5
STATEWIDE IMPLICATIONS: 4 MILLION CORD ANNUAL HARVEST

This section of the study describes the modelling assumptions used and the outputs from the lowest level of harvesting modelled, termed the *base* level of harvest. The section is intended to provide an understanding of what was harvested and why; what effects this had on the forests and their associated resources and values as defined in the FSD issues of concern; what mitigations should be used to ameliorate the significant adverse impacts that result from this level of timber harvesting and forest management activity; and the effectiveness of those strategies at mitigating impacts as well as those impacts that will likely not be mitigated.

Background information is provided here which is not repeated in the sections that examine the two higher levels of timber harvesting and forest management activities. Those sections focus on the impacts projected to occur at the higher levels of timber harvesting and forest management in addition to those projected to occur at the current or base level.

This section draws heavily on information and analyses presented in the GEIS technical and background papers. Those papers set out in greater detail the methodology used and also identify the limitations of the methodology and the data used to undertake the analyses. Section 2.3 of this document discusses how the three statewide scenarios were generated. Unless stated otherwise, this section refers to the second model run results.

One final point—although already stated, it is important for the reader to understand that all three timber harvest scenarios were specified by the EQB as those levels of harvest to be explicitly examined in the GEIS. Therefore, this and the two subsequent sections discuss the likely harvesting activity, future forest conditions, and impacts on various forest and related characteristics that are projected to occur if these levels of timber demand were, in fact, achieved.

5.1
Description of Harvesting Activities

5.1.1
Underlying Assumptions

The base scenario was modelled using the existing levels of roundwood consumption as the basis for demand over the modelled period of 50 years. This assumes that no further forest-based industrial developments take place within this period. This further assumes that total demand from existing mills will be constant throughout the entire planning period; and that statewide logging intensity will remain static.

However, initial results indicated that the assumptions used to develop the second runs, which are described in detail in the Maintaining Productivity and Forest Resource Base technical paper (Jaakko Pöyry Consulting, Inc. 1992a), would make it infeasible to sustainably harvest the current level of aspen demand over the 50-year planning period and beyond. Therefore, an assumption was made that other species could be substituted for a proportion of the current aspen demand. It is likely that decreasing aspen supplies together with associated increases in aspen prices relative to other species will stimulate such substitutions in the real market. Predicting the extent of the shift is difficult, due to the long time horizon involved. Significant changes in demand for a species can occur over relatively short periods, as demonstrated by the case of aspen, which only twenty years ago was considered a weed species and experienced little demand.

It was assumed that hardwoods would be substituted for aspen as the output from the initial model runs indicated the state had a surplus of these species under current levels of harvest and the additional demand could be readily met. It was further assumed that 25 percent of aspen demand would be shifted to hardwood species even though feasible schedules could be developed with somewhat smaller shifts. Table 5.1 summarizes the assumed harvest levels by period and market. Note that the state was modelled in two parts, a northern and southern region.

There also was concern about the availability of high quality oak. This question was treated by the specification of red oak sawlog harvest levels for the southern region shown in table 5.1. However, continued availability of high quality red oak will depend heavily on silvicultural and harvesting practices that encourage the development of high quality logs.

5.1.2 Covertypes and Species Harvested

Table 5.2 summarizes the base scenario output that describes the total acres, acres uncut, acres clearcut once in 50 years, acres clearcut twice, acres thinned but never clearcut, acres thinned and clearcut for both the southern and the northern study regions, and the state as a whole. These data indicate that approximately 7.2 million acres of timberland would be harvested under the base scenario over the next 50 years. Conversely, adding the area of productive land *not* cut (1990–2040) to the productive land *not considered* in the scheduling model shows that a total of 7.6 million acres of timberland *would not* be harvested over this same period modelled under this scenario. Note that acres *not* cut would contain those young stands recently harvested and some that might be harvested beyond the 50-year study period. In addition, the 1.9 million acres of reserved and unproductive forest acreage (not included in table 5.2) would not be disturbed by harvesting. This means that under the base scenario 7.2 million acres of Minnesota's forest land would experience some harvesting and 9.5 million acres would not be harvested.

Table 5.3 shows the acreage harvested and not harvested by covertype. Most of the harvesting activity is concentrated in the aspen and other hardwood covertypes. Results for these two species groups show the effect of a shift in demand to the latter necessary to achieve long-term sustainability. The

Table 5.1. Assumed roundwood consumption levels by species group and market for the base harvest scenarios (thousands of cords per year).

Species Group Market	Period 1 (1990–99)	Period 2 (2000-2009)	Periods 3-6 (2010–49)
Aspen			
Bemidji	572	522	435
Brainerd	256	260.1	216.75
Cook	210	182.7	152.25
Duluth	506	454.5	378.75
Grand Rapids	433	390.6	325.5
I. Falls	415	412.2	343.5
subtotal	2,392	2,222.1	1,851.75
Spruce-fir			
Brainerd	70	70	70
Duluth	220.5	219.5	219.5
Grand Rapids	115.5	118.5	118.5
subtotal	406	408	408
Pine			
Bemidji	159	188	188
Duluth	151	153	153
I. Falls	111	98	98
subtotal	421	439	439
Northern Hdwds			
Bemidji	83	147	234
Brainerd	190	226.9	270.25
Cook	51	79.3	109.75
Duluth	93	145.5	221.25
Grand Rapids	61	112.4	177.5
I. Falls	48	94.8	163.5
subtotal	526	805.9	1,176.25
Total, North	3,745	3,875	3,875
Southern Region			
Red oak sawlogs	50	50	50
Other wood	250	250	250
Total, South	300	300	300
Total, Statewide	4,045	4,175	4,175

Source: Jaakko Pöyry Consulting, Inc. (1992a).

Table 5.2. Summary of original timberland acres clearcut and/or thinned for the base scenario, 1990–2040.

Action Category*	North	South	Total
1 Total Timberland			14,773,400
2 Not Considered			1,356,500
3 Considered	12,409,900	1,007,000	13,416,900
4 Not cut	5,591,300	652,200	6,243,500
5 Clearcut once	5,775,300	320,700	6,096,000
6 Clearcut twice	846,000	0	846,000
7 Thinned but not clearcut	197,300	34,100	231,400
8 Thinned and clearcut	2,100	19,900	22,000
9 Total not cut, sum (2+4)			7,600,000
10 Total cut, sum (5-7)			7,173,400

Source: Jaakko Pöyry Consulting, Inc. (1992a).
**Not considered* are those plots representing young stands, old growth or areas assumed not available and therefore not considered for harvest in the period 1990-2040. *Considered* are those plots representing stands that are available and in terms of age, etc., feasible to consider for harvest during the 50-year study period. Action category 8, thinned and clearcut, is included in the clearcut once category.

acreages are displayed by the initial FIA covertype. A second clearcut was possible within the 50-year planning horizon only for aspen and balsam poplar, as only these covertypes had a minimum rotation (40 years) that would potentially allow two cuts within the 50-year planning period. Any other covertypes shown in table 5.3 as having a second clearcut are covertypes that were clearcut in the first planning period and then were regenerated in a way that assumed the covertype would change to aspen or balsam poplar.

Tables 5.2 and 5.3 probably underestimate the acreage likely to be cut because the model imposed selection harvests on only about 3 percent of the harvested acreage while the silvicultural survey conducted by Jaakko Pöyry Consulting, Inc. (1992m) found that these practices comprised approximately 8 percent of the harvest by area. Also, for interpretation, the model projects gradually improving per acre stocking levels over the study period and concentrates the harvest on the most economic (most accessible and productive) lands. Thus future per acre volumes for harvested stands are expected to increase in many cases over the study period. This implies that the acreage required to meet a particular harvest level may decline from the present. In comparing these projected harvests to the current harvest area—estimated at approximately 200,000 acres (Jaakko Pöyry Consulting, Inc. 1992m)—it is important to note that this estimate is also subject to important assumptions. In light of these factors, differences between present and projected harvest areas are to be expected.

Table 5.3. Projected acres of timberland (by initial covertype) that are harvested and not harvested in the base scenario, 1990-2040.

Forest Type	Clearcut Once	Clearcut Twice	Thinned	Total Acres Harvested	Total Acres	Acres Never Harvested	Harvest Acres as % of Total Acres	Harvest Acres as % of Total Harvest	Forest Type Acres as % of Acres
Jack pine	117,700	5,900	1,100	124,700	446,600	321,900	27.9	1.7	3.0
Red pine	188,900	6,700	11,600	207,200	354,700	147,500	58.4	2.9	2.4
White pine	37,900	1,700	0	39,600	68,600	29,000	57.7	0.6	0.5
Black spruce	281,900	15,500	5,200	302,600	1,349,900	1,047,300	22.4	4.2	9.1
Balsam fir	311,000	46,400	16,800	374,200	809,200	435,000	46.2	5.2	5.5
Northern white cedar	10,200	0	0	10,200	648,400	638,200	1.6	0.1	4.4
Tamarack	45,300	0	4,000	49,300	719,400	670,100	6.9	0.7	4.9
White spruce	23,700	1,300	2,900	27,900	91,700	63,800	30.4	0.4	0.6
Oak-Hickory	466,900	0	23,200	490,100	1,124,700	634,600	43.6	6.8	7.6
Elm-Ash-Soft maple	248,800	2,900	13,400	265,100	1,124,600	859,500	23.6	3.7	7.6
Maple-Basswood	314,400	3,100	17,900	335,400	1,470,200	1,134,800	22.8	4.7	10.0
Aspen	3,436,600	660,300	113,100	4,210,000	5,242,200	1,032,200	80.3	58.7	35.5
Paper birch	335,500	4,000	8,200	347,700	819,000	471,300	42.5	4.8	5.5
Balsam poplar	277,200	98,200	14,000	389,400	504,200	114,800	77.2	5.4	3.4
Total	6,096,000	846,000	231,400	7,173,400	14,773,400	7,600,000	48.6	100.0	100.0

Source: Jaakko Pöyry Consulting, Inc. (1992a).

Breakdown of Harvest Volumes by Product Group

Table 5.4 summarizes the scheduled harvests for products within each group for the northern and southern regions of the state. In developing management schedules, target outputs were defined for product groups. Relative value differences were recognized for products within the pine group. In comparing sawlog volumes with pulp volumes it is important to note that the schedules do not necessarily imply that all of the sawlog quality

Table 5.4. Scheduling model harvest summary under the base scenario (thousands of cords per year).

Product Group	Component	Period					
		1990-99	2000-09	2010-19	2020-29	2030-39	2040-49
a) **Northern region**							
Aspen	Aspen pulp	1,297.7	1,281.2	1,276.80	1,379.1	1,334.6	1,375.4
	Aspen saw	1,083.8	956.5	587.70	475.3	532.2	481.4
	Total	2,381.8	2,237.6	1,864.70	1,854.4	1,866.7	1,856.6
	Target	2,392	2,222.1	1,851.75	1,851.75	1,851.75	1,851.75
Spruce-fir	S-fir pulp	240.2	204.3	176.10	156.9	159.5	144.5
	S-fir saw	165.1	204.3	229.60	244.4	252.5	264.4
	Total	405.3	408.5	405.60	401.3	412.1	408.8
	Target	406	408	408.00	408	408	408
Pine	Pine pulp	77.1	93	79.80	74	108.1	119.5
	R&W saw	303.1	258.7	283.90	311.5	243	212.9
	Other saw	34.6	89.5	71.50	52.3	91.1	109.9
	Total	414.8	441.1	435.30	437.9	442.1	442.2
	Target	421	439	439.00	439	439	439
N. Hardwoods	Pulp	406.5	552.1	746.40	698	695.5	676.7
	R Oak saw	45.7	74.3	136.70	133.3	102.9	59.5
	Other saw	78.4	175.3	293.80	343.7	373.1	438.9
	Total	530.8	801.4	1,176.80	1,175	1,171.4	1,174.9
	Target	526	805.9	1,176.25	1,176.25	1,176.25	1,176.25
All Groups	Total	3,732.7	3,888.6	3,882.4	3,868.6	3,892.3	3,882.5
	Target	3,745	3,875	3,875	3,875	3,875	3,875
b) **Southern Region**							
Red oak	Sawlogs	50.3	50.4	49.3	49.1	49.9	49.6
	Target	50	50	50	50	50	50
Other Wood	Various	246.2	249.9	255.4	253.8	246.7	244.5
	Target	250	250	250	250	250	250
All Groups	Total	296.5	300.3	304.7	303.9	296.6	293.6
	Target	300	300	300	300	300	300

Source: Jaakko Pöyry Consulting, Inc. (1992a).

material will be used as sawlogs. This was a major consideration in developing relative product values. Higher values were not assumed for aspen, spruce-fir, or northern hardwood sawlogs as at least some of this material will be used as pulpwood. Under the base scenario, the quantity of aspen sawlogs produced over time drops from over 1 million cords per year in period 1 to approximately 475,000 cords in period 4. Aspen is the only species to experience such a drop. However, even with the drop, production of aspen sawlog size material is still substantially above the estimated 210,000 cords consumed annually by Minnesota sawmills.

5.1.3 Harvesting by Ownership

As discussed in section 2.3.1, the second model runs assumed that allocation of timberlands to be harvested was constrained by assumed levels of availability by ownership category. These constraints reflect current and prospective agency policies and land management practices, as well as past trends in availability for ownerships with no articulated policies. Table 5.5 shows the total volume harvested from timberlands on each ownership under the base scenario.

Table 5.5. Original timberland acreage harvested by ownership under the base scenario, 1990-2040.

			Timberland	
Ownership	Acres Harvested	Percent	Acres	Percent
Chippewa National Forest	160,200	2.23	567,200	3.84
Superior National Forest	349,500	4.87	1,253,900	8.49
Miscellaneous federal	53,700	0.75	197,700	1.34
Native American	171,200	2.39	490,600	3.32
State	1,296,900	18.08	3,077,900	20.83
County and municipal	1,612,800	22.48	2,505,600	16.96
Forest industry	451,400	6.29	751,300	5.09
Other private	3,077,700	42.90	5,929,200	40.13
Total	7,173,400	100.00	14,773,400	100.00

Source: Jaakko Pöyry Consulting, Inc. (1992a).

The projected harvesting activities by ownership must be considered in the context that the GEIS is **not** a *planning* document and that the harvesting scenarios are not meant to predict that specific stands will or will not be harvested. The scenarios were developed as a tool to determine how much of the forest would have to be harvested statewide to meet the levels of demand specified in the FSD. The emphasis is on *statewide*, as this is the level of analysis that the GEIS is directed toward.

A substantial proportion of all forests were regarded as available for harvest (table 5.2). Certain categories of stands were excluded, including those in reserved and unproductive categories; those assumed to be unavailable because of age (too young); and those protected under existing policies, such as apply to areas of old growth and riparian corridors. Economic criteria were used to select the cutting sequence for available areas.

In modelling the distribution of timber harvesting activity across the state, the state's timberlands were treated as if the decisionmaking were controlled by a single entity, and as if meeting the specified wood demands economically subject to the assumed constraints was the only objective. With the exception of limiting the volume cut from the national forests to comply with existing allowable sale quantities (ASQs), the model did not recognize the ownership of a plot when allocating harvest. These are obviously simplifications of the real world with its diverse ownerships and even more diverse objectives of management.

Two main areas where differences exist between the modelled scenarios and actual or planned levels of harvest are:

1. the existing constraints for those ownerships that limit the area available for harvest to meet policy objectives; and
2. allocation of harvest levels to achieve a uniform flow of product on a sustainable basis for each ownership or even for certain blocks of timberland within an ownership.

The likely policy-based constraints on harvesting have been identified in the Public Forestry Organizations and Policy background paper (Jaakko Pöyry Consulting, Inc. 1992k) and were incorporated into the modelling process via assumptions of the percentage of total timberland that will be available for harvest. The level of cutting on national forests is also projected to be below existing allowable cut volumes, which is in line with existing harvest levels. Averaged over the modelled period, the level of cutting on the state timberlands was similar to existing harvest levels.

However, several other important trends in the acreage harvested and the volume projected to be yielded from certain ownerships can be confidently interpreted from the model output. The volume of timber harvested would have to increase substantially over current levels of harvest occurring on county lands, forest industry lands, and private property. Consequently, even the present database for harvests on private lands lacks reliability, which underscores a risk in forecasting removals from such lands. On the whole, increased levels of cutting on these ownerships will have significant implications for the management of these lands.

In particular, substantial increases in the level of harvesting on private property lands will have statewide implications. The standard of management and planning on nonindustrial private forests is highly variable. Therefore, an increase in the amount of harvesting on this ownership will have implications for the overall standard of forest management, as well as the standard of site level operations. Increasing the level of harvesting on county lands will affect county land management organizations. Typically, these organizations have limited resources and the existing staff may have difficulty coping with additional responsibilities associated with increasing the level of cut.

5.1.4 Spatial Distribution

Table 5.6 describes the patterns of harvesting by ecoregion. Figure 5.1 shows the plots harvested during the first ten-year harvest period, and figure 5.2 shows the total number of plots harvested under the base scenario. The projected harvesting patterns indicate that harvesting is projected to occur in virtually all forested regions of the state. This pattern reflects the well-developed road network in Minnesota and the decentralized nature of the timber industry, meaning that few stands in Minnesota are ruled out for harvesting because of their location.

The area covered by dots in figures 5.1 and 5.2 is a rough approximation of the area harvested. The dots cover approximately 1,200 acres each, and most FIA plots represent about 900 to 1,500 acres.

Table 5.6. Original forest acreage and timberland acres cut and not cut by ecoregion under the base scenario, 1990-2040.

	Ecoregion							Total
	1	2	3	4	5	6	7	
Total forest land acres	3,372,000	2,023,700	903,000	8,172,900	934,700	637,200	666,300	16,714,800
Reserve/unproductive	509,600	973,900	36,300	359,800	24,400	17,300	20,100	1,941,400
Timberland acres (1-2)	2,862,400	1,049,800	871,700	7,813,100	910,300	619,900	646,200	14,773,400
Acres not cut, **base**	1,566,000	619,200	546,900	3,447,300	629,200	408,200	378,200	7,600,000
Acres cut, **base**	1,296,400	430,600	319,800	4,365,800	281,100	211,700	268,000	7,173,400

Source: Jaakko Pöyry Consulting, Inc. (1992a).

Figure 5.1. Location of harvested plots under the base scenario, 1990-2000.

Figure 5.2. Location of harvested plots under the base scenario, 1990-2040.

5.1.5 Temporal Distribution

The pattern of harvesting showed no real trends at the ecoregion level of resolution, especially when assessed at ten-year intervals. However, such patterns would likely emerge at a local level. For example, harvesting in a particular area might be concentrated into a comparatively short span of time following upgrading of an access road. Subsequently, there would be a prolonged period when no harvesting would occur as the forests were regenerated.

5.1.6
Relationship to Long-term Sustainable Timber Removal

The modern concept of sustainability is concerned with the continuity of growth and yield of timber and also the continuity of nontimber goods and services from the forest. Managing a forest for sustained yield requires maintenance of the productive capacity of the forest to meet all these demands. *However, as requested in the FSD, the focus of the discussion in this section is on timber only. The importance of nontimber aspects of Minnesota's forests is introduced and discussed in subsequent sections.*

Definition of Allowable Cut and Sustained Yield

Forest regulation lies at the heart of forest management. It involves the consideration of site, stocking, structure, growth, and yield. It also involves the size and timing of timber cuts.

Forest regulation utilizes the concept of sustained yield. Sustained timber yield management is usually described as the management of a forest property for continuous production with the aim of achieving, at the earliest practicable time, an approximate balance between net growth and harvest, either by annual or somewhat longer periods.

Long-term Sustained Yield Analyses

Based on long-term sustained yield analyses similar to the analysis techniques used by the MNDNR, a timberland area of approximately 7.4 million acres could sustain close to a 4 million cord annual harvest level. This would leave over 7.5 million potentially harvestable acres unharvested over the long-term. This analysis was done twice; once using volume control, the tabular check method and the GIP model, and second, using GROW model simulation of the best economic stand management alternative until yields stabilized. Analyses were developed for at least 200 years in all cases. The effect of ownership constraints and mitigations such as extended rotations and buffer zones were considered by limiting the harvest and management alternatives for these areas or corresponding acreage (see sections 5.11 and 6.13 of Jaakko Pöyry Consulting, Inc. [1992a] for details of this analysis and models used). Comparisons showed the two approaches produced similar results. This analysis strongly suggests that it would be feasible, from a purely wood fiber production perspective, to sustain annual harvest levels higher than 4 million cords once the forest age class structure is regulated. This conclusion assumes appropriate site-specific or other mitigations below the modelled level of resolution are implemented and do mitigate otherwise significant impacts. It also suggests that large areas of timberland could potentially be shifted towards other nontimber management objectives, such as wildlife habitat, without severely impacting timber production at the 4 million cord level in the long-term. This result helps explain why forest industries see development opportunities in Minnesota.

5.2 Characterization of Future Forest Resource Conditions and Impacts

Forests, as with any living entity, change naturally over time, irrespective of human intervention. In addition to these natural changes, human activities such as harvesting can also change the forests. There are certain key characteristics of a forest that can be used to describe many other features. Among these key characteristics are age class, covertype, and species composition. The GEIS has been structured to identify the key characteristics that are likely to change; to project the extent of these changes under the three levels of harvesting; and to examine the implications of such changes for the identified issues of concern.

This section describes the projected changes to these key forest characteristics or descriptors that occur as a consequence of harvesting at the 4 million cord level, as well as those associated with the background levels of change that would occur over a 50-year period. The descriptors discussed include covertypes and their extent, age class distribution, abundance and diversity of tree species within covertypes and structural changes in the patterns of forest cover.

5.2.1 Forest Area and Covertype Abundance

Forest Area

Historical data from past surveys were used to generate predictions of likely changes to the *area* of forest in Minnesota over the period 1990 to 2040. The projected acreage changes are shown in table 5.7. Although these results are presented by FIA unit they need to be interpreted with caution at that level of resolution. The projected statewide gain of 0.8 percent for total forest area is probably the most reliable figure on which to base analysis. The trends show substantial (30 to 40 percent) increases in southern Minnesota, predominantly in agricultural or other nonforested land uses. Much of these gains are expected to come from reversion of marginal agricultural lands back to a forested condition. In the case of wooded pasture, this reversion to full forest cover can occur quickly. However, full recovery of such lands in terms of species composition and ecosystem functions may take much longer. Restoration of forest cover on bare land can take many decades. In the mostly forested northern part of the state, a decrease in total forest land area is predicted. This is because land use changes in that area, such as to urban uses or agriculture, are likely to occur in forest areas, hence the anticipated loss of forest land.

Covertype Acreages

Forest covertype classifications depend on a range of factors, and the relative numbers of trees from each species is an important parameter. For some stands, it is comparatively easy to decide on the appropriate covertype classification.

For example, it is straightforward to classify a pure jack pine stand as *jack pine*. In contrast, many stands have mixtures of species which greatly complicate the process of covertype classification. Covertypes that fall into this category have been identified in the following analysis, because under these circumstances the classification can change as a consequence of a small change in the relative numbers of species present. These classification changes can mask more significant changes in species composition.

Table 5.7. Projections of total forest land area change by survey unit for the second runs, 1990–2040.

FIA Unit	1990	2040	Change	Percent Change
a) Timberland				
Aspen-birch	5,878,700	5,524,119	-354,581	-6.0
Northern pine	5,975,500	5,456,956	-518,544	-14.6
Central hardwood	2,275,400	2,988,059	+712,659	+31.3
Prairie	643,000	910,315	+266,515	+41.4
All units	14,773,400	14,879,449	+106,049	+0.7
b) Total Forest Area				
Aspen-birch	7,362,000	7,007,419	-354,581	-4.8
Northern pine	6,336,400	5,816,556	-519,844	-8.2
Central hardwood	2,357,200	3,098,307	+741,107	+31.5
Prairie	660,400	934,697	+274,297	+41.5
All units	16,714,800	16,856,979	+142,179	+0.8

Source: Jaakko Pöyry Consulting, Inc. (1992a).

Following harvesting (or other natural disturbances), or as stands age, the proportions of species that make up a stand can change. When this occurs, the covertype classification may also change. Changing acreages in the various covertypes can be an important indicator of more fundamental changes in the state's forests.

Table 5.8 describes the projected covertype acreages for timberland, reserved and unproductive forest land.[1] The key projected changes for timberlands as a consequence of the level of harvesting projected under the base scenario are:

[1]In making projections, it was not possible to project forward the FIA covertype classification. Consequently, a simpler forest type classification was developed—one that approximated the FIA classification and could be projected. Background on that is described in appendix 2.

Table 5.8. Forest type acreage (as determined by GEIS covertype algorithm) for timberland, reserved and unproductive plots under the base scenario, 1990 and projected 2040, statewide (thousand acres).

Forest Type	1990				2040			
	Timberland	Reserved	Unproductive	Total	Timberland Base Scenario	Reserved	Unproductive	Total Base Scenario
Jack pine	487.1	125.9	1.2	614.2	329.6	56.2	1.2	387.0
Red pine	350.6	78.6	0.9	430.1	452.4	87.7	.9	541.0
White pine	137.3	9.7	1.3	148.3	141.0	32.6	1.3	174.9
Black spruce	1,320.8	129.6	527.5	1,997.9	1,001.2	88.3	547.5	1,637.0
Balsam fir	1,012.5	117.0	21.9	1,151.4	657.4	72.9	18.5	748.8
Northern white cedar	322.4	8.2	37.3	367.9	360.9	8.5	40.7	410.1
Tamarack	696.2	7.9	118.1	822.2	678.7	6.9	118.2	803.8
White spruce	137.1	43.9	0	181.0	227.9	106.7	0	334.6
Oak-Hickory	1,288.0	13.6	14.0	1,315.6	1,370.2	18.6	18.8	1,407.6
Elm-Ash-Soft maple	1,564.2	64.9	33.4	1,662.5	1,744.0	95.4	35.2	1,874.6
Maple-Basswood	1,301.8	30.6	2.1	1,334.5	1,460.2	34.8	2.1	1,497.1
Aspen	4,496.0	358.1	33.9	4,888.0	5,238.7	393.5	36.8	5,669.0
Paper birch	1,179.3	109.7	6.1	1,295.1	803.4	123.6	6.5	933.5
Balsam poplar	480.1	15.4	10.6	506.1	413.7	14.5	9.5	437.7
Nonstocked	0	0	0	0				
Other	0	0	0	0				
Total	14,773.4	1,113.1	828.3	16,714.8	14,879.4	1,140.2	837.3	16,857.0

- The jack pine type declines in acreage due to succession to other types and increased harvesting (from 487,100 to 329,600 acres for timberland in the base scenario).
- The red pine covertype increases by approximately 100,000 acres. That appears due to retention of this long-lived species, succession, planting and natural regeneration.
- The white pine covertype increases in acreage.
- The acreage in the black spruce covertype declines by 2040 with subsequent gains to the tamarack and aspen covertype acreages. (For timberland the decline in black spruce is from 1,320,800 to 1,001,200 acres.)
- The balsam fir acreage on timberland declines from 1990 to 2040 from 1,012,500 to 657,400 acres. The aspen covertype appears to be a major recipient of that acreage.
- The northern white cedar type acreage increases over the study period due largely to succession and harvesting of other lowland conifer covertypes.
- The acreage of tamarack decreases slightly over the study period.
- The white spruce covertype acreage, like that for white pine, is very sensitive to the covertype definition. The projections indicate a substantial increase in the area of this covertype.
- Oak-hickory covertype acreage increases from 1,288,000 to 1,370,200 acres for timberland in the base scenario or about 6 percent.
- Elm-ash-soft maple covertype acreage increases substantially over the study period, partly due to forest area increase in the southern portion of the state.
- Maple-basswood covertype acreage increases for the base scenario.
- Aspen covertype acreage increases 16.5 percent over its initial extent (4,496,000 acres). However, several other covertypes, notably paper birch and balsam fir, have stands with high proportions of aspen that could, by a slight change in species composition or the algorithm for determining that covertype, be called aspen. Likewise, much of the aspen acreage is mixed and with a slight change could be reclassified as paper birch, balsam fir, jack pine, etc.
- The paper birch covertype declines by several hundred thousand acres. However, as with aspen, many acres are composed of mixed species. Consequently, while the acreage classified as *paper birch covertype* has changed, the overall species composition change of the original areas was probably less than the covertype area change would suggest. Aging of this covertype is also a factor contributing to succession to other species.
- The balsam poplar covertype acreage declines.
- In the northern region of the state, large percentage declines in acreage in reserved areas are noted for jack pine, black spruce, and balsam fir. Large percentage increases are noted for white pine and white spruce. These changes are due to projected species succession as stands age.

Reserved acreage increases in the south are due to the assumptions incorporated into the model regarding forest area increases there.

- The acreage of the major unproductive forest types (black spruce, tamarack, northern white cedar, and aspen) appear stable over the study period.

These results are heavily dependent on the (1) extent of harvesting, (2) the probability of covertype retention or change at the time of harvest, and (3) postharvest succession. In the case of aspen, transition matrices associated with harvesting show that most upland covertypes, except oak and northern hardwoods, show an important percentage convert to aspen, especially if ten percent or more of the stand is already aspen. Conversely, existing aspen stands remain such about 90 percent of the time following harvesting. Postharvest succession, however, shows very little conversion to aspen and a long-term pattern of aspen being replaced by other covertypes and species. A summary of the transition patterns is presented in the Maintaining Productivity and the Forest Resource Base technical paper, notably sections 4.5.4 and 5.9.

A further caution in interpreting these results is that long-term covertype change, in the absence of harvesting, is strongly affected by new trees growing into a stand. Given limitations in projection model capability, these factors probably lead to an underestimate of natural processes of stand dynamics and species replacement, leading in turn, to underestimates of naturally occurring covertype change.

Overall, results suggest that future covertype areas will change under the base level of harvesting and that the response is either species or covertype specific. For the case of several covertypes, percentage increases or decreases over a 50-year period can be large. In considering practices to contain or direct such changes, however, natural stand dynamics and succession can be important contributors to covertype change. Finally, covertype classification is still subjective and needs to recognize the highly mixed species structure of the forests in Minnesota.

5.2.2 Covertype Size and Age Class Structure

A summary of average stand age from 1977 to 2040 for the base harvest scenario is shown in table 5.9. For a more complete description of age class structure by covertype, see table 2.2 in appendix 2. Forest development from 1977 to 1990 indicates the average age of most covertypes continued to advance despite harvesting during that period. The clear exceptions are aspen and balsam poplar, which are major pulpwood species with potentially short rotation ages. The areas of timberland designated as *not available*, which includes old growth and other areas assumed to be unavailable, and ERF and other silvicultural constraints have all contributed to this trend of increase in average age.

Table 5.9. Average stand age by covertype under the base scenario 1977-2040.

Covertype	Average Age of FIA Plots (years)*		
	1977	1990	2040
Jack pine	42	48	77
Red pine	43	44	54
White pine	73	80	104
Black spruce	46	59	89
Balsam fir	42	46	82
Northern white cedar	82	97	116
Tamarack	52	57	99
White spruce	33	42	90
Oak-Hickory	63	69	78
Elm-Ash-Soft maple	56	56	86
Maple-Basswood	61	58	90
Aspen	38	41	34
Paper birch	49	58	92
Balsam poplar	39	41	33

Source: Jaakko Pöyry Consulting, Inc. (1992a). Projected ages for stands not clearcut were determined by adding 50 years. See appendix 2, table 2.2 for more detail.

* Weighted by acreage.

A simple interpretation of these results is that under the existing level of harvesting Minnesota's forests will continue to age; and there will be more acreage of the older age classes for most covertypes. The aspen covertype goes against this trend, and the implications for wildlife populations need to be carefully evaluated because such a high proportion of the forests are in this covertype.

Also important in this interpretation of age is that the current model distribution of stand ages near their covertype mean will change. Because of aging and harvesting, most of the covertypes will show both more acreage in the younger age classes and more acreages in the oldest age classes, i.e., the distributions will tend toward more balance and extend over more age classes than at present.

Further background on age class distributions and their interpretation is given in appendix 2.

Changes in age class structure will have important implications for many other values of the forest. Certain characteristics only become apparent after forests reach certain stages. These stages have been recognized for most covertypes, and specific management objectives have been developed. The following section describes these stages and the consequences of the base level of harvesting.

Old Growth Forests
The following is the MNDNR's definition of old growth which was used in the GEIS analysis as required by the FSD:

> "Old-growth forests have developed over a long period of time essentially free from catastrophic disturbances. They contain large, old trees of long-lived species that are beyond rotation age. Typical old-growth forest stands experience frequent ongoing mortality, including some mortality of canopy trees. Such stands contain a relatively high frequency of large snags and large-diameter, downed logs in various stages of decay" (MNDNR 1992).

Old growth can develop in the following forest types: black ash, lowland hardwoods, northern hardwoods, oak/central hardwoods, red and white pine, white spruce, upland white cedar, and lowland conifers. MNDNR guidelines state that stands should generally be greater than 20 acres in size, meet a minimum age or minimum tree diameter criterion, plus exhibit little or no human disturbance. Example criteria are older than 120 years (90 years for white spruce), negligible human disturbance (natural origin), and/or an average tree diameter of at least 20 inches in red and white pine, 15 inches in other forest types in southern Minnesota, and 10 inches in other forest types in northern Minnesota.

Upland Hardwoods and Conifers and Lowland Hardwoods: The amount of old growth in these types that will be reserved depends on two factors: (1) the acreage of natural origin stands left, and (2) the political and administrative processes that determine how much of this remaining old growth is reserved. Political pressures will probably lead to establishment of a target amount of old growth in each administrative unit, or possibly to all qualifying stands being designated as old growth and reserved. To date, at most, half of all candidate pine stands on MNDNR lands have met the criteria for old growth when surveyed in detail in the field. However, the rate of qualification may change for other covertypes (Rose 1993). This rate is due to the fact that inventory records typically do not contain the detail necessary to precisely determine qualification as old growth. Field survey follow-up thus is essential. Similar proportions are likely to qualify as old growth on national forest lands. There is also some old growth on county and private timberlands in the state, but this was not assessed due to a lack of data.

Regardless of the level of harvest, timber harvesting per se will have little impact on the acreage of old growth in these forest types. It is probable that a small acreage will be unknowingly harvested, primarily on private and possibly county lands. However, political and administrative processes will largely determine the ultimate acreage set aside. As an example, within the MNDNR each candidate stand and future old growth stand will likely be officially reserved or officially released for harvest after the appropriate administrative procedures. A similar procedure is also likely to be formalized for other public ownerships. Procedures for designating old growth on private land remains to be developed and will likely require some MNDNR leadership. Some of these sites are already documented in the MNDNR Natural Heritage Information System.

Swamp Conifers: A majority of the old swamp conifer acreage over 120 years of age is of natural origin, and therefore qualifies as old growth. This is because past demand for lowland conifers has been limited, compared with demand for upland types. None of the available timberlands >120 years old was projected to be cut in the base scenario meaning that there would be no reduction in the area of old growth lowland conifer forest under this scenario.

Old Forests

There is no official MNDNR definition of old forest. As used in this report, old forest includes (1) old growth; (2) forests that meet old growth criteria for age (120 years for most conifers, 90 years for white spruce), stand and tree size, but that may have had some selective harvest or other management activities; plus (3) seral stands of (generally short-lived species) >70 years old. This acreage is summarized for 1990 and the base scenario in table 5.10.

For most covertypes, the area of old forest is projected to increase substantially at the base level of timber harvesting. It appears that most of the projected increase in old timberland will come from acreages never cut during the 50-year planning horizon, reflecting the current overabundance of stands that date from major logging around the turn of the century. Whether these old stands would continue to exist in the following 50-year period as the forest approaches a regulated, or balanced age-distribution condition is not clear. Those stands that are in areas not available for harvest or uneconomical are likely to remain.

Red and White Pine: Currently, there are approximately 21,000 acres of old red pine on all forest lands. Under the base scenario this area would quadruple by the year 2040. The increase in the acreage of white pine would be of similar magnitude, from the current 12,300 acres to 91,674 acres.

Table 5.10. Area of old forest for 1990 and projected to 2040 for the base harvest scenario, all forest lands (acres).*

Forest type (threshold age)	Current 1990	Base Scenario 2040
Red pine (120)	21,200	107,496
White pine (120)	12,300	91,674
Black spruce (120)	157,800	614,219
White cedar (120)	60,000	225,600
Tamarack (120)	73,000	299,604
White spruce (90)	27,400	211,815
Oak-Hickory (120)	51,400	342,702
Elm-Ash-Soft maple (120)	69,400	483,185
Maple-Basswood (120)	37,000	404,502
Jack pine (70)	115,100	244,518
Balsam fir (70)	304,000	452,468
Aspen (70)	467,500	982,911
Balsam poplar (70)	24,900	76,629
Paper birch (70)	324,400	643,809

Source: Jaakko Pöyry Consulting, Inc. (1992a,e).
* Acreages are those determined from GEIS covertype algorithm.

