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APPROACHES FOR ANALYZING THE EFFECTS OF WILDFIRES ON RESOURCE VALUES IN ALASKA

Prepared for

Alaska Department of Natural Resources

by

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I. INTRODUCTION

Purpose of the Study

The Alaska Department of Natural Resources (DNR) is responsible for providing fire protection for all state-owned and certain private lands in Alaska. Because of the high cost of suppressing wildfires, the Department would like to focus its protection efforts on those areas where wildfires would result in significant resource losses. At the same time, where practical and effective, the Department would like to relax its fire protection efforts for those lands where wildfire may have benign or even beneficial effects. In order to effectively allocate its fire suppression resources in this way, the Department needs to develop a workable and defensible method for quantitatively evaluating the effects of wildfire on resource values.

The author was contracted by the Department "to review and evaluate methods to measure in quantitative economic terms the resource values typically lost and gained as a result of wildfires in Alaska." This paper is the product of that contract.

Difficulties in Assessing Effects of Wildfires in Resource Values

For a number of reasons, it is difficult to quantify the effects of wildfires on resources values. We may briefly review several of these reasons.

Every fire is different.

Fires have different effects in different ecosystems. In addition, the effects vary depending upon the successional stage of the ecosystem, the weather conditions prior to and during the fire, and the suppression activities used to fight the fire. These factors determine the physical effects of the fire. The economic effects of the fire also vary depending upon the location of the fire and the present and possible future uses of the resources of the area. Thus, it is very difficult to make general conclusions about the effects of fire. Conclusions such as "fire is good for moose" or "fire is bad for mature timber stands" are valid only under specific circumstances which may or may not apply to any given fire.

Fire affects many resources.

These include sawtimber, fuelwood, water, many different species of wildlife important for hunting and trapping, air quality, and real property, to name a few. Fire may have beneficial effects upon some resources and harmful effects upon others. In order to assess the overall effects of fire in quantitative economic terms, a common value unit must be found for all of those resources. Since some resources are very difficult to value, it is difficult to obtain reliable overall values.

The environment is a dynamic system. Fire may reduce productivity for certain resources for a period of time. However, without fire, over time subarctic ecosystems also tend to lose productivity. A difficult but essential part of any economic evaluation of the effects of fire in Alaska is the comparison and weighting of resource flows, with and without fire, over very long periods of time.

Not only does fire affect many different resources, but the effects upon the resources vary over time. In estimating overall economic effects of fire, both short and long-run effects of fire must be considered. It would be no more correct to ignore long-run beneficial effects for wildlife and timber than it would be to ignore short-term losses of real property or timber.

It is a very difficult task to compare value losses and gains over long periods of time. The standard procedure is to discount future value changes using a discount rate. The choice of the discount rate, while extremely important to the outcome of the analysis, is by no means a simple decision.

Many of the values affected by fire are nonmonetary.

If merchantable timber is destroyed by a fire, the value change is primarily monetary. However, many resources affected by fire, such as scenery, air quality, or personal use food and fuelwood, are not bought or sold. It is more difficult to value these resources which provide nonmonetary returns.

Fire suppression policies are controversial political issues. Because values may be used to support policies, the calculation of values is also controversial.

The employment, property, and livelihoods of many people are affected by fire suppression policies. The values affected by fire are important to the determination of these policies. Disagreement over the definition and calculation of values will also reflect disagreement as to the proper interpretation of these values and the tradeoffs which may be made based on them.

There is a deep-rooted preconception among Americans that fires are bad.

An entire generation of Americans has grown up with Smokey the Bear admonishing them to prevent forest fires. Established terminology in evaluating the effects of fires, such as "values-at-risk," implies that fire causes losses. Usually special studies and plans are required to relax wildfire suppression. Concern is much greater for short-term losses resulting from fire rather than from long-term losses resulting from not having fire.

Organization of the Study

This study discusses methods which may be used to quantify the economic effects of wildfire in Alaska. Chapter II discusses concepts in defining and measuring value change due to wildfire. Chapter III discusses methods currently used by various agencies in

Alaska, the rest of the United States, and Canada to assess the effects of wildfire, and discusses their limitations. Chapter IV suggests a methodology for assessing economic effects of wildfire in Alaska. Chapters V-VII apply this methodology to assessing value changes for timber and wildlife. Chapter VII assesses the economic effects of the 1977 Bear Creek fire. Conclusions are provided in Chapter VIII.

Limitations of the Study

Certain limitations of the study should be stated at the outset. First, the author is an economist, and not a biologist. The report does not attempt to discuss in detail the many complicated physical effects of fire. Instead, it discusses the economic evaluation of certain kinds of effects which are generally believed to occur. A description of certain physical effects of fire, borrowed from another study, is reproduced as Appendix A.

Second, the time and budget available for the report did not permit extensive collection and analysis of data. The value calculations in the report are examples based upon limited data. Calculation of values for the purposes of planning fire suppression policies will require systematic and extensive data collection and analysis.

Finally, this study focuses on methods which may be used to quantify the economic effects of wildfires in Alaska. It does not discuss fire suppression policies in Alaska. Analysis of these policies is a much more complicated and difficult task, in which the evaluation of the economic effects of fire is only one part, along with evaluation of the costs of fire suppression, legal responsibilities for suppression, and the social, economic, and environmental effects of suppression activities.

II. CONCEPTS IN DEFINING AND MEASURING VALUE CHANGE DUE TO WILDFIRE

Defining Value

Much disagreement in valuing resources arises from differences in the definition of value which is being used. Generally, people define value as "what a resource is worth to society." However, this definition is not sufficiently specific to produce agreement about value since not everyone agrees about what resources are worth. A person often implicitly defines value as what he feels a resource is worth to society. Therefore, someone who likes wilderness will say that wilderness has a high value, while someone who dislikes wilderness will say that wilderness has a low value. In order to obtain agreement about "value," some agreed-upon method is needed for taking account of differences in opinion about what resources are worth.

> Economists generally define value as the total amount which society would be willing and able to pay for a resource, given the existing distribution of income.

Thus, the value in dollars of a resource is the total amount which all the different individuals who benefit from the resource would be willing and able to pay for it. The value of a resource which is used by or benefits just one individual is the maximum that any one individual would be willing and able to pay for it; the value of a resource which is used by or benefits many people is the sum of what they would each be willing and able to pay for it. This definition provides a way of taking into account differences in opinion about what resources are worth to society. Each individual's opinion is reflected in what he himself would be willing and able to pay for the resource.

This definition of value reflects the distribution of income and the tastes of the current generation.

If rich people like cross-country skiing and poor people like snow-machining, then according to this definition, a cross-country ski trail will be more valuable than a snow-machine trail. "Value" will not take account of the welfare of future generations except to the extent that people are willing to pay for future generations' welfare today.

Value derives from current or future human use.

If people are unable to use a resource and do not expect to be able to use it, they would not be willing to pay for it, and according to the economic definition, the resource would have no value. Thus, timber which is not and never will be economically accessible, or wildlife which cannot be hunted, viewed, or otherwise enjoyed, has no value. For some otherwise unused resources, people may derive satisfaction from just knowing that the resources are there or knowing that they are preserved for the possible use of future generations. To the extent that people would be willing to pay for this satisfaction, the resources have value.

> There are differences of opinion among economists over the interpretation of this definition of value. However, these differences have little practical importance for the problem of measuring value change due to wildfire in Alaska.

These differences relate to whether "willingness-to-pay" is measured with or without compensation to the payer for the cost of the resource.

Resource Value Versus Secondary Value

> The value of a resource should be distinguished from the value or income which is generated in extracting and processing the resource. This income may be referred to as "secondary value.".

For example, suppose that logs on the dock ready for export sell for 100 dollars per thousand board feet. If the cost of cutting the logs and transporting them to the dock from a remote interior site is 95 dollars per thousand board feet, then the value of the standing timber is only five dollars per thousand board feet. If a thousand board feet of timber were destroyed by a fire, the net value change would be only five dollars. However, 95 dollars worth of income would also be lost in cutting and transporting timber. These losses in income may be further "multiplied" to the extent that they result in a decline in spending for goods and services, reducing the total value of goods and services produced. These losses in income are "secondary values" lost due to the fire.

Measuring Resource Value

If resources are traded in a competitive market, then price will generally be a good measure of value, since the price reflects what people are willing to pay for the resource. However, there are a number of cases where market prices may not be a good measure of value, and other indicators of willingness-to-pay must be used to measure value.

When the amount of the resource being valued is large relative to the total market, the current market price may significantly overstate or understate the average value of the resource. For instance, a small local sawmill might be willing to pay a certain price for ten thousand board feet of timber. This does not mean that it would be willing to pay that same price for ten million board feet of timber. In measuring the value of the timber, some allowance would have to be made for the effect that a large increase in supply would have upon the price.

The presence of "externalities," or benefits or costs to people other than the owner of the resource, may also result in an understatement or overstatement of value by the market price. For example, the price paid by a sawmill for stumpage reflects only the value of the trees for timber. To the extent that the trees provide scenery or wildlife habitat for which people other than the owners of the sawmill would be willing to pay, their value is greater than the value of the stumpage.

If a resource is not traded in the same market for which a price is observed, that price may not be a good indication of the value of the good. For example, the market price of coastal timber should not be applied to inaccessible interior timber for which there is currently no market. Standing timber in a wilderness area or park which cannot legally be cut should not be valued at the price of marketable timber.

For nontraded resources such as subsistence hunting, clear air, or wilderness, no market price exists, so alternative measures of value are required which reflect what people might be willing to pay for the resource. One measure is the market price of substitute resources. Thus, the price of an equivalent amount of store-bought food could be used to value subsistence hunting and fishing.

However, this is not a perfect way of measuring value, since store-bought food is not a perfect substitute for subsistence food, since subsistence hunting provides other benefits in addition to food, and since the quantity of subsistence food is large in many parts of Alaska compared to the total market for store-bought food. Another method of measuring the value of nontraded resources is to ask a sample of people what they would be willing to pay for the resource, extrapolating the responses to calculate society's total willingness to pay. One problem with this approach is its expense. Another problem is eliciting a truthful response, since people may tend to overstate their willingness to pay if they will not actually have to pay, or understate their willingness to pay if they perceive that they will have to pay an amount based on their responses. More indirect approaches for calculating value for nontraded resources are based on study of travel costs and other expenses incurred in using the resources, and how the use of resources changes as the costs of use change.

Values received in the future have a lower current or present value.

A sum of money received today, if invested, would grow over time, and is thus more valuable than money received in the future. Put differently, money received in the future, since it cannot be invested today, is less valuable than money received today.

Present value is calculated by discounting future value by a "discount rate" for each year of delay before the value is received. Present value is extremely sensitive to the choice of discount rate. Unfortunately, the appropriate discount rate to use in evaluating future resource values is highly controversial.

The formula for calculating present value is

$$PV = \frac{FV}{(1 + R)^t}$$

where PV = present value

FV = future value

R = discount rate

t = period over which value is discounted

Suppose $100 is to be received ten years in the future. At a discount rate of 1 percent, the present value of this sum would be $90.53. At a discount rate of 5 percent, its present value would be $61.39, and at a discount rate of ten percent, its present value would be only $38.55.

Present value is what one would be willing to pay today for a prospective value received in the future. We would expect the amount paid today to appreciate at least as fast in providing the future return as other investments we might make involving a similar level of risk. Therefore, economists generally argue that the proper discount rate to use in calculating present value is the rate of return which could be earned on an investment of similar riskiness. If we can receive the highest "safe" rate of monetary return from U.S. government bonds, then we should use this rate in discounting future monetary returns from a "safe" resource. However, a high discount rate means that returns received at distant times in the future have very little present value. Uneasy at this result, some economists suggest that lower discount rates should be used in calculating present value for certain kinds of future returns.

This study does not recommend a particular discount rate to be used in assessing resource values. The choice of discount rate is an important policy decision for the state. The rate or rates chosen should be consistent with those used by the state in other resource value analyses and project evaluations.

This study uses discount rates of 1, 3, 6, 9, and 12 percent in order to illustrate the effects of different discount rates. The recommendation of a discount rate is beyond the scope of this study. However, real discount rates of 3 and 6 percent are probably more reasonable than 1, 9, or 12 percent.

<u>The value of a resource which provides returns over a number of years is the sum of the present values of the returns in each year.</u>

For example, if the discount rate is ten percent, moose habitat which provides $1,000 worth of moose every year for five years (starting next year) has a present value of

$$\sum_{t=1}^{5} \frac{1,000}{1.1^t}$$

$$= 909.09 + 826.45 + 751.31 + 683.01 + 620.92$$

$$= \$3,790.78$$

<u>Measuring Value Change Due to Wildfire</u>

<u>The value change due to a fire is the sum of the value changes for each resource affected by the fire. This in turn is the sum of the changes in the present values of all future returns provided by the resources.</u>

Mathematically, the total value change may be defined as

$$T.V.C. = \sum_{i,t} \frac{V.C._{it}}{(1 + R)^t}$$

where T.V.C. = total value change
$V.C._{it}$ = change in the return from resource i in year t

R = discount rate
i = subscript for resources
t = subscript for years

An example of this formula is provided by Table 1, which illustrates the value change caused by a fire this year which affects three resources: timber, moose habitat, and marten habitat. The fire is assumed to lower the value of timber by $6,000 at harvest five years from now. It causes the value of moose harvests to increase by $1,000 per year for five years in a row, starting next year. Finally, it causes the value of marten trapped to decline by $450 for two years in a row, starting next year, and subsequently to increase by $350 for three years in a row.

Table 1 illustrates the sensitivity of the value change calculations to the discount rate chosen. If a low discount rate is used, the fire results in a net value loss. However, if a high discount rate is used, the fire results in a net value gain. This is because the net value gain for wildlife habitat in the earlier years is weighted relatively greater compared to the later timber value loss when a high discount rate is used.

TABLE 1. VALUE CHANGE FOR A FIRE AFFECTING TIMBER, MOOSE HABITAT, AND MARTEN HABITAT, FOR DIFFERENT DISCOUNT RATES

Resource	Undiscounted Value Change	Discounted Value Change — DISCOUNT RATE 1%	3%	6%	9%	12%
Timber (Year 5)	-6000	-5709	-5176	-4484	-3900	-3405
Moose						
Year 1	5000	990	971	943	917	893
Year 2	5000	980	943	890	842	797
Year 3	5000	971	915	840	772	712
Year 4	5000	961	888	792	708	636
Year 5	5000	951	863	747	650	567
Total		4853	4580	4212	3889	3605
Marten						
Year 1	-450	-446	-437	-425	-413	-402
Year 2	-450	-441	-424	-400	-379	-359
Year 3	350	340	320	294	270	247
Year 4	350	336	311	277	248	222
Year 5	350	333	302	262	277	199
Total		122	72	8	-47	-91
TOTAL		-734	-524	-264	-58	109

SOURCE: See text for assumptions.

The three basic components of measuring value change due to wildfire are (1) assessing the physical changes in resource benefits over time caused by fire, (2) determining the undiscounted value changes associated with the physical changes in resource benefits, and (3) summing the value changes for each year and each resource after discounting future value changes at an appropriate rate.

Table 1 provides an example of the last step in this procedure for a fire with simplified and stylized effects. Chapters VI through XI discuss how this approach might be practically applied in assessing the effects of fire in Alaska.

A general way to check a calculation of total value change from a fire is to compare it with one's intuitive answer to the question: what is the most that everyone affected by the fire, together, would be willing to pay to prevent or to cause the fire?

Assuming a fair system could be found to find the answer to this question, the timber owner would be willing to pay no more than the present value of his timber; the trapper would be willing to pay no more than the loss in value of his trapline; and airlines and residents of nearby towns might pay something to avoid the problems caused by smoke. Moose hunters might pay to cause the fire, but no more than the value that they anticipated from increased harvests; and sporting goods owners might be willing to pay for the fire up to the level that they anticipated increases in their profits from sales to moose hunters. If no one can be imagined who would pay anything either to prevent or to cause a fire, as seems reasonable for fires in many remote areas, then it is probable that the value change from the fire is close to zero.

III. METHODS OF ASSESSING THE EFFECTS OF WILDFIRE ON RESOURCE VALUES CURRENTLY USED BY AGENCIES RESPONSIBLE FOR WILDFIRE SUPPRESSION

This chapter examines the estimation and use of resource values by the BLM, the United States Forest Service, and Canadian agencies responsible for fire suppression. Only the Forest Service attempts to systematically value nontimber resources in dollars. Canadian agencies are developing a methodology to do so.

