fatal accidents occurring on each of the six road segment types is shown in Table F-1. The table shows that county roads account for over three-quarters of all fatal accidents involving trees within Michigan. Interstate highways, on the other hand, are very rarely the scene of such accidents, with only three occurring during 1976.

TABLE F-1

Number of Fatal Tree Accidents at Each Type of Road Segment

	Road Segment Type						
	Interstate Curve	Interstate Straight	Trunkline Curve	Trunkline Straight	County Curve	County Straight	Total
Number of Accidents	0	3	10	17	40	56	126
Percent of Total	0	2.3	7.9	13.5	31.7	44.4	100.0

The danger posed by trees in the roadside environment is shown quite clearly in Table E-2. In this table the number of vehicle miles traveled (VMT) on each of the six road types if presented, along with the number of VMT per tree-related fatality.* Considering exposure in the form of VMT, curved county road segments are by far the most dangerous. Trunkline curves are the second most dangerous, followed by straight county road and state trunkline segments.

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*Within each of the three road classes, interstate, trunkline, and county, curve segments are assumed to account for one percent of the total road mileage and hence, VMT. For a discussion of this assumption see the Phase 2 Report, p. C-2.

Table F-2 clearly shows that fatalities arising out of impacting trees are very rare occurrences along interstate highways in Michigan. Given the heavy traffic loads interstate highways carry, the danger of such accidents per VMT is much less than is true of other types of roads, particularly county roads. In fact, the danger of a fatal accident involving a tree along an interstate highway is almost negligible. Accordingly, the analysis to follow will consider only county and state trunkline road segments.

HAZARD PROFILE ANALYSIS

The objectives of this analysis are to identify; 1) a series of critical factors that tend to be present at the sites of fatal tree crashes along each of four types of road segments, and, 2) hazard profiles--combinations of these critical factors that occur frequently at fatal crash sites along each road segment type. Such hazard profiles will allow potentially dangerous sites to be designated and treated. Less dangerous sites along a given road segment type can be given lower priority for treatment.

The methodology for identifying critical factors and hazard profiles is relatively straightforward. Initially the 123 cases (126 minus the three

TABLE F-2

Miles Traveled Per Fatal Tree Accident on Each Type of Road Segment

	Road Segment Type						
	Interstate Curve	Interstate Straight	Trunkline Curve	Trunkline Straight	County Curve	County Straight	Total
Total VMT (Billions)	.136	13.446	.188	18.390	.200	19.800	52.160
Percent of Total	.261	25.778	.360	35.257	.383	37.960	100.0
Miles per Fatal Tree Accident (Millions)	Infinite	4,482	18.8	1,082	5.0	353.6	

interstate fatalities) are divided into the four road segment types. Within each road type, distributions of the possible values for each measure are examined. An example is the variable measuring horizontal alignment. While the only possible value this variable can have for straight segments is "straight alignment," on curved segments the curve can either be to the left or to the right. Assuming that each type of turn occurs with equal frequency, if far more fatal tree/vehicle accidents occur on left than on right turns, one can conclude that left turns are indeed critical factors.

Measures are thus identified wherein certain values (e.g., left turns but not right turns) are highly associated with fatal tree/vehicle accidents. The value that is closely related to such accidents is noted as a critical factor. Measures with notable dispersion and containing values disproportionately related to fatal tree/vehicle crashes are then cross-tabulated; that is, a two-way table is constructed. The objective here is to determine whether specific combinations of values on the two variables occur frequently at fatal tree/vehicle accident sites. If they do, part of a hazard profile is identified. An example might be horizontal alignment (right or left turn) and vertical alignment (level, uphill, downhill) within the county road curve segment category. Suppose that left turns and downhill gradients are shown to occur together at a substantial fraction of the accident sites. These two factors would constitute part of a hazard profile. Each of these two measures is cross-tabulated with other measures in search of other components of the road type category's hazard profile. It is important to note that a separate hazard profile will normally occur for each type of road segment.

Curved County Road Segments

Examining a wide variety of measures describing sites at which fatal accidents involving collisions with trees occurred, a number of critical factors emerge. The values in parentheses indicate the percentage or fraction of all fatal tree/vehicle accidents occurring along curved county roads where the particular factor was present.

