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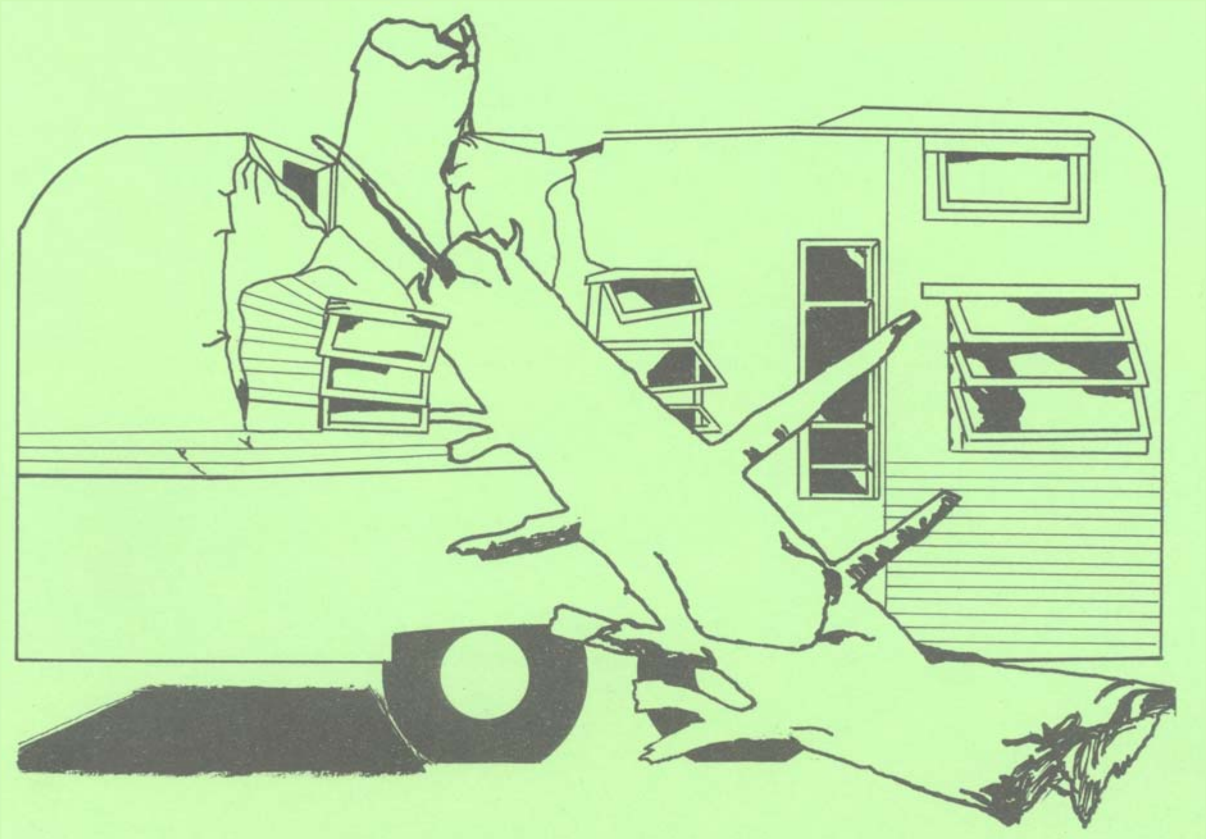
administrative goals and safety standards for hazard control on forested recreation sites



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For efficient control of tree hazard on recreation sites, a specific administrative goal must be selected. A safety standard designed to achieve the selected goal and a uniform hazard-rating procedure will then promote a consistent level of safety at an acceptable cost. Safety standards can be established with the aid of data for past years, and dollar evaluations are feasible. Cost optimization is possible but impractical with available data. The legal risk in adoption of safety standards is considered acceptable.

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Retrieval Terms: hazard trees; recreation areas; accident prevention; tree failure; safety standards; management goals; safety engineering.

CONTENTS

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Accidents resulting from the failure of trees occur on most forested recreation sites. On public recreation lands, tree hazard poses serious economic and public relations problems.

Resource management agencies control hazards on developed recreation sites as a matter of public responsibility. Performance of the control programs can be judged by their success in meeting safety policy aims and by the cost of control for a given level of protection. But administrative goals and safety standards have rarely been established. The control of tree hazard is often hampered by an ill-defined policy and inadequate supervision. The success or even the value of a program may be in doubt; when no realistic policy aims have been set, there is little basis for evaluation.

Tree hazard losses and control cost for developed recreation sites are estimated at about $2 million annually on State and Federal lands in California alone. Thus, efficiency in operation is essential even when protection is judged adequate.

This paper describes some of the options available to the administrator in selecting agency goals and standards.

One proposal, described in detail, is recommended for use by public land agencies in managing large administrative units in the United States. The important consideration is the establishment of a definite goal, to which hazard control programs can be tailored, and against which their success can be gauged.

ESTABLISHING GOALS AND SAFETY STANDARDS

Hazard may be defined as the probability of mechanical failure or uprooting of a tree with conesquent injury or property loss. It can never be eliminated on forested recreation sites as long as any trees remain standing *(fig. 1).* Yet, managers of sites to which the public is specifically invited are held responsible for the “elimination” of hazard. Because they are also responsible for maintaining attractive recreation sites in a forest ambient, they must arrive at a balance between too great hazard and too few trees.