Swamp Conifers: The base harvest scenario projects a major increase in the acreage of old black spruce, tamarack, and white cedar forest over the next 50 years. Old black spruce forest acreage would increase from the current 157,800 to 614,219 acres. Old tamarack acreage would increase about fourfold from the current 73,000 acres and old northern white cedar would increase from 60,000 to 226,000 acres under the base scenario. The primary reason for these trends is that the projected level of harvesting under the base scenario in these covertypes is well below the level of growth these forests experience.

White Spruce: A sevenfold increase of the current 27,400 acres in old white spruce is projected for the base harvest scenario.

Elm-Ash-Soft Maple Forest: Old forest in this type would increase from about 69,400 to 483,185 acres, under the base harvest scenario.

Oak-Hickory and Maple-Basswood: There is a common pattern to the projections of these two types. The acreage of old oak-hickory forest is projected to increase from 51,400 acres to 342,702 acres in the year 2040. Maple-basswood is projected to increase from around 37,000 acres to 404,502 acres. Unlike the other forest types discussed so far, much of the oak-hickory type is in small parcels owned by numerous individuals. Thus, the projections to the year 2040 indicate that future patterns of forest cover could look more like southern Wisconsin and Michigan, which currently have large acreages of old oak-hickory and maple-basswood forest in woodlots.

5.2.3 Tree Species Abundance and Diversity

Changes in tree species composition can occur in the form of species composition within a covertype, often related to stand age or stage of development, and in terms of covertype acreage. Table 5.11 presents a summary of species composition in 1990 and that projected to occur in 2040 for the base scenario across all covertypes. Note that the table includes all tree species reported in the FIA database. The figures for American elm and butternut should be interpreted with caution since there was no data available allowing the GEIS to incorporate the effects of dutch elm disease or butternut canker.

The ownership constraints and mitigations used in the second model runs appear to have been very effective in moderating changes in species statewide. This is evident for upland, lowland, and riparian species. Changes, as a percent of 1990 values, are small for most species. The species showing notable declines between 1990 and 2040 under the base scenario are: jack pine, Kentucky coffee tree, other hardwoods, and paper birch.

Because most species are found in many covertypes, results across covertypes are emphasized. The pattern also was found to be similar for trees with a girth, or dbh, of ≥4.5 inches. Unfortunately, a lack of FIA plot data for reserved and some unproductive plots precludes a separate analysis for trees located in those categories of forest.

Additionally, the results in table 5.11 are based on the *association* of tree species with the various covertypes and age classes. As such, the table does not provide for projections of change where the association is altered. As an example, butternut is a common but minor species associated with hardwood covertypes, but it seems to be facing a decline due to a canker disease. Consequently, butternut tree numbers may be overestimated. The same overestimation is suggested for elm because of dutch elm disease.

Reduction of Conifer Component in Aspen Stands

Estimated acreage of aspen forest *with no or inadequate* conifer understory is high—about 73 percent in the 1977 FIA. A conifer understory is considered inadequate if the number of trees is so small that to regenerate the conifer the stand would require some treatment, such as planting, in addition to a regeneration cut. In addition, analysis indicated that from 1977 to 1990

Table 5.11. Summary of projected tree species numbers on timberlands for 1990 and 2040 for the base harvest scenario (thousands of trees ≥1.0 inch dbh).*

Tree species	1990	2040
Ailanthus	39	15
American hornbeam	14,419	12,049
American basswood	192,090	191,702
American elm	150,006	147,215
Apple	386	430
Balsam fir	979,317	863,263
Balsam poplar	266,466	283,080
Bigtooth aspen	73,184	82,074
Bitternut hickory	8,044	8,573
Black ash	527,482	662,467
Black cherry	35,429	46,605
Black locust	455	133
Black maple	154	125
Black oak	710	792
Black spruce	1,039,098	911,752
Black walnut	2,289	2,222
Black willow	5,702	4,721
Boxelder	66,672	82,430
Bur oak	190,446	183,028
Butternut	2,941	4,442
Chokecherry	33,848	36,689
Eastern cottonwood	2,735	2,272
Eastern redcedar	14,051	17,977
Green ash	86,474	79,551
Hackberry	14,714	14,842
Hawthorn	8,810	8,922
Ironwood	117,990	130,328
Jack pine	164,593	93,530
Kentucky coffee tree	445	142
Mountain ash	1,497	3,273
Mountain maple	105,825	115,557
Northern white-cedar	386,818	615,904
Northern pin oak	5,975	5,541
Northern red oak	111,893	97,402
Other hardwood	41,155	32,342
Paper birch	570,934	440,801
Peachleaf willow	489	642
Pincherry	13,140	16,541
Ponderosa pine	398	387
Quaking aspen	1,986,789	2,730,630

Table 5.11. (continued)

Tree species	1990	2040
Red maple	290,717	223,765
Red mulberry	988	985
Red pine	97,800	107,691
River birch	185	1,682
Rock elm	1,572	1,881
Scotch pine	1,630	1,123
Shagbark hickory	9,145	11,075
Siberian elm	399	391
Silver maple	9,552	8,890
Slippery elm	23,016	27,284
Striped maple	463	397
Sugar maple	283,728	266,355
Swamp white oak	454	1310
Tamarack	361,461	299,180
White ash	2,494	2,835
White oak	10,058	11,377
White pine	29,566	29,709
White spruce	78,620	76,604
Wild plum	5,331	5,361
Yellow birch	11,746	20,882
Grand Total	8,442,827	9,029,168

Source: Jaakko Pöyry Consulting, Inc. (1992a).

aspen covertype acreage increased by 12 percent among harvested, naturally regenerated stands. Most conversion occurred from harvested conifer covertypes including white pine, white spruce, red pine, black spruce, and balsam fir. Except for red pine, fewer FIA plots changed from aspen to conifer than changes from conifer to aspen during the 13-year period. This suggests that large-scale conversion of types to aspen is taking place.

However, the real question is whether the forests later succeed back to conifers at a rate sufficient to balance postharvest conversion to aspen. Further analysis of postharvest conversion to aspen shows that only 89 percent of stands that were aspen prior to harvest remain aspen after harvest. Also, the covertype change matrix for older undisturbed stands shows some conversion of aspen to other types. Thus stands are converted in both directions and overall succession is not clear.

Trend information for the conifer component in aspen stands comes from conifer volume and number of stems data by age class. The proportion of conifer volume in the aspen forests is fairly constant with age, but begins to climb around age 80.

The actual number of trees per acre for balsam fir in the aspen covertype increases steadily to age 65. After age 65, the trends become erratic. Similar trends occur for white spruce and black spruce. The trend for white pine is an exception because the number of stems does not rise substantially until after age 95. These data suggest that, except for white pine, there is currently a sufficient conifer component in the aspen stands for future seed source and maintenance of conifers as aspen stands reach old age.

In summary, the data are helpful but incomplete. More data are necessary to determine at what age it is safe, on average, to harvest aspen stands without causing permanent future loss of the conifer component. In addition, the degree of site disturbance, time of year of harvest, amount of residual left after harvest, and other factors are certain to influence the successional sequence.

At this point, it is impossible to predict whether conifers will be lost in short rotation harvest. However, if a reduction in conifers did occur, the impact on biodiversity would be adverse and directly proportional to the level of harvest.

5.2.4 Forest Fragmentation

Fragmentation of forests changes the structural diversity of forested landscapes, but can affect all three components of biodiversity. These components of diversity are:

- compositional (number of species present in an area and the genetic variation within species);
- structural (spatial arrangement within and between stands and across regions); and
- functional (variety of natural processes occurring in a region).

The number of plant species within an isolated block of forest is roughly a function of the logarithm of land area and its distance to other blocks of forest. One effect of fragmentation involves a change in the *environment* within isolated forest stands. Small fragments of forest landscape provide a different environment from that provided by larger areas of forest. Small fragments provide more edge habitat, which can be characterized as having more light and more exposure to wind. Therefore, edge habitat generally has lower humidity and drier conditions than forest interior habitat. Certain groups of species have adapted to *edge* habitat, while other groups of species have adapted to forest interior habitats. Therefore, a landscape with many small isolated forest stands may ultimately exclude forest interior species.

A second effect of fragmentation is changing *competitive relationships* among species. An example is the relationship between plants such as grasses, and interior forest plants, such as woodfern and maidenhair fern. The ferns will grow better with more light at the edge of the forest, but they cannot compete with the grasses, which grow even better in high light.

A third potential effect of fragmentation is loss of local genotypes or ecotypes, because *inbreeding* may result if seeds and pollen, or individual animals cannot travel between woodlots. Inbreeding results in a decreased reproductive rate among many plants and animals. Genetically isolated islands of habitat must be large enough to maintain a minimum viable population so that inbreeding will not become significant.

There is an unknown *time lag* between the isolation of a block of forest, and a decline in the species richness that may later occur. This is because many forest species are perennials, such as trilliums, violets, ferns, shrubs, and trees, which live for many decades. If the structure or natural functions within a woodlot change so that some species can no longer reproduce, the species may not disappear for a century or more. During this time, it may not be clear whether or not a genuine failure of reproduction is occurring. By the time the failure of reproduction is noticed, it may be too late to save the population.

A fourth effect of fragmentation is *disruption of structure and function* of the landscape. Reducing a forested landscape to scattered fragments (e.g., Twin Cities metro area) impacts the extent of evapotranspiration occurring in the summer and could change the climate of a region. This can lead to a regional increase in mean summer temperature of several degrees F. The change in temperature could, in turn lead to further changes in species composition of forest remnants. Fragmentation can also lead to changes in water flow, soil building processes, and cycling of nutrients that affect the function of future forests. If the natural structure of the landscape is disrupted, it is difficult for species to respond to disturbance. Local catastrophes (windstorms or disease, etc.) may eliminate a species from a forest isolated by surrounding farmlands, or by other types of forest. Under natural conditions without fragmentation, migration of new individuals from adjacent stands would have allowed recovery of the locally lost species.

In Minnesota, two types of forest fragmentation occur. First, there is conversion to nonforest land uses such as field crops, leaving islands of forest surrounded by open habitat. Fragmentation of this type is highly significant in ecoregions 5, 6, 7, and parts of southern ecoregion 4. The second type of fragmentation—more relevant to future harvesting within densely forested northern Minnesota—is fragmentation within a forest. This concept deals with the juxtaposition of forests of different types and ages on the landscape.

Fragmentation exists where small conifer stands are surrounded by large areas of aspen, or old growth is embedded within a large area of young forest. This is the case with pine forests in Minnesota, because much of the original pine has been converted to aspen. No detailed studies of within-forest fragmentation have been found for Minnesota. However, conifer patches in a hemlock-sugar maple patchwork in Upper Michigan are larger and have a more complex shape in primary forest than second growth. The result was that the landscape was better *connected*, in that plants and animals could disperse seeds or move relatively long distances while still being within a certain type of habitat.

It is important to realize that the landscape was fragmented prior to settlement. In Minnesota, the large number of lakes, frequent fires and windthrow contributed to a natural pattern of fragmentation on the landscape. However, land use and forest management can change the degree and type of fragmentation, as has happened in ecoregions 5 and 6. It is generally agreed among ecologists that managed forest landscapes are more fragmented than natural landscapes.

The model output did not have sufficient resolution to permit a detailed analysis of the implications of the base level of timber harvesting on fragmentation. However, certain conclusions can be drawn from the output and also from the assumptions that were used to formulate the runs.

The ownership constraints implemented as model constraints have important implications for fragmentation. First, any given ecoregion should, over time, develop a broad range of age classes. Older age classes will come about through old growth reservation, ERF, riparian zone management via BMPs, and forest that is not available for harvesting. Young age classes will develop from harvesting, fire or other disturbance. The expansion of forest area in the southern part of the state should also aid the linking of important habitat. The degree to which land use change and development will diminish the linking of forest areas is uncertain.

Inbreeding

The exact distance scale of isolation needed to cause inbreeding is unknown for forest trees and plants. The farther either pollen or seeds are dispersed, the more isolated a population can be without becoming inbred. Qualitative assessment of susceptibility to inbreeding due to fragmentation is possible, based on general knowledge of seed and pollen dispersal (see table 5.12). No significant fragmentation impacts due to harvesting are expected in Minnesota for species listed in the very low or low susceptibility groups. This is because the species are widespread, and few populations are isolated by more than a few miles in Minnesota, the one exception being woodlots in ecoregion 7. On the other hand, timber harvesting will usually have a significant impact on the genetic architecture of forest herbs listed as high susceptibility (table 5.12). The imposition of a different covertype between two populations only a few hundred yards apart could cause a loss of gene flow between populations. This may result in inbreeding and the loss of some populations.

However, other populations of forest herbs will have a large enough number of individuals and enough variability within one population so that the population is viable, even when isolated. If the gene flow is cut off, isolated populations could evolve into new varieties and (after a few thousand years) new species. This is exactly how the dwarf trout lily, which occurs only in southeastern Minnesota, is believed to have evolved from the white trout lily. There is no way to assess the number of species that would be affected without a detailed map of individual timber harvests.

Table 5.12. Qualitative estimate of susceptibility to inbreeding due to fragmentation. The same species listed as high susceptibility (forest herbs) to inbreeding, species or groups of species in Minnesota. Pollen and seed dispersal effective distances: VL= very long distance (more than 2 miles), L=long distance (0.5-2 miles), M=medium distance (0.1-0.5 mile), S=short populations. The spatial scale of forest operations is similar to that of distance (<0.1 mile).

Species/Group	Pollen/Seed Dispersal	Geographic Scale of Genetic Variation	Overall Susceptibility
Aspen	L/VL	Ecoregion	Very Low
White, red and jack pines, birches	VL/M	Ecoregion	Low
Berry producing shrubs, cherry, mountain ash	S/VL	?	Low
Oaks	L/L	Ecoregion	Low
Spruces, white cedar, tamarack	M/M	Ecoregion	Medium
Walnut, hickory	M/S	Ecoregion	Medium
Maples, basswood, fir	S/M	Ecoregion	Medium
Forest herbs[a]	S/S	Township/county or smaller	High

Source: Jaakko Pöyry Consulting, Inc. (1992e).
[a] Forest herbs includes hundreds of species, and exceptions to short distance pollen and seed transport are sure to occur.

Direct Loss of Genetic Diversity

The same species listed as having high susceptibility to inbreeding (forest herbs), also have relatively fine-scale spatial differences in gene frequencies among populations. The spatial scale of forest operations is similar to that of genetic structure of forest herbs. Therefore, losses of distinctive genetic material of forest herbs caused by changes of covertype, such as plantations that extirpate local populations, will occur as a consequence of forest harvesting.

Species of the low susceptibility group are unlikely to be greatly impacted with the exception of habitat islands, such as swamp conifers separated by many miles (mainly ecoregions 5 and 6). In addition, other outliers (i.e., sugar maple in ecoregion 3) may have genetically distinct populations that would be lost if covertype conversions occurred.

Relationship of Fragmentation to Old Growth

Old growth forests are generally *interior* forests. Old growth communities are those that have an environment of low light (except for the top of the canopy), high humidity, and low windspeed. Old growth areas of 20 acres or more (MNDNR minimum area criterion), probably have some interior-type habitat in the middle. The entire area of a 20-acre stand can be interior forest if a 300-foot wide buffer surrounds the stand. Therefore, buffers are an important component in maintaining old growth interior habitat. Harvesting these buffers can cause impacts on the habitat value of the old growth. Some animal species such as Pileated Woodpeckers require 100 acres or more of contiguous forest.

Relationship of Fragmentation to Climate Change

Timber harvesting at all levels can cause fragmentation that may interfere with the ability of species to adjust to their range when the climate changes in the future, thus impacting genetic diversity of forest herbs and trees.

5.3 Physical Resource Impacts

Harvesting activities will change aspects of the physical or nonliving environment. This section discusses the types of impacts affecting forest soils and water resources (water quantity and quality) expected to occur at the base level of timber harvesting.

5.3.1 Soil Resources

Productivity and Nutrient Availability

All forest harvests remove nutrients contained within the product being removed. Some harvesting activities may also displace nutrients from sites where trees are growing and concentrate them at a single site (e.g., removing branches and tops at the landing rather than at the stump). Finally, some activities associated with preparing a site for subsequent regeneration may also displace and concentrate nutrients (e.g., windrowing as a site preparation technique).

Nutrients are continuously being added to forests through atmospheric deposition and by geological weathering, and being lost by leaching. Over the long-term, rates of removal that exceed rates of replenishment can be considered to be *mining* the nutrient capital of a site. The initial nutrient capital of a site (i.e., the nutrients stored in the soil) should also be considered when nutrient removal is assessed as it affects the degree of nutrient depletion at a site over a rotation. Therefore, although a site may irreversibly lose nutrients, the amount may be a small proportion of the nutrients present on a site with high initial capital. In that case, the mining may be considered relatively insignificant and economically and biologically justifiable. Sites with low capital will be more heavily impacted by equivalent amounts of nutrient removal without replenishment. Impacts will be increasingly severe as the nutrient capital of a site is depleted over many rotations.

Impacts will occur wherever harvesting activities are conducted. As described above, impacts will be most severe on sites with low nutrient capital. These sites can be broadly categorized as those on coarse-textured soils. Such soils occupy about one-fourth of the forested area of Minnesota, or about 4.5 million acres (based on Land Management Information Center [LMIC] forest covertype and soil maps) and are scattered throughout the forested parts of the state.

Data on nutrient removal by harvest and on nutrient additions by atmospheric deposition are comparatively good; it can be assumed that they are accurate with uncertainties of less than an order of magnitude. Similarly, nutrient capital of soils classified into general texture and drainage classes can be estimated with an uncertainty of less than an order of magnitude. There is, however, large uncertainty associated with rates of return of nutrients via geological weathering.

Another major source of uncertainty is the precise quantification of the relationship between quantity of nutrients and stand productivity. Using agricultural experience as an analog, it is known that depletion of nutrients leads to reductions in productivity. In some areas (e.g., upstate New York), soils that have been depleted of nutrients by agricultural activities cannot support normal forest growth without nutrient additions; even species with low requirements require added nutrients. The addition of nutrients via fertilization (especially N and P) to some forests (in the Pacific Northwest and the southeast U.S., respectively) can increase productivity. Although there are suggestions of *second-rotation* productivity declines in pine plantations in the Southern Hemisphere, the cause of such declines has not been unequivocally determined. Part of the uncertainty is due to the characteristics of natural forest systems; systems that are low in nutrients are often also limited in available water and have other characteristics that make them less suitable for tree growth than high-nutrient sites. Experiments that demonstrate decreases in productivity with nutrient depletion have not been carried out. In summary, quantification of the relationship between productivity and nutrient quantity, especially under conditions of nutrient depletion, is lacking.

The time required to replenish a site subject to nutrient depletion can be long-term. If the interval between harvests or other disturbance is long enough, natural processes will replace nutrients and the site will regain its original nutrient capital. Where large quantities of nutrients have been removed from a site that has low rates of natural replenishment, such restoration will require more than 50 years and is, therefore, considered to be long-term. Artificial nutrient addition via fertilization can shorten the duration of the impact.

Under the base scenario, and harvesting the merchantable bole, 1.8 million acres of forest land are projected to lose potassium, 5.0 million acres to lose calcium, and 2.7 million acres to lose magnesium in excess of their replenishment. It should be noted that these assessments of area are not additive, some soil type/covertype combinations are projected to lose two or more nutrients. Both phosphorus and nitrogen are projected to be adequately replenished by natural processes. Almost one million acres associated with potassium loss are coarse-textured soils, and about 700 thousand acres are organic soils. About half the area (2.5 million acres) associated with calcium loss is medium-textured soils, and 1.7 million acres are coarse-textured soils. The large area of medium-textured soils associated with calcium loss is related to the predominance of aspen-birch on those soils, and to the high levels of calcium in the bark of aspen. Coarse-textured and organic soils each account for about one-third of the total acres projected to be depleted of magnesium under the base scenario.

Impacts on Total Nutrient Capital

The loss of each of these nutrients should be evaluated with respect to the nutrient capital present on the sites. For example, potassium losses are the highest proportion of the capital of any of the three nutrients of concern. On coarse-textured soils, potassium losses are about half of the capital. Fortunately, potassium is quickly replenished so losses are replaced in about 40 years. On medium-textured soils, potassium losses are about a third of the capital, and are replaced within about 20 years. Because potassium is replaced at a rapid rate, less area is associated with its depletion than is associated with the depletion of calcium and magnesium. Although the latter two nutrients are depleted from more acres, on most sites depletion is a smaller proportion of total capital. For example, on the average coarse-textured soil, calcium losses associated with harvest are about 10 percent of the capital; harvest removes a smaller proportion on medium- and fine-textured soils (about 5 percent). In the case of magnesium, harvest also removes about 10 percent of the capital on coarse-textured soils but only about 2 percent on fine soils.

Organic soils are a special case because they do not have an input of mineral weathering to replenish nutrients; they depend on atmospheric deposition. Organic soils are commonly recognized to be low in potassium. Harvest removes most of the immediately available potassium on organic soils and rates of replenishment are low; about 100 years are required to rebuild potassium reserves to their original level. Conversely, only about 5 percent of the calcium and magnesium reserves on organic soils are lost by harvesting.

Utilization Levels

The volumes of wood removed and utilized affect the amounts of nutrients removed. Both phosphorus and nitrogen are naturally replenished at adequate rates, irrespective of utilization levels. The other three nutrients, magnesium, potassium, and calcium, differ in their biogeochemistry and therefore, the impact of increased utilization on their loss also differs.

If harvest is restricted to the bole (i.e., the trunk) with the bark stripped off (*bole-only*), then magnesium is not adequately replenished on about 1.4 million acres of harvested forest land under the base scenario. About half of this area is fine-textured soils where magnesium is naturally being lost at a greater rate than it is being replaced; harvest does not affect that loss. For these soils, each rotation removes less than 2 percent of the total magnesium capital. The other large area of magnesium loss, about half of the 1.4 million acres, are organic soils. In this case, harvest removes about 5 percent of the magnesium capital. Removing only the bole, without bark, has a relatively small impact on the magnesium capital of sites.

In contrast, full-tree harvest has significant impact on magnesium depletion, affecting 4.1 million acres of forest land under the base scenario. Under full-tree harvesting, the bole, bark, branches, and leaves/needles are removed from the stump. Major areas of magnesium loss associated with full-tree harvest under the base scenario are coarse-textured soils (about 1.8 million acres) and organic soils (about 1 million acres).

Potassium behaves similarly to magnesium, showing marked increases in the area of land affected as utilization increases from bole-only to full-tree (to about 3 million acres under the base scenario). Potassium is primarily stored in the tree's leaves and branches, which are retained on site in both bole-only and merchantable bole (bole and bark) harvests.

Because of its high levels in bark, but lower levels in branches and leaves, differences in area of calcium loss between bole-only and merchantable bole (with bark) removal are significant. If the harvest is restricted to bole-only, the area at risk decreases from 5.0 million acres to less than 1.5 million acres under the base scenario. The increase in area with significant calcium loss when utilization shifts from merchantable bole to full-tree harvest is relatively smaller (about 1 million acres).

Other Aspects of Forest Management

Other aspects of timber harvesting and forest management can impact the nutrient status of harvested sites. These are discussed below.

Delimbing and topping: Based on the summary of timber harvest operations carried out as part of the GEIS, delimbing and topping is carried out at a landing in about one-third of the harvests. This practice does not recycle or replenish the nutrients on the site, and is equivalent to a full-tree harvest in terms of nutrient depletion. The area estimates developed for harvest of merchantable bole should be increased to take this practice into consideration. The area affected by potassium loss should be multiplied by 2.25, for calcium loss by 1.5, and for magnesium loss by 2.0 to account for the present extent of delimbing and topping at landings.

Mechanical site preparation*:* Nutrient depletion varies depending on site preparation techniques. A survey conducted for the GEIS estimated that about 18,000 acres are affected annually by mechanical site preparation. Site preparation techniques that displace material can significantly alter site nutrient status. Mechanical techniques that create slash piles or windrows either remove nutrients from the site or localize them, depleting the remainder of the area. In contrast, site preparation techniques that incorporate materials, or only displace materials a few feet, will not produce those negative impacts.

Compaction: Physical damage to soil structure, notably compaction, can occur in the course of harvesting. Whether or not a site is impacted depends on certain variables such as season of harvest and related site factors, soil type, equipment used, and harvest and related road planning.

Soil sensitivity to compaction is a function of soil strength which is governed by soil physical structure, texture, and moisture status. Soils with low strength are unable to support the heavy equipment used in some forest management activities. Also, because of the likely higher levels of compaction, the time needed for recovery of soil physical structure is greater for soils exhibiting low strength. The most sensitive soils are wet soils with a high percentage of silt and clay, and organic soils. It is expected that one to three equipment passes would result in at least a moderate level of site disturbance on the most sensitive soils. Soil sensitivity decreases with increased sand and coarse fragment content or drier conditions. On moderately sensitive soils, four to twelve equipment passes would cause at least a moderate level of disturbance. Sites with the lowest sensitivity are the coarsest, driest sites. More than 12 equipment passes would be required to cause a moderate level of disturbance on these sites.

The seven soil groups identified for the GEIS analysis can be categorized according to their relative sensitivity to physical damage. Soils that are more susceptible when wet appear under more than one category to account for seasonal differences. Soils can be in one of three conditions—wet, dry, or frozen. Soil water status is highly correlated with season, though it is also a function of the texture and drainage class of the soil. Soil water status (and hence season) is a major factor in determining the sensitivity of a site to equipment impacts.

In summary, the degree of compaction is highly variable and depends on combinations of the above variables. The proportion and degree of compaction on a site can range from slight compaction, which ranges from no disturbance up to light scarification; moderate compaction, which shows depressions up to 2 inches deep in the mineral soil; and severe compaction, which shows depressions or ruts in the mineral soil greater than 2 inches deep. All of the area occupied by haul roads is severely impacted.

Compaction reduces site productivity because less soil is available for root development. In addition, site hydrological processes are altered. More overland flow of water is generated, leading to increased potential for erosion and subsequently sedimentation. Additional research is required to fully quantify the effects of these disturbances on Minnesota's forest resource. Although, it has been clearly documented that compaction and related disturbance reduces forest growth, the magnitude and duration of the impact is uncertain. Further uncertainty is added by the fact that, for the purposes of growth, trees adjacent to forest openings may benefit from less canopy competition, thereby reducing the impact. Impacts are likely to persist over the short- to long-term. Recovery rates vary and depend on the severity of damage and the rate of recovery of soil physical characteristics; however, these relationships are not well understood and more data are required.

Based on the 4.0 million cord level of harvesting and the seasonal distribution of harvesting activities outlined in the Silvicultural Systems background paper (Jaakko Pöyry Consulting, Inc. 1992m), approximately 840,000 acres would be vulnerable to moderate or severe compaction within areas harvested and an additional 60,000 acres would be impacted in areas developed as haul roads, assuming haul roads occupy an area equal to one percent of the area harvested.

The type of harvesting equipment used can have a major influence on how much of these sites is actually affected. Approximately 30 percent of highly sensitive sites harvested using hand-felling operations are likely to be compacted, compared with approximately 55 percent for mechanical-felling operations. It was estimated that about 25 percent of the area within moderately sensitive sites would be negatively affected by equipment trafficking for both harvesting configurations.

Based on the above percentages and estimates of the proportion of harvesting operations using hand and mechanical harvesting, it is possible to calculate crude estimates of the potential impact of compaction and related disturbances on future productivity. It was estimated that under the base scenario, the *actual* area moderately or heavily compacted within harvest units totalled approximately 330,000 acres. An additional 60,000 acres would be impacted assuming that 1 percent of the area harvested is occupied by haul roads. Assuming that productivity is reduced by 25 percent in lightly trafficked areas, by 50 percent in heavily trafficked areas, and by 75 percent in haul roads, these impacts would translate to losing the wood-producing equivalent of as much as 170,000 acres under the base scenario.

The statewide results are not distributed evenly between soil types. Most harvesting occurs on well-drained medium-textured soils followed by well-drained coarse-textured soils. As discussed, there are significant differences in the sensitivity of varying soil types to harvesting impacts. The well-drained fine-textured soils, poorly-drained fine-textured soils, and the poorly-drained medium-textured soils are the types most susceptible to these impacts. This is because of the lower soil strength associated with finer soil textures and wetter soil conditions. In contrast, well-drained, coarse-textured soils rarely experience such impacts. The disparities between soil types means that compaction impacts will be more widespread in ecoregions containing higher proportions of the more sensitive soils.

This is illustrated by comparing the relative level of impacts likely in two ecoregions. Ecoregion 1 is dominated by an old lake bed and thus contains a high percentage of poorly-drained, fine-textured soils. In contrast, ecoregion 2 has a low percentage of the three most susceptible soils. It was estimated that 27 percent of the area harvested in ecoregion 1 would be significantly impacted, compared with only 8 percent of the area harvested in ecoregion 2.

Soil Erosion: Forest management activities have the potential to affect site quality if they result in an erosion rate greater than the soil loss tolerance value (T value) as defined by the Soil Conservation Service. The T value is strongly based on the rate of soil formation. Soil formation processes vary considerably and this is reflected in the variation between one and five tons per acre. Variation in the rate of formation is due to several factors including: depth of loose materials above bedrock, climatic conditions (particularly temperature and precipitation), parent material, topography, and vegetation. The T index has been developed for use in agricultural areas. An analogous index has not been developed for use in forests. Consequently, all erosion work in forests has been compared with established T values, resulting in a substantial body of literature from which to consider when assessing impacts.

The impact timber harvesting has on the rate of soil erosion depends on many variables including soil type, site conditions, season, application of water quality BMPs, and timber sale layout and design. Typically, lower levels of erosion occur with care in the location, construction, and maintenance of roads and use of soil conservation measures identified in BMPs.

Erosion impacts vary from short- to long-term. Short-term impacts are associated with the soil loss that accompanies typical harvesting operations prior to revegetation. Longer-term impacts occur when the quantity of soil eroded would require many decades to replace at the prevailing rate of soil formation.

Soil loss impacts site productivity by removing nutrients bonded to eroded particles and by reducing the volume of soil available on the site. Nutrient loss can be exacerbated by losses of the organically rich upper horizon due to surface erosion. Offsite impacts can occur via sedimentation, which reduces water quality and can adversely affect aquatic ecosystems.

Moderately and heavily trafficked areas (skid trails) within harvest units and on haul roads are the areas most likely to be eroded. Erosion is most likely to occur in well-drained mineral soils on steeper slopes.

Under the base scenario, it is estimated that about 25,000 acres subject to harvesting would develop erosion rates that exceed T values. Accelerated erosion caused by skidding and felling activities would exceed T values on less than 1 percent of the total area harvested during the 50-year period.

The greatest erosion rates were estimated to occur in ecoregion 6, particularly a period 1 to 4 years following disturbance when sites are most exposed to erosive forces. This ecoregion has the steepest slopes (averaging 45 percent in many areas) of any ecoregion. The southern portion of the state also has the highest rainfall intensity. It was estimated that initial erosion rates could exceed 14 ton/ac/yr in some areas in ecoregion 6. Initial erosion rates were generally less than 5 ton/ac/yr in other ecoregions.

If an area equal to 1 percent of the harvest area were utilized for haul roads, T values would be exceeded on an additional 6,000 acres under the base scenario. These totals indicate that erosion rates would be exceeded on about 8 percent of the haul road area.

Erosion associated with haul roads would occur faster than erosion on other areas of the harvested site. This is because of the more complete removal of surface protection and smoothing of the ground surface in haul roads. The analyses indicated that maximum initial erosion rates in haul roads could approach 100 ton/ac/yr in some areas.

The effects of timber harvesting and forest management activities on slumping (referred to as mass movements) were not quantified. These activities would increase the probability that mass movements would occur. The literature suggests that mass movement events may at least double following timber harvesting. Poorly located roads pose the greatest risk for triggering mass movement events and can increase the risk up to 25-fold. This is particularly true when road construction activities disrupt marginally stable slopes. The greatest potential for mass movements would occur in areas with steep slopes such as the Coulee region of southeastern Minnesota (in ecoregion 6) and areas with shallow soils over bedrock (ecoregions 2 and 3). However, there is currently no evidence suggesting that mass movements are a major problem in forested portions of Minnesota.

The results of the GEIS analysis are consistent with other reports, finding that surface erosion would rarely exceed T values within harvest units but can be a major concern in conjunction with skid trails and haul roads. These results are attributed to the rapid revegetation and surface roughness within harvest units, which greatly reduces the surface erosion that will occur there. The initial removal of vegetation and forest litter is much more complete in heavily trafficked areas which leads to higher initial erosion rates.

Accelerated erosion was evaluated in the GEIS as a short-term impact (i.e., recovery after four years). If the soil loss had been averaged over a longer period, such as the rotation length, then erosion rates would have exceeded T values in fewer areas.

It appears that accelerated erosion within harvest units due to timber harvesting activities will have a minimal effect on forest productivity in Minnesota. This judgement is based on the minimal area within harvest units (less than 1 percent of total harvest area) where initial erosion rates >T are projected to occur. Furthermore, in terms of productivity, T values represent the annual amount of soil that can be lost indefinitely—not just over the first four years following harvesting.

The higher erosion rates that would occur on haul roads may be more important in terms of water quality impacts. As discussed above, compaction and related disturbances on haul roads would greatly reduce the productivity of these areas. It would be difficult to evaluate the added effect of erosion on productivity. However, the large amount of soil that can be eroded from roads can contribute greatly to water sedimentation problems.

5.3.2 Water Resources

Waterbodies in Minnesota's forested regions are generally of high quality and are not currently subject to significant broad-scale impact from forest management practices. However, these water resources do have local impacts at a variety of spatial and temporal scales. The types of impacts that can occur as a consequence of forest management include: sedimentation; nutrient loading; changes to key aspects of the aquatic environment (discussed further in section 5.4.2) such as the amount of light, stream temperature and organic matter inputs—leaf litter, and larger woody material; and changes to the amount, duration, and timing of runoff.

Sedimentation

At the statewide level assessed in the GEIS, there is a low risk of high rates of sediment production resulting from levels of timber harvest and forest management activities depicted in the base harvest scenario. Minnesota's relatively flat landscape reduces the ability of water to transport sediment from the land surface to water. Roads in most areas of the state do not contribute much sediment input for precisely the same reason; i.e., surface flow is restricted by generally flat to gently sloping terrain. As discussed under soil erosion in the previous section, some areas of the state exhibit naturally high rates of erosion and sediment production. Past experience suggests that incautious harvesting in these areas of steeply sloping, variable terrain with highly erodible soils carries an increased risk that disturbed areas will erode, leading to increased sedimentation of local water bodies. In Minnesota, the North Shore and Nemadji areas and the karst areas of the southeast are areas of high erosion potential, with or without harvest activity.

The levels of harvest projected to occur under the base scenario are not predicted to significantly affect the quality of the state's waters when assessed at the ecoregion scale. The development and application of BMPs is an important factor that reduces the likelihood of impact. BMPs are a set of standard practices that are intended to achieve a balance between forest management activities and water quality protection. The types of practices covered by BMPs include retention of filter strips between harvest sites and water courses and undertaking earthworks to control erosion on disused haul roads. BMPs are applied on a voluntary basis in Minnesota. Most timber harvest in Minnesota now follows BMPs. Recent evidence based on field audits of recently harvested areas indicates the percentage of sites complying with BMPs varies according to ownership. The lowest level of compliance, around 70 percent, is on nonindustrial private forests. Compliance on the industrial private lands and public ownerships is very high, nearly 100 percent. The GEIS assumed slightly more conservative compliance levels of 50 percent for nonindustrial private forest lands and 90 percent for all other ownerships. These assumptions were used in impact analyses conducted as part of the study.

Implementation of BMPs in areas of high slopes and erodible soils will reduce the level of sediment related impacts, as will restricting harvest activities to less sensitive times of the year. The literature suggests that it is safe to assume little deviation from expected levels of sediment production on timberlands managed with BMPs. The relative size of the projected areas harvested without BMPs is small and does not significantly increase the rate of sediment production at the ecoregion scale. Site-specific impacts in erodible areas can be expected in areas that do not follow BMPs. The most effective way to minimize sediment impacts is to increase use of applicable BMPs for all timber harvest.