Bureau of Land Management

The 1982 BLM Alaska State Fire Plan summarizes the BLM fire management policy for Alaska as follows (Sections 10.33 C and D).

> Aggressive action is taken on all new fires on or threatening national resource lands with sufficient forces to contain the fire during the first burning period. Suppression action for fires that escape containment during the first burning period is planned to minimize the total resource losses, suppression costs, rehabilitation costs, and environmental damage. When multiple fires are experienced, suppression priority is given to fires threatening areas of highest value . . . .. In areas where controlling fires is extremely difficult or where the values threatened do not warrant the expense associated with the usual suppression procedures, managers may prepare advance plans for limited suppression actions for the approval of the State Director.

Despite the reference to values in the policy statement, the Alaska State Fire Plan makes no reference to how values are to be calculated. In addition, the wording of the policy statement implies that value changes due to wildfire are always assumed to be negative, through the use of such terms as "total resource losses," "environmental damage," and "values threatened."

Nationwide, the BLM has a "point system" for classifying resource values. This point system has been modified to apply to Alaska. Point values on a scale of 1-100 are assigned for each of six resource categories: soil, water, grazing, forestry, wildlife, and recreation. An example of the point system classification for wildlife is provided in Table 2. Minus (-) points are assigned when fire is considered a benefit to the resource, for example by improving moose habitat. The point system was used to construct maps classifying areas by total resource value points for use in determining priority in fighting fires.

Since the point system does not provide dollar values, it cannot be used to compare the costs with the benefits of fighting a fire. Another problem with this system arises when different resources are being compared. Not only the ordering of point ratings for each resource, but also the value of point ratings becomes important. Since points do not necessarily have the same value for different

TABLE 2: BLM POINT SYSTEM
CLASSIFICATIONS FOR "WILDLIFE" VALUES

(1)	Land areas having crucial habitat that is a limiting factor for rare and endangered species	61-80
	Alaska interpretation: Endangered species, eagle and osprey habitat	80
(2)	Land areas having crucial habitat that is a limiting factor for rare and endangered species	41-60
	Alaska interpretation: Caribou winter range	60
	Trumpeter swan nesting habitat	60
(3)	Land areas having good to excellent quality habitat for a variety of wildlife species. A high habitat potential and production capability exists.	21-40
	Alaska interpretation: (a) Habitat that is in good condition at present and supplies an essential part of a species' year-round requirement (Dall sheep, mountain goat, etc.).	40
	(b) Caribou summer range	21
(4)	Land areas having fair to good quality habitat for a limited number of wildlife species. A medium habitat potential and production capability exists.	0-20
	Alaska interpretation: (a) Waterfowl habitat	0
	(b) Habitat having low potential for moose, as well as poor accessibility; habitat with unknown wildlife populations; or habitat with fire effects unknown.	0
(5)	Habitat-type conversion to supply subclimax vegetation and edge effect.	0-(-79)
	Alaska interpretation: Habitat having high value for moose, plus accessibility	-20

resources, point value totals for lands with different combinations of resources are not necessarily good indicators of total value change.

In addition, the point system does not take account of the fact that the value change for a given resource may vary over time. Thus, fire may have a short-run negative effect on caribou habitat while having a long-run positive effect. A simple point system hides this important characteristic of fire effects, even if a "net" overall point value is used.

A simpler rating system for values was developed in preparation of the Tanana/Minchumina Interagency Fire Management Plan (March 1982). The system categorizes the effects of both fire and fire suppression on a variety of resources, using a seven-category scale ranging from "high negative impact" (H-) to "high positive impact" (H+). This categorization is provided in Table 3. The rating system was used in the plan to measure the anticipated effects of fire on resources for each of 17 different management areas, given the protection levels recommended by the plan. The ratings for the Big River management unit are shown in Table 4. These ratings take account of the differences between long-run and short-run effects of fire. They do not attempt to compare or sum up the effects of fire on different resources, but provide a qualitative reference for describing the effects of fire and fire suppression. They do not

TABLE 3: TANANA/MINCHUMINA PLAN CATEGORIZATION OF GENERAL EFFECTS OF FIRE AND FIRE SUPPRESSION

Environmental Component	Fire	Suppression Activities
Soils	(H+)* Increased temperature and active layer thickness enhances nutrient availability and turnover.	(M-) May cause severe erosion where firelines are bulldozed and access roads are built.
	(L-) Slight potential for permafrost degradation on steep slopes through soil slumping and subsidence.	
Air	(M-) Short term interference with visibility due to smoke.	(L-) Use of large burnout operations may increase smoke.
Water	(L-) Potential siltation due to fire burning shoreline vegetation.	(M-) Increased silt load due to erosion of bulldozed firelines.
Cultural		
Surface	(H-) Potential for complete destruction of historic structures.	(L-) Fire camps, heliports, and other activities may damage both surface and subsurface resources by compaction, disturbance, or removal of artifacts.
Subsurface	(L-) Extremely severe fire may damage historic and prehistoric artifacts.	
Visual	(M+) Long term effect by adding vegetation diversity to a scene.	(H-) Long term residual effect from fire breaks, cat lines, etc., caused by straight and harsh contrast lines in the landscape.
	(M-) Large fires may have short term effect by imposing a blackened, disrupted, unpleasing scene.	

* 0 = no impact; L = low impact; M = moderate impact; H = high impact
+ = positive; - = negative

Table 3 (Continued)

Environmental Component	Fire	Suppression Activities
Wildlife		
Terrestrial	(H+) Long term effect by increasing habitat diversity and forage quality.	(L+) Long term effect by creating edge effects and diversity along firelines.
	(H-) Short term effect by loss of habitat with large fires.	(M-) Short term disruption of animals during suppression period.
	(M+) Snags are created and are habitat for cavity nesting birds.	
Aquatic	(M+) Fire killed trees may fall into streams to create cover for some species.	(H-) Direct drops of fire retardant into streams can cause very localized fish kill.
	(L+) Increased nutrient enrichment of water from fire ash.	(M-) Siltation increases due to construction and erosion of fire lines.
Threatened and Endangered Species		
Plants	(H+) Fire sets back stages of plant succession. Over long term, this benefits plants which thrive in early stages of succession.	(H-) Localized plants may be destroyed by construction of fire lines, compaction in camp areas, etc.
	(L-) Possible removal of localized plants.	(H-) Fire retardant may harm plants in localized areas.
Animals	(H+) Fire enhances prey species habitat.	(M-) Short term disruption by human activities may have long term effects if breeding failure or mortality of young occurs.
	(L-) Unlikely event of fire causing nest abandonment or death.	
Wilderness	(H+) Fire is a natural component of the ecosystem.	(H-) Long term effect by construction of fire lines, access roads, etc.

Table 3 (Continued)

Environmental Component	Fire	Suppression Activities
Vegetation	(H+) Long term effect by increasing diversity and vigor. (L-) Short term effect by loss of vegetation.	(L-) Fire line construction causes loss of vegetation in localized areas.
Socio-Economic	(L+) Long term effect on trapping and hunting through improved wildlife habitat.	(M+) Hiring of local residents for suppression activities enhances economy.
	(H-) Possible short term loss of marketable forest resources.	(L-) Social disruption due to influx of crews in small communities.
	(H-) Private property such as cabins may be lost. (H-) Possible disruption if a home or community were evacuated.	(M+) Regional economy is enhanced because of contract services related to fire management operations.
	(M-) Short term elimination of trapping and hunting in areas of a large burn.	(H-) Current cost of existing fire management practices is extremely high.

TABLE 4: TANANA/MINCHUMINA PLAN RATING OF ANTICIPATED RESOURCE EFFECTS OF MODIFIED AND FULL SUPPRESSION CATEGORIZATION OF BIG RIVER MANAGEMENT UNIT

MANAGEMENT UNIT: Big River

AGENCY: BLM

LAND STATUS: BLM; State of Alaska; Native corporations

SPECIAL CONSIDERATIONS: Presuppression plans at historical sites and Iditarod Trail; install Remote Automated Weather Stations (RAWS) to aid in prescription development; clear trails after fire; contour firelines; avoid retardant in salmon streams; clear log jams as needed; no suppression at T&E species sites; limit heavy equipment.

PREFERRED ALTERNATIVE(s): Modified, Full

NATURE OF CRITICAL SITES: Native allotments

ENVIRONMENTAL COMPONENT	FIRE SHORT-TERM	FIRE LONG-TERM	FIRE SUPPRESSION
Soil	H+	H+	L−
Air	H−	0	M−
Water	0	0	L−
Cultural:			
Surface	0	0	L−
Subsurface	0	0	H−
Visual	L−	H+	L− to M−
Wildlife:			
Terrestrial	0 to L−	H+	L−
Aquatic	0 to L−	0	L−
Threatened and Endangered Species:			
Plants	0 to L−	H+	L− to M−
Animals	0 to L−	H+	L− to M−
Wilderness/Rec.	L−	H+	L− to M−
Vegetation	0 to L−	H+	L−
Socio-Economic	L±	H+	L−

provide a means of comparing the costs of a fire management scheme with its benefits, or comparing the benefits of fighting two different fires, except in a subjective fashion. In making a decision based on these ratings, the user implicitly values the effects of fire on resources rather than explicitly assigning dollar values to these effects. One important feature of the ratings is that they do not implicitly assume that fire causes a net value loss.

Canada

A research project on developing a model for the assessment of actual and potential economic impacts from forest fires, for use by Canadian forest fire control agencies, is currently underway at the Petawawa National Forestry Institute, under Will Clark. According to Clark, most Canadian agencies use value judgements . . .

> for the purpose of establishing broad priority zones for fire protection. Life and property are accorded highest priority, usually followed by timber, and then by any of a number of other "values." Some jurisdictions assign and map value classes that serve as broad guides to relative protection priority.
>
> Quantitative methods for determining post-fire economic impact ("damage appraisal") are now in place in every province and territory. Value loss statistics in present form are little used, however. In the case of budgeting, for example, the use of value loss statistics is limited to a supporting role, with losses not linked directly to costs in any benefit/cost sense. Methods vary considerably in terms of scope of factors considered and basic approach, but none provide defensible loss estimates. Property loss estimates are highly inconsistent, even among appraisers in the same province. Personal judgement is usually relied upon to provide estimates based on either market value or replacement cost. Timber losses are generally valuated in isolation from the economic context of supply and demand and opportunities for substitution. Every fire is

detrimental. Prices range from arbitrary stumpage prices to finished product prices. Moreover, they may be derived from a schedule or may represent a broad average. In one instance replacement cost is used. Other types of forest values (e.g., recreation, wildlife, watershed, forage) are either ignored or are evaluated subjectively. (Clark, personal communication, 1982.)

United States Forest Service

The Forest Service has a well-developed system for assigning dollar values to National Forest resources. Dollar values were originally developed in connection with the National Forest management planning process. Procedures for estimating net value change due to fire are currently being refined in a Forest Service research project headed by Tom Mills at the Forest Fire Laboratory in Riverside, California.

The net value change figures are used in three ways:

(1) Escaped Fire Situation Analysis: choosing between alternatives for controlling escaped fires.

(2) Planning of fire suppression responses for fire management areas.

(3) Evaluating economic efficiency of current fire management programs on national forests and on nonfederal wildlands.

In all of these uses, a "least cost plus net value loss" criterion is used to choose among alternative choices for controlling particular fires or managing fire control for large areas. For each alternative, estimates are made of the total area which would burn, taking account of weather, fuel, and other conditions. Using assigned "net value change per acre" figures for different resources, the total net value change is calculated for each alternative. This is added to the cost of the alternative to determine total cost plus value change. A simplified worksheet illustrating the procedure is shown in Table 5.

The Forest Service value estimates are based theoretically on a "willingness-to-pay" definition of value, as was discussed in Chapter II. Timber values are drawn from records of historical transactions on the assumption that timber markets are relatively competitive and that fires would not destroy enough timber to significantly change market prices. Value estimates for resources such as water and recreation, which are not traded or are traded under imperfect market conditions, are based on relatively few studies of willingness-to-pay for these resources. Because of the variation in the results of those studies and because of the site-specific nature of the studies, the Forest Service recognizes the values as imperfect, but uses them because they are the best information available.

TABLE 5. FOREST SERVICE WORKSHEET FOR ESCAPED FIRE SITUATION ANALYSIS

	Alternatives A	B	C	D
1. Size (Predicted final size in acres)				
2. Market elements: Timber Improvements Recreation Wilderness Wildlife Fish Water Forage				
Sum of Net Value Change	$	$	$	$
3. Non-market elements: Air Visual Fuels Threatened & Endang. Sp.				
Sum of Net Value Change	$	$	$	$
4. Social elements: Firefighter Safety Employment Public Concern Public Safety Cultural Other				
Sum of Net Value Change	$	$	$	$
5. Suppression Costs	$ -	$ -	$ -	$ -
6. Cost plus net value change	$	$	$	$

INSTRUCTIONS

(1) Evaluate only the significant economic, environmental or social elements in this fire area. Only those economic, environmental and social effects which result from impact on planned or existing uses should be included as value changes.
(2) Enter dollar values if possible using the best available information when estimating net value change. Value change may be positive (+) or negative (-) but record only the net + or - value.
(3) If dollar values are not possible use + or - symbols, they may range from +++ to + for positive change and from --- to - for negative change.
(4) Cost plus net value change is calculated as the sum of net economic value change, the net environmental value change, plus net social value change, plus the suppression costs (suppression costs are always negative (-)).

The Forest Service does not attempt to place dollar values upon certain resources. According to a recent Forest Service publication,

> "All direct effects which cannot be readily measured in dollars, such as the effect of fire on endangered plant or animal species, the option value of a wilderness area to nonusers, or the loss of human life are excluded. These unvalued effects should be considered in the fire program decision, however. The relative weights between the dollar valued and nondollar valued outputs should be supplied by the decisionmaker. The economic efficiency analysis is, therefore, only a partial analysis rather than a whole decision model" (Althaus and Mills, 1982, page 3).

The dollar values currently used by the Forest Service for valuing resources in Alaska are summarized in Table 6.

TABLE 6: STANDARD FOREST SERVICE RESOURCE VALUES USED FOR ALASKA

Resource	Output Measure	Value
Timber		
Timber hardwood sawtimber	MBF	1.01
Timber softwood roundwood	MCF	32.72
Timber hardwood roundwood	MCF	5.56
Timber softwood roundwood	MCF	3.67
Water		
Water yield	AF	0.50
Net sediment reduction (avg.)	AF	2.00
Recreation		
Dev. recreation use - public	RVD	3.00
Dev. recreation use - private	RVD	3.00
Dispersed recreation use	RVD	3.00
Wilderness		
Wilderness use	RVD	8.00
Wildlife and Fish		
Hunting, big game	RVD	18.90
Hunting, waterfowl	RVD	19.20
Hunting, small game	RVD	32.00
Hunting, upland birds	RVD	24.00
Nature study, wildlife (nongame use)	RVD	29.00
Fishing, cold water	RVD	15.75
Fishing, warm water	RVD	-
Ice Fishing	RVD	21.00
Fishing, salt water (Anadromous sport fishing)	MLBS	40.95
Range		
Grazing use (livestock)	AUMs	3.00

*Abbreviations used: AF - acre feet, AUM - animal unit months, HW - hardwood, MLBS - million pounds, RVD - recreation visitor days, RW - roundwood, ST - sawtimber, SW - softwood.

SOURCE: Althaus and Mills (1982), page 8.

Calculation of values such as those used by the Forest Service represents the second of the three components of measuring value change mentioned in Chapter IV: determining the undiscounted value changes associated with the physical changes in resource benefits.

Using units of resource benefits such as "recreation visitor days," as opossed to the resource itself (wildlife), is appropriate since these benefits can be measured and it is through them that the resource derives value. The general forest service procedures for assigning values to resource benefits are consistent with the principles discussed in the Chapter II. However, over a large area such as Interior Alaska, the undiscounted values associated with resource benefits would vary widely in different areas. A single set of values, such as those shown in Table 6, would be inadequate.

Missing in the Forest Service's approach to assessing net value change is explicit recognition of the fact that the physical effects of fire occur over a long period of time, and that for any given resource, fire may first cause a decline in benefits followed by an increase in benefits, or vice versa. The Forest Service's approach assumes, for example, that a single change in "recreation visitor days" can be estimated, to which a single value can be applied. Ideally, an estimate of the change in "recreation visitor days" would be calculated for each year in which there is a change, recognizing that this change may be positive in some years and negative in other years.