To provide for a consistent and economical balance, the administrative office must (a) select a goal in finite terms, (b) set a safety standard based on the

Figure 1—Even relatively sound trees pose a definable hazard on recreation sites.

defined goal, (c) provide a uniform method for rating hazard, and (d) set a hazard rating (hazard control level) below which hazard will not be controlled. Periodically, as conditions change, the hazard control level can be adjusted to satisfy the safety standard.

The need for administrative goals is clear. Administrators must provide the highest level of public safety commensurate with budget restrictions, technical expertise, and esthetic considerations. Vaux[1] notes that "[Goals] are part of the feedback mechanism through which an organization evaluates its performance." Until current performance is evaluated with reference to a reasonable goal, no program can be judged either effective or noneffective.

There is adequate precedent in the field of public safety for finite goals. State and municipal traffic departments characteristically base remedial action on guides limiting the number and severity of accidents. Personnel safety programs in government and industry are also organized to meet practical goals, even though they must be revised from year to year. The establishment of such goals for recreation site hazard management will be beneficial in terms of both economy and public safety.

Definitions and Limitations

To define goals and safety standards, specific terms must be chosen. In this discussion, property damage or personal injury resulting from tree failure is an *accident;* a *failure* has the potential for causing an accident, whether or not it actually does so; an *accident-failure* is a tree failure involved in an accident. The term "failure" does not imply that any defect could necessarily be detected prior to failure. A *nondefective failure* is one in which no defect directly contributing to the failure is detectable.

The Report of Tree Failure *(fig. 2),* currently in use by government agencies, provides data on numbers and types of failures and accidents. From these reports, accident rates were found to be more variable than failure rates. Therefore, although a goal can be stated in terms of allowable accidents, the safety standard is better defined in terms of allowable failures.

The site categories to which a goal and safety standard will apply should also be defined. Responsibility is clearest for sites that are signed and that implicitly or explicitly invite public entry, but other sites may also require control or inspection *(fig. 3).* In general, the defined categories should include (a) developed sites which invite public use, (b) those perimeter areas and volunteer sites on which control is normally practiced, and (c) other sites on which the agency retains a responsibility for inspection.

Sites with no tree cover will logically be excluded when setting or applying standards. A few nonforested sites may be included, however, as part of the defined area for the administrative goal. This will affect the apparent target density (exposure of fixed property or recreationists to failures), but the allowable failures and resulting accidents will not be changed significantly on the forested area.

Goals and safety standards are based on periods when accidents are a potential consequence of failure: (a) the period in which the site is normally in active use (in-season), and (b) out-of-season periods on sites where fixed facilities, improvements, homes, or other properties are subject to potential loss from failures.

It will help if the goal and safety standard are expressed in terms of a unit of recreationist exposure (visitor-days, visits, etc.). This term will vary with the agency, but its use must be consistent. If one-half day use by one person is considered a visitor-day, two visitor-days should imply twice the exposure.

Our ultimate aim is to maintain a given low rate of accidents within an administrative region. The goal, then, can appropriately be defined as the maximum allowable number of accidents per visitor-day per year. The sample selection of a goal described in the following section is based on this definition, although other bases could easily be substituted. For example, the goal could be stated as the total number of allowable accidents per year. Some managers, however, have indicated their preference for a rate expressed in terms of visitor exposure. After the goal has been selected, the safety standard necessary to achieve the goal may be estimated.

With appropriate field procedures, a uniform safety standard will result in consistent levels of hazard control with emphasis on high hazard. In the absence of standards, managers of low hazard sites may use disproportionately large budgets to control hazard to excessively low limits. Valuable trees may be removed in efforts to completely eliminate hazard. Safety standards tend to minimize overcontrol, as well as to insure that public safety is maintained at a reasonable level.

Setting the Goal

Selection of a goal may be guided by the minimum attainable accident rate and the current accident rate. Cost optimization would be possible only if adequate

[1]Vaux, Henry J. *Goal setting: Meeting ground of management and policy. J.* For. 66(10): 799-803. 1968.

REPORT OF TREE FAILURE[1]

(Mechanical break, collapse, or uprooting)

Reporting Agency: ____________________

Unit: ____________________

(A) Tree and stand

Species of failing tree: ____

Approximate dbh of tree: ____ inches

Approximate age of tree: ____ years

Forest type: ____

Stand age class: ___ Overmature

___ Mature

___ Young-growth

___ All-age

Elevation of site: ____

(B) Class of mechanical failure

____ Upper bole (top half)

____ Lower bole

____ Butt (lower 6 feet)

____ Limb

____ Root, including uprooting

(C) Defect or fault leading to failure[6]