Land use changes that convert forest to agricultural or urban uses can increase sediment production. If large, contiguous tracts of land become the harvesting norm, then large areas of high site disturbance will appear and these could alter sediment equilibria. The scenarios examined in the GEIS are expected to follow standard silvicultural techniques where trees replace trees, rather than representing land use conversion. Thus, harvested forest sites will be assumed to remain under forestry land use following harvesting. Sediment relationships will not significantly deviate from the level of natural variation as long as sites remain forested. Use of mechanical site preparation techniques to regenerate sites exposes waterbodies draining those sites to greater risks of sedimentation. Lower risks occur if techniques requiring no mechanical disturbance of the soil are used. The Silvicultural Systems background paper (Jaakko Pöyry Consulting, Inc. 1992m) estimated that only approximately 11 percent of regeneration areas were prepared using mechanical techniques.

Nutrient Loading

Results from studies in Minnesota suggest that instream concentrations of nitrate and phosphorus are not likely to increase with increased levels of timber harvest in the Northern Lakes and Forests and North Central Hardwoods ecoregions. However, total loadings (i.e., the total amount yielded from a given area in a given time) are likely to increase temporarily due to increased water yields associated with harvesting.

Nutrient increases in waterbodies following timber harvesting in catchments have been reported in the literature from other states. Increased stream nitrate following timber harvest occurs in many areas, particularly the eastern United States. The most significant increases have been reported in Hubbard Brook (NH), Tennessee, and Arizona. In general, sites in New Hampshire, Tennessee, southern Canada, and Arizona had comparable increases following harvesting while other areas of the country had lower increases in nitrogen export. Increases in stream phosphorus have been reported much less frequently.

The impact of timber harvest on lake nutrient levels has not been studied in Minnesota, but the effects on streams draining areas burnt by wildfire offers some insight. Results from wildfire studies cannot be directly extrapolated to timber harvest scenarios in Minnesota, certain parallels can be drawn. These suggest that increased timber harvest by itself is not likely to pose a significant threat to the nitrogen balance of lakes or streams in Minnesota. Predicted increases in phosphorus concentrations in steams and lakes will not reach levels likely to cause eutrophication of lakes or streams.

Runoff From Uplands

In general, water yield from upland mineral soil watersheds increases as forest cover is reduced. These increases in water yield are observed from normal timber harvesting or clearing of land that is converted to croplands. The important difference between timber harvest and land conversion is that with normal timber harvesting, hydrologic changes diminish as the stand regrows on the site. In the case of land that is converted to agriculture or urban development, hydrologic changes are more permanent.

The magnitude of increased water yield is generally proportional to the percentage of a watershed cleared at any one time, and depends to some extent on the type of forest cover harvested or cleared and stand characteristics (i.e., density). Also, the greater the annual precipitation, the greater the increase in water yield will be due to harvesting. These generalities apply to all ecoregions and forest types in Minnesota with one exception: clearcutting black spruce in peatlands has no effect on annual water yield, although the pattern of streamflow response is altered.

Clearcutting of forests can alter streamflow pattern in two ways: (1) magnitude of stormflow peaks and volumes may be affected; and/or (2) magnitude of streamflow discharge during dry season flow may be affected. These effects have not been studied for every forest type and ecoregion in Minnesota. However, some generalizations can be made, particularly for the northern hardwoods, which has been studied.

Stormflow and *flooding* need to be defined precisely to avoid confusion concerning the effects of timber harvesting. Flooding refers to events in which streamflow exceeds bank full capacity of the streambank and overflows, sometimes causing economic damage or even loss of life. Rises in streamflow which have distinctive peaks and result in greater than normal flows are referred to as stormflow events; some of these result in flooding, while others do not. Hydrologists rate the magnitude of peaks based on the frequency with which they are expected to occur in the future. For example, a 5-year recurrence interval (RI) peak would be expected, on the average, to be equaled or exceeded once every five years. Therefore, there is a 20 percent probability that in any given year the peak would be equaled or exceeded. The magnitude of the 5-year RI peak would be smaller than that of the 20-year RI, which would be smaller than of the 100-year RI. Effects of timber harvesting on stormflow must be discussed in terms of magnitude and RI.

For a given RI, the peak discharge (or maximum flow rate) of stormflow can be increased on small catchments by forestry activities. Peak flow can be sensitive to any modification in the catchment, including minor variations in road or skid trail layout and density, or harvest location and intensity.

Stormflow volumes and peaks can be affected by timber harvesting and forest management activities in the following ways:

- removal of forest cover can increase stormflow volumes and peaks with relative effects diminishing as the amount of snowmelt and/or rainfall causing the stormflow becomes very large;
- activities that reduce infiltration of water into the soil cause more surface runoff and can promote greater stormflow from rainfall events. These occur locally, in association with compacted soils due to roads, skid trails and/or recreation sites;
- development of roads, skid trails, and drainages that facilitate movement of water from an area to stream channels can promote higher peakflow. Such activities may be separate from or in support of logging activities; and
- activities that increase delivery of sediment into stream channels reduce the conveyance capacity of the channel and can result in more frequent over bank flow (i.e., flooding).

Because timber clearcuts are normally small areas, increases in peak flows would be important only in certain instances, including:

- determining the size of culverts for temporary roads (e.g., logging roads);
- small stream confluences in which more frequent large flows could damage stream channel morphology; and
- trout streams with considerable sediment and/or debris are present within a channel where they can be affected by more frequent, high level discharge.

Timber harvesting activities on upland sites will not affect the flood characteristics of larger river systems. This is because harvesting and regenerating trees within a predominantly forested area will not cause large changes in peak flows for large areas. However, forest landscapes that are cut and converted to croplands or pastures can produce more permanent increases in streamflow discharge and often greater amounts of suspended sediment.

Low relief terrain and high water tables cause wetlands to act much like lakes (see below). When wetlands and lakes make up between 5 and 20 percent of the total area of a basin and are connected to the major drainage system, they can reduce peak flows by up to 75 percent compared to watersheds without lakes or wetlands.

The first large snowmelt of the year often produces the highest peak flow event of the season. Forests can influence snow accumulation and timing of runoff peak discharges. Peak flows from harvested or nonforest areas can occur five days earlier than from mature forest areas. A mosaic of mature forest together with harvested or nonforest areas has the effect of desynchronizing peak runoffs within a watershed, and thus lowering the combined peak discharge at the watershed confluence. Forest stands up to 15 years of age can be combined with nonforest areas in this context, in order to assess their effect on spring snowmelt. As a result, in the northern portions of the state where snowfall accumulates throughout the winter without complete melt off until spring, snowmelt peaks can dramatically increase if forest cover on a watershed is reduced from 50 percent of the total area to 30 percent or less.

No adverse effects to water quantity or the pattern of streamflow in any ecoregion are predicted under the base harvest scenario. However, on a site-specific basis water yield might increase. Stormflow might increase on small watersheds; however, none of these changes would be evident at the ecoregion level.

Annual Water Yield From Wetlands

The influence of timber harvest on evapotranspiration from wetlands is closely related to the depth of water table. Where the water table depth is normally less than 12 inches (as measured from hollow bottoms), herbaceous layer plants proliferate after timber harvest and can transpire as much or more water as did the trees. Where the depth to water table is greater and wetlands have fine-grained mineral soils, transpiration rates of shallow rooted herbaceous layer plants remaining after timber harvest do not equal those of deeper rooted trees. In the latter case, water yield response is more similar to that of upland areas, with increases following clearcutting commonly 20 to 30 percent of pre-impact conditions.

When the water table depth is normally less than 12 inches and annual precipitation is within 30 percent of average, harvesting trees on natural peatlands does not affect average water table elevation or annual water yield. No estimates of effects of timber harvesting on annual water yield outside of this range of precipitation were found. Therefore, no change in annual yield from wetlands due to timber harvesting and forest management activities under the base level scenario is predicted.

In addition to water quality impacts from natural sources there are other potential sources related to human land uses. These sources include fertilizers, compost, sludges and pesticides.

Fertilizers

There is minimal, if any, fertilization of forest lands in Minnesota. This is unlikely to change. Therefore, there are no demonstrable effects of forest fertilization at present, and none are predicted.

Compost

Compost is not currently used on Minnesota forested lands. Future field studies would have to be employed to determine the site-specific impacts of such applications. It is not anticipated that such use will have regional implications under any scenario.

Sludge

Municipal sludge is currently used on only one forested site in Minnesota. Water quality impacts from that application are not evident. Future field studies would have to be employed to determine the site-specific impacts of future applications. It is not anticipated that such applications would have regional implications under any scenario.

Pesticides

Pesticide use currently is minimal on Minnesota forested lands. Under the present usage pattern there is estimated to be less than 18,000 acres treated annually for site preparation and release (Jaakko Pöyry Consulting, Inc. 1992m). If this level of usage continues, no regional impact on water resources is anticipated. In the event that nuisance outbreaks (e.g., gypsy moths) require large-scale spraying, impacts of forest insecticides could be significant. There is currently no evidence to suggest that such impacts will occur, nor that increases in nuisance outbreaks would be correlated with harvest scenarios.

Summary of Cumulative Impacts by Scenario for the Base Scenario

As previously stated, timber harvesting for the base scenario is not likely to alter the quality of Minnesota's water resources. However, if harvesting occurs without widespread *adherence to BMPs*, smaller watersheds (i.e., <third order) would exhibit a variety of local scale changes, as described in tables 5.13 and 5.14. Probably the most dramatic of these small-scale changes would be increases in sediment production in streams, increases in light and decreases in large woody debris in streams and lakes, and decreases

Table 5.13. Worst case (without BMPs) site-specific water resource impacts projected under the base level harvest scenario.

Variable	Ecoregion	Predicted Change
Streamflow volume	All	Localized increases in first and second order watersheds
Light reaching streams	1,2,4	Increase
Stream temperature	1,2,4	Increase
Stream sediment	6	Increase, high uncertainty
Stream organic matter	1,2,3,4,5,6	Small but variable decreases in all but 4; major and variable decreases in 4
Stream coarse woody debris	1,2,3,4,5,6,7	Small but variable decreases in all
Stream periphyton	1,2,3,4,6	Small but variable increases in all but 4; larger and variable increases in 4
Stream macroinvertebrates	1,2,3,4,6	Small but variable increases in all but 4; larger and variable increases in 4

Source: Jaakko Pöyry Consulting, Inc. (1992d).

Table 5.14. Summary of predicted **worst case** (no BMPs) site-specific impacts to the fish community.

Fish Community	Ecoregion	Predicted Change and Comment
Coldwater streams	2	Small decrease with relatively high uncertainty
	3	Slight decrease with relatively high uncertainty
	4	Decrease with relatively high uncertainty
	5	Slight decrease with relatively high variability and high uncertainty
	6	Large decrease with relatively high variability and very high uncertainty
Coldwater lakes	4	Slight decrease with high variability and very high uncertainty
	5	Slight decrease with relatively high variability and very high uncertainty
	6	Slight decrease with very high variability and very high uncertainty
Coolwater streams	1	Decrease with relatively high variability and relatively high uncertainty
	2	Slight decrease with relatively high variability and very high uncertainty
	3	Slight decrease with relatively high variability and very high uncertainty
	4	Decrease with relatively high variability and relatively high uncertainty
	5	Slight decrease with relatively high variability
	6	Decrease with very high uncertainty
Coolwater lakes	1	Slight decrease with high variability and very high uncertainty
	2	Slight decrease with relatively high variability and very high uncertainty
	3	Slight decrease with relatively high variability and very high uncertainty
	4	Slight decrease with relatively high variability and very high uncertainty
	5	Slight decrease with relatively high variability and very high uncertainty
	6	Slight decrease with very high variability and very high uncertainty

Source: Jaakko Pöyry Consulting, Inc. (1992d).

in stream fish population densities in some regions (especially ecoregions 1, 4 and 6). Small watersheds harvested with BMPs would still have increases in nutrient loads, sediment loads, stream channel morphology and would have altered, but not necessarily worsened the structure and functional rates of the aquatic communities. These changes would generally be limited to a few hundred meters below a timber harvest site. With respect to the fish community, harvesting with BMPs would effectively eliminate the changes predicted in table 5.14, i.e., there would be no impact.

5.4 Biological Resource Impacts

5.4.1 Plant and Animal Species Abundance and Diversity

Animals

In assessing significant impacts, the GEIS analysis assumed that current population levels are appropriate and that deviation from those is a basis for concern. However, target population levels for many species could logically be considered either higher or lower than those that exist today. The current population levels are a function of a complex history, the present extent, composition and structure of Minnesota's forests, and several exogenous factors. Given that the current forest age class structure is far from balanced, then it is possible that habitat dependent wildlife population levels are also out of balance and target populations higher or lower than present may deserve consideration.

Minnesota's forest dependent wildlife can be broadly categorized under four separate subgroups—small- and medium-sized mammals, large mammals, birds, and herptofauna (amphibians and reptiles). Within each of the four subgroups certain species depend on forested habitat for their survival. Species that meet this criterion include 22 small- and medium-sized mammals, 5 large mammals, 138 birds, and 12 herptofauna.

Timber harvesting and forest management activities can alter the habitat value of stands for these various species and species groups. A wide range of habitat factors can change as a consequence of harvesting. These changes can either reduce or enhance habitat values with the potential to impact animal populations accordingly. The following example illustrates these linkages between habitat and population.

Grey squirrel and fox squirrel are strongly dependent on trees that produce food, especially oaks, hickories, and walnuts. These species also use tree cavities as nests and to store food. Complete clearcutting of a stand removes all trees that provide food and cavities, making the stand unsuitable habitat.

After decades, the second growth stands acquire the habitat values required by these species, becoming suitable habitat for these species again.

Statewide data were available for two key factors affecting the habitat value of forests that are relevant to wildlife populations, and are likely to change as a consequence of timber harvesting. These factors are tree species mix and the age or size classes of these trees.

Based on the imputed characteristics of these covertype/age (or size) class combinations, other assumptions regarding the presence or absence of habitat elements can be made. For example, cavities are likely to be found in a 150 year old stand whereas they are not likely to be found in a recently clearcut stand.

Each species of mammal and bird will be relatively more or less abundant (including being absent) in each combination of covertype and age/size class. Using the example above, squirrels would likely be very abundant in a mature oak-hickory stand, while they would likely be absent from a newly regenerated stand. Therefore, the direction and magnitude of population change in each animal species of interest can be estimated by examining projected acreage of forest types and size classes.

A caveat is appropriate for riparian species. Selective harvesting was allowed in those areas and thus the original covertypes were essentially unchanged. However, model resolution did not allow consideration of direct disturbance or subtle changes in stand conditions due to this harvesting that could affect the animals present. Thus, the model may overestimate available habitat. The concern is especially relevant for the Bald Eagle, Osprey, and many herons.

Each of these species has an estimated range distribution within the state. Limitation of a species' occurrence to forests within its range makes it meaningless to assess impacts on *that* species due to habitat changes in forests outside of its range.

The major emphasis in assessing wildlife impacts was at the ecoregion level and results of impact analyses are developed in section 5.6.4. However, for illustration, table 5.15 describes the general direction of projected population levels for the species groups considered under the base harvest scenario. Statewide over the 50-year study period, 97 percent of the total number of species are projected to remain stable or increase under the base scenario; while the populations of five species are projected to decrease. Nearly all species projected to increase statewide under this scenario are *early-succession* species that have considerable habitat outside of forests (open areas, brushland, etc.). As was shown in table 5.7, about 875,000 acres of forest are projected to be lost in the aspen-birch and northern pine FIA units over the next 50 years. This conversion to nonforest within the main forested portion of the state will favor some early succession species. Although forest area is projected to increase in other parts of the state (Central Hardwood and Prairie FIA units), much of this new forest on former farmlands also will be young forest. The increases in these early successional species should not be viewed as offsetting decreases in species more strongly dependent on forests.

Table 5.15 Number of species of interest that are projected to decrease by 25 percent or more, remain stable*, or increase by 25 percent or more, statewide on all forest lands under the base level of harvesting.

Species Group (total number of species)	Decreasing (No. of species)	Stable (No. of species)	Increasing (No. of species)
Small Mammals (22)	0	21	1
Large Mammals (5)	0	5	0
Birds (138)	5	111	22
Herps (8)	0	6	2
All (173)	5	143	25

Source: Jaakko Pöyry Consulting, Inc. (1992f).
* *Stable* is a change of less than 25 percent.

Endangered, Threatened, or Special Concern Species

Species with limited populations in the state have been assessed at a state and federal level and have been classified according to certain criteria that assess the degree to which the populations are at risk. The following criteria are applied by the state to undertake this assessment (Jaakko Pöyry Consulting, Inc. (1992f).

1. *endangered*, upon showing that such species is threatened with extinction throughout all or a significant portion of its range; or
2. *threatened*, upon showing that such species is likely to become endangered within the foreseeable future throughout all or a significant portion of its range; or
3. *species of special concern*, upon showing that while a species is not endangered or threatened, it is extremely uncommon in Minnesota, or has a unique or highly specific habitat requirements and deserves careful monitoring of its status. Species on the periphery of their range which are not listed as threatened may be included in this category along with those species which were once threatened or endangered but now have increasing or protected, stable populations.

Timber harvesting and forest management activities have the potential to affect populations of species (animals and plants) of special concern, threatened, or endangered. Populations of listed species differ in terms of the species ability to rebuild population numbers and to cope with disturbance. Relevant factors influencing this ability include:

- species life history, dispersal ability, ecological, and genetic factors; and
- management objectives and practices of landowners.

State and federal ownerships have policies that are directed towards improving conditions for species on these lists. Other ownerships have less explicit management objectives, with a consequent increase in the risk of adverse impacts.

Medium- to long-term impacts would be associated with reductions of populations. The timeframe would depend on the factors identified above. Irreversible impacts could occur where a species is lost from within and outside Minnesota. There is the potential for a loss of biodiversity as these species diminish or are lost from the ecosystem.

Endangered, Threatened, and Special Concern Animals

The assessment of changes to wildlife populations as a consequence of timber harvesting and forest management activities is centered on changes to habitat. The following sections identify the species with endangered, threatened, or special concern status; and assesses the implications of the level of harvesting projected under the base scenario for the populations of the species explicitly considered in the GEIS analysis.

Birds.—There were five state- or federal-listed, forest-dependent bird species considered in the analysis. At the base level of harvesting, these species are predicted to be affected in the following manner:

1. Osprey: An overall statewide increase is predicted, both on timberland and for all forest lands.
2. Bald Eagle: Stable statewide populations are predicted.
3. Red-shouldered Hawk: An overall statewide decrease is predicted on timberlands and on all forest lands.
4. Loggerhead Shrike: A significant increase in statewide populations on timberlands and all forest lands is predicted. However, it is uncertain if this candidate federally-listed species has a population that uses forest land in Minnesota.
5. Louisiana Waterthrush: Stable populations are predicted statewide.

Herps.—There were four state-listed forest-dependent species considered in the analysis. At the base level of harvesting these are expected to be impacted as follows:

1. Wood turtle: A stable or slightly increasing habitat statewide is predicted.
2. Timber Rattlesnake: A stable or slightly increasing acreage of habitat is predicted.
3. Hognose snake: A >25 percent increase in habitat statewide is predicted.
4. Pickerel Frog: A large increase (>50 percent) in habitat acreage statewide is predicted.

Small Mammals.—There was one state-listed, forest-dependent small mammal considered in the analysis. At the base level of harvesting it is expected to be affected as follows:

1. Pine Marten: Stable or increasing populations are projected.

Large Mammals.—There was one threatened (state and federal) forest-dependent large mammal considered in the analysis. At the base level of harvesting, the effect on this species would be as follows:

1. Timber wolf: No appreciable and direct impact on the timber wolf is expected.

Endangered, Threatened, and Special Concern Plants

A recent inventory of the vascular plants of Minnesota lists 1,618 species. The number of species of mosses in Minnesota is probably around 380; and there are more than 550 species of lichens. Sixty-seven plant species currently are listed as endangered, threatened, or of special concern. These include 8 lichens, 2 mosses, and 57 vascular plants.

In general, the forest-dependent rare plant species of Minnesota are poorly adapted to trampling types of injury. Most (except for the one tree species listed) are of small stature and easily broken. Any harvest that would allow heavy equipment to drive through a population of rare plant species would cause impacts.

There are large numbers of occurrences of endangered, threatened, or special concern plants within Minnesota's forests, in all ecoregions. Table 5.16 summarizes the numbers of species by ecoregion that are projected to be adversely impacted under the base level harvesting scenario.

Table 5.16. Summary of the numbers of rare plant species likely to be adversely impacted directly by harvesting, by ecoregion.

Ecoregion	Endangered	Threatened	Special Concern
1	1	1	5
2	1	3	7
3	4	3	12
4	2	3	17
5	1	2	6
6	4	5	24
7	0	0	3
All ecoregions	9	7	37

Source: Jaakko Pöyry Consulting, Inc. (1992e).

5.4.2 Aquatic Ecosystems

Harvesting activities that remove or alter forest cover and other types of forest management activities within a watershed have wide-ranging effects on waterbodies and the plants and animals that live within them. As discussed in section 5.3.2, these activities can affect the amount, timing, and quality of water yield. The flux of nutrients and ions from the landscape to the water resource is usually altered to some degree. Similarly, disturbance to the soil surface can increase erosion and sediment inputs to waterbodies. In addition to these changes to the physical characteristics of the aquatic environment, there are likely to be changes in the biological component. Changes in the riparian canopy alters inputs of organic matter (a central food resource for the aquatic community) and affects the amount of light reaching the water surface. Light in turn affects primary producers (i.e., algae and higher plants) and may cause water temperatures to increase. All these changes affect the species composition, growth, and production of the animals that inhabit the water resource. Thus, invertebrates as well as fish communities are often changed in type and in function (i.e., the ways they process matter, nutrients, and energy).

It is uncertain how a change in landscape management will affect a specific water resource. Each of the changes discussed above has its own variability as well as an associated uncertainty. For some effects (e.g., water volumes), a significant amount of research has been conducted in the forested regions of Minnesota. Therefore, some degree of confidence is appropriate in discussing probable changes in response to increased timber harvest. In other cases (e.g., stream or lake biology or wetland plant communities) the analysis has relied on research and literature from other parts of the country or the world. Those studies were often conducted under conditions quite different from Minnesota. Because of those differences, generalities were developed from the available literature and professional experience of the authors, and then used to postulate effects that might occur under Minnesota conditions.

The following provides an overview of the key parameters and projected impacts under the base level of harvesting.

Light and temperature
If stream corridors were harvested to the water's edge, large increases in light reaching the stream channel would occur. This could increase the temperature of smaller streams and change the species composition and rates of production of the stream community. These impacts would be local, and not evident at the ecoregion scale. If watersheds are harvested in compliance with BMPs, no significant effects on light or temperature would be expected. Generally speaking, no change in light reaching lakes under any harvest scenario is predicted. The level of light reaching small streams is expected to increase in ecoregions 1, 2, and 4. This will probably cause a small localized increase in average temperature, lasting for two to five years following harvesting.

Organic matter
Harvest in compliance with BMPs may change species composition in the riparian canopy, thereby altering the quantity and chemistry of leaf material that enters a stream or lake. Such changes would probably alter the species composition of insects in the stream of the riparian zone of the lake. Those changes may in turn affect the fish community. In general, such changes are expected to be minimal under the base level scenario. One exception was in ecoregion 1, where the analysis predicted there would be measurable reductions in organic inputs to streams and lakes.

Site-specific changes to organic inputs to wetlands are likely when harvesting is conducted without BMPs. However, no cumulative regional changes to organic inputs to wetlands are projected under the base level scenario.

Coarse Woody Debris
Wood provides a substrate, food resource, and habitat for stream and lake organisms. Wood also serves to control the stream channel (i.e., through debris dams, overhangs, channel obstructions). Changes in the riparian zone related to timber harvest are likely to change inputs of wood to streams, lakes, and wetlands. Those changes would be most important to small streams, exerting their influence on a local, site-specific basis. Effects might include changes in stream animal populations, in rates of flow, and in energy utilization patterns. More specifically, the analysis predicted that large woody inputs to lakes will not change and inputs to streams will be

significantly reduced in all ecoregions except 1 (and 8, for which no wood predictions are made).

Primary producers

Timber harvest in stream riparian zones would alter light and temperature, thus affecting stream algal growth. However, harvest in compliance with BMPs will have no adverse impacts on light and thus none on stream periphyton or lake phytoplankton. More specifically, at the local scale large short-term increases in stream periphyton are predicted in small streams in ecoregion 4, and small increases are predicted in ecoregions 1, 2, 3, 5, and 6. No changes in lake phytoplankton are predicted.

Macroinvertebrates

Water quality, sediment, light, leaf, and woody organic matter all influence macroinvertebrate kinds, numbers, and activities. Therefore, predictions about macroinvertebrate changes are affected by any uncertainty in predicting other changes. Harvest in compliance with BMPs will usually protect the stream and lake from large changes in these variables, and thus in macroinvertebrates. Specifically, the analysis predicts that macroinvertebrate communities in lakes will not change in response to timber harvest at the levels projected to occur under the base level scenario. Substantial increases in macroinvertebrate populations are predicted in streams in ecoregion 4, and small increases in the other ecoregions are predicted.

Forest dependent fish and their habitat

A wide variety of fish species lives in, and is dependent upon the conditions existing in Minnesota forested landscapes. If all timber harvests employ BMPs, no great impacts to fish communities are predicted under the base level scenario (see table 5.18 in section 5.3.2). If BMPs are not enforced, the amount of suitable coldwater fish habitat in ecoregions 3, 4, and 6 is predicted to be reduced by 1 to 3 percent, with the possibility of similar reductions in fish populations. In this case, the analysis predicts there also would be small to slight reductions in the populations of fish in all other coldwater streams, all coolwater streams and lakes, and coldwater lakes in ecoregions 4, 5, and 6 (see table 5.17 section 5.3.2). These impacts would not be evident if BMPs were in place.

Ephemeral ponds and fishless permanent ponds

Timber harvesting can impact these aquatic habitats by siltation or by removal of shade and increased exposure, resulting in early drying. Removal of shade can also lead to increased water temperatures which may exceed tolerance levels for some species of amphibians. These habitats are important for species such as wood frogs, treefrogs, spring peepers, eastern newts, and blue spotted salamanders. In addition, some harvesting practices, particularly full-tree harvesting during winter, can result in substantial volumes of slash being deposited in these and other small wetland habitats. This is likely to eliminate the habitat value for many species.

5.4.3 Riparian Corridors

Riparian corridors are the strips of land and associated plant communities located adjacent to waterbodies. These areas can often be the focal point for resource management conflicts because of their importance for such widely differing forest values. Because of high soil moisture and nutrient availability, riparian zones are highly productive for both fiber and, in the southeast, fine hardwood sawlogs. Riparian zones are one of the most important components of the water/land interface due to their influence on (1) habitat within the aquatic system, (2) transport of pollutants and erosion to a stream, wetland or lake, (3) habitat for terrestrial species, (4) aesthetic characteristics of the landscape, (5) recreational opportunities for the public, and (6) site of cultural and historical resources.

Harvesting activities in timberlands in riparian zones along larger streams and lakeshores is becoming more constrained. This was reflected in the model assumptions which limited the types of timber harvesting and forest management activities within 100 feet of water; and within 200 feet of lakes or major streams in ecoregions 4, 5, 6, and 7. These measures meant that no riparian bird species were projected to be adversely impacted under the base level of harvesting and that nine of a total of 20 species were projected to show increasing populations. Similarly, herp populations would also benefit.

Maintaining the integrity of riparian vegetation is an important management objective and a frequent objective of BMPs. Note that current BMPs only require an intact filter strip of ground vegetation, and that overstory, understory and shrub layers can be removed without violating these guidelines. In this regard, impacts to aquatic systems occur almost exclusively when the riparian corridor has been disturbed, either by harvesting or roading. Poorly planned and maintained stream crossings can be the main sources of sediment pollution of streams in forested catchments. Impacts to aquatic ecosystems from management within the riparian corridor are apparent through changes in material and energy flows between the terrestrial and aquatic environments.

Reductions in organic matter inputs, changes in timing of inputs and changes in the quality of litter inputs are likely to occur on a site-specific basis when harvest occurs within 200 feet of the stream channel.

A survey of randomly selected tracts of timberlands via aerial photo and ground examination was conducted as part of the GEIS study process. This survey concluded that 29 percent of the locations contained harvesting within 200 feet of water (see table 5.17). Where harvest did occur within 200 feet

Table 5.17. Aerial photo evaluation of recent (within last ten years) timber harvesting near water from 30 FIA locations randomly located throughout the state.

Plot Characteristic	Value
Total Number of FIA Sample Locations	30
Average Size of Tract (acres)	446
Survey Units Examined	
Aspen Birch	12
Northern Pine	12
Central Hardwood	6
Percent of Locations with Water	77
Percent of Locations with Clearcuts <10 yrs old	50
Average Number of Cuts Per Location	1.6
Range in Size of Clearcut (acres)	10-40
Percent Locations with Clearcuts and Water	37
Percent Locations with Partial Cuts and Water	7
Percent of Locations with Cuts within 200 Feet of Water	
Near Streams	3
Near Lakes	3
Near Wetlands	23
Percent of Cuts within 200 Feet of Water	
Aspen Clearcuts	10
Conifer Clearcuts	10
Hardwood Clearcuts	10
Conifer Partial Cuts	3
Average Distance of Cut to Water (feet)	472
Median Distance of Cut to Water (feet)	0

Source: Jaakko Pöyry Consulting, Inc. (1992d).
*All percentages calculated on the basis of 30 locations. Note, that because half of all plots surveyed were immediately adjacent water, the "median" distance to water is statistically set at "0".

of water, half of the harvests were located immediately adjacent to the waterbody. Thus, only one-third of that recent harvesting occurred near water but those activities occurred within a short distance of water. Most of the water was actually wetland, as distinct from streams or lakes. Fewer wetlands and more streams would probably be seen if the photography were extended to southern Minnesota.

5.4.4
Forest Insect and Disease Concerns

Forests are presumed to be healthy when biotic and abiotic influences do not threaten the attainment of current or future management objectives. Although specific aspects of forest condition can be quantified and measured objectively, assessing forest health depends in part on subjective evaluations and value judgements.

Insects and diseases are important components of the forest ecosystem; they are fundamental agents of change impacting long-lived communities. The effects of insects and diseases on forests in the Lake States include tree mortality, tip dieback, or top-kill; loss of reproduction and regeneration; loss of tree form; and reduced resistance to other stresses. These effects can be translated into impacts such as loss of productivity due to mortality, decay, reduced growth rates and increased risk to fire. In addition, insects and disease can impact the recreational and aesthetic aspect of forest resources. Pests and diseases can also affect wildlife habitat values. Fungal decay provides habitat by creating hollows in trees, and insect pest larvae are a source of food for many species. However, widespread pest outbreaks leading to high levels of tree mortality may also reduce the habitat values for other wildlife species. This is a particular problem where natural checks and balances controlling a pest population cease to function, or where a new pest is introduced and there are no natural controls to check its growth.

The risk to a forest stand of a pest attack or infestation (susceptibility) and the likelihood of damage if an attack occurs (vulnerability) are frequently related to stand age. Typically, as stands get older they become more susceptible to damage and are at greater risk of infestation. However, there are exceptions to this generalization where seedlings and young trees are preferentially attacked. Harvesting that requires multiple entries into a stand may also increase risk. For example, if care is not exercised, harvesting can damage residual trees, leaving them open to attack by insects and disease. Finally, atmospheric pollutants can weaken or stress trees, potentially increasing their susceptibility and vulnerability.

The amount of damage incurred during outbreaks of insects or disease is generally related to stand attributes and environmental conditions. In some cases, especially for insects, pest populations can be regulated by biological control organisms including predators, parasites, and pathogens. Stand and site-related factors associated with severe impacts vary with the nature of the health problem. However, low vigor trees, particularly those stressed by drought, are most likely to be severely affected by insects and diseases. Species and age class diversity within and among stands may reduce impacts relative to large, continuous areas of similarly-aged host trees.

The possible effects of an increase in timber harvesting and associated forest management practices on forest health in Minnesota include changes in the proportion of susceptible/vulnerable age classes, and the incidence of multiple entry harvesting operations.

Under the base scenario, projected harvesting levels will increase the acreage of younger stands for most covertypes. This harvesting will tend to reduce the incidence of many insect pests and diseases that are favored by older forests. Insect species in this category include spruce and jack pine budworm and two-lined chestnut borers. In addition, diseases such as white trunk rot of aspen are also likely to be reduced. Other diseases including cankers and decay of upland hardwoods and oak wilt, will probably decrease in the short-term but may ultimately increase.

In contrast, the incidence of some insect pests, such as white pine weevil, are likely to increase as a consequence of the base level harvests. This is due to an increase in acreage of susceptible younger stands. The incidence of some diseases are also likely to increase, including *Diplodia* shoot blight and canker, and possibly *Scleroderris* canker of red pine. Some of the predicted increases in susceptibility and vulnerability are based on the following assumptions: (1) that an increase in timber harvesting would substitute young, more susceptible stands of pine species to replace older stands that have been cut; (2) changed management objectives including longer rotations will result in more susceptible/vulnerable age classes of other forest types; and (3) increased use of thinning and selection harvests will increase the risk of damage to retained trees.

5.5 Socioeconomic Resource Impacts

5.5.1 Outdoor Recreation Opportunities

Timber harvesting and forest management activities can have an impact on recreation opportunities in a variety of ways. Harvesting can affect the type of recreation opportunities available, the quality of the recreational experience, and the number of hours of recreational activity at a given site. Some of these impacts are related to the recreational user's visual perception and the attractiveness of the forest setting. Some of the impacts are long-term while others are short-term and/or subject to change from forest growth and dynamics on that site or over a broader context or area.

A summary of potential impacts of timber harvesting and forest management on forest recreation opportunities is provided in table 5.18. Impacts 1 through 5 are impacts on recreation opportunities and impacts 6 through 8 are impacts on aesthetic characteristics that affect the recreation opportunities. There is a close relationship between recreational value and aesthetic value.

Table 5.18. Potential impacts of timber harvesting and forest management on forest recreation opportunities.

Impacts
1. Change can, in some cases, eliminate the more primitive recreation opportunities.
2. Harvest operations can create travel barriers and create negative recreation use impacts along improved and unimproved roads in the forest areas (e.g., slash on roadsides, trails, landing and staging areas, ruts in roadways).
3. Harvest operations can create new and improved forest roads. This improved system of roads can change the nature of the recreational opportunity and change the use of the area.
4. Increased harvest operations have the potential to increase offroad vehicle use in forest areas due to increased access via logging related road building. Increased ORV use has the potential to cause recreational user conflicts, stream and trail damage and impacts on sensitive wildlife.
5. Traffic conflicts can occur between logging vehicles and recreational drivers for use of roadways, increased dust from logging traffic, etc.
6. The aesthetic and natural experience of many outdoor recreation users can be reduced by large clearcut areas. Research shows that many outdoor recreation users seek an aesthetic experience, such as viewing the landscape in a natural or relatively unmodified setting. Clearcutting may produce more resources for consumptive recreational use (game, berries) in some areas, but it also will reduce the aesthetic/natural experience opportunities sought by many of these recreational users.
7. Visual and noise impacts of timber harvest operations can change recreational opportunities for persons in adjacent parks, waterways, and other recreation areas designated to provide aesthetic and primitive recreation experiences.
8. Visual impacts of timber harvesting operations on adjacent properties can adversely affect the visual setting of resorts. Noise impacts can also be a nuisance.

This impact assessment clearly indicates that timber harvesting and forest management activities have direct effects on the recreational use of forests. In some cases, harvesting decreases the quality of the recreation experience and increases the amount and kind of recreational activity at a site. In other cases the opposite might occur. And, in still other instances, no change might be expected.

In nearly all cases where the quality of the recreational experience was judged to decrease, activity hours were estimated to increase. The reason for this apparent contradiction is that roads constructed for harvesting operations can provide access into previously inaccessible areas. Improved accessibility enables more people to use the area. In formerly unroaded areas, provision of motorized access can increase the range of recreational uses possible in such an area. However, increased numbers of users may be undesirable for the opportunity provided at the site, and may displace existing users. The implications from a management perspective largely depend on the management objectives for the area. Ownerships that recognize and manage for recreation may take steps to control access, and therefore limit the range of uses, by closing off roads as harvesting is completed. Other ownerships may elect to do nothing and to accept whatever uses occur. The following section discusses the impacts by categories of ROS class and ownership.