The Forest Service does not attempt to measure secondary effects, such as the effect on local income or employment. According to Althaus and Mills:

> The exclusion of secondary effects originates in part from the difficulty of tracing the multiplier effects throughout the market, and identifying the net secondary effects...Although secondary effects can have significant local implications, the question is whether they have a net regional impact...The general conclusion for most resources affected by fires is that they do not have a net regional impact. (Althaus and Mills, page 2.)

IV. A METHODOLOGY FOR ASSESSING THE ECONOMIC EFFECTS OF WILDFIRE IN ALASKA

Methdology for Quantifying Direct Value Changes Due to Wildfire

Chapter IV provided a mathmatical definition of total value change. A worksheet for calculating value change for individual resources, using this formula, is included as Table 7.

Definition of Units

> The first step in quantifying value change for a resource is to define units in which benefits provided by the resource are measured.

The importance of the definition of units is illustrated by a resource such as wildlife habitat. For this resource, units such as "acres burned" are usually not appropriate because the change in the area of wildlife habitat is not a benefit (or harm) to which value can be directly applied. Wildlife habitat has value because it provides benefits such as moose hunting, fur-bearer trapping, and recreational viewing of wildlife: it is the change in these benefits which should be measured. Units such as the number of moose taken or days of sport hunting or number of big game species seen by recreationists would be more appropriate.

TABLE 7. WORKSHEET FOR ASSESSING DIRECT VALUE CHANGES DUE TO WILDFIRE

Resource: ______________________

Units Used to Measure Physical Changes in Benefits: ______________________

Discount Rate: ______________________

Location and Size of Fire: ______________________
____

Description of Effects of Fire: ______________________
____

Years After Fire	Physical Changes in Benefits Due to Fire	Undiscounted Value Per Unit of Benefit	Undiscounted Value Change	Discounted Value Change

Total Discounted Value Change: ______________________

Quantification of Physical Changes in Benefits Over Time

The second step in assessing value change is to quantify changes in physical benefits provided by resources affected by wildfire, based upon both biological and economic analysis.

Information on the effects of fire on the potential physical benefits provided by the resource over time is generally based on biological studies of the effects of fire. Information on the extent to which the present and future use of these potential physical benefits might change due to wildfire requires economic analysis. For example, in assessing timber value change, we would need to know not only whether timber is destroyed by a fire but also to what extent harvests are actually reduced.

Substitution of unburned for burned resources may reduce value changes attributable to wildfire.

Assessing the actual change in benefits due to a fire is complicated by the fact that people tend to substitute resources in other areas for the resources in burned areas. If fishing along one stream is ruined, people will fish on other streams. If moose hunting in one area is improved by fire, other areas may be hunted less intensely. If fire destroys timber in one area where a road had been contemplated to permit future timber harvests, the road may be built to another area. The effect of these "substitution effects" is to reduce the net change in benefits and, hence, the value change attributable to wildfire.

The importance of substitution effects depends upon the extent to which resources are fully utilized and the costs of switching to use other resources. The greater the cost of traveling to other fishing streams and the more other streams are already fished, the less they can substitute for a stream harmed by wildfire. Similarly, less accessible timber may fully substitute for more accessible timber, but a value loss would result due to higher harvesting and transportation costs. To account for this, the worksheet calculations might show a decrease in the harvest of higher-valued timber and an increase in the harvest of lower-valued timber.[1]

The risk that other fires will occur anyway in the future reduces the value change attributable to a given fire.

An unburned area accumulates fuel and may become very susceptible to fire. Especially in "bad fire years," which occur about once per decade in Alaska, such areas may burn despite suppression efforts because fires are so difficult to control or because suppression forces are spread so thin. The loss in one fire of resources such as immature timber is not so great if it is likely that the timber would have burned anyway before it could have been harvested. A risk in expending large sums of money to protect such resources is that they will merely have been saved to burn another year.

Calculation of Values for Changes in Physical Benefits

The third step in assessing value change is to calculate undiscounted unit values for changes in physical benefits.

As discussed in Chapter II, a variety of measures of willingness-to-pay, such as market price, prices of close substitutes, willingness-to-pay surveys, or travel cost studies, may be used to calculate these values. Standard procedures have been developed to measure resource values using these methods. Values may rise or fall over time. In many respects, calculation of unit values is easier than quantifying changes in physical benefits. However, it may be very difficult to project values for distant periods in the future.

Finally, physical changes in resource benefits are multiplied by the unit values to calculate undiscounted value change, discounted to calculate present value change, and summed.

Methodology for Quantifying Secondary Effects of Wildfire

It is a complicated task to trace the secondary effects of wildfire. These include changes in direct employment and income associated with resources affected by the fire as well as further induced changes in employment and income as effects are multiplied throughout the economy.

<u>Approximate secondary effects of fires may be calculated by multiplying changes in physical benefits by employment and income multipliers.</u>

These multipliers may be calculated as the total employment and income generated per unit of resource use in the region of impact. Data will generally permit only approximate estimates of these multipliers. One reason for this is that average ratios of employment and income to resource use differ from marginal ratios. However, these calculations may serve to indicate the relative magnitude of secondary effects. Table 8 provides a worksheet for calculating secondary effects of wildfire.

TABLE 8. WORKSHEET FOR MEASURING SECONDARY EFFECTS OF WILDFIRE

Resource: ____________________

Location and Size of Fire: ____________________
____

Units Used to Measure Physical Changes in Benefits: ____________________

Employment Coefficient for Changes in Benefits: ____________________

Income Coefficient for Changes in Benefits: ____________________

Discount Rate: ____________________

Years After Fire	Physical Changes in Benefits Due to Fire	Change in Employment	Undiscounted Change in Income	Discounted Change in Income

Total Discounted Change in Income: ____________________

As with the calculation of value change, assessments of secondary effects should take account of possibilities for substitution of underutilized, unburned resources for burned resources. Net secondary effects for the state may be much smaller than local secondary effects.

If a fire destroyed all merchantable timber within the vicinity at a sawmill, this would have a large impact upon the local economy. However, the net effect upon the statewide economy might be smaller if the loss in timber production in one area were partially offset by increases in production in other areas. Similarly, if fire ruined business for one hunting lodge, business would tend to improve at other hunting lodges, resulting in smaller net secondary effects. Substitution possibilities are limited by the extent to which resources are underutilized and by the costs of using alternative resources.

V. EFFECTS OF WILDFIRE ON TIMBER AND FUELWOOD VALUES

Units

<u>Physical effects of fire on timber should be measured in terms of the change in volume harvested.</u>

Timber and fuelwood values are derived from harvests of these resources. The effects of a fire should not be measured as the change in the standing volume of timber, but rather the change in volume harvested. These may be quite different.

Effects of Wildfire on Timber and Fuelwood Harvests

<u>Wildfire in timber stands may decrease, increase, or have no effect upon actual timber harvests.</u>

Depending upon the severity and intensity of a fire, mature and immature timber stands may or may not be killed. For example, high moisture content of white spruce along river corridors in Alaska tends to reduce the destruction of spruce by wildfire. If killed, sawtimber and fuelwood may still be salvageable for a period of time. Dried timber killed by wildfire may be a superior source of fuelwood and house logs.

If timber stands are not harvested or burned, they eventually become overmature. Decay in overmature timber stands lowers their quality for timber harvests and makes them more susceptible to destruction by windthrow or fire. Nature eventually destroys all unharvested timber stands. Following the destruction of a timber stand, by fire or other means, new successional stages of vegetation appear, resulting eventually in mature timber stands.

Timber stands will be harvested only if they are economically accessible, so that the delivered value of the harvested logs exceeds the cost of harvest. In Alaska, transportation access and the availability at markets are the primary factors determining economic viability of timber harvests. Vast areas of timber are not currently economically accessible. However, future road and railroad access, as well as timber price increases, may eventually make them economically accessible.

If fire destroys a mature timber stand which is economically accessible, or an immature stand which would have been economically accessible by the time it reached maturity, this may cause a decrease in timber harvets. An actual decrease in harvests will occur only to the extent that the timber cannot be salvaged and other timber stands which would otherwise not have been harvested cannot be substituted for the burned timber. Fire would cause a decline in harvests for most mature timber stands close to existing or planned road and railroad transportation systems in Alaska.

If fire destroys a mature timber stand which is economically inaccessible, and which would become accessible only in the distant future, then a future increase in timber harvests may result. This is because fire may allow a vigorous new timber stand to become established which would be mature or close to maturity by the time it becomes economically accessible, whereas the existing stand might have decayed, preventing or delaying the establishment of new stands. Fuelwood harvests may also increase (or increase in value) as a result of fire, if fire kills and dries green timber.

Fire will have no effect on timber harvests if timber stands are not harmed, if timber stands are and will remain economically inaccessible, or if timber supply in the area exceeds present and future local and export demand. In this case, fire would cause no change in value.

Stumpage Values

> Sawtimber stumpage values vary dramatically depending upon factors such as species, terrain, distance from existing roads, stand volume, and hauling distance to a mill.

Stumpage value may be expressed as

$$\left(\begin{array}{c}\text{Value of Timber Deliv-}\\\text{ered at the Mill or}\\\text{Point of Export}\end{array}\right) - \left(\begin{array}{c}\text{Average Fixed Costs}\\\text{of Harvest and}\\\text{Transport}\end{array}\right) - \left(\begin{array}{c}\text{Variable Costs of}\\\text{of Harvest and}\\\text{Transport}\end{array}\right)$$

Fixed costs are primarily road construction costs which depend upon terrain and distance from existing roads. Average fixed costs depend upon the total size of the sale as well. Variable costs include felling, skidding, loading, and hauling costs. Felling and skidding costs depend upon average volume per acre, while hauling costs depend upon road distance from a mill or point of export. Differences among these factors make it impossible to assign a single current stumpage value to timber in different stands. Instead, stumpage value must be estimated based upon stand characteristics and location.

Approximate ranges for Interior Alaska for several variables affecting current stumpage values for white spruce sawtimber are shown in Table 9. These figures are based on conversations with state forestry officials and sawmill operators. Although more specific data are available for particular areas, these figures serve to illustrate how different factors may affect stumpage values.

TABLE 9. APPROXIMATE RANGES FOR FACTORS AFFECTING STUMPAGE VALUES FOR SAWTIMBER AND FUELWOOD IN INTERIOR ALASKA

Sawtimber	
Value of delivered sawlogs (white spruce)	$125-200/thousand board feet
Felling costs	$5-10/thousand board feet
Skidding costs	$10-30/thousand board feet
Loading costs	$5-15/thousand board feet
Hauling costs	$.50-1.50/mile/thousand board feet
Timber volume per acre	0-20,000 board feet/acre
Road construction costs	$5,000-50,000/mile
Distance from existing roads	0-300 miles
Road distance from a mill	0-300 miles
Fuelwood	
Value of delivered fuelwood	$60-130/cord
Felling, skidding, and loading costs	$32-48/cord
Hauling costs	$.50-1.50/mile/cord
Fuelwood volume per acre	0-25 cords/acre
Road construction costs	$5,000-50,000/mile
Distance from existing roads	0-300 miles
Road distance from markets	0-300 miles

SOURCES: State forestry officials; sawmill operators.

Table 10 illustrates how road construction costs and hauling distance to a mill may affect sawtimber stumpage value, given assumed values for other factors. These assumptions are based on intermediate values from the ranges provided in Table 10. In this example, stumpage values vary from over $100/MBF to zero, given different combinations of road construction requirements and hauling distances.

Table 11 shows different combinations of road construction requirements and hauling distance resulting in zero current stumpage value, based on the assumptions used in Table 9. These figures provide a rough approximation of the limiting conditions for transportation of sawtimber in Interior Alaska. They suggest that current stumpage values are likely to be insignificant if more than 60 miles of road must be constructed in order to harvest the timber, or if the road distance to a mill exceeds 225 miles. Timber stands smaller than 5,000 MBF, or with road construction costs higher than $10,000/mile, may have to be much closer to existing roads and mills in order to be economically harvestable at present.

TABLE 10. ILLUSTRATION OF CALCULATION OF SAWTIMBER STUMPAGE VALUES

Assumptions:

Value of timber delivered at mill	\$150/Mbf
Felling, skidding, and loading costs	\$35/Mbf
Road construction cost per mile	\$10,000/mile
Hauling cost	\$.50/mile/Mbf
Total stand volume	5,000/Mbf
Stand volume per acre	10 Mbf/acre

Calculation of Stumpage Value

$$\text{Stumpage Value per Thousand bf} = 150 - 35 - \frac{10{,}000 \times \text{Road miles to be constructed}}{5{,}000} - \text{Hauling Distance} \times .5$$

$$= 115 - 2 \times \text{Road miles to be constructed} - \text{Hauling distance} \times .5$$

Examples of Stumpage Values

Road Miles to Be Constructed	Hauling Distance	Stumpage Value Per Thousand	Stumpage Value Per Acre (500 acres)
1	20	103	\$1,030
1	50	88	880
1	100	63	630
5	20	95	950
5	50	80	800
5	100	55	550
20	20	65	650
20	50	50	500
20	100	25	200
50	20	5	50
50	50	less than zero	less than zero
50	100	less than zero	less than zero

TABLE 11. COMBINATIONS OF ROAD CONSTRUCTION REQUIREMENTS AND HAULING DISTANCE RESULTING IN ZERO STUMPAGE VALUE*

Road Miles to be Constructed	Hauling Distance
1	226
2	222
5	210
10	190
20	150
30	110
40	70
50	30
57.5	0

*Based on assumptions used in Figure 2.

Table 12 illustrates calculations of fuelwood stumpage value for different combinations of road construction requirements and fuelwood hauling distances. As with the sawtimber value calculations, these results are dependent upon the specific assumptions used about other factors, such as total stand volume and hauling costs. The results suggest, however, that fuelwood is unlikely to have significant current commercial stumpage value if it must be transported more than 100 miles, or if it is more than a few miles from an existing road.

TABLE 12. ILLUSTRATION OF CALCULATION OF FUELWOOD STUMPAGE VALUES

Assumptions:

Value of delivered fuelwood	$90/cord
Felling, skidding, and loading costs	$35/cord
Road construction cost per mile	$5,000/mile
Hauling cost	$.50/mile/cord
Total stand volume	750 cords
Volume per acre	15 cords/acre

Calculation of Stumpage Value

$$\text{Stumpage Value per Cord} = 90 - 35 - \frac{5{,}000 \times \text{Road Miles to be Constructed}}{750} - \text{Hauling Distance} \times .5$$

$$= 55 - 6.67 \times \text{Road miles to be constructed} - \text{Hauling distance} \times .5$$

Examples of Stumpage Values

Road Miles to Be Constructed	Hauling Distance	Stumpage Value Per Cord	Stumpage Value Per Acre
0	1	$54	$810
0	20	45	675
0	100	5	75
2	1	41	615
2	20	32	480
2	100	less than 0	less than 0
5	1	21	315
5	20	12	180
5	100	less than 0	less than 0

The appropriate stumpage value is that which will hold in the year in which the timber would have been harvested.

In the long run, real timber prices and demand for timber both within Alaska and in export markets are likely to rise, despite low growth in periods of recession. Also, it appears reasonable to expect that over the next few decades road, rail, and river transportation developments in Alaska will greatly expand access to timber resources. Thus, currently economically inaccessible timber may have positive stumpage value in the future.

Examples of Timber Value Change Calculations

As an example of the calculation of timber value change due to wildfire, consider the following hypothetical examples. Suppose that white spruce stands reach a volume of 5,000 board feet per acre at age 80 and that this is the optimum harvest age. After age 80, they stop growing; they begin to decay at age 120, allowing regeneration of a new stand at age 150. We may consider two cases in which fire kills 500 acres of 110-year-old spruce and 1,000 acres of 60-year-old white spruce.

In the first case, illustrated by the worksheet in Table 13, the timber is located along the road system near Fairbanks. Timber resources in this area are and will continue to be fully utilized, so there is no potential for substitution of unburned for burned

TABLE 13. EXAMPLE OF CALCULATION OF TIMBER VALUE CHANGE DUE TO WILDFIRE

Resource:	Timber
Units Used to Measure Physical Changes in Benefits:	Sawtimber harvests (MBF)
Discount Rate:	6 Percent
Location and Size of Fire:	1,500 acres on road system near Fairbanks
Description of Effects of Fire:	Burns 500 acres of 110-year-old spruce and 1,000 acres of 60-year-old spruce

Years After Fire	Physical Changes in Benefits Due to Fire	Undiscounted Value Per Unit of Benefit	Undiscounted Value Change	Discounted Value Change
0	-2,500	100	-250,000	-250,000
20	-5,000	200	-1,000,000	-312,000
80	+7,500	300	+2,250,000	+21,000

Total Discounted Value Change: - $541,000 timber. Assume that real stumpage values in this area are $100/MBF at present and are projected to grow to $200/MBF in twenty years and $300/MBF in eighty years. The fire kills the 110-year-old spruce, which was ready for harvest. However, half of it can be salvaged. The physical loss is 2,500/MBF, for a value loss of $250 thousand.