Critical Factors:

- Left turn (60%). But, since right-hand curves were present at 40% of the sites they cannot be ignored.
- Downhill gradient (over 1/4). Whereas downhill gradients occur with equal frequency as uphill, they are found at accident sites three times as often.
- Multiple curves in the preceding 1/4 mile (40%).
- Downbanks (over 1/3).
- Dense tree area (only 15% involved lone trees). In 85% of all accidents another tree was struck prior to the fatal one.
- Inadequate signs (38%).

Hazard Profiles:

- Super-elevated cross-sections with downhill segments, downbanks, and unstable shoulders.
- Left turns and narrow lanes, particularly on downhill segments.
- Clusterings of trees at the curve, the clusters often being 20 feet or more from the road edge.

Not Factors:

- Paved shoulders (3%).
- Upbanks (5% hit an upbank prior to the tree).
- Trees near road edge (1/4 of the accidents involved trees less than 10 feet from the road).

Straight County Road Segments

Critical factors for straight segments of county roads differ substantially from those of curved segments. In general, ditches play a more critical role, and the impacted trees tend to be closer to the road edge.

Critical Factors:

- Downhill gradients (over 1/6). While this is not a large fraction, downhill accidents outnumbered uphill by a factor of nine.
- Ditches (over 50% entered ditch prior to striking tree).
- Trees close to road edge (2/3 were less than 15 feet).
- Multiple trees (3/4). Very rarely was impacted tree a lone tree. One-third of all trees struck in fatal accidents were parts of rows and another 20% were in woodlands.
- Previous accident sites (1/4). Given the low probability of the same site occurring randomly, this fraction becomes quite impressive.
- Unstable shoulders (1/5).

Hazard Profiles:

- Crown cross-section, narrow shoulder, and a ditch. The crown cross-section and narrow shoulder appeared to pull the vehicle into the ditch. This is much more evident on straight segments than on curved.
- Narrow shoulders, trees close together, and trees 10-14 feet from the road edge. In 72% of all cases another tree was struck prior to the fatal one. In every case where another tree was struck prior to the fatal one, the trees were less than five feet apart.
- Trees in ditches. In approximately 38% of all accidents where the vehicle entered a ditch prior to impacting the tree, the ditch led the vehicle into the tree. Eighty percent of such vehicles struck another tree prior to the fatal one.
- Downbanks leading to woodlands.

Not Factors:

- Super-elevated cross-sections (not found at any site).
- Uphill gradients (only one site was on an uphill segment).

Curved State Trunkline Segments

While the absolute number of deaths on curved segments of state trunklines was comparatively low, 10, on a per mile basis the risk is shown to be quite high. As was the case with curved county road accidents, vehicles often missed a left turn and plunged down an embankment into a tree. The road's slope was less a factor on trunklines than on county roads, however.

Critical Factors:

- Left turn, all accidents occurred on left-handed curves.
- Super-elevated cross-sections (70%).
- Vehicle ran down an embankment prior to striking the tree.
- Clusters or groupings of trees (90% hit another tree prior to the fatal one).
- Trees 20 feet or over from the road edge (90%).
- Scene of previous serious accidents (40%).

Hazard Profiles:

- Vehicle running down a bank, striking a tree, and careening into the fatal tree.
- Missing a left turn and striking a tree 20 feet or more from the road edge.

Not Factors:

- Shoulder condition; it was almost always stable.
- Entering a ditch prior to striking the fatal tree (only three cases).
- Ditch leading car to tree (10%).
- Slope (70% of the accidents were on level terrain).

<u>Straight State Trunkline Segments</u>

Fatal accidents involving trees along straight segments of state trunklines are relatively rare, an accident occurring on average of only once every billion vehicle miles. As was the case with straight county road segments, the vehicle often entered a ditch and subsequently struck several trees. The fatal trees tended to be farther from the road edge and the ditch less of a factor in accidents on trunkline segments.

Critical Factors:

- Vehicle entered a ditch prior to striking the tree (29%).
- Another tree was struck first (65%).
- The fatal tree was 20 feet or more from the road edge (65%).

Hazard Profiles:

- Vehicle entered a ditch first, then it hit another tree prior to striking the fatal tree (80% of the vehicles entering a ditch struck another tree first). The fatal tree was typically 20 feet or more from the road edge, but the first tree struck was most often ten feet or less from the road edge.
- In every case where a vehicle ran down a bank and hit a tree, that tree was 20 feet or so from the road edge. About 1/3 of the trees struck were part of a woodland.