Primitive and Semiprimitive Nonmotorized Recreation Opportunities

The management guidelines definition of ROS primitive and semiprimitive areas used by the USDA Forest Service are:

- *Primitive areas* are three or more miles from all maintained roads or railroads. Primitive areas are unmodified natural environments. Evidence of trails or recreational use can exist. Structures in use are rare. Contact with humans is rare and chances of seeing wildlife are good.
- *Semiprimitive nonmotor areas* are one-half to three miles from all maintained roads or railroads. They may be close to primitive roads or trails used only occasionally. Modifications to the natural environment are evident, such as old stumps from prior logging operations, but they are not apparent to the casual observer. Structures in use are rare. Human contact is low and chances of seeing wildlife are good.

Given these specifications, it is clear that the most primitive opportunities are destroyed when such areas are roaded and motorized uses are introduced. Under these circumstances, the opportunities available would shift to those more suited to developed sites.

Across all FIA forested plots (timberland, reserved, and unproductive) in Minnesota, only 3.1 percent of the total were in the ROS primitive class and 9.6 percent of plots were in the semiprimitive nonmotorized class. Of these statewide totals, 0.4 percent and 7.2 percent, respectively, occur on timberland.

Timber harvesting and associated roading on any of these plots has an impact on the plot itself and also on the number and distribution of areas in the state where opportunities for the more primitive and recreation opportunities will be available in the future.

Developed Recreation Opportunities

Timber harvesting and forest management activities in the more developed ROS classes cause changes that are reversible over time. The types of impacts that could be expected include those associated with an increase in the accessibility of an area, and impacts to the setting caused by changes to the vegetation. The consequences of these changes are twofold. For existing users who appreciate comparatively natural surroundings and lower levels of contact with other groups, the quality of the recreation experience diminishes. However, the improved access increases the opportunities for people who were previously constrained by a lack of access. Therefore, the amount of activity increases as a consequence of the increase in the levels of use. The persistence of these changes depends to a large degree on how the area, and particularly the roads, are planned and managed before, during, and after harvesting is completed.

Some ownerships, notably the USDA Forest Service and MNDNR, employ (or are in the process of introducing) VMGs in the planning and execution of timber harvesting and the subsequent management and regeneration of harvested areas. Under these circumstances, impacts on users are minimized. Also, these ownerships restrict access by closing logging roads not required for other management or land use purposes. Therefore, the recreation values for users seeking relative isolation will be restored as the forest regenerates and usage levels drop. Use of VMGs will likely lessen the time taken to restore the setting sought by this category of user.

However, where ownerships do not use VMGs and apply ad hoc management to access, it is likely that these changes will persist. Unauthorized, or authorized use of unmaintained logging roads by all terrain vehicles (ATV) and offroad drivers will continue to diminish recreation values for users seeking relative isolation.

Table 5.19 describes how harvesting at the base scenario will impact the six recreational opportunity classes. Although the ROS system is not used or appropriate across all ownerships, it is helpful in understanding the opportunities from a statewide perspective.

Harvesting at the base scenario would subject 50.4 percent of the timberland plots to harvesting. Of these, 7.6 percent are currently classified as nonmotorized areas. When all forest land is considered, 5 and 25 percent of plots in the primitive nonmotorized and semiprimitive nonmotorized classes, respectively, are subject to harvesting. Harvesting beyond the year 2040 would tend to concentrate on the accessible and productive plots harvested in the first 50 years, i.e., additional harvesting is not likely to extend far beyond the set of plots harvested in the first 50-year period.

Table 5.19. Distribution of FIA forest and timberland plots and plots projected to be harvested, by ownership and ROS class, 1990–2040.

ROS Class	Total number of plots, all forest	Total number of timberland plots	Percent of timberland plots by ROS class	Number and (percent) of timberland plots harvested by ROS class — Base Scenario	
				State/federal lands	Other lands
Primitive	425	53	.4	8 (15.1)	15 (28.3)
Semiprimitive nonmotorized	1,306	876	7.2	150 (17.1)	173 (19.7)
Semiprimitive motorized	3,409	3,074	25.4	529 (17.2)	925 (30.1)
Roaded natural	5,232	5,049	41.7	662 (13.1)	2,121 (42.0)
Rural	3,107	3,030	25.0	140 (4.6)	1,366 (45.1)
Urban	57	36	.3	1 (2.8)	18 (50.0)
All classes	13,536	12,118	100.0	1,490 (12.3)	4,618 (38.1)

5.5.2
Aesthetics and Visual Quality

The constraints and mitigations assumed on state and federal lands are driven by the presence of specific management goals, plans, and related policies and the need to be directly responsible to the public. Given that, there appears to be a tendency to harvest areas of high visual sensitivity at a lower rate than areas of moderate to low sensitivity. The converse was found on private lands (see table 5.20). There is also a concern that harvesting may take place on lands adjacent to designated recreation areas such as state and national parks, wilderness areas, wild and scenic rivers, and long distance trails.

Timberlands not in federal or state ownership do not have VMGs in place and therefore, there is a stronger likelihood of adverse impacts on these lands. Under the base scenario, 38 percent of nonfederal and nonstate owned timberland plots were projected to be impacted (see table 5.19).

In terms of dynamics over time, the forests of Minnesota are aging and under the base scenario would continue to do so. Ownership constraints and mitigations that preclude certain areas from clearcutting also increase the area of older forest. Under the base scenario, most future forest covertypes would have an average age older than that of today. Given 50 years of growth, the oldest ages would be greater than found today for many areas. It follows that average tree size, which is an important component of attractiveness, would not be negatively impacted under the base scenario for most covertypes. The covertypes that would be adversely impacted are those subject to substantial harvesting including aspen, balsam poplar, and maple-basswood.

Table 5.20. Percent of FIA timberland plots projected to be harvested (1990–2040) by visual sensitivity rank and by ownership (excluding primitive, semiprimitive nonmotorized, and urban ROS classes).

	Percent of timberland plots harvested by visual sensitivity rank	
	Base Scenario	
Visual Sensitivity Rank	State/federal lands	Other lands
High	10.4	49.6
Moderate	11.4	44.5
Low	12.7	37.3
Very low	13.0	32.5
All ranks (high to very low)	12.1	39.6

5.5.3 Unique Cultural and Historical Resources

Heritage resources can be divided into five main categories: cultural landscapes, standing structures, archaeological sites, cemeteries, and traditional use sites.

Cultural Landscapes are a collection of features which represent interaction between humans and the environment. People may assign cultural meaning to natural features or features which have been made or modified by humans.

Standing Structures include buildings and structures made and used by people, generally in the recent past. Standing structures are rare within the timberlands considered in the GEIS.

Archaeological Sites are located on or below the surface of the ground or under water. They include two major categories: Native American sites such as the remains of large and small villages, camps, and processing sites; and Euro-American sites such as fur trade posts, homesteads, and logging camps. Most of these sites are not visible at the ground surface and require special techniques to locate. Many sites are present within forested areas and could be adversely affected by timber harvesting activities. Most pre-Euro-American sites are probably located within 1,000 feet of past or present water features (including swamps, marshes, abandoned river channels, etc.).

Cemeteries may contain the remains of one or more human beings and are common on forested lands in Minnesota. These include Native American and Euro-American cemeteries.

Traditional Use Sites are locations which have been historically used by one or more groups of people for some type of activity. They may lack the physical evidence of artifacts or structures, and are often characterized by plants, animals, and/or topography which are of cultural and religious significance to Native Americans.

Site Location Density and Size

Inventory of heritage sites has been carried out intermittently for over a hundred years. Site data are entered into the state listing of known sites. This listing is maintained by the state archaeologist's office and contains over 3,000 records; less than one percent of all estimated sites. However, as well as being incomplete, the inventory contains numerous inaccuracies.

Current Inventory Procedures Used in Timberlands

The USDA Forest Service is the only ownership that routinely surveys all timber sales to identify heritage resources. The entire sale area is surveyed.

Site Density

Site density figures were estimated for archaeological sites and cemetery sites combined as one category. No densities could be determined for cultural landscapes or traditional use areas.

Estimated site density varies from 3 sites per 1,000 acres to 32 per 1,000 acres. These estimates are based on a review of existing file data for all the state with the exception of ecoregion 7, which lacked sufficient data on site density in timberland areas to enable an estimate to be made. Of the ecoregions examined, the Eastern Prairie/Forest transition zone (6) probably has the highest density, with an estimated average of 4 sites per 125 acres. For the Western Prairie/Forest transition zone (5) there is an estimated average of 3 sites per 125 acres. For the Central Pine-Hardwood Forests, the estimate is 3 sites per 200 acres. For the Border Lakes and Lake Superior Highlands unit, the estimate is 1 site per 200 acres. For the Glacial Lake Plains, the estimate is 1 site per 325 acres.

Site Size

Most archaeological sites are probably under 5 acres in size, although this varies by ecoregion. Sites in the Eastern Prairie/Forest transition zone may be the largest, generally occupying 5 to 10 acres. Sites in the Central Pine-Hardwood Forests are generally under 5 acres, but over 1 acre. Sites in the Lake Superior Highlands are frequently less than 1 acre. Cemetery sites vary considerably in size, from less than 1 acre to 25 acres. Cultural landscapes range from small features, such as portions of rock outcrops, to large areas which include major topographic features. Traditional use areas may be less than 1 acre to 100 acres.

Impacts on Cultural and Historical Resources

Most heritage sites are extremely fragile and can be seriously affected by timber harvest and associated activities, such as road construction. They are fragile because dislocation of artifacts and the sediments which contain them can destroy or seriously compromise the essential information which they contain. Earth-disturbing activities do not have to be very intense to negatively affect such sites.

Traditional use sites can be altered by modern harvesting operations through change of vegetative cover, reduction of availability of certain plants and animals, and changed frequency and mode of public access.

Past Impacts

A substantial proportion of archaeological and cemetery sites in ecoregions 6, 7, and parts of 5, have suffered damage from plowing. In some cases, this has been severe enough to destroy most of the scientific value of the archaeological sites. In the northern ecoregions, land clearance with chisel plowing has affected only a small portion of the land surface.

Cemeteries retain their religious significance even if they have been plowed or furrowed.

Number of Sites Potentially Impacted

The estimates of site density were applied to the estimates of the total number of acres harvested in each ecoregion under the three scenarios. The maximum number of sites potentially impacted by the level of harvesting projected under the base scenario is 105,000 sites or 55 percent of the estimated total number of sites.

The analysis used several assumptions that are likely to substantially reduce the actual number of sites potentially impacted at the base scenario from the estimated maximum of 105,000. These assumptions are the following:

- More sites are located in shorelands which are less likely to be impacted by timber harvesting because of existing state and/or local regulations, e.g., shoreland ordinances.
- Surveys by the USDA Forest Service locate sites on their lands prior to harvest.
- A proportion of sites are likely to be protected because they are located in areas harvested when the ground is frozen. Approximately 43 percent of all harvesting is undertaken during the winter months in northern and central Minnesota.
- The extent of *undisturbed* areas left after logging varies with the type of operation, from 15 percent (mechanically-felled) to 37 percent (hand-felled). Therefore, a proportion of sites will be wholly or partially retained intact where they are located in undisturbed parts of the site.
- Past land use activities, particularly plowing, have affected a substantial proportion of sites in ecoregions 6, 7, and parts of 5; but relatively small areas of 1, 2, 3, and 4.

Archaeological and Cemetery Sites
Analyzing timber harvesting impacts at the base scenario, the predicted *maximum* number of sites that could be destroyed is 100,000. This total excludes the impacts on USDA Forest Service lands. The actual number of sites affected can be confidently predicted to be less than this total because of the nature of the assumptions discussed above that were used to generate this estimate. In addition, experts consulted as part of the GEIS process conclude that 50 percent of these sites would not contain significant scientific value and could therefore be destroyed without the need for mitigating action.

Cultural Landscapes
There is insufficient data to assess, even qualitatively, the extent of impacts on these sites. Impacts are likely to occur and the relative number of impacts will increase as the level of harvesting increases.

Traditional Use Sites
Traditional use sites will be impacted. However, the extent cannot be quantified, as these sites have not been inventoried.

5.5.4 Economic Impacts

Because the base level of harvesting modelled reflects the existing levels, no changes to the level of economic activity were expected to occur. Estimates of the economic impacts expected to result from the two increased levels of timber harvesting are presented in subsequent sections.

Forest Industries
The following section describes Minnesota's economy and the existing contribution of the timber industry to employment, levels of employee compensation, and total industry output.

In 1988, total employment in Minnesota was about 2.5 million jobs. Personal income in the state amounted to approximately $54 billion. The forestry and forest products sectors of the state provide 54,000 jobs, 2 percent of the state total, and $2.2 billion of personal income, 4 percent of the state total.

The importance and nature of the forest products industries varies from one part of the state to another. Because of these differences, the state was divided into four regions: a north region, a southeast region, a southwest region, and the metro region. The north region is much more heavily forested than the rest of the state, with 45 percent of the region occupied by timberland. The forest products industry is especially important to the economy of the north region, and it is dominated in that part of the state by large pulp and paper producers and OSB and flakeboard mills. Forest products industries are also important, but less so, in the southeast region where hardwood sawmills are the most important industry. There is significant employment in forest products industries in the metro region, but this is a relatively small proportion of the total employment in the metro area. Also, the forest products industries in the metro region are typically secondary producers who do not purchase or process roundwood directly. There is relatively little forest land in the southwest region, and the forest products industries are a relatively small part of the region's economy.

The key primary forest products industries—those purchasing and processing roundwood—are the pulp and paper industry, the OSB and the waferboard industries, and the sawmilling industry. In 1990, pulp and paper mills in the state consumed about 1.0 million cords of pulpwood harvested from timberland in Minnesota. In that same year, OSB and waferboard mills consumed 0.9 million cords of pulpwood, and hardboard/sheathing/other mills consumed 0.2 million cords. Lumber accounted for an additional 0.5 million cords, and residential fuelwood accounted for 0.5 million cords. All other uses accounted for 0.3 million cords. Logging is also an important primary forest products industry; it is unique in that it serves as a provider of roundwood to the other primary producers.

The tourism and recreation industries in Minnesota are responsible for approximately 4 percent of the total employment in the state, 3 percent of the wages and salaries, and 4 percent of industry output. The metro region of the state accounted for over half of these economic impacts of travel and tourism. The north region accounted for 29 percent of the jobs, compensation, and output in the state's travel and tourism industries.

Impacts on Outdoor Recreation and Tourism

Outdoor recreation is highly popular with Minnesota residents and visitors alike, and provides an important contribution to the state's economy. Statewide, in 1985 (the most recent data available), it contributed 2.5 percent of the total economic output of the state, and 3.3 percent of the total number of jobs (including seasonal and part-time) in the state. The metro region accounted for about a third of total economic output. Outdoor recreation is particularly important to the northeastern part of the state, where it accounts for over 10 percent of the total economic output of that region.

Of the wildlife-related outdoor recreation in the state in 1985, sport fishing accounted for $820 million in expenditures, 26,800 jobs, $360 million in wages and salaries, and $1,250 million in industry output in the state. Hunting accounted for $190 million in expenditures, 5,800 jobs, $100 million in wages and salaries, and $370 million in industry output. Nonconsumptive use of wildlife accounted for 5,400 jobs, $100 million in wages and salaries, and $330 million in industry output. The combined impact of wildlife-related recreation amounts to approximately 38,000 jobs, $560 million in wages and salaries, and $1,950 million in industry output.

All travel and tourism expenditures in the state outside of the metro region, together with nonmetro outdoor recreation equipment expenditures, would generate approximately 59,000 jobs and account for $2,670 million in total economic output. This includes the outdoor recreation and wildlife-associated outdoor recreation impacts in those regions.

Data are not available to establish a long-term trend in the economic impacts of travel and tourism in Minnesota. However, data on annual gross sales from lodging places can serve as an index to tourism expenditures in the state. Gross sales from hotels/motels, resorts, and other lodging places increased from $376 million in 1980 to $695 million in 1990. However, when these gross sales were deflated using the Travel Price Index for Lodging, there was no discernable long-term trend during this period. From 1980 to 1990, annual gross sales of lodging places in Minnesota fluctuated between roughly $660 million and $770 million in 1990 dollars.

Research or studies that examine and quantify how recreation and tourism are directly affected by different levels of timber harvesting are not available. Therefore, it was not possible to directly link the level of timber harvesting with changes in recreation and tourism activities and expenditure patterns. Additionally, it was not possible to quantitatively assess how timber harvesting and forest management activities would impact the economic sectors related to recreation and tourism. Anecdotal evidence suggests increased harvesting can adversely impact individual resort and tourism businesses as well as affected communities. However, specific cause-effect relationships between timber harvesting and tourism sectors have not been documented. Even without these direct linkages, however, it is still possible to quantify what a change in the state's outdoor recreation sector would mean to the state's economy. A ten percent change in outdoor recreation expenditures could affect 3,200 jobs and $160 million in total economic output.

5.5.5 Land Management Organization Service Delivery

National forests and other federal lands account for 14 percent of Minnesota timberlands. Land owned and administered by the state accounts for 21 percent of the timberland area. County ownership accounts for 17 percent. All public agencies in the state account for almost 52 percent of all the timberland in the state. The other 48 percent is in private ownership, including: Native American lands (3 percent); forest industry (5 percent); other corporation (4 percent); farmer (15 percent); and miscellaneous private individuals (21 percent).

Levels of Harvest

Federal, state, and most county lands are under some form of multiple use management, with formal land management plans and professional land management expertise. Although emphasis varies by public ownership, considerable attention is paid to the long-term sustained yield of timber production. However, policy and associated constraints on timber production efforts vary among agencies. For example, some of the county lands have a considerably lower level of land management for multiple uses than federal or state ownerships. Private industry lands are managed intensively for timber production. Few private nonindustrial timberland owners have formal land management plans, and for most timber production is a secondary goal of land ownership. However, most private land will likely become available for harvest at some time.

Projections of the timber volumes harvested from various landownerships over time were made with the assumption that timber harvests would be constrained and/or mitigated by environmental, aesthetic, socioeconomic, and other concerns. These *projections* reflect major existing and prospective land use policies and practices.

The potential impacts of the base level of timber harvesting on forest management organizations in the state under these constraints are summarized below. In reviewing this information, it is important to understand that the GEIS is not a plan of future harvesting activity. Instead, the following reflects what might likely occur on these different ownerships based on the location and composition of the forest land base, as well as the major policies and practices of management.

Based on the projected level and distribution of timber harvesting associated with the base scenario and the assumptions used to develop that characterization, timber harvests from the national forests in Minnesota are projected to decline by roughly 10 to 15 percent from the current level of harvest under the base scenario. This reduction in timber harvest would persist for several decades and reflects increased environmental, aesthetic, economic, and other constraints imposed by this ownership. This relatively small reduction in timber harvests would be unlikely to have much impact on national forest timber management activities.

Constrained projections of timber harvest from MNDNR lands indicate little change from current harvest levels, and thus would have little effect on timber sale activities of the MNDNR, other than those required to meet increasing environmental and aesthetic standards.

Under the base scenario, sales of timber from county lands are projected to increase during the first decade by approximately two-thirds over current levels. If such a large immediate increase in timber harvest occurred, it would have a major impact on county forest management, and would undoubtedly require substantial increases in funding and personnel to handle the increased timber sale activity while meeting environmental and aesthetic constraints. Since most counties have only modest staffing, additional staffing to meet this need would seem to be feasible. However, it would have to be justified at the county level and, at least in part, by increased timber prices.

Constrained projections of timber harvests from forest industry lands indicate that timber harvests would remain roughly at current harvest levels during the first two decades for all three scenarios, followed by sharp increases during the third and fourth decades, and a substantial decline during the fifth and sixth decades.

Timber harvests from Native American lands are projected to rise rapidly during the first decade, followed by a decline in harvests during the following decades for the base scenario.

Constrained projections of timber harvests from other private lands indicate a substantial rise in timber harvest during the first two decades. During the third decade timber harvests would remain high followed by a decline during the fourth and fifth decade. Achieving these increases in timber harvests from other private lands will require considerable timber sale and land management assistance from forest industry and the state and federal government if potential environmental and aesthetic degradation is to be avoided or minimized.

5.6
Identification of Significant Impacts

Criteria were developed and used by the study groups to assess the significance of impacts projected to occur at each level of harvesting. The criteria and relevant background information are reproduced in full in appendix 1.

The following sections list the criteria and present the significant impacts that are projected to occur at the base level of harvesting. The significant impacts have been drawn from the assessments in the technical papers. Criteria have been grouped under the following headings to aid in presentation:

- Forest Resources - Extent, Composition, and Condition;
- Soil Resources;
- Water Resources and Aquatic Ecosystems;

- Wildlife Populations;
- Recreation and Aesthetics;
- Unique Cultural and Historical Resources; and
- Economics.

5.6.1 Forest Resources - Extent, Composition, and Condition

The criteria in this section were used by the Maintaining Productivity and the Forest Resource Base, Forest Health, and Wildlife and Biodiversity study groups to identify projected significant changes in the extent, composition and condition of Minnesota's forest resources.

These criteria cover a wide range of issues, from the size of the forests to their genetic makeup. This section also includes assessment of the impacts on plant species that are federal- or state-listed of special concern, threatened or endangered and their habitats. Impacts on animals are discussed in the following wildlife section.

Changes to Minnesota's Forests - Size and Composition of Forest Land Base (public and private)

> An impact is considered significant if it is projected that there will be cumulative over the 50-year study period:
> • A change of 3 percent in the size of the total Minnesota forest land base.
> • A change of 3 percent in the area of timberland (commercial forest land) available for wood production.
> • A change of 7 percent in the area of the total forest land base by ecoregion.
> • A change of 7 percent in the area of timberland by ecoregion.

The estimated trends by ecoregions are presented in table 5.21.

Projecting estimates of forest area change is always difficult and can seem exaggerated. However, the history of forest clearing, regrowth, harvesting, and reservation here and elsewhere suggests changes can be large and rapid. Additionally, both the U.S. and state populations are expected to grow substantially over the period to 2040.

Statewide. The total forest area is expected to remain stable over the period 1990–2040, but a significant drop (greater than 3 but less than 7 percent) is expected in commercial forest or timberland area, or that actually available

Table 5.21. Estimated direction of changes in total forest area and timberland by ecoregion, 1990–2040.

Ecoregion	Change in Forest Area			
	All Forest Land		Timberland	
	Direction	Significance	Direction	Significance
1	-	*	-	*
2	no change		-	*
3	-	*	-	*
4	-		-	*
5	+	*	+	*
6	+	*	+	*
7	+		+	
Statewide	no change		-	*

Source: Jaakko Pöyry Consulting, Inc. (1992a).
* Significant.

for harvesting. Thus while table 5.8 projects an increase in timberland acreage, it is likely that formal land reservation and/or ownership constraints on harvesting or certain practices will preclude all of the projected timberland acreage from being available for harvesting. This drop is anticipated due to additional reservation of timberland and, more importantly, from the implementation of constraints on forest management and timber harvesting to meet concerns for nontimber values. Reservation will occur primarily on public lands; constraints will develop on all lands with public lands leading the way. However, this comparatively static statewide picture includes considerable variation in the direction and magnitude of changes when assessed at the ecoregion level. These are described below.

Ecoregion 1, Glacial Lake Plains. This region will continue to decline in total forest area, due primarily to conversion to agriculture in the west. That change could be moderated by agriculturally-related conservation programs. Unproductive areas will remain as such, thus development will occur on productive uplands or timberland. These changes are considered significant for both total forest area and timberland.

Ecoregion 2, Border Lakes. This region has a large proportion of reserved forest land and is not well-suited to development. No significant change in forest area is expected, but projected timberland availability will be reduced by constraints on management and harvest practices. These constraints will effectively diminish the area of available timberland. The reduction in timberland actually available will likely exceed 7 percent and is considered a significant impact.

Ecoregion 3, Lake Superior Highlands. This small region will likely see a significant (greater than 7 percent) decline in forest area and timberland from 1990 to 2040, due primarily to recreation related development along the North Shore, located mostly in the southern portion of the region. Since it is primarily forest now, any development will diminish the area of private timberland.

Ecoregion 4, Central Pine-hardwood Forest. This ecoregion will likely see an overall decrease in forest land and a somewhat greater reduction in the area of timberland. However, conditions will vary widely across this region due to differences in agricultural history, recreation potential, and proximity to existing urban areas. Federal, state and county ownership is large in the region and those areas will remain in forest. Lowland forest acreage will remain stable. Timberland availability will be reduced by constraints on management and harvest practices that will effectively diminish the area available for timber production. The estimated decrease in forest area will be 3 to 7 percent. The corresponding decrease in timberland will likely exceed 7 percent and is considered significant.

Ecoregion 5, Western Prairie/Forest Transition Zone. Forest area in this ecoregion is likely to increase in excess of 7 percent. However, available timberland acreage will be reduced from that expectation near existing urban centers. Land use will shift from agriculture, back to forest and then, for some areas, to urban development or reservation. In its western parts, this region could benefit significantly from conservation programs.

Ecoregion 6, Eastern Prairie/Forest Transition Zone. Forests in this ecoregion have benefitted from the decline of livestock-based agriculture over the last several decades. Reduced grazing, watershed management concerns, and a decline in agriculture have led to a substantial percentage increase in forest area. Both total forest area and timberland acreage are estimated to show significant (greater than 7 percent) increases. However, urbanization and nonfarm rural development will slow positive changes in timberland actually available relative to increases in total forest area.

Ecoregion 7, Western Prairies. The natural forest regrowth potential of regions 5, 6, and 7 has been grossly underestimated in previous analyses. Total forest area and timberland acreage in this region, though a small portion of the state total, will increase significantly (in excess of 7 percent). Although it will take three to four decades before this regrowth can contribute much to timber supply, it will be important sooner for nontimber values.

Another aspect of the projected increase of forest cover in the prairie region, is that some of the increase will come at the expense of native prairie and savanna, both rare natural communities in the state. Many remnants of prairie and savanna are succeeding to forest, due to the lack of fires, which previously maintained the open conditions.

Changes to Minnesota Forests - Patterns of Forest Cover in Areas of Mixed Land Use

> An impact is considered significant if noncontiguous forested tracts or patches less than 300 acres in size are projected to experience clearcutting of more than 20 percent of the tract or patch in any one decade.

Statistics on the regrowth of the oak and elm-ash-cottonwood forest types common to agricultural regions suggest that forest cover is returning to ecoregions 5, 6, and 7 quite rapidly on a percentage basis. However, even the large percentage increases estimated for the next 50 years would barely return these regions to the forest acreage levels of the 1950s. Additionally, the concentration of oak-hickory in older age classes (see appendix 8, Jaakko Pöyry Consulting, Inc. 1992a) coupled with currently high harvest levels could negatively affect the overall habitat value of existing forest patches. The small average stand sizes in this covertype and these ecoregions and the projected acreage of unharvested stands suggest these forest patches are being harvested and that this could be a significant impact. However, data limitations in this study preclude the ability to document impacts on a site-specific basis.

These changes in forest patterns have implications for several mammal species as well as forest interior birds occurring largely or entirely in these more developed portions of the state. Note that significant declines were projected for several species in ecoregions 5, 6, and 7. The projected significant impacts on these species discussed in subsequent parts of this section can be assumed to be closely related to further fragmentation of remnant forest patches. Some of the species in question are: gray and fox squirrels, Ovenbird, Cerulean Warbler, and Yellow-throated Vireo. The Red-shouldered Hawk, a species of special concern, will be significantly impacted if further fragmentation of forest cover in mixed land use regions of the state occurs.

Changes to Minnesota Forests—Tree Species Mix

> An impact is considered significant if projected gross changes in the relative proportion of any tree species exceeds 25 percent for the respective covertypes over the 50-year planning period.

Timber harvesting will affect the age class structure and thereby the species composition of Minnesota's forest. Under the changes projected at the base scenario, no species would be reduced to a level that would jeopardize their continued presence in the forest. These results plus the generally rich tree species composition by forest type suggest that major species composition changes within types will not occur, except for those changes associated with stand age. Species composition changes do occur from implementation of harvesting or silvicultural practices in specific stands. However, natural forces plus a changing mix of management objectives and harvest operations over time do not show a clear pattern of change in species composition within types. Given the high frequency of mixed species stands, future directions for type acreage could be largely determined by consistent choice of rotation age and harvest practices.

Future covertypes appear to be sensitive to the level of harvesting, both in retaining covertypes and in favoring change to other species. Results are clouded because of an imprecision in determining forest covertypes both now and in the future. This imprecision is due largely to the mixed species composition of Minnesota's forest. However, results suggest the base level of harvesting will contribute to diminishing the area of the jack pine, black spruce, balsam fir, and paper birch covertypes on timberlands by as much as 32, 24, 35, and 32 percent, respectively. However, some of these changes are a consequence of successional changes as stands age, and are not due to harvesting per se. Furthermore, because many stands have very mixed species composition, these changes will not necessarily drastically change the vegetation at a regional level or on specific sites. Instead, a major species may simply become less abundant or may be reduced to a minor species on a particular site.

Minor Tree Species. The minor tree species listed below are an important component of biodiversity. In many cases they are species near the edge of their range, or are species that simply are not abundant within their range:

American hornbeam
Bitternut hickory
Black cherry
Black oak
Black walnut
Butternut
*Eastern hemlock
Hackberry
*Heart-leaved birch
*Honeylocust
Kentucky coffeetree
Mountain ash
River birch
Rock elm
Shagbark hickory
Slippery elm
Striped maple
Swamp white oak
*Sycamore?
White ash
Yellow birch

*Yellow oak

* indicates that this species was not included in the FIA data and analyses by covertype. Sycamore is listed with a question mark because it is not certain whether the species is native to the state. If any naturally-occurring sycamore are found they likely would be in the extreme southeast corner of ecoregion 6.

The analysis of stem numbers for the base level timber harvesting scenario in the year 2040 reveals that Kentucky coffeetree would be significantly impacted (>25 percent reduction in stem number). Significant impacts on honeylocust, yellow oak, and sycamore (if investigation shows it to be native) are also likely under the base level of harvesting.

The five asterisked species in the above listing are not included in the FIA data. Four of these species (all except heart-leaved birch), and probably striped maple as well, are so rare in Minnesota that they should never be harvested, unless there is a clear plan for regeneration using native seed stock at the harvest site. Eastern hemlock is a state-listed species and should not be harvested under any circumstance.

Reduction of Conifer Component in Aspen Stands. As discussed in section 5.2, the issue of retention of conifers in aspen stands cannot be resolved due to a lack of data. Therefore, it is not possible to predict whether conifers will be lost in short rotation harvest (and therefore whether the significance criterion is triggered). However, if such a reduction in conifer component were to occur, the impact on biodiversity would be significant and directly proportional to the level of harvest.

Changes to Minnesota Forests - Age Class Structure.

> An impact is considered significant if the projected replacement age class structure of forests, by covertype, at the end of the 50-year planning period, is insufficient to provide replacement of mature stand acreage (i.e., sustainability of forest communities).

This criterion requires examination of age class structures (appendix 8, Jaakko Pöyry Consulting, Inc. 1992a) at the end of the 50-year study to assess the feasibility of relatively short-term sustainability. This examination indicates that, at the base level of harvest, the replacement age class structure for timberland appears deficient for paper birch. This covertype remains unbalanced through the study period because of its current age class structure imbalance. Thus, this covertype is considered to exhibit a significant impact.

The results show increased or stable acreages for white pine, northern white cedar, and white spruce. White cedar is projected to have a very low harvest so the concerns are not a direct consequence of harvesting. Concerns regarding white pine center on the very limited acreage under this covertype. It is likely that much of the acreage increase referred to above is due to covertype definition or determination procedure or succession from other covertypes. Thus, concern for the present or 1990 acreage remains.

The age class structure of aspen is important as its existing imbalance (an accumulation of older age classes) plus constraints and mitigations in the second model runs forced substitution of other species for 25 percent of the aspen demand. This solved the problem of an aspen supply shortfall in the middle of the 1990–2040 study period. In the long-run, given a balanced age class structure, the substitution for aspen would probably be reduced.

Old growth forests.

> An impact is considered significant if there is projected to be any net loss of area of forest meeting the DNR definition for old growth by covertype by ecoregion over the 50-year study period.

Timber harvesting per se, will have no significant impact on old growth in upland forest types as long as each candidate stand and future old growth stand is either officially reserved or officially released for harvest after the appropriate administrative procedures. However, some areas of old growth may be harvested if they are not identified by an inventory since not all government land managers have old growth field inventory and protection programs in place. No lowland conifer stands that meet old growth criteria are projected to be harvested under the base scenario. Although few stands meet the requirements of old growth as defined in this study, analysis of future forest conditions as a result of harvesting at current levels suggests a considerable increase in the amount of old forests. It should be noted that the MNDNR has limited consideration for future old growth to stands that are of natural origin and have experienced little or no human disturbance. Table 5.10 in section 5.2.2 indicates that all major covertypes are projected to experience a substantial increase in the acreage of old forest in 2040, relative to current acreages. In many instances, the expected increase is several times the current level of abundance.

Forest species - genetic variability.

An impact is considered significant if there is projected to be a loss of genetic variability in forest plant or animal species as measured by:
1. a reduction or isolation of habitat or communities supporting a species, or
2. a reduction of geographic ecotypes such that a species now present as a viable population disappears or is approaching extirpation from any ecoregion.

Major tree species. Many tree species have clinal variation from warm-dry climates to cold-wet climates (southwest to northeast in Minnesota) (Jaakko Pöyry Consulting, Inc. 1992e). Therefore, timber harvesting and forest management activities that eliminate or isolate one or more populations of species in the regions listed in table 5.22, constitutes a significant impact on genetic diversity.

Table 5.22. Major tree species with range limits occurring within Minnesota (ER = ecoregion).

Species	Location of Range Limit
Basswood	Northern Limit: ER 1,2,3
Balsam fir	Western Limit: W. ER 1,4; N ER 5 Southern Outliers: ER 5,6
Balsam poplar	Western Limit: ER 7 Southern Outliers: ER 4,5,6
Bigtooth aspen	Western Limit: W. ER 1,4,5
Black ash	Western Limit: ER 7; W. ER 5,6
Black spruce	Western Limit: ER 7; W. ER 1,4,5 Southern Limit: S. ER 4; ER 5
Bur oak	Northern Limit: ER 1,2,3
Jack pine	Southwestern Limit: ER 7; W. ER 1,4; N ER 5
Paper birch	Western Limit: ER 7; W. ER 1,4 Southern Limit: ER 5,6
Quaking aspen	Western Limit: ER 7
Red maple	Western Limit: ER 7; W. ER 4 Southern Limit: ER 5,6
Red oak	Northern Limit: ER 1,2 Western Limit: ER 7; W. ER 4,5
Red pine	Southwestern Limit: W. ER 1,4; N. ER 5
Sugar maple	Northern Limit: ER 1,2,3 Southwestern Limit: W. ER 4,5; ER 6
Tamarack	Southwestern Limit: W. ER 1,4; S ER 5; N. ER 6
White cedar	Southwestern Limit: W. ER 1,4; ER 5
White oak	Northern Limit: N. ER 5,6; S ER 4
White pine	Southwestern Limit: W. ER 1,4; ER 5,6
White spruce	Southwestern Limit: ER 7; W. ER 1,4; N. ER 5

Source: Jaakko Pöyry Consulting, Inc. (1992e).

Endangered plant communities. Table 5.23 describes the status and occurrence of rare plant communities. Most of these communities occur in the forest transition zone—ecoregions 5 and 6—where agriculture and urban development have caused extensive habitat loss and fragmentation. In northern Minnesota (ecoregions 1 to 4) there have been few surveys of rare plant communities so that remaining occurrences are often unknown. Many of the occurrences are not protected, and any harvest in a listed community would be a significant impact. Accidental harvest of unidentified remnants of these natural communities is likely.

Table 5.23. Occurrence of critically endangered (1), endangered (2), or threatened (3) communities, by ecoregions. Subtypes and geographic sections recognized by the Natural Heritage Program are matched to the GEIS ecoregions as far as the data will allow.