The 60-year-old timber is too small to be salvaged. It could have been harvested in twenty years, when it would have had a volume of 5,000/MBF. At the projected future price of $700/MBF, the undiscounted value loss would be $1 million. If we assume a discount rate of 6 percent, the discounted value loss for the 60-year-old timber would be $312 thousand.

The fire allows new white spruce stands to become established, allowing 7,500 MBF to be harvested in 80 years, for a discounted value gain of $21 thousand. The net value change for all of these effects is a loss of $541 thousand.[2]

In the second case, illustrated by the worksheet in Table 14, the timber is located in a remote area where timber will not be economically accessible until 50 years from now. Assume that stumpage values will be $100/MBF at that time and $150/MBF 80 years from now. There is no value loss due to the destruction of the 110-year-old timber since it would have decayed before it became accessible. However, the 60-year-old timber could have been harvested in fifty years. The loss of this timber results in a

TABLE 14. EXAMPLE OF CALCULATION OF TIMBER VALUE CHANGE DUE TO WILDFIRE

Resource:	Timber
Units Used to Measure Physical Changes in Benefits:	Sawtimber harvests (MBF)
Discount Rate:	6 percent
Location and Size of Fire:	1,500 acres in remote, inaccessible area
Description of Effects of Fire:	Burns 300 acres of 110-year-old spruce and 1,000 acres of 60-year-old spruce

Years After Fire	Physical Changes in Benefits Due to Fire	Undiscounted Value Per Unit of Benefit	Undiscounted Value Change	Discounted Value Change
50	-5,000	100	-500,000	-27,000
80	+7,500	150	+1,125,000	+11,000

Total Discounted Value Change: - $16,000 discounted value loss of $27 thousand. This loss is partially offset by the discounted value from the harvest 80 years from now of the new stands which arise after the fire, for a value gain of $11 thousand. The net value change for both effects is a loss of $16 thousand. If all of the timber had been 110 years old at the time of the fire, there would have been no value loss since none of the burned timber would have survived until harvest. In this case, the fire would have resulted in a net value gain.

It may be that the limiting factor for future timber harvests in some remote areas of Alaska will not be the volume of timber, but rather demand--especially given the high cost of developing transportation access. Fires in these areas today may have no effect upon future timber harvests since the supply of remote timber would exceed demand whether or not fires decrease or increase timber volume in these areas. In these areas, the timber value change due to fire would be zero.

VI. EFFECTS OF WILDFIRE ON WILDLIFE VALUES

Units

Physical effects of fire on wildlife values should be measured in terms of changes in numbers of animals harvested.

Wildlife provides three main kinds of benefits. These are harvests for personal consumption; harvests for commercial sale; and recreation from fishing, hunting, and wildlife viewing. Effect of wildfire on harvests for personal or commercial use may be quantified in terms of changes in the number of animals harvested. Effects of wildfire on "recreation" are more difficult to quantify. However, hunting provides recreation which is probably reasonably proportional to sport fishing and hunting harvests. Therefore, we may measure changes in sport hunting recreational benefits in terms of changes in sport harvests although we actually mean the recreation associated with the harvests.

In some areas such as parks, the primary benefits derived from wildlife are from wildlife viewing. Wildlife viewing may be measured in numbers of big game seen. An alternative, less-precise measure is visitor days.

A very wide variety of species provide important values in Alaska and may be affected by wildfire. Some of the most important are moose, caribou, bear, marten, wolf, lynx, fox, muskrat, and beaver.

Where a wide variety of species are harvested, as for personal consumption uses, it may be easier to measure changes in benefits in units such as the share of total food requirements, rather than to calculate effects upon a variety of different species.

Effects of Wildfire on Wildlife Benefits

> Wildlife harvests are generally proportional to species abundance. The abundance of a given species may vary dramatically depending upon the successional stage of an ecosystem. Fire returns an ecosystem to the postfire successional stage. Peak abundance for some species such as moose comes earlier following fire. Peak abundance for other species such as caribou comes much later. However, because fire is an integral part of subarctic ecosystems, productivity for almost all species eventually tends to decline if fire is prevented.

One biologist summarized this point with the phrase, "You can't pickle a forest."

The effect of a fire on harvests of a given species can only be specified in the context of a given time period. Since peak abundance of moose comes early after fires, fires tend to initially increase the abundance of moose. Conversely, caribou feed upon lichens which appear only decades after fires. Where lichens are destroyed by fire, caribou habitat may be reduced. However, without fire, lichens will eventually be shaded out by mosses, resulting in a decline in caribou habitat.

Similar effects can be described for almost all wildlife species. However, effects vary widely depending upon the severity, intensity, and size of the fire.

<u>In general, the most productive ecosystems are those which are most diverse.</u>

A mosaic of different successional stages can provide habitat for many different species. Without fire, diversity of habitat tends to decline, and overall wildlife productivity declines although it may increase for some species.

<u>Substitution effects should be allowed for in considering the effects of fire on wildlife harvests.</u>

In particular for personal consumption uses, if harvests of one species in an area decline, harvests of other species unaffected by fire may increase to partially offset their losses. For example, fire does not destroy the labor used to harvest personal consumption foods, which constitutes a large share of the value of these foods.

Wildfire may greatly increase wildlife viewing benefits by improving visibility.

In addition to increasing abundance of many species, fires remove forest cover, permitting big game to be seen more easily. This enhances wildlife viewing for recreation as well as for hunting.

Wildlife Values

It is generally easier to discuss the effects of wildfire upon direct and secondary wildlife values together, rather than attempting to distinguish between them.

Wildlife resources generally do not have separate, easily measurable values attributable to the resource itself, which would be analogous to stumpage prices for timber (limited entry permits for fishing are an exception). However, it is useful to remember that many "wildlife values" are technically secondary values generated in connection with harvesting wildlife. For example, much of the value of a pelt should technically be attributed to the cost of traps and the trapper's labor, rather than the direct value of the furbearer. Much of the combined meat and recreational value of a moose hunt is actually cost of the hunt, such as cost of transportation and guide services.

Commercial wildlife harvests may be valued by the prices of pelts, meat, and other harvested products.

Year-to-year fluctuations in the prices of these products suggest that any particular set of prices will, at best, be approximate.

Minimum values for sport hunting harvets may be calculated from expenditures made by hunters or from the costs of buying an equivalent amount of meat.

The value of an equivalent quantity of meat serves as a minimum measure of the value of sport harvests. However, sport hunting also provides recreation, the value of which is not included in food value of harvests.

An alternative procedure for valuing sport hunting harvests is to examine the total costs incurred by sports hunters. These serve as a minimum measure of the value of the food combined with the recreational experience since hunters are "willing-to-pay" at least this amount. This procedure also provides an estimate of the contribution to the economy provided by hunters. Sport hunting may actually be worth much more than the cost of hunting in some cases--that is, hunters would be willing to pay more than the actual costs that they incur.[3] In sum, the figures provided by both methods provide a reasonable, conservative estimate of sport hunting values. They suggest that big game values are in the hundreds of dollars per animal harvested.

Personal-use wildlife harvests may be valued by the cost of substitutes.

Substitutes are generally store-bought food and materials. If units such as the share of total food requirements are used, the value of these may be measured by the cost of living of store-bought food. Cash costs of harvesting personal consumption food, such as costs of transportation and ammunition, should be subtracted from these values.

An Example of Commercial Value Change Calculations: Trapping

Trapping accounts for most of the commerical wildlife values in Alaska. Trapping is widely distributed over the state, with most good trapping areas being trapped to some degree. Most trapping takes place in drainages, primarily near streams. The most heavily trapped areas are within 15 miles of the road system, where they are easily accessible by snowmobile. Trapping is also heavy within a radius of about 50 miles of interior villages and along major river systems. Other areas may or may not be trapped.

The state does not register traplines as is done in the Northwest Territories in Canada. Trappers may trap where they wish within the restrictions issued by the Department of Fish and Game. However, trappers tend to have regular trapping areas which are enforced by custom if not by law.

At present, data on total numbers of furs taken and the value of furs are incomplete. According to the personnel of the Alaska Department of Fish and Game's furbearer program, an approximate range of the raw value of furs taken annually in Alaska before processing is between six and ten million dollars. Most furs are exported from the state. However, small but important fur industries such as hat making exist in some parts of the state, and they have important subsistence uses as well. Although the total value of furs taken is tiny compared to the production value of major resources such as oil and fish, trapping represents a significant, widely distributed source of cash income in rural areas of Alaska.

There are about 25,000 people licensed to trap in Alaska (trapping licenses are issued for a nominal fee of three dollars). Many trapping license holders actually do very little trapping. Perhaps about 10,000 people carry on a significant amount of trapping, with a much smaller number deriving their entire income from trapping. Professional trappers in the interior may earn from $15-30 thousand per year and considerably higher when high fur prices combine with high catches. At present, data are not available which provide a breakdown on the number of people who trap by income earned. However, assuming 10,000 trappers and an annual value of $6 million earned, we may derive some idea of the possible range of this breakdown. These figures imply an annual average income of $600. However, if "professional" trappers earned $15,000 per year, 400 professional trappers would account for the entire value trapped. Evidently, the number of trappers earning this much money is considerably smaller.

Some additional indications of the income and costs associated with trapping are provided from information in a report on forest fire management in the Northwest Territories in Canada:

> In the Fort Smith area, . . . a registered trapline system was introduced in the 1940s. Here the trappers have invested considerable time in developing trails, building cabins, and learning how to manage the furbearer populations . . .. The trading price for a registered trapline . . . may be as much as $20,000. In 1977-78 . . . there were 130 registered trappers, of whom 62 earned more than $600 from fur sales. Fifteen earned more than $4,000 . . .. The approximate cost to an individual who wishes to become a trapper is about $12,000. This would provide a main cabin, one or two line cabins, a snowmobile, boat and motor, traps, and the labor to cut traplines (Murphy et al, p. 70).

Most trapped species do not appear to be significantly harmed by wildfire, even in the short run, unless the fire is particularly hot and severe so as to totally destroy habitat (see Appendix A). Large fires in mature white spruce stands are commonly thought to be detrimental to marten due to loss of denning habitat. Fires may also destroy trappers' cabins and other property.

The Alaska Department of Fish and Game is currently carrying out a study to assess the effects of fire on furbearers. As part of the study, a number of trappers are being interviewed in pre- and post-burn areas. Preliminary results of the study should be available during the spring of 1983. According to the authors of the Tanana-Minchumina Plan, "a number of residents expressed a desire (during meetings in villages) to see more fires in areas where their traplines now exist because the habitat production is decreasing and trapping success is declining" (page 103). In contrast, a study on forest fire management in the Northwest Territories reported that a major demand was "to apply a higher level of fire control to trapping areas." The difference in opinions may reflect the strong vested interests of the Canadian trappers in protecting their registered traplines.

Another uncertain effect of fire upon trapping results from changes in access. Some burned areas may become more accessible due to reduction of plant cover (and bulldozed firelines), while others may become less accessible due to river log jams and fallen timber along traplines and trails.

The value of trapping may vary widely in different areas. An order-of-magnitude estimate of the value of trapping for large areas may be obtained from comparing the area of Alaska (365 million acres) with the total annual value of furs taken ($6 million). If one-tenth of the area of Alaska is trapped, this would imply an annual value of 16¢ per acre. In fact, certain areas will contribute much higher values to trapping and other areas will contribute much lower values. If a fire burns over a very large area, the value for the area might average out to a figure resembling this statewide average. Thus, a 100,000-acre fire might burn over an area producing furs valued at $16,000 per year, and possibly considerably more. A more direct approach is to estimate the number of trappers operating in a given area, and to make some estimate of their annual incomes. A "professional" trapper earning $15,000 per year may run a 50-mile trapline. If a 50-mile trapline effectively "covers" a strip three miles wide (much of which will not be good trapping area), the total area covered is approximately 100,000 acres. This suggests a figure for value produced per acre comparable to that estimated above.

One indication of the effects of fires on trapping values is provided by the report on Forest Fire Management in the Northwest

Territories, where forest fires in the Fort Smith district burned 3.5 million acres in 1979.

> Data received from the Hunters and Trappers Association of Fort Smith indicates that capital values alone destroyed by fires in 1979 may have exceeded $75,000, made up of the following components: trapping equipments, $38,025; cabins, $22,577; household goods, $9,895; clothing, $3,855; and food supplies, $1,178. At present, the Government of the Northwest Territories employs a Trappers and Hunters Disaster Compensation Program that will pay trappers up to a maximum of $3,000 should they sustain losses as a result of forest fires or severe storms. To be eligible, a resident trapper must hold a General Hunting License and receive at least half of his total income from trapping and/or hunting. Following the 1979 fire, 26 claims were submitted, averaging $4,265 (Murphy et al, p. 71.)

Insurance claims for losses totaled $111 thousand dollars, or about 3¢ per acre. However, this estimate considers only short-term losses of selected trappers. It does not include other short-run or long-run gains which may occur as a result of increased furbearer abundance.

An estimate of net value change including gains as well as losses could be made by summing the discounted value of the change in total trapper income over time. Because of the variety of species affected, it may be more appropriate to compute rough estimates of changes in total income than to attempt to compute changes in the value harvested over time for each species. Suppose that average losses due to fires such as that in the Fort Smith District totaled $4,000 in the year of the fire and $1,000 in the first three years after the fire but that subsequently the value of harvets increased by $500 per year for a 20-year period. At a discount rate of 6 percent, the net present value change would be a loss of $1,860. Slightly different figures for changes in values, or a lower discount rate, could easily result in a net present value gain from fire.

<u>In accessible areas, potential trapping value changes due to wildfire appear to be relatively small compared to reasonable ranges of value change for timber.</u>

Because of the variety of species which are trapped, the changes in values among different species tend to balance each other. Therefore, changes in total trapping values due to fire are likely to be relatively low. Assuming that the present value of trapping income changed by no more than 25 percent, the rough value figures developed above suggest that the present value gains or losses from a 100,000-acre fire might be on the order of several thousand dollars per year.

<u>An important factor in the consideration of trapping values is that losses from fire will tend to fall upon a few private individuals heavily dependent upon this one source of income</u>.

Although traplines are not registered by the state so that an individual whose trapline burns may, in theory, trap elsewhere, it may be difficult in practice to find another area with which the individual is familiar and which is not already being trapped. In addition, the fixed capital associated with the trapline may be lost. Long-term benefits to trapping in the area will not necessarily be enjoyed by the individuals harmed by the fire. After the 1979 fires in the Northwest Territories, "many of the older trappers pointed out that the productivity of their traplines would never recover during their lifetimes. Some even believed that they would not have the stamina to build new cabins" (page 109).

The figures developed above on trapping values are highly speculative and are intended only as illustrations of possible effects of fire upon trapping values. Better estimates would require better data on the intensity of trapping, changes in overall furbearer harvests due to fire, and values of trapline improvements vulnerable to fire.

An Example of Sport Hunting Value Change Calculations: Moose Hunting

Fire may substantially increase moose values.

Fire can have an enormous impact upon moose abundance. At its most stagnant (in the absence of fire for many years), moose abundance can be as low as .01 moose per square mile, or one moose per hundred square miles. A more typical level of moose abundance in unburned areas would be about .2 moose per square mile, or one moose per five square miles. In contrast, moose abundance following a burn may rise to as high as eight moose per square mile.

In order to gain a rough approximation of the effect of fire on moose values, we may consider the effect of a fire which increases moose abundance by a factor of ten, from .2 per square mile to 2 per square mile, for a period of ten years, assuming a conservative estimate for the value of a moose of $700 and a discount rate of six percent. Assuming a ten percent annual harvest of the moose population, harvests would rise from .02 to .2 moose per square mile for a ten-year period. The value of moose harvets would rise from $14 to $140 per square mile, or from 2.2¢ to 22¢ per acre. This would be an increase in moose hunting values of roughly 20¢ per acre. The present value of this increase over a ten-year period would be $1.56 per acre. Thus, the present value increae due to a 100,000-acre fire would be $156,000, or a substantial gain in value.