____ Rot (trunk, limb, or root)

____ Sweep

____ Tree dead – snag

____ Fire wound

____ Leaning

____ Lightning wound

____ Mechanical wound

____ Cracks or splits

____ Fork or multiple top

____ Twin bole or basal fork

____ Dead top or branch

____ Widow-maker or hang up

____ Canker, rust

____ Canker, mistletoe

____ Other (____________________)

____ Unknown or none

(D) Contributing factors

____ Wind

____ Snow

____ Erosion

____ Soil saturation

____ Stream bank erosion

____ Shallow rooting

____ Tree striking tree

____ Other (____________)

____ Unknown or none

(E) Time and location of incident

Approximate hour: ____

Month, year: ____

County: ____

State: ____

During season for public use: Yes__ No__

(F) Land ownership

____ Federal

____ State

____ Other public (____________)

____ Private

____ Public utility

(G) Site category

____ Established camp or picnic ground

____ Other established public use site[2]

____ Volunteer site[3]

____ Marked trail

____ Special use site[4] (____________)

____ Roadside

____ Residence site[5]

____ Other (____________)

(H) Property or person affected

____ Agency ____ Contractor

____ Recreationist ____ Public Utility

____ Forest industry

____ Permittee-Concessionaire

____ Other (____________)

(I) Consequences

____ Clean-up work required

____ Property damage (____________)

Loss estimate $ ____

____ Injury

____ Medical attention required

____ Fatality

(J) Comments: ____________________

____

____

Name of site:[7] ____________________

Forest Service Form PSW-4600-3 (Rev 6/72)

Figure 2—Data from the Report of Tree Failure report are a valuable aid to the selection of goals and standards in tree hazard control programs.

①A report should be made for:

(1) each tree failure involving property damage or bodily injury;

(2) each failure adjacent to permanent recreation site facilities, home sites, etc., where failures are a threat to property, and;

(3) each failure on recreation sites during the season of public use, whether or not the failure causes damage or injury.

"Recreation sites" refers to those categories listed under (G) Site. Off-season blowdown and other off-season failures are excluded except when individual failures fall under (1) or (2) above. Do not report failures occurring during fire suppression or logging operations.

Only failures of a size capable of inflicting some damage or injury, or which required clean up, should be reported. Minor limb failures should not be reported unless they are potentially dangerous. Do not report simple mortality of a tree or part of a tree unless it resulted in mechanical failure.

②Other established public use site: Winter sports, beaches, viewpoints, visitor centers, etc.

③Volunteer site: Undeveloped site with concentrated public use.

④Special use site: Resorts, service facilities, etc.

⑤Residence site: Agency, private, or permittee-lessor.

⑥Check only those defects and contributing factors which lead to the actual failure.

⑦Published analyses will not indicate the source of specific incidents.

If many failures occur in your area, reports may be limited to sites normally subject to inspection and hazard control. Where information is available, however, reports from volunteer and other noninspected sites will be of equal value.

NOTE: A SEPARATE FORM SHOULD BE COMPLETED FOR EACH INDIVIDUAL FAILURE. Inclusion of more than one failure on a report prevents correlation of data.

Additional forms may be obtained from your headquarters or by writing to the following address:

Return to: Lee A. Paine
U.S.D.A. Forest Service
P.O. Box 245
Berkeley, California 94701

Phone: 415-841-5121, Ext. 210
FTS: ____-415-841-3210

☆ GPO 791-816

Figure 2— *Continued*

Figure 3—Responsibility for public safety is greatest on formally recognized and signed recreation areas.

data were available. The procedure of cost optimization sheds light on the relation between levels of control and total costs, however, and is illustrated in the Appendix.

To set the goal in terms of an allowable accident rate, reasonable limits must be established. With our present capabilities in the evaluation of tree hazard, a certain proportion of failures are unpredictable and thus set a practical lower limit to accident control. Nondefective failures (defects "Unknown or none," item C, *fig. 2*) are a useful guide to this limit.

Thus, in the calculation below, the lower limit or minimum possible accident rate, r_d, is derived from the number of nondefective accident-failures each year, h_{nd} (using items C and I, *fig. 2*). The current accident rate, r_c, may be taken from the total accident-failures (defective and nondefective) each year (h). More than one year's data should be used, if possible, to provide an average value for recent years. In the following calculations 10 million visitor-days is a convenient exposure rate factor, but any appropriate value can be used.

The lower limit for a goal is thus:

$$r_d = \frac{10^7}{n} \Sigma \left[\frac{h_{nd}}{v} \right] \qquad (1)$$

in which n is the number of years of data, and v is the number of annual visitor-days.

The current accident rate is determined in a similar manner:

$$r_e = \frac{10^7}{n} \Sigma \left[\frac{h}{v} \right] \qquad (2)$$

in which h is the total number of accident-failures per year.

Guided by the minimum and the current accident rates, r_d and r_c, an administrator may select a goal (allowable accident *rate*). The total allowable accidents for the coming year (h_{max}) can then be calculated:

$$h_{max} = \frac{g\, v_e}{10{,}000{,}000} \qquad (3)$$

in which v_e is the estimated visitor-days for the coming year, and g is the allowable number of accidents for 10 million visitor-days.

Whether the goal is selected with the aid of cost optimization, or by the method outlined here, costs must be considered. In addition to property and personal injury losses, total losses include such contingencies as costs of tree replacement, loss of esthetic values and site quality for many years, and damage to public relations. Total losses are very high as compared with those specific losses resulting only from accidents and they accrue from all failures rather than from accident-failures alone. With any method of goal selection, these contingent costs must be weighed. The problem is explored in the section "Dollar Evaluation of the Standard."