Community, Status	Ecoregion						
	1	2	3	4	5	6	7
Oak savanna, mesic subtype,(1)					X	X	
Jack pine woodland (1)	X			X	X		
Oak savanna, hill subtype (1/2)					X	X	X
Oak savanna, gravel subtype (1/2)					X	X	X
Mixed oak forest, Bigwoods section, mesic subtype (2)					X	X	
Mixed oak forest, central section, mesic subtype (2)					X		X
Maple-basswood forest (Bigwoods section) (2)					X	X	
White pine forest, southeast section (2)						X	
Upland white cedar forest bluff subtype (2)						X	
Northern hardwood-conifer forest, bluff subtype (2)						X	
Oak savanna-bedrock bluff subtype (2)						X	
Jack pine barrens (2)	X	X		X	X		
White cedar swamp seepage subtype (2)	X	X	X	X			
Mixed oak forest, southeast section, mesic subtype (2/3)						X	
Mixed oak forest, southeast section, dry subtype (2/3)						X	
Northern hardwood forest (southern section) (2/3)						X	
Maple-basswood forest, southeast section (2/3)						X	
White pine forest, central section (2/3)	X			X			
Upland white cedar forest, yellow birch subtype (2/3)	X	X	X	X			
White pine-hardwood forest, southeast section, mesic subtype (2/3)						X	
White pine forest, southeast section, dry subtype (2/3)						X	
Northern hardwood-conifer forest, yellow birch-white cedar subtype (2/3)	X		X	X			
Oak savanna dune subtype (2/3)							X
Aspen openings (2/3)							X
Mixed oak forest, Bigwoods section, dry subtype (3)					X	X	
Mixed oak forest, northeast section (3)			X	X			
Northern hardwood forest, northern section (3)	X	X	X	X			
Maple-basswood forest, west central section (3)					X		X
Maple-basswood forest, east central section (3)				X	X		
White pine forest, northeast section (3)		X	X	X			

Community, Status	Ecoregion						
	1	2	3	4	5	6	7
Red pine forest (3)	X	X	X	X	X		
Upland white cedar forest (3)	X	X	X	X			
White pine-hardwood forest, north central section (3)	X			X	X		
Northern hardwood-conifer forest (3)	X	X	X	X			
Aspen brush prairie (3)							X
Black spruce bog, raised subtype (3)	X	X	X	X			
Black ash swamp, seepage subtype (3)				X	X	X	
Mixed hardwood swamp, seepage subtype (3)				X	X	X	
Mixed oak forest, central section, dry subtype (3)				X	X		
Maple-basswood forest, northern section (3)				X			
Northern conifer scrubland (3)	X	X	X	X			

Source: Jaakko Pöyry Consulting, Inc. (1992e).

The major implications of table 5.23 are:

1. Natural forest communities that depend on frequent fire are endangered or critically endangered. This includes savannas and woodlands, both dominated by pines and oaks. The major problem has been fire suppression, which has allowed former savannas and woodlands to convert to dense forests.
2. Natural forest communities that depend on infrequent severe fires are endangered or threatened. This includes mixed oak forests, white and red pine forests, and pine-hardwood community types. The main problem with the pine communities, in addition to fire suppression, is a failure to restore the pine acreage after early exploitation and land clearing. Limited success in regenerating white pine over the past several decades has contributed to the failure in restoring the white pine acreage to historic levels. This failure in regenerating a large acreage is due in part to the impact of white pine blister rust, expansion of the deer herd, reduced incidence of fire, and the difficulty in controlling competing vegetation. Although red pine has been extensively planted in recent decades, most of it is still young. In addition, pine seed sources were removed over large areas in parts of the state, so that natural reseeding has been slow.
3. Natural forest communities that originally covered the Bigwoods and Prairie-Forest transition zone (ecoregions 5 and 6) are endangered by clearing and conversion of land to other uses, primarily agriculture and urban areas. Included are mixed oak forests, *natural* maple-basswood forests, and the southernmost white pine and pine-hardwood forests.
4. Upland white cedar forests are endangered. Like the former white and red pine forests, these have been converted to aspen types by land clearing. Reproduction is also hindered by high levels of deer browsing in parts of Minnesota.

Fragmentation. Fragmentation caused by timber harvesting and forest management activities can lead to a range of impacts, which can be categorized under three headings: inbreeding, direct loss of biodiversity, and relationship of fragmentation to climate change. These are discussed separately below.

1 Inbreeding. The exact distance scale of isolation needed to cause inbreeding is unknown for forest trees and plants. The farther either pollen or seeds are dispersed, the more isolated a population can be without becoming inbred. A qualitative assessment of susceptibility to inbreeding due to fragmentation was presented in section 5.2.4 and 5.4.1.

No significant fragmentation impacts due to harvesting are expected in Minnesota for species listed in the very low or low susceptibility groups. This is because the species are widespread, and few populations are isolated by more than a few miles, the one exception being woodlots in ecoregion 7. In contrast, timber harvesting will usually have a significant impact on the genetic pool of forest herbs that are rated as being highly susceptible (see section 5.4.1). Separating two populations by changing the intervening covertype, even for a distance as little as a few hundred yards, could cause loss of gene flow between populations. This may result in inbreeding and the loss of some populations.

However, other populations of forest herbs will have a large enough number of individuals and enough variability within one population, so that the population is viable, even when isolated. If gene flow is cut off, isolated populations could evolve into new varieties and (after a few thousand years), new species. This is exactly how the dwarf trout lily is believed to have evolved from the white trout lily. There is no way to assess the number of species that would be significantly impacted without a detailed map of timber harvests superimposed over a map showing the ranges of all forest herbs.

2 Direct Loss of Genetic Diversity. The same species listed as high susceptibility (forest herbs) to inbreeding also have relatively fine-scale spatial differences in gene frequencies among populations. The spatial scale of forest operations is similar to that of genetic structure of forest herbs. Therefore significant impacts will occur with gross covertype changes such as the establishment of plantations on sites previously carrying native forest. Under these circumstances, extirpation of local herb populations can result in losses of distinctive genetic material.

Significant impacts are unlikely among species of the low susceptibility group. There is one exception, however. Habitat islands such as swamp conifers separated by many miles (mainly ecoregions 5 and 6), and other outliers (i.e., sugar maple in ecoregion 3) may have genetically distinct populations that would be lost if covertype conversions occurred.

3 Relationship of Fragmentation to Climate Change. Timber harvesting at the base level scenario can cause fragmentation that will have a significant impact on genetic diversity of forest herbs and trees under a changing climate. This is because fragmented landscapes create barriers to the dispersion of many plant species. Thus, some species may be prevented from becoming established in new locations which have a favorable climate; while at the same time being confined to sites with increasingly unfavorable climates. Under these circumstances, local populations at least would be extirpated.

Deer Browsing The geographical distribution of forest covertypes and ages caused by forest management directly influences the local deer population, which in turn has consequences for biodiversity. Some plant species are reduced in abundance, or locally extirpated, by high deer populations, including showy and yellow lady slipper orchids, blunt-leaf orchid, tall northern bog orchid, purple fringed orchid, indian cucumber root, large flowered trillium, and Canada yew. In addition, deer browsing can change the entire species composition and dynamics of the woody plants in a community. In Minnesota, deer can cause failure in regeneration for two important tree species—white cedar and white pine. Yellow birch, a minor tree species, and eastern hemlock, a special concern species, can also be reduced in abundance by deer browsing. Significant impacts on biodiversity are likely in areas where the spatial and temporal pattern of harvesting leads to high deer populations.

Federal- or state-listed plant species of special concern, threatened, or endangered or their habitats.

An impact is considered significant if any harvest or forest management activity is projected to diminish the habitat and disturb a species listed as of special concern, threatened, or endangered (either federal or state).

In general, the forest-dependent rare plant species of Minnesota are poorly adapted to trampling types of injury. With the exception of the one tree species on the list, all species are of small stature and easily broken. Operation of harvesting equipment can significantly impact populations of rare plant species within areas harvested. The lack of knowledge regarding the locations of rare species in the state makes it impossible to undertake a more quantitative analysis. In any case, the comparatively coarse level of resolution of the model output would preclude such an analysis. Table 5.16 provided estimates of the numbers of endangered, threatened, or special concern plants by ecoregion. Statewide, 9, 7, and 37 species listed as endangered, threatened, or of special concern, respectively, are projected to be adversely impacted by harvesting.

Forest Health—change in susceptibility or vulnerability

> An impact is considered significant if projected changes to the forest and activities undertaken lead directly or indirectly to changed susceptibility (risk of an outbreak/infection) or vulnerability (damage if an outbreak occurs) to more than 10 percent by area by covertype.

All timber harvesting and forest management activities affect forest health; all have impacts. Those impacts range from nearly none (where the management activity is minimal) to very significant (where major changes are brought about in the forest). Given changes, vulnerability to impacts is a function of the insect, disease or other health vector, the harvesting or management related disturbance that would favor its expansion or development, and the susceptibility of the forest as defined by relevant vegetation patterns, forest age class structure, etc. The continuum of impacts is impossible to treat in any quantitative sense, so a threshold must be established. Impacts that are greater than that threshold merit attention; impacts below the threshold are not large enough to justify further consideration.

Certain assumptions were made out of necessity to model and analyze significant impacts on forest health. In particular, it was assumed that the MNDNR pest management guidelines and other guidelines would be followed by all ownerships. However, in reality, their application on NIPF lands is highly debateable today. In this light, if the guidelines are not followed, impacts of harvesting on the health of Minnesota's forests could be more severe. The use of ERF in certain areas may increase susceptibility and vulnerability and that will heighten the need for active and integrated pest management. This is because the guidelines are intended to prevent pests and diseases from becoming established by avoiding the creation of conditions that are suitable for pests. The significant impacts projected to occur under the base level harvesting scenario are discussed below.

Aspen-birch forest type group. The area of the aspen-birch forest type group more than 40 years old decreases by more than 10 percent when the final age class distribution projected at the base harvest level is compared with the existing distribution. This change will alter the susceptibility and vulnerability of this forest type group to outbreaks of specific insect and disease pests.

The decrease in the proportion of aspen stands in the older age classes may reduce vulnerability to damage from the forest tent caterpillar. Consequently, mortality and volume loss associated with defoliation may decrease, although quantitative data to support this judgement are lacking. Therefore, this is a significant positive impact. Other impacts, including effects of forest tent caterpillar on aesthetic and recreational values, are not likely to change.

In addition, the incidence and severity of decay due to white trunk rot should be reduced as the older, more decayed stands are cut. Aspen less than 40 years old will not be free from decay but the percent of wood decayed will be less in the younger stands. To maximize the possibility of a positive impact, management must be followed that minimizes decay. Well-stocked aspen stands on average sites grown to a rotation age of 40 to 45 years may be affected less by decay than stands that are maintained to rotation ages in excess of 50 years.

Under the base harvest level, Hypoxylon canker should decrease if management guidelines for its control are followed. Aspen stands with a greater than 25 percent infection rate from Hypoxylon canker should be converted to other species to increase productivity on the site. Good harvesting practices should ensure well-stocked stands, reducing infection.

Under the projected harvest level, Armillaria may increase. Root rot incidence can increase as a function of stand age, but if soil compaction and rutting occur during the harvest, root injury may occur and increase the incidence of *Armillaria* in younger, regenerating stands.

Harvesting will also affect both the susceptibility and vulnerability of birch to dieback and mortality. Under the base harvest scenario, the average age of birch will increase compared to 1990. This will likely increase the potential for losses from the bronze birch borer as a result of the increased percentage of brood trees in the older stands. An increase in bronze birch borer activity may also contribute to increasing levels of *Armillaria* root rot in the stands. Harvesting or other disturbances in pure and mixed birch stands can also cause significant negative impacts as stands are opened up and subjected to drier and warmer conditions. This in turn may lead to stress on the trees and to increased susceptibility and vulnerability to bronze birch borer and *Armillaria* root rot.

Black spruce forest type group. Under the base harvest level in the year 2040, the area of black spruce forest type group less than 40 years old is projected to decline by more than 10 percent, and the area over 60 years old is projected to increase by more than 10 percent. These changes are likely to increase the incidence of root and butt rots caused by *Inonotus tomentosus* which become more prevalent in stands older than 60 years. Therefore, this is a significant negative impact.

Sanitation practices are the key to controlling dwarf mistletoe on black spruce. If sanitation practices are followed when harvesting dwarf mistletoe infested stands, species composition may be moved toward tamarack and lowland brush.

Lowland conifers forest type group. Under the base level of harvest, the area of lowland conifers less than 40 years old is projected to decrease by more than 10 percent, while the area older than 60 years is projected to increase by more than 10 percent. Impacts on balsam fir stands are as discussed under spruce-fir below. For the remaining species, the effects of significant changes in harvest intensity on the susceptibility or vulnerability of lowland conifer stands to insect and disease pests is unknown.

Lowland hardwoods forest type group. The area of lowland hardwoods forest type group less than 40 years old is projected to increase by more than 10 percent under the base harvest levels. In addition, the area in the more than 60-year-old age class would increase by more than 10 percent. There are relatively few major pests that are likely to be affected by changing the level of harvest in lowland hardwood types.

Pine forest type group. Changes in age class structure would be near or less than 10 percent under the base harvest level. Incidence of *Diplodia* and *Sirococcus* shoot blights and canker and possibly *Scleroderris* canker on young (<40 years old) red pine may increase if the areas replanted to red pine are not carefully chosen. Neither of these pests are major problems on older red pine, so the projected increase in area of pine more than 40 years old should not have a significant effect on disease incidence in older red pine. There is a potential for an increase in diseases such as needlecasts and gall rust as nursery seedlings are planted to replace the harvested trees.

Lophodermium needlecast on red pine and gall rust of jack pine are two diseases that can be introduced into the field on infected nursery stock. Additionally the overall increasing average age of jack pine will likely lead to an increase in vulnerability and susceptability to budworm damage.

An increase in the area of older pine forest type group may increase the amount of pine that is less vigorous and able to resist Ips beetles following damage by wind, lightning, flooding, defoliation, or pathogens. Incidence of Ips may therefore increase.

At the base harvest level, harvested white pine stands are projected to be replaced by younger stands which are more susceptible and vulnerable to white pine weevil. This is particularly true for plantations. Therefore, this is a significant adverse impact. The increase in younger white pine could increase the incidence of white pine blister rust, especially if white pine is regenerated in northern Minnesota. This concern includes underplanting efforts in historic pine areas. Therefore, this is a significant adverse impact.

Spruce-fir forest type group. The area of spruce-fir forest type group less than 40 years old is projected to decrease by more than 10 percent under the base harvesting level, and the area more than 40 years old would increase by more than 10 percent at that level. The overall increase in tree age within this forest type group will increase vulnerability and susceptibility of stands to budworm damage. Older trees produce more staminate cones and are more likely to experience population outbreaks. Older trees are also generally less tolerant of defoliation than young trees. The probability of wildfire will increase since risk factors such as mortality, breakage, and windthrow that follow budworm outbreaks will increase. Therefore, this is a significant negative impact.

The increase in area of older spruce-fir forest type group will lead to an increase in the level of susceptibility and vulnerability of these species to trunk, root and butt rots. This is a significant negative impact.

Upland hardwoods forest type group. The area of upland hardwoods forest type group less than 40 years old is projected to increase under the base harvest level, and the area over 60 years old would also increase by more than 10 percent.

Under the higher levels of harvesting intensity, the area of younger trees will increase. Younger trees generally grow more vigorously and have more starch reserves than older trees. They are, therefore, less affected by drought and other environmental stress and are presumably less susceptible to severe damage by two-lined chestnut borer. The reduced susceptibility of the younger trees will be offset by an increase in the area of older forest.

Clearcutting stands of the upland hardwoods forest type group should reduce the incidence of decay in the mid-term (10 to 50 years) and cankers in the short-term (<10 years) as decayed and cankered trees are removed from the stand. However, selection and shelterwood cuts are often preferred methods of regenerating stands of upland hardwood forest type groups. If some type of multiple entry harvest is chosen, the chances of wounding residual trees increases; the incidence of decay and cankers is also likely to increase. Thinning and other stand entries are projected to increase substantially in stands of upland hardwood forest type. Hence the overall impact of increased harvesting is a likely increase in decays and cankers and a reduction in timber quality. However, the impact of multiple entries may be offset by judicious use of the opportunities they provide to remove damaged and decaying timber.

Under the base level timber harvest, a medium-term (10 to 50 years) decrease in the incidence of oak wilt is expected if clearcutting is the method of harvest.

Clearcutting would eliminate oak wilt pockets within the clearcuts. Multiple stand entries may tend to injure oak, making them more susceptible to infection. Given that multiple entry harvest will predominate, the amount of oak wilt is therefore projected to increase (with high uncertainty of prediction).

5.6.2 Soil Resources

Nutrients

> An impact is considered significant if nutrients removed and/or redistributed during harvest and followup activities are not replaced over the term of the projected rotation.

Harvest of merchantable bole did not remove either nitrogen or phosphorus beyond their rates of replenishment. Areas at risk for loss of calcium are most closely associated with harvest of aspen-birch and upland hardwoods on medium-textured soils and especially on coarse-textured soils. Because of this, approximately 5 million acres are at risk for calcium loss. Loss of magnesium beyond rates of replenishment is especially associated with harvest on coarse-textured soils and organic soils. Under the base scenario, about 2.5 million acres are at risk for magnesium loss. Finally, potassium loss is primarily associated with harvest of aspen-birch on coarse-textured soils and the harvest of all deciduous types on organic soils. Under the base scenario, about 1.5 million acres are at risk for potassium loss.

Other Activities

Delimbing and Topping. Based on the summary of timber harvest operations carried out as part of the GEIS, delimbing and topping is carried out at a landing in about one-third of the harvests. This practice does not recycle or replenish the nutrients on the site, and is equivalent to a full-tree harvest in terms of nutrient depletion. The data developed for harvest of merchantable bole should be increased to take this practice into consideration as described in section 5.3.1.

Mechanical Site Preparation. Although not directly considered by the three harvesting scenarios, nutrient depletion related to site preparation techniques has also been evaluated. The Silvicultural Systems background paper (Jaakko Pöyry Consulting, Inc. 1992m) indicates that each year about 18,000 acres are treated using mechanical site preparation techniques. There is virtually no justification, from the standpoint of nutrient status, for any site preparation technique that displaces material. Mechanical techniques that create slash piles or windrows either remove nutrients from the site or localize them, depleting the remainder of the area; from the standpoint of nutrient conservation such techniques should be abandoned. Site preparation techniques that incorporate materials, or only displace materials a foot or two, do not have those negative impacts.

Compaction and Related Disturbances

> An impact is considered significant if the proportion of the harvest unit projected to be moderately to severely compacted/puddled exceeds the following threshold proportions:
> - 5 percent on highly sensitive sites;
> - 10 percent on moderately sensitive sites; and
> - 20 percent on sites with low sensitivity.

The statewide analysis of significant impacts under the base level of harvests indicates that impacts were most frequent on the well-drained medium-textured soils, which are the most common soils in the state, and the poorly-drained medium and poorly-drained fine soils which have the lowest strength.

The following figures are the cumulative results for the 50-year planning period assuming the base level harvesting scenario and the seasonal distribution of harvesting activities outlined in the Silvicultural Systems background paper (Jaakko Pöyry Consulting, Inc. 1992m). Approximately 6.3 million acres would be harvested statewide. The significance criteria would be exceeded in harvesting units representing about 840,000 acres. If 1 percent of the area harvested were devoted to haul roads in order to extract the timber, an additional 60,000 acres would be significantly impacted.

The impact assessment indicated that increased levels of timber harvesting will invariably lead to increased amounts of compaction and related disturbance. The significance criteria were exceeded by both mechanical- and hand-felling operations on moderately and highly sensitive sites. It was estimated that about 25 percent of the area within moderately sensitive sites would be negatively affected by equipment trafficking for both harvesting configurations. The portion of highly sensitive sites that are negatively impacted could increase to about 30 percent for hand-felling operations and 55 percent for mechanical-felling operations.

These results reflect the seasonal harvesting distribution on all soil types within each ecoregion. Limiting timber harvesting to specific seasons on individual soils or sites could greatly affect the impact assessment. The MNDNR and some counties are starting to implement these practices on upland sites, in addition to the long-standing use of these practices on organic soils.

Based on the above results, crude estimates of the potential impact of compaction and related disturbances on future productivity can be made. The *actual* area impacted within harvest units where significance criteria were exceeded is about 330,000 acres. An additional 60,000 acres would be impacted under the base scenario if 1 percent of the area harvested is occupied by haul roads. Assuming that productivity is reduced by 25 percent in lightly trafficked areas, by 50 percent in heavily trafficked areas, and by 75 percent in haul roads, these impacts would translate to losing the wood-producing equivalent of as much as 170,000 acres.

Soil Erosion

> An impact is considered significant if the rate of soil loss is projected to exceed the limits prescribed by the U.S. Soil Conservation Service expressed as:
>
> $$\text{rate} > T$$
>
> where T varies between 1-5 (tons/ac/yr)

Surface erosion rates exceeded T values on less than 1 percent of the area harvested, and this significant impact was predominantly limited to well-drained soils which exist on steeper slopes.

These results represent the total area impacted over the 50-year planning period. The analyses indicated that significance criteria would be exceeded only in moderately and heavily trafficked areas (skid trails) within harvest units and on haul roads. Also, significant impacts were concentrated in well-drained mineral soils, which is to be expected since they are the soils with steepest slopes.

Under the base level of harvest, about 25,000 acres within harvest units would develop erosion rates that exceed T values. Accelerated erosion caused by skidding and felling activities would exceed T values on less than 1 percent of the total area harvested during the 50-year period.

The greatest erosion rates were estimated to occur in ecoregion 6. This ecoregion has the steepest slopes. The southern portion of the state also has the highest rainfall intensity. It was estimated that initial erosion rates could exceed 14 ton/ac/yr in some areas in ecoregion 6. Initial rates rarely exceeded 5 ton/ac/yr in other ecoregions.

If an area equal to 1 percent of the harvest area were utilized for haul roads, T values would be exceeded on an additional 6,000 acres under the base level of harvest. These totals indicate that erosion rates would be exceeded on about 8 percent of the haul road area.

Erosion associated with haul roads would occur at faster rates than erosion within harvest units. This is a function of the more complete removal of surface protection and smoothing of the ground surface in haul roads. The analyses indicated that maximum initial erosion rates in haul roads could approach 100 ton/ac/yr in some areas.

The effects of timber harvesting and forest management activities on mass movements were not quantified. The greatest potential for mass movements would occur in areas with steep slopes such as the Coulee region of southeastern Minnesota (in ecoregion 6) and areas with shallow soils over bedrock (ecoregions 2 and 3). However, there is currently no evidence suggesting that mass movements are currently a major problem in forested portions of Minnesota.

5.6.3 Water Resources and Aquatic Ecosystems

These criteria were applied to identify significant impacts affecting water resources and aquatic ecosystems.

Lakes, rivers, streams and wetlands - level of sedimentation/nutrient loading.

An impact is considered significant if timber harvesting and associated management activities are projected to cause changes in the level of sedimentation and/or nutrient loading of waterbodies such that more than 25 percent of monitoring observations following harvest exceed the 85th percentile of preharvest or reference conditions.

Lakes, rivers, streams and wetlands - runoff.

An impact is considered significant if projected timber harvesting and associated management activities cause changes that result in greater than 60 percent of a *Minor Watershed*[2] to be in a *disturbed condition*[3] at any time.

[2]Minor watersheds as defined in MNDNR 1979 Watershed Map.

[3]Disturbed condition is defined as cleared land or regenerated forest younger than age 15 years.

Lakes, rivers, streams and wetlands/peatlands - aquatic ecosystems.

An impact is considered significant if timber harvesting and forest management activities are projected to result in changes to one or more aquatic ecosystem variables such that:

a. more than 25 percent of observations exceed the 85th percentile of preharvest or reference conditions for the following variables:
   - sediment levels,
   - water nutrient levels; or
b. peak streamflows more than double or if minimum flows fall below the *7Q10*[4] level; or
c. more than 25 percent of observations exceed the 85th percentile or fall below the 15th percentile of preharvest or reference conditions for
   - *aquatic community structure, community function or fish populations*[5].

Application of the above criteria to the impacts identified in section 5.3.2 indicates that the effects of timber harvest at the ecoregion level will not cause impacts that will exceed the thresholds specified in the criteria.

However, there will be a series of changes in the landscape and water resource. Most of those changes will be relatively local and short-term. Timber harvest which complies with Minnesota BMPs will have significantly fewer local water resource impacts than timber harvest carried out in the absence of BMPs.

Timber harvest is, by nature, a disturbance to the forest community and the landscape. The degree to which a given disturbance represents an *impact* is a matter of scale. For example, few if any landscape modifications associated with timber harvest will be detectable in large rivers such as the upper Mississippi. As one progresses further upstream, the probability of detecting impacts increases as changes outside of the identified standards and tolerances become more noticeable.

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[4] The 7Q10 designation is a measure of the lowest flow for any 7-day period within any 10-year interval, and is widely used to protect water quality. Other methods for which significance criteria could be developed (e.g., wetted perimeter, Tennant's method, Instream Flow Incremental Methodology) would be more appropriate in representing fish habitat values.

[5] Specific variables to be measured might include kinds and numbers of organisms, rates at which the community processes energy or nutrients or the populations of fishes. The specific variables to be measured will be chosen by scientists assessing any given timber harvest operation(s).

Thus, one can imagine a landscape drained by a series of lakes and rivers, and within which timber harvest occurs. In the lowest reaches of the watershed (i.e., in the largest waterbodies) no water resource changes are attributable to the timber harvest. As one moves further upstream, changes in the water resource become more apparent. At a higher intensity of timber harvest, changes will be detectable further downstream. The first (i.e., furthest downstream) changes that will be detected will be slight increases in annual water yield and peak snowmelt runoff. There will also be a relatively small area in which peak snowmelt streamflow will double, compared to baseline conditions. The next most upstream change will be increases in stream dissolved ions, followed by increases in lake nitrogen. These kinds of changes might be detectable in a third-order watershed. (Stream ordering compares streams within and among watersheds. Small streams at the uppermost part of a stream system or watershed are called *first order*. Two first-order streams join to form a *second-order* stream, two second-order streams join to form a *third-order* stream, etc.)

5.6.4 Wildlife Populations

These criteria were used to determine the significance of impacts of projected changes in wildlife populations.

Forest-dependent wildlife - habitats.

> An impact is considered significant if the available habitat of a species is projected to be changed by 25 percent in any ecoregion.

In most circumstances, reduction in area of habitat was regarded as a negative impact. However, in some cases, an increase in habitat may also have negative impacts, e.g., where the species are known to have ecological or economic impacts under certain circumstances, such as cowbirds, foxes, deer (in some regions), and beavers.

There may also be positive impacts from increases in habitat, particularly for favored game species that increase with increasing early succession forests, such as deer and Ruffed Grouse.

The criterion was not applied in cases where the species increase is not of any presently perceived ecological or economic importance.

A total of 173 species of interest were assessed by the above criteria (22 small- and medium-sized mammals, 5 large mammals, 138 birds, and 8 herptofauna). Of the various significance criteria that relate to biodiversity and forest wildlife, the criterion *forest-dependent wildlife - habitats* can be tied most directly, explicitly, and quantitatively to the FIA data; the harvest model output; and the subsequent analyses. In an attempt to maintain the strongest link possible between the analyses and the FIA data/model output, all four subgroups (small- and medium-sized mammals, large mammals, birds, and amphibians and reptiles) emphasized use of this criterion in assessing impacts.

The term *available habitat* used in the criterion has been interpreted to indicate not only the habitat in which a species is present, but also differences in abundance among several habitat types used by the species. Under this approach, a change in forest composition that involves a shift in proportions of high and low density habitats, even where total acreage remains the same, would be projected into a change in potential population abundance (via habitat association). Such an approach was used for all species categories except herps. Data on distribution and habitat requirements of herps are inadequate to permit this level of analysis.

A second criterion listed in this section assesses the significance of impacts on populations of endangered, threatened, or species of special concern. Its application is directly related to the analyses used to assess the overall population changes under the first criterion presented in this section. This second criterion uses **any** negative change in habitat as the threshold for significance. A decrease of 5 percent in habitat or population index statewide was interpreted to be a significant impact to allow for error in the analyses; a 1 or 2 percent decrease in the type of projections used here may not be statistically valid.

Table 5.24 summarizes the wildlife species showing significant negative impacts by this criteria and the second one involving endangered, threatened, or species of special concern or their habitat. Note that with the first criteria, an adverse impact occurred whenever a species in any ecoregion and decade met the criteria. Forty-six species, about 27 percent of all wildlife species included in the analysis, were projected to be significantly impacted over the 50-year study period under the base scenario. Most species significantly impacted under this scenario were also projected to be impacted under the medium and high scenarios; for some of these the number of ecoregions and/or decades in which the impacts occurred was higher under the medium and high harvest scenarios.

Table 5.24 (as well as the analogous tables for the medium and high harvest scenarios, section 6.6.4 and 7.7.4), shows those species that are expected to decline at least 25 percent statewide, as well as by ecoregion. It is well known that changing the geographic extent of a land unit changes the resulting projected impacts. For example, the appropriate habitat for a given species may comprise only 1 percent of the land area of ecoregion 1, but most or all of the land area in other ecoregions. In this case, one small harvest in ecoregion 1 may negatively impact the species, whereas large areas of harvest would not adversely impact the species in any other ecoregion, and the statewide population could be stable. On the other hand, if the species occurred only in one ecoregion, and there was a significant impact in that ecoregion, then there would also be a statewide impact. The

Table 5.24. Species significantly negatively impacted on all forest lands under the base level of harvest using criterion 8 (≥5 percent statewide decline for a species listed as endangered, threatened, or special concern) and criterion 11 (≥25 percent decline in any ecoregion). Numbers in parentheses indicate ecoregions with a projected decline ≥25 percent. Double x (xx) shows those species with a ≥25 percent decline statewide, plus all species affected by criteria 8.

Species	Species Significantly Impacted
Small- and medium-sized mammals:	
Beaver	x (2,6)
Northern flying squirrel	x (5)
Gray squirrel	x (4,7)
Fox squirrel	x (4,7)
Bobcat	x (3)
Lynx	x (3)
Birds	
Green-backed Heron	x (3,6)
Cooper's Hawk	x (4)
Northern Goshawk	x (4)
Red-shouldered Hawk	xx (4,5,6)
Eastern Screech-owl	x (4)
Great Gray Owl	x (3)
Whip-poor-will	x (7)
Hairy Woodpecker	x (6)
Northern Flicker	x (2)
Pileated Woodpecker	x (6)
Eastern Wood Pewee	x (4)
Acadian Flycatcher	x (6)
Eastern Phoebe	x (2)
Gray Jay	x (3)
Boreal Chickadee	x (3)
Eastern Bluebird	x (2)
Swainson's Thrush	x (3)
Gray Catbird	x (2)
Brown Thrasher	x (2)
Yellow-throated Vireo	xx (4,6)
Yellow Warbler	x (2)

Table 5.24. (continued)

Species	Species Significantly Impacted
Magnolia Warbler	x (3)
Cerulean Warbler	x (6)
Ovenbird	x (6)
Louisiana Waterthrush	x (7)
Connecticut Warbler	x (3)
Common Yellowthroat	x (2)
Hooded Warbler	xx (6)
Wilson's Warbler	xx (2)
Yellow-rumped Warbler	x (3)
Scarlet Tanager	x (6)
Song Sparrow	x (2)
Lincoln's Sparrow	xx (1,2,3,4)
Dark-eyed Junco	x (3,4)
Common Grackle	x (2)
Northern Oriole	x (4)
Purple Finch	x (3)
Pine Siskin	x (5)
American Goldfinch	x (2)
Amphibians and Reptiles:	
Ringneck snake	x (1)

Source: Jaakko Pöyry Consulting, Inc. (1992f).

reason for showing statewide impacts is simply to provide the reader with comparisons of projected wildlife populations at different spatial scales. The main reason for assessing the significance of harvesting impacts at the ecoregion level, is so that an increase in population of a given species in one ecoregion cannot be seen as balancing a decrease in another ecoregion. If this were the case, then a species could contract its range without showing a significant impact. The GEIS Advisory Committee and consultant consider developing a strategy for managing forests that allows species to maintain their entire range within Minnesota to be very important.

No large mammals would be significantly impacted under the base scenario. Six small mammals would be negatively impacted. Species included beaver, bobcat, northern flying squirrel, gray and fox squirrels, and lynx. Thirty-nine bird species (28 percent) were projected to be adversely affected.

Small mammals: The six small mammals adversely impacted at the base harvest level include gray and fox squirrels, which are associated with mature oak forests. The northern flying squirrel requires large tracts of forest to maintain stable populations and may be adversely affected by forest fragmentation. Beaver are projected to be impacted for one decade in two ecoregions. The projected decline in this species must be viewed against a trend of population increases elsewhere. The remaining species showing negative impacts, lynx and bobcat, occupy a variety of covertypes and impacts on these species may reflect an overall reduction in the area of mature forests in these covertypes.

Birds: Three hardwood dependent species, Red-shouldered Hawk, Yellow-throated Vireo, and Hooded Warbler were projected to be impacted statewide when all forest land was considered. Lincoln's Sparrow (conifer dependent) and Wilson's Warbler were the other two species impacted. Loss of mature, contiguous hardwood forest in the southern part of the state was the likely cause of projected declines in the Hooded Warbler population. Projected loss of mature hardwood forests in ecoregions 4, 5, and 6 is the likely cause of the predicted drop in the population of Yellow-throated Vireo. The Red-shouldered Hawk was adversely affected by projected declines of contiguous, mature, deciduous forests in ecoregions 4, 5, and 6.

The changes for some species also translate into 25 percent or more declines on a statewide basis. These are summarized in table 5.19 in section 5.4.1. Statewide, 5 species would decline by 25 percent or more under the base scenario. The statewide declines include one species that is listed as endangered, threatened, or of special concern (Red-shouldered Hawk).

Herps: The ringneck was the only species showing adverse impacts under the base scenario.

Federal- or state-listed wildlife species of special concern, threatened, or endangered or their habitats.

> An impact is considered significant if any harvest or forest management activity is projected to diminish the habitat and disturb a species listed as of special concern, threatened, or endangered (either federal or state).

For analysis, a decrease of 5 percent or more in habitat or population index statewide was interpreted to be a significant impact.

Under the base level of harvest the following significant impacts are projected to occur for animal species within these categories.

Birds

- Red-shouldered Hawk: *An overall statewide decrease is predicted on timberlands and on all forest lands.*

In addition to the direct assessments of population change listed above, two other criteria were used to identify impacts on key habitat factors for some species. These criteria and the assessments of significance are discussed below.

Forest-dependent wildlife - habitats (lowland conifers).

An impact is considered significant if, by ecoregion, net loss of patches of mature lowland conifer between 10 and 200 acres is projected to exceed 25 percent of total patches over the 50-year study period.

This issue is relevant in regions of the state where lowland conifers occur as relatively small, separate patches within more extensive upland forests. As part of a forest mosaic, these patches provide local cover for a variety of mammals, and are often being more important in winter than summer, except in the case of moose. For deer, one study recommends that in northern Minnesota lowland conifers comprise a minimum of forest cover within each square mile. Mature northern white cedar is the most suitable for thermal cover.

Good year-round habitat for deer, moose, and snowshoe hare includes lowland conifer cover adjacent to productive young hardwood stands. Both the snowshoe hare and its chief predators, the lynx and bobcat, are closely tied to lowland conifers, and during years of low hare abundance, this is the primary habitat where they are found during winter. Other closely associated species are the northern flying squirrel, pine marten, and fisher. Spruce Grouse are seldom found anywhere in winter other than lowland conifer, generally dominated by black spruce and tamarack. Characteristic breeding bird species are the Connecticut Warbler, Palm Warbler, Yellow-bellied Flycatcher, and Swainson's Thrush.

Available data do not allow quantifying the number and acreage of these patches. However, covertype acreage changes in table 5.8 suggest it can be at least locally important for patches of black spruce and balsam fir.

In regions where great expanses of lowland conifers, particularly black spruce, predominate on the landscape, protection of this covertype is not as critical to wildlife as where the type occurs as isolated patches.

Forest-dependent wildlife - food species.

An impact is considered significant if, by ecoregion, the projected rate of removal of tree species that provide vital food for wildlife (oaks, hickories and mountain ash), exceeds their projected rate of replacement.

Under the base harvest level, some species projected to have significant declines in certain ecoregions, such as the grey and fox squirrels, rely on mature oak forests for food and cavity resources. However, precise estimates of trends in specific food trees was not possible. In cases where the food producing species is also part of the dominant cover and the age at which that species begins producing the food were known, then the relationship was modelled. An example is the projected changes in populations of acorn-eating mammals such as the two mentioned above. These projections were based on the projected changes in oak-dominated covertypes in ecoregions 5, 6, and 7 and the southern part of ecoregion 4.