Numerous studies on the effects of fire on moose have been undertaken as well as on the values associated with moose hunting. It would be a relatively straightforward task to quantify economic effects of fire on moose hunting values in different locations.

Given the magnitude of the values included, this would be an important and fruitful area for further research.

Effects of Fire on Professional Guides

Not all species are affected as benefically by fire as moose. For example, under certain conditions, fire may reduce caribou habitat for a number of years or alter caribou migration routes. Changes such as these may have important effects on individual professional guides. These guides are assigned guiding areas by the Alaska Guide License Control Board. If fires alter wildlife abundance for a period of time in their guiding areas, guides may suffer financially, even though total state wildlife harvests may not change and long-run wildlife abundance within the guiding area may be increased.

Effects of Fire on Personal-Use Wildlife Values

Because a variety of wildlife species are harvested for personal use, fires are not likely to cause dramatic, long-term losses in personal-use wildlife values. Abundance of some species may increase for a time, while abundance of other species may decline. On balance, higher wildlife productivity where fire is present in an ecosystem suggests that fire will generally increase personal-use wildlife values in the long run although short-run value losses may occur. There is likely to be wide variation in these effects depending upon the locations, intensities, and sizes of fires. Value changes quantified for one situation would not neccessarily hold for other areas.

VII. ASSESSMENT OF A FIRE: THE 1977 BEAR CREEK FIRE

This chapter briefly assesses economic effects of the 1977 Bear Creek Fire. The Bear Creek fire burned approximately 345,000 acres near McGrath during an extended drought in August and September 1977. Over $2.4 million was spent on efforts to suppress the fire. The location of the fire is shown on the map in Figure 1. Descriptions of the effects of this fire are taken from a summary report prepared by Bill Hanson.

Timber Value Change

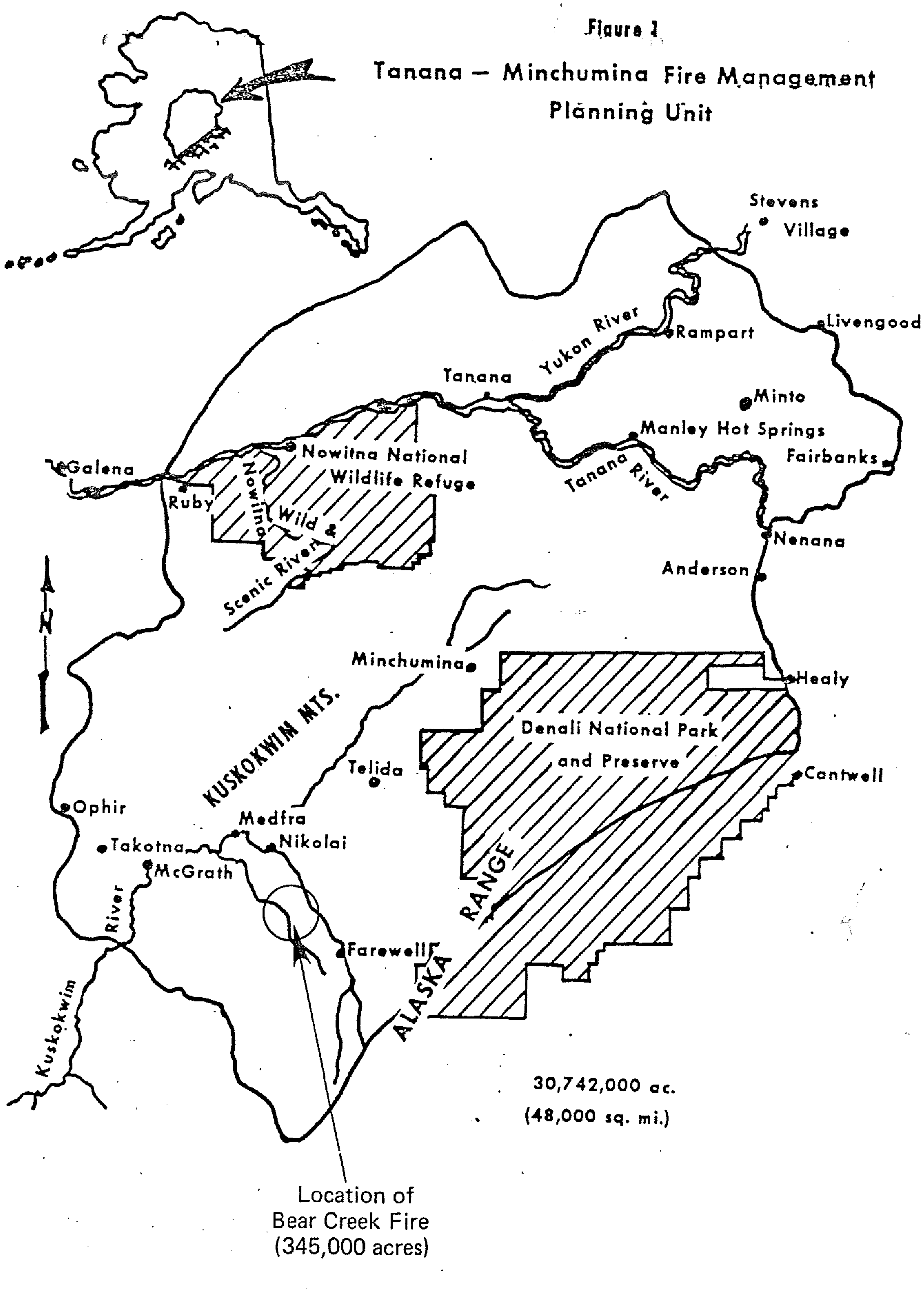
There were extensive stands of good quality white spruce and mixed hardwoods located in the area of the Bear Creek fire. Many, though not all, of these stands were burned. The summary report on the fire stated

> It is very difficult to place a value on timber which is currently unused and inaccessible. There is simply no way to predict when or if it might be economically feasible to harvest such timber in the future. It could be only ten years from the present, or it might never be feasible . . . .. While long term economics are always speculative, it is unlikely that these white spruce stands have much immediate value other than for local house log markets. Although they are of commercially valuable size, they are very inaccessible. (pages 57, 58)

This summary illustrates the difficulty of assigning values to inaccessible timber stands. The Bear Creek fire was not sufficiently close to any communities to have significantly

Figure 1

Tanana – Minchumina Fire Management Planning Unit



increased the difficulty of obtaining house logs for local markets at any time in the significant future. Therefore, the value loss for the local housing market may be considered to be zero. Any estimate of when the Bear Creek fire area might become economically accessible for timber harvests is necessarily speculative. A liberal guess is that good quality white spruce in the area will have a stumpage value of $50/Mbf in 25 years, due to transportation developments and timber price increases.

Had the Bear Creek fire not occurred, timber which burned in that fire in the area might have had only a 50 percent chance of surviving for another 25 years, given the possibility of other fires and other risks. Assuming that these stands would have had a volume of 5,000 board feet per acre in twenty-five years and that the loss of half of these stands may be attributed to the Bear Creek fire as opposed to future fires, the fire might have caused a loss of 2,500 board feet per acre twenty-five years from now in commercial timber stands burned in the fire. If 5 percent of the area of the fire consisted of commercial timber stands, then the total volume loss would be 43,125 MBF. At a value of $50/MBF, the undiscounted value loss would be $2.16 million. At a discount rate of 6 percent, the present value of this loss would be $502 thousand.

Obviously, this result is highly speculative and could change dramatically if different assumptions were used. Uncertainty about the future accessibility and value of this timber is a particularly important source of potential error. Unless transportation access should be developed to the area, the value loss will be zero. In addition, the estimate does not take account of possible increases in future timber values due to establishment of new stands.

Wildlife Value Changes

The resource team which evaluated expected resource losses during the Bear Creek fire was concerned that there would be severe damage to valuable marten habitat if large stands of white spruce along the South Fork of the Kuskokwim burned. Subsequent evaluation concluded that this concern was not well-founded. "Despite the tremendous fire intensity, many 'stringers' of white spruce along streams within the burn, as well as most of the large white spruce stands along the South Fork and Windy Fork, survived. The openings created by the fire may actually benefit marten by increasing food supplies" of small mammals.

According to the summary report, "trappers are continuing to use the area. Snowmobile trails stretched in several directions from the road house into the burn during winter 1979." A local part-time trapper, using fire lines for access, trapped along the southern edge of the fire during winter 1979 and enjoyed about the same rate of success as in earlier years.

No sizable declines in abundance or harvests of other species were reported in the summary report on the fire. The report stated, "Several hunting guides are located near the fire, and although we have not yet interviewed them, it can be assumed that their business was hindered by the fire. They may benefit in the long run as wildlife populations increase" (p. 62). According to one guide in the area, his primary concern with the fire had been the danger to his hunting camp, to which the fire came very close. The fire does not appear to have significantly harmed his hunting business. While moose changed their rutting areas, the fire has provided a lot of grass for the bison herd (personal communication, December 1, 1982).

The summary report concluded that the most important effect upon subsistence users of the area "will include changes in accessibility to traditionally used areas. Some areas may eventually become more accessible through reduction of plant cover and availability of bulldozed firelines. However, logjams on rivers and fallen timber along traplines and trails could prevent access to traditionally used areas" (p. 62.).

Given the lack of data on harvest intensity and fire effects, it is particularly difficult to quantify the long-run change in wildlife values due to wildfire on the Bear Creek fire. However, based on the reasoning of the previous chapter, it seems reasonable to assume an increase in the value of wildlife harvests at between

1¢ and 10¢ per acre, or between $2,450 and $34,500 for the entire burn. Over a ten-year period, the present value of this gain would be between $27 thousand and $270 thousand.

In sum, while the evidence is only sketchy, it suggests that there has been no significant decline in wildlife values as a result of the Bear Creek fire, while gains in wildlife values may be expected in the future.

Recreation Value Changes

About 36 miles of the Iditarod Trail passes within the Bear Creek burn between Farewell and Nikolai. The burn has hindered dog mushers in the annual Iditarod Race. Removal of the tree canopy has exposed the trail to strong winds and made the trail difficult to locate in winter. Destruction of two roadhouses eliminated the only commonly used shelters over a 60-mile section of the trail.

A willingness-to-pay value could be calculated for this loss. For example, perhaps the Iditarod Trail committee and other dog-mushing enthusiasts might have been willing to pay $10 thousand to keep the trail in its original condition indefinitely. However, it is unlikely that they would have been willing to pay as much to stop just the Bear Creek fire, given the probability of other fires in the future. It does not appear unreasonable to assume a value loss of several thousand dollars due to damage to the Iditarod Trail.

Real Property Value Changes

Several cabins and historic roadhouses were destroyed by the Bear Creek fire, some of which were of historic value. Based on an intuitive willingness-to-pay criterion, the value of these structures probably exceeded $10 thousand and was less than $100 thousand.

Value Changes Due to Smoke

According to the report, "the largest recreation problem caused by the fire was the result of dense smoke which engulfed Mt. McKinley National Park, 160 km (100 miles) away." In addition, "smoke caused severe air transportation problems as far away as Fairbanks and Anchorage. Fairbanks Airport was completely closed for several days and McGrath, Nikolai, Medfra, and Farewell were smoked in for much longer. Smoke made fire suppression extremely difficult. It was often difficult to see the fire, much less to map fuels or to implement tactical plans" (p. 62).

As fires increase in size, value losses due to smoke increase disproportionately. The shutdown of Fairbanks Airport probably caused losses in the tens or even hundreds of thousands of dollars. Similarly, total recreation losses would have amounted to tens of thousands of dollars. Assuming, for instance, a loss in recreation value of $20 per day per visitor for 500 visitors to McKinley Park during a twenty-day period of heavy smoke would imply a $20,000 loss in value.

Another way of assessing value losses due to smoke is to consider willingness-to-pay to avoid the smoke. Overall, it would not be unreasonable to assume that 50 thousand residents of the interior might have been willing to pay between $1 and $10 apiece to avoid the inconvenience of the smoke--which suggests a value loss of between 50 and 500 thousand dollars due to smoke.

Conclusions

The values suggested in this chapter are obviously highly speculative, based on simple reasoning and very little data. They suggest a value loss due to the Bear Creek fire of between $100 thousand and $1 million. Well over half of this estimate is attributable to timber losses, based on an optimistic assessment of future transportatin access. The other most significant losses may be attributed to heavy smoke during the period of the fire, which disrupted air travel and recreation over a wide area. For smaller fires, this smoke damage would have been proportionately much smaller. These value losses are offset to an uncertain but potentially substantial degree by long-run improvements in the productivity of wildlife habitat.

In interpreting these value change calculations, it is important to remember that the costs of fire suppression should be compared not with what was lost but with what was saved.

Nothing can be inferred from these calculations about whether the $2.1 million cost incurred in fighting the Bear Creek fire was worthwhile. The answer to this question would depend upon the value change which would have resulted had the fire not been fought or had it been fought differently.

VIII. CONCLUSIONS

This chapter presents a number of conclusions with respect to the economic effects of wildfires in Alaska and methods which may be used to quantify these effects.

Economic Effects of Wildfires

In general, fires tend to cause short-term losses and long-term benefits. Losses are likely to be concentrated among specific individuals or groups, whereas benefits are shared among a broader public. Fire suppression policies, therefore, require tradeoffs between short-run and long-run benefits and between the interests of specific, affected groups and those of the broader public.

Benefits of fires arise from increased diversity and productivity of ecosystems, of which fire is a natural component. Short-run losses arise from destruction of real property; losses of timber; visibility and air quality reduction due to smoke; and sometimes declining wildlife harvests by trappers, hunting guides, and local residents.

Economic effects of wildfire vary widely depending upon the severity, intensity, and size of the fire; the environment in which the fire burns; and the present and projected future uses of the resources affected by the fire.

A fire which would cause great loss in one area may have no economic effect or may even be beneficial in another area where resource use is different.

Methods for Quantifying Economic Effects of Wildfire

Contrary to an often-expressed opinion, it is possible to objectively quantify the economic effects of wildfires.

Accepted theoretical procedures are available to assess these effects. However, precise assessments are difficult due to data scarcity and variation between individual fires. It is much more difficult to objectively make tradeoffs between the interests of different groups affected by fires. Much of the disagreement over values arises from disagreement over the conclusions which may be drawn from value calculations and the political uses which may be made of these calculations.

Quantification of economic effects of wildfires must be based upon quantification of physical effects of wildfires on benefits provided by resources.

Biologists and economists must work together in assessing these effects. Without an assessment of how physical resource benefits are changed by fire, economists cannot quantify value changes. Qualitative descriptions of the effects of fire are insufficient.

Expertise is available in Alaska to quantify economic effects of wildfires. The limiting factor in quantifying these effects would be availability of data.

The individuals listed at the end of this study constitute a wealth of expertise on the effects of wildfire in Alaska. Many people in government, the university, and private consulting firms could contribute to quantifying the economic effects of wildfire if the scope, purpose, and method of this task were well-defined. However, lack of data would make precise assessments difficult. As mentioned above, there is great variation in the economic effects of wildfires. For any given fire or potential fire, the benefits from assembling the data for a precise estimate of value change may not be worth the cost.

The first step in a research effort to quantify economic effects of wildfire in Alaska should be to define the purpose and intended uses of this research.

Even limited research on this topic could be useful. However, prior to the start of research work, the intended users of the research results should specify the kinds of fires to be studied, the kinds of values to be specified, and the groups and regions for which impacts are to be identified. The purpose of the analysis and its role in determining fire suppression policies should be clear. Individuals associated with the U.S. Forest Service and Canadian research efforts on assessing economic impacts of wildfire should be consulted for their suggestions as to the design and scope of such a project.

Assessment of economic effects of fire should be coordinated with land-use planning.

DNR is presently carrying out extensive planning efforts for different regions of the state. These plans involve detailed studies of resource values, descriptions of present land uses, and projections of future land uses. Calculations of the effects of fire on resource values--as well as fire management planning generally--should be coordinated with this planning process.

Attempts to place dollar values on the effects of wildfires on resource values should be limited to those resources where the concept of dollar value is well-defined and well-understood.

These resources include real property, timber, wildlife resources, and recreation. Dollar values for effects on resources such as endangered species habitat are more difficult to calculate and are unlikely to be particularly useful to policy makers.

ENDNOTES

1. A slightly different form of the "substitution effect" may occur when resources are being managed in such a way as to produce less than maximum value. An example of this form of management is the policy of delaying harvest of mature timber in order to achieve "nondeclining even flow" in timber harvests. Delaying harvest of mature timber results in less than maximum present value being received from this timber since the income is received later and must be discounted. Under this policy, if a fire destroys a mature timber stand, other stands are substituted for harvest, with the effects of the fire being reflected in slightly smaller harvests over a number of years (the allowable cut effect). The total value loss due to the fire is reduced because much of the decline in income occurs in future years when the value loss can be discounted.