Setting the Safety Standard

An administrative safety standard for recreation sites specifies the total failures allowable during the following year, based on total allowable accidents. The safety standard includes all in-season failures and those out-of-season failures which are a potential threat to facilities on areas subject to control or inspection.

Restricting the safety standard to represent only "predictable" failures, rather than total failures, would exclude some failures responsible for accidents, and would require a more specific definition of "predictable." In an accident, the question of whether an individual failure was predictable is often decided by the courts. Thus, the administrative standard is better expressed as an acceptable rate of total failures.

The total number of accidents per year, h, is a function of the total number of failures per year, f, and the target density, here expressed as v/s, (visitor-days per year, v, divided by the area, s, in acres).[2] The following relationship using constants a and b provides a good fit to available sample data provided that slope b is positive.

$$h = a + b \cdot \left[\frac{fv}{s}\right] \tag{4}$$

Using equation 4, and assuming that a and b have been derived, if v and s are estimated for the following year, the safety standard (f_{max}) may be expressed as the allowable number of failures for the next year (equation 5). The total allowable number of accidents is h_{max} , the estimated visitor volume is v_e, and the acreage for the next year is s_e.

$$f_{max} = \frac{s_e(h_{max} - a)}{b\, v_e} \tag{5}$$

Evaluation of Constants

Setting the safety standard with equation 5 requires a simple evaluation of constants a and b. If only 1 year of data is available, the best estimates will be a = 0, and b = sh/fv. For 2 or more years of data,

$$b = \frac{n\sum\left[\frac{fvh}{s}\right] - \left[\sum\frac{fv}{s}\right]\left[\sum h\right]}{n\sum\left[\frac{fv}{s}\right]^2 - \left[\sum\frac{fv}{s}\right]^2} \tag{6}$$

in which n is years of data, f is total annual failures, v is annual visitor-days, h is total annual accidents, and s is area in acres.

$$a = \frac{\sum h - b\ \sum\left[\frac{fv}{s}\right]}{n} \tag{7}$$

This procedure requires only a few moments with a calculator once a year.

Because standards of control and reporting will probably be changing over the years included in the calculation, equation 6 may result in a negative value for b. If so, we may assume a = 0 and b = **[**Σ(sh/fv)**]** /2 using only data for the last 2 years. When standards and control procedures have been established, the problem will disappear.

A negative value for b may also result if the reporting area is too small to provide consistent data. The 2-year data procedure (a = 0 and b = **[**Σ(sh/fv)**]** /2) may be followed, but b may then be a poorer estimate. Even when data are consistent, a straight line should not be fitted to long-term data (more than 5 years), if the trend obviously calls for a second-degree equation.

A Practical Example

Derivation of a safety standard may be illustrated with field data from one administrative region *(table 1).* The minimum accident rate and the current accident rate are first examined as a basis for setting the administrative goal, using equations 1 and 2.

$$r_d = \frac{10^7}{n}\sum\left[\frac{h_{nd}}{v}\right] = \frac{28.1914}{4} = 7.0$$

$$r_e = \frac{10^7}{n}\sum\left[\frac{h}{n}\right] = \frac{44.4500}{4} = 11.1$$

The administrative goal selected with reference to the values of r_d and r_c might be set at nine accidents per 10 million visitor-days per year. Then, using equations 3, 6, and 7, the total allowable accidents and the constants a and b are calculated:

$$h_{max} = \frac{9(22{,}530{,}900)}{10{,}000{,}000} = 20.28$$

$$b = \frac{n\sum\left[\frac{fvh}{s}\right] - \left[\sum\frac{fv}{s}\right]\left[\sum h\right]}{n\sum\left[\frac{fv}{s}\right]^2 - \left[\sum\frac{fv}{s}\right]^2}$$

$$= \frac{(4)(5{,}257{,}799) - (209{,}917)\ (88)}{(4)(11{,}816{,}911{,}000) - 44{,}065{,}290{,}939}$$

$$= 0.000798944$$

$$a = \frac{\sum h - b\sum\left[\frac{fv}{s}\right]}{n}$$

$$= \frac{88 - (0.000798944)\ (209{,}917)}{4}$$

$$= -19.927982$$

[2]This interpretation of target density ignores the fixed property attached to the site. This omission is considered allowable because (a) the safety standard is a flexible guide open to subsequent adjustment to meet the defined goal, and (b) emphasis is placed on protection of the recreationist.

Table 1-*Summary of failure data for an administrative region*

Item	Year[1] 1	2	3	4	5	Total
Total failures (f)	64	51	81	38	-	[2]234
Nondefective failures (f_{nd})	26	20	48	10	-	84
Defective failures (f_d)	38	31	33	28	-	130
Accident failures (h)	26	13	39	10	-	[3]88
Nondefective accident failures (h_{nd})	14	6	33	3	-	56
Defective accident failures (h_d)	12	7	6	7	-	32
Acres (s)	22,150	22,150	22,150	22,150	[4]22,150	-
Visitor-days (v)	18,536,230	19,463,040	20,436,190	21,458,000	[4]22,530,900	-

[1]Yearly values for all tree species combined, by year.
[2]Conifers: 148; oak: 54; other hardwoods: 32.
[3]Conifers: 68; oak: 14; other hardwoods: 6.
[4]Projected for fifth year.