The following list includes some of the more obvious instances of vital linkages between food trees and individual bird or mammal species:

- porcupine—white pine, red pine, maples, oaks, basswood, and tamarack;
- black bear, white-tailed deer, southern flying squirrel, fox squirrel, gray squirrel, Wood Duck, and Wild Turkey—oaks and other trees that produce mast;
- red squirrel—conifers, particularly white spruce;
- Ruffed Grouse—quaking aspen;
- Pine Grosbeak, American Robin, Cedar and Bohemian Waxwings, and red fox—mountain ash and cherries; and
- Pine Siskin and Common Redpoll—birches.

Although these tree species are conspicuously important as food sources for some wildlife, both reproductive and vegetative parts of *all* tree species provide some type of forage to some bird or mammal.

Forest species - genetic variability.

An impact is considered significant if there is projected to be a loss of genetic variability in forest plant or animal species as measured by:
1. a reduction or isolation of habitat or communities supporting a species, or
2. a reduction of geographic ecotypes such that a species now present as a viable population disappears or is approaching extirpation from any ecoregion.

The issue here is one of fragmentation, isolation, and, finally, the loss of local segments of a species' geographic distribution, assuming that distinct genetic variation is spread across that geographic range. That is, loss of population segments that are separated by many miles from the nearest segment may mean a permanent loss of unique genetic traits that are an integral part of the species genetic diversity. The importance of a change affecting individual species can be assessed by weighing several factors, including the overall size of the population, the distances involved, and particularly the mobility of the animal. Thus, birds would probably be the least affected and herps would be the most vulnerable, particularly those that are unlikely to disperse along major streams and rivers. Some species show genetic variability over their range; others have a more homogeneous genetic makeup. Information on this is essentially lacking, so this discussion must be confined to generalities. This issue is fully discussed with regard to plants in the Biodiversity technical paper.

In general, when fragmented populations at or near the boundaries of a species range are in jeopardy, genetic loss is much more likely than when an equal degree of local loss occurs well inside the geographic range of a species. Minnesota, with its great diversity of forest and climatic types, includes the distributional limits of many wildlife species—including cases of northern, southern, eastern, and western edges of species' distributions. Thus, among midwestern states, Minnesota has an unusually large number of cases where the edges of a species' genetic variability might be jeopardized. Species with significant predicted impacts from timber harvesting that reach the edge of their range in the state include: black bear, fisher, pine marten, northern flying squirrel, fox squirrel, red squirrel, woodland jumping mouse, lynx, Great Gray Owl, Boreal Owl, and red-backed salamander.

5.6.5 Recreation and Aesthetics

Changes to Minnesota forests - Patterns of forest cover in predominately forested areas-forest roads

An impact is considered significant if there is projected to be development of permanent forest roads in areas meeting the criteria for either of the following Recreation Opportunity Spectrum (ROS) categories: • unroaded primitive areas. • semiprimitive nonmotorized areas.

The two ROS classes used in the criterion are defined as:

Primitive.—An area three or more miles from all maintained roads or railroads and which has an unmodified natural environment. There can be evidence of foot trails, or recreational use. Structures in use are rare. Contact with humans is rare and chances of seeing wildlife are good. Example: BWCAW. Approximately 3 percent of total forest land and 0.4 percent of timberland in Minnesota meet these criteria.

Semiprimitive nonmotorized.—An area one-half to three miles from all maintained roads or railroads, but which can be close to primitive roads or trails used only occasionally. Modifications to the environment are evident, such as old stumps from logging, but are not apparent to the casual observer. Structures in use are rare. Human contact is low and chances of seeing wildlife are good. Example: Recently undisturbed state lands. Approximately 9 percent of total forest land and 7.2 percent of timberland meet these criteria.

A permanent forest road is defined as a formed road that is graveled or paved and is maintained in a trafficable condition (as distinct from being allowed to revegetate). The criterion is intended to identify changes in the pattern of disturbance to the least disturbed areas of the unreserved forest lands. The ROS criteria assess levels of disturbance, particularly roads. The criterion was applied to northern counties that are predominantly forested (see table 5.25).

Harvesting and the development of roads needed to access timber from forests within these categories of lands is indicative of an increased level of disturbance. Improved access provides opportunities for additional use by people who depend on motorized access. This will likely displace a proportion of existing users and will impact animals that are adversely affected when the level of human contact increases.

Table 5.25. Distribution of FIA timberland plots and percent of plots projected to be harvested in primitive and semiprimitive nonmotorized ROS classes, by physiographic class under the base scenario.

		Percent of timberland plots harvested by scenario and ownership*			
		Base Scenario			
	Total number	State/federal lands		Other lands	
ROS Class	of plots	dry	wet	dry	wet
Primitive	53	11.3	3.8	20.7	7.6
Semiprimitive nonmotorized	876	10.8	6.3	15.3	3.9

* See table 5.19 for total number of plots harvested by scenario.

According to the criterion used, only plots harvested on dry sites constitute significant impacts to primitive and semiprimitive nonmotorized recreation opportunities. The criterion specified for use in assessing impacts on primitive class lands further requires identification of those areas designated unroaded *primitive* lands and *semiprimitive nonmotorized* lands, where construction of permanent forest roads is projected.

Under the base scenario, 32.0 percent of the 53 timberland plots designated as primitive and dry are projected to be harvested and therefore significantly impacted. Additionally, 26.1 percent of the 876 timberland plots designated as semiprimitive nonmotorized are projected to be significantly impacted. These impacted plots correspond to 4.0 and 17.4 percent of all forested plots in the primitive and semiprimitive nonmotorized ROS classes, respectively. Based on the criterion, no significant impacts occur when plots in the "wet" physiographic classes are projected to be harvested. These plots would be accessed when the ground is frozen and therefore are assumed not to require permanent roads.

Forest Recreation and Aesthetics

An impact is considered significant if VMGs are not used in the planning and execution of projected timber sales for visually sensitive areas.

The criterion refers to VMGs, which are planning tools used by the federal and state ownerships to reduce visual impacts. Significant impacts can be avoided where visual planning is used to identify *where* and *how* harvesting and associated forest operations should take place, i.e., road location and design, use of buffers, size and shape of cut, and slash and debris disposal practices.

Harvesting can reduce the aesthetic experience for subsequent users, therefore limiting the recreation value of harvested areas and the adjacent unharvested areas. However, harvest operations and associated roading can also create additional recreation opportunities of a more developed type.
Visually sensitive forested areas recognized in this criterion can include such areas as those adjacent (within one-fourth mile) to water (lakes and rivers), important tourist and recreation areas, and along recognized tourist access routes. The criterion assumes that significant impacts occur where harvesting operations take place in visually sensitive areas on lands where owners do not practice formalized visual management planning. For example, the USDA Forest Service has had formalized VMSs in place for a long time. Other ownerships, including MNDNR Management Region 2 and Beltrami County, are in the process of developing and applying guidelines. Once developed,

the MNDNR guidelines are expected to be extended to other MNDNR regions over the next several years.

Typically, other ownerships do not have formalized systems in place. Hence, while in some cases efforts are made to reduce visual impacts on a site by site basis, impacts can still occur when viewed from a wider context.

The certainty of the impact is dependent on the degree to which visual planning is used in timber sale layout and BMPs are adhered to in the execution of the harvesting and postharvest closure of the site. Impacts can extend into the medium-term depending on the circumstances. Existing guidelines that mitigate against impacts are:

- USDA Forest Service VMS;
- DNR - Draft VMGs;
- Wisconsin DNR - Silvicultural and Forest Aesthetics Handbook;
- Shipstead-Newton-Nolan Act;
- Statewide Shoreline Rules (p.31 subpart 8) prescribes use of BMPs within
  - 1,000' of lakes, ponds, flowages
  - 300' of rivers and streams
  - floodplains;
- Upper Mississippi Headwaters Ordinances seeks to preserve the scenic and aesthetic character of the shoreland along the river;
- DNR operational order (95) establishes a ¼-mile buffer around BWCAW for leasing minerals;
- Federal Wild and Scenic Rivers Act (1968) established a 200-foot buffer; and
- State Wild and Scenic Rivers Act.

There are no direct biological implications associated with the use of visual planning to plan harvesting activities although some side effects may occur under certain circumstances. For example, the retention of riparian vegetation as visual buffers along major waterbodies is likely to benefit plant and animal species that live in this habitat. Also, visual planning may increase the amount of older forest and forest managed with selective harvests. If this occurs, it will have biological implications for plant and animal species found in older stands. Changes in recreational use will also impact the recreation/tourism industries that have developed to support such uses.

Based on the interpretation of the significant impact criterion, significant visual impacts occur when timber harvesting and forest management activities do not follow VMGs. Analysis found that 58.7 percent of the timberland area harvested under the base scenario would not be treated according to VMGs and these are therefore judged to be significantly impacted.

5.6.6

Unique Cultural and Historical Resources

An impact is considered significant if heritage resources including cultural landscapes, structural remains, archaeological remains, Native American traditional use sites are destroyed; or cemeteries are disturbed.

Use of the criterion requires that the term *destroyed* be defined prior to analyses of significance. The term destroyed has been interpreted to mean damage to a site such that its scientific, cultural, or spiritual values are diminished in whole or in part. Adoption of this interpretation will result in a *conservative* assessment of impact by including those sites with a partial loss of values; however, this is appropriate for the purpose of a GEIS.

The following maximum levels of significant impacts are predicted for each type of heritage resource, based on the above interpretation of destroyed and the assessments of impacts presented in section 5. There is insufficient data to assess, even qualitatively, the extent that these sites will be impacted. However, significant impacts are likely to occur, and the number of impacts will increase as the level of harvesting increases.

Archaeological and Cemetery Sites

Based on the analysis presented in section 5.5.3, the predicted *maximum* number of sites that would be destroyed is set out in table 5.26.

Table 5.26. Predicted maximum number of archaeological and cemetery sites to be destroyed in ecoregions 1 to 6 under the base harvesting scenario.

Harvest Scenario	Number of Sites Destroyed	
	Number	Percent of Total Predicted Sites Affected*
Base	100,000	52

Source: Jaakko Pöyry Consulting, Inc. (1992g).
*The total number of sites predicted in ecoregions 1 to 6 (see section 2.3) is approximately 190,000.
Note: excludes impacts on USDA Forest Service lands.

Due to the reasons discussed in section 5.5.3, the actual numbers of sites affected can be confidently predicted to be less than these totals. However, because of the assumptions used to generate these estimates, it is impossible to quantitatively assess the effects of most of these assumptions. The only data that can be quantified are the acres that are projected to be harvested on national forests. Preharvest surveys detect most sites on these lands and therefore it is valid to assume that no impacts occur. The figures in table 5.26 reflect this reduction. However, it is not possible to set a lower bound on these estimates.

Traditional Use Sites
As discussed in section 5.5.3, traditional use sites will be impacted. However, the extent cannot be quantified, as these sites have not been inventoried. Therefore, there will likely be significant impacts that will increase with the level of harvesting.

5.6.7 Economics

Regional economics - changes in economic parameters.

An impact is considered significant if there is projected, for each region (north, south, and metro), a change in the following economic parameters by economic sector over 50 years:
- output ± 5 percent
- employment ± 5 percent
- income (wages and salaries) ± 5 percent

The base scenario depicted the current level of harvesting and therefore no changes to forest industries and hence level of economic activities were projected. The base level of economic activity is described in section 6.6.7 and 7.6.7 in comparison with the medium and high scenarios.

5.6.8 Summary of Significant Impacts

The base scenario significant impacts identified in sections 5.2 to 5.5 are summarized below:

1. projected significant loss of forest area in ecoregions 1, 2, 3, and 4 due to land use change (also includes consideration of the loss of timberland in the north);
2. projected harvesting affecting patterns of forest cover in areas of mixed land use (considers amount, type, and fragmentation of cover important to wildlife habitat);
3. projected changes to tree species mix (important to maintaining biodiversity and wildlife habitat; four tree species show significant declines in stem number);
4. projected changes in the age class structure of paper birch (important to community replacement capability for this species; the young age classes appear deficient in acreage for replacing the older age classes);
5. projected harvesting affecting genetic variability of plant or animal species (important to maintaining biodiversity; critically endangered, endangered or threatened communities are identified);
6. projected harvesting affecting federal- or state-listed plant species of

special concern, threatened, or endangered or their habitats (statewide 9, 7, and 37 species listed as endangered, threatened, or of special concern are projected to be adversely impacted by harvesting);

7. changes in the susceptibility and vulnerability of covertypes to forest health risks (important to community stability and productivity; largely dependent on age class structure and the amount and type of harvesting activity);
8. projected harvesting affecting site nutrient capital, i.e., nutrient supplies present and/or actually available (important to sustainability of forest growth and yield; results indicate nutrient losses with certain types of harvesting on various types of soils, approximately 5 million acres are at risk for calcium loss);
9. projected harvesting affecting soil physical structure (important to maintenance of forest growth; the actual area where significance criteria for compaction are exceeded is estimated at 330,000 acres plus haul road area);
10. projected harvesting causing accelerated erosion from forest roads (important to site productivity and water quality; about 25,000 acres plus haul roads are estimated to be impacted with major concern in ecoregion 6);
11. projected changes in the populations of forest dependent wildlife (by changes in amounts of habitat available; 46 species, about 25 percent of all wildlife species studied, were projected to be significantly impacted). Negative impacts are projected for the ringneck snake, beaver, northern flying squirrel, gray and fox squirrels, bobcat, lynx, as well as 39 bird species, for example, Cooper's Hawk, Great Gray Owl, Pileated Woodpecker, Eastern Bluebird, Ovenbird, Song Sparrow, Yellow Warbler and Hooded Warbler;
12. projected harvesting affecting populations of endangered, threatened, or special concern species of animals (Red-shouldered Hawk and Louisiana Waterthrush are negatively impacted);
13. projected harvesting affecting patterns of mature lowland conifer stands (important to wildlife habitat; many important patches of lowland conifer habitat may be lost with harvesting);
14. projected harvesting affecting the availability of food producing trees (important to wildlife; particularly oaks and other mast producing species);
15. projected harvesting in the absence of VMGs on visually sensitive areas (important to aesthetics and recreational use; visual aspects of landscapes and recreational settings are impaired);

16. projected development of permanent forest roads in primitive (undeveloped) and semiprimitive nonmotorized areas (important to maintaining primitive or undeveloped recreational opportunities; harvesting leads to a loss of such areas); and
17. projected harvesting affecting unique cultural and historical resources (important to the protection and integrity of these resources; disturbance from harvesting can effectively destroy these resources).

5.7 Recommended Mitigation Strategies

The mitigation strategies presented in appendix 1 were recommended by the study groups as ways to mitigate the significant impacts projected to occur at the base level of harvesting. The recommended strategies were selected from a wider range of possible mitigation alternatives that were developed in each of the technical papers. These alternatives were assessed using the mitigation strategies criteria described in section 2.3.2. The strategies described in the appendix cannot mitigate all impacts; those that cannot be mitigated are identified in section 5.7.4.

5.7.1 Recommended Strategies Development

Mitigation Alternatives Criterion

The significant impacts identified in sections 5.2 to 5.5 are projected to occur at the base level of harvesting if management practices, including selected mitigations, are applied as described for the second model runs. The impacts also include exogenous factors such as land use change. They apply in varying degrees to all ecoregions.

The criterion used to select among the mitigation alternatives is reproduced below.

> Based on an analysis of mitigation alternatives identified, preferred mitigation strategies will be selected by considering in relative terms:
> 1. the effectiveness at mitigating the identified significant impacts;
> 2. the beneficial effects on other resource values;
> 3. the adverse effects on other resource values;
> 4. the physical, biological, administrative (implementation and oversight), financial (costs, public and private, direct and indirect), and social (ability to organize, support and effect implementation) feasibility; and
> 5. the probability of success and duration of success.

In practice, the verbal and written input from the Advisory Committee on the potential mitigation strategies led to acceptance, rejection, and/or refinement of the potential strategies. These results were then approved by the EQB and comprise the strategies considered and evaluated in detail. Additionally, for this analysis the above criteria were grouped as follows:

1. *Effectiveness* addresses a mitigation strategy in terms of its ability to either avoid or reduce the identified impacts.
2. *Feasibility* addresses the likelihood that the mitigation strategy can be implemented, based on existing or future economic, social, biophysical, or administrative constraints.
3. *Duration* of mitigation can be divided into four classes: 1=long-term—greater than 50 years and irreversible; 2=medium-term—10 to 50 years; 3=short-term—2 to 10 years; 4=very short-term—less than 2 years.
4. *Concomitant effects* refers to those strategies with the potential to significantly affect other resources. No forest management practice will affect only a single resource; forests are intricately interacting ecosystems, and each practice affects many resources.
5. *Probability of success*, though not explicitly tabulated in the following tables, is a combination of effectiveness, feasibility and duration with minimal negative concomitant effects. The strategies identified as highly effective, highly feasible, of long duration, and with minimal negative concomitant effects are assumed to have the greatest chance of success in the long-term.

These criteria were applied to the various mitigation strategies for the purpose of selecting preferred mitigation strategies.

Evaluation of Specific Strategies

A variety of strategies can mitigate potential adverse impacts of timber harvesting and forest management activities at the base harvest level. A comparison of the strategies under each of the groupings used in section 5.6 is presented in the following section.

5.7.2 Recommended Strategies

This section identifies the strategies developed to mitigate significant impacts projected to occur at the base level of harvest (4.0 million cords per year). These strategies, many of which reflect the mitigation measures developed in the technical papers, have been combined and modified where required in order to achieve multiple objectives and resource protection goals. Mitigation strategies that would improve the standard of forest practice in Minnesota but do not directly mitigate significant impacts are also presented.

The strategies recommended to address significant impacts at the base level of harvesting are presented under three categories which reflect their main focus:

1. forest-based research;
2. landscape-level responses; and
3. site-level responses.

Forest-based Research: Strategies in this category are intended to: obtain the information needed to undertake strategic and operational planning; to monitor changes at the landscape- and site-level; and to provide the basis for developing management and direction and planning tools. The responses considered here are:

- monitor the age class and covertype structure of the state's forests;
- complete an inventory of the state's biodiversity features;
- conduct an inventory of old growth forests across all ownerships;
- develop and fund a research program to investigate the effects of timber harvesting and forest management activities on the tourism and travel industry in Minnesota; and
- upgrade and maintain a listing of known archaeological, historical, and traditional use sites in the state.

Landscape-level Responses: These are typically long-term or broad-based solutions that require coordinated planning and/or implementation to identify and achieve the intended objectives of developing regional or statewide responses. A key to the success of these responses is to provide direction and coordination across ownerships. The responses considered here are:

- measures to reduce the area of forests converted to other land uses;
- balancing age class and covertype structure;
- riparian corridors;
- ERF;
- protection of sensitive sites for plant species;
- landscape-based road and trail plan;
- VMGs; and
- IPM strategies.

Site-level Responses: Strategies in this category are intended to modify operational procedures used in the planning and execution of timber harvesting and forest management activities on an individual site or local scale. The responses considered are:

- modifications to harvesting practices and equipment;
- modifications to silvicultural practices;

- protection of sensitive sites for wildlife; and
- increasing the wood fiber productivity of timberlands.

The following discussion describes these strategies.

Forest-based Research

Monitor the age class and covertype structure of the state's forests and their pattern across the landscape. This strategy would develop monitoring of the age class and covertype structure of the state's forests. This would provide the information necessary to set statewide resource objectives for age class distributions by covertype and covertype acreage to achieve several resource objectives. These age class and covertype acreage objectives are crucial to minimizing future impacts. Further, monitoring progress toward these objectives is essential to their utility as the forest changes naturally and due to human influences. Trends in age class changes in certain covertypes and covertype area were determined to be the cause of significant impacts for forest health, tree species mix, wildlife habitats, and biodiversity. Thus these subject areas have a need to be involved in the design of monitoring and analysis of results. Additionally, it is important that the pattern of cover across the landscape be monitored to assist in developing an understanding of wildlife-pattern relationships and appropriate management.

Any research program examining trends in the structural aspects of forests should be coordinated with statewide inventories. Additionally, forest growth and change models should be used to project future age class and covertype distributions based on likely demand scenario(s). The USDA Forest Service NCFES and the UofM's College of Natural Resources are both well-placed to undertake this analysis. The MFRMA of 1982 specifically charters the College of Natural Resources for such support (as part of the MAES of the UofM).

It is also evident that the frequency of this monitoring is presently inadequate. FIA inventories have been 10 to 15 years apart, leading to much uncertainty about trends. Thus, monitoring that provides results or updates in a shorter time period are needed. That might be accomplished through more frequent surveys or design changes that provide for frequent updates.

A recent report by the Blue Ribbon Panel on Forest Inventory and Analysis (1992) includes the timeliness of forest inventory data as a major concern and recommends a five-year inventory cycle.

There is also a need to coordinate current and future inventories of natural resource being undertaken by agencies at the state and federal levels.

Undertake an inventory of the state's biodiversity features. Minnesota currently has a County Biological Survey Program. However, this program has completed comprehensive inventories in only a few counties, the majority of which are predominantly nonforested. Thus this strategy will speed up the identification of the occurrences of rare plant species and communities, old growth forests, and key habitat features for wildlife species classified as endangered, threatened, or of special concern in forested areas. Knowledge of the locations of these features permits forest planners and managers to avoid or modify operations in relevant areas. This mitigation, when combined with other operational mitigations, would address significant impacts on: plant and animal species classified as endangered, threatened, or of special concern; wildlife populations; old growth forests; and biodiversity.

At current staff and funding levels, the MNDNR's County Biological Survey will complete the last county in Minnesota by the year 2020. Based on the current level of harvest (as projected under the base scenario), approximately 6.3 million acres will be harvested at least once over the 50-year modelled period ending in 2040. Thus, approximately 3 to 4 million acres will have been harvested before the inventory is completed. Therefore, an accelerated inventory of the state's biological resources is needed to identify and develop appropriate protection for many of the populations of rare plants and animals found within the state's forested regions. If an accelerated inventory is economically infeasible, then attention should be given to redesign of the inventory or prioritizing its application across the state. The intent of redesign would be to provide at least some information for all areas soon by interpolation and extrapolation.

Conduct an inventory of old growth forests across all ownerships. Federal, state, and, to some extent, county land management agencies have begun inventories of old growth, but little is known about the types and extent of old growth on private lands. Further, since these data may be gathered by several different agencies, there is a need to insure that all vegetative databases are compatible with each other and the county biological survey efforts. This effort needs the leadership of the MNDNR to provide necessary coordination. Also, monitoring of old growth stand protection and health, regardless of the level of harvesting, seems appropriate and could provide for updating of databases. These data will help ensure the protection of these important sites, although once the stands are identified, strategies for their protection will have to be implemented, and specific guidelines will have to be developed for USDA Forest Service, MNDNR, and county-managed lands.

Develop and fund a research program to investigate the effects of timber harvesting and forest management activities on the tourism and travel (particularly outdoor recreation) industry in Minnesota. This strategy is intended to define and quantify the relationship between changes in the forest resource and induced changes in recreational/tourist user patterns in forested areas in the northern part of the state. This information would enable more informed regional planning regarding the spatial and temporal distribution of timber sales, use of VMGs, and other mitigations.

Upgrade and maintain a listing of known archaeological, historical and traditional use sites in the state. This strategy seeks to upgrade the quality, extent, and utility of the database on the state listing of known sites and their locations. A more accessible, secure, useable, and accurate database would be useful for assessing the probabilities of finding sites under certain circumstances. Access to this data would assist forest planners and managers to avoid impacting known sites, and would also be valuable for refining procedures to locate or avoid sites not yet identified. Database security and utility also will be key for effective long-term applications.

Forest management is one land use that will likely impact the state's cultural and historical resources. Other land uses, particularly urban and infrastructural developments, are also likely to adversely impact these resources. The state archaeologist office has the responsibility for these resources. The state should provide staffing and funding, that are not tied exclusively to forest management programs. The current level of funding clearly fails to recognize the magnitude of the problem.

The release of information on traditional use sites is a sensitive issue for contemporary Native Americans. However, this information is required before efforts can be made to avoid adverse impacts caused by timber harvesting and forest management activities, as well as other land use changes. The office of the state archaeologist has well-developed contacts with Native American groups living in the state. Information on traditional use sites could be provided through the state archaeologist, who could maintain the high level of confidentiality required by traditional users.

Landscape-level Responses

Measures to reduce the area of forests converted to other land uses. This strategy seeks to develop policy instruments to discourage conversion of forested land to other, nonforest, land uses. Loss of forest area to agricultural or urban uses is not a consequence of timber harvesting and is therefore independent of the level of harvesting. These policies would be directed at private property as conversion activities are unlikely to occur on public lands. Thus, any initiatives that seek to limit or control uses must be framed in ways that recognize private property rights, including the rights of owners to use their land for its highest economic use. Currently, there are a variety of policy instruments directed at retaining forest land that are available at the federal, state, and local level. The effectiveness of these policy instruments to compete with economic forces varies considerably across the state. They are likely to be less effective and/or more costly closer to major urban areas, where the value of the land for other purposes increases. Conversely, in the northern part of the state these instruments will likely be more effective where they are applied as the relative value of land decreases. Also, *any* change in land use in heavily forested areas will likely reduce the area of forest land, as there are limited stocks of nonforest land in such regions.

The projected loss of forest area in the northern part of the state exacerbated impacts on some wildlife species and the projected increase in forest area in the south mitigated impacts on some species that would otherwise have been significant. Therefore, the strategy to reduce the loss of forest area will be important if the modelled trend towards an increase in forest land is reversed in ecoregions 5, 6, and 7 which are located in the southern and southwestern parts of the state.

Policies should be prioritized to favor the retention of key habitat types such as those on riparian lands particularly those in the southern and western parts of the state. Existing mechanisms such as shoreland rules already give some protection to these lands. Additionally, land zoning regulations and special property tax laws may offer protection to these areas. A comprehensive assessment of the effectiveness of these laws and regulations is needed before any additional policy instruments are developed.

The strategy is rated as being of low effectiveness because of the constraints identified above, particularly as they relate to private property rights. Changes brought about under this mitigation are likely to persist over the medium-term.

Balancing age class and covertype structure. The future age and/or size class and covertype structure of the state's forests will have important implications for forest wildlife habitat, biodiversity, timber production, recreation and aesthetics, and forest health. Significant impacts such as those projected for forest health, biodiversity (tree species mix), and wildlife populations were associated with changes to the age class structure for some key covertypes and covertype acreage itself. For example, some impacts were projected to occur because the low level of harvesting in some covertypes meant that average stand age increased: the paper birch cover type is a good example of this. In contrast, the oak-hickory covertype is projected to show a substantial acreage in the young age classes and old (>100 years) age classes, while there are comparatively few acres in the middle (35- to 95-year) age classes.

Aside from large-scale natural disturbance, timber harvesting and forest management activities, including fire are the only tools available to effect large-scale changes to the age class structure; and these changes can only be effected over a very long time. Therefore, this strategy seeks to develop statewide objectives that cross ownership boundaries. The age class monitoring identified above will be essential to the strategy and would provide both the initial data to identify where imbalances exist to allow objectives to be set; and subsequently, to monitor changes.

Statewide targets for areas of older age classes could be coordinated with existing ERF and old growth forest programs of the MNDNR and USDA Forest Service. In addition, other strategies that promote older age classes, such as management of riparian zones and connected landscapes (discussed below), should be considered when assessing age class targets. By combining these targets with other strategies, opportunities to achieve multiple objectives can be maximized. The inventory of the state's biodiversity features could be used to guide selection of sites. For example, where rare or threatened communities depend on older forests, known locations of these communities should be included in meeting targets of increased acreages of older age classes. Note that target development needs to include the normal public participation mechanisms at all levels, referenced elsewhere in this study (primarily sections 4 and 8).

Maintaining a proportion of the forest in each age class in each covertype will provide ongoing habitat for the full range of plant and animal species. Depending on the forest type and existing age class distribution, the process of achieving a balanced age and/or size class distribution and overall acreage for the range of covertypes in Minnesota will invariably affect some wildlife species positively and some negatively.

This strategy would also alter tree species composition, particularly if combined with variations in the types of harvesting and silvicultural practices used for particular covertype/age class distributions which are discussed further under site-level responses.

Balancing age classes and maintaining covertype acreages is technically feasible, but practically it is dependent on markets and/or management investments to fund implementation. Such investments are most likely to develop for species with commercial value. This balance also needs to be considered in the context of the desired species composition for the forest and the long-term goals for that. The task is complicated by the varied forest land ownership. These mitigations would logically apply to public ownerships with a mandate for managing to promote biodiversity at a state or national level.

Administration of this mitigation is feasible and could be coordinated with the existing ERF programs of the MNDNR and USDA Forest Service. Manipulation of stands to effect species or covertype changes would necessarily be a long-term process. The feasibility of this alternative would be constrained by the ability to obtain consistent funding and the willingness of all major landowner categories to participate. The NIPF lands can potentially participate in this program formally via covenants or through purchase of land by organizations such as The Nature Conservancy. The contribution of such stands to the maintenance of biodiversity and the provision of other values, including aesthetics, would make expenditures by public ownerships more justifiable.

Riparian corridors. Riparian corridors are the strips of land and associated plant communities that border waterbodies. These areas are often the focal point for resource management conflicts because of their importance for widely differing forest values. Riparian zones are one of the most important components of the water/land interface due to their influence on (1) habitat within the aquatic system, (2) transport of pollutants and erosion to a river, stream, wetland or lake, (3) habitat for terrestrial species, (4) aesthetic characteristics of the landscape, (5) recreational opportunities for the public, and (6) cultural and historical resource sites.

Harvesting activities in timberlands in riparian zones along larger streams and lakeshores are becoming more controlled through combinations of policies and programs. These constraints vary considerably. For example, BMPs, are widely used voluntary codes of practice intended to minimize water quality impacts caused by timber harvesting and related activities that take place near waterbodies. Other constraints are imposed by policies generated from within land management agencies. The MNDNR's 200-foot leave strip prohibits clearcutting on state lands along designated state wild rivers. The USDA Forest Service also designates a 200- to 300-foot wide buffer along streams and rivers that is managed to optimize riparian values. Lastly, there are externally imposed constraints such as shoreland rules and regulations that restrict certain activities in riparian areas. The existence of these constraints was reflected in the harvesting model assumptions for all ownerships, which limited the types of harvesting and forest management activities in stands occurring within 100 feet of water and within 200 feet of lakes or major streams in ecoregions 4, 5, 6, and 7.

Riparian management zones specified in BMPs and regulations used elsewhere in the United States vary in the designation of width and the types of activities that are permitted. In Minnesota, the width of riparian or streamside management zones can vary from zero to 300 feet. The types of harvesting permitted within the nominated zone range from clearcutting to maintenance of at least 50 percent of the existing canopy or volume of standing timber.

Maintaining the integrity of riparian vegetation is an important management objective within riparian zones and can be supported by the proper use of BMPs. Timber harvesting impacts on aquatic systems occur when riparian corridors have been disturbed, either by inappropriate harvesting or by roading. Poorly planned and maintained stream crossings can be the main sources of sediment pollution of streams in forested catchments. Impacts to aquatic ecosystems from management within riparian corridors are apparent through changes in material and energy flows between the terrestrial and aquatic environments. Site-specific reductions in organic matter inputs, changes in timing of inputs, and changes in litter quality associated with different types of litter inputs are likely to occur on a site-specific basis when harvest occurs within 200 feet of a stream channel.

Visual values are also important within riparian zones. Protection of these values is important for recreational uses and to maintain the settings of many resorts and other tourist/recreation facilities with water-based settings.

The importance of these zones for wildlife habitat and the potential for offsite impacts such as localized sedimentation and visual impacts requires more uniformity in the standards of management applied across all ownerships. The existing Minnesota BMPs have been well accepted and there has been a high level of compliance across most ownerships. Notably, compliance on private lands is approximately 70 percent. However, BMPs were intended primarily to address one key factor, sedimentation, that impacts riparian resources. Other factors likely to be affected such as visual amenity, wildlife habitats, and recreational uses are not particularly well served by the existing BMPs guidelines. Consequently, it is appropriate to expand the existing BMPs.

The modified standards would vary reflecting the differing needs and the variety in riparian lands and their relative importance in different parts of the state. In the southern and western parts of the state (ecoregions 5, 6, and 7), rivers have relatively wide bottomlands that contain valuable wildlife habitat. Furthermore, they often exist as corridors through otherwise nonforested land. In the northeast (ecoregions 1 through 4), bottomlands are not as common. There are many lakeshores, with relatively low erosion hazards, and the riparian zones are embedded in a forest landscape, so that the habitat is not as critical. Therefore, riparian zones would be wider in the south than the north, are more critical as a landscape corridor, and would appear to be more unique to their surrounding environment than in the north. In the southwestern portion of the state where riparian zones are critical habitat for many plant and animal species, buffers of 200 feet on both sides of watercourses would be required. Harvesting can be carried out within these buffers; however, uneven-aged management or thinning rather than clearcutting are the most appropriate silvicultural systems. Choice of silvicultural system within these buffers would mitigate negative effects of harvesting on wildlife species that live within the riparian zone. Wildlife species that would benefit include most herps as well as birds such as the Prothonotary Warbler, Louisiana Waterthrush, Northern Waterthrush, Cerulean Warbler, and tree nesting species such as herons and egrets. In addition, harvests planned using statewide visual management BMPs (discussed below) would protect recreational uses and visual amenity.

In the remainder of the state, riparian zones 100-feet wide along lakes, wetlands, and each bank of rivers and streams (<third order) would be designated. Existing shoreland rules apply only to the extent that they recommend the application of voluntary BMPs on water quality. The choice of silvicultural system is important in this zone. Thinning, ERF or uneven-aged management are the preferred systems. Application of statewide visual management BMPs (discussed below) within these buffers would mitigate negative effects of harvesting on visual amenity and recreational uses.

Mechanisms that could be applied under this mitigation strategy range from statewide regulations to voluntary guidelines. Uniform application of this strategy is important to protect values within these essentially linear environments. If several landowners fail to comply with the guidelines there could be serious consequences for visual, recreation, water quality, and wildlife habitat values above and below the disturbed area, i.e., offsite impacts. The estimated current levels of compliance with voluntary BMPs on private lands make it unlikely that uniform compliance will be achieved.

ERF. ERF can be described as: *any forest managed on a rotation length that is longer than that recommended for the covertype for timber production*. Typically, these stands are managed on rotations approximately 50 percent longer than normally prescribed. ERFs are an effective strategy because they directly help to mitigate a large number of the potential effects of shorter rotations on biodiversity. Management as ERF does not preclude harvesting and therefore does not remove lands from the timberland base; yet it helps provide many of the biodiversity features of older forests over large areas.

Generally, with increased frequency of timber harvest, there is an increased short-circuiting of both plant succession and the development of structural diversity. ERF assure the continued presence of large tree gaps, dead wood, and the species that depend on them, without being designated old growth and removed from the base of timberland. Extended rotations can mimic the natural rotation period for Minnesota forests. Management with shorter rotations can be compatible with biodiversity, as long as sufficient area in other portions of the landscape are managed with extended rotations.

The harvesting scenarios assumed that 20 percent of state and federal lands would be managed, explicitly or implicitly, under an ERF-based management regime. Levels in that order of magnitude are feasible and consistent with the policies of these agencies. For example, the MNDNR expects to manage between 10 and 25 percent of state forest lands as ERF (Jaakko Pöyry Consulting, Inc. 1992k).

However, increased recognition of nontimber values on county lands is expected. While there are no written policies concerning ERF on county lands, there is some scope for the larger counties to adopt more flexibility in the silviculture applied on their lands, particularly with regard to the rotation length for a proportion of stands. In addition, an unknown proportion of NIPF timberlands will be managed without harvesting for prolonged periods, effectively increasing ERF acreages. Because of the uncertainty regarding management objectives, this latter category of ERF lands cannot be relied upon as part of a formal strategy in the same way as public lands. The exceptions are where such lands are managed under a conservation covenant or have been purchased by groups such as The Nature Conservancy, which has explicit conservation management objectives outlined for each property. At present, such lands represent only a small fraction of the total NIPF landbase.

The existing age class distributions show that substantial areas of many covertypes could already be classified as ERF using the above description. The projected age classes show trends of increasing acreages being recruited into the older age classes (section 5.2.2).

Increasing the proportion of ERF stands will also increase the volumes of sawtimber-sized logs produced, which is likely to benefit the sawmilling industry.