Althaus and Mills of the U.S. Forest Service contend that this second kind of substitution effect should not be taken into account in analyzing net value change. They write:

> Whether unburned resources should be substituted for burned resources is an important question that arises in any evaluation of a fire management program . . .. The evaluation of fire management programs should, in our judgment, as clearly as possible reflect only inherent site productivity . . .. We recognize that the measurement of fire effects . . . in the absence of substitution does not reflect the actual cash flow that comes from an area encumbered by its institutional setting. Such measurement does, however, more accurately reflect the inherent productivity of the site and the fire management program (Althaus and Mills, 1982, page 2).

Will Clark of the Canadian research effort on resource values indicated that he disagreed with this conclusion and felt that all substitution effects should be allowed for. In essence, the decision whether to allow for this substitution effect should take into account whether one wants to measure the value which would be lost if management were directed towards maximizing value, or the value which will actually be lost, given the management policy which is being followed.

2. Fire causes an infinite series of "gains" and "losses" in future years due to the rescheduling of future rotations. However, beyond the period of a full rotation, these value changes become so small that they may be ignored. In addition, they tend to balance each other.

Technically, the effect of fire is to interrupt either the man-made or the natural rotation cycle of the forest. Depending upon the timing of when the forest becomes economically accessible, this may result in a net value gain or a net value loss.

3. The extra amount that hunters would be willing to pay is referred to as "consumer surplus." Methods, based on comparison of travel cost expenditures for different kinds of activities, permit calculation of this component of value. However, studies of this type are expensive and probably not necessary for obtaining approximate values.

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APPENDIX A

PHYSICAL EFFECTS OF FIRE

The author of this study is not qualified to address the physical effects of fire. This appendix, which is excerpted from the March 1982 Tanana/Minchumina Fire Management Plan, addresses the effects of wildfire on soils, vegetation, wildlife, and air quality. Although the discussion is addressed to the Tanana/Minchumina Fire Planning Area, it is generally applicable to most areas of Interior Alaska where fire problems are most significant.

SOILS

In general, the soils on raised areas along moraines and hills, or along major drainages, are well-drained, sandy or gravelly loams. These are the warmest, most productive, and frequently the driest sites. Severe fire can damage soils on these sites if the organic mat is thin. However, these sites usually support deciduous plant or white spruce/moss communities, which are relatively fire-resistant.

In lowlands, extensive areas are underlain by cold wet soils, usually with a thick organic mat and often with permafrost. Fire effects on these sites can vary widely with the severity of fire and the nature of the permafrost.

Permafrost is a condition in which ground temperature remains below freezing for two or more years. Above the permanently frozen soil is an "active layer" which thaws and freezes each year. Thawing is retarded by the insulating effect of a thick organic layer. The active layer found in the Tanana/Minchumina area ranges from 10 to greater than 60 inches in depth.

Fine-grained permafrost soils may contain up to 50 percent water. They are extremely unstable and easily eroded when the insulating cover of vegetation is removed because water released by the melting ice can cause runoff even on very gentle slopes. Sandy soils can have a fairly high ice content but resist erosion because of their large particle size. Coarse-grained gravelly soils tend to be very stable because they are generally well-drained.

Many of the soils and substrates in the planning unit are composed of fine-grained materials. North-facing slopes, south-facing toe slopes, valley bottoms, and areas shaded by heavy tree cover are completely underlain by ice-rich permafrost. Complete removal of the shading or insulating vegetation mat results in rapid melting of the ice-rich, fine-grained soils and substrates. Rain may greatly accelerate melting. If the vegetation mat is removed to the edge of a water body, silt and organic material may wash into the water. Significant erosion rarely occurs after wildfires in interior Alaska because fires rarely consume the entire organic mat, although slumping and landslides occasionally occur on steep slopes after severe fires.

While wildfires have little effect on watershed values, major erosion frequently results from the use of mechanized fire equipment on ice-rich, fine-grained, permafrost soils. Complete removal of all of the vegetation and organic material during fireline construction causes much deeper permafrost melting than occurs in adjacent burned areas. Runoff channels and deep gulleys frequently form, and stream siltation can result.

VEGETATION

1. Major Plant Communities

The flora of the Tanana/Minchumina planning area is typical of interior Alaska. The immense area includes nearly all plant communities found in the Interior, ranging from conifer and hardwood forests to alpine tundra. The predominant forest cover types include black spruce, white spruce, hardwood, and mixed deciduous-conifer.

a. Black Spruce Woodland - Black spruce forests with a canopy closure of less than 25 percent, but greater than 10 percent, typically occur on poorly-drained permafrost sites. The understory is dominated by sphagnum moss on wetter sites and feathermoss/lichens on drier sites. Ericaceous shrubs[2], dwarf arctic birch, and cottongrass are also important. The trees are often very stunted due to the harshness of the site. These black spruce communities often have a thick organic mat, which surface wets and dries out quickly in response to changes in relative humidity. This, along with the continuity of fuel over larger areas, allows this vegetation type to burn readily when ignited during dry periods of time, usually with a crown fire. The site will be ready to burn again in 30-40 years, once a moss/lichen layer has developed in the new black spruce stand.

b. Open/Closed Black Spruce Forest - Black spruce stands with canopy cover greater than 25 percent occur throughout the planning area. Paper birch and tamarack are occasional components. These stands are usually located on slightly drier sites than are woodland black spruce communities, and the trees are often taller. The understory is usually dominated by feathermosses, although lichens may form a nearly continuous mat in some stands. Ericaceous shrubs, dwarf arctic birch, and low willows make up most of the shrub layer. Open/closed black spruce forests burn with a frequency similar to that of black spruce woodlands.

c. Open/Closed White Spruce Forest - White spruce forests with canopy closure greater than 25 percent form large, productive stands on warm well-drained sites, especially along major rivers. White spruce also commonly forms "stringers" along smaller streams and around lakes. Paper birch and balsam poplar often comprise a significant part of the tree canopy in these stands.

In open stands, a wide variety of shrubs and herbs dominate the understory, along with feathermoss. Alder, tall willow, prickly rose, buffaloberry, bunchberry, twinflower, and ericaceous shrubs are common. Fire occurs much less frequently in these forests than in the black spruce types. When they occur they tend to have lower intensities, although, occasionally, fires kill white spruce, particularly in older stands.

d. Open/Closed Deciduous Forest - Pure stands of birch, aspen, or mixtures of the two species are common on upland sites in the Interior. Aspen are most common on warm, well-drained sites, and grade into birch on colder, wetter sites. Aspen is an intermediate stage leading to white spruce, while paper birch sites may later be dominated by white or black spruce. A well developed understory of alder, willow, highbush cranberry and low shrubs is usually present, as well as herbaceous vegetation, mosses and lichens. Fires are infrequent in deciduous forests and generally are low intensity when they do occur. However, these fires often kill the thin-barked overstory, after which a new hardwood stand will quickly reestablish.

e. Tall Shrubland - Tall willow, alder, and shrub birch form dense stands between treeline and alpine communities, and in some riparian zones. The understory varies considerably, consisting of dense grasses and herbs, or mosses and lichens. Fires tend to burn very slowly and with very low intensity on the rare occasions when they occur in this vegetation type.

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[2] Ericaceous shrubs include blueberry, cranberry, Labrador tea, and other shrubs belonging to the taxonomic family Ericaceae.

f. Low Elevation Shrublands - Tall willows form extensive communities in low areas, particularly near the foothills of the Alaska Range. On moist sites the understory consists of a dense feathermoss/ericaceous shrub mat, while on dry sites there may be nearly continuous cover of lichens. The meager fuels and typically moist conditions seldom support fires of any notable size.

g. Shrub Bogs and Bogs - Vast shrub bog communities, dominated by ericaceous shrubs, are found over much of the area. Stunted black spruce and dwarf arctic birch are often scattered throughout. Shrub bogs occur on wet cold sites, generally underlain by permafrost, and have a thick organic mat. This community grades almost imperceptibly into black spruce woodland and low shrublands. On very wet sites, all shrubs disappear and a bog characterized by sphagnum dominates. These areas are often left unburned when large fires burn surrounding, drier areas.

h. Grasslands - Grassy meadows are scattered throughout the area on old lacustrine and glacial deposits. They are generally dominated by bluejoint grass and provide vital habitat for several wildlife species.

i. Tussock Tundra - Tussock tundra, dominated by cottongrass, is found on gentle slopes underlain by permafrost in mountain valleys in the northwest part of the planning unit. Other important species include ericaceous shrubs, mosses, and lichens, and frequently other sedges, shrub birch, and cloudberry. Fires in tussock tundra can burn with high intensity at any time of the summer because of the large amount of dead material. Fires can burn very deeply into the organic mat after a long dry period, but more characteristically consume only the surface organic layer.

j. Other Tundra Communities - Other tundra communities are also found within the planning area, but do not readily burn. Shrub tundra, dominated by dwarf birch, blueberry, Labrador tea, and dwarf willow, is fairly common at higher elevations, above the shrub bog communities with their stunted black spruce. Fires which burn into these communities from lower elevations frequently go out because of the moist conditions and sparse fuel. Fires which do burn have very slow rates of spread and low intensity.

The following communities are probably found within the planning unit at higher elevations, although their extent is unknown. Herbaceous tundra, meadow communities dominated by grasses and other herbaceous plants, are found on adequately drained, protected sites. Fires would be infrequent and of low intensity, because of low fuel loading, and summer-green conditions. Sedge-grass tundra is usually too wet to burn, and also has a very low quantity of fuels.

Mat-and-cushion tundra communities are located where harsh environmental conditions limit the development of vegetative cover. Discontinous low growing mats of vegetation, primarily of Dryas species and prostrate willow are found, along with ericaceous shrubs, other forbs, sedges, and sometimes lichens. Fire occurrence is very low because fuels are sparse and discontinous, and any fire would be quite small.

2. Fire Effects on Vegetation

Fire may be the chief factor maintaining vegetative productivity in cold Alaskan soils, in which the lack of nutrients is a major factor limiting plant growth. Most nutrients are tied up in the vegetative overstory and in the thick moss and organic layers, and are unavailable to plants. The insulating effect of the organic mat limits summer warming of soil, and keeps the level of permafrost close to the surface.

Burning organic material changes nutrients from complex forms unavailable for plant growth, to more simple and readily available forms in ash. The soil becomes warmer because the overstory and moss layer have been removed, the organic layer is thinned, and the darkened soil surface absorbs more of the sun's heat. The active layer becomes much deeper, increasing the volume of soil from which plants can extract nutrients. The soil nutrient regime is greatly improved by the increased activity of decomposing and nitrogen fixing organisms. The degree to which these changes occur is closely related to the amount of organic matter removed by the fire, a factor which can vary considerably for different fires and for different areas of a single fire.

The amount of organic layer consumption is the result of an interaction between the organic layer moisture content and the amount of heat released by burning fuel. The depth of burning, fire severity, is much greater if the organic layer has been dried by a long period of sunny weather, than if the fire occurs after only a few drying days. The type and amount of initial revegetation of the burned area will be closely related to the severity of the fire.

The three major means of plant regeneration after burning are: resprouting from the stumps of plants killed by fire, resprouting from lateral roots and rhizomes (buried stems), and plant development from buried or wind carried seeds. The depth of organic material remaining as a mat on the mineral soil will determine which of these means of revegetation will be the most important.

In Alaskan forests with deep organic layers, most of the below-ground plant parts are found in the organic mat, rather than in the soil. Roots and rhizomes of plants such as blueberry, mountain cranberry, and twin-flower are located in the upper portions of the organic layer, while rhizomes of other species, such as rose, raspberry, and fireweed tend to be more deeply buried. Many of the roots of willow and some of the lateral roots of aspen also grow in the organic mat. Because these plant parts are the source of new sprouts after fire kills above-ground stems, the depth of burn has a great effect on the amount of postfire sprouting, and the species likely to dominate the postfire community. If fire just scorches or burns the surface of the organic mat, killing, for the most part, just the above-ground stems, rapid and often prolific sprouting occurs from roots and rhizomes of those species found in the surface organic layers. If fire heat penetrates into the organic mat, killing plant parts to some depth but not consuming all organic matter, sprouts may originate from more deeply buried plant parts, and the sprouts may take longer to grow to the surface. Species with more deeply buried rhizomes and roots will be favored over those species which root primarily in the upper organic layer.

Complete consumption of the organic layer removes many or all of these potential sprouting sites, truly killing most plants on the site. A fire which burns away most or all of the organic layer will greatly limit the amount of vegetative reproduction which can occur after fire, but will favor development of new plants from seeds by creating good seedbed conditions.

Most plants of interior Alaskan forests require bare or nearly bare mineral soil as a prerequisite for successful seed establishment. When a seed falls on a blackened, but deep organic layer, it will germinate when there is plenty of moisture, such as after snowmelt or spring rains. However, the seedling will frequently die in a warm summer, because it is rooted in the organic layer which dries out. Because mineral soil retains moisture much longer than organic material, a seed landing on a mineral soil seedbed is much more likely to develop into a mature plant. Also, because postfire sprouting is limited on deeply burned sites, the amount of competition from other plants will be greatly reduced for several years.

A mosaic of fuel, organic layer and soil moisture conditions on a site can lead to a variable pattern of burn severity, and thus favors the development of a vegetation mosaic after the fire. Sprouts, seedlings, and vegetation which survived the fire may all be found. Successful re-establishment of seedlings, however, depends on more than the presence of a suitable seedbed. Other factors are also critical, such as the type and age of prefire vegetation, the time of year when the fire burned, the distance to the nearest seed source, the amount of seed consumed by rodents and birds, and the periodicity of seed crops. White spruce, for example, is physiologically capable of producing good cone crops every two or three years, but the lack of favorable weather for cone formation can greatly increase the interval. A ten year period between large cone crops is not unusal.

3. Postfire Vegetative Recovery

a. White Spruce - Although the amount and rate of postfire revegetation will vary, general successional sequences for Interior Alaska forests have been developed. Foote (1980) decribes six postfire stages for upland white spruce/ feathermoss communities:

1) Newly burned stage - lasts for a few weeks to a year. The forest floor is covered with a layer of charred organic material and ash. Suckers of rose, highbush cranberry, willow and aspen appear first; then seedlings of fireweed, aspen, paper birch, and rarely, white spruce. Red raspberry, and other herbaceous species will be present in lesser amounts.

2) Herb-seedling stage - (1-5 years postfire). This stage is dominated by shrubs, aspen, and herbaceous plants, particularly fireweed, and Ceratadon and Polytrichum mosses and the liverwort Marchantia, which colonize bare mineral soil. Vegetative cover increases, litter accumulates and a thin organic layer begins to form.

3) Tall shrub-sapling stage - (6-25 years postfire). The overstory is dominated by one to two meter tall willows, prickly rose, highbush cranberry, and aspen, with an understory of herbs, tree seedlings, and litter. The organic layer thickens to about 8 cm.

4) Dense hardwood stage - (26-45 years postfire). Hardwoods form a dense canopy and shade out the shrub understory. As the stage progresses, hardwoods begin to thin, and an understory of small spruce develops. Cladonia lichens are more abundant in this than any other stage, although they are not a significant part of the ground cover. Organic layer depth does not increase.

5) Mature hardwood stage - (46-150 years postfire). These stands are characterized by well developed aspen and/or paper birch, or mixtures of hardwoods and white spruce. Because paper birch trees tend to outlive the aspen by 30 to 50 years, older stands usually contain paper birch or birch/spruce mixtures. Highbush cranberry, prickly rose, twin-flower, and horsetails dominate the understory; leaf litter covers the forest floor; willows, mosses and lichens are not important. The organic layer depth averages 11 cm.

6) Spruce stage - (150 to 300+ years postfire). Mature white spruce dominates, with a few remaining hardwoods in younger stands. Prickly rose and highbush cranberry are the major understory species, but may be replaced by green alder in older stands. Twin-flower and horsetails are common. Feathermosses cover the forest floor, over a 12 cm organic layer.