The correlation coefficient for fit of the sample data to a line with constants a and b was 0.98.

Given the projected acres s_e, visitor-days v_e, and h_{max} = 20.28, the safety standard of total allowable failures may be derived for the following year with equation 5.

$$f_{max}\ \frac{s_e\left(h_{max-a}\right)}{b\ v_e}$$

$$= \frac{22{,}150\ (20.28 + 19.93)}{(0.000798944)\ (22{,}530{,}900)} = 49$$

In the example, the 4th year was best in terms of both failures and accidents. It easily meets the safety standard of 49 allowable failures per year, as well as the selected administrative goal.

If only one year of data were available, (fourth year), rates r_d and r_c would fall between 1.4 and 4.7. If a goal of only 4.5 accidents per 10 million visitor-days were selected, the safety standard (f_{max}) would be 16 allowable failures for the fifth year. The cost of meeting such a standard might well be excessive. But, the addition of data for subsequent years will automatically suggest a reasonable modification.

A goal such as that selected in the example (i.e., nine accidents per 10 million visitor-days per year) and the resulting standards can only be set and applied by an administrative office responsible for large areas of developed recreation sites.

USING GOALS AND STANDARDS

Modifying the Safety Standard

Changes in the developed site acreage, visitor-days or improved hazard control can be expected to affect the accident/failure ratio in future years. Consequently, the safety standard or allowable failures may need occasional modification to meet a constant goal Equation 5 for the safety standard need only be recalculated periodically with updated values of projected acreage and visitor-days.

Should the derived safety standard fail to satisfy a goal (e.g., because of poor fit of available data to the curve), f_{max} can be modified directly for the subsequent year. Average values for minimum failures ($\bar{f}_{nd}$) and current failures ($\bar{f}$) can be taken as a guide. Using the sample data,

$$\bar{f}_{nd} = \frac{\sum f_{nd}}{n} = \frac{104}{4} = 26 \qquad (8)$$

and

$$\bar{f} = \frac{\sum f}{n} = \frac{234}{4} = 68.5. \qquad (9)$$

In the example, because the ratio of allowable failures to allowable accidents (f_{max}/h_{max}) is about 2½ to 1, adjustments of the safety standard should be made in increments of two or three allowable failures.

Applying the Safety Standard

Except for cost figures, all data necessary for setting goals and safety standards are available from the Report of Tree Failure *(fig. 2).* Maintenance of these reports at the administrative headquarters will provide for modifications of the hazard control level, to insure that the safety standard can be met.

A designated hazard control level is the key to economical distribution and use of hazard control funds. Further, a properly chosen and applied control level results in attainment of the same standard of safety over a wide variety of sites. All field units of an administration (to which one safety standard applies) are normally instructed to operate at one control level. Essentially, the control level provides a decision rule. Each tree inspected is given an appropriate rating, and control is carried out only when the rating exceeds the hazard control level. Hazard evaluation and rating are discussed in a separate report.[3]

For the first year, or if the budget is limited, it may be desirable to inspect all hazard ratings from the field before the control level is specified. If the budget permits only limited control work, the control level will be set at a value above which all the most dangerous trees can be treated with available funds.

Thereafter, the control level should be modified (with an adequate budget) so that the designated hazard control level provides satisfactory compliance with the safety standard.

Table 2—*Average accident losses and failure cleanup costs (from reports of 262 accidents, 1,420 failures)*

Species group	Average loss per accident[1]	Average cleanup cost per failure[2]
	Dollars	
Conifers	2,482.41	49.55
Oaks	1,070.98	32.17
Other hardwoods	605.65	47.12

[1]No injuries or fatalities were reported in connection with oak or other hardwood failures. In order to indicate the Personal injury potential of these groups, a dollar loss representing one fatality was distributed between the oak and the other hardwood categories in proportion to the average property loss caused by each. The actual property loss per accident in the two groups was 29 percent of the values shown above.

[2]Cleanup costs were assumed, in this example, to be one-fourth of these sample control costs: bole, butt, root–$175 (oak), $200 (other hardwoods and conifers); limb–$75 (oak), $50 (other hardwoods and conifers).

Table 3—*Average loss per accident in 262 accidents*

Tree group	Failure class: Upper bole	Lower bole	Butt	Root	Limb
	Dollars				
Conifer	2,095	5,349	2,356	1,850	498
Oak[1]	52	112	345	2,031	966
Other hardwoods[1]	259	204	906	696	615

[1]An arbitrary loss equivalent to one fatality has been distributed between the oak and other hardwood categories in proportion to reported property losses.

Dollar Evaluation of the Standard

It may be useful to translate the safety standard into a dollar figure representing allowable or anticipated accident losses. This dollar value will vary with the species of tree. Generally the accident rate per failure is about the same for conifers and for oaks (one accident in every four failures). Many more conifer than oak failures are reported, however, and average losses associated with conifers are much higher than for either oaks or other hardwoods *(table 2).* For other hardwoods, the accident rate per failure is less than one-third as high (only one out of 13).