Note: Linkages between remnant areas of older forest or natural areas are potentially very important. The need for these linkages is based on an understanding of the ecological needs and dynamics of natural dispersal of many plant and animal species associated with large tracts of mature forest habitats. Populations can be jeopardized by fragmentation of mature forests into islands of inadequate size. Linkages can be provided by *connected landscapes*, which may take the form of riparian corridors, wide corridors of ERF, or uneven-aged selection harvest forest between core areas such as patches of old growth, research natural areas, and scientific and natural areas. In other cases, an ERF or uneven-aged buffer can be used to reinforce a riparian corridor. The networks potentially reduce the effects of fragmentation without reserving large contiguous blocks of forest. They can be achieved by changing the spatial pattern of harvest, not the amount of harvest. The widths may be prescribed on the basis that one half of a corridor's width could be harvested and the corridor could still function.

The connected forest corridors could be managed under ERF as part of the recommended ERF forest percentage in the state or where appropriate under uneven-aged management. In addition, buffers managed under ERF guidelines or uneven-aged management would also be maintained around old growth forest patches. Linkage of patches of old growth by ERF managed corridors could overcome some of the current problem of old growth patches that are probably too isolated to allow exchange of genetic material among old growth species. This problem exists in all ecoregions except the border lakes (ecoregion 2).

Creating corridors for the dispersal of plant and animal species would be a way of allowing Minnesota's forest to respond to future climate change. Genetic variation in Minnesota generally occurs along a cline correlated with climate, from southwest to northeast. For some species, it is important not to disrupt the spatial genetic structure of vegetation by harvesting. Paleoecology shows the climate perpetually changing and this will continue, whether or not human-caused global warming occurs. However, predictions under climate change models indicate that the rate of change is likely to be much faster than in the past. The prospect of accelerated climate change adds impetus to the need to make provision for vegetation to respond to changing climate, and gene flow and the movement/distribution of seed/propagules from southwest to northeast should be facilitated.

In the northern ecoregions, the focus for these networks would be on public lands where existing policies and mandates to manage for biodiversity already exist, and ownerships manage substantial, often contiguous, blocks of land. Planning corridors on lands managed by a single agency will be comparatively straightforward. However, interagency cooperation will be required where corridors cross agency boundaries. The need for consultation and reconciling certain issues on the ground will likely add to the complexity of the planning task. Overall, agencies should be encouraged to incorporate linkages in their plans to advance their joint goals.

The area of land under public ownership is small in the lower central, western, and southern ecoregions. Most forested land in these ecoregions is on private land. Forests are typically in small blocks, hence coordination becomes more difficult as the number of individual landowners increases. Therefore, in these parts of the state, the strategy should focus on strengthening existing corridors. The riparian zones discussed above are the most suitable corridors within this part of the state. These zones already contain a significant proportion of the forest cover in ecoregions 5, 6, and 7. Riparian areas are also afforded some protection under existing Shoreland Rules. Where future management within identified corridors is unlikely to be consistent with ERF guidelines, some benefits can accrue by changing the silvicultural and harvesting systems used on these private lands. For example, owners of lands within such zones should be encouraged to employ partial cutting techniques when harvesting.

There are likely to be ongoing opportunities to expand existing corridors and provide additional linkages to other remnant patches of forest. Federal and state agencies responsible for existing agricultural land retirement programs should be encouraged to preferentially fund replanting or restoration of sites that link with, or augment such corridors.

Given the potential of connected landscape concepts, they are an appropriate area for research. However, since their utility by species can vary and because of their potential expense (Simberloff et al. 1992), they are recommended as an area of research rather than for broad application at this time.

Protection of sensitive sites for plant species. The known locations of rare plant species (see Jaakko Pöyry Consulting, Inc. 1992e for complete list) and rare plant communities (listed in table 5.23) that are likely to be sensitive to harvesting impacts should be excluded from harvesting. The strategy depends on the availability of information from an inventory of biological resources, as described under research strategies, to be able to pinpoint the landscapes these sites are found in, or better, the specific locations of these sites.

The MNDNR and USDA Forest Service currently afford such protection to some of these areas through registry sites, Research Natural Areas, or Scientific and Natural Areas. Extending this protection to other ownerships will be more problematic due to differing ownership management objectives.

Landscape-based road and trail plan. This strategy would involve planning and coordination between ownerships to develop landscape-based road and trail plans. Landscape-based plans would be most appropriate in the northern ecoregions. These plans could be used to mitigate significant impacts under several issue areas including soil compaction, recreation, wildlife, and cultural resources. The plan would cover the following: development of new roads, particularly in primitive and semiprimitive nonmotorized areas; long-term access needs; and closure policies.

The complex patterns of ownership in Minnesota mean that significant benefits can accrue from coordination of road and trail plans. The likely benefits include:

- insuring that development of new roads in primitive and semiprimitive nonmotorized areas minimize inadvertent adverse impacts on nonmotorized recreation opportunities within these areas;
- rationalizing road layouts by removing ownership constraints from route selection to reduce the length of new roads and the number of stream crossings;
- developing fewer roads but of a better, more uniform standard of construction and maintenance, thereby reducing the amount of poorly planned, constructed, and maintained forest roads;

- providing opportunities for consultation with traditional users in areas where such uses continue to reduce access-related impacts on traditional uses; and
- making consistent decisions on road closures to maintain adequate access for fire control and other management requirements, while reducing the likelihood of impacts from recreational use of roads by off-road vehicle users.

Development of landscape-based plans would require a leadership role to initiate the process and to coordinate responses from other ownerships. The MNDNR is the agency best placed to undertake this role. This strategy is feasible given the MNDNR responsibility to produce an inventory of state forest roads under the MFRMA of 1982. In addition, the number of ownerships likely to be developing new roads in remote areas is limited. The cost of adopting this mitigation would center on the additional planning that some ownerships would require before participating. Additional costs would also be incurred by the MNDNR in coordinating and compiling inputs from others.

Develop VMGs. VMGs are a highly effective way of retaining primitive kinds of recreational opportunities in the overall landscape and in specific areas that will be harvested. VMGs, especially if used in conjunction with nonpermanent roads, give attention to the important social attributes and long-term benefits of primitive recreation opportunities.

VMGs would also address maintaining visual quality and recreation opportunities for all ownerships on all forest lands. The state is already moving in this direction. The approach would also ensure that resort interests were addressed. VMGs could also incorporate buffer zones for the most visually sensitive areas.

IPM strategies. The state should initiate and oversee development of IPM strategies for the major pests likely to increase as a consequence of timber harvesting. In addition, IPM strategies are required to prepare for the likely introduction of exotic pest species such as the gypsy moth.

Pests are a community problem, particularly those species that are prone to major outbreaks. Development of regional, statewide, and interstate IPM strategies in advance of pest outbreaks allows time for all parties to agree on the types of intervention that are appropriate; the circumstances under which the various methods of intervention can be used; and the responsibilities and cost sharing arrangements that should apply where outbreaks occur. Development of these endorsed IPM approaches will reduce the potential for conflict at the time when early, decisive action can be most effective. Examples of IPM strategies include

- undertake a risk/hazard rating to identify susceptible areas;

- monitor populations;
- implement appropriate control methods, such as release of sterile males, pheromone traps, insecticide spraying, and silvicultural treatments, when populations reach predetermined levels; and
- increase tree diversity at site and landscape levels.

Certain aspects of IPM strategies may be controversial and gaining the level of support needed will require the active participation of representatives from the following: MNDNR; USDA Forest Service; counties; forest industries; NIPF owners; other forest ownerships, e.g. Native American bands; the resort and tourism industries; conservation groups; and the state Department of Agriculture. A leadership role is required to initiate this process and to promote implementation of the resulting IPM strategies. The MNDNR is the most appropriate state agency as its responsibilities extend over many of the aspects of Minnesota's forests likely to be affected by pest outbreaks. The MNDNR already is (along with certain other ownerships) engaged in the recommended insect and disease-related strategies. Research support for IPM as per the MFRMA of 1982 should come from the UofM's MAES. Additional research activity by the USDA Forest Service NCFES would be a major asset.

The process used to develop the *Memorandum of Agreement regarding the aerial herbicide spraying program of the Division of Forestry, MNDNR* provides a precedent for the development of this initiative. This process proved to be unsuccessful in practice because of a lack of sustained effort to implement the agreement by all involved parties. Also impeding its success was the lack of funding for research which was an integral part of the agreement. However, the experience gained in that effort could be a valuable lesson in how to shape the process needed to develop IPM strategies.

Programs to monitor pest populations are an integral part of IPM strategies. The current Forest Health Management (FHM) program is currently supported by the USDA Forest Service and the MNDNR. However, pest problems are a community problem and the responsibility should therefore be shared. Counties and the forest industry should actively participate in this program as an effective way of bringing additional resources to monitor pest populations. This measure gains added urgency in view of the likely introduction of gypsy moth into Minnesota, which will undoubtedly have significant impacts on industry and all forest ownerships.

Additional support for the FHM program will increase its effectiveness and will insure that resources are directed towards all forested lands in the state. The projected increases in the area of older age classes for many covertypes will require closer monitoring of pest populations.

Site-level Responses

Modifications to harvesting practices and equipment. The following modifications to the practices and equipment used in Minnesota can be used to mitigate significant impacts projected to occur as a consequence of timber harvesting and forest management activities.

1 Retain Slash. This strategy is intended to modify harvesting systems and techniques in order to reduce the loss of nutrients from harvested sites (especially those with aspen-birch and upland hardwood on coarse-textured soils, and organic soils), and to maximize habitat values for small animals in the resulting cutovers. These two objectives can be achieved in part by retaining slash from harvesting as close as possible to the tree stump. Slash comprised of branches and leaves/needles can either be trimmed in the cutover, or be returned to the cutover as part of the logging operation. This mitigation is feasible using existing equipment and requires a modification to existing operational practices. The Harvesting Systems background paper (Jaakko Pöyry Consulting, Inc. 1992l) estimated that nearly one-third of operations delimbed at the roadside (1 percent of operations did not delimb). Under these circumstances, large slash heaps remain at the landing. These heaps represent a redistribution of site nutrients and do not provide good wildlife habitat.

Redistribution of slash can also have both positive and negative impacts on regeneration activities. For example, it can provide a healthy microclimate that stimulates seed germination and young stem establishment. Hand- planted seedlings also will likely benefit in this regard. However, redistributed slash may interfere with site preparation activities and certainly can be an impediment to machine planting. The potential also exists for the redistributed slash to facilitate new growth of vegetation that competes with seedling development. Then there is also the issue of habitat for diseases and pests as well as the potential to add to the low level fuel mass in event of a wildfire. Overall, then, the redistribution of slash does have many positive aspects, but each situation needs specific consideration in light of potential drawbacks.

Redistribution of slash can be accomplished using existing logging equipment. Grapple skidders, which make up more than two-thirds of offroad log transporters used in Minnesota, can return slash into the cutover as backloads during normal operations with little added cost. Cable skidders or slash pilers would require more effort to load; however, the practice is feasible. Slash should be distributed away from ephemeral wetlands and ponds within the cutover.

The exceptions to slash retention would include circumstances where pest management guidelines require that slash and debris be removed to prevent the build-up of pest populations. Such debris removal is termed *stand hygiene* and applies in covertypes such as red pine which can be attacked by the Ips bark beetle. In addition, if a stand is in a visually sensitive area and the presence of slash causes adverse visual impacts, then slash should not be redistributed within the nominated visual buffer.

The necessary modifications to practices relating to slash retention could be achieved through a range of measures. Changing the specifications that form part of the stumpage sale agreement is likely to be the most straightforward approach. The specifications could be modified to preclude loggers from leaving slash piles and could specify that slash is not to be piled or distributed in small wetlands and ponds within the cutover. Education programs for loggers to equip them with an understanding of preferred techniques would also be useful. Finally, a code of logging practice could specify such modified practices.

In addition to the above measures, site nutrient losses can be reduced by retaining bark in the cutover for operations where species type and product specifications allow debarking prior to delivery to the mill. Debarking in the cutover is not commonly practiced in Minnesota. Unbarked logs are usually transported to the mill where the bark is removed. Past attempts at infield bark removal have been aimed at meeting mill bark specifications. This mitigation is not directed at achieving this level of removal, but it is aimed at developing techniques to remove as much bark as feasible. Therefore, for some easily debarked species it should be feasible to remove a high proportion of bark in the cutover. Lower levels of removal would have to be tolerated where species have bark that is more difficult to remove or where the difficulty in removing bark varies by season or where other important operational considerations conflict significantly. For example, debarked logs can become slippery and create handling safety problems, or they can degrade wood quality by accelerated stem drying at the mill yard.

Equipment is available that can debark in conjunction with the tree processing function at the stump. This equipment is used elsewhere for smooth-barked species similar to aspen and should be investigated for its application in Minnesota. In addition, there is other equipment that can debark at the landing. Landing-based debarking would require bark to be transported from the landing and redistributed throughout the cutover. Testing such equipment under Minnesota conditions is likely to be beyond the means of most loggers in Minnesota. Therefore, these tests could be sponsored by industry and major land ownerships, possibly through some subsidy for innovative loggers that encourages them to undertake such trials.

Removing bark at the site rather than the mill may adversely affect those mills which use bark as part of their energy needs or other markets for this resource. The energy equation for these mills would be altered if a substantial proportion of the bark was no longer available.

2 Equipment and practices for use in multiple entry harvesting operations. The projected increase in the use of multiple entry, i.e., thinning, or uneven-aged silviculture will require modifications to existing equipment and practices to avoid excessive damage to retained stems during harvesting operations.

Damage can degrade retained stems, leading to an increased incidence of diseases and pests and to a reduction in the quality and volume of usable wood.

Harvesting practices and equipment that minimize damage to residual stems and the site have been developed, notably in Scandinavia. Training of fellers and operators to be aware of damage to retained stems and teaching them falling and equipment operating skills that minimize damage using existing equipment would be a good interim measure.

In the long-term, changes to the types of equipment used will be required if damage levels are to be reduced. Possible machines were discussed in the Harvesting Systems background paper (Jaakko Pöyry Consulting, Inc. 1992l) and include the *long-reach one-grip harvester* and *low ground pressure forwarder*. Use of this equipment with well-trained operators can reduce levels of damage to less than 2 percent of residual stems in thinning operations.

This equipment can also mitigate significant impacts associated with compaction. These machines reduce the proportion of the site impacted because the reaching booms mean they are not required to drive up to each tree. The harvester can delimb and stack logs ready for collection by the forwarder and can deposit the slash in windrows which can provide additional support. Use of this equipment and operating techniques can reduce the area affected as well as the degree of compaction.

As discussed previously, logging companies in Minnesota are unlikely to have the financial resources to undertake field scale equipment evaluations. Consequently, new types of equipment are unlikely to be introduced into Minnesota, unless loggers are provided with some form of assistance.

The forest industry could take the initiative by evaluating alternative systems and then promoting trials of the most suitable systems. Financial support for loggers willing to participate in the trials may be required for the period between when the new systems are introduced and when they reach full productivity. Voluntary contributions or a levy on the volume of wood cut or used by each processing or logging company would be equitable ways to obtain funding from the industry at large. The federal, state, and county governments could also provide support.

The forest industry, loggers, and major public ownerships should cooperate to develop logger training programs. These programs should be backed with a form of skill certification that would be required before people could be employed in the forest. Proof of attendance at training sessions would be a basic requirement before certification could be issued.

3 Modify season of equipment operation to minimize compaction. This strategy is intended to reduce compaction by identifying susceptible sites and limiting operations on those sites to the period when the soil is frozen and the risk of compaction is lowest.

Because differences in susceptibility to compaction and related disturbances are due to soil texture and soil water status, identification of susceptible sites is requisite to developing strategies for minimizing these disturbances. Table 5.27 identifies the combinations of soil types by season that are susceptible to equipment related disturbances.

Table 5.27. Susceptible soil types by season.

Soil type	Winter	Spring	Summer	Fall
Well-drained fine		X		X
Poorly-drained fine		X	X	X
Well-drained medium		X		
Poorly-drained medium		X		X
Well-drained coarse				
Poorly-drained coarse		X		

Source: Jaakko Pöyry Consulting, Inc. (1992b).

Based on these assessments, equipment operations should be limited on susceptible soil types during the spring and fall periods. Medium- and fine-textured soils most often exhibit low soil strength during the spring and fall, with low strength most often occurring in poorly-drained positions. Forest managers need to be aware that the strength of medium- and fine-textured soils can decrease rapidly during the summer and fall in response to intense rain storms. Equipment operation on some poorly-drained soils will be limited to frozen soil conditions. The strength of coarse-textured soils will be adequate for all but the wettest conditions which generally occur in poorly-drained areas in the spring. Where possible, well-drained, coarse-textured soils should be identified and held in reserve for wet season harvesting.

Site susceptibility must be identified at an operational scale if preventative measures are to be effective. In most areas, soil maps and other tools are *not* available at the stand or harvest unit scale. Confirmation of site susceptibility will require on-the-ground inspection by natural resource professionals. Site disturbance can be effectively reduced by carefully monitoring soil strength conditions before and during forest management operations. This may require additional training and staffing of forest management organizations. In reality, these measures will be easier to implement on public agency lands than NIPF lands which lack organization structures and mechanisms to facilitate effective actions.

Imposing seasonal restrictions on harvesting on some soil types or delaying operations that are already underway could cause financial hardship to loggers, depending on the availability of other harvestable sites not considered susceptible to compaction. In addition, these restrictions may interfere with the continuity of supply to some mills.

These problems may be alleviated by:

- stockpiling wood near all-weather roads during the winter for subsequent delivery during the spring;
- identifying sites that can be harvested during spring and fall periods and retaining these exclusively for harvest during these periods;
- increasing stockpiles at mills by increasing the levels of harvest during winter; and
- introducing lower impact harvesting equipment and techniques as discussed previously.

This mitigation will require cooperation between landowners, the forest industry and loggers. A leadership role is required to develop techniques to enable field identification of susceptible soil types, and to develop operational guidelines for harvesting on these types. This role would best be handled by the MNDNR in conjunction with the other major land ownerships.

Identification of soil types that are not susceptible to compaction should be a priority. Sites of these soil types should be set aside for wet weather harvest.

The forest industries should re-examine their wood supply requirements to identify opportunities for seasonal changes in delivery schedules.

Modifications to silvicultural practices. The Silvicultural Systems background paper (Jaakko Pöyry Consulting, Inc. 1992m) provided a summary of the applicability of various silvicultural systems to Minnesota covertypes.

The following mitigation strategies specify the circumstances where modifications to normal silvicultural practices are required to maintain wildlife habitat and aesthetic values. Typically, the modifications represent a shift from clearcutting to techniques that retain a proportion of the stand following harvesting.

1 Patterns of forest cover in areas of mixed land use. A strategy to mitigate the negative impacts of changing patterns of forest land in the southern parts of the state requires modifications to the silvicultural practices used and specification of the size of individual cuts. Thinning or uneven-aged management should be used where feasible. Potentially suitable covertypes for these systems include: lowland hardwoods, red oak, and northern hardwoods (see table 3.2, Silvicultural Systems background paper [Jaakko Pöyry Consulting, Inc. 1992m]). The application of these silvicultural systems in any stand should be subject to stand conditions and the owners' management objectives. Harvesting should be limited to small portions of any given tract in any one decade.

Use of thinning or uneven-aged management silvicultural systems will minimize the reduction in key habitat features found only in older forests. These features include food trees, cavities, dead trees for cavity excavators and suitable forest floor cover, humidity conditions, and shade. They are needed by some small- and medium-sized mammals, birds, amphibians, and reptiles. This pattern of cutting will favor deer year-round, by leaving thermal cover while producing temporary patches of forest herbs and of shrubs that provide good quality summer and winter browse. In addition, selective cutting in forests inhabited by gray squirrels should retain cavity trees at around 2.4 trees/acre. Southern flying squirrels and tree-cavity nesting birds would also benefit.

When forests dominated by oaks are cut in this manner rather than clearcut, all mast (acorn) dependent wildlife will be favored; particularly fox squirrel and gray squirrels, bears, deer, Wood Ducks, and Wild Turkey. The habitat needs of many forest birds are maintained by the use of these systems. These species would disappear from clearcut stands until the regrowth matured.

Since most hardwood stands cut for sawlogs are in private ownership, education, incentive and assistance programs would likely be most cost effective. Regulation of practices is an alternative, but is likely to be very expensive due to the scattered ownership. In reality, partial cutting as opposed to clearcutting is feasible and the most common practice in such regions. Unfortunately, much of this harvesting is really *high grading*, which can impair the future timber productivity of the stand. The impacts of changes to harvesting practice are likely to be long-term, but are subject to the vagaries of changing ownership.

Some forest raptors can be protected by reserving a few acres around nesting sites. Although the Red-shouldered Hawk may not tolerate even this level of disturbance. More data are needed to determine the extent to which this species will tolerate harvesting and at what times. Because of the sensitivity of this species to disturbance, relatively large tracts (>300 acres) of mature forest in ecoregions 4, 5, 6, and 7 should be encouraged. These larger sized blocks will also mitigate harvesting impacts on the gray squirrel and all forest interior birds in that part of the state including: Pileated Woodpecker, Acadian Flycatcher, Cerulean Warbler, Black-and-white Warbler, Ovenbird, and Scarlet Tanager. Much of this mitigation is related to reducing nest parasitism by the Brown-headed Cowbird, also an edge species.

The fragmented ownership structure in NIPF lands in the southern parts of the state make it unlikely that large blocks of forest would be held under single ownerships. Therefore, retention of larger blocks may be achievable only where specific blocks are identified and the current owners approached and asked to participate in such a scheme. The MNDNR County Biological Survey should be used to identify candidate sites. Special incentive programs should be developed for this purpose. Alternatively, these sites would be good candidates for purchase to augment the state's reserve system.

2 Retention of key habitat requirements in clearcut areas. Certain key habitat can be retained within clearcuts to maintain some habitat values required for the species that formerly occupied the stand. Habitat requirements can be maintained by retaining snag trees, trees with cavities; and retention of conifer patches and isolated trees when harvesting in predominantly deciduous forests, using *Forestry-wildlife guidelines to habitat management* (MNDNR 1985) as a model.

Clearcutting with residuals generally prescribes:

- the number of snags to be left uncut, e.g., 2 to 6 per acre;
- inclusion of dense, lowland conifer patches of 5 to 10 acres each; and
- the types of live trees to be retained on the site, with preference to food producing trees such as oaks, hickories, mountain ash, and cherries as well as rare tree species.

Deer, moose, snowshoe hare, and pine marten will use the conifer inclusions as cover from heat, cold, or predators while still having access to the emergent forage in the clearcut. Black bears will use conifer shade in summer while feeding on berries in clearcuts. A variety of birds will use the snags for nesting when cavities develop, including Tree Swallows, Northern Saw-whet Owls, Eastern Bluebirds, and most woodpecker species (which can create cavities). Other birds use the snags for territorial singing perches, including Golden-winged Warbler, American Robin, and Chestnut-sided Warbler. Raptors, including the Red-tailed Hawk, American Kestrel, and Northern Saw-whet Owl, use the snags for hunting perches.

3 Retention of cavity trees or mature trees that are likely to produce cavities in stands that are clearcut, will provide nesting and security substrate for a wide range of birds as well as some mammals in postharvest forests. This mitigation is intended to provide these resources pending new cavity formation in the regrowth forest, which begins after a number of decades for most tree species. Diseased or damaged trees typically have more cavities, or have a high potential for developing that cavities. Snag retention should be directed toward trees that are not infested with insects and diseases other than wood decay. This restriction would not be necessary when stands are regenerated to nonsusceptible forest species. In southern Minnesota, tree quality is frequently low and thus cavities are probably not in short supply.

Individual animal species' requirements for cavity trees are not fully understood and more research is needed to gain a quantitative understanding of wildlife requirements.

Harvesting in forests inhabited by gray squirrels and southern flying squirrels should aim at retaining a minimum of 2.4 cavity trees/acre. This mitigation should be applied over all Minnesota ecoregions, but for mammals it may be critical within the range of the gray squirrel, projected to be heavily impacted under all harvest scenarios.

Many bird species depend upon cavities for nesting, and some overwintering song birds such as chickadees require cavities for thermal protection in cold weather. Tree-cavity nesters range through all forest types and stand sizes; some species prefer lone trees in openings, hence the importance of cavity-snags on edges and within clearcuts. Cavity nesters in Minnesota forests include owls—Boreal, Barred, Screech, and Northern Saw-whet; woodpeckers—Red-headed, Red-bellied, Downy, Hairy, Three-toed, Pileated, Black-backed, and Northern Flicker; Black-capped and Boreal Chickadees; Red-breasted and White-breasted Nuthatches; Eastern Bluebird; Tree Swallow; Yellow-bellied Sapsucker; and several ducks—Common Goldeneye, Common and Hooded Mergansers, and Wood Duck.

These mitigations would require nontechnical guidelines that could be applied by loggers or land owners. These guidelines should reflect many of the current practices on the major public ownerships. Their adoption by NIPF landholders is likely to depend on the owner's management objectives and the value of timber foregone by retaining trees which could be sold. Therefore, the guidelines need to include educational materials that explain the value of these habitat requirements.

Protection of sensitive sites. Sensitive nest sites, habitats, rookeries, and rare communities should be identified and protected by appropriate buffers. Current guidelines followed by the MNDNR and USDA Forest Service around nests of Bald Eagles and rookeries of colonial birds should be used as the model for protecting sensitive sites for all rare species, including plants. Rare communities should be protected by establishing Scientific and Natural Areas (state lands), Research Natural Areas, or Special Botanical Areas (federal lands). The Nature Conservancy conservation easement program would be a good model for protecting rare communities on county and private lands.

The Bald Eagle guidelines include: no new roads or trails and no logging, even during the nonbreeding season, within 660 feet; all activities prohibited except those related to protecting the site, within 330 feet; no activities during the breeding season from mid-February to early October, within 1,320 feet; and no logging even in the nonbreeding season, within 660 feet. These recommendation are based on studies and management applications by the Chippewa National Forest. These guidelines also include a lakeside buffer of one-fourth mile, rather than 200 feet, in areas where eagles are likely to feed. However, modifications would be appropriate where eagles colonize already active logging areas or right-of-ways.

Based on current MNDNR guidelines, for rookeries of colonial wading birds (herons and egrets), there should be no logging within 330 feet, and no logging or other disturbance during the nesting season (April to July inclusive) within 660 feet. Finally, no logging should be carried out within 300 feet of bluffs with hibernacula of massasauga and timber rattlesnakes, or near known populations of five-lined skinks, rat snakes, and lined snakes. Many of these sites are likely associated with the riparian zones discussed previously.

The locations of some of these sensitive sites are already known and where there is a risk of disturbance from harvesting, owners can be made aware of the risks to these species. In addition, assistance should be provided to insure that appropriate mitigations can be implemented by the landholder.

The USDA Forest Service and the MNDNR undertake identification and management of some rare species and communities on their lands. The MNDNR is the most appropriate agency to oversee preparation of suitable guidelines for application on NIPF lands and on other ownerships which do not have access to the skills necessary to properly manage these sites.

Increasing the wood fiber productivity of timberlands. The area of timberlands available for harvesting in the state is projected to decrease. The reduction is likely due to land use changes, as well as to additional reservation of land and the imposition of constraints on the types of practices that can be undertaken on the remaining lands.

This strategy identifies ways to increase the yield of wood fiber from the land base managed primarily for wood production. There are two elements to the strategy. The first provides short- to long-term benefits, and the second provides medium- to long-term benefits.

1 Increasing Utilization. In Minnesota the level of utilization of wood from an individual stand varies depending on a range of factors. There are differences in the standards of utilization achieved by individual logging companies. In addition, the harvesting and silvicultural prescriptions imposed by some landowners reduce the level of utilization.

This strategy is intended to increase utilization by making maximum use of the stems (not slash) available for harvest. This strategy must be applied carefully while taking into consideration the strategy noted previously for slash retention to avoid conflicts in implementation of both strategies.

Utilization standards are specified by industry. Typically, these standards specify minimum diameters, log lengths, and wood quality. Existing standards and practices likely reflect the relatively low stumpage paid for most wood in Minnesota which, in turn, reflects the relative abundance of wood. The consequences of the existing specifications are graphically illustrated at sites where topping and slashing occurs on the landing. Substantial volumes of potentially usable wood are left at the landing following application of current minimum diameter standards.

The strategy has several components. The first involves using more of each stem harvested by relaxing the minimum top diameter and length specifications of logs. This strategy would particularly apply to the conifer-based pulp and paper industry. Industry should actively seek ways to adapt processing equipment to handle smaller, less uniform pieces of wood and subsequently, to improve utilization. This includes the development of technology to attain increasing product standards using resources of lower quality.

The second component involves changing production processes, especially in the pulp industry, to accept the range of species available from the mixed species stands typical in Minnesota. This industry is selective in its use of species so there are substantial volumes of undesirable species that are left in the cutover following harvesting. Some of these trees meet wildlife needs and therefore would not be harvested irrespective of industry specifications. However, the remaining trees could be utilized and thus increasing the productivity of the site (as measured by fiber yield).

The feasibility of this alternative depends on the ability of the forest products industry to adapt to changing input specifications while remaining competitive with other domestic and international competitors. New industries are moving in this direction; retrofitting existing plants will be more difficult.

The third component of the strategy would take up the same theme as the second but would provide more immediate benefits. Purchasers of stumpage should insure that all the wood potentially available from each stand is put to its best end use. This mitigation would require some of the current exclusive arrangements between loggers and particular industries be relaxed to allow more effective movement of wood to multiple industries from a single sale. This could be achieved through direct negotiation between loggers and specific industries, or through greater use of brokers specializing in this service.

The last component of the strategy is to train loggers in ways to improve utilization. This includes techniques as simple as reducing the stump height which can add to the volume yielded. The forest industry, loggers, and the major landowners should develop logger training programs to improve the levels of utilization.

Removal of more biomass under improved utilization practices would need to be cognizant of concerns about soil nutrients and wildlife habitat. Both are affected by the amount, distribution and nature of slash and residual trees left after logging. The major landowners should utilize existing guidelines on all lands and where needed develop additional standards on minimum levels of utilization to apply on their lands. These minimum standards should incorporate guidelines covering the retention of large logs and slash needed to meet wildlife management objectives.

This strategy would provide benefits ranging from immediate/short-term extending into the long-term. The forest industry is the most suitable to take a leadership role in implementing this strategy. The long-term security of timber supplies for the state's forest industry will depend on maximizing yields.

2 Increasing Productivity. Increasing productivity of existing and future stands is likely to be a more effective way to maintain future resource security than relying on gross area of forests. There are many ways to increase productivity of timberlands. Regeneration to full stocking levels and site-species matching are two of the most readily implemented and effective ways on a statewide scale. This mitigation would be feasible as much can be achieved by changing the way harvesting is done, and through improved site survey and planning. The focus of this mitigation is on NIPF timberlands where standards of harvest planning and silvicultural management can be most improved. Improving these standards and therefore stand productivity is feasible using a combination of landowner education and broad BMPs that include good harvesting practices likely to maximize regrowth success. This alternative would provide long-term mitigation. Additionally, intermediate harvests (thinnings) and stand hygiene practices could capture much of the natural mortality although some snags and trees with cavities should be retained for the benefit of wildlife.

Additionally, improved pest management program also would lead to enhanced productivity and also should be a focus of productivity enhancement efforts.

In addition to improving productivity of NIPF lands, the forest industry is also likely to have strong incentive to invest in their own timberlands. These decisions will be motivated by the individual company's perceptions of the financial returns from such ventures and the security of the company's future wood supply.

Where plantations are contemplated, care should be taken in the choice of exotic and hybrid stock to avoid the potential loss of biodiversity. As background, exotics by definition introduce nonnative genes. Hybrids can be formed from exotic parents, from a combination of native and exotic stock, or simply from combining different native plant materials. By contrast, tree improvement efforts primarily involve selection from among native species or genotypes. In practice, hybrids developed from native stock and tree improvement efforts typically seek to improve growth and disease resistance by increasing a tree population's frequency of genes that are effective in promoting such performance.

Further, such efforts also attempt to conserve or retain the full breadth of genes in the population originally. In contrast, exotic stock, if aggressive, can potentially lead to a reduction in the original gene pool. In Minnesota, forest tree genetics programs are or will likely emphasize tree improvement over approaches involving exotics. In terms of risk, a long history of Scotch pine planting and plantings of a wide variety of poplars have shown little impact on native forest tree species. However, some introduced shrub species are very aggressive and have displaced native species, especially in areas subject to human disturbance and development.

Judicious plantings can increase the habitat value of landscapes now largely in a single covertype. Because of their high productivity, plantations can also greatly reduce the acreage that might otherwise need to be harvested.

The major landowner groups, forest industries and loggers should develop guidelines for effective harvest and silvicultural practices for application in all harvesting operations in the state. These guidelines would be similar to the existing water quality BMPs and would be directed at site level operations and planning. Other existing USDA Forest Service and MNDNR guidelines should be at least considered here to assure a more efficient and useful set of statewide guidelines.

5.7.3 Effectiveness at Mitigating Significant Impacts

The base level harvest scenario significant impacts identified in section 5.6 were summarized in section 5.6.8. The following section discusses the relative effectiveness of the strategies recommended in section 5.7.2 as mitigations for significant impacts projected to occur under the base scenario.

1 Impact
Projected significant loss of forest area in ecoregions 1, 2, 3, and 4
Reduce the area of forest converted to nonforest land uses: The process of land use conversion is independent of the level of harvesting. The proposed strategy seeks to influence NIPF ownership to maintain forested land under forest cover, irrespective of their management objectives.

As discussed in the previous section, the likelihood of influencing landowner decisions depends largely on the economic value of the property. The policy instruments available to the state to influence decisionmaking by the NIPF ownership including zoning, property tax, financial incentives, and purchase of easements are limited and likely to be marginally effective given the number of forest land holdings in the state. Past experience in the state has shown a limited willingness to adopt these increases on a scale commensurate with the problem.

2 Impact
Projected harvesting affecting patterns of forest cover in areas of mixed land use
These impacts would affect species that depend on the features of mature forest and forest interior species. The following mitigation strategies will mitigate these impacts.

Maintain patches of forest intact in areas of mixed land use: This can be done by reducing clearcutting and even-aged silvicultural systems and by linking patches and augmenting existing patches of forest. This strategy incorporates aspects of mitigations concerning management of riparian corridors and use of uneven-aged silvicultural systems in the patches that are harvested. These mitigations will benefit the animal species that depend on features of mature forest such as cavities and mature mast trees. Other forest interior species will likely remain impacted. Modification of existing silvicultural systems (e.g., clearcutting) has to be consistent with acceptable practices on the covertype in question.

Mitigations to maintain populations of forest interior species and the Red-shouldered Hawk will need to maintain forest interior conditions in remnant patches. Large (>300 acre) blocks of mature forest will likely have to be retained with only periodic disturbance to maintain the most sensitive species.

Effectiveness: If applied at a regional scale, this mitigation strategy will likely be effective at mitigating impacts by maintaining these important habitats.

Feasibility: The feasibility of this strategy depends on NIPF owners adopting constraints on management of their forests. The restrictions on the use of clearcutting are likely to be successful as this method of harvesting is not routinely practiced in the areas affected. Therefore, that aspect of the strategy will likely be moderately effective as a proportion of landowners will probably adopt these guidelines for management of their forests. The modification of harvesting and silvicultural practices has to be consistent with workable practices for those covertypes and regional goals for such cover.

Retention of large blocks of undisturbed forest is less likely to be successful because this aspect of the strategy will likely require cooperation of more than one NIPF landowner. As more landowners become involved, the likelihood of **all** owners cooperating will decrease. Purchase of these blocks for inclusion in the state's forest ownership system is probably the most effective means to achieve this mitigation. However, the state investment required could become large.

The GEIS analysis was unable to quantify the projected extent of these impacts, and therefore it is not possible to quantify the effectiveness of the proposed mitigations.

3 Impact

Projected changes to tree species mix

Projected changes to tree species mixes in the state's forests are likely to result from changes in the age class distributions of covertypes, as well as from covertype acreage changes and direct impacts on minor tree species. Consequently, the strategy seeks to monitor and, where needed, to manipulate age class and covertype distributions. The strategy depends on several distinct elements which are discussed below.

Monitor the age class and covertype structure of the state's forests and their pattern across the landscape: This mitigation would not mitigate impacts directly but would contribute information that would allow informed decisions to be made concerning other mitigations.

Complete the MNDNR county biodiversity inventory: This mitigation would not mitigate impacts directly but would contribute information that would allow informed decisions to be made concerning other mitigations.

Conduct an inventory of old growth forests across all ownerships: This mitigation would not mitigate impacts directly, but would contribute information to assist decisions on other mitigations.