It has been suggested that without fire, some old upland white spruce sites would eventually be replaced by black spruce and bog, or a treeless moss/lichen association, although others believe that white spruce stands are the final vegetation stage. Substantial evidence indicates that older white spruce stands on floodplains are replaced by black spruce as permafrost develops under accumulating moss and lichen layers.

b. Black Spruce - Postfire revegetation of black spruce/feathermoss sites follows a sequence similar to that for white spruce sites, but the duration and dominant species of later stages differs. Permafrost is close to the surface on most black spruce sites. Fire's consumption of some of the organic layer, and the blackened surface will result in a warming of the soil profile. Depth of the active layer will increase and soil and vegetative productivity will markedly improve. The following sequence of postfire vegetative changes have been detailed by Foote (1980).

1) Newly burned stage - (0-1 year after fire). Within a few days of the fire, sprouts of willow, prickly rose, bog blueberry, bluejoint, Labrador tea, cloudberry, and Polytrichum moss appear. Charred materials cover most of the forest floor throughout this stage.

2) Moss-herb stage - (1 to 5 years postfire). Other species also become important, including black spruce, aspen, paper birch, additional species of willows, resin birch, mountain cranberry, Ceratodon moss and Marchantia, as well as bluejoint, cloudberry and horsetail. The active thaw zone increases greatly during this stage.

3) Tall shrub-sapling stage - (5 to 30 years postfire). Tall shrubs and/or saplings dominate the overstory, especially willow and aspen. Black spruce and hardwood seedlings are abundant. Ceratodon moss, fireweed, bluejoint, blueberry, Labrador tea and mountain cranberry dominate the low growing vegetation. The active layer reaches its maximum depth, averaging 82 cm.

4) Dense tree stage - (30 to 55 years postfire). An overstory of numerous young birch and/or aspen trees is present, with extensive patches of low shrubs, feathermosses and Cladonia and Cladina lichens. Cover of herbaceous plants and willow has greatly decreased, while resin birch, prickly rose and green alder are still common. The trees begin to self-thin during this period. These stands are highly flammable and frequently burn.

5) Mixed hardwood-spruce stage - (56 to 90 years postfire). A mixed overstory of black spruce, aspen, and/or paper birch dominates. Hardwoods are mature and begin to stagnate and die out. Prickly rose, mountain cranberry, blueberry, bluejoint, bunchberry and feathermosses are the major understory species. The permafrost table begins to advance, averaging 57 cm below the surface. Many stands burn during this successional stage.

6) Spruce stage - (91 to 200+ years postfire). This final stage has an overstory of black spruce and perhaps a few relict aspen and paper birch. A mid-vegetation layer of green alder, smaller black spruce and sometimes prickly rose overtops the forest floor layer of feathermosses, Sphagnum moss, mountain cranberry, blueberry, and a few herbs. A few Cladina and Cetraria lichens are present. With increasing stand age, sphagnum mounds increase in size, the moss layer thickens, the depth to permafrost decreases, and vegetative growth stagnates, because of cold soils and unavailability of nutrients.

Without fire, wet boggy conditions and a fairly open stand of stunted black spruce will develop on colder and wetter sites. On mesic black spruce sites, stands may increase in density, maintaining themselves by layering and rooting of lower branches, or may decrease in density, with many dead and dying trees and little reproduction. Fire is the only way to restore upland black spruce sites to a productive state.

c. Tussock Tundra - Fires in tussock tundra remove varying amounts of cottongrass, shrubs rooted in the cottongrass tussocks, tussock mounds, and adjacent mosses, lichens and organic matter. Vegetative recovery after most fires will begin within a few weeks, with sprouting of cottongrass, other sedges, shrub birch, ericaceous shrubs, and cloudberry. Because flowering and seed production of cottongrass increase manyfold, seedling establishment occurs on favorable seedbeds. Lightly burned lichens may regenerate from unburned basal parts. After 7 or 8 years, little direct evidence of fire may be visible.

Revegetation on severely burned sites will proceed more slowly. Many cottongrass tussocks will be partially or completely consumed by fire, and less sprouting will occur. Some shallow rooted shrub species, such as mountain cranberry and crowberry, may be temporarily eliminated from the site. Cottongrass reestablishment from seed will be a major means of revegetation. Lichens will initially establish from wind blown lichen fragments which land on moist microsites, but it is not known how many years will be required before lichens regain their prefire abundance.

The tussock growth form is a very important adaptation to these cold sites. Higher than the general ground level, tussocks receive more sunlight, thaw more quickly in the spring, reach maximum summer temperatures sooner, average 6-8° C warmer than soils beneath the surface, and have more favorable nutrient regimes because of the warmer temperatures. The tussock growth form ensures much higher productivity for tussock sedges and associated plants (Chapin, Van Cleve, and Chapin, 1979).

Productivity will decline as sphagnum and other mosses fill in the spaces around the tussocks. Tussocks will no longer receive additional sunlight, so their internal temperature will be as cold as soil temperatures, and growth of most vegetation will stagnate. Some tussocks may eventually be completely buried by sphagnum. Because tundra fires cannot be dated with present methods, it is not known how long this process takes. The effect of sphagnum moss accumulation on tussock tundra lichen production is not known, but it may be detrimental, as it is on black spruce sites.

d. Other Non-forested Sites - Postfire revegetation in shrublands and bogs is primarily by resprouting of shrubs, grasses, sedges, and low growing herbaceous plants. Because these vegetation types are fairly wet, fires rarely burn severely enough to burn all roots and rhizomes. After the rare event that a fire burns deeply into the organic layers, seed reproduction will assume greater importance, and recovery of the prefire vegetation will initially be slower.

Fires in grassy meadows can be intense, but are usually beneficial, even in the short term. Sprouting occurs within a few days. Removal of accumulated litter and darkening of the soil surface promotes earlier snowmelt and green-up, and therefore a longer growing season. Seed production is much greater, and grass production will increase for several years, only declining as litter accumulates to prefire levels. Fire will also benefit meadows by removing or killing back encroaching trees and shrubs.

Postfire revegetation of sedge-grass, and mat-and-cushion tundra has not been studied in Alaska. It is likely that plant recovery will be by sprouting if perennating plant parts are not destroyed. If sprouting sites are killed, recolonization of the small burned areas will probably be from seed, or from roots and rhizomes which spread into the burned area from adjacent living plants.

WILDLIFE

1. Fire Effects on Habitat

Fire is a natural occurrence within Alaskan ecosystems. Generally, the effects of fire on habitat are much more significant than the effects on existing animals. Habitat changes determine the suitability of the environment for future generations of animals. Fires may have a short-term negative impact on existing animals by displacing or sometimes killing them or by disrupting critical reproductive activities. However, these animal populations recover quickly if suitable habitat is provided. Generally, fire improves the habitat for a wide variety of species. The adverse effects that the immediate generation of wildlife may experience are usually greatly offset by the benefits accrued to future generations.

Most of the planning area is covered with a mosaic of forest and bog habitat types that have been collectively termed the northern boreal forest. Fire is the primary agent of change in the boreal forest and is responsible for maintaining habitat heterogeneity. Wildlife have evolved in the presence of fire and have adapted to its presence. Indeed, the continued well-being of most species of wildlife depends on periodic disturbance of the habitat by fire. Even those species normally associated with mature stages of vegetation are able to accommodate and benefit from some level of disturbance by fire.

The grasses and herbaceous plants that quickly reestablish on burned areas provide an ideal environment for many species of small mammals and birds. A rapid increase in microtine population usually occurs following a fire. This abundance of small prey animals in turn makes the recently burned area an important foraging area for predatory animals and birds. However, the size of the fire and the subsequent proximity to cover, and denning or nesting sites affects the degree of use by these larger animals.

Fire severity and frequency greatly influence the length of time that this grass and herbaceous plant stage will persist. Severe burning delays the reestablishment of shrubs, a benefit to grazing animals and seed-eating birds. Frequent reburning of a site further retards generation of shrubs and seedlings and prolongs the grassland environment.

For some species of wildlife, such as bison, this perpetuation of a grassland environment is beneficial. Where bison are present, a management program that entails periodic burning to preclude invasion by shrubs and trees can supplement the rangeland that is naturally available along the braided river courses.

Browsers such as moose, ptarmigan and hares can benefit from the fire as soon as shrubs and tree seedlings begin to reestablish. If a fire leaves most of the shrub root and rhizome systems intact, sprouting will occur very soon after burning. In the case of early season fires, some forage may be available by the end of the growing season and limited use by browsing animals may occur. Forage quality is much improved, with higher digestability, protein, and mineral content for some years after fire. As tall shrubs and tree saplings begin to dominate, the site becomes increasingly able to provide shelter and forage for a greater variety of wildlife. Although the rate of regrowth varies among burned areas and is dependent on many factors discussed earlier, this productive stage can persist for as long as 30 years after fire.

The greatest variety of wildlife will be found during the tall shrub-sapling stage. Many species, which up to that point have frequented the burned area only to hunt or forage, begin to find that it provides shelter and denning or nesting sites as well. This abundance and diversity of wildlife, in turn, makes these burned areas extremely important to people, whether it be to hunt and trap or to view and photograph.

On most sites the young trees outgrow the shrubs and begin to dominate the canopy after 25-30 years. At this point the shrub component thins out and changes, as more shade-tolerant species replace the willows. Subsequently, use by browsing animals such as moose, hares, and ptarmigan declines. On mesic sites which are developing into black spruce forest, lichens become important during this period and increase in abundance for 50 to 60 years.

As the forest canopy develops and the understory species disappear, a burned site becomes progressively more unproductive. Relatively few animal species can find the requirements necessary for their survival in the mature spruce forest that will eventually develop in the absence of further fire.

Because lichen cover increases in these more mature stages of black spruce stands, these areas are very valuable for lichen foraging animals such as caribou at this stage of development. However, in older stands, lichens are slowly replaced by feather and sphagnum mosses. On valley bottoms where a muskeg-bog situation exists, lichen cover also develops but, contrary to the upland sites, lichens may persist as succession advances.

Generally speaking, large, severe fires are not nearly as beneficial to wildlife as are more moderate fires. Lighter fires quickly benefit browsing animals and their predators by opening the canopy, recycling nutrients, and stimulating sprouting of shrubs. In addition, the mature trees which are killed but not consumed by the fire, provide nesting sites for hole nesters such as woodpeckers, flickers, kestrels, and chickadees, as well as some cover for other animals. A severe fire that burns off the aboveground biomass and kills root systems, removes all cover and slows the regeneration of the important browse species, which must now develop from seeds.

Some sites, however, have progressed so far toward a spruce forest community that very little shrub understory exists from which revegetation of the site may occur. Furthermore, many sites are so cold and poorly drained that black spruce have a competitive edge over the less tolerant shrub species. In these situations, a light fire simply results in more spruce. Severe fire, or frequently recurring fires are necessary to kill the seeds in the spruce cones and prepare a suitable seedbed for other species. Then the value of the site to most species of wildlife is enhanced.

2. Wildlife Response to Fire

a. Moose - Moose were formerly much more abundant within virtually all portions of this planning area. Quality of moose browse in much of the area appears to be deteriorating and until fire or other disturbances are permitted to occur, overall carrying capacity for moose will not significantly increase. Fire suppression activites have interrupted the natural fire regime in much of the area to the overall detriment of moose and other species dependent on early forest seral stages.

Moose populations usually increase following fire due to increased production of high quality browse in the burned area. However, if the moose population has declined for reasons other than poor habitat, moose may be slow to utilize new habitat created by burning, and numbers may not increase dramatically. Under these circumstances the remaining moose have little trouble obtaining sufficient browse without utilizing the new burn. Use of a burned area will depend largely on whether it is situated in an area traditionally used by moose or through which they migrate. Dispersal to new areas will be slow. If, however, a fire occurs in an area where the moose population is near carrying capacity of the range, then competition for food and social pressures between individuals will result in more rapid exploitation of new habitat created by a fire. The use of burned areas by moose is also related to the amount of available cover. Fires of moderate size or large fires that contain numerous unburned inclusions create more edge effect than extensive severe fires, resulting in better moose habitat.

b. Caribou - It appears that caribou may not be adversely affected by fire to the degree once believed. The short-term effects of fire on caribou winter range are mostly negative. These include destruction of forage lichens, reduced availability of other preferred species in early postfire succession, and temporary alterations in caribou movements. However, forage quality of vascular plants will be improved by fire.

Long-term effects are generally beneficial. Light fires may rejuvenate stands of lichens with declining production. Fire helps maintain diversity in vegetation type, replacing old forest stands where lichens have been replaced by mosses, thereby initiating the successional cycle which leads to the reestablishment of lichens. Fire creates a mosaic of fuel types and fire conditions that naturally precludes a series of large, extensive fires that may be devastating to caribou habitat. Caribou are nomadic and each herd has historically utilized a range much larger than necessary to meet its short-term food needs. Thus, gradual rotation of the forest system by fire can be accommodated and, as pointed out, may be essential to prevent large severe fires which burn huge portions of a herd's range and result in an immediate lowering of range carrying capacity.

The long-term effects of fire on caribou range may be negative in some cases, however. Fires that recur frequently over a relatively short period of time may result in forests being replaced by grasslands or shrub-dominated communities, although this is not likely to occur over large areas. Also, large severe fires can create monotypes which would lead to irregularity in productivity and abundance of forage lichens.

While historic reasons for the decline in caribou distribution and abundance are not well known, loss of winter range to fire is not a probable cause. Although much of the caribou range occurs in an area of high fire frequency, there is no indication that natural wildfire has occurred more frequently in recent years than in the historic past. In fact, it is likely that less acreage has burned annually in recent times because of improved fire suppression capabilities.

c. Dall Sheep - Winter range, lambing areas, and mineral licks are critical elements of Dall sheep habitat. Because the vegetative cover found on sheep range does not carry fire well in most cases, fire normally does not play a significant role in sheep population dynamics. Under some circumstances, fire may enhance sheep range by depressing treeline in areas where the boreal forest has encroached on alpine habitat.

d. Bison - Wildfires are extremely beneficial to bison. The present habitat is maintained primarily by river erosion and flooding; however, fire has the potential for greatly expanding suitable bison habitat away from the floodplain. The grasses and forbs that are the mainstay of their diet quickly reestablish after a fire. Burning serves to stimulate new growth and remove the mat of old material, causing earlier green-up. In addition, an extensive severe fire may result in a long lasting grass stage, by killing sprouting trees and shrubs, and tree seeds. Repeated fires can have the same result by killing tree and shrub vegetation before it is mature enough to produce seeds. The August 1977 fire in the Farewell area created new grassy areas which were utilized by bison during the summer, fall, and winter.

e. Black and Grizzly Bears - Black and grizzly bears are both benefited by fire, responding in much the same way as do their prey species. Both are omnivorous, and fires increase the availability of both plant and animal foods. Blueberries, cranberries, and soapberries increase following fire, particularily in upland areas. Moose calves are important in the diets of both the black and grizzly bears in the springtime. Early stages of plant succession tend to increase moose production, therefore, more calves are available as prey. Small mammals are more readily available and play an important role in bear diets during the snow-free months. The grizzly, in particular, should benefit from increased large rodent populations following fire, although this is speculative and not yet proven. Because black bears make extensive use of lowland marshy areas during spring, fires ocurring in such areas should be considered beneficial for this species.

f. Upland Game Birds and Small Game Mammals - Upland game birds and small mammals are also herbivores and as such, generally benefit from the increased forage and diversity created by fires in the boreal forest.

Sharp-tailed grouse prefer the open, shrubby areas created by fire over the dense forest. In the absence of fire sharp-tailed grouse frequent the open muskeg bogs; however, openings created by fire apparently are preferred and are not nearly as limited. Sharp-tailed grouse extensively utilize young burns both for foraging and for essential reproductive activities such as "lekking" (display activity on communal dancing grounds).

Ruffed grouse numbers may be initially depressed by the occurrence of a fire; however, they begin using the burned areas extensively as foraging sites when the sapling stage develops. Most researchers believe that the overall effects of fire upon ruffed grouse are beneficial and that fire may indeed be essential for the maintenance of healthy populations of ruffed grouse in the boreal forest.

Fires in ptarmigan summer habitat are a rare occurrence, since breeding occurs in the alpine areas at higher elevations. However, fires near treeline could increase ptarmigan nesting habitat by removing spruce trees that are encroaching on alpine tundra sites. Because most ptarmigan migrate to lowland areas for the winter months where their primary winter foods are young willow and birch, fires in the boreal forest can improve habitat for ptarmigan.

Spruce grouse appear not to be benefited by fires because of their preference for mature coniferous forest habitat. Changes in habitat that affect availability and suitability of nesting areas, brood rearing areas, feeding places or roosting sites would greatly impact spruce grouse.