The figures given in *table 3* include National Safety Council evaluations of losses resulting from injuries and fatalities. The National Safety Council figures apply specifically to automobile accidents, but loss figures for a fatality or for an injury with more than 1 day disability should apply adequately to forest accident fatalities and to injuries requiring medical treatment.

To arrive at a dollar cost, the allowable number of failures and accidents for each species group should be prorated according to the reported numbers and costs of accidents caused by each species group. Average post-failure cleanup cost per tree, assumed here to be one-fourth of the cost of control (prefailure haz-

[3]Paine, Lee A. *Accident hazard evaluation and control decisions on forested recreation sites.* USDA Forest Serv. Res. Paper PSW-68. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 10 p., illus. 1971.

ard reduction), can also be derived for each species group and prorated according to frequency of failure classes (*table 2,* footnote 2). For conifers, for example, estimated cleanup costs per failure = **[**(conifer limb failures) (conifer limb control costs) + (other conifer failures) (other control costs)**]** **[**¼**]** ÷ **[**total conifer failures**]**.

For the sample data presented earlier, average cleanup costs prorated by failure classes were conifers, $48.47; oaks, $40.62; and other hardwoods, $29.86.

For each species group, the losses for the following year may be estimated as follows: **[**(Average loss per accident for group) (h_{max}) (h for group) ÷ Σh**]** + **[**(Average cleanup cost per failure for group) (f_{max}) (f for group) ÷ Σf**]**. Average loss per accident here is taken from *table 3.* Average cleanup cost was computed for the example, but *table 3* values may be used. Other values are taken from the data summary *(table 1).* The summation of species groups provides an estimate of expected annual loss:

Conifers
$$\frac{(\$2{,}482.41)\ (20.28)\ (68)}{88} + \frac{(\$48.47)\ (49)\ (148)}{234} = \$40{,}404$$

Oaks
$$\frac{(\$1{,}070.98)\ (20.28)\ (14)}{88} + \frac{(\$40.68)\ (49)\ (54)}{234} = \quad 3{,}915$$

Other Hardwoods
$$\frac{(\$605.65)\ (20.28)\ (6)}{88} + \frac{(\$29.86)\ (49)\ (32)}{234} = \frac{1{,}038}{\$45{,}357}$$

These values do not include the high contingent losses for each failure, such as cost of replacement and esthetic value. For this example, with a goal of nine allowable accidents per 10 million visitor-days (h_{max}), = 20.28, f_{max} = 49), the annual loss estimate of $45,357 for the expected fifth year visitor load gives a rate of $20,131 direct loss per 10 million visitor-days. For the years reported, the estimated average annual losses, calculated in the same way, were $49,015 per year, or $24,540 per 10 million visitor-days. Thus, the safety standard of 49 allowable failures for the fifth year would provide an estimated 7 percent reduction in total dollar loss below the average for the preceding 4 years—even with 10 percent increase in visitor-days—and an 18 percent loss reduction per 10 million visitor-days.

Using these figures, the average loss per accident during the 4 years may be estimated at $2,130. This is somewhat lower than the more precise figure of $2,141 based on *table 3* and the actual distribution of failures.

Legal Implications of Setting Goals

A regional safety standard, based on the administrative goal, makes uniform and economical hazard control possible on recreation sites. Assuming that hazard evaluation and control are carried out in line with the safety standard, some failures and accidents will still occur. Statistically, they will meet the safety standard and the goal. In the example, quite reasonably, the goal was not set at the minimum possible value based on nondefective accident-failures. Such a goal would be extremely expensive to satisfy. We must expect and accept some preventable failures and some preventable accidents. Of course, this is true with or without adminstrative goals. The process of setting a goal simply recognizes the certainty of accidents and establishes a reasonable limit, which may or may not be lower than the existing accident rate.

On the site, some trees will not be controlled because the hazard, though recognized, falls below the designated hazard control level *(fig. 4).* One of these trees may fail and cause an accident resulting in legal action.

Although we cannot foresee the court's reaction, we should expect the court to consider that (a) there is some predictable hazard associated with every tree on a recreation site; (b) intensive examinations result in control of the worst hazard, providing a safer environment for the recreationist *(fig. 5);* (c) the economic and esthetic costs make lower levels of hazard unattainable or prohibitive; and (d) because the goal cannot be set at zero, a certain number of accidents are necessarily expected.

If we accept the challenge of providing the best available protection to the public, we must also accept the risk that recognized low-hazard trees may cause accidents. It seems a small risk compared with the opportunity for making significant improvements in public safety and reducing property losses and personal injuries at reasonable costs.

Figure 4—Hazard should not necessarily be controlled just because a tree has some recognizable defect.