Not Factors:

- Grade (82% of the accidents occurred on level ground).
- In no case did ditch physically channel vehicle into tree.
- Site of another accident (only one accident occurred at the site of a previous accient).
- Close trees (82% of the fatal trees were 15 feet or more from the road edge).
- Unstable shoulders (no site had them).

SUMMARY OF THE ANALYSIS

Examining the incidence of fatal crashes involving trees it becomes immediately apparent that county road and state trunkline curves constitute a substantially greater danger than do straight sections of either road type. Clearly the most dangerous road segments are curved county roads where a fatality arising out of a collision with a roadside tree occurs once in every five million miles, on average. Such accidents on trunkline curves occur roughly one-third as often. Fatal tree/vehicle accidents along county road straight segments happen only onenineteenth as often as along trunkline curves. On a per mile basis, the conclusion is inescapable that curves should have the higher priority for treatment.

Considering total numbers of fatalities, however, straight county road segments are the leading category. Treatment is something of a problem with this road segment type because it represents by far the greatest number of miles of roadway within the state. The cost-effective approach is to rank order the road segment types by fatalities per VMT and treat them in this order. Assuming that the treatment costs per mile are not markedly different, this approach will allow the greatest increase in safety per unit cost.

Turning to the hazard profiles, curved county road accident sites are found on left hand turns (a slight majority) with downhill gradients following a series of curves. Likelihood of an accident increases with tree density near the outside of the curve. Noteworthy is the fact that the impacted tree is often 20 feet or more from the road edge. This finding calls into questions the advisability of tree removal on county road curves where trees are part of a woodland. In all probability, many trees would have to be removed, at a considerable distance from the road edge.

Accidents along state trunkline curves occurred on left hand curves in every case. As was true with county road curves, the fatal tree was one of a cluster of trees most often, and was rarely the first tree struck. Frequently the vehicle ran down an embankment into the cluster of trees. It is noteworthy that 40 percent of all accidents in this category occurred at the scene of at least one previous accident that was serious. It terms of treatment, much the same can be said about the State trunkline curves and county road curves. If anything, treatment of trunkline curves is more difficult in that the trees tend to be even farther from the road edge. Because speeds are higher on trunklines the vehicle's momentum is likely to carry it farther.

Straight segments of county roads had quite different hazard profiles than curves. Distances of the fatal tree from the road edge tended to be appreciably less along straight county roads. Quite often the vehicle entered the ditch (the shoulder was typically narrow and often unstable) which then channelled the vehicle into several trees. Rarely was the fatal tree the only one struck. This analysis thus indicates that trees in ditches are particularly dangerous along straight county roads.

Straight State trunkline segments differ from the county roads mainly in that the impacted trees were farther from the road edge. The ditches, being wider, were less likely to direct the vehicle into a tree. As was the case with county roads, another tree was usually struck first, the vehicle then careening into the fatal one.

LIMITATIONS OF THE ANALYSIS

The foregoing analysis of fatal roadside tree accidents in Michigan has revealed that certain characteristics tend to be present at accident sites, and that these certain characteristics often differ quite substantially between types of road segments. The chief limitation of the analysis is that we do not know precisely how common these characteristics are along road segments where a fatal accident did not occur. If, for example, it is found that 30 out of 40 accidents along a given road type occur where the shoulders are unstable, we would normally consider unstable shoulders to be a critical factor. Suppose, however, that on all segments of this given type across the state, 80 percent have unstable shoulders. If that were indeed the case, unstable shoulders would be underrepresented among accident sites, in which case they may not be a critical factor at all. There really is nothing that can be done to remove this limitation, short of a statewide survey of roads and roadside environments.

A second limitation pertains to implicit causation. The fact that certain attributes were present at accident sites does not necessarily imply that they in any way caused or even contributed to the accident. Therefore, this limitation requires that common sense accompany the results of this analysis as the determination is made whether a given site is dangerous enough to warrant treatment.

A related limitation is that the hazard profiles are by necessity generalizations. Few critical factors were present at every fatal accident site within a specific category. It is also highly likely that other site-specific factors played a role on an individual basis.