Snowshoe hares normally prefer older stands of black spruce and thick alder tangles during lows in their 10-year cycles. During population highs, however, hares will use even severely burned areas. Hares normally use open areas during summer months when their diet consists largely of herbaceous plants and leaves from low shrubs which are more abundant and nutritious on recently burned sites. Small fires or large fires with numerous unburned inclusions of black spruce or other heavy cover should provide optimal habitat for hares.

g. Aquatic Furbearers and Waterfowl - When fires occur in riparian (streamside) areas and marshes, they can be beneficial to muskrat, beaver, goose, duck, and swan populations. Without fire, ponds will usually be filled in by marsh vegetation. Organic matter accumulation will then favor the establishment of shrubs and trees. Fire rids marshes of dead grass, sedges, and shrubs and thereby tends to open up dense marsh vegetation to a degree that suits feeding waterfowl. Burning also stimulates the growth of new shoots which are of greater forage quality. Fire can have a short term negative impact when it occurs during nesting or molting periods.

Fire also is an important factor in the maintenance of marsh systems. In dry summers, peat marshes can burn down to the point where new bodies of water are created. Burning also alters the insulative effect of old marsh vegetation and allows solar heat to penetrate and alter the marsh subsurface where permafrost or ice lenses are prevalent. Subsequent melt-outs can result in new ponds and altered vegetative cover.

h. Terrestrial Furbearers - The furbearers other than beaver and muskrat are carnivorous and tend to respond to fire in a manner similar to that of their primary prey populations. Some predators such as lynx are very specific, concentrating their efforts toward securing snowshoe hares. Others such as the red fox are less specific and are able to thrive on a variety of prey species such as rodents, hares, birds, and even fruits and berries at certain times of the year.

Because of their extremely large home ranges, wolves should not be harmed by fires of small or moderate size and will derive benefits from such fires as habitat conditions develop that favor prey species. Extremely large fires in caribou winter range, however, may cause changes in caribou migration routes and choice of wintering areas. In that case, wolves would also be forced to cease using the area, or switch to alternate prey species.

Fire probably benefits wolverine in most cases because ample food sources are apparently their key habitat requirement.

Red foxes have been characterized as animals of open grasslands and low shrubs, subsisting primarily upon rodents and hares. Therefore, depending upon the numerical response of red-backed and meadow vole populations on a site, the first 10 to 20 years following fire should benefit red foxes.

Lynx appear to prefer the same habitat types as snowshoe hares, their primary prey; therefore, fires which benefit hares by increasing browse production in association with adequate cover will also benefit lynx. Numerous small fires with numerous unburned inclusions should create optimal conditions for hares and lynx.

There is a common assumption that all fires are detrimental to pine marten populations, and intense fires do remove large trees which provide denning habitat. However, at the same time the food base for marten may be expanded. The food preferences are broad and marten are not dependent upon a particular prey species. Mice and voles constitute the main source of food, along with birds, squirrels, and berries. The frequently voiced assumption that martens depend heavily upon red squirrels probably is not valid in Alaska.

Large fires that result in extensive replacement of mature spruce with aspen and birch are decidedly detrimental to marten. Marten usually abandon these burned-over sites. However, the mosaic created by small fires or fires with unburned inclusions of spruce probably benefit marten populations more than they harm them. Cover and denning sites are retained in the unburned portions, while nearby foraging areas (openings created by fire) are improved.

Both the least and short-tailed weasel benefit from the increased prey abundance that usually follows burning.

Coyote populations are benefited by fires that result in many openings within the boreal forest or which result in replacement of forest with grassland.

i. Small Mammals and Birds - Fires either benefit most small mammals or cause only temporary declines in their populations. Because vegetative recovery enormously increases available biomass on burned areas, population declines are more than compensated for in a short time. Red-backed voles, a species known to inhabit mature black spruce forests, will quickly exploit newly burned areas adjacent to mature stands of black spruce. Meadow voles often will begin using the same burned area in about the third year. Peak rodent densities in one study occurred when environmental conditions could be tolerated by both red-backed and meadow voles 7 to 16 years following fire. The implications of these observations are that predators largely dependent upon rodents will derive maximal overall benefits from a fire during that period of rodent super-abundance.

Although most small mammal species thrive best in very early seral stages of vegetation, a few, like the red squirrel and flying squirrel, are adapted to old-age coniferous forests. These squirrels are dependent on white spruce for food and cover, and would be adversely affected by fire.

The habitat requirements for passerine birds varies greatly. Some like the pine grosbeak are specialized seed eaters that prefer spruce forest. However, most species frequent younger seral stages of vegetation and are most abundant in areas of greatest plant diversity. All burned areas will not be the same age nor size in an area with a history of fire, nor will conditions in like-age burns be the same because of differences in prefire vegetation, and fire severity. This presents a diverse vegetative mosaic that will support a wide spectrum of bird life. Extensive stands of black spruce present a rather narrow set of enviromental conditions which restricts the number of bird species which can inhabit such areas.

Studies of songbirds in relation to fire in the north are scarce; however, one study (Klein, 1963) graphically demonstrated the changes that can occur following fire in the boreal forest. After burning of a white spruce forest in

Alaska in 1948, only 19 birds of 7 species were seen during 20 hours of observation. By 1957, 9 years later, nearly 200 birds of 19 species were seen, but by 1961, 13 years later, only 16 species were observed. Woodpeckers were well represented because of insects in the fire-killed spruce.

j. Raptors - Hawks, owls, eagles, and falcons generally benefit from fire. Small raptors that feed on mice and voles benefit most rapidly, since the herbaceous vegetation that is preferred by these small rodents returns to a burned site quickly after a fire. Raptors that specialize in preying on hares, grouse and ptarmigan benefit the most when shrubs and sapling trees invade the burned site. Small fires or large fires with many unburned inclusions would generally be best because of the vegetative mosaic that would result. The sharp-shinned hawk is probably the only raptor in Alaska that might be adversely impacted by fire. These hawks forage in the scrubby, open black spruce muskegs and prefer spruce trees for nesting sites. Other raptors are not nearly so restrictive in their foraging and nesting requirements. Golden eagles, great gray owls, great horned owls, boreal owls, goshawks, and hawk owls will nest in conifers, but neither require them nor necessarily prefer them. Kestrels, hawk owls, and boreal owls nest in tree cavities created by nesting woodpeckers. Burning produces standing dead trees that are readily utilized by woodpeckers, flickers, and other hole nesting species. Other raptors such as short-eared owls and harriers forage and nest in grassy meadow situations which are usually created and maintained by fire.

k. Fish - Fire effects which can directly impact fish populations are increased siltation and increased water temperature. Indirectly, any alteration of the nutrient flow which adversely affects aquatic organisms will also in turn affect fish populations.

Very little surface erosion normally occurs on burned sites in interior Alaska (except where heavy equipment is used to suppress the fire); thus, stream siltation is usually negligible. The few studies which have been conducted on fire effects on stream temperature indicate no postfire increases in the temperature of streams within a burned area. Thus, fish species which are adapted to the cold water in Interior streams are not likely to be affected. Burning also does not seem to adversely impact the aquatic fauna in the Interior.

Fire has the potential for initiating other changes in a riverine system. A stream that coursed unimpeded through white spruce before a burn, may become dotted with beaver colonies 10 to 20 years after a fire. Beaver ponds provide excellent rearing waters for salmon fry and can also benefit grayling and pike. On the other hand, beaver dams may restrict fish migrations and could temporarily result in the absence of grayling from the upper reaches of some streams. Probably in most cases the presence of beaver ponds is beneficial to the fish resource of the area and should be viewed as a positive attribute of fire.

The inevitable fate of vegetation is decomposition and eventual incorporation into soil. During a very short period of time while a fire is burning, processes of oxidation and chemical transformation occur which are similar to those that slowly occur in decomposition, with the concurrent production of some materials that go into the atmosphere and are eventually returned to the vegetation system. There is a great chemical similarity between the products of combustion of forest fuels and the products of decay. A summary of emissions (Figure 2) from forest burning indicates relatively large amounts of carbon dioxide, water, particulates, and carbon monoxide. Lesser amounts of hydrocarbon and nitrogen oxides, and essentially no sulfur oxides are produced from forest fires (Martin, 1976).

There are substances, termed and regarded as "pollutants," which emanate from forest burning and enter the atmosphere. Carbon dioxide (CO_2) and water (H_2O) emissions are not considered pollutants. Carbon monoxide (CO) is toxic and lethal concentrations of CO have been found in the active part of some fires. High CO concentrations at the fire site decrease rapidly in any direction to ambient conditions. The burning of forest fuels contributes only 1/600 of the total CO emitted from other natural sources. Unsaturated hydrocarbons (HC) of low molecular weight are related to Los Angeles-type photochemical smog. Hydrocarbons known to be photochemically reactive are present in wood smoke but, with the exception of ethylene, in very small amounts. Hydrocarbons are extremely widespread in the plant world in volatile oils, waxes, and resins. The most prevalent HC in the atmosphere is methane (marsh gas) which originates primarily from the decay of organic material. The relative importance of HC emitted from forest fires, as far as photochemical smog is concerned, appears to be very small. Nitric oxide (NO) is also regarded as an important pollutant because of its involvement in photochemical smog processes which may produce damaging compounds such as ozone (O_3) and peroxyacylnitrates. NO is not a combustion product, but forms when air is heated higher than 2800° F. On a global basis, natural production of NO, mostly by soil organisms, exceeds man's production by 15 to 1. Forest fires are an insignificant source of NO. There is no evidence that the emissions from combusion of forest fuels are a threat to human health (USDA Forest Service, 1976).

The visible column of smoke from a forest fire contains a lot of water, very small aerosols of organic matter, and some unburned carbon in finely divided form. The water condenses on the particulates, forming a cloud of water droplets. The total accumulation of particulates or aerosols from burning wood is very small in comparison with that emanating normally from forests. The principal valid objection to the burning of forest fuels as regards particulate pollution is the temporary interference with visibility. Military, commercial, recreational, and even fire detection and fire suppression aircraft activities can all be adversely affected by smoke. However, data from the Alaskan interior indicate that smoke conditions severe enough to impact aircraft (visibility reductions to 6 miles or less) do not occur to the extent generally assumed (refer to Table 1). Yearly occurrences of heavy smoke range from an average of about 6 days per year at Tanana to about 2 days per year at McGrath. Even when heavy smoke is present, it is rarely (less than 40%) so severe as to exceed the Visual Flight Rule (VFR) weather minimums for aircraft within a control zone airspace and very rarely (less than 15%) exceeds VFR minimums for areas outside of control zone airspaces. The historical occurrence, extent, and duration of heavy smoke in the interior of Alaska indicate the problem is minimal.

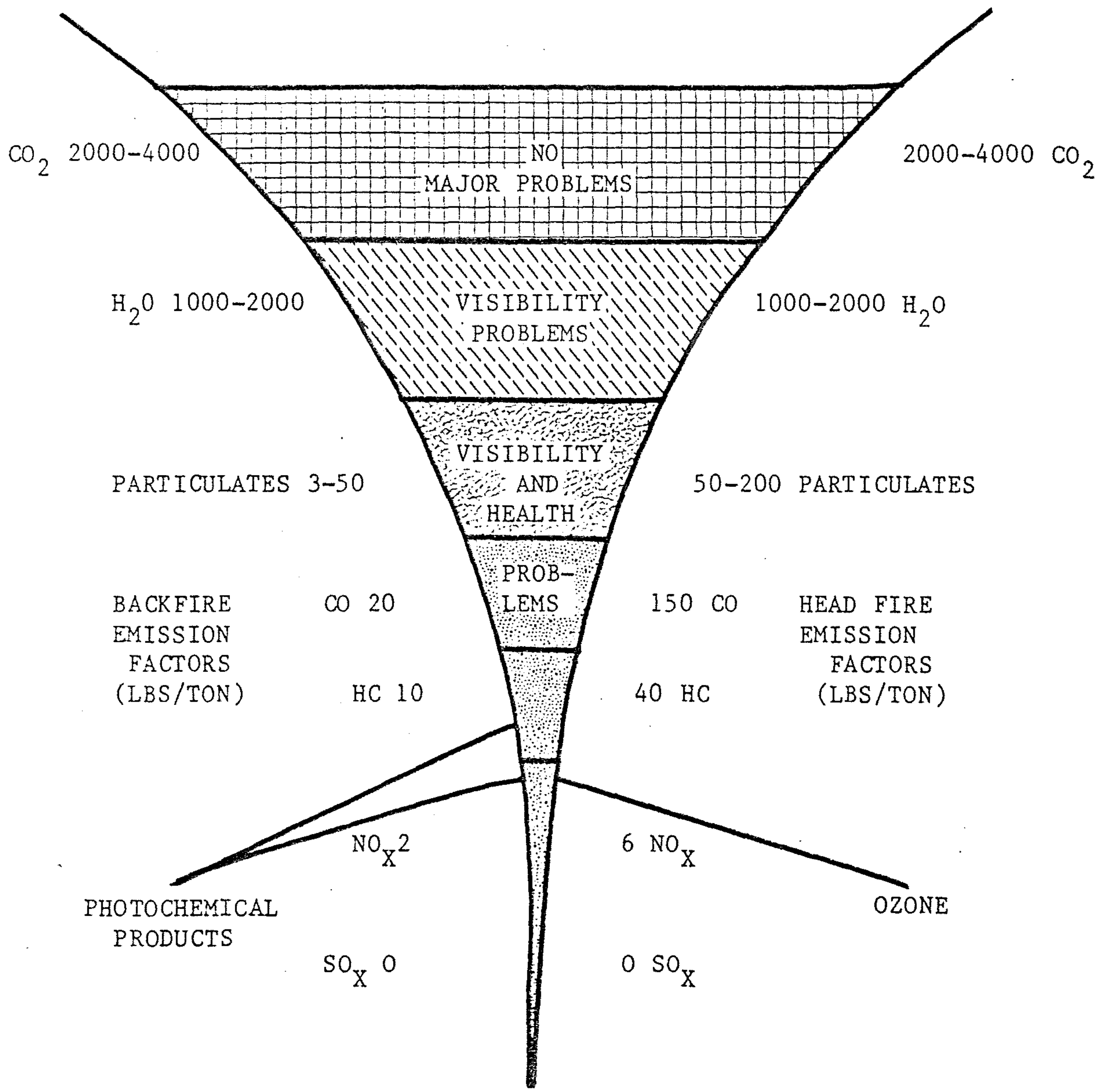

Figure 2. Range of emission factors from forest burning. Because difficulties in sampling and the complexity of the problem, estimated levels of emission factors may vary greatly from these data. (Figure is adapted from that of P. W. Ryan, Southern Forest Fire Laboratory, USDA Forest Service, Macon, Ga. Figures for emissions of carbon dioxide, water, and particulates have been modified.)

Table 1

Occcurrence of Heavy Smoke[1] Conditions in Interior Alaska

STATION NAME	NUMBER OF YEARS OF DATA	TOTAL NUMBER OF SMOKE DAYS[2]	YEARLY AV. NUMBER OF SMOKE DAYS[2]	TOTAL NUMBER OF DAYS VISIBILITY WAS LIMITED BY HEAVY SMOKE BY DISTANCE CLASS (MILES) 0-1/8	3/16-3/8	1/2-3/4	1-2½	3-6
Fairbanks	24	116	4.8	0	2	14	28	72
Farewell	13	30	2.3	0	1	4	10	15
Galena	18	67	3.7	1	7	5	26	28
Indian Mountain	20	69	3.5	1	2	8	12	46
Lake Minchumina	22	46	2.1	0	1	4	9	32
McGrath	20	38	1.9	0	1	5	14	18
Nenana	24	101	4.2	0	2	7	19	73
Tanana	15	85	5.7	0	1	9	20	55
TOTAL NUMBER OF SMOKE-DAYS		552		2	17	56	138	339
% OF TOTAL NUMBER OF SMOKE-DAYS BY DISTANCE CLASS				.4	3.1	10.1	25.0	61.4

(1) Heavy Smoke - Visibility reductions to 6 miles or less.

(2) Smoke-Day - Any day in which smoke, haze, or smoke and haze was reported at any one of eight tri-hourly observations for the given station.

VFR weather minimums for airports within a control zone airspace are a 1,000-foot ceiling and 3-mile visibility.

VFR weather minimums for aircraft operations outside of the control zone airspace are "clear of clouds" and "1-mile visibility."

(Table is a modification from Barney, R. J., and E. R. Berglund. 1974. Wildfire Smoke Conditions: Interior Alaska, USDA For. Serv. Res. Pap. PNW-178, 18 p., illus. Pacific NW For. and Range Exp. Stn., Portland, Oregon).