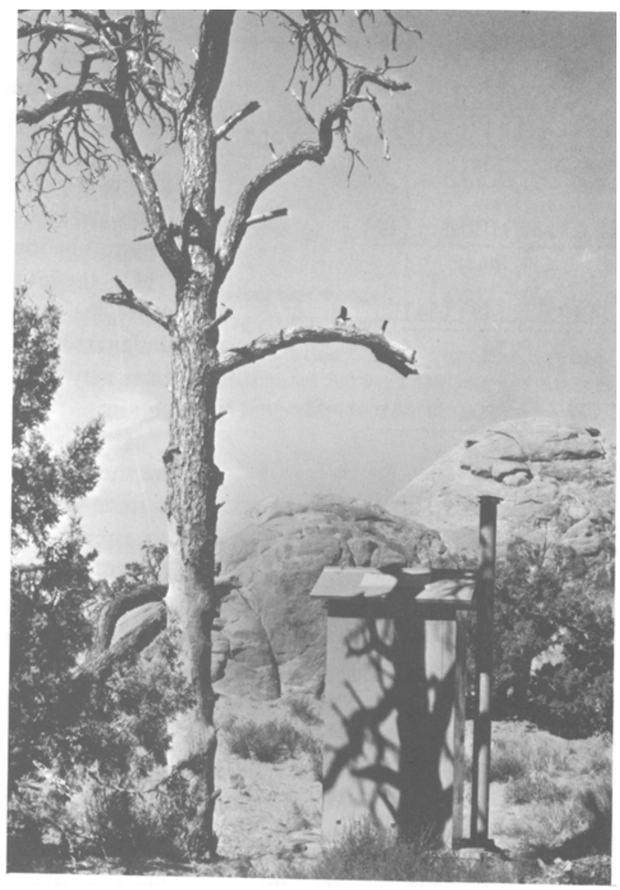

Figure 5—Highly visible hazard is almost certain to be reduced if a control program is in operation.

SUMMARY

Paine, Lee A.

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Retrieval Terms: hazard trees; recreation areas; accident prevention; tree failure; safety standards; management goals; safety engineering.

The control of hazard associated with defective or faulty trees on recreation sites is an important responsibilty of administrators of public lands. Administrative units, such as Forest Service Regions, need a goal tailored to the philosophy and needs of the unit and capable of translation into effective field directions.

Selection of the goal should involve consideration of personal injury and property losses, esthetic values, site quality, and inspection and control costs. Calculation of the safety standard necessary to achieve a goal is illustrated.

The cost-optimizing procedure outlined in the Appendix emphasizes the relationships that should be considered in goal selection and demonstrates the high contingent costs associated with a control program.

APPENDIX: Cost Optimization

For computation of a goal by cost optimization, costs would include both inspection and control costs; losses would include cleanup costs plus contingent losses associated with all failures, and direct damage losses from each accident.

For illustration, we assume that 1 million trees on recreation sites are inspected and that the cost of inspection varies with the intensity or thoroughness of inspection. In the absence of inspection cost data, we assume that the cost per tree for increasing levels of control will increase slowly at first and then more rapidly to extremely high costs for nearly complete control. The equation y = kx/(1-x) is a curve of this general type, in which y is the inspection cost per tree; x is the proportion of defective potential failures which were detected prior to failure. This curve can be defined with the following data: if the inspection cost is $0.25 per tree for a control level of 1050/1082.5 (defective trees controlled[4] divided by the sum of defective trees controlled plus defective failures),

$$k = \frac{[1-x]y}{x} = \frac{\left[1 - \frac{1{,}050}{1{,}082.5}\right] [0.25]}{\left[\frac{1{,}050}{1{,}082.5}\right]}$$

$$= 0.00773810$$

and

$$y = \frac{[0.00773810]\,x}{[1-x]}$$

For 1 million trees, then, the total inspection cost for any given level of inspection is 1,000,000 y. The average control cost per tree (based on the species and the sample class-of-control costs given in the text, and prorated by actual species and control-class frequentcies in the example) was $177.97.

Total inspection and control costs for the 1 million trees, then, will be

$$c = \frac{7{,}738.10x}{(1-x)} + 177.97z$$

[4]"Defective potential failures detected" are assumed, in this case, to be the same as "defective trees controlled."