Maintain desired age class distributions for each covertype: This offers the prospect of modifying the tree species mix by insuring the presence of adequate areas and numbers of stands that are likely to provide suitable conditions for the full range of species. Age class distributions can be manipulated by increasing harvesting of a particular covertype, using prescribed fire, or by managing a proportion of stands as ERF. This strategy is the only mitigation likely to be able to modify tree species mix at a landscape scale.

Maintain desired covertype distributions: This provides for maintenance of tree species mix by management to achieve acreage goals by covertype. The available tools include harvesting and a range of silvicultural practices that favor certain species and covertypes. In some areas, restoration of forest cover by planting or enrichment may be appropriate. In other situations minimal disturbance might be effective to allow natural succession.

Effectiveness: This mitigation strategy would likely be only moderately effective, requiring long periods to achieve detectable change. Because harvesting and silvicultural practice are the only practical tools available for these landscape scale manipulations, there are inherent constraints on the range of covertypes likely to be manipulated. Typically changes will be on covertypes dominated by the more commercial species. Stands of noncommercial covertypes and those within reserved forests will likely continue the trend towards older age classes. Use of other tools such as fire and special silvicultural systems would likely be very expensive and confined to small areas.

Feasibility: The mitigation strategy is moderately feasible as the major public ownerships have policies to maintain biodiversity. The other ownerships typically have no clear management objectives in this area and are less likely to direct their management to achieve these goals. Therefore, the mitigation would be focussed on the major public owned forests. However, to be successful, coordination among ownerships is essential, especially in areas with intermingled ownership. Success will also require agreement on acreage and age class goals for specific covertypes.

4 Impact

Projected changes in the age class structure of paper birch

This was the only covertype projected to have significant changes to the age class distribution. The covertype showed a trend towards older age classes with little young acreage and reflects the low level of harvesting projected for this species. The following elements comprise the mitigation strategy for this covertype.

Monitor the age class and covertype structure of the state's forests and their pattern across the landscape: This would not mitigate impacts directly but would contribute information that would allow informed decisions to be made concerning other mitigations. As described in section 5.8.1, FIA survey design refinements could add measurably to the timeliness and effectiveness of this monitoring.

Conversion of older stands to young stands to balance the age class structure: This would require that old stands be harvested and new stands regenerated.

Effectiveness: If a proportion of older stands could be replaced by younger stands, then the mitigation would be effective.

Feasibility: The mitigation strategy is unlikely to be feasible because the covertype is not a widely sought after commercial species, and it is difficult to regenerate once stands become too old to reliably stump sprout. Major public ownerships are likely to undertake limited regeneration efforts but these will probably be inadequate to balance the age class distribution statewide. Research on the ecology of birch regeneration may be a prerequisite to success.

5 Impact
Projected harvesting affecting genetic variability of plant or animal species
Harvesting is projected to lead to further fragmentation of the forest and to impact outlier populations of some species and plant communities. These impacts can create conditions likely to reduce genetic variability of plant and animal species. The following elements make up the mitigation strategy to mitigate these impacts.

Complete the MNDNR county biodiversity inventory: This would not mitigate impacts directly but would contribute information that would allow informed decisions to be made concerning other mitigations.

Develop blocks of ERF: This would promote additional diversity of covertype and provide habitat for species dependent on mature/older forest. ERF policies are likely to be confined to the major public ownerships.

ERF and riparian corridors would likely maintain many opportunities for transfer of genetic materials between separated populations of forest plants and animals. In the northern ecoregions where public ownerships dominate ownership patterns, remnant old growth is being preserved, and ERF policies are being implemented. In contrast, the increasing proportion of lands under NIPF ownership in the south of the state means few areas are managed in a way likely to maintain the conditions needed to assure genetic transfer in the long-term. In this region, the riparian zones will likely be an important vector for genetic transfer for some species, i.e., for connecting key habitat features of landscapes.

Modified silvicultural systems: The use of uneven-aged management and thinning for harvesting and retention of key habitat requirements would likely maintain conditions that are suitable for many of the species likely to be significantly adversely impacted. NIPF owners are more likely to adopt these modified silviculture systems in the southern part of the state than in the north. This is because the covertypes and range of products sought in the south are more suited to these systems.

Effectiveness: Combinations of these mitigations will likely be effective at reducing significant impacts by providing a range of age classes in each covertype and linkages for transfer of genetic material.

Feasibility: The major public ownerships have mandates to manage for biodiversity. However, application of these mitigations by other landowners is likely to be mixed, and will depend on owners' objectives. Consequently, the mitigation is rated at low to moderate feasibility. It will likely be more feasible in the north and less feasible in the south of the state.

6 Impact

Projected harvesting affecting federal- or state-listed plant species of special concern, threatened, or endangered or their habitats

Impacts on populations of these species of plants and the communities that contain them are interpreted to occur as a consequence of harvesting because little is known of their locations. The significant impact criterion threshold was set at any diminution or disturbance of habitat or populations of these species.

The strategy directed towards maintaining genetic variability discussed previously will mitigate some of these significant impacts.

Complete the MNDNR county biological survey: There is a strong likelihood that populations of these species and the communities which support them will be disturbed and diminished if the locations of these species remains unknown. Therefore, significant impacts are likely to be higher in areas that have not been surveyed by the MNDNR county biological survey.

Effectiveness: The effectiveness of the strategy depends on access to information on the locations of these species and the communities that support them. If the locations of these populations were noted, then plans to redirect harvesting could be made. Therefore, the effectiveness of the strategy relies largely on increasing the funding and staffing allocated to the MNDNR county survey and/or refinement of the design as suggested earlier in this section. This strategy would also require some administrative procedure to ensure appropriate notice and protection.

The inventory of old growth could be conducted by several agencies, but coordination is appropriate to ensure database compatibility.

Feasibility: The strategy is likely to be moderately feasible subject to needed survey design changes and adequate funding being provided to complete the biodiversity survey. Also important here is the need to secure at least a sample coverage of the entire state within ten years.

7 Impact

Changes in the susceptibility and vulnerability of covertypes to forest health risks

Impacts were interpreted based on projected changes to age class distributions and circumstances where multiple-entry harvesting systems were used. The projected changes in forest health primarily reflect the increasing age of stands in noncommercial covertypes on timberlands and all covertypes within reserved lands. These impacts are not a consequence of timber harvesting per se. How the management responds to these changes to forest health will depend on the management objectives for the stand. Increases in insect and disease attacks would likely be viewed as an integral part of the stands' ecology by the manager of a reserved area. In contrast, the same attacks would be viewed as a threat to productivity by managers concerned with wood production. Consequently, the need for mitigation and the likely responses would be different under each circumstance. Conflicts are expected between production-oriented landowners and reserved forest management when they are in close proximity because insect and disease problems endemic to older reserved forests may spill over to nearby timberlands. Both ownerships would view attacks from introduced pests such as the gypsy moth as a major adverse impact.

The mitigation strategy is aimed at developing statewide plans to handle pest outbreaks and to modify the equipment and techniques used in multiple-entry harvests. The following section outlines the elements of this strategy.

IPM: This will assist to mitigate impacts associated with major outbreaks such as gypsy moth. The planning advocated under this mitigation will allow a more rapid response and is therefore likely to reduce the level of impact experienced.

Modify equipment and practices for use in multiple entry harvesting operations: This will likely reduce damage to residual stems and will therefore reduce the incidence of pests and diseases that are associated with wounds. This will have particular application in the south of the state.

Maintain desired age class distributions for each covertype: Seeking such distributions will provide opportunities to reduce the proportion of susceptible and vulnerable covertypes on ownerships with wood production objectives. This mitigation would only effect change over the long-term.

Effectiveness: These three mitigation strategies are likely to be moderately effective at reducing damage caused by major outbreaks of pests, particularly pests such as gypsy moth. The localized impacts caused by damage to retained stems would likely be reduced if the changes to equipment and practices were introduced.

Feasibility: These strategies are likely to be moderately feasible, subject to participation by the major stakeholders in the development of IPM strategies. Adoption of new harvesting equipment and techniques will likely be of moderate feasibility subject to the provision of assistance to undertake trials and subsequently, the loggers willingness and ability to make the investments needed to replace equipment.

8 Impact

Projected harvesting affecting site nutrient capital

Nutrient losses above estimated levels of replenishment were projected for several combinations of covertype/soil type/harvesting practices. These significant impacts can be mitigated by changing the length of rotations and the harvesting methods used. The following strategy has been developed to mitigate these impacts.

Retain or redistribute slash within the cutover: This will maintain the nutrients contained in the leaves (needles) and branches within the cutover. This can be achieved either by favoring use of equipment and/or harvesting practices that retain slash at the site where the tree was felled; or, slash from landings can be redistributed using existing equipment.

The mitigation would require the development of guidelines to specify acceptable patterns of redistribution, including avoidance of ephemeral wetlands and small ponds.

The development of systems that could undertake partial or full bark removal in the cutover would also greatly aid nutrient retention. These systems are untried in Minnesota.

Manage a proportion of stands under ERF guidelines: Would extend the period for nutrient replenishment prior to the next harvesting operation.

Effectiveness: The mitigation of retaining or returning slash and (if feasible) bark within the cutover is likely to be very effective in reducing nutrient loss. Longer rotations are also effective, allowing natural processes to replenish the nutrients lost in harvest or in site preparation. The duration is long term, but effectiveness is reduced with time as species reach advanced ages and become less vigorous and more susceptible to forest health problems.

Feasibility: In some cases the strategy can be implemented easily. However, overall feasibility will depend upon operational and technical constraints, particularly on the harvesting technique, the equipment available, and, to some extent, the season of harvesting as it facilitates removal of bark. Equipment to remove branches and bark at the stump is currently operational overseas. In the long-term, feasibility should be high. Return of slash to a site from a landing or elsewhere would also be similarly effective and long-term. Its feasibility would be affected by the added cost of another pass of equipment over the site and the potential compaction and puddling associated with such an activity. Returning material in winter would minimize the latter effect. The duration of the effect is long-term.

The feasibility of applying longer rotations is problematic for short-lived species, and benefits diminish with time as nutrient levels return to preharvest levels.

9 Impact

Projected harvesting affecting soil physical structure

Compaction and puddling is projected for the most frequently impacted well-drained medium-textured soils (the most common soil in the state) and poorly-drained medium- and fine-textured soils. The likelihood of impacts is affected by the extent of roading, the type of equipment and the season of harvest. Therefore, the strategy is intended to manipulate these aspects in order to mitigate impacts. Additionally, implementing these recommendations may require soil survey information. However, soil surveys are not complete in several forested counties. The following section describes this strategy.

Develop landscape based road and trail plans: This strategy would involve planning and coordination between ownerships to develop landscape-based road and trail plans. The plans would cover development of new roads, long-term access needs, and closure policies.

The complex patterns of ownership that exist in Minnesota mean that significant benefits can accrue from coordination of road and trail plans. The likely benefits include rationalizing road layouts by removing ownership constraints from route selection which can reduce the length of road developed and reduce the number of stream crossings; and developing fewer roads but of a better, more uniform standard of construction and maintenance, thereby reducing the extent of poorly planned, constructed, and maintained forest roads.

Modify times of equipment operation to minimize compaction: This will reduce the occurrence of compaction likely to occur by identifying susceptible sites and limiting operations on those sites to periods when the risk of compaction is lowest. Based on these assessments, equipment operations should be limited on susceptible soil types during the spring and fall. Medium- and fine-textured soils most often exhibit low soil strength during the spring and fall, with low strength most often occurring in poorly drained positions. In addition, the strength of medium- and fine-textured soils can decrease rapidly during the summer and fall due to intense rainstorms. Equipment operation on some poorly-drained soils will be limited to frozen soil conditions. The strength of coarse-textured soils will be adequate for all but the wettest conditions, which generally occur in poorly-drained areas in the spring. Where possible, well-drained, coarse-textured soils should be identified and reserve for wet season (spring) harvesting.

This mitigation will require cooperation between landowners, the forest industry and loggers. A leadership role is required to develop techniques to enable field identification of susceptible soil types, and to develop operational guidelines for harvesting on these types. This role could best be handled by the MNDNR in conjunction with the other major landownerships. Identification of soil types that are not susceptible to compaction should be undertaken as a priority. These sites should be set aside for wet weather harvest.

Effectiveness: If fully implemented, the strategy would likely be moderately effective at mitigating the significant impacts.

Feasibility: Development of landscape-based plans would require a leadership role to initiate the process and to coordinate responses from other ownerships. The MNDNR is the agency best placed to undertake this role. This strategy is feasible given the existing MNDNR responsibilities to produce an inventory of state forest roads under the MFRMA of 1982. In addition, the number of ownerships likely to be developing new roads in the more remote areas is limited. The cost of adopting this mitigation would center on the additional planning that some ownerships would have to undertake to participate in the process. Additional costs would also be incurred by the MNDNR in coordinating and compiling inputs from others.

Constraints on equipment operation during susceptible periods will require assessments of site susceptibility at an operational scale if preventative measures are to be effective. In most areas, soil maps and other tools are *not* available at the stand or harvest unit scale. Confirmation of site susceptibility will require on-the-ground inspection by natural resource professionals. This will likely require additional training and staffing of forest management organizations. The MNDNR, USDA Forest Service and possibly the larger counties and forest industries are best equipped to undertake this mitigation. It is unlikely that planning and assessments on NIPF lands would reach this level of sophistication and consequently this mitigation is less feasible on these lands.

The feasibility of imposing seasonal restrictions on harvesting on some soil types or delaying operations that are already underway would likely be constrained by possible financial hardship to loggers. In addition, these restrictions may interfere with the continuity of supply to some mills. The feasibility will therefore be constrained by the flexibility of forest industries delivery schedules.

10 Impact
Projected harvesting causing accelerated erosion from forest roads
Forest roads are the primary sources of accelerated erosion from harvested areas. The most susceptible region in the state is in the southeast where steep slopes exacerbate erosion problems. The strategy aimed at reducing compaction will mitigate erosion impacts.

The key elements of this mitigation strategy include: adherence to BMPs, consistent road closure policies; a reduction of the length of road constructed; and an improvement in the standard of design, construction and maintenance.

Effectiveness: These mitigations will reduce the extent of poor standard forest roads that are likely to cause erosion. If applied throughout the state, this strategy would provide moderately effective mitigation of the impact.

Feasibility: The main erosion problems in the state occur in the southeast, where there is less likelihood that these measures will be adopted because of the predominance of NIPF lands in this region. Thus, a variety of programs will be required to increase compliance with harvesting practice codes. These include education, technical assistance, and/or possibly more stringent measures.

11 Impact
Projected changes in the populations of forest dependent wildlife
Projected changes to wildlife populations were based on changes in the amount and quality of likely habitat within the known ranges of each species or group of species. The mitigation strategy is intended to:

- identify and protect important habitats;
- provide a range of age classes within each covertype with particular attention to maintaining habitat features of old and old growth forests;
- maintain patches of forest in areas of mixed land use;
- provide a landscape with connections necessary for movement of animals among separated populations;
- modify harvesting practices to maintain within cutovers some of the key habitat needs for animals dependent on features of mature forests; and
- distribute logging slash to provide cover for small animals in clearcuts.

The following section discusses each element of the proposed mitigation strategy and assesses the overall effectiveness and feasibility of the strategy.

Complete the MNDNR county biological survey: The information from the survey is essential to identify important habitats for forest dependent species.

Conduct an inventory of old growth forests across all ownerships: This information is important to identify habitat for species dependent on old growth forests.

Develop blocks of ERF: This would promote additional diversity of covertype condition and would provide habitat for species dependent on mature/older forest. ERF policies are likely to be confined to the major public ownerships.

Maintain linkages between patches of remnant forest or old growth via corridors: This would likely maintain opportunities for movement of animals between separated populations. In the northern ecoregions where public ownerships dominate ownership patterns, remnant old growth is preserved and, on state- and federal-managed lands, ERF policies are being implemented. In contrast, the increasing proportion of lands held under NIPF ownership in the south of the state means that few areas are managed in a way likely to assure that connections will be maintained in the long-term. In this region, the riparian zones will be the most important vectors for genetic transfer for some species. However, the limitations currently existing for use of such linked landscapes must be kept in mind.

Maintain patches of forest intact in areas of mixed land use: This can be done by reducing use of clearcutting silvicultural systems, linking patches, and augmenting existing patches of forest. This mitigation strategy incorporates aspects of other mitigations, including management of riparian corridors and use of uneven-aged silvicultural systems in the patches that are harvested. These individual mitigations will benefit animal species that depend on features of mature forest such as cavities and mast trees. The habitat needs of the species dependent on forest interior will be met by mitigations to maintain forest interior conditions in remnant patches. Large (>300 acre) blocks of mature forest will likely have to be retained with no disturbance to maintain populations of the most sensitive species, especially the Red-shouldered Hawk.

Modify silvicultural systems to maintain key habitat components: This includes the use of uneven-aged and thinning systems as substitutes for clearcutting where appropriate, i.e., in certain covertypes that can be managed using these systems. For covertypes managed by clearcutting systems, the retention of key habitat requirements including mast trees, cavity trees, snags, and conifer inclusions is prescribed to maintain key habitat requirements.

Retention of trees with cavities and trees that are capable of forming cavities as the regrowth forest develops is an important part of this mitigation. This mitigation will maintain these important habitat features over the period of decades required for cavities to develop in regrowth trees.

Redistribute slash across the cutover: This would maintain cover for small mammals in cutovers following clearcutting. Maintenance of suitable habitat conditions for these small mammal species will also benefit predator species.

Effectiveness: The maintenance of key habitat requirements and slash spreading would likely be moderately effective at maintaining habitat for adversely impacted species in covertypes harvested using clearcutting systems. Strategies that substitute uneven-aged silvicultural systems for clearcutting are likely to be effective at maintaining suitable habitat conditions for species dependent on elements of mature forests. However, these strategies would likely provide only moderate to low levels of mitigation for species dependent on forest interior conditions and limited disturbance.

ERF, old growth, riparian, and other corridors would provide habitat for species that depend on old forest and forest interior species. These mitigations are likely to focus on the northern half of the state because of the pattern of ownership. They are less likely in the south because of predominantly NIPF ownership. Maintenance of large patches of forest unharvested for long periods in these areas will likely be moderately effective at maintaining populations of forest interior species present in the south.

Species specific mitigations appropriate to bird populations are shown in appendix 3.

Feasibility: Modifications to maintain key habitat features are widely practiced on lands by the major public ownerships and are being introduced by some counties. The successful introduction of these mitigations to NIPF and industrial lands is likely to depend on the costs associated with their adoption, the owner's awareness of the need for these mitigations, and the willingness of loggers to implement the mitigations at an operational level.

Replacement of clearcutting with uneven aged silviculture systems is actively being considered by the major public landowners as part of their ERF programs. In addition, these systems are likely to be used on NIPF lands in the south of the state. This is because the covertypes and range of products sought in the south are more suited to these systems. However, the changes in harvesting and silvicultural systems need to recognize the costs of doing so. In some cases it may mean covertype change and/or shifting the costs of maintaining a covertype to the regeneration stage of management. For example, harvesting systems that cause minimal site disturbance may not create conditions that are required for regenerating white pine. If these systems are used, additional effort and expense will be required as part of regeneration efforts to ensure suitable conditions are created for this species.

ERF, old growth, and corridors are likely to be most feasible on public lands in the northern part of the state. These measures are consistent with the mandate given these ownerships. As discussed previously, it is less feasible to maintain large blocks of forest or corridors in the south because of the problems associated with coordinating uniform management with more than one owner.

The overall strategy is likely to be moderately successful at mitigating impacts on those species projected to be significantly impacted.

12 Impact
Projected harvesting affecting populations of the Red-shouldered Hawk
This was the only animal species listed as a federal or state species of special concern, threatened, or endangered projected to be significantly impacted at the base level of harvesting as a result of cutting in larger patches of forest. As discussed under the previous strategy, this species requires large (>300 acres) blocks of forest that experience little disturbance (the amount the species will tolerate has yet to be determined).

The strategy discussed above under impact 11, which seeks to mitigate impacts on all significantly impacted wildlife populations, includes all the elements likely to benefit the Red-shouldered Hawk.

13 Impact
Projected harvesting affecting patterns of mature lowland conifer stands
Patches of mature lowland conifers are important habitat, particularly in those parts of the state where lowland conifers occur as small isolated patches within more extensive upland forests. The strategy is intended to maintain such stands as an ongoing part of the landscape. The following section describes the proposed elements of this strategy.

Retention of conifer patches in clearcut stands: This is part of existing federal and state management guidelines. This mitigation would seek to retain these patches in harvested areas on other ownerships that are primarily directed at obtaining upland species.

Effectiveness: If applied, the mitigation would maintain these habitat elements within cutovers in predominantly upland stands.

Feasibility: The mitigation is straightforward and could be easily applied at an operational level. The major public ownerships already undertake elements of this mitigation in their current management strategies guidelines, particularly for deer management. It is less likely that industrial owners will adhere to these guidelines because of the cost of retaining conifers. The level of compliance will likely reflect the value of the species retained. Similarly, the level of compliance by unsupervised loggers harvesting on private lands will likely be higher where no markets exist for the lowland conifers. In general, NIPF owners have a relatively high level of interest in wildlife habitat, and this will be reflected in the level of compliance.

14 Impact
Projected harvesting affecting the availability of food producing trees
The loss of food producing trees such as oak and hickory was projected to impact species like the gray and fox squirrels, which rely on mature oaks to provide food and shelter (cavities). The following mitigations make up the strategy directed at maintaining these habitat features.

Clearcutting with residuals: This will retain mature food producing trees in covertypes that include such trees as part of the species mix. This would favor retention of trees such as oak, hickory, mountain ash, and cherry. Federal and state management guidelines favor retention of these trees on the major public timberlands.

Effectiveness: This mitigation would preferentially maintain these important habitat elements in areas subjected to clearcutting. Retention of these trees would be moderately effective in sustaining populations of animals dependent on food from these trees.

Feasibility: The feasibility of this mitigation depends on ownership. The state and federal lands are likely to forgo the possible revenues from the sale of these trees (especially oak). In contrast, the mitigation is less feasible on NIPF and industry owned lands and on many county managed lands as these owners are less likely to forgo the revenues. In addition, operations on these lands are less likely to be planned to maintain these habitat features prior to harvesting.

15 Impact
Projected harvesting in the absence of VMGs on visually sensitive areas
Timber harvesting and forest management activities that occur within the visual catchment of resorts or other outdoor recreation facilities are projected to cause significant impacts on aesthetic values where VMGs are not used. The mitigation strategy is aimed at developing (1) VMGs that can be applied as a minimum standard for all timberlands, and (2) coordinated planning of future road and trail development and closures.

Develop landscape-based road and trail plan: This would enable resort operators to be aware of future harvesting activities likely to affect the visual amenity of the resort setting or access to it. This mitigation would allow resort owners to have input into plans that might affect their operations.

***Development and promotion of VMGs for use on all timberlands*:** This would reduce the level of visual impact likely to occur as a consequence of harvesting related activities on ownerships that do not use VMGs.

***Effectiveness*:** This strategy would provide a moderate level of effectiveness at reducing the likelihood of conflicts between the forest products industry and the tourism/recreation resort industry.

Feasibility: There is already some dialogue between resort owners and timber producers regarding timber harvesting within the visual catchment of resorts. By active promotion on timberlands that are important to their resort setting, and on travel corridors that are used by their clients, resort operators could then contact local timber producers and landowners to make them aware of their interest in how these lands are managed. A variety of options are available that range from a cooperative agreement with the landowner to limit logging and/or to use VMGs if logged to purchase of visual easements.

16 Impact

Projected development of permanent roads in primitive and semiprimitive nonmotorized areas

Harvesting is projected to result in the development of permanent roads in primitive and semiprimitive nonmotorized areas. Doing so affects these sites by changing the recreational opportunities present and restoration to the original opportunities is by definition not possible.

Develop landscape-based road and trail plan: This would improve the chances for minimizing roads and trails that would change recreational opportunities on the more primitive sites and ensure that a variety of recreation opportunities are maintained across ownerships.

Develop guidelines for management road construction: Would provide for protection of recreational values and use in primitive and semiprimitive nonmotorized areas which are managed for timber production.

Effectiveness: In addition to the above noted benefits of road and trail planning for resort operators, such plans would provide the overview needed to develop an understanding of where primitive and semiprimitive nonmotorized recreational opportunities exist and might exist in the future. Coordination between ownerships is important to the success of this planning.

The basis for guidelines for nonpermanent road construction has already been developed. Use of nonpermanent roads and VMGs can reduce the degree and period over which impacts persist.

Feasibility: These alternatives are potentially feasible subject to cooperation of the major timberland ownerships. However, this will require leadership by the MNDNR as the most appropriate agency to initiate and oversee the planning and development of nonpermanent road guidelines and their implementation. There would be costs associated with the efforts and implementation of nonpermanent road guidelines would vary by ownership. This planning and the development and implementation of guidelines would have long-term benefits.

17 Impact

Projected harvesting affecting unique cultural and historical resources

Harvesting is projected to significantly impact a range of archaeological, cemetery, and traditional use sites used by contemporary Native Americans. The archaeological sites may be buried or on the surface. Soil disturbance caused by logging equipment and road construction are likely to damage or destroy the scientific and cultural values of these sites. Traditional use sites can be adversely impacted by changes in the types of animals and plants present at these sites. In addition, changes in access can adversely affect these uses. The extent of impacts is related to the level of harvesting and the site specific impacts are a function of the harvesting method, equipment used, and season.

Provide adequate resources to maintain the state listing of known sites: This would allow the state archaeologist to discharge current responsibilities to maintain an important reference describing the occurrences of sites in the state; and to provide a leadership role in developing a better understanding of the state's heritage resources. This mitigation is not linked to just timber harvesting but extends to all land uses that involve soil disturbance and is driven by the likelihood of positive results.

Increase the proportion of harvests undertaken during winter: Reducing soil compaction by changing the season of harvest for susceptible soil types will mitigate some impacts, as frozen soil will not experience the levels of compaction that would occur during other seasons. However, it is not possible at this time to *quantitatively* assess the degree to which such sites would or would not be damaged or protected as a result of shifting harvesting to the winter months.

Development of a landscape-based road and trail plan : This would provide opportunities for traditional users to comment on roading issues during the planning phase. This could avoid conflicts between forestry and these uses.

Effectiveness: This strategy would provide a low level of effectiveness at mitigating the significant impacts projected to occur. The USDA Forest Service lands have a more effective mitigation strategy which reflects their mandate regarding these resources.

Feasibility: The feasibility of these mitigations is likely to be relatively low, due to the low priority given these resources by the majority of ownerships.

5.7.4 Cumulative Unmitigated Significant Impacts

The mitigation strategies described in the previous section will likely mitigate many, but not all, of the significant impacts projected to occur under the base level of harvesting. This section identifies the cumulative unmitigated impacts that are likely to remain despite implementation of the mitigation strategies.

Loss of Forest Area and Timberlands

There is a strong likelihood that the area of forest in the north of the state will continue to decline. The area of timberlands will continue to decline as a consequence of the loss of forest area and the increased area of forest managed primarily for nontimber values. These reductions are unlikely to significantly constrain wood supply at the base level of harvesting. Increasing the productivity of the acres that remain available for harvest is achievable and could offset any losses of acreage. However, increasing productivity would likely require additional investments.

Changes to Age Class and Covertype Structure

The levels of harvesting projected to occur under the base level of harvesting will cause shifts away from balance in the age class distributions for several of the less frequently harvested species and/or covertypes. The shift will be towards older age classes. This is a consequence of aging, the comparatively low levels of harvesting projected, and the maturing of forests in areas where harvesting is constrained or prohibited.

Changes to the paper birch covertype were assessed as being the only significant impact under the relevant criterion. Other covertypes including black spruce, white cedar, tamarack, and white spruce, will be similarly affected, but not to the same degree.

These trends are likely to continue unmitigated as there are no management methods aside from harvesting and fire to achieve the required replacement of old stands with regrowth. The consequence is succession to other covertypes and/or to uneven-aged stand conditions.

Incidence of Pests and Diseases
The likely increase in the vulnerability and susceptibility of some covertypes to impacts from pests and disease is closely linked to the age class changes discussed above. Despite the effectiveness of an IPM plan, some impacts cannot be mitigated for the reasons set out above. The incidence of losses to pests and disease will likely increase and may cause age class changes via the broad-scale mortality of some covertypes. An example of this is spruce budworm outbreaks in the balsam fir covertype.

Impacts on Biodiversity
The lack of knowledge concerning the distributions and specific populations of endangered, threatened, and special concern species and their vulnerability to forest disturbance will likely lead to ongoing localized impacts on these species as a consequence of timber harvesting operations. In the absence of this data, impacts on these categories of plants will continue.

Populations of the Red-shouldered Hawk will likely be maintained under the proposed mitigations, although there is some uncertainty due to inadequate knowledge of the precise habitat requirements of this species.

Impacts on Forest Soils
Some forest soils will continue to lose a proportion of their nutrient capital; others may be compacted and experience accelerated rates of erosion. The following discusses the consequences of these impacts for Minnesota's forests.

Nutrients. Over the long-term, rates of removal that exceed rates of replenishment can be considered to be *mining* the nutrient capital of a site. Impacts will be most severe on sites with low nutrient capital. These sites can be broadly categorized as those on coarse-textured soils. Such soils occupy about one-fourth of the forested area of Minnesota, or about 4.5 million acres, and are scattered throughout the forested parts of the state.

The initial nutrient capital of a site will affect the degree of depletion over a rotation. Although a site may irreversibly lose nutrients, the amount lost may be a small proportion of the nutrients present on a site with high initial capital. In that case, the mining may be relatively insignificant and economically and biologically justifiable. Sites with low capital will be more heavily impacted by equivalent amounts of nutrient removal without replenishment. Impacts will be increasingly severe as the nutrient capital of a site is depleted over many rotations.

The duration of the impact of nutrient depletion is long-term. If natural processes continually replenish site nutrients, then with sufficient time between harvests or other disturbances, a site will regain its original nutrient capital. The probable implication of continued mining of nutrients is a decline in the productivity of those forests. This decline will be most apparent on sites low in nutrients (i.e., on coarse-textured soils) that are currently occupied by aspen-birch or upland hardwood forests. However, impacts will have to be closely monitored to ascertain their occurrence as a decline in a nutrient(s) will manifest itself differently for various combinations of nutrients, species, site and management.

Soil physical structure. Harvesting and roading activities will inevitably cause significant impacts on soil physical structure. For example, all nonwinter haul roads are heavily compacted. Under the base level of harvesting, approximately 60,000 acres are projected to be impacted. This level may be reduced as a consequence of the proposed mitigations. However, a substantial area will remain impacted.

Compaction and puddling will also result from equipment operation within harvested areas. Compaction and puddling will likely impact site timber productivity by reducing the growth rates of trees that become established within compacted areas. This effect will likely be offset by increased growth from adjacent trees because of a reduction in canopy competition. In addition, a proportion of heavily compacted areas such as log landings will not return immediately to forest cover but will provide grassy openings that are beneficial for wildlife species. The estimate of 330,000 acres projected to be affected under the base level harvesting scenario will be reduced by the mitigation strategy proposed. However, these reductions are likely to be in the lightly trafficked areas. Therefore, compaction will remain unmitigated in the heavily trafficked areas.

Erosion. Erosion from roads and other compacted areas will continue. Improved road design, construction, and maintenance will likely reduce the rates of soil loss. Consistent road closure policies and practices will also likely reduce the incidence of erosion by allowing unused roads to stabilize. Erosion in ecoregion 6 is likely to remain the most significant problem because of the combination of steep slopes and mainly NIPF ownership of forest lands.

Increased erosion can have subsequent impacts on water quality. Hence the localized (but insignificant) water quality impacts will likely continue, but at fewer sites as improved riparian management practices begin to show benefits.

Impacts on Archaeological and Cemetery Sites
Uncertainty regarding the locations of these sites and their vulnerability to damage means that impacts will continue except on timberlands owned by the USDA Forest Service and on the comparatively high proportion of other lands where operations are conducted when the ground is frozen.

Of the sites impacted, approximately 50 percent would not meet the criteria for inclusion on the State or National Registers of Historic Sites and thus would not be mitigated even if the location were known prior to harvesting occurring. Since most of these sites have not been inventoried, it is difficult to quantify impacts.

Impacts on Traditional Use Sites
Improved liaison between forest managers and Native American groups regarding future roading plans will likely reduce the incidence but is unlikely to eliminate impacts on these uses. Impacts are difficult to quantify as many of these sites have not been inventoried.

Loss of Primitive and Semiprimitive Nonmotorized Recreation Opportunities
Roading in these areas will likely reduce the areas of primitive and semiprimitive nonmotorized recreational experiences that are potentially available in the state. The consequences of this loss cannot be accurately gauged because the amount of use within these areas and the number of users affected is not known. Use of VMGs and the development of a coordinated road and trail plan will likely reduce the adversely impacted area and the duration of impacts.

Impacts on Motorized Recreational Uses
Harvesting in visually sensitive areas without VMGs will adversely impact existing users of these sites. However, the maturing of many areas of forest, including formerly harvested areas, will likely provide new or replacement opportunities for these recreational activities. Users seeking motorized recreational activities will likely find additional sites as new roads are constructed.

Impacts on the Tourism and Travel-based Industries
The lack of information on relationships between the level of harvest and its consequences for the tourism industry means the likelihood of unmitigated impacts cannot be quantified. However, resorts and other tourism-based facilities depend on the visual amenity of the surrounding forest for their setting. It is likely that individual resort operations will be adversely impacted by visually obtrusive harvesting operations within their viewshed or along access routes. The consequences for the use levels of the facility or the recreational experience of users would depend on the expectations of

the clientele attracted to the resort. Use of VMGs will likely reduce the area adversely impacted and duration of impacts.

5.8 Conclusions

The study results indicate that the base level of harvesting is well below the level of tree and forest growth potential if timber production was the only objective. It also appears sustainable from a biological standpoint as it would allow retention of other forest characteristics and values of concern in this study. Yet, as with any modelling effort, this conclusion is valid within a range of error and subject to the assumptions used representing actual on-the-ground conditions. In this light, the harvesting projected to occur at the base level (4 million cords) will likely be sustainable in a broad sense. That means this timber harvest level could be continued indefinitely and other forest resource characteristics such as soil productivity, water quality, wildlife habitat, and aesthetic values can be maintained providing recommended mitigation strategies are implemented. The following paragraphs discuss the degree of certainty in these conclusions and implications.

There will be changes to the forest; however, the most profound of these will be a consequence of the natural forest aging process.

Localized impacts will continue, even with the introduction of proposed mitigations. These impacts will likely be on NIPF lands as a consequence of generally lower standards of planning and supervision of field operations compared to large ownerships with professional staffing. However, the mitigations proposed would reduce the likelihood of significant impacts that might degrade the long-term sustainability of the state's forest resources. The only exception is the projected reductions in the nutrient capital of some low productivity sites. These reductions will need to be carefully monitored. The relationship between changes in nutrient capital and changes in site productivity also needs to be closely observed.

The current standard of harvesting practices in Minnesota are consistent with those found in most lightly regulated jurisdictions. Equipment used by the logging industry is typically old and there are no regional or statewide mechanisms to promote the introduction of new equipment and harvesting techniques.

The base level of harvesting is well below the level of sustainable yield of Minnesota's forests as defined from a biological standpoint. Consequently, there is considerable flexibility in terms of meeting timber supply demands while making provision for nontimber values. The comparative abundance of timber means that few investments to increase productivity of timberlands are warranted at a statewide level. However, additional investments can increase the productivity of stands thereby decreasing the area harvested and allowing more area to be used for other activities, specifically nontimber uses.

Aspen, which has experienced significant increases of demand coupled with an unbalanced age class distribution, is one covertype where current consumption levels pose difficulty. Consequently, there will likely be constraints in the supplies of this species during the middle of the modelled period. The base scenario projections assumed that 25 percent of the demand for this species would be transferred to the northern hardwood species. Current industry expansion proposals emphasize the need for this shift. Widening the range of acceptable species to more closely reflect the mixed species stands found in Minnesota will benefit the management of the forests and possibly reduce the area that has to be harvested by reducing the amount of potentially usable wood fiber left on harvested sites.

The proposed mitigations will require a leadership role to oversee their development and application. At present, there is no agency with the authority for such responsibility extending across ownerships to discharge these responsibilities. In addition, the current diverse ownership patterns and associated objectives means that there is no broad-based direction or goals for a future forest condition being set within the state.

Future forest industry developments should be directed towards addressing the unbalanced age class distributions identified in this analysis. The assumed timber demand used to prepare the medium scenario provides some guidance for possible species mixes for forest industries that could address these age class distribution concerns. The next section indicates the consequences, positive and negative, that are projected if these developments occur.