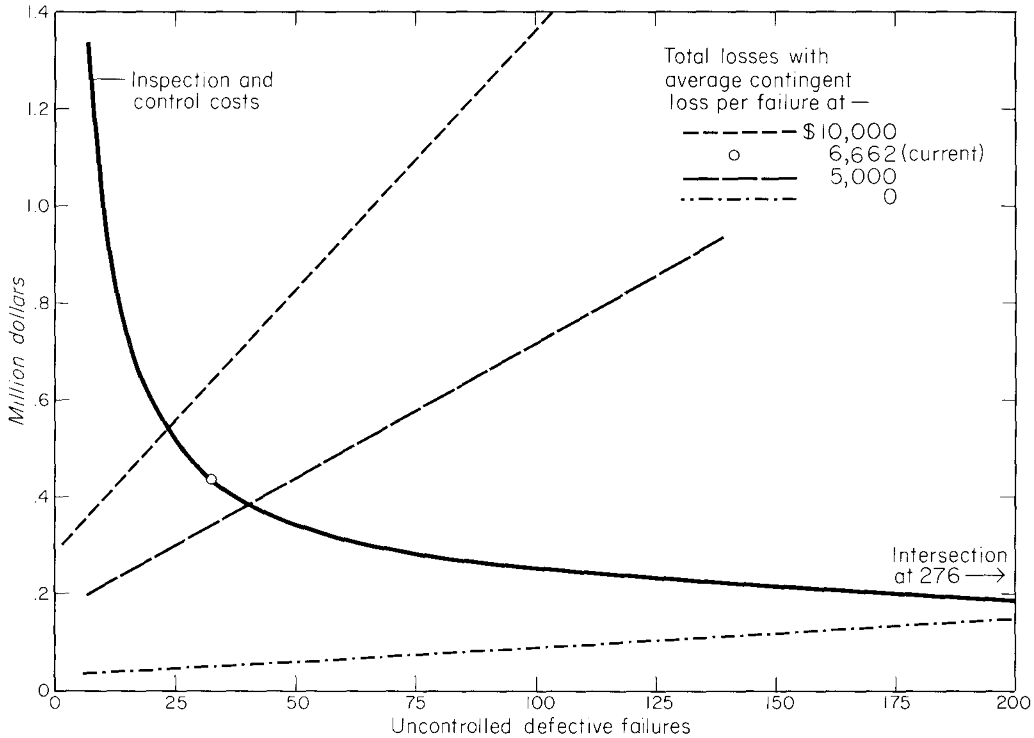

Figure 6—Cost optimization of hazard control. Costs and losses are functions of the number of uncontrolled defective failures.

in which x is the control level (defective trees controlled divided by the sum of defective trees controlled and current defective failures), and z is the number of defective trees controlled for the million trees inspected. The expected number of uncontrolled defective failures, u, for the example is 1,082.5 — z. Inspection and control costs, y, are shown as a function of uncontrolled defective failures, u *(fig. 6)*. In this example, the same inspection cost was assigned to each tree inspected. Other procedures are available for partitioning inspection and control costs more efficiently, but they are not appropriate for use with the limited data available.

Direct accident losses were derived for the example with the aid of *table 3*. The average direct loss per accident was $2,141. Cleanup costs for each failure were assumed to be one-quarter of sample control costs, or an average of $44.49 per failure.

The direct and contingent losses plus cleanup costs are expressed as

$$P = [f_d + f_{nd}]\,[\text{average cleanup cost} + \text{average contingent loss per failure}] + \left[(f_d)\left(\frac{h'_d}{f'_d}\right) + h_{nd}\right]\,[\text{average accident loss}].$$

In this equation h'_d/f'_d is the average ratio of defective accident-failures to defective failures, which is 8/32.5 for the example. The total loss, p, as a function of uncontrolled defective failures, u, is drawn for three levels of contingent loss per failure: $0; $5,000; and $10,000 *(fig. 6)*. The point at which the cost and loss curves intersect is designated as the optimum level of operation for a given level of contingent loss per failure. The control level and cost for the optimum level of operation may be read from the x and y axes.

The contingent loss is, in effect, the additional loss per failure (undefined as to source) that would justify inspection and control operations at a given level. A reasonable "optimum" level of control may require a rather high value for contingent losses.

Contingent losses, distributed among such factors as site damage and loss of public confidence, are exceedingly difficult to evaluate at present. Until such evaluations can be made, it would be more appropriate to assign a value that results in optimization at a chosen level of control. It is, however, desirable to be aware of the implied losses which justify the accepted goal.

Assignment of no contingent losses to failures would result in costs balancing losses at 276 total failures (one-quarter of the potential failures) or 75.5 accidents per year.[5] A contingent loss value of $6,662 results in a balance at the current level of control (average 58.5 total failures) at a control cost of $436,900. The defective or "preventable" accident-failures at this level are only 13 percent of the expected defective accident-failures with 276 failures. A $5,000 contingent loss value suggests a level of 66 total failures, whereas a $10,000 value suggests a level of 49 total failures for the example *(fig. 6)*. Total costs are indicated on the y-axis.

Defective failures may be interpreted in terms of expected or allowable accidents for this example as follows:

$$h_{max} = \left[\frac{8}{32.5} f_d\right] + 14.$$

Thus, expected accidents per year are 75.5, 22, 24, and 20, respectively, for defective failure rates of 250, 32.5, 40, and 23. With cost optimization, the optimum level of control would define the goal. The administrative safety standard, however, should still be used for establishing the field hazard control level.

Unfortunately, the preceding figures cannot be accepted as accurate, since the point of cost optimization is influenced by the shape of the cost curve (especially the effect of inspection costs). The relationship $y = kx/(1-x)$ was used to approximate an inspection-cost curve, but no data are available to confirm such a relationship. If the actual relationship were better approximated by $y = kx/(1-x)^2$, the optimal costs as indicated by the point of intersection would be lower with even fewer failures. Unless reliable cost figures for the individual administration are available, it will be more productive to select a goal using procedures outlined earlier in this paper.

[5]Figures include a constant 14 nondefective accident-failures per year. Control costs and total failures include a constant 26 nondefective failures per year.

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For efficient control of tree hazard on recreation sites, a specific administrative goal must be selected. A safety standard designed to achieve the selected goal and a uniform hazard-rating procedure will then promote a consistent level of safety at an acceptable cost. Safety standards can be established with the aid of data for past years, and dollar evaluations are feasible. Cost optimization is possible but impractical with available data. The legal risk in adoption of safety standards is considered acceptable